Human Health

Colorado State University

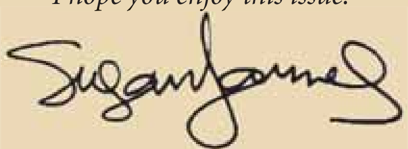
COLLEGE OF ENGINEERING

Welcome to our Health issue –

Please take the time to read the exciting stories about how our faculty, students, and alumni are engineering solutions to health care's most challenging problems. You'll see several themes emerge over and over again in the stories on the following pages, including the treatments for common diseases we're all quite familiar with, technology transfer and economic development resulting from University research, the use of cutting-edge technology by interdisciplinary teams, and efforts to extend the benefits of this technology beyond our country's borders to tackle large worldwide health problems. A few years ago, the College of Engineering made a strategic decision to focus our research and educational resources on three broad themes: health, energy, and the environment. This issue showcases just a few of the outcomes from that strategic focus.

The health-related research in our College complements our growing educational programs in this area. The U.S. Bureau of Labor Statistics predicts a 21 percent increase in the number of biomedical engineers required by 2016. To meet the need for more B.S., M.S., and Ph.D. graduates in the field, I led an interdisciplinary team of faculty to develop CSU's School of Biomedical Engineering, serving as its first director. In addition to offering an undergraduate interdisciplinary studies program (similar to a minor), and master's and doctoral degrees, the College is poised to introduce the first bachelor's degree in biomedical engineering in Colorado. We anticipate full approval of the new degree this summer and soon will begin recruiting new undergraduates to study in this exciting field. For more information on our research and the School of Biomedical Engineering, visit our website www.engr.colostate.edu/sbme where you can see the latest news and also view our videos.

I hope you enjoy this issue.



Susan James, *professor of mechanical engineering and the director and professor of the School of Biomedical Engineering*

Seniors Redesign a Neonatal Transport Incubator for Most Vulnerable Population

The excitement that parents experience when taking their new baby home from the hospital is something long remembered. But it can sometimes be anxiety-filled if the baby has medical conditions or is born prematurely and requires extraordinary professional care.

A special incubator developed by pediatricians in the 1950s was designed to transport neonates – infants less than a month old – between hospitals. Incubators have gradually evolved over the years, but neonatologists would like to see these intricate devices improved to better protect and support the life processes of these fragile beings.

Six female undergraduate engineering students at Colorado State University devoted their senior year to perfecting the current neonatal transport system, and earned first place at the 2009 Engineering Days for their innovative design.

As team member Amy Hermundstad explains, "One of the reasons I got involved in the neonatal transport incubator project is that my uncle is a neonatologist. He's an inspiration to me; I've heard stories over the years about how he does everything in his power to ensure the survival of newborns. This project drew my attention because I could apply mechanical engineering to situations that can be really life-changing and have an impact."

The goal of the senior design team was to create a prototype that would dramatically improve the existing Neonatal Transport Incubators. The 2008-2009 team consisted of Hermundstad, who worked on suspension, thermal control, and restraints; Daphen Pino, who focused on mattress design; Jennifer McHenry, who worked on the drawer, suspension, mattress design, and thermal system; Jennifer Serrao, who led the thermal control studies; Nicole Ward, who researched the incubator design, material selection, and noise reduction; and Stacey Hill, who worked on suspension.

The team began by researching existing NTIs, gathering published data, and then meeting with neonatal specialists at general and children's hospitals. Poudre Valley Hospital's Neonatal Intensive Care Unit was the first place the students contacted in order to develop an understanding of the problems with existing incubators.

"We talked with nurses and a neonatologist and had a chance to observe some of the units they used in the hospitals so we could see what the problems were," says Serrao. "We then met with the Flight for Life paramedics at Denver Children's Hospital because they use the actual incubator we worked on."

"Children's Hospital's Flight for Life team took us on individual ride-alongs with patients," explains Ward. "I became slightly nauseous because the ride was rougher than expected; it put in perspective how much work we had to do."

The team focused on the design, construction, and testing of a prototype that could be used in both richer and poorer countries, with the goal of producing a product that was not only better for the baby and caregivers, but also less expensive, easier to use, and energy-efficient.

Their faculty advisers were fully behind them, applauding their enthusiasm and motivation to design a fully operational prototype in one year. Dr. Susan James notes, "This was a great project that allowed the team to apply their mechanical and biomedical engineering skills to a real-world problem – designing an NTI that reduced the vibrations and loud sounds experienced by the neonate while maintaining the incubator at a comfortable temperature regardless of the ambient conditions."

In the United States, federal agencies evaluate NTIs based on safety features, heating and cooling mechanisms, air systems, and functionality. Tests on biocompatibility and potential toxicity of component materials are conducted.

CSU's prototype is designed to reduce noise, vibrations, and heat loss while also enhancing the baby's overall safety and the ease with which medical personnel can access and treat the baby during transport.

Stabilization of these delicate human beings during transport is a primary concern of physicians. "The major problem medical staff identified with the existing device was the vibration, and that is also what we found when we performed our tests," says Serrao. Vibration from the road surface, ventilation machines, and other equipment impairs monitoring during transport, and can cause brain damage, bruises, and discomfort to the infant. "Neonates, particularly when premature, are very touchy and even too much light can upset them. So we needed to design the incubator to meet even the small details of comfort while creating a much safer system," says Ward.

A transport incubator is attached to a pram with seat belts, and the pram is then fastened to the floor of the ambulance. The students strapped the incubator into an ambulance and used sensors and an accelerometer to measure the vibration frequencies in the incubator.

"When we saw the videos and the vibration data, we could see how much the baby would be jostled," says Serrao.

The NTI that the students studied did not include a suspension system. In order to reduce vibration, the students added eight bump stops and two air springs. This reduced the G-forces by 58 percent on city roads and 95 percent over rough railroad tracks.

"When we tested it again, the vibrations were virtually eliminated," says Serrao. "We showed our data to the hospital team and they were really excited that we had come up with this particular solution to what they saw as the biggest problem with NTIs."

Redesigning the mattress was another way the students could decrease vibrations. They investigated several types of polymers and selected polyacrylate, a diaper gel, for its thermal conductivity and potential to remove 99 percent of the vibrations not eliminated by the suspension system. Polyacrylate conforms to the baby's shape, preventing excess movement during transport.

Serrao joined the chemical engineers in studying the polymer's conductivity. "It was really important to make sure the gel absorbs heat in order to maintain a comfortable temperature when the incubator is open," says Serrao. "Neonates have such thin layers of skin and it's hard to keep them warm." The polyacrylate gel holds heat longer than other foam and gel mattresses, a definite advantage in the event of a sudden power loss.

> "I realized that biomedical engineering is a great way to integrate two of my passions, and was something that could really make a difference in people's lives."
>
> **Jennifer Serrao,** *CSU alumna, B.S. mechanical engineering, 2009*

Their research showed that conduction was the superior method for heating the incubator. Thin, flexible Omega Kapton and waterbed heaters were placed under the mattress, with a mechanical thermostat to control temperature and prevent overheating.

Straps and buckles used in conventional restraint systems can also damage a neonate's skin, and not all NTIs even have restraint systems. After talking with the transport teams, the students decided to design a new type of restraint system that is adjustable, has fewer pressure points, and permits access to the umbilical line. "We wanted to recreate the feeling of the womb," says Hermundstad, "so that the incubator surrounds the baby and also straps over the babies to restrain them, which is particularly critical if the ambulance is in an accident."

The CSU team utilized Visco memory foam, which is both pressure and temperature sensitive, as side wedges to secure the infant. They determined that a restraint system using two straps – one over the chest and one over the upper thighs – provides better protection and eliminates the possibility of the infant choking if it moves.

Another area the medical team asked them to address was excess noise, which is not only distressing to infants but can also damage their hearing.

