Fall 2018

BUILDING NEW FOUNDATIONS

Research Magazine for Colorado State University

GAME CHANGER:
NEW VIRTUAL REALITY PROGRAM

EXQUISITE RESOLUTION:
Microscopes illuminate hidden, intracellular worlds

PLAGUE BACTERIA
may be hiding in common soil or water microbes

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AgInnovation Summit 2018

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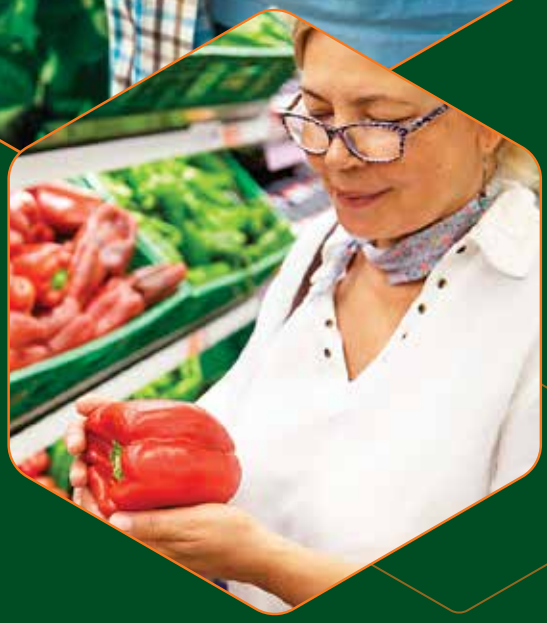

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COLLEGE OF AGRICULTURAL SCIENCES
VICE PRESIDENT FOR RESEARCH

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ON THE COVER

The new Chemistry Research Building provides 60,000 square feet of hood-intensive lab space, integrating collaborative student and faculty research across multiple areas of chemistry. Photo by Bill Cotton.

Send comments, news, or story tips to:
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BUILDING NEW FOUNDATIONS

Research Magazine for Colorado State University

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State of Research

Dear Friend,

Knowledge creation and translation are thriving at Colorado State University! Led by a vibrant faculty and staff of scholars and their students committed to pursuing their ideas and making a difference in our world, we have prepared ourselves for great things ahead. Our research enterprise is a strong engine with more than $300 million in annual expenditures since 2010, producing high-impact knowledge products of discovery and application and working on the ground to make an impact with our research in local communities and across the world. We have created rich partnerships that will facilitate our continued impact, including with our beautiful city of Fort Collins and community business and civic stakeholders, creating a unique innovation ecosystem that was recently recognized as a place of Innovation and Economic Prosperity by the Association of Public and Land-grant Universities.

CSU's research impact is widely felt across our planet and touches unmet needs in agriculture, health, energy, and the environment. The land-grant ethos is strong in our pursuit in these areas, always seeking to nurture deep understanding of our world with the passion to make an impact. We also recognize that impact requires development and attention to scaling ideas to practice and have mature assets, such as the Energy Institute Powerhouse Campus and the Infectious Disease Research Center, to meet these challenges. These, and other areas, are supported by strong patent production and the creation of new companies that can take CSU ideas to market. These also provide fertile grounds for training a new workforce ready to take on these challenges as they look at new careers ahead.

We recognize that to thrive, we need to nurture all of the elements that help ideas grow. We are establishing best practices across our research enterprise to facilitate the pursuit of these dreams with diverse sponsors and investors from government, foundations, donors, and industry. To help drive our next chapter of discovery and impact, we recently launched a new research and scholarly success initiative that will prioritize our investments around providing new opportunities for our research community to come together and pursue new solutions and ideas that will dramatically prepare us for future research endeavors. Early investments in this initiative have been highly successful, including the Catalyst program that enables new teams of researchers to come together to pursue grand challenge problems; new investments in core research infrastructure; and a new VPR graduate research fellowship program.

In this inaugural edition of our new research magazine, we are proud to highlight just a few of the exciting things we are doing, showcasing new ideas and actions and the thought leaders and students on campus who inspire us. We hope it inspires you too.

Go Rams!

Alan S. Rudolph, Ph.D., M.B.A.
Vice President for Research

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THREE-MINUTE CHALLENGE

winners are 2018-19 research fellows

by Lauren Klamm

(continued on next page)

A three-minute timer loomed over 36 graduate students competing for a spot in the Vice President for Research Fellowship on Feb. 12, 2018.

The 16 participants in the Three-Minute Challenge who were selected to become VPR fellows will receive $4,000 in scholarship and travel support. Fellows will also participate in professional development workshops, mentorship, leadership, and engagement opportunities over the 2018-2019 academic year.

As students quickly summarized their research, judges from across the University and from local industry scored on criteria associated with the content and comprehension of the presentation, as well as students' effective engagement and communication skills.

TALENTED AND DEDICATED

"CSU students are extremely talented and dedicated, and it was my distinct privilege to witness their success at the Three-Minute Challenge," said Ellen Fisher, assistant vice president for research and lead coordinator of the Fellows program. "Every one of the graduate students who participated demonstrated intense passion and outstanding ability to communicate their research to a broad audience."

This initiative was created in 2016 by the Office of the Vice President for Research's Research and Scholarly Success Initiative to support excellence in graduate research and scholarly works and to promote cross-college and cross-department collaborations. Participants in the Three-Minute Challenge were selected from the Colorado State University Graduate School's Graduate Student Showcase.

"Our goals for the VPR Fellowship program are to provide a transformative leadership experience and to help prepare the next generation of diverse, innovative creators for future stages of their careers in the global marketplace," said Alan Rudolph, vice president for research.

THE 2018-19 VPR FELLOWSHIP COHORT

A.J. Brown

- Three-Minute Presentation: "Mitigating Adverse Effects of Soil Salinity on Global Crop Production: New Approaches to Irrigation and Water Table Management"

Cody Carrell

- Three-Minute Presentation: "3-D-Printed Rotational Manifold for Point-of-Care Salmonella Detection"

Jimikaye Courtney

- Three-Minute Presentation: "Rescuing Our Rescuers"

Nora Flynn

- Three-Minute Presentation: "Making the Most of Colorado Water with Sustainable Farming Practices"

Maybellene Gamboa

- Three-Minute Presentation: "A Roadmap for Reintroductions to Resurrect Our Lost Ecosystems"

Mohammadhasan Hedayati

- Three-Minute Presentation: "A Slick Solution to a Sticky Problem – Blood Clots on Implant Surfaces"

Elle Holbrook

- Three-Minute Presentation: "Man's Best Friend: Integrating Human and Animal Big Data to Understand Disease"

Ashlie Johnson

- Three-Minute Presentation: "In the Eyes of a Child: A Deeper Look into Food Advertising for the Children of Nepal"

Sarah Leichty

- Three-Minute Presentation: "On the Cutting Edge of Tillage Research: Stabilizing Soil Carbon for Resilient Farming"

Frank Marrs

- Three-Minute Presentation: “Who Influences Whom in Environmental Politics?”

Clifton McKee

- Three-Minute Presentation: “Bad Roommates? Inferring Bacterial Interactions in Coinfected Individuals”

Brian Mitchell

- Three-Minute Presentation: “Does Fruit Cluster Pruning Improve Organic Tomatoes in High Tunnels?”

Kayla Nuss

- Three-Minute Presentation: “Assessing the Heart Rate and Energy Expenditure Accuracy of the Apple Watch Series 1 and the Fitbit Charge HR”

Alyx Shigenaga

- Three-Minute Presentation: “Agriculture in a Changing Climate: Preventing Heat-Induced Plant Disease Susceptibility”

Ingrid Slette

- Three-Minute Presentation: “Don’t Forget Your Roots: Gaining a Deeper Understanding of Ecosystem Responses to Drought”

Maggie Weinroth

- Three-Minute Presentation: “Fingerprinting: The Hunt for Superbugs in Livestock”

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Colorado State University graduate student Kayla Nuss competes in the Vice President for Research Three-Minute Challenge, Feb. 12, 2018.
Credit: Bill Cotton/CSU Photography

Plague bacteria may be hiding in common soil or water microbes, waiting to emerge

by David Markman

Editor's Note: David Markman, a Ph.D. candidate at Colorado State University and a Vice President for Research Graduate Fellow, wrote this piece for *The Conversation* in February 2018. Colorado State is a contributing institution to *The Conversation*, an independent collaboration between editors and academics that provides informed news analysis and commentary to the general public.

Children at a school in Antananarivo, Madagascar, during a plague outbreak, Oct. 3, 2017. *AP Photo/Alexander Joe, File*

Plague is a highly contagious disease that has killed millions of people over the past 1,400 years. Outbreaks still sporadically occur in as many as 36 countries worldwide. Perhaps one of the greatest remaining mysteries surrounding plague is how and where it survives between outbreaks.

Like many other pathogens, the bacteria that causes plague, *Yersinia pestis*, cannot survive for long periods of time in the environment without protection. Despite this, plague outbreaks continually recur in many locations. This suggests that the bacteria are able to find refuge and survive for several years after an outbreak before reappearing, seemingly out of nowhere, and starting another infection cycle. Understanding where they hide and how they survive and reappear is extremely important for preventing future outbreaks.

Our recent study conducted at Colorado State University's Infectious Disease Research Center shows that amoebae – common soil and waterborne micro-organisms that eat bacteria – could play a role in protecting this dangerous

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pathogen between outbreaks. This relationship may give plague bacteria a place to replicate and bide their time before conditions are right for another outbreak to occur.

