University of Wisconsin–Madison
Federal Research Highlights and Impacts 2016

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UNIVERSITY OF WISCONSIN–MADISON

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Over the past 168 years, researchers at the University of Wisconsin–Madison have created a remarkable legacy of scientific discovery and innovation. As one of the leading research universities in the world, we are proud of our strong history of research advances and achievements. Here are some highlights from the past:

- In 1890, researchers developed a milestone in modern dairying — a simple and accurate measure of the butterfat content of milk that transformed the industry.
- In 1917, researchers confirmed the cause of goiter and later developed a process to stabilize added iodine in table salt. This provided a universal way to prevent goiter.
- In 1924, researchers discovered how to produce Vitamin D. Application of this discovery virtually eliminated rickets, once a debilitating bone disease in children. Proceeds from this discovery were used to create and fund the Wisconsin Alumni Research Foundation — one of the nation's premier university intellectual-property and commercialization organizations.
- In the 1930s, researchers identified an anti–blood-clotting agent in spoiled hay. This discovery led to the development of Warfarin, which is widely used to treat thrombosis and other clotting disorders.
- In the 1940s, UW researchers were the first to identify the wavelength of ultraviolet light that produces skin cancer, laying the foundation for Sun Protection Factor (SPF) ratings.
- In the 1950s, researchers at UW–Madison led the team that discovered how to use satellite technology to measure the heat budget of the earth.
- Also in the 1950s, the UW–Madison became a pioneer in the field of bacterial genetics with a discovery of conjugation in bacterial cells.
- In the 1980s, UW researchers developed the *Wisconsin Solution*, a means of cold storage for organ preservation used during transport and surgery.
- In the 1990s, researchers were the first to successfully derive human embryonic stem cells in the laboratory.
- In 2007, researchers succeeded in genetically reprogramming human skin cells to create cells indistinguishable from embryonic stem cells.

These are but a few of the important contributions made by UW–Madison researchers. There are so many more — from leading the way in genetic engineering for plant and food crops to helping to create the nation's social security system. At the University of Wisconsin–Madison, we are proud of our past, but always looking toward the future — all ways forward.

Building on this record of achievements, our researchers continue to push boundaries and explore cutting-edge concepts that lead to economic prosperity. This document provides just a sample of some of the ways our researchers are currently utilizing federal research dollars to solve some of society's most pressing problems. Federal funding is what makes these advancements possible, and continued federal investment in university research is what will fuel new discoveries that will influence and impact generations to come.

We hope you enjoy and appreciate these research highlights and invite you to read more about these latest projects or to visit our campus. If you have any questions or would like additional information about the research enterprise at UW–Madison, please contact:

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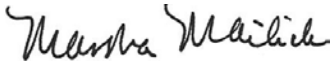

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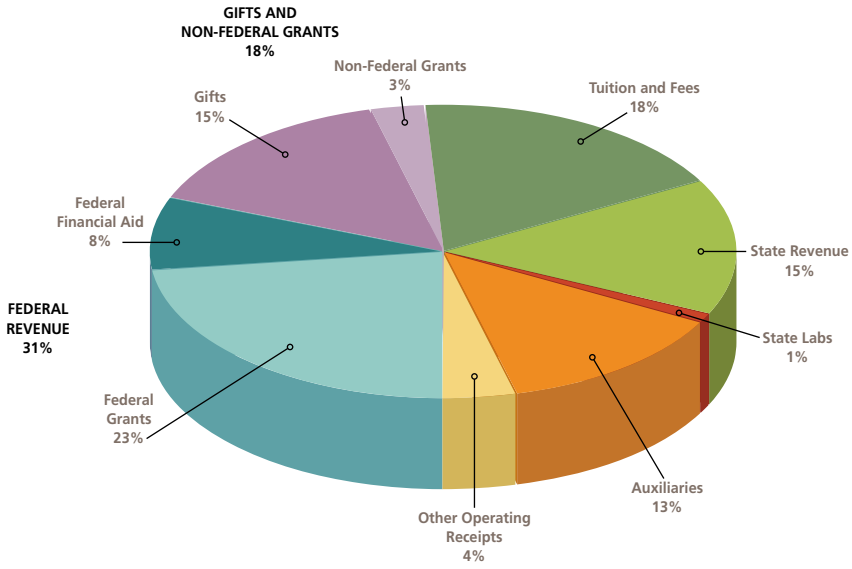
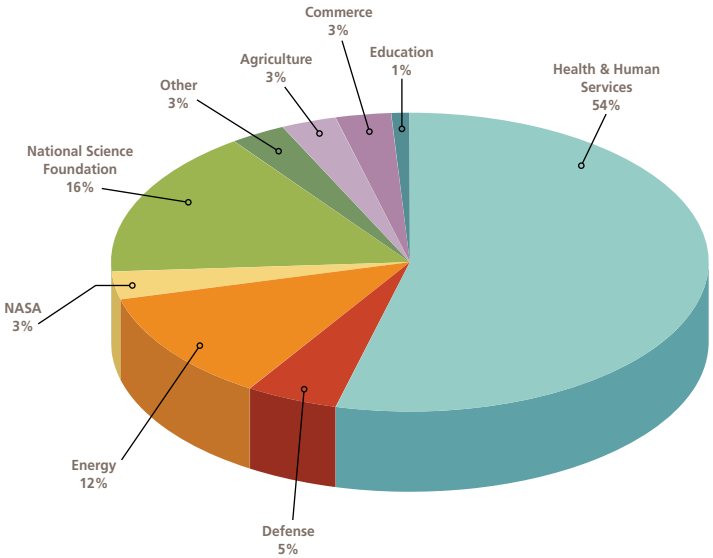
Revenue Sources

The largest portion of the university's budget, approximately $890 million, or 31 percent, is from the federal government. Most of this is competitively awarded to UW–Madison for specific research projects and supports research time for faculty, staff, and students, as well as research facilities.