A neonatal incubator is covered by a transparent shelter, or Isolette. "When I was first redesigning the shape, I thought of a stealth fighter jet – no 90 degree angles," says Ward. The standard Isolette is rectangular in shape, and the team wanted to redesign it to reduce noise levels and improve accessibility. "The Isolette opens like a breadbox," says Ward. "It was designed to deflect more noise. The rounded shape and the copolyester material were a big improvement." With a rectangular Isolette, the noise reaching the baby can exceed the established safe decibel limits. Ward chose a half-cylinder shape and added acoustical foam to the inside, bringing noise levels to under 45 dB, a 10-15 dB reduction. She also designed a removable acoustical foam blanket that covered the back half of the Isolette. "The blanket reduced noise by another 1-2 dB and, additionally, helped retain heat and reduced light and UV," says Ward.

For the Isolette material, the team chose Eastman Tritan Copolyester, which is three times as strong under impact as acrylic, and also lighter and less flammable. "The material is actually used in some baby bottles, and it has a higher scratch resistance and clarity, making it easier to see problems inside," says Ward.

Nurses and EMTs have to use the side access door as a temporary bed when they need to work on the baby during transport. CSU's redesigned NTI includes a retractable sliding mattress tray that allows optimal access to the neonate while maintaining its comfort and safety.

Although the team designed its prototype with a base budget of just $2,000, the improvements they recommend are significant and will add to the manufacturing cost. Current NTI units cost $300,000, keeping them out of reach for some facilities. So the 2009-2010 team is focused on a new type of design for developing and newly industrialized countries, such as Brazil. That small initial investment, combined with the energy, creativity, and enthusiasm of a dedicated group of engineering seniors, could potentially be used to help some of the world's youngest and most vulnerable citizens. ■

CSU's "Backpack NTI" May Save Even More Lives

Mechanical engineering's 2009-2010 Neonatal Transport Incubator team has created a backpack version of the NTI for use in newly industrialized countries and rural areas around the world that lack access to ambulances, helicopters and developed roads. Brazil is an example of a newly industrialized country where newborn babies die every year due to lack of neonatal transport.

Students Jeff Belval, Phillip Brox, Harold (Casey) Dean and Brett Raver adapted CSU's prototype and added new design elements to produce a lighter weight device that accommodates all newborns and is easier to transport than the conventional gurney-style NTI.

With the new backpack design, EMTs can maneuver through difficult terrain to reach babies wherever they are, whether in multi-story apartment buildings with no service elevator, in mountainous areas, or during disasters such as severe storms. Advantages over industry standard models sold in the U.S. and Europe include:

- Ability to regulate the temperature in the NTI via a thermocouple and sensor that triggers changes to the air temperature as a baby's temperature changes.
- A hand controller with displays in English or Portuguese.
- The mattress can be tilted 30 degrees vertically or used in the horizontal position to alleviate pressure and stress on the baby, and is adjustable for different size babies.
- Vibrations during transport over railroads and dirt roads are reduced by 68% and 54%, respectively.
- Improved ventilation and heating systems.
- A redesigned restraint system that keeps the baby's airway open.
- PETG, a copolyester used in the new Isolette, provides additional safety to the baby, based on a Charpy impact test of PETG as compared to acrylic.

"We know this will save lives, and given the various crises happening around the world, this will make a difference in any environment," says Brox. "My brother-in-law, who is an EMT in Brazil, is very excited about our NTI."

Dean adds, "This would also be very beneficial in places such as Haiti where an ambulance can't move through the rubble from their recent earthquake. You can just throw our backpack on and get to work."

CSU and Envirofit Study Worldwide Impact of Indoor Air Pollution

Not many university students can say that the research they are conducting in the lab provides direct health and environmental benefits to people around the world. That real-world application of their research is the driving force behind the Envirofit/CSU clean cookstove team and what makes them so passionate about their work.

> "Our cleaner burning stove is making a real difference to the health of so many, especially women and children."
>
> **Morgan DeFoort** *earned his master's and Ph.D. degrees in mechanical engineering at CSU while employed in the Engines and Energy Conversion Laboratory. He serves as co-director of the lab and teaches a graduate course in energy technology. DeFoort lives with his wife and their daughter in CSU's Academic Village.*

Melanie Sloan came to Colorado State University because of her desire to improve people's lives and reduce environmental pollution. Her classes in mechanical engineering introduced her to the Engines and Energy Conversion Laboratory and Envirofit International, a nonprofit company spun off from the EECL in 2003. Today, as an Envirofit technician, Sloan is responsible for research and development testing of their clean technology cookstoves. Last year she joined graduate student Christian L'Orange on a trip to India to observe Envirofit stoves in the field, conducting research on the sociological and mechanical attributes from the user's point of view.

"Seeing the reality of how people are living and cooking in India enhanced my understanding of the need for improved stoves," says Sloan. "For example, I saw how they tried to spread their fuel by using other forms of biomass such as coconut husks and dung." Those fuels don't burn as well as wood and produce more indoor air pollution in the form of carbon monoxide and particulate matter.

Envirofit's fuel-efficient stoves reduce toxic emissions from traditional biomass fuel sources by as much as 80 percent. "I find that a very exciting aspect of the work I do with Envirofit at the EECL," says Sloan. "Our R&D can result in a positive change in the lives of millions."

Now Sloan is collaborating with CSU student Brie Hawley to evaluate the inflammatory effects of emissions from various cookstoves. Sloan is performing the first phase of standardized tests, burning fuel in three types of stoves at a steady state for 45 minutes, the cooking time typical in a home. She uses Fourier Transform Infrared spectroscopy to capture the gaseous emissions. Hawley works in another area of the lab to expose human lung cells to the particulate matter generated by the stoves during testing. A graduate student in environmental and occupational health, Hawley is guided in her research by Dr. John Volckens, an aerosols specialist with an engineering background.

"The impact on human health, as well as the environmental impact, is driving the design of the cookstoves," says Dr. Morgan DeFoort, technical lead on the project. "Our collaborators across the campus are shedding new light on how the human body reacts to gaseous emissions and small particulates emitted by a variety of cookstoves."

Hawley is also partnering with undergraduate student Melissa Bushey, a CSU freshman who is taking advantage of this opportunity to gain experience in a research lab. They culture human lung cells over a three- to four-week period until the cells show signs of differentiation typical of lung cells found within the body. They then expose the cells to emissions generated by the stoves.

"We are evaluating whether the particles from an improved wood stove are more or less inflammatory to human lung cells when compared to the '3-stone fire,' which is a laboratory re-creation of an open fire traditionally used in households," Hawley explains.

"We are measuring the inflammatory potential of the cookstove emissions by looking at the expression of three different inflammatory genes at one and 24 hours post-exposure to evaluate the acute response of human lung cells to the emissions," continues Hawley. "Earlier epidemiological studies have identified associations between exposures to biofuel emissions and pulmonary disease, childhood respiratory infections, eyesight degradation, cancer, and adverse pregnancy outcomes. However, epidemiologists often have to wait for diseases to appear and at that point, the damage has already been done. I am trying to show that we can use an improved *in vitro* model of the lung to predict health outcomes from wood smoke exposure specifically, but it is an approach that can be used more widely in modeling any aerosol exposure."

Sloan and L'Orange may conduct more field experiments when Envirofit expands into new markets in Africa, Asia, and Latin America. People in those countries use similarly inefficient cookstoves as those found in India, wasting costly fuel, increasing deforestation, and producing toxic byproducts such as carbon monoxide, benzene, and formaldehyde.

Indoor air pollution is responsible for killing 1.6 million people every year, more than 85 percent of them women and children under age 5. In addition, recent research has shown the soot from these global cooking fires is second only to carbon dioxide in contributing to global warming. With these wide-ranging social, environmental, and human health issues, the work being done by Envirofit and the EECL becomes even more critical. These dedicated researchers are providing solutions that will improve the lives of millions worldwide. ■

Unique Laboratory Producing New Technologies and Partnerships

Since 2002, the Engines and Energy Conversion Laboratory has been the center of an international technology development program at Colorado State University. EECL's focus on increasing energy efficiency and reducing the environmental and health impacts of transportation, electric power production, and household energy is making a worldwide impact.

The EECL's development and testing facility is unique, and the companies that have spun out of the lab, such as Solix Biofuels and Envirofit International, are providing cutting-edge solutions to global energy challenges.