AN ANCIENT AND MYSTERIOUS KILLER

Plague has caused three deadly worldwide pandemics. The Plague of Justinian killed millions of people in the Byzantine Empire between the years 541 and 750. Next, the notorious Black Death ravaged much of Asia and Europe from 1330 to 1480, killing approximately 30 percent of all Europeans. Most recently, plague reappeared in China in 1855 and spread to ports worldwide over the following century, killing some 12 million people. Thousands of small outbreaks have occurred between and following these events.

Part of what makes understanding plague so difficult is its ability to infect more than 250 mammals and many species of insects via multiple routes of transmission. For example, it can be transmitted through a bite from an infected flea or by inhaling bacteria coughed up by an infected animal.

Plague outbreaks also occur across very diverse environments. They range from prairie ecosystems in the Western United States to highland forests in central Madagascar and temperate deserts in western China. The fact that few characteristics unify all of these regions may indicate that plague bacteria use different survival mechanisms in each location. However, one unifying factor is the presence of amoebae in the soil.

ABUNDANT HOSTS

Amoebae are single-celled microorganisms that live in almost all soils and water bodies across the globe. They feed on bacteria, but scientists have discovered that some bacteria are resistant to being digested by amoebae. Interestingly, they include plague's most closely related ancestors, *Y. pseudotuberculosis* and *Y. enterocolitica*.

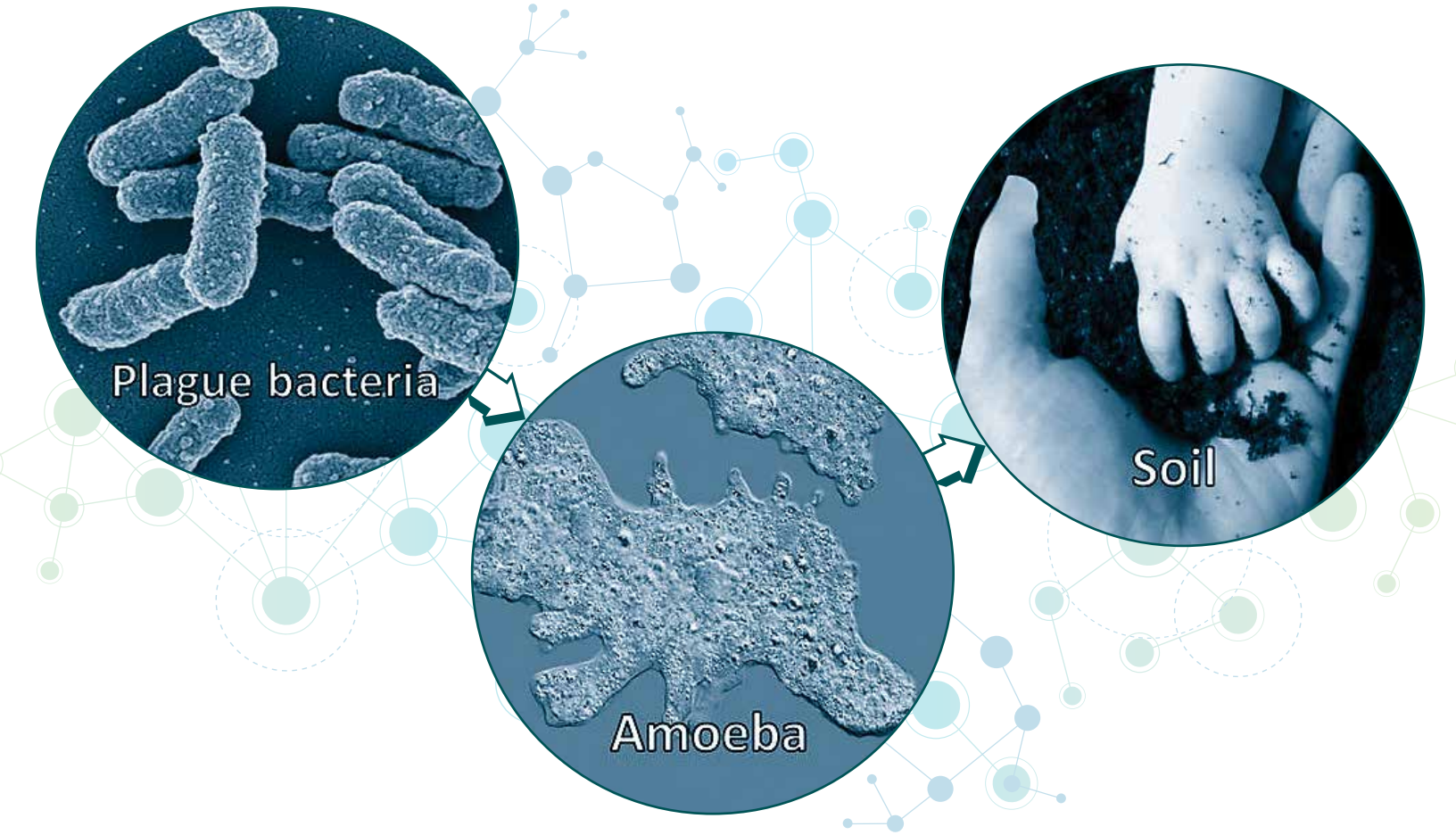
Living in the soil, alongside amoebae, required these bacteria to evolve ways to avoid being eaten. Given this evolutionary history, our research team hypothesized that when plague evolved from *Y. pseudotuberculosis* approximately 10,000 to 40,000 years ago, it may have retained the ability to survive inside amoebae.

Global distribution of natural plague regions

as of March 2016

Potential plague regions based on current and historical data

Source: World Health Organization 2016



Credit: David Markman

NATURAL DISEASE INCUBATORS

To test our hypothesis, we collected soil samples from prairie dog burrows in northeastern Colorado, because prairie dogs are known hosts of plague. This involved finding prairie dog colonies that were experiencing a plague outbreak and inserting a long flexible probe into burrows to collect samples from deep within, while avoiding potentially infectious fleas emerging from the burrow. After isolating amoebae from the soil in our lab, we identified five species to use in future experiments.

The next step was to determine how plague bacteria interacted with the various amoeba species we identified. In a special high-containment laboratory designed to prevent dangerous pathogens from accidentally escaping, we combined amoebae and various strains of plague bacteria obtained from the U.S. Centers for Disease Control's laboratory in Fort Collins, Colo. We used a genetically altered strain of plague that fluoresces neon green to determine if and when amoebae were ingesting plague bacteria by viewing them under a high-powered microscope.

Next, we used a transmission electron microscope to obtain even more detailed images of the inside of infected amoebae. This revealed that the plague bacteria were alive and possibly replicating. To confirm this, we selectively cracked open the infected amoebae at different time points to compare the number of bacteria inside. Our results are the first to demonstrate that plague bacteria are able to survive and replicate inside amoebae.

The next challenge is understanding how long plague bacteria can survive in amoebae. Part of an amoeba's life cycle includes transforming into a cyst – a form in which it

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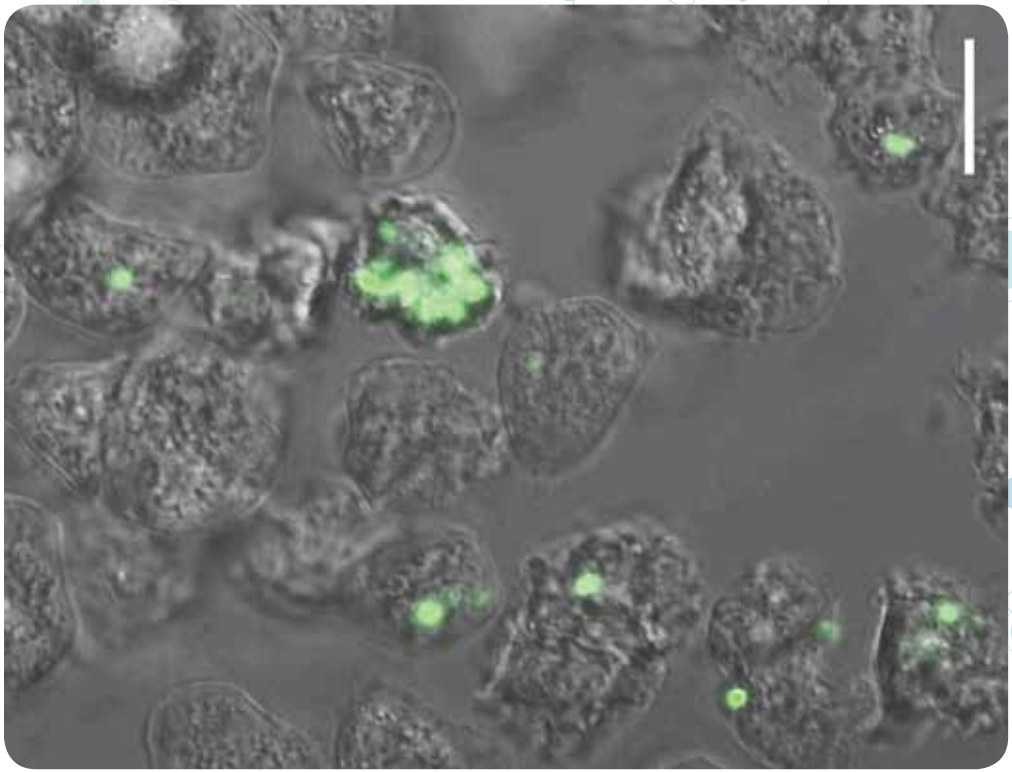