Sources of Federal Research Funding

UW–Madison receives federal research awards from many federal agencies including the Department of Health and Human Services, the National Science Foundation, and the Department of Energy. For more than two decades, the university has ranked in the top five annually in total research dollars among all academic institutions in the country. In fiscal year 2014, UW–Madison spent more than $1.1 billion from the federal government and private sources for research. Federal research dollars have declined nationally in recent years due to federal budget cuts, leading to a decline in federal dollars at UW–Madison. These federal research dollars are awarded competitively for specific projects and require faculty to be entrepreneurial in applying and competing for funds with researchers around the country.



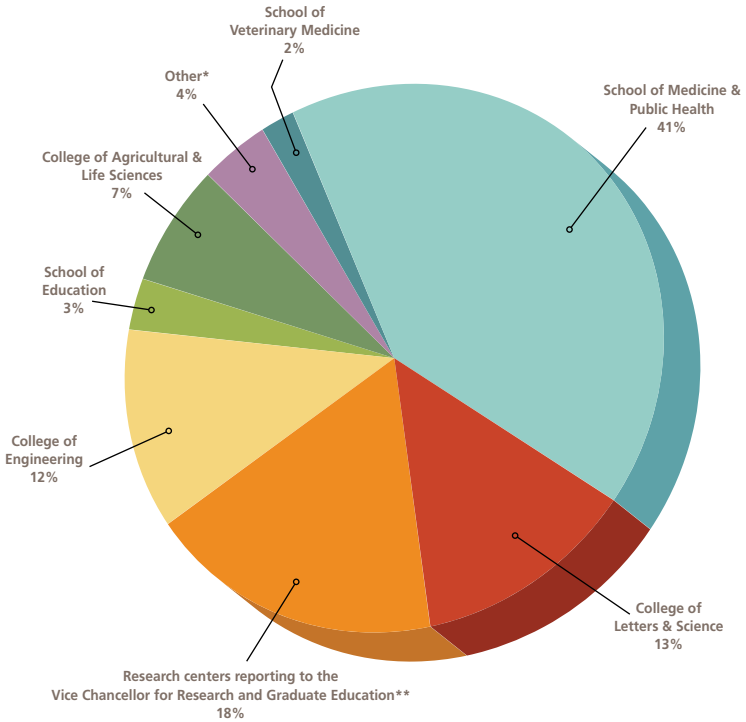
Funding allocation by specific federal agencies for research projects on the UW–Madison campus

Total Research Funding Trend

Distribution of Federal Research Funds

Faculty and staff across the university — in science, engineering, business, education, social sciences, arts and humanities — compete for research dollars, which helps make UW–Madison a premier research institution.

This research fuels economic growth and development through the money spent in the state of Wisconsin to support the research infrastructure. The research reputation of UW–Madison attracts businesses and generates new start-up companies.



* Other includes the Wisconsin School of Business, Nelson Institute for Environmental Studies, School of Human Ecology, The International Division, University of Wisconsin Law School, School of Nursing, and School of Pharmacy.

** Centers include such entities as the Waisman Center, the Biotechnology Center, and the Wisconsin Institute for Discovery.

HUMAN HEALTH

UW–Madison received $296.9 million in federal research awards from the U.S. Department of Health and Human Services (2014–15).

United States Department of Health and Human Services

National Institutes of Health

UW–Madison College of Engineering

Understanding how ovarian cancer spreads: With approximately 22,000 diagnoses annually in the United States, ovarian cancer isn't among the most commonly occurring cancers. Yet, the mortality rate for women who have ovarian cancer hovers above 60 percent. Progress in treating ovarian cancer over the last 30 years has been limited. One reason is that the disease is nearly universally diagnosed too late, so understanding ovarian cancer's early stages might lead to new screenings for the disease as well as potential treatments. Researchers at UW–Madison are developing laboratory models to mimic the way ovarian cancer cells spread through a woman's body and how they develop resistance to chemotherapy. They are examining what factors cause ovarian cancer cells to progress from their origin in a woman's fallopian tube, through the ovaries, and on to metastatic sites where they become resistant to chemotherapy drugs.

UW–Madison School of Nursing

Brain Alterations and Cognitive Impairment in Older Adults with Heart Failure: Cognitive impairment is a widely recognized clinical challenge for older persons with heart failure (HF). Little is known about the relationship between brain structure and function and cognitive impairment in older persons with HF. Researchers at UW–Madison are exploring this correlation by comparing 40 adults with HF to 40 healthy matches using high-resolution MRI structural and perfusion scans and obtaining neuropsychological measures of multiple domains. This study will be the first to report findings related to real-time, large-vessel brain-blood flow in patients with heart failure. The results of this research will have significant implications for the fields of nursing, medicine, and neuroscience.