Envirofit's G-3300 Clean Cookstove, a revolutionary design developed in partnership with the EECL, the Shell Foundation, and the High Temperature Material Laboratory at Oak Ridge National Laboratory:

- Reduces the emission of toxic gases by up to 80 percent,
- Reduces the amount of fuel used by up to 60 percent,
- Improves cooking efficiency by up to 40 percent,
- Has a five-year warranty on the combustion chamber, and,
- Can be mass-produced.

Envirofit conservatively estimates that the more than 100,000 cookstoves sold to date have improved the livelihood, health, and economics of more than 250,000 consumers in India. The environmental impacts of the stoves sold to date are also impressive:

- A savings of more than 50,000 tons of wood (the traditional fuel source).
- A reduction of more than 100,000 tons of carbon dioxide and 2,000 tons of carbon monoxide emitted into the atmosphere.
- The elimination of more than 50,000 kg of particulate matter and 20,000 kg of black carbon from cookstove emissions.

Sixty Envirofit employees in India are currently selling 7,000 to 10,000 stoves each month. Cookstove samples have been sent to more than 20 countries around the world, and pilot programs are starting in Africa.

The important breakthroughs made by the EECL and Envirofit have not gone unnoticed, with the founders earning several recent distinctions:

- Professor Bryan Willson, the EECL's founder and director, was listed along with President Barack Obama and Microsoft Chairman Bill Gates in the inaugural "*Scientific American* 10" – an honor bestowed on those guiding science to serve humanity.
- *Time* magazine named CSU alumni and Envirofit co-founders Tim Bauer and Nathan Lorenz "2010 Heroes of the Environment."
- The cookstove design and development teams at Envirofit, Red Ingot, and the EECL won Bronze in the International Design Excellence Awards' Ecodesign category.
- *Popular Science* showcased the Envirofit Clean Cookstove in its "Best of What's New" in the Green Tech category.
- CSU's highest honor, the William E. Morgan Alumni Achievement Award, was presented to Bauer and Lorenz in April 2010.

Visit www.eecl.colostate.edu for further information on the EECL, and www.envirofit.org for further information on the Envirofit cookstoves.

Biomedical Engineer Susan James Leads Efforts to Expand Research in this Vital Area

Discoveries in biomedical research are providing treatments and cures for injuries that were sometimes debilitating just 20 years ago. Many of these medical breakthroughs take place in university research laboratories where engineers and scientists develop cutting-edge technologies that are adopted by major pharmaceutical or medical device companies.

Professor Susan James is among the researchers actively involved in discovering new technologies to improve the lives of many. She has been researching total joint replacement materials since arriving at Colorado State University as an assistant professor in 1994. Her industry background in materials science, combined with her education at Carnegie Mellon and MIT, enabled her to quickly establish a very strong research and educational program in biomedical engineering.

The Colorado State University Research Foundation licensed technology on a new biomaterial named BioPoly™, developed by James's research group, that will vastly improve the performance of orthopedic implants by incorporating a natural biomolecule found in cartilage into the surface of plastic implant materials. Several years of laboratory testing and 12 months of animal testing have produced promising results, and this year the Indiana-based company, Schwartz Biomedical, which has licensed the technology from CSURF, will be launching BioPoly™ implants in Europe, with a United States launch soon after.

BioPoly LLC, a Schwartz Biomedical subsidiary, has raised more than $2 million in its first round of equity financing. This capital will be used to complete product development and initiate launch of its first orthopedic products into the market. One of the implant applications that is being developed includes using the BioPoly™ material as a synthetic cartilage for partial resurfacing of the knee. By partially resurfacing, the surgeon can replace the defective cartilage instead of the entire joint (total joint replacement), thus allowing the patient to retain more of his/her native tissue. The BioPoly™ material's hydrophilic (water-attracting) nature along with robust mechanical properties provides implants that optimally interface with orthopedic tissues.

James's research into new biomaterials continues today with funding from the state of Colorado's Bioscience Discovery Evaluation Grants Program to develop new implant coating technologies for integrating implants into bone that can also locally release drugs. CSU's Cancer Supercluster has provided matching funding to study the implant coatings and their potential to release chemotherapy drugs locally at the cancer site. ■

"The future for this program is really exciting. We're attracting the best and brightest faculty and students to CSU's School of Biomedical Engineering, and I'm so pleased to have played a key role in its development."

Susan James *is a professor of mechanical engineering and the director and professor of the School of Biomedical Engineering. She is also the co-director of the Orthopaedic Bioengineering Research Laboratory and, beginning July 1, 2010, she will become the head of the Department of Mechanical Engineering at CSU. Through her work as a role model and mentor, she has quickly expanded the number of young women enrolled in biomedical engineering at Colorado State. Her extracurricular activities include hiking in the mountains with her husband and two sons, oil painting, and creating her own line of personal skin care products.*

Engineering New Strategies to Improve Food Safety

> "The rapid detection of food-borne pathogens at very low concentrations remains a significant challenge that must be overcome to mitigate public health threats caused by food-borne pathogens."

Matt Kipper *is an assistant professor in chemical and biological engineering; an Iowa State University alumnus, he joined CSU in 2006. Randy Bartels is an associate professor in electrical and computer engineering and alumnus of the University of Michigan; he came to CSU in January 2003. Kipper and Bartels are core faculty members in CSU's School of Biomedical Engineering. Larry Goodridge is an associate professor of animal science.*

Regardless of how careful consumers are when selecting, preparing, and cooking their food, contaminated products are still finding their way onto our tables. Recent outbreaks of pathogenic *E. coli* traced to fresh produce and meat are evidence that current technologies lack the sensitivity to detect infectious pathogens before they reach the market.

Three Colorado State faculty members have combined their expertise in biomolecules, nanomaterials, optical sensors, and food microbiology to creatively address this problem. Drs. Matt Kipper, Randy Bartels, and Larry Goodridge are developing new strategies for detecting food-borne bacterial pathogens that are sensitive to very low concentrations in food and water samples. Undergraduate and graduate students are also involved in this collaboration.

Food-borne diseases cause approximately 76 million illnesses, 325,000 hospitalizations, and 5,000 deaths in the United States each year. Known pathogens account for an estimated 14 million illnesses, 60,000 hospitalizations, and 1,800 deaths, and three of these – *Salmonella spp*., *Listeria monocytogenes*, and *Escherichia coli* O157:H7 – are responsible for more than 85 percent of the deaths caused by food-borne bacterial pathogens. The elderly and children under 5 years of age are especially vulnerable. There is a critical need for more rapid, robust, simple, and sensitive detection methods.

A single colony forming unit of a pathogenic bacteria in food can multiply to many times the pathogenic concentration during the time between an agricultural product being sampled and its transportation, storage, delivery, and ultimate consumption. However, sampling and detection limitations preclude the identification of a single cell in a complex matrix. Thus, food sampling and detection must often be coupled with an enrichment step to detect food-borne bacteria.

Culturing food samples on solid media is a slow process, requiring 24-48 hours to achieve results. Immunoassays and molecular techniques are labor-intensive, time-consuming, and may require extensive training. With funding from CSU's Infectious Disease Supercluster, the researchers hope to develop new strategies that will enable rapid detection (< 24 hrs) of very low concentrations (~10cfu/ml) of pathogens from complex food matrices with minimal sample preparation and manipulation steps.

"By developing novel signal amplification and detection strategies for serious threats to food safety and security, pathogens can be detected before they pose serious threats to public health," says Kipper. ■

Students Develop New Cancer Detection Techniques

Professor Kevin Lear has been applying lasers and optics to new applications in the life sciences since joining the University in 1999. While developing new optical biosensors and diagnostic devices, Lear and his group have discovered they can detect and differentiate canine lymphoma and hemangiosarcoma cells from white blood cells without special chemistry that is required by conventional technologies.

Colorado State University's Cancer Supercluster is currently supporting a separate study in Lear's lab to evaluate if the new technique can determine the malignancy of individual cancer cells, information that would be very useful in analyzing small biopsy samples.