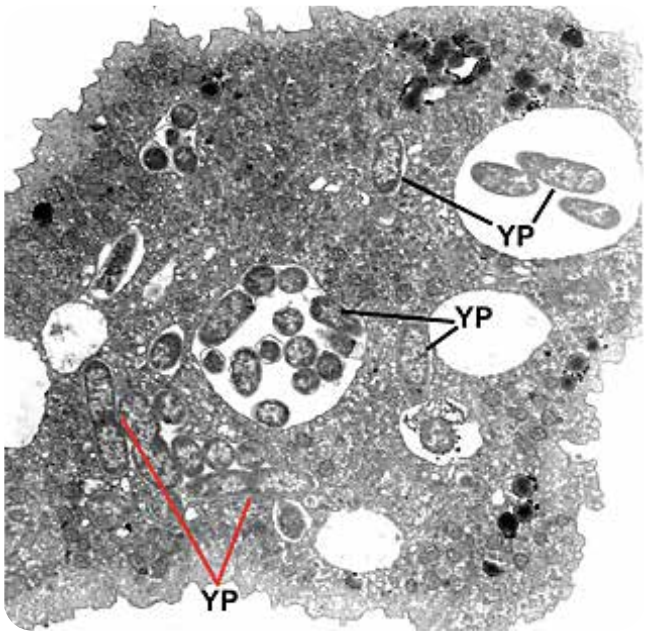
Fluorescent plague bacteria inside amoebae. Scale bar indicates 30 microns. *Credit: David Markman*

can lie dormant for up to 20 years before it reanimates and resumes eating and multiplying. This enables it to survive during adverse environmental conditions, such as extreme temperatures or drought. If plague bacteria can survive inside dormant amoebae cysts for many years, this could explain how and where they persist between outbreaks.

AMOEBAE AS DISEASE TRAINING GROUNDS

Amoebae are already recognized for their potential role in protecting, amplifying, or guiding the evolution of more than 225 other bacteria, viruses, and fungi. Famously, it is hypothesized that they played a role in the first known outbreak of Legionnaires' disease in 1976 by providing a protected space for *Legionella* bacteria to multiply. Amoebae can also act as transport vessels for pathogens, enabling the bacteria to enter and infect new hosts.

Some scientists hypothesize that amoebae can guide harmless bacteria to evolve into dangerous pathogens. The reasoning behind this is that amoebae are very similar



Transmission electron microscope image of plague bacteria inside an amoeba. YP indicates *Yersinia pestis* (plague bacteria). The red lines indicate bacteria that appear to be replicating. *Credit: David Markman*

to macrophages – the white blood cells in mammals that are responsible for finding and killing invading bacteria. If harmless soil bacteria evolve the ability to survive and multiply within amoebae, then they might also be able to do so in the white blood cells that comprise our immune system, thereby becoming new human pathogens.

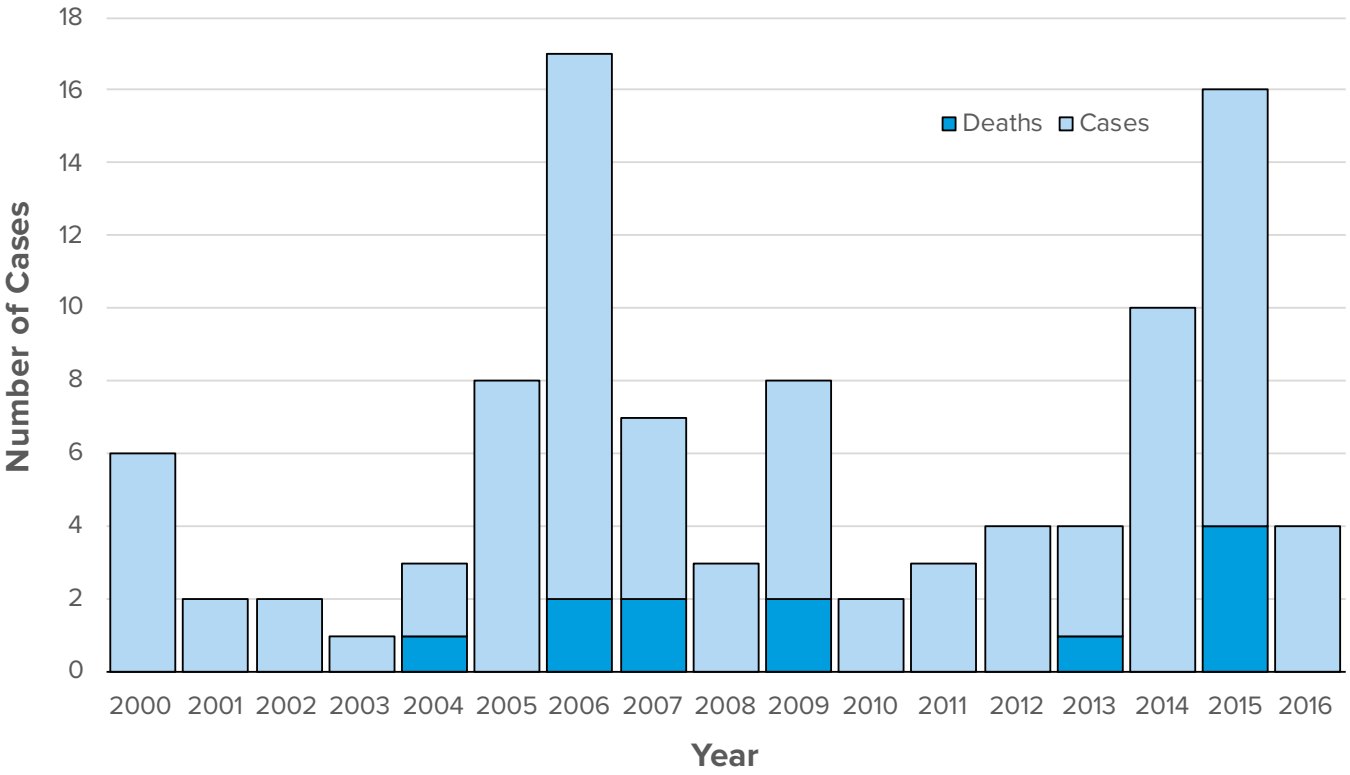
Did this ability to avoid destruction and multiply within white blood cells arise from ancient soil-borne bacteria learning to exploit amoebae?

The idea of amoebae acting as "training grounds" for the evolution of dangerous pathogens such as plague conforms with what scientists already know about human plague infections. In human cases, plague is engulfed by white blood cells, but has evolved a way to avoid destruction by escaping the portion of the cell responsible for digestion. Then, it multiplies inside the white blood cell before exiting and disseminating throughout the human body.

This process is nearly identical to the process our research team observed in amoebae. Did this ability to avoid destruction and multiply within white blood cells – which is found in many human pathogens – arise from ancient soil-borne bacteria learning to exploit amoebae? Perhaps practice really does make perfect.

Pathogen-harboring amoebae could be serious public health threats, since we currently have no way to efficiently monitor them in the environment or predict when they might release infectious agents. They may also pose a biosecurity threat that a hostile power could use to disperse existing pathogens or create new ones. We need more research on the complex interactions that allow pathogens to survive, disseminate, and evolve so that we can learn to predict and prevent disease outbreaks and their consequences.

Human plague cases and deaths in the United States,
2000-2016



Source: CDC

GAME CHANGER:

Virtual reality program to transform how students learn about the human body

by Rhea Maze

One former student's simple desire to help his peers better understand how the human body works has unexpectedly grown into a unique virtual reality program with the power to revolutionize medical education.

The human anatomy virtual reality project allows students to manipulate magnified structures of the human brain and nervous system and visualize functional signaling of neural networks. *Credit: John Eisele/CSU Photography*

Natascha Heise, a biomedical sciences Ph.D. candidate, tests out CSU's new human anatomy virtual reality program, which will be housed in the new Health Education Outreach Center. *Credit: John Eisele/CSU Photography*

In early 2017, three people in the Department of Biomedical Sciences made it possible to visualize and manipulate magnified models of the human brain and nervous system in all dimensions. The team is now working to expand the program to include all the structures of the body.

The groundbreaking program, with multiple features that set it apart from others, will be housed in the new Health Education Outreach Center and used not only to enhance human anatomy education, but also to help CSU become a landmark institution for cutting-edge virtual and augmented reality technology.

A SERIES OF FORTUNATE EVENTS

When Brendan Garbe, human anatomy teaching lab coordinator in the Department of Biomedical Sciences, was a graduate student, he noticed two kinds of students in his anatomy classes: those who looked at illustrations of anatomical cross sections and immediately understood them, and those who continuously struggled to comprehend how they translated to real life.

"Neuroanatomy students currently learn a lot of structure from two-dimensional cross sections, but they have to picture the systems in 3-D in order to understand complete circuits. I saw that many students had different methods of spatial understanding and couldn't grasp these concepts from flat textbook pictures," Garbe said. "I wanted to try and find a novel way to make all of the spatial relationships more intuitive."

Garbe approached Tod Clapp, an assistant professor in the Department of Biomedical Sciences and head of its human anatomy program, with his idea to improve anatomy curriculum and began working on it as part of an independent study course. He started by making screen-capture videos from an anatomy iPad application in order to better incorporate muscle motions into the curriculum.

Around the same time, Clapp was shown some impressive virtual and augmented reality technology by Kaden Strand, the former virtual reality lead for the Office of the Vice President for Research. When he learned of the Virtual Reality Symposium and Hackathon the office was sponsoring in October 2016 as part of its Virtual Reality Initiative, he talked Garbe into attending.

At the Hackathon, teams had two days to create an immersive virtual experience that includes a teaching, research, or outreach component. Garbe's team won third place with a project showing the interconnectedness of spatial neurologic circuits in 3-D.