UW–Madison School of Pharmacy

Omics Approaches to Natural Product Discovery: Drug-resistant infectious diseases are currently the largest threat to global health. While resistance increases, the number of new drug leads is decreasing. Researchers at UW–Madison are working to discover new antibiotics by targeting understudied bacteria with a focus on symbiotic communities that have co-evolved with an animal host, and by developing a strategy that facilitates the identification of unique, small molecules from bacterial collections. As an example of this work, a novel antibiotic, eecteinamycin, is currently under preclinical development as a potential therapeutic for *Clostridium difficile*, a bacterium that is one of the most common causes of infection of the colon in patients taking antibiotics. In many patients, a toxin produced by *C. difficile* causes diarrhea, abdominal pain, and severe inflammation of the colon that can lead to death.

UW–Madison School of Veterinary Medicine

Modeling Host Responses to Understand Influenza Virus: The influenza virus infects millions of people annually. Influenza vaccines are typically produced based on the most prevalent strain isolated from the previous year. Unfortunately, the influenza virus has the capacity to mutate quickly. Researchers at UW–Madison have developed a fundamentally new and unique method for producing influenza vaccines that are effective against multiple strains of virus, thereby increasing the potential that vaccines will produce immunity against the strain of virus that emerges as cases of influenza increase in a particular year.

UW–Madison Institute for Molecular Virology

Role of the Estrogen Receptor in Breast Cancer Signaling: Extending from the previous study of the human papillomavirus (HPV), researchers at UW–Madison, in collaboration with the Morgridge Institute on campus, have shown for the first time that cancerous cervical tissue in humans shows increased DNA replication and cell growth with significant metabolic shifts. These shifts include a dramatic and progressive decrease in the estrogen receptor in tumor cells, but not in the surrounding stromal fibroblasts. Estrogen signaling in these supportive cells contributes to the tumor's microenvironment, which promotes continued tumor growth. These findings support a critical role of stroma-to-tumor estrogen signaling in the development of cervical cancer, and as a result, suggest important ways to treat, manage, and control this virus-induced cancer in women throughout the world.

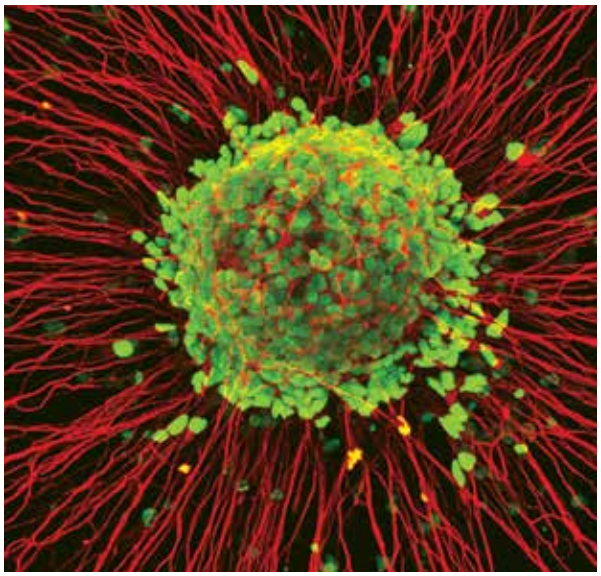
UW–Madison Institute on Aging

Understanding and Improving Aging: The Institute on Aging has been leading a national study of health and well-being in a sample of more than 12,000 U.S. adults for over two decades to gain advanced knowledge of how psychological, social, and behavior factors influence diverse health outcomes as individuals age. Data from this longitudinal study, known as MIDUS (Midlife in the U.S.), and its sister study, MIDJA (Midlife in Japan), are publicly available and are two of the most frequently downloaded studies at the National Data Center, used by scientists from all over the world to advance the goal of positive aging.

Waisman Center

A New Way to Edit Genes in Stem Cells: Pluripotent stem cells have the potential to develop into many different types of cells. In order to derive a particular cell, such as a nerve cell, stem cells need to be meticulously guided down a specific molecular path. Waisman Center researchers have pioneered a new way to edit genes in stem cells that has the potential to revolutionize the process of generating specific cell types for research and cell-based therapies to treat diseases and disorders. These cells have been made available to researchers worldwide through the not-for-profit WiCell Research Institute.

HONG CHEN, SU-CHUN ZHANG



A microscope photo of motor neurons created in the laboratory of Su-Chun Zhang at the Waisman Center. Green marks the nucleus and red marks the nerve fibers.

Wisconsin National Primate Research Center

New Blood Regenerative Therapies for AIDS: Curing HIV by transplanting bone-marrow-derived hematopoietic stem cells from HIV-resistant patients has shown the power of stem-cell-based therapies for AIDS. However, limited sources for these therapeutic cells restrict widespread use of this approach in the clinic. Researchers at the Wisconsin National Primate Research Center (WNRPC) are working to overcome this limitation by developing technologies for producing HIV-resistant, engraftable hematopoietic cells from induced pluripotent stems cells that are reprogrammed from adult somatic cells. Great challenges remain with this approach, but these researchers have proven expertise in primate genetics, stem cells, immunology, and virology, especially in matters concerning HIV.