A new team of senior design students is working with Lear and his colleagues again this year on the cancer detection project. They have developed an inexpensive chip using an optical biosensor that traps and sorts normal cells from abnormal cells. Once their methods are perfected, these portable disposable chips could be used in clinics everywhere.

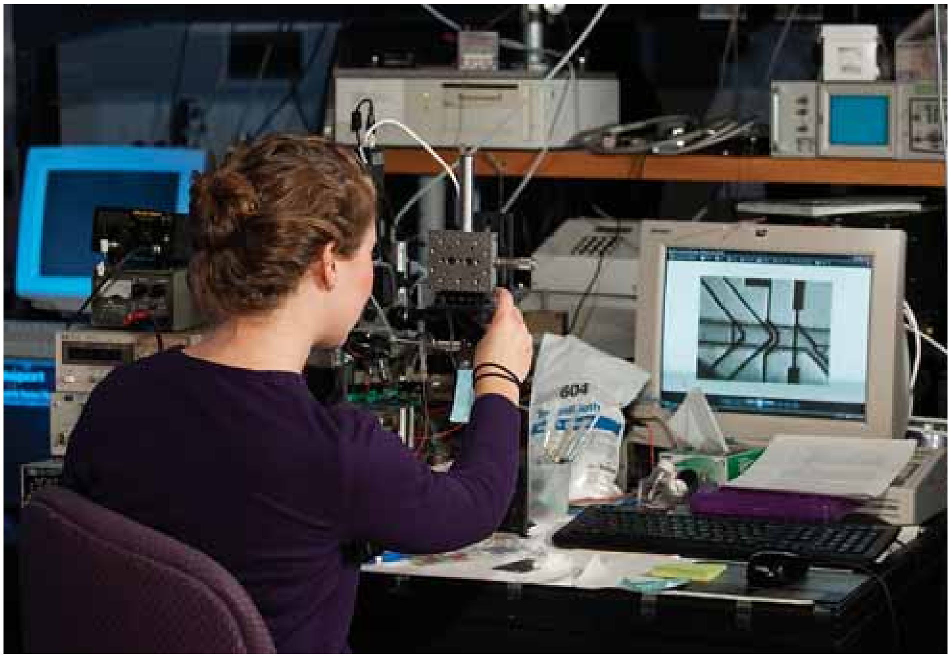
DNA mutations in cells are common in humans and animals, but not all abnormal cells are cancerous and most do not cause any symptoms initially. Left undiagnosed and untreated, however, these mutant cells can develop into cancer. While death rates for the four most common cancers are declining in the United States, there has been a rise in the incidence of other types of cancer.

Physicians have an array of imaging and laboratory tests they can order to detect mutant cells; unfortunately, these procedures can be costly and don't always work, especially in the early stages of cancer. When a cancerous tumor becomes large enough to be diagnosed, the likelihood increases of the cells spreading to other parts of the body.

Cancerous cells grow rapidly and tend to have a larger nucleus with more DNA and proteins than in healthy cells. Canine cells are being used in the study because naturally occurring tumors in dogs are biologically and clinically similar to those in human patients.

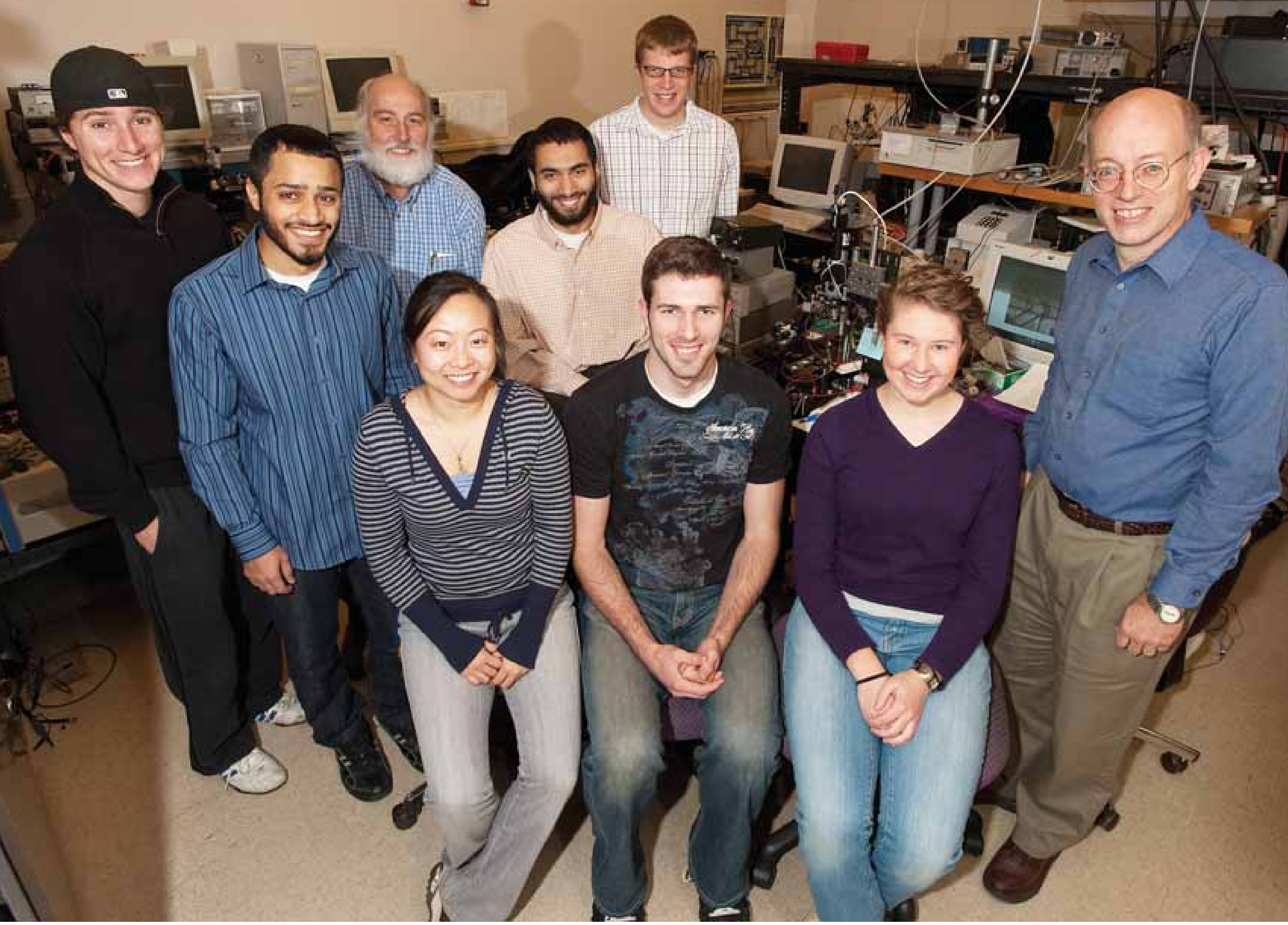
> "It's fun to share the students' excitement when they get to apply the concepts they've learned in class to problems that inspire them."

Kevin Lear *received his bachelor's degree from the University of Colorado and M.S. and Ph.D. degrees in electrical engineering from Stanford University. He was a senior member of the technical staff at Sandia National Laboratories and chief scientific officer at Micro Optical Devices Inc. before joining CSU in 1999 as the Rockwell Anderson Associate Professor of Electrical and Computer Engineering. He is also a member of CSU's School of Biomedical Engineering.*



The method incorporated in this study requires several areas of expertise, so Lear recruited students from his own department as well as chemical and biological engineering to join his team. Chemical and biological engineering seniors Mohamed Eldeiry and Liesel Mundhenke joined electrical and computer engineering seniors Wesley Fuller, Torsten Kiljan, Mujahid Naqbi, and Ashley Stewart. Lear, graduate students Weina Wang and Joel Kindt, faculty affiliate Dr. Susan Hunter, and Dr. Dave Kisker of eOptra LLC are mentoring the students. Clinical Sciences collaborators on the project are Drs. Doug Thamm and Sue Lana.