"Before going to the Hackathon, I thought virtual reality was just for show and video games," Garbe said. "Then I put the headset on and realized that I was completely wrong – it's a night-and-day difference. The problem is, unless you put the headset on, people can't describe to you what it's like – it's impossible. Even videos can't get across what it's actually like."

After Garbe's team re-created a very difficult-to-understand neurological system in just 48 hours, Clapp was convinced that virtual reality was worth pursuing. He recruited Chad Eitel, a computer scientist and research associate in the Department of Biomedical Sciences, to be the team's lead developer in January 2017 – and the rest is history.

"It was very lucky how it all happened," Clapp said.

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ON THE CUTTING EDGE

One of the program's most powerful tools is its capacity to have multiple people interact in the same virtual space at the same time, providing endless opportunities for students, clinicians, etc., to collaborate, teach, and learn.

"What we're hearing back from people in the industry is that they're amazed we've programmed this in multiplayer, which means I could put the headset on and be in the exact same room as someone in another state or country, in real time," Clapp said. "And the cross-sectional piece of our program is what any anatomist is going to see and say, 'OK, it was a neat program until I saw this – now I need it.'"

The team also plans to create interactive lesson plans and teaching modules that will allow groups or individuals to learn from a virtual instructor on demand, as well as virtual lectures that students can access at home using their smartphone and a Google Cardboard headset.

The young program has already led to a variety of cross-University collaborations. In addition to the Department of Biochemistry and Molecular Biology, the School of Biomedical Engineering used the program to test the design of a new research device. The team is also in talks with community organizations to create a partnership that would better inform patients about surgery. And, the Department of Biomedical Sciences' animal anatomy program used the equipment to test its longstanding Virtual Canine and Equine Anatomy program, which consists of actual anatomical

The list of possible applications for the program's educational features extends well beyond medical studies.

THE 'AHA!' MOMENT

Writer Rhea Maze gets a virtual tour of nerve pathways

Headset on, I watched an avatar of developer Chad Eitel enlarge, shrink, and move a virtual cadaver all around the room as he walked me through the visual field, a neural circuit that many students find difficult to learn. The virtual room was bright, clean, and inviting, with wooden beams and a high glass ceiling exposing a blue sky dotted with clouds. Colorful lines coursed through the virtual cadaver's body, representing the routes that nerve pathways travel.

"I once watched Tod Clapp ask his class what would happen to a person's vision if there was a tumor here," Eitel said as he placed a gray "lesion" disc onto a section of the virtual cadaver's brain. As he did so, the colorful representation of its four quadrants of vision clearly showed blindness in one eye. "No one had an answer, and everyone was trying to figure it out – but with this program, rather than having to imagine this scenario by studying textbook drawings, students can see how it actually happens in 3-D."

While I took virtual notes and labeled objects via my hand controls, Eitel showed me an enzyme molecule rendered in 3-D with the help of Aaron Sholders, an undergraduate program coordinator in the Department of Biochemistry and Microbiology. As we walked around it, I flashed back to being an 11th-grader and having to spend my lunch hour in "formula club" for bombing a chemistry exam. I couldn't help but think how helpful the ability to tease apart a molecule and actually see how it interacts with other molecules would have been to me back then.

Others who have tested the program have had similar reactions. "Every physician we've gotten in here asks, 'Why couldn't this have existed when I was going through medical school?'" Garbe said. "It's almost always the first thing they say. We believe this could be a cornerstone of medical education in the next decade."

Check out the Human Virtual Anatomy Project on Facebook at facebook.com/CSUHumanVirtualAnatomy.

Chad Eitel, a research associate in the Department of Biomedical Sciences, demonstrates the human anatomy virtual reality program in development at CSU. *Credit: John Eisele/CSU Photography*

models created by high-resolution photographs. The animal anatomy team is working to move this widely used and successful program into a virtual space in order to make it a more interactive, multidimensional learning experience.

The list of possible applications for the program's educational features extends beyond medical studies. "We can use this program to visualize anything," Garbe said. "It's more about how people can work together, interact, and learn. Our initial goal wasn't to do something in virtual reality, it was to be able to convey information in a way that we didn't have the tools for until we started using it."

The program is on track to be fully functioning by Spring 2019 and will occupy about 4,000 square feet of space in the new Health Education Outreach Center, slated for completion in December 2018. Fifty stations could accommodate up to 200 students learning in virtual reality at any given time, allowing them to take concepts learned in a virtual space and apply them in the actual lab where they will get the tactile experience of putting it all together.

"I've done a complete 180," Clapp said. "I've never been part of something that's moved this fast or gotten the attention of so many people. When we put students in there, I'm amazed to hear them say how it's helping them make sense of things. People are a little reluctant to try it out at first, but once they do, within seconds they have big grins on their faces, and they will stay in there for half an hour when they have somewhere to be."


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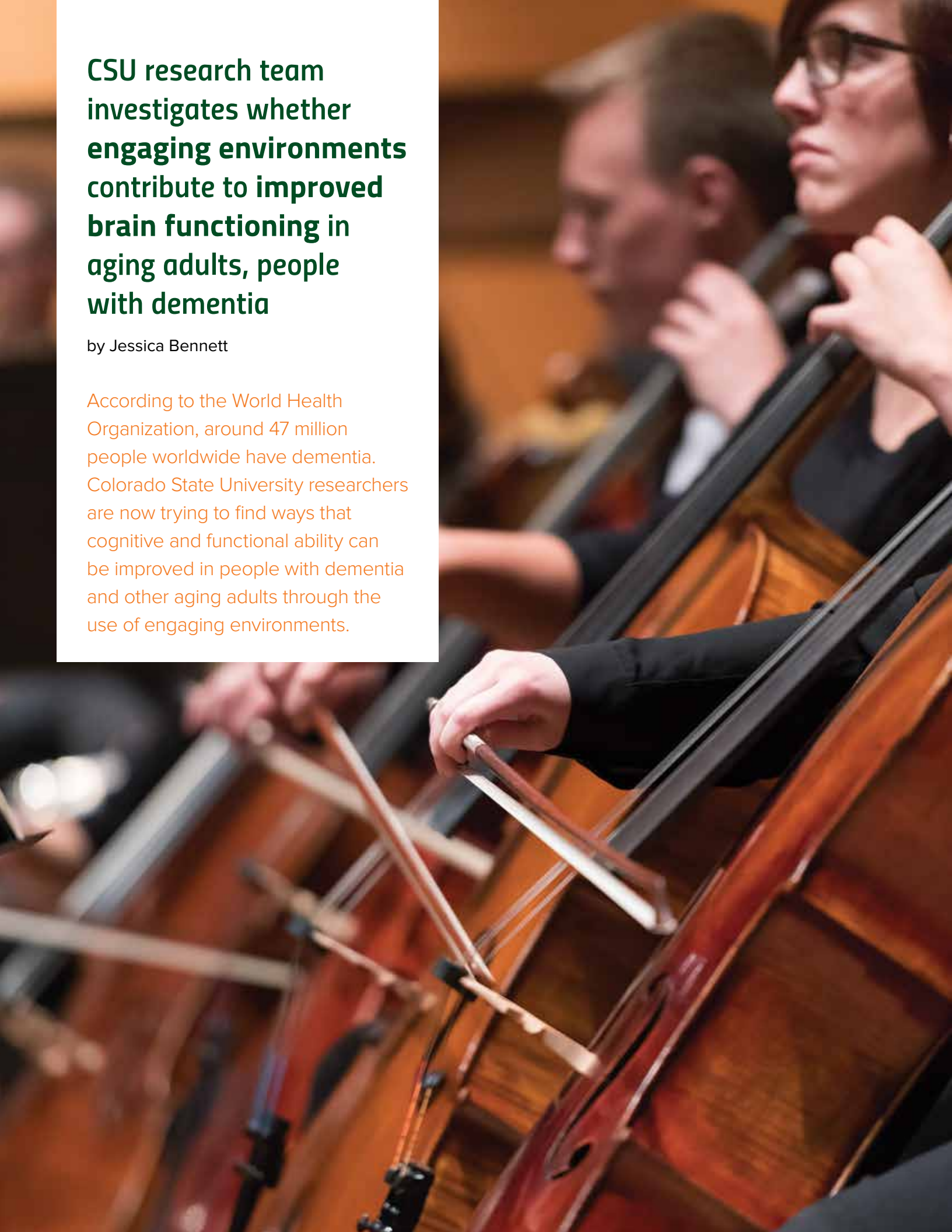
IMPROVING RESEARCH FACILITIES ACROSS CAMPUS

- **Biology and Chemistry Research Buildings** – These buildings, part of the growing campus research mall, include collaborative spaces for students, designed to promote creativity and collaboration, as well as classrooms with connected lab space and state-of-the-art research facilities for faculty and students to work side by side.
- **JBS Global Food Innovation Center in Honor of Gary and Kay Smith** – This addition to the existing Animal Sciences Building will enrich Colorado State University's teaching and research in meat sciences, as well as offer a space for industry collaboration through continuing education and training and equipment development and testing. Students will learn about meat processing in a hands-on environment that is not currently available in existing CSU facilities.
- **C. Wayne McIlwraith Translational Medicine Institute** – The institute will bring together educators and innovators from academia, industry, public agencies, and other entities to pursue development of promising medical technologies, with special attention to those with potential for commercialization. Its state-of-the-art equipment, research space, clinical resources, and conference areas are designed to support this collaboration among animal and human medical specialists. John and Leslie Malone provided the transformational lead gift of $42.5 million to establish the research institute and Princess Abigail K. Kawananakoa of Hawaii donated the institute's naming gift of $20 million.
- **Richardson Design Center** – A creative space for students and faculty in many programs including interior design, design and merchandising, landscape architecture, art, engineering, product development, entrepreneurship, construction management, and others. Nancy and Curt Richardson have pledged $8.1 million to create the design center, which is scheduled to open in January 2019.
- **Health and Medical Center** – The new home of the CSU Health Network provides a full range of medical, counseling, and health education and prevention services that are open to all enrolled CSU students, regardless of their health insurance plans. The 113,000-square-foot, four-story building also houses a range of services for CSU faculty, staff, and community members.
- **Avenir Museum** – 10,000 square feet have been added and the existing 8,000 square feet have been renovated to now contain three galleries, classroom and seminar space, a library, a conservation laboratory, and expanded collection storage and management areas.
- **Arboviral Infectious Disease Laboratory** – The new Foothills Campus addition will house researchers who conduct basic and applied research aimed at the overall goal of reducing the global burden of infectious diseases, in particular those that are emerging and transmitted to humans by arthropods or zoonotic reservoirs.