UW–Madison College of Letters & Science

Wisconsin Longitudinal Study: For nearly 60 years, the Wisconsin Longitudinal Study (WLS) has closely followed the lives of roughly a third of Wisconsin high school graduates from the class of 1957. WLS is the first large-scale longitudinal study of American adolescents. It provides the opportunity to study individuals life-course from late adolescence through their early to mid 60s. Over the next few years, WLS project investigators will be exploring how environment and social interaction influence the composition of and changes to the gut microbiome. Through the context of this long-range study, researchers hope to advance our understanding of how intestinal flora impacts human health and well-being.

UW–Madison School of Medicine and Public Health

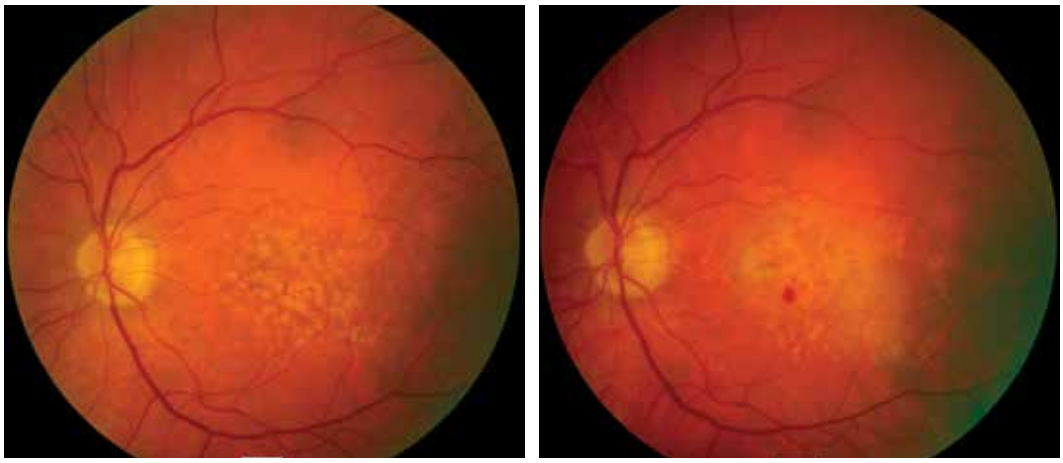
Fighting Childhood Asthma: Asthma is a common, chronic pediatric disease. It inflicts 6.3 million children in the U.S. One in three school-aged children report absences due to asthma— in Wisconsin this figure rises to one in two. As part of the Childhood Origins of ASThma (COAST) study, researchers at UW–Madison are examining the genetic and environmental factors that influence childhood allergic diseases and asthma. Since the inception of the study in 2002, significant strides have been made in combating the asthma epidemic by identifying severe risk factors for the disease and developing effective clinical strategies for asthma management.

UW–Madison School of Medicine and Public Health

Addressing Inner-city Asthma: Asthma is a serious worldwide disease, especially for inner-city children in the U.S. living in poverty. For these children, asthma is more prevalent and of greater morbidity and mortality. UW–Madison researchers, through the Inner-City Asthma Consortium (ICAC), have made a number of key observations that serve to expand research into mechanisms by which prenatal and early life exposure to allergens, bacteria, stress, and pollutants likely contribute to the development of asthma. Researchers are testing new ways to prevent the disease, as well as applying immune-based strategies to reduce the severity and to stifle its progression, thereby addressing high-priority needs that are currently unmet in the fight against inner-city asthma.

UW–Madison School of Medicine and Public Health

Combating Age-Related Macular Degeneration: Age-related macular degeneration (AMD) is the leading cause of severe vision loss in people over 60. Researchers at the UW–Madison School of Medicine and Public Health are participating in the world's longest-term large-scale study to determine whether having a low density of two dietary plant pigments in the retina of the eye predicts aging of the retina, development and progression of AMD, and loss of vision more than



COURTESY OF THE DEPT. OF OPHTHALMOLOGY AND VISION SCIENCES

Before and after photos of the same eye taken as part of a longitudinal eye study of aging. The first shows early age-related macular degeneration (AMD) with drusen and retinal pigmentary abnormalities. Four years later the condition has progressed to late AMD with drusen plus retinal detachment, subretinal hemorrhage, and scarring.

ten years later. In addition, researchers are also studying how mechanisms of cellular clearance through autophagy in the retinal pigment epithelium can assist in targeting the earliest stages of AMD, and how the knowledge of autophagy can be used to identify novel therapies for AMD.

UW–Madison School of Medicine and Public Health

One-Stop-Shop Imaging for Acute Ischemic Stroke Treatment: With support from the National Institute of Biomedical Imaging and Bioengineering, our researchers have partnered with industry to translate a new, groundbreaking technology called SMART-RECON into a commercial product that can be applied to clinical practice. SMART-RECON enables hospitals' current, slow-imaging platforms to simultaneously generate anatomical, functional, and physiological information from a one-minute scan. This efficient collection of information will allow physicians to diagnose, triage, and treat potential stroke patients in a single operating room, negating the time-consuming need to transport patients to various locations within the hospital.

UW–Madison School of Medicine and Public Health

Healthy Children, Strong Families: Healthy Children, Strong Families (HCSF) is a community-based, multimodal, early childhood intervention that addresses the growing problem of obesity in American Indian children. HCSF works with five American Indian communities to test interventions designed to increase adoption of healthy lifestyles and to reduce obesity among preschool-aged American Indian children and their primary caregivers. If successful, HSCF will be the first evidence-based, culturally adapted, healthy lifestyles intervention for American Indian families with young children that addresses the obesity epidemic.