How their system works is similar to how jellybeans are sorted on a produc-



tion line. In this case, the "inspection line" is the automated cell sorting unit, or ACSU chip, made up of two mirror-coated pieces of glass separated by 20-30 micrometers of a polymer called SU-8. Depending on the chip design, the SU-8 has 100 to 200 micrometer-wide channels through which the fluid flows.

In simple terms, the cells flow down the channel one at a time and reach a trap, where they are held in place while light is shot through the cell and a spectrograph records the exact wavelengths, i.e. colors, that pass through the system. If the transmitted wavelengths indicate the cell is cancerous, the cell is steered into a side channel for further analysis. Metal electrodes at the top and bottom of the channel create electric fields that can trap and steer the cells under the control of circuits and software.

"Our chip gives us the ability to hold cells stationary while we perform a spectrum analysis," explains Wang.

"Malignant cancer cells travel through the bloodstream to other parts of the body; detecting these cells before they spread the cancer could help with treatment," adds Fuller.

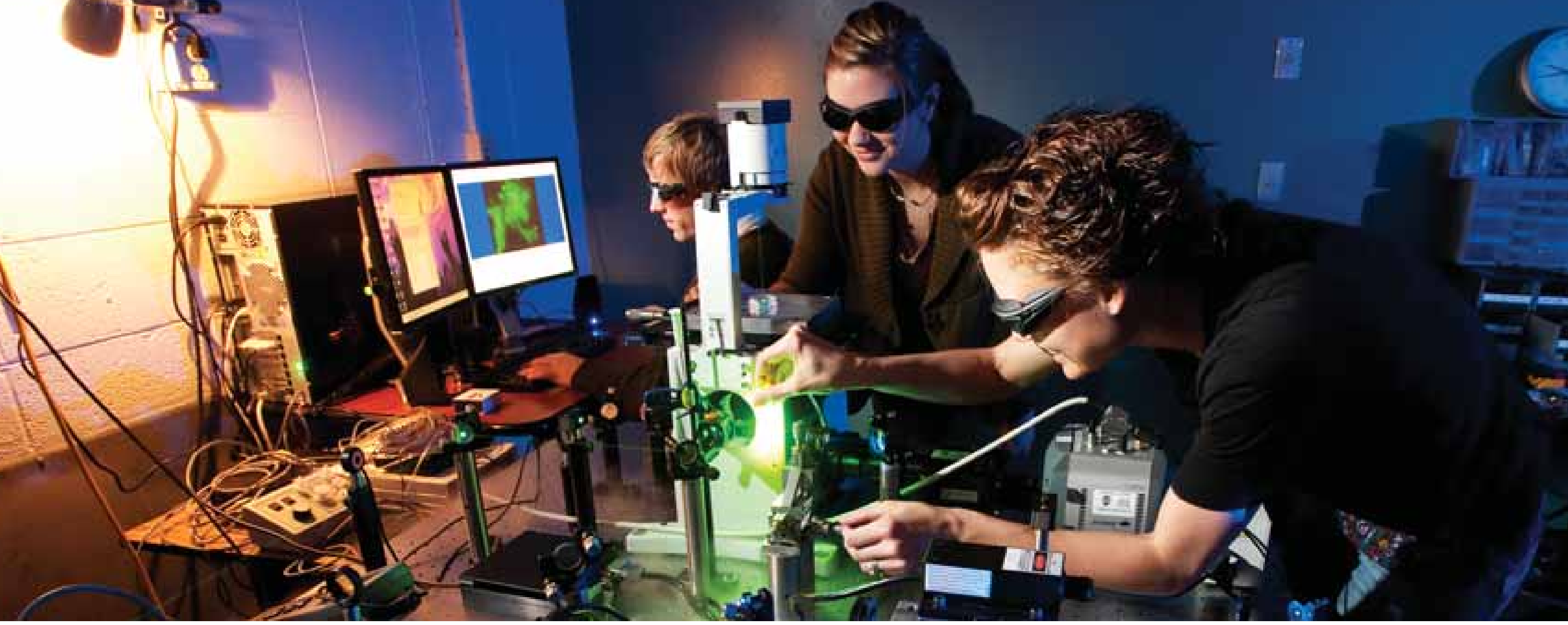
"When you measure the light being passed through cells placed between mirrors, you can determine how the spectrum differs for a cancerous cell as opposed to a healthy cell," says Mundhenke. "We still have a lot of things to learn. For example, at different phases in its life cycle, a cell displays different morphology and protein content, and we need to understand how that affects the spectrum."

Mundhenke chose this project for her Honor's thesis in addition to participating on the senior design team. "I was eager for the opportunity to apply my knowledge in an environment that was geared toward developing a technology that has real-world application and could revolutionize cancer diagnostics," she says.

The senior design project was begun in Fall 2007. The 2009-2010 team has developed new and improved chip designs and chip control software, and also enhanced the circuitry that interacts with the chip and the software in order to automate the cell capturing system.

"This is a very dynamic process, and it is going to be exciting to see the challenges it still brings," says Kiljan.

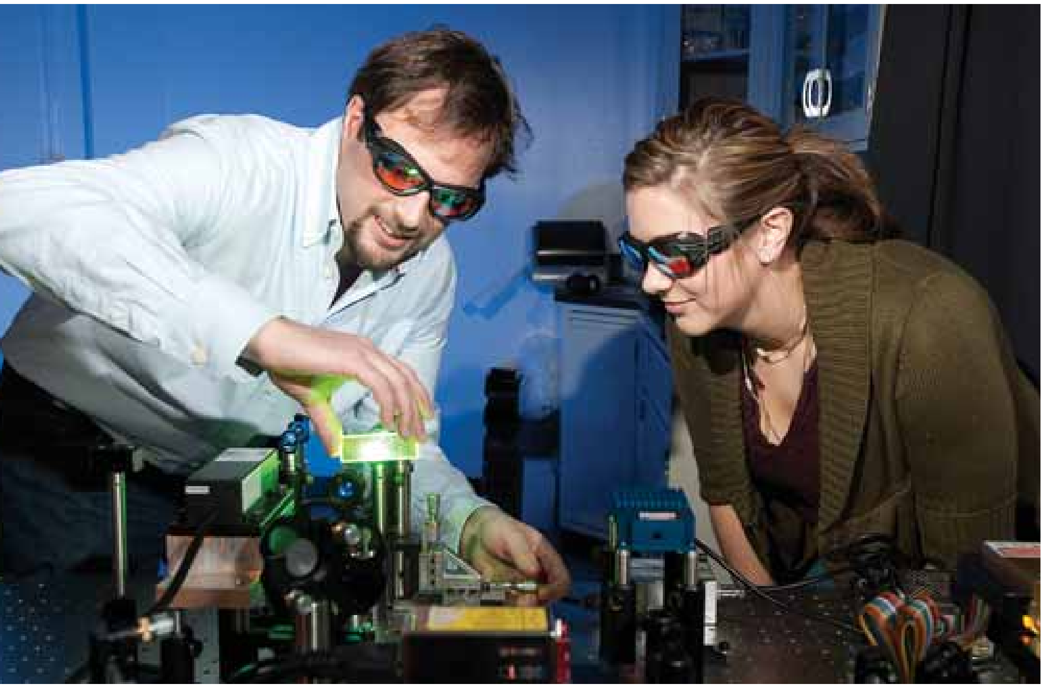
"The students did a good job and I'm proud of their work," says Lear. "They've learned a great deal, not just about microfluidics and cells and electric field design, but about how to plan, execute, and evaluate engineering projects." The team won top college honors at Engineering Days in April 2010. ■



Researcher Exploring Point-of-Care Method for Detecting Tuberculosis

Every year, 9 million people around the world develop tuberculosis and more than 1.5 million people die from the disease. It is estimated that 2 billion people carry a form of latent TB, with 10 percent going on to develop active TB during their lifetimes. Creating new methods for early tuberculosis detection is a critical step to reducing these numbers, and a challenge that professors and students at Colorado State University are meeting head-on.