CSU research team investigates whether **engaging environments** contribute to **improved brain functioning** in aging adults, people with dementia

by Jessica Bennett

According to the World Health Organization, around 47 million people worldwide have dementia. Colorado State University researchers are now trying to find ways that cognitive and functional ability can be improved in people with dementia and other aging adults through the use of engaging environments.



IT ALL STARTED AT THE SYMPHONY

Deana Davalos

This research team grew out of the initial data from a study known as the B-Sharp program. In the B-Sharp program, people with dementia and their caregivers were given passes to five concerts performed by the Fort Collins Symphony.

"We found that engagement in the B-Sharp program resulted in improved performance on a series of cognitive tests after a nine-month period," explained Deana Davalos, associate professor in the Department of Psychology at CSU and the director of CSU's Aging Clinic of the Rockies. "This happened in spite of including participants with a neurodegenerative disorder."

This study's promising results led to research that is now underway in the "Enriched Environments for the Healthy, Aging Brain" project, part of the Catalyst for Innovative Partnership Initiative funded by CSU's Office of the Vice President for Research. The project includes researchers from the colleges of Natural Sciences, Liberal Arts, and Health and Human Sciences.

"In our continued studies," said Davalos, "we hope to better understand the mechanisms of enriched environments that are most beneficial for the aging brain. We're interested to see whether we can deliver the programs in other ways, such as through virtual reality and other types of activities, without losing effectiveness."

THE NEXT MOVEMENT

Lindsey Wilhelm

The research team includes Davalos; Jeni Cross, associate professor in the Department of Sociology at CSU and a co-director of the Institute for Research in Social Sciences; Lindsey Wilhelm, assistant professor of music therapy and a coordinator of clinical practicum in the School of Music, Theatre and Dance; and Aga Burzynska, an assistant professor in the Department of Human Development and Family Studies, as well as the Molecular Cellular and Integrative Neurosciences graduate program. Other faculty members include Meara Faw, Laura Malinin, and Wendy Wood. The University researchers also have a partnership with Kaden Strand of Blue Penguin LLC.

Agnieszka (Aga) Burzynska

"This team offers the opportunity to collaborate and interact with researchers from across campus with the end goal of improving interventions for aging adults, such as people with dementia and their caregivers," explained Wilhelm. The project will use stimulating and immersive environments to test the effects on cognitive function.

"I am especially excited about the opportunity to carry out some of the complex and immersive interventions in people's homes, using virtual reality," said Burzynska.

Jeni Cross

The program includes many facets of immersive environments, including virtual reality, equine therapy, visual design, in-home music, and dance. "I'm a community sociologist," explained Cross, "and this program is community designed and implemented."

The program will use the various environments to stimulate the brain, measuring the cognitive function of the individuals before and after the stimuli. A system called RBANS (Repeatable Battery for the Assessment of Neuropsychological Status) measures cognitive performance in 30-minute intervals by testing immediate memory, visuospatial memory, language, attention, and delayed memory. In addition to the cognitive tests, the individuals and their caregivers will periodically be given assessments to discern their moods, well-being, and daily functions.

THE GRAND FINALE

The team hopes to find a set of non-pharmacological interventions for aging adults, centered on engaging environments that can be used to improve the functioning and well-being of people with dementia and their caregivers. "In this project, we hope to find similar results to the B-Sharp program for other activities," said Cross. "I am specifically interested in examining how building social connectedness relates to health outcomes."

The study's findings will hopefully show how environmental stimulation helps us optimize our cognitive capacity and brain health as we age, indicate which environments are viable, and allow the team to create intervention plans based on interests and mobility of the aging population and people with cognitive impairment, such as dementia.

CSU annual research spending tops $338 million

by Mary Guiden

Colorado State University generated $338.4 million in research expenditures in Fiscal Year 2017, a boost of nearly 2 percent, which affirms the University's research prowess in the face of downward trends in national research support. CSU researchers also obtained a record 66 patents in that same timeframe, an indication of the University's strength in innovation.

This marks the 10th consecutive year that research expenditures at the University have topped $300 million. The $338.4 million total is up from $332 million in the previous year. Research expenditures include money from federal, private, state, and local organizations.

Alan Rudolph, CSU's vice president for research, said the numbers highlight the continued impact and performance of research at the University.

"Research is an integral part of our mission," he said. "CSU is sustaining our position among top-tier universities, and we've strengthened our position in some areas, based on the excellence of our faculty. We continue to address the unmet challenges of our day, including weather prediction and climate resiliency, translational medicine, and infectious diseases, through research conducted by our faculty and students."

EXPENDITURES UP FROM FEDERAL FUNDING

Federal funding of research at CSU increased by 16 percent, to $247.3 million. On the national level, federal funding of research and development held steady in recent years, according to the American Association for the Advancement of Science.

Rudolph acknowledged that research universities face challenges when competing for federal funding.

"Research is an integral part of our mission. CSU is sustaining our position among top-tier universities, and we've strengthened our position in some areas, based on the excellence of our faculty."

"Funding for science is experiencing uncertain times and, yet, the importance of science in key issues facing our planet and our nation has never been more critical," he said. "CSU has positioned itself well as an objective source of discovery and translation of science and will continue to contribute objectively to the dialogue."

Research spending on projects supported by the U.S. Department of Health & Human Services totaled $41.4 million, a slight increase from expenditures in the previous fiscal year of $37.3 million. U.S. Department of Defense-related expenditures were $58.8 million, a slight drop from $60.1 million in FY 16.

Expenditures supported by the National Science Foundation totaled $32.3 million in FY 2017.

TECH TRANSFER SETS NEW RECORDS

CSU Ventures, the University's technology transfer office, continues to set records.

The office negotiated 44 agreements with companies to license CSU technologies. In addition, researchers filed 101 invention disclosures and were issued 66 patents, nearly double the number from the previous fiscal year.

"We used to get a handful of patents issued each year; now, with the University's strong commitment to innovation and research, we see numbers in the 60s," said Todd Headley, president of CSU Ventures.

Licensing revenue for FY 17 totaled more than $3 million, and CSU Ventures also launched six new startup companies.

"We're continuing to evolve and to support the University as best we can," said Headley. "I'm really encouraged by CSU faculty and industry engagement. We continue to see excellent participation."