UW–Madison School of Medicine and Public Health

Supporting Older Adults Discharged from the Emergency Department: Older adults use the emergency department (ED) as an important source of acute care. Unfortunately, many patients often do poorly after being discharged, with up to 20 percent having repeated ED visits within 30 days. The validated Care Transition Intervention (CTI) was designed to improve the hospital-to-home transition and to decrease hospital readmissions by teaching patients how to manage their health before being discharged. UW–Madison researchers have adapted the CTI program to account for the unique aspects of the ED setting, and they are studying whether it improves the health of older adults being discharged from ED, thereby addressing a significant deficiency in the quality of care for this vulnerable population.

UW–Madison School of Medicine and Public Health

Match Complex Patients to Treatments: Researchers are developing and disseminating innovative statistical scoring methods to rank possible treatments for patients according to their likelihood of achieving the desired patient outcomes. The ranking is based on patient characteristics such as demographics and socioeconomic variables, inpatient/outpatient diagnoses, comorbidity, pharmacy claims, health system, and clinical information. Researchers at UW–Madison aim to develop practical and validated systems that provide patients, healthcare providers, and other clinical decision-makers with information that will help them make better-informed choices.

UW–Madison School of Medicine and Public Health

Models for Predictive Neural Toxicity: Hundreds of new molecules are introduced into our environment every year, including drugs, herbicides, and other new commercial and industrial compounds, but the majority are not tested for neural toxicity to a developing fetus or young children. To address this, our researchers have developed a new approach by creating realistic 3D micro-tissue models that include seven different cell types and supporting vasculature. The micro-tissue models are used to predict the developmental neural toxicities in these new molecules to better protect vulnerable populations from environmental hazards.

UW–Madison School of Medicine and Public Health

Fighting Opioid Addiction: Over the past decades, opioids have been increasingly used to treat chronic non-cancer pain. This trend has been accompanied by an alarming increase in prescription opioid misuse, addiction, and diversion. UW–Madison researchers are working to develop an evidence-based, quality-improvement approach to reduce variation in opioid prescribing. When completed, this project will develop guidelines for prescribing opiates that should help stem the rising tide of opioid abuse.

UW–Madison School of Medicine and Public Health

E-Cigarettes: Dynamic Patterns of Use and Health Effects: Rates of e-cigarettes use have risen at a dramatic rate over the last five years. Currently, e-cigarettes are unregulated and there is minimal critical scientific information on use patterns, health effects, and safety data. Researchers will follow a cohort of both cigarette and dual (cigarette and e-cigarette) users for two years, collecting data on patterns of use, cancer biomarkers, and health outcomes to better inform policy, clinical, and research decisions.

UW–Madison School of Medicine and Public Health

Center for Computational Predictive Phenotyping: This center, which is one of twelve NIH Big Data to Knowledge (BD2K) centers, focuses on developing new computational methods for identifying and predicting "phenotypes" of importance for human health. A phenotype is the composite or sum total of all the characteristics associated with a gene. Part of the project focuses on applying machine learning algorithms to de-identified patient clinical histories derived from an electronic health-record system. Using these data, the goal is to predict which patients will have any given disease diagnoses in the near future. This project will lead to increased health and quality of care at a decreased cost.

FOOD AND AGRICULTURE

UW–Madison received $18.4 million in federal research awards from the U.S. Department of Agriculture (2014–15).

United States Department of Agriculture

UW–Madison College of Agricultural and Life Sciences

Making Better Food-spoilage Sensors: Enteric bacteria such as *Escherichia coli* (*E. coli*) and *Salmonella* cause unpredictable outbreaks of foodborne and waterborne diseases that can have dire consequences for our health and economy. Researchers at UW–Madison are working to develop a nanobiosensor that can detect the presence of even a few cells of these pathogenic bacteria within minutes, yielding a result that is visible to the naked eye. Researchers are working to develop a highly sensitive, rapid biosensor customized for any food product. They will evaluate the effectiveness of this biosensor for detecting the presence of *E. coli* and *Salmonella* in fresh produce and other foods, and help ensure the safety of our food supply and prevent catastrophic outbreaks.

UW–Madison College of Agricultural and Life Sciences

Understanding Native Bees in Cranberry Agroecosystems: Wisconsin is the number one producer of cranberries in the United States, producing more than 50 percent of the nation's cranberry crop. Cranberries are dependent on insect pollination to achieve high yields, but honeybee pollinators are in decline. Native, wild pollinators are a potential source of free, effective and prolific pollination of cranberries, but growers generally do not take their services into account. UW–Madison researchers are developing models to predict native bee abundance

and diversity within the cranberry-growing region of central Wisconsin. They are working to generate detailed high-resolution maps of where native bees are most prevalent and diverse in the landscape. The results of this project will also shed light on what broad-scale and local-scale features of the environment have positive or negative effects on native bee populations. These findings can help growers better plan for their pollination needs and can also suggest conservation options for enhancing the habitat for native bees.

PHOTO BY SEVIE KENYON

Workers harvesting cranberries in Tomah, Wisconsin. UW researchers are investigating ways to employ native bees to provide a natural, low-cost means of pollination for this important Wisconsin industry.