The challenges to overcoming this life-threatening disease are numerous. Specialized facilities and trained medical personnel are essential to proper diagnosis of infectious diseases, but these are lacking in remote regions of Southeast Asia and Africa, causing many cases to go undetected. The workhorse of TB diagnostics in these areas is sputum smear, a very old technology that has only 60 percent sensitivity and also is unable to detect latent forms of TB.



The bacterium that causes TB continues to mutate, and resistance to multiple drugs has made TB a global health emergency. According to the World Health Organization, each person with active TB disease will infect on average 10 to 15 people every year.

Dr. Diego Krapf has found a new way to detect traces of tuberculosis bacteria in fluids that would allow for a more sensitive and accurate detection of the deadly disease. An assistant professor of electrical and computer engineering and a faculty member in the School of Biomedical Engineering, Krapf was recently recognized by the Optical Society of America for his work.

"There is a great need for simpler and more sensitive diagnostic tests for TB in order to eliminate delays in treatment," says Krapf. "An effective test for latent TB could save 400,000 lives annually. The detection problem is so drastic that at least half of the people with latent TB do not know they carry the disease."

“I am very motivated to develop techniques that will enable us to understand new physics of cells and biological molecules.”

Diego Krapf *was born in Rosario, Argentina, and received his B.Sc. in physics and Ph.D. degree in applied physics from the Hebrew University of Jerusalem. He joined Colorado State in 2007, following completion of biophysics research in a postdoctoral position in The Netherlands. Krapf and his wife have two children who enjoy skiing and hiking in the great Colorado outdoors. When not in the lab, Krapf plays racquetball, enjoys reading, and likes to relax with friends while barbequing.*

Krapf has developed a biosensor that uses a combination of chemistry and lasers to detect the presence of proteins prevalent in TB. Krapf mixes a sample with fluorescent antibodies for the targeted TB proteins and coats the glass slide with a molecular brush that will stick only to those proteins. Using a homemade microscope, Krapf can determine whether a large number of the proteins are present, which indicates the test is positive for TB.

The end goal of the project is to develop a platform for the detection of TB that is portable, affordable, and does not require highly trained personnel.

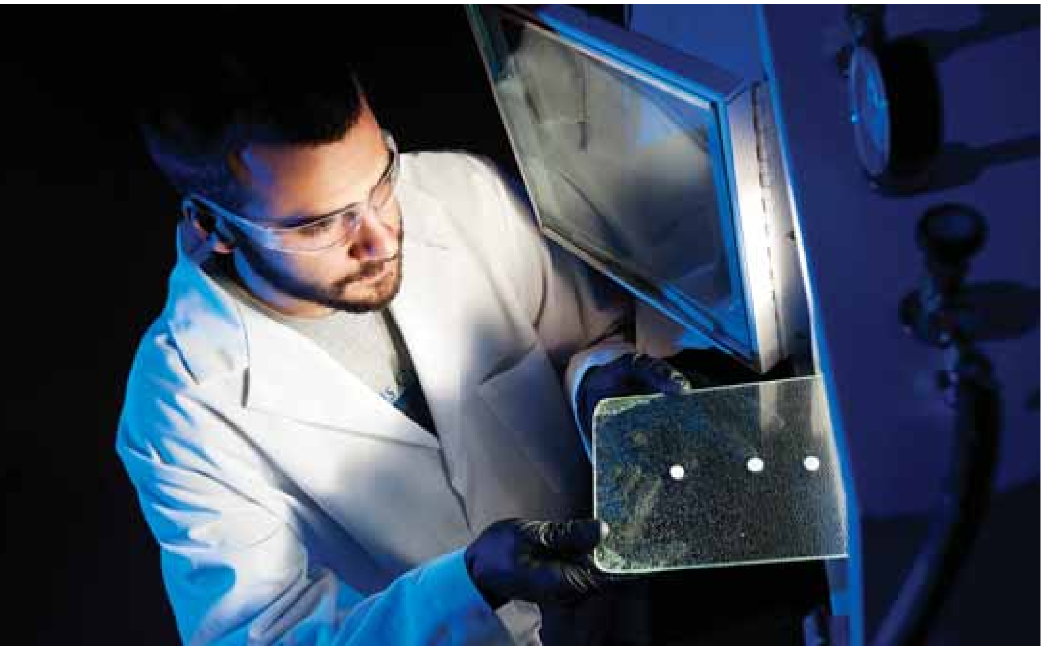
Krapf is collaborating on the research with Mike McNeil, Mike Scherman, and John Spencer in the Department of Microbiology, Immunology and Pathology at Colorado State.

“We are excited about the possibility of combining our knowledge and doing something that could improve the detection of TB in very poor countries,” says Krapf.

Krapf’s graduate students, Kristen Jevsevar and Aubrey Weigel, are focusing on the fluorescence measurements and working closely with Jeremy Stone, who is performing these same experiments in a portable prototype. Nathan Proper is developing the electronics to drive and operate a small fluorescence device that could ultimately be used for point-of-care diagnostics. Proper and Stone are electrical and computer engineering undergraduates; their research is the basis of a senior design project. Proper presented their results at the American Physical Society meeting in Portland, Ore., in March.

“We are developing chemical and optical techniques for the analysis of single molecules that ultimately will lead to more effective diagnostic methods for TB and other infectious diseases,” Krapf says. ■

Nanotechnology and Tissue Engineering Promise Health Benefits to Many



Advances in nanomedicine and tissue engineering could enhance the quality of life for millions of people in the world. At Colorado State University, new discoveries are being made that may lead to improved materials for bio-scaffolding and stem cell therapies, implantable medical devices, nerve regeneration, prosthetics, and joint replacements.

Dr. Ketul Popat directs the Biomaterials and Surface Micro/Nano-engineering Laboratory where some of this innovative research is taking place. With support from the National Science Foundation and Colorado's Bioscience Discovery Evaluation Grant Program, Popat and his team are designing biomaterials for a wide variety of tissue engineering applications.

In the first year of the three-year NSF project, Popat and his team developed a new method to locally deliver antibiotic drugs in a more precise and controlled way, by using tiny tubes of titanium that adhered to a prosthetic skeletal implant. Their approach not only eliminates side effects resulting from higher drug doses administered by traditional techniques such as injections, but also allows delivery of a combination of drugs without any systemic effects.

During phase two of the project, Ph.D. student Barbara Smith is investigating the blood and skin cell interactions with these tiny tubes. In the United States, more than 500,000 total joint replacements and 100,000-300,000 dental implant surgeries are performed each year. The success of these implants depends on acquiring and retaining stable fixation of the device at the bony site, but many fail within eight to 10 years because of loosening of the implant. As people age and natural bone loss increases, additional surgeries to restore mobility are no longer an option and some may be confined to wheelchairs. Because multiple surgeries and new implants are required as their bodies grow, children who begin receiving implants at an early age may face these same issues even earlier in their lives.

Smith and Popat are designing implants that induce controlled and guided growth resulting in rapid healing. They are using new nanotextured titanium that is biocompatible and increases bone marrow cell's differentiation toward formation of new bone around the implant. Titanium implants whose surfaces have been altered with highly uniform nanotube arrays are less likely to fail or to trigger physiological immune responses because these modified materials mimic natural biological tissue hierarchy. It is expected that patients will recover faster since a stronger bond forms between the implant and the bone. Antibiotic drugs

> "Nanotechnology is pushing the forefront of medical health science research. Fundamental research in the area is vital for long-term success of these technologies for practical application."

Ketul Popat *(pictured on page 15) is an assistant professor of mechanical engineering who came to CSU in December 2007. He earned his M.S. in chemical engineering from the Illinois Institute of Technology and his Ph.D. in bioengineering from the University of Illinois at Chicago. As a postdoctoral fellow at the University of San Francisco, he started research on orthopedic materials and nanomedicine that he is continuing at CSU. Popat enjoys the many outdoor activities that Colorado has to offer and loves traveling.*

can be placed inside the nanotubes to prevent infection around the implant.

Tim Ruckh, who was involved in the initial project, will be the first of Popat's group to graduate with a Ph.D. in bioengineering. Ruckh's research centers on development of highly engineered biomimetic scaffolds for bone regeneration. Such scaffolds will benefit thousands of patients undergoing joint replacement, tumor resection, maxillofacial repair, and bone loss due to trauma.