2017 RESEARCH AND INNOVATION

CSU WELL POSITIONED AS SOURCE OF DISCOVERY AND TRANSLATION OF SCIENCE

10th consecutive year research expenditures topped **$300M**

Federal funding of research increased by 16 percent to **$247.3M**

Expenditures supported by the National Science Foundation **$32.3M**

Licensing revenue totaled more than **$3M**

$338.4M in research expenditures

U.S. Department of Defense-related expenditures **$58.8M**

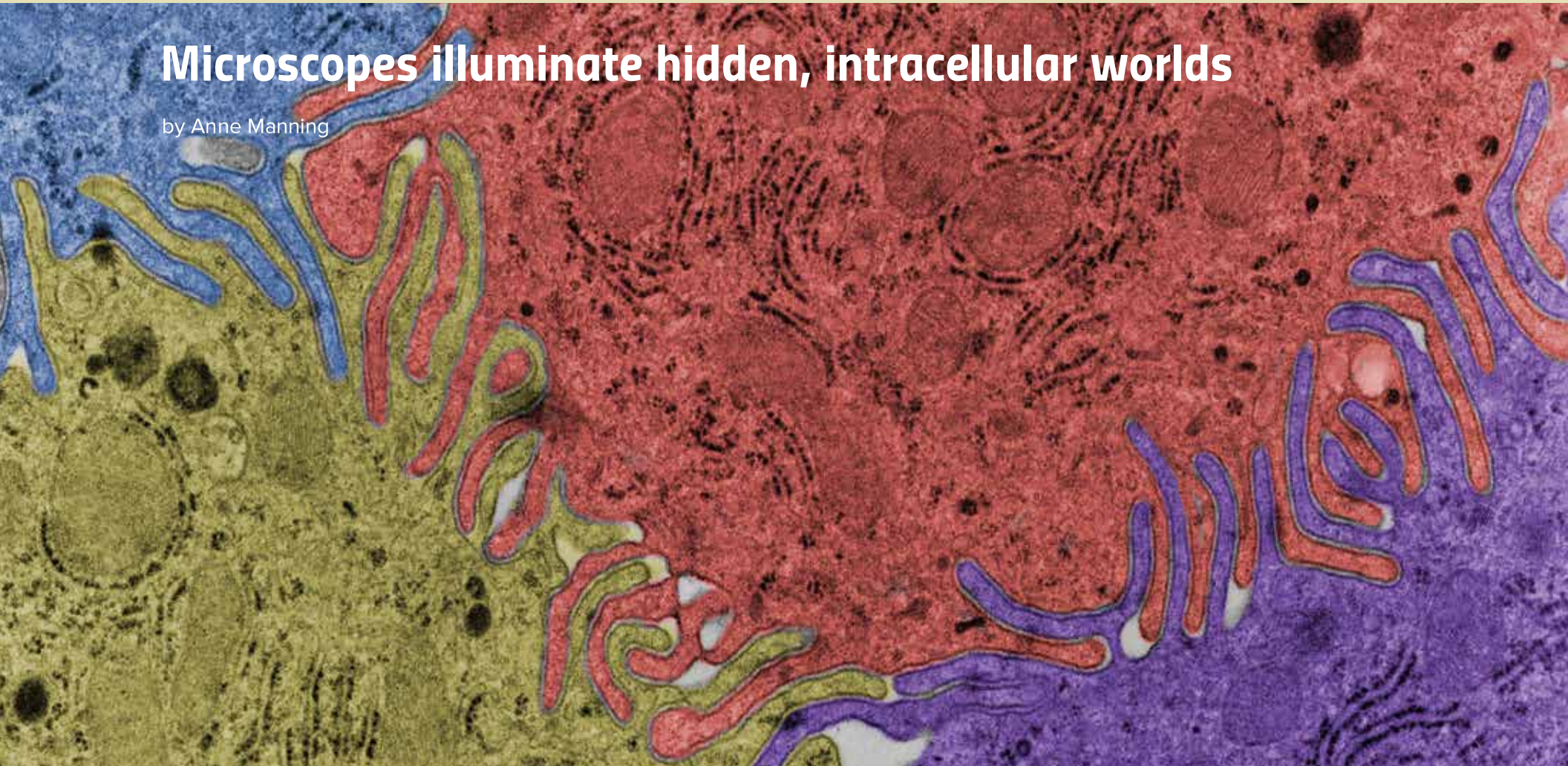
Research spending on projects supported by the U.S. Department of Health & Human Services **$41.4M**

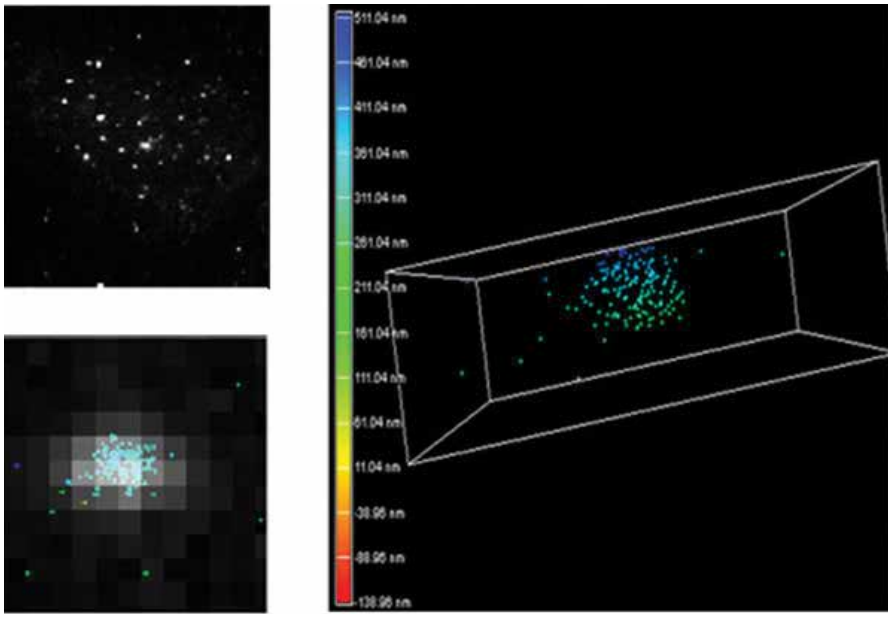
101 invention disclosures and **66 patents,** nearly double the number from the previous fiscal year

Exquisite resolution:

Microscopes illuminate hidden, intracellular worlds

by Anne Manning





Top left: A conventional fluorescence microscopy image of all the telomeres in a cell. **Bottom left:** A map of fluorescent probes detected by the STORM microscope, overlaying a single telomere from the conventional image. **Right:** the same map of probes from an individual telomere, enlarged and in three dimensions. *Credit: Chris Nelson/ Bailey Lab*

Like the plastic tips on shoelaces, telomeres are bits of genetic material that cap the chromosomes inside our cells. Damage to these protective caps is linked to disease, and scientists such as Chris Nelson are on a quest to know why.

Nelson, a graduate student in the lab of Professor Susan Bailey in the Department of Environmental and Radiological Health Sciences, is using a fluorescence-detection microscope at CSU to visualize and study telomeres that are much too small to see with the naked eye.

This powerful microscope, called a Total Internal Reflection Fluorescence-Stochastic Optical Reconstruction Microscope, is one of several instruments that make up CSU's Microscope Imaging Network.

The MIN, open to all University researchers, is a centrally funded consortium of research microscopes for live- or fixed-cell biological imaging. This resource gives scientists such as Nelson and Bailey access to cutting-edge equipment they'd otherwise have to buy or leave campus to find. The MIN is one of four Foundational Core Facilities supported by CSU's Office of the Vice President for Research.

"Without the MIN, our project would not have been possible," Nelson said. "There is enormous overhead associated with many specialized forms of microscopy, so it's important that we use these technologies as efficiently as possible for scientific discovery."

The TIRF-STORM, which retails for more than $300,000, can do superresolution imaging, a technique that skirts the natural diffraction limit of light to offer crisp images of things much smaller than cells.

In order to visualize their telomeres using superresolution, Nelson and Bailey first tagged them with fluorescent probes. "Conventional fluorescent microscopy of telomere-bound probes makes each telomere indistinguishable from the next – a fuzzy glowing dot, roughly spherical in shape," Nelson explained. "With STORM, each telomere becomes unique in shape and allows us to evaluate them at the level of the individual fluorescent probe such that we can determine how densely or loosely they are packed – a surrogate to how tightly folded the DNA is."

The MIN is led by Director Jeff Field, a physicist by training who also works closely with electrical engineering Professor Randy Bartels to develop new imaging techniques and instrumentation. "I love working on applying physics techniques and engineering tools to biological systems and working at that interface," Field said. "Every time I interact with someone who wants to solve a biology problem, I learn a little bit more – like what are the holes in imaging technology, and what are the things we'd like to do that don't exist yet?"

The MIN operates under a fee-for-service model; users pay for time and training on the microscopes. Like all the foundational cores, the MIN offers Ph.D.-level skills and knowledge, through Field and a team of experts, to educate users and help them decide which instrument they need.

(continued on next page)

DEEP ROOTS

The MIN is managed through the Department of Biochemistry and Molecular Biology in the College of Natural Sciences. It has been a centrally operated campuswide resource for nearly 10 years, but its history stretches back further than that.

Jim Bamburg, professor emeritus of biochemistry and molecular biology, founded the MIN and serves on its board of directors.

"In 2008, when the first call for research infrastructure applications came out from the (Office of the Vice President for Research), we put forward a proposal to bring together many of the dispersed microscope units on campus under a single committee," Bamburg said. "And we called this the MIN." Since then, the model has saved researchers, colleges, and departments hundreds of thousands of dollars in equipment purchases and service contracts. The MIN was officially named one of CSU's Foundational Core Facilities in 2015.

"As faculty, all of us know where our money comes from," Bamburg said. "Why shouldn't we do the most we can for everyone, with the money we have, since people are investing in us and want the best to come from our results?"

WHAT'S AVAILABLE?

As a result of its incremental history, MIN microscopes are scattered throughout different physical locations, including one at the Foothills Campus, as well as in the Molecular and Radiological Biosciences Building and the Anatomy/Zoology Building.

Among the offerings: two electron microscopes, three laser scanning confocal microscopes, a spinning disk confocal microscope, and two wide-field microscopes, as well as the superresolution TIRF-STORM that Nelson and Bailey use.

The TIRF-STORM and spinning disk microscopes detect fluorescence and are especially designed for live-cell imaging.

Advances in fluorescence microscopy have allowed scientists to visualize things, while they still are alive and dynamic, that are just nanometers in length. Such microscopes are sensitive to fluorescent probes – glowing tags that bind only to certain proteins of interest – that have opened new doors for targeted, intracellular studies.

"These are things we used to have to extract and purify, and see how they behaved in test tubes," Bamburg said. "Now, we can look at their behavior inside the cell. We can look at mitochondria, lysosomes, or even the nucleus of a cell."

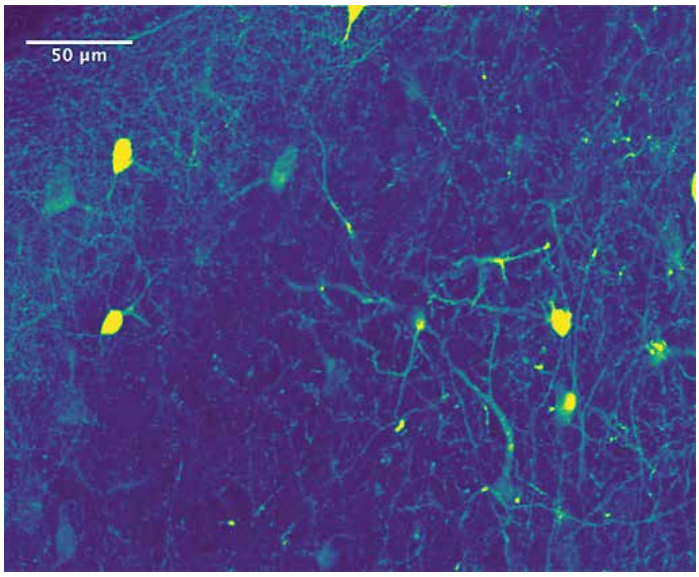
Electron microscopes, also available through the MIN, can go to much higher magnifications than fluorescence microscopes, but they're not useful for live-cell imaging because they would destroy the samples. Electron microscopy requires vacuum chambers and fixed-tissue staining with heavy metals. These microscopes offer high-resolution, molecular-level imaging.