UW–Madison College of Agricultural and Life Sciences

Measuring Dairy Cattle Fiber Digestion From Corn Silage, Alfalfa, and Grasses: Cows will eat a great deal more of things they like best, and when cows eat to capacity, they produce milk to capacity, resulting in greater sales for farmers. With this in mind, UW–Madison researchers discovered that the amount a cow digests and the amount of milk it produces are correlated to the rate of fiber digestion. To assist in measuring the rate of digestion, researchers then developed the Total Tract Neutral Detergent Fiber Digestibility (TTNDFD) test. UW researchers joined forces with Rock River Labs in Watertown to successfully validate the test, which farmers are now learning to use. TTNDFD could be used to allow farmers to evaluate crops prior to buying or planting seeds.

PHOTO BY KAINE KORZEKWA

UW dairy nutrition consultant Augusta Hagen discusses feeding strategies with herdsman Don Gilbertson at Mahon Farms Dairy in Winslow, Illinois.

ECONOMIC DEVELOPMENT

United States Department of Transportation

Federal Highway Administration

UW–Madison College of Engineering

Connecting jobs and transportation needs: The U.S. Department of Transportation Federal Highway Administration selected the UW–Madison as the Midwest Transportation Workforce Center (MTWC). The MTWC will be instrumental in connecting jobs with transportation needs that contribute to the economy and the region. The scope of the transportation workers in the Midwest is very diverse. These workers — traffic technicians, logistics workers, commercial drivers, bridge and highway engineers, planners, etc. — who design, build, use, and maintain our highways, ports, and intermodal facilities have specific skills and therefore require specific training and education. The MTWC will work with industry to identify current and future needs and partner with K–12 and secondary schools, community and technical colleges, and universities to align education with these needs and to support career pathways for current and future transportation workers. The MTWC is one of five regional centers that will collaborate to form a national network of workforce strategies and promising practices. The MTWC region includes nine Midwest states: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.

United States Department of Agriculture

UW–Madison College of Agricultural and Life Sciences

Gaining and Retaining Young People in Wisconsin's Rural Communities: A multidisciplinary team at UW–Madison is involved in a research project to identify community-based strategies for recruiting and retaining young people in rural communities. This will be a two-step project: the first step will be for the researchers to conduct analysis of residential moves at the municipality level across the state of Wisconsin. This analysis will identify municipalities in rural areas that are gaining, maintaining, or losing young people. Then, the researchers will choose a selection

PHOTO BY SEVIE KENYON

A UW–Madison dairy science student at the Marshfield Agricultural Research Station (MARS) exemplifies the College of Agricultural and Life Sciences' effort to gain and retain youth in rural communities.

of those municipalities to study in-depth to gather information on why some communities are witnessing a net increase in the younger population and others a net decrease. The research involves collaboration with local UW–Extension educators, government agency representatives, civic organization representatives, and young people in leadership positions. The research process will identify factors leading to the successful recruitment and retention of youth in rural communities. The results will be distributed throughout UW–Extension and local government organizations across Wisconsin.

United States Department of Health and Human Services

UW–Madison College of Letters & Science

Center for Demography of Health and Aging: With more than 17 years of funding, researchers at UW–Madison are interested in the formulation of models for the study of determinants of health status and mortality among the elderly. This research includes (a) development of new statistical techniques for the study of aging with applications of multistate hazard models to represent illness, disability, and mortality; and (b) mathematical representation of population changes, with special emphasis on the assessment of changes in the early life experience of different birth cohorts, and the longer-term impacts of the experience on longevity. Also, research is focused on the link between poverty and biology. Poverty may have direct implications for early brain development, saddling children of low-income families with slower rates of growth in key brain structures. By age four, children in families living with incomes under 200 percent of the federal poverty line have less gray matter (brain tissue critical for processing of information and execution of actions) than children growing up in families with higher incomes.

UW–Madison Institute for Research on Poverty

Poverty Research Center: UW–Madison researchers at the Institute for Research on Poverty (IRP) examine the causes and consequences of poverty and social inequality in the United States. It is one of three National Poverty Research Centers sponsored by the Assistant Secretary for Planning and Evaluation (ASPE) in the U.S. Department of Health and Human Services. The center provides a focused national, regional, and state agenda for expanding our understanding of the causes, consequences, and effects of inequality and poverty and of policies and programs to remediate and alleviate poverty, inequality, and their effects. Seminars, workshops, conferences, a publications program that includes print and electronic dissemination, and a challenging graduate student research-training program are designed to support the goals of the center. In the current five-year funding period, IRP's core activities are focusing on three major themes: (1) building human capital and economic potential; (2) family complexity, poverty, and public policy; and (3) promising programs to reduce the intergenerational transmission of poverty.

UW–Madison Institute for Research on Poverty

Child Support Noncustodial Parent Employment Demonstration Evaluation (CSPED): In the past several decades, changes in family structure have led to a substantial increase in single-parent households in the United States. As a result of high divorce rates and an increasing proportion of births to unmarried parents, almost a third of children did not live with both parents in 2014. In fall 2012, the Office of Child Support Enforcement (OCSE) within the Administration for Children and Families in the Department of Health and Human Services (DHHS), launched the Child Support Noncustodial Parent Employment Demonstration Project (CSPED) in eight states to provide enhanced child support, employment, parenting, and case management services to noncustodial parents who are having difficulty meeting their child-support obligations. UW–Madison IRP researchers, along with colleagues at Mathematica Policy Research and in collaboration with the Wisconsin Department of Children and Families, are conducting an evaluation of the demonstration utilizing a random assignment design. The evaluation will inform critical national debates about how best to serve noncustodial parents and their children.