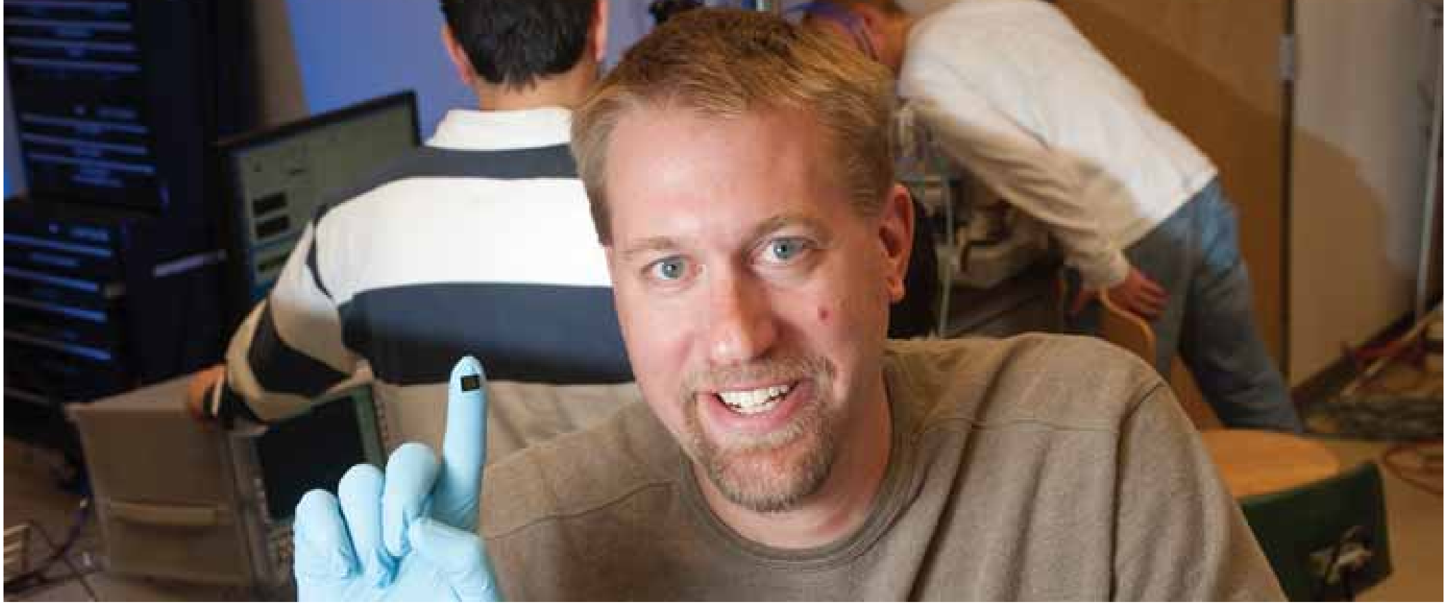
One of the challenges in orthopedic tissue engineering is growing and maintaining a viable colony of physiologically capable cells on three-dimensional biocompatible scaffolds for bone repair and regeneration. Ruckh is working on a more physiologically accurate approach by developing nanofiber scaffolds that can maintain the growth and differentiation of bone cells, leading to improved healing of bone.

In a related project, graduate student Sam Bechara is developing nanomaterials and tissue engineering therapies for nerve regeneration, focusing on spinal cord injuries in particular because of the drastic effects they have on the body. More than 250,000 people in the United States have spinal cord injuries. The majority of the 11,000 new injuries each year occur in people between the ages of 16 and 30, primarily as a result of vehicular accidents.

There is no clinically proven way to reverse spinal cord damage, and rehabilitation can be prolonged and difficult due to the extensive scarring caused by changes in blood flow, neurotransmitter release, and nerve cell death. Tissue engineering coupled with cell therapies has the potential to allow patients to regain function that might otherwise be lost for a lifetime.

"My goal is to use these polymeric nanowire surfaces for neural tissue engineering applications such as spinal cord injuries," explains Bechara. "We have cultured neural cells and found enhanced proliferation, adhesion, differentiation, and viability on these surfaces as compared to regular control surfaces without nanowires. We hope one day to implant these materials and be able to form neuronal networks effectively *in vivo*, moving us closer toward regaining the function of the spinal cord. The ultimate goal is to have a tissue-engineered material that is able to span the spinal column break and encourage cell growth on both sides to regenerate the column."

With their vision and drive, Popat and his team are well on the way to creating new fundamental research solutions that have practical application and will benefit so many. ■



BioMEMS Fracture Sensors Offer Physicians Greater Insight

Physicians treat more than 6 million bone fractures in the United States every year and about 10 percent of these fractures don't heal properly. Multifragmentary or "comminuted" fractures, where the bone splits in several pieces, are especially difficult to treat and often require the implantation of screws and a plate to stabilize the healing bone.

During the early healing phase, the plate and screws protect the fracture site by taking on most of the loading at the site. As time goes on, the healing tissue starts to share more of the load. The first three months is a critical time period when physicians closely monitor the patient to make sure the bone is healing properly. However, conventional X-rays cannot discriminate whether this is actually occurring.

Dr. Christian Puttlitz is providing physicians with the tools they need to determine if early healing is occurring properly. Puttlitz came to Colorado State University in 2005 after working as a professor at the University of California, San Francisco while directing a biomechanics laboratory at San Francisco General Hospital. It was his experience at SFGH that motivated Puttlitz to try to design a wireless fracture monitoring system that ultimately would lead to better patient outcomes.

"My mission as a bioengineer is to have a positive impact on human health," says Puttlitz. "If we can develop this technology to the point where patients with difficult fractures experience less pain and have fewer long-term complications, then I think we will have fulfilled this goal."

Puttlitz and his collaborators have developed a new sensor that uses the changes in the load sharing between the implanted plate and healing tissue to assess whether the bone is healing correctly.

"The wireless sensor that we're developing will provide physicians with a more precise technique to assess how the healing in complicated fractures is progressing," says Puttlitz. "By engineering newer designs, we have been able to optimize the sensor's sensitivity and fully characterize its response to different forces."

A three-year, $900,000 grant from the National Institutes of Health was recently awarded to Puttlitz, principal investigator on the project, and Dr. Hilmi Volkan Demir, a physics and electrical engineering professor at Bilkent University in Ankara, Turkey. The investigative team also includes experts in human and veterinary orthopedic surgery. This grant enables them to continue exploring biomedical engineering applications of wireless radio-frequency microelectromechanical systems strain sensors.

As part of this novel study, they are developing and testing the use of telemetric sensors that have been shown to be a vast improvement over traditional radio-frequency structures.

"Our laboratory data indicate that we can achieve the maximum level of sensitivity and accuracy across a broad range of frequencies," notes Puttlitz. "We are ready to start designing studies for human use." ■

> "Monitoring the strain on a plate as a fracture heals, and doing it in real time from remote locations, will give physicians the data they need to help design optimal treatments for patient healing."

Christian Puttlitz *is associate professor of mechanical engineering and a faculty member in the School of Biomedical Engineering. He and his wife have one daughter. The family enjoys all the outdoor activities that Colorado has to offer, such as hiking, camping, and traveling around the Rocky Mountains.*

Team Studies Impact of Toxic Chemicals on Human Health

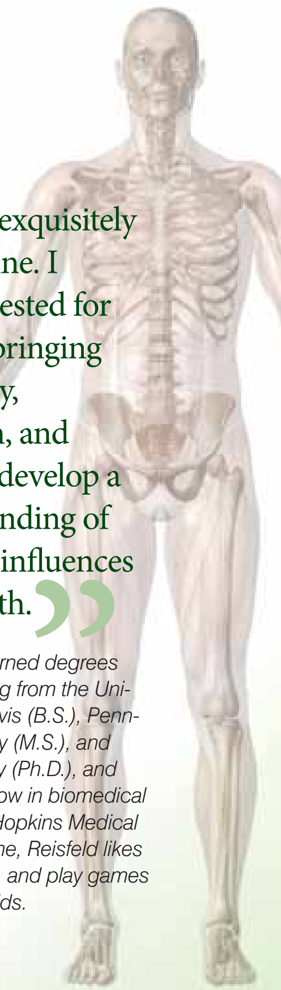
Chemical and biological engineering Professor Brad Reisfeld is leading a multidisciplinary team at Colorado State University and Mississippi State University to conduct risk assessment of toxic chemicals and develop new ways to test people for exposure to pesticides and insecticides. These widely used organophosphates are cholinesterase inhibitors with characteristics like nerve agents – not as potent but affecting many of the same systems – that can have significant neurological impact on children's brains. People of all ages are routinely exposed to these toxins; they are common residues on food and surfaces, and also leach into our nation's water systems where conventional treatment does not always remove all of these compounds or their byproducts.