CUSTOMIZED SOLUTIONS

In addition to providing access to commercial microscopes, the MIN can also provide pathways to customized instruments tailored to specific users' needs. Field consults with potential MIN users to determine whether the microscopes in the core facility can provide what they need. In some cases, such as the telomere project, the right instrument for the job is already in place and ready for use.

Yet many researchers need data beyond what can be provided by a MIN microscope. In such cases, Field builds on more than 12 years of experience designing lasers and microscopy systems for biological imaging to design new microscopes for the job.

In addition, the MIN funds a small number of pilot projects for faculty in the form of facility access. Check the MIN website at vpr.colostate.edu/min for details.



A two-photon fluorescence image of neurons in a mouse cortex. This image was taken with a microscope designed and built by MIN Director Jeff Field. *Sample provided by the Hentges Lab.*

University invests $1.5 million into research facilities upgrades

by Lauren Klamm

The Office of the Vice President for Research and the Office of the Vice President for University Operations are investing $1.5 million into improvements to nine research facilities. These efforts align with the first phase of the CSU Research and Scholarship Success Initiative.

"We are excited to invest in our research infrastructure at CSU. Our great faculty thrive using state-of-the-art facilities and equipment for scholarly and research activities," said Alan Rudolph, vice president for research. "Our recent call for proposals to invest also created greater awareness, sharing, and collaboration among our faculty, as we know these facilities can catalyze new and uncommon collaborations."

The funding program identified direct infrastructural facilities improvement or renovation needs for research facilities. This included renovations, alterations, repairs, and other improvements that will stimulate future research opportunities.

"The University is committed to helping our faculty thrive in research and discovery – a core tenet that makes Colorado State University what it is," said Lynn Johnson, vice president for University operations. "It's important to support those initiatives with facilities that provide scientists with the tools they need to be innovative and successful, as well as safe."

AWARDED FACILITIES:

Plant Growth Facility: Improve the environmental conditions in CSU greenhouses by replacing greenhouse roofing and upgrading select lighting for optimized plant growth.

Colorado State University C-band Polarimetric Radar: Deploy the C-band precipitation radar to provide real-time maps, short-term forecasts, and statistics of precipitation for both agricultural and meteorological applications.

Computer Science Building: Revamp machine rooms to increase space, power, and cooling capabilities for enhanced computer science research.

Engineering Research Center: Refurbish the pipeline carrying water used for research in the Engineering Research Center, the Advanced Beam Laboratory, and the Air, Water and Energy Research building.

Center for Literary Publishing and Public Lands History Center: Connect the future Center for Literary Publishing and the Public Lands History Center offices to the University's computer networking system and updated VOIP phone lines.

Deer Facilities Mechanical Systems and Wastewater Systems: Renovate the Deer Facilities, located at the Foothills Campus, used to study prion diseases.

The Functional Foods for Health Clinical Research Facility: Restore a portion of the Gifford Building to develop the Functional Foods for Health Clinical Research Facility. The facility is used for clinical and human research related to crops, foods, nutrition, and health.

Central Instrument Facility Laboratory CORE: Increase square footage, refurbish workspace, and replace HVAC systems of the laboratory on the first floor of the Chemistry Building located on Center Avenue.

Applied Isotope Research for Industry and the Environment Program: Replace ventilation hoods in the AIRIE laboratory, used to study rhenium-osmium isotope geochemistry.

Fort Collins' risk became a Powerhouse in energy science

by Bryan Willson

Editor's Note: Dr. Bryan Willson is the director of the Energy Institute, a professor of mechanical engineering at Colorado State University, and the founder of CSU's Engines and Energy Conversion Lab. In these roles, he has worked for more than 25 years to develop large-scale solutions for global energy needs with a significant focus on reducing environmental impacts from natural gas production and use.

Twenty-five-years ago, the city of Fort Collins took a chance on energy innovation, and on me. I was an assistant professor in mechanical engineering at Colorado State University, and I was looking for a space to start CSU's Engines and Energy Conversion Lab. I wanted to find a place where my students, colleagues, and I could build and test clean energy solutions at large scale.

I found that in an unlikely space – the decommissioned coal-fired municipal power plant on the north edge of downtown Fort Collins. This 35,000-square-foot facility had the heavy structure and space we needed. Fort Collins, even then in 1992, was willing to imagine the space as something more than the abandoned and deteriorating building it was at the time and take a risk alongside us as we worked to build what is now the Powerhouse Energy Campus. Our continuing partnership with the city of Fort Collins is truly unique in town/gown relationships across the U.S.

Our earliest work focused on reducing emissions from the massive engines used to power our natural gas pipeline system. Now, almost every engine on the pipeline uses some technology we helped to create, and every year this reduces pollution (NOx emissions) in the U.S. by the same amount as removing 150 million automobiles from the highway. Later, we became interested in the future of the electric grid, and once again the city of Fort Collins stepped up. Leaders allowed us to connect our experimental grid laboratory to the city's

grid, which incurred some reliability risk but ultimately helped to grow local companies, such as Spirae, and allowed the development of new electric grid solutions being implemented in the U.S., on the national grid in Denmark, and now in sub-Saharan Africa.

We have also sought to improve access to energy among the world's poorest populations. Envirofit International, a company we launched from the lab in 2003, is now the largest manufacturer of clean cookstoves for the developing world. Factor(e) Ventures, a company we started in 2013, has helped to launch 15 companies that use technology to improve the human condition in the developing world.

In 2014, we completed a 65,000-square-foot addition to the building; now our 100,000-square-foot facility is one of the largest free-standing energy research facilities at any university. The new space allowed us to expand from just developing technology to addressing the entire energy spectrum; technology, energy policy, human behavior, health, entrepreneurship, and access to energy in the developing world. With this expanded focus, we changed our name to the Powerhouse Energy Campus to reflect the broad interdisciplinary and collaborative nature of the energy work being done. Powerhouse now houses more than 30 faculty and research scientists, 15 energy companies, and more than 150 graduate and undergraduate students. On most days, there are more than 250 people working in the building to: (1) do great energy science, (2) turn that science into real-world solutions, and (3) figure out how to get those solutions implemented at large scale. That's cool.

This interdisciplinary nature of the Powerhouse is not an afterthought; it is by design.

The collaborative ecosystem of researchers, professors, engineers, writers, students, established companies, and startup companies extends to the greater Fort Collins community; this unique partnership on clean energy led to the inclusion of Fort Collins in the Smithsonian Institution's *Places of Invention* exhibit in Washington, D.C.

As we celebrate our 25th anniversary, I want to use this moment to thank the Fort Collins community for taking a risk all those years ago. This is as much a celebration of our achievements as the Powerhouse Energy Campus, as it is a celebration of the unique commitment and support the Fort Collins community has shown for energy innovation.

University invests in interdisciplinary research teams

by Lauren Klamm

Five interdisciplinary teams of researchers from across the eight colleges of Colorado State University will be collaborating on some of the world's most pressing global problems as part of the Catalyst for Innovative Partnerships initiative. The Office of the Vice President for Research launched the CIP initiative in 2015 and has now chosen its second cohort.

The program seeks to build multidisciplinary research teams that will forge partnerships to pursue new opportunities for translating discoveries into practice.

"The first class was a resounding success with new team formation and more than $16 million raised with significant scholarly outputs," said Vice President for Research Alan Rudolph.

The second class of teams will be seeded with up to $200,000 each. They will be provided infrastructural support by the University to nurture the creation and delivery of solutions in disease transmission, healthy aging, food systems, biomolecular imaging, and biosecurity.

"This unique program provides support for teams pursuing big ideas and creates uncommon collaborations for funding interdisciplinary and disciplinary depth," said Rudolph. "The OVPR is pleased to be part of the new catalyst teams' future success."

2017-2019 CATALYST FOR INNOVATIVE PARTNERSHIP TEAMS

TerraForma: Simulating Reality in Artificial Ecosystems

To understand diseases better, this team will look at creating artificial ecosystems, or "worlds-in-a-bottle," to evaluate and control the role of environmental changes in the transmission of animal and plant pathogens.

Colleges represented: College of Agricultural Sciences, College of Veterinary Medicine and Biomedical Sciences, Walter Scott, Jr. College of Engineering.

Other partners represented: Office of the Vice President for Research

Enriched Environments for the Healthy, Aging Brain

This team will provide one of the only large-scale, transdisciplinary assessments of non-pharmacological intervention in the U.S. for diseases such as Alzheimer's and dementia.

Colleges represented: College of Natural Sciences, College of Health and Human Sciences, College of Liberal Arts

Other partners represented: Blue Penguin

Securing Life Science Infrastructures

This team will examine the adoption of security policies that protect life-science infrastructures from exposure to biological agents that can compromise human health, food supplies, or natural resources.

Colleges represented: College of Business, College of Liberal Arts, College of Natural Sciences, College of Veterinary Medicine and Biomedical Sciences, Walter Scott, Jr. College of Engineering

Other partners represented: Merrick & Co., Inspirion Biosciences, Virginia Tech

TagTeam: New Molecular Tags for In Vivo Imaging and Editing

To better facilitate future basic and applied research that depends on the imaging or editing of specific molecules inside living cells, this team will produce new reliable molecular tools to "click" biomolecules together.