United States Department of the Treasury

UW– Madison School of Human Ecology

Teaching Financial Literacy at an Early Age: This innovative program is designed to increase the financial capability of elementary school students. With this program, 5th- and 6th-grade students practice making decisions about spending and saving while learning about the consequences of their choices in real time within their classrooms. This project will increase our understanding of the impact of financial capability education at the elementary-school level and contribute to the educational policy and approach related to financial capability for the youngest Americans.

SCIENCE AND TECHNOLOGY

UW–Madison received $88.6 million in federal research awards from the National Science Foundation (2014–15).

National Science Foundation (NSF)

UW–Madison College of Engineering

Understanding of Neutral Particle Physics to Generate a Helicon Wave Driven High Density Laboratory Plasma: The quest to discover the fundamental laws that govern the universe require particle physicists to conduct experiments on massive particle accelerators. Current accelerators need to be immense in order to accelerate particles to the very high energies required for these discoveries. For example, the planned International Linear Collider, an electron accelerator, would extend for about 20 miles and cost an estimated $8 billion to construct. Faced with the enormous size and cost of these machines, the particle physics community is seeking a new acceleration technology that makes future linear particle accelerators dramatically more compact and affordable. A new plasma-based particle acceleration technique called plasma wakefield acceleration may hold the key for shrinking future linear particle accelerators.

UW–Madison researchers are working on generating and understanding high-density plasma regimes using a helicon, which is a low-frequency electromagnetic wave. Their goal is to generate a plasma with a density high enough to be a versatile test environment for various industrial and scientific applications. In addition to making a plasma wakefield accelerator feasible, this plasma regime would, for instance, have direct applications for improving fusion devices or building new spacecraft propulsion systems using plasma thrusters.

UW–Madison College of Engineering

PHOTO COURTSY OF DAN LUDOIS

A tabletop motor using an entirely new driving principle is under development at C-Motive Technologies, a start-up business that is commercializing technology from the UW–Madison College of Engineering.

Direct Drive E-Field Motors for Sustainable Power Conversion: Most of the technology we rely on ultimately depends on motors converting electrical power into mechanical power and generators doing the reverse. Electric motors use magnetic fields acting on electric currents in copper windings to make torque, and to get that magnetic field, they often require rare-earth element magnets. These materials and the copper windings can incur expensive manufacturing. Eliminating the need for magnetism would lead to a significant reduction in the cost and environmental impact of making electric motors.

UW–Madison researchers are exploring how to create torque using electric fields generated with the help of dielectric fluid and a much smaller quantity of conducting metal, thus eliminating magnets and copper windings that are an integral part of conventional motors. Having proven the concept in their lab and in their work at the spinoff company C-Motive Technologies, researchers are now developing the analytical tools needed to design electric field-based motors that can serve on a practical scale.

UW–Madison College of Engineering

Developing New Semiconductors: New materials drive innovation in electronic, opto-electronic, and digital technologies. These technologies currently rely largely on semiconductor compounds and alloys that are in their most stable state. To expand the range of compositions that can be used to make semiconductor materials, a group of researchers at UW–Madison's Materials Research Science and Engineering Center on Structured Interfaces is working to make semiconductors that are intrinsically unstable yet preserved in "frozen" states. This advancement is opening up the possibility of making semiconductors from a vastly expanded range of compositions, with electronic properties not previously realized. New semiconductors discovered so far have exhibited properties that appear attractive for solar cell and solid-state laser applications, among others, and these new advances will help decrease our nation's dependence on fossil fuels and revolutionize modern telecommunication. Other aspects are leading to materials that have the potential to revolutionize biotechnology and the life sciences.

UW–Madison College of Engineering

Increasing Participation in Science, Technology, Engineering and Math (STEM): The Women in Science and Engineering Leadership Institute (WISELI) promotes the participation and advancement of women in academic science and engineering. WISELI also has a broader goal of broadening participation in all STEM fields, and as such WISELI is home to the Wisconsin Alliance for Minority Participation (WiscAMP), an NSF-funded program with a goal of increasing the numbers of under-represented minority students receiving Bachelor's degrees in a STEM discipline. Between 2009 and 2013, WiscAMP successfully doubled the numbers of under-represented minority students receiving Bachelor's degrees in STEM fields across the state of Wisconsin. This achievement helps the state and the nation successfully utilize more of its talent, broadening participation in STEM fields. WiscAMP works successfully with campuses throughout Wisconsin: all 13 UW System schools, Alverno College, Beloit College, Lawrence University, and Milwaukee School of Engineering, the UW Colleges, and Madison College.

An advisor in the College of Engineering talks with an undergraduate during a UW Majors Fair as part an effort to encourage women and minority students to enroll in STEM (science, technology, engineering, and math) programs.

UW–Madison IceCube Particle Astrophysics Center

Exploring the Extreme Universe from the South Pole: IceCube is a cubic-kilometer detector at the South Pole that records the interactions of nearly massless, subatomic particles called neutrinos. Very-high-energy neutrinos are detected using the faint blue light called Cherenkov radiation, produced by the interactions of the neutrino with the Antarctic ice. The discovery of astrophysical neutrinos by IceCube launched the era of neutrino astronomy and a new understanding of our universe. However, at the highest energies, neutrinos can be most efficiently detected using the Askaryan Radio Array (ARA), which was designed to accumulate those highest-energy neutrinos produced by the interaction of cosmic rays with cosmic background radiation. These very-high-energy neutrinos are seen as the ideal agents to explore the extremes of the universe, such as black holes and neutron stars. In the coming years, the identification of the first source of astrophysical neutrinos will allow us to answer one of the oldest questions in science: what are the engines that power the extreme universe?