Since the body can change these chemicals as they are absorbed, toxicologists must examine the chemicals themselves and the compounds into which they break down before they can begin to assess their impact on humans. Their task is further complicated by the fact that there are more than 40 OP insecticides on the market; as a result, people are exposed to a wide variety of mixtures, and more complex and comprehensive analyses are necessary.

Under a $748,600 grant funded by the Environmental Protection Agency's Science to Achieve Results Program, Reisfeld and his colleagues in CSU's Quantitative and Computation Toxicology Research Group are developing a software tool to interpret biomarkers of human exposure to select OP pesticides and insecticides. Utilizing epidemiological data from the National Health and Nutrition Examination Survey, they are creating a computer-assisted framework that utilizes biomarker data to characterize and elucidate human exposure to these chemical mixtures.

Along with the modeling and simulation activities at CSU, the project team at MSU is acquiring new types of data on rodent exposures for use in model testing and validation. "What we have learned so far is that the models we have developed agree well with the data gathered by previous investigators," Reisfeld explains. "We are now reaching a point where we can extend our analyses to gain new insights into OP insecticide exposures and their impacts on human health."

The next phase involves a more focused study utilizing California health data to see if the model can predict the data gathered on children of farm workers. "Ultimately, we anticipate that this tool will be used by the EPA to better evaluate exposure levels and provide a sound scientific methodology to inform risk assessment and regulation of these compounds," says Reisfeld. ■



"The body is an exquisitely complex machine. I have been interested for many years in bringing together biology, medicine, math, and engineering to develop a better understanding of environmental influences on human health."

Brad Reisfeld *earned degrees in chemical engineering from the University of California, Davis (B.S.), Pennsylvania State University (M.S.), and Northwestern University (Ph.D.), and was a postdoctoral fellow in biomedical engineering at Johns Hopkins Medical School. In his spare time, Reisfeld likes to exercise, cook, hike, and play games with his wife and two kids.*

CSU Alumna Tara Ruttley is Living Her Dream at NASA

"I am doing more than I had ever dreamed. Even though I'm not an astronaut (yet), I am having the time of my life at a job that is almost as great."

Tara Ruttley *is an associate program scientist for the International Space Station at NASA*

From the time she was a child in Louisiana, Tara Ruttley has been fascinated with space exploration and discovery. Since viewing her first space shuttle launch, she has followed NASA's missions and scientific achievements, particularly in the medical field. Now, through hard work and an unfailing sense of optimism, Ruttley is realizing her lifelong dream of taking human health research to new heights and depths.

Ruttley's first contact with NASA began when she led Colorado State University's American Institute of Aeronautics and Astronautics student design team in creating a novel gravity-independent, resistive exercise machine to help prevent muscle atrophy and bone weakness on long space voyages.

CSU's team of mechanical engineering, biology, and exercise physiology students named their creation the Constant Force Resistive Exercise Unit. Their unique design earned the team a trip to Johnson Space Center to participate in NASA's reduced-gravity flight program for undergraduates. This program gave the students an opportunity to test their exercise machine in a microgravity environment during KC-135 airplane flights that followed a trajectory of a series of parabolas over the Gulf of Mexico.

The experience working with mechanical engineers prompted Ruttley to change her focus and expand on her bachelor's degree in biology. "I decided I wanted to be able to build hardware based on meeting the needs of the world of physiology or medicine, and it had to be space-related. CSU gave me the support I needed to make this happen by encouraging me to pursue a master's in mechanical engineering with a biomedical concentration."

NASA's support was equally in evidence. Ruttley's team received a $70,000 NASA contract to build and test a bigger and better prototype. When she and her husband, Paul Colosky (B.S., M.S. Health and Exercise Science), graduated from CSU, they applied for and received a patent on the CFREU design.

Ruttley's next project with NASA involved testing their exercise equipment in an underwater habitat during a simulated space mission. The extreme environment of living in an underwater habitat for long periods of time serves as an ideal environment to simulate the day-to-day tasks of living and working in space. Ruttley had a chance to experience that firsthand when she joined a team of aquanauts on NASA's NEEMO 6 mission (NASA Extreme Environment Mission Operations) in 2004.

"The NEEMO team decided that the addition of an exercise machine to our mission would add to the space simulation component, since astronauts have to exercise daily in space," says Ruttley. "We needed something that could also be evaluated for potential use in space one day, so I suggested the CFREU, and we subsequently redesigned the machine that we had developed at CSU, rebuilding it with features that would be suitable for potential spaceflight. The NEEMO mission also tested technology such as environmental and physiological monitoring hardware that NASA had an interest in possibly pursuing for spaceflight. Three astronauts and I were living and working in an underwater habitat for 10 days, in a space analog environment. Use of the CFREU allowed us to integrate exercise into daily routine, as would be done in space, but it was also a way to get engineering feedback on how we might be able to improve

on the design further if it should potentially be used in space one day.

"The human body is designed to live in our gravity environment," continues Ruttley. "The thing I love most about spaceflight research on the human body is the fact that when the gravity vector is removed, the behavior of so many systems changes in a way that uncovers so many hidden components and pathways that we never realized existed. Understanding these hidden changes has led to meaningful improvements in life on Earth."

Ruttley's lead role in the CFREU project brought her to the attention of a new NASA office charged with developing medical hardware designed to mitigate issues experienced by astronauts who worked in microgravity conditions.

"I was hired by the Biomedical Systems Division as the only engineer with a biomedical concentration," she explains. Ruttley's first project was to develop a detector that can sense the presence of hydrazine (a toxic fuel for the International Space Station) on astronauts' spacesuits following a spacewalk. She then began working on different aspects of the exercise bicycle that is still in use by ISS crews.

Recently, Ruttley's role at NASA expanded significantly when she was named associate program scientist for the ISS. She and her team are involved in representing, evaluating, prioritizing, and reporting on all experiments conducted by the ISS crew. Around 150 experiments are currently on board the ISS, covering a wide range of human health, engineering, and science topics. Ruttley also coordinates projects for the ISS partners in Japan, Canada, Russia, and Europe, and communicates the latest scientific and technological discoveries to the public and professional groups.

Ruttley's achievements have earned her numerous awards. CSU presented her with the Graduate of the Last Decade Award in 2008, and NASA presented the Group Achievement Award to her team in 2009. The Council on Opportunity in Education recognized her as an inspiration to first generation and underrepresented students, naming her a 2007 National Tri-O Achiever Award winner.

Ruttley and Colosky are raising their daughter Anna-Marie in Houston, where Anna-Marie has been watching shuttle launches since she was 5 months old. Colosky is currently working with scientists at NASA Johnson Space Center to design an exercise machine for the next generation crew exploration vehicle.

A true advocate for education and consummate multitasker, Ruttley completed her Ph.D. in neuroscience in 2007 from the University of Texas Medical Branch in Galveston while concurrently working as an engineer at NASA Johnson Space Center. Ruttley serves as an adjunct professor at the University of Houston, teaching courses in human physiology with an enthusiasm she learned from CSU's anatomy instructor, Mark Frasier.

When young people ask her the secrets of her success, Ruttley, a former McNair Scholar, passes on a favorite quote from Ronald McNair: "Whether or not you reach your goals in life depends entirely on how well you prepare for them and how badly you want them." ■

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