Colleges represented: College of Natural Sciences, College of Veterinary Medicine and Biomedical Sciences, Walter Scott, Jr. College of Engineering

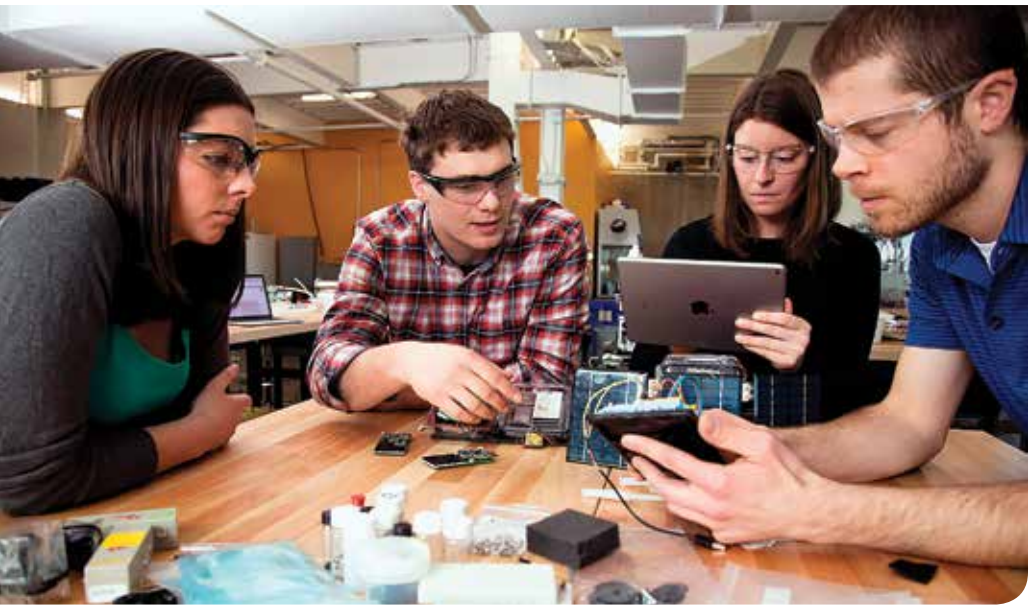
Rural Wealth Creation: Exploring Food Systems-Led Development Strategies

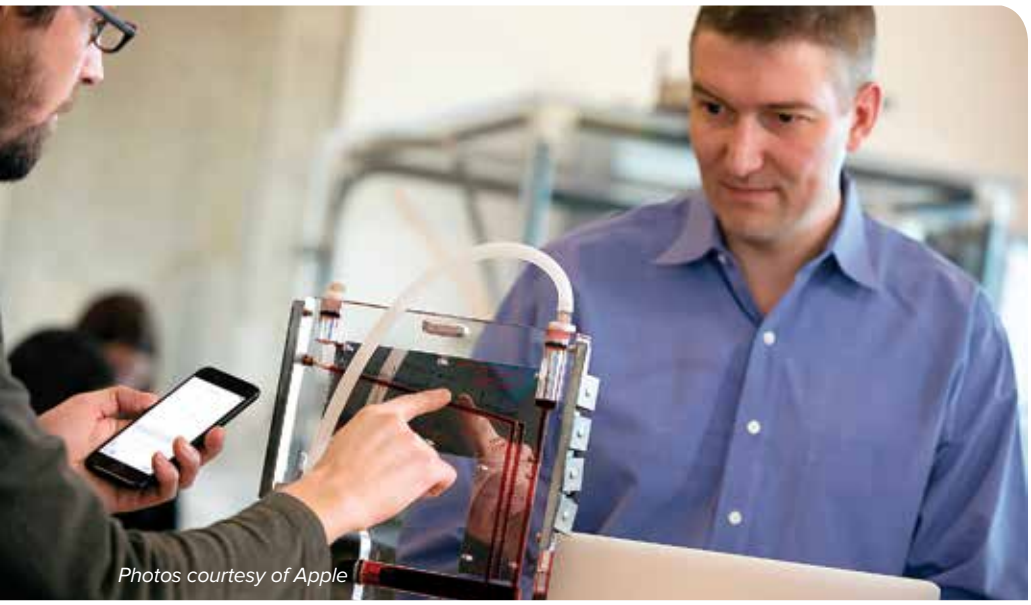
The project seeks to understand how food systems strategies can contribute to social, cultural, human, political, physical, natural, and financial capital in rural communities.

Colleges represented: College of Agricultural Sciences, College of Health and Human Sciences, College of Liberal Arts, College of Veterinary Medicine and Biomedical Sciences, Walter Scott, Jr. College of Engineering, Warner College of Natural Resources

Air pollution project harnesses the power of backyard science

by Anne Manning





Photos courtesy of Apple

This past year, a handful of motivated Fort Collins citizens did something a little out of the ordinary: They collected cutting-edge scientific data from their backyards that may soon help NASA create global maps of air pollution.

The volunteers were part of a network of citizen scientists for a NASA-funded, Colorado State University-led project called CEAMS: Citizen-Enabled Aerosol Measurements for Satellites. In recent months, the project received the green light for full speed ahead. Following a successful pilot phase in Fort Collins, NASA has re-funded CEAMS to the tune of $1.6 million over the next three years. That means recruiting more citizen scientists across Denver, the Northwest, and Los Angeles.

The goal of CEAMS is to improve understanding of local air quality through dispersed, ground-based measurements. Data on this scale could eventually help NASA satellites provide higher-resolution air quality data than is possible today.

"NASA is interested in solving global problems," said CEAMS leader John Volckens, CSU Energy Institute researcher and professor of mechanical engineering. "Most governments can't afford to monitor air pollution at all." Yet, air pollution is a leading cause of death and disease on the planet – responsible for more deaths worldwide than HIV and malaria combined.

Air pollution monitoring is a tricky and expensive business, according to Volckens. In the U.S., the Environmental Protection Agency maintains about 1,000 active air samplers for fine particulate matter air pollution across the country – about one for every three counties. But pollution from vehicles, power plants, wildfires, and a host of other sources varies at much finer spatial scales than the county level.

NASA uses a combination of satellite imaging and computer algorithms to model air pollution, but models can say only so much about details of ground-level air quality. That's where the CSU team comes in.

"If we want to develop better algorithms to make the air quality maps from satellite images more representative, we need more data on the ground," Volckens said. "This project is designed to develop those datasets."

Smaller, cheaper, and more of them

Typical EPA monitors that detect particulate matter smaller than 2.5 microns, or "PM 2.5," cost about $30,000 each and are complicated to run. The CSU CEAMS effort is focused on distributing a large number of compact, low-cost, solar-powered instruments that can be deployed in backyards by volunteers. And with many hands making light work, the scientists can collect better, more high-resolution data on the local scale than any satellite could from outer space.

"If we establish a network with 100 monitors across a metro area, we will have access to an incredibly powerful dataset that NASA can use to improve maps of air quality," says Jeff Pierce, associate professor of atmospheric science and co-investigator on the project.

The CEAMS sensors take two primary types of measurements. One is aerosol optical depth, or AOD, which is related to the amount of particulate matter present in a vertical column of air from Earth to space. The other is ground-level PM 2.5, which is of most concern for human health. "These two measures, taken together, are valuable not just to NASA but to anyone interested in local air quality," says Eric Wendt, a graduate student in mechanical engineering who helped design the sensor.

The interdisciplinary team, involving engineers, atmospheric scientists, and social scientists, are all members of the CSU Partnership for Air Quality, Climate, and Health – an organization that synergizes expertise at CSU to deliver solutions to societal problems at the intersection of air quality, climate, and health. The PACH team was created in response to the Office of the Vice President for Research's Catalyst for Innovative Partnership program, which seeks to solve global challenges using interdisciplinary science. The CEAMS team, a subset of PACH, includes Volckens, Pierce, and co-investigators Shantanu Jathar of mechanical engineering and Marilee Long of journalism and media communication, as well as members of their research groups.

Long's role is helping determine best practices for recruiting and training citizen scientists. "Citizen science isn't about just using people to make scientific measurements," she said. "There is a value to them as well. If we have a lot of people out there learning, we're also encouraging them to think positively about science. Their feedback also helps us design better instruments for future volunteers."

Tapping a homegrown network

Luckily for the CEAMS team, they had access to a ready-made, homegrown citizen science network: the snow and rain spotters who collect precipitation data for the Community Collaborative Rain, Hail and Snow Network, CoCoRaHS, through the Colorado Climate Center. The center staff connected CEAMS managers with local citizens willing to volunteer for the air pollution project.

The CEAMS website, csu-ceams.com, contains narrated videos providing step-by-step instructions on how to set up the monitors and collect data. Team member Casey Quinn, a graduate student in the Department of Environmental and Radiological Health Sciences, created a smartphone application through which the citizen scientists upload their data directly to the CEAMS team.

In Fort Collins, volunteers were asked to take a sample every two days for about two weeks. Thanks to feedback from their pilot volunteers, the researchers plan several improvements for the samplers when they expand into other cities. These include increasing wireless capabilities for data management and adding a reflective bead to help ensure the sensors are properly aligned.

Apple features CSU air pollution research

Technology giant Apple launched a new podcast channel last year called *Higher Education Stories*. Its inaugural episode featured CSU's air pollution researchers, led by John Volckens.

The story can be viewed via Apple iTunes: apple.co/csu-research-story.

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