United States Department Defense

Office of Naval Research

UW–Madison College of Engineering

Creating Smaller and Smarter Antennas for Military Use: The long wavelengths and propagation characteristics of radio waves in the 3 to 300 megahertz range enable long distance communication and can penetrate or diffract around natural obstacles, making them useful in many military communications systems. This frequency range is also a crucial tool in electronic warfare — by jamming an enemy's communications or, conversely, tracking down the source of a jamming signal in an electronic attack. UW–Madison researchers are exploring how to make compact, powerful antennas for transmitting jamming signals in an electronic attack, and how to develop better antennas for finding the source of a hostile signal.

United States Department of Energy

UW–Madison College of Letters & Science

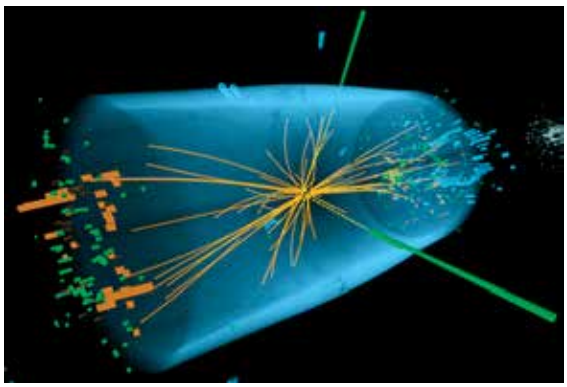


ILLUSTRATION COURTESY OF CERN

A reconstruction of a particle collision captured by the CMS detector at the Large Hadron Collider, a strong candidate for the long-sought Higgs boson.

Discovering the Higgs Boson Particle: In 1964, two researchers theorized the existence of a subatomic particle that gives all other particles mass. Nearly 50 years later in 2012, a global team of researchers found evidence that supports the existence of the Higgs Boson particle at the Large Hadron Collider (LHC) in Geneva, Switzerland. The duo received the 2013 Nobel Prize in Physics, a point of pride for the hard-working network of scientists around the world focused on the project, including a group from UW–Madison. Researchers in the UW–Madison Department of Physics led research teams in search for this *God particle* while a professor of computer sciences and principal investigator of the Open Science Grid (NSF) helped create the computing technologies and infrastructure to store and process the data produced by the LHC.

United States Department of Health and Human Services

National Institutes of Health

UW–Madison College of Agricultural and Life Sciences

Expanding the Frontiers of Biomolecular NMR Spectroscopy: The National Magnetic Resonance Facility (NMRFAM), housed in the Department of Biochemistry, is a resource center for biomolecular nuclear magnetic resonance (NMR) spectroscopy and small angle X-ray scattering (SAXS). NMRFAM strives to be a model to the larger biological community for demonstrating cutting-edge capabilities of NMR spectroscopy; expanding the frontiers of biomolecular NMR spectroscopy through resource technology and development. NMRFAM facilitates the efficient pursuit of new knowledge by providing researchers with resources matched to their particular needs. A major goal is to develop methods for making these investigations faster and less costly as well as applicable to larger classes of proteins and nucleic acids of importance in human health. NMRFAM provides young investigators and experienced spectroscopists access to state-of-the-art instrumentation with support for multiple modes of data collection either as service or collaborative projects. NMRFAM conducts annual workshops and group training sessions as other means for training its user base and for disseminating its novel technology. Mechanisms used to disseminate NMRFAM technology include workshops, newsletters, the NMRFAM website, software servers, a metabolomics database, presentations at meetings, and the publication of articles and reviews.

DEFENSE AND NATIONAL SECURITY

UW–Madison received $27.6 million in federal research awards from the U.S. Department of Defense (2014–15).

United States Department Defense

Office of Naval Research

UW–Madison College of Letters & Science

A researcher holds a Petri plate containing a bacteria sample in a lab at the UW–Madison Microbial Sciences Building. UW researchers are exploring how bacteria communicate and how to disrupt this communication to thwart the spread of infectious diseases.

Understanding Infectious Disease: Renewed appreciation for the power of small molecules as tools to explore living systems has fueled an explosion of interest in chemical biology. Within this broad context, researchers at UW–Madison are focused on the development of new methods to accelerate the discovery of biologically active molecules. They are strategically combining elements of microwave-assisted organic chemistry, solid-phase synthesis, and combinatorial chemistry to provide access to new classes of chemical probes. They are applying these small-molecule tools to bacterial communication and host/microbe interactions, previously unexamined areas of chemical biology. This research explores how both plants and animals sense and respond to invasion by pathogenic microbes. The ability of bacteria to communicate with each other and function as a group is a critical step in the development of infectious disease. The reliance of bacteria on a language of small molecules places organic chemists in a unique position to discover the fundamental principles underlying this communication network and design tools to modulate it at the molecular level. Surface coatings, which may inhibit bacterial colonization and growth, are important to the defense industry. In additional to the Office of Naval Research, NSF and NIH also provide support for this project.

Department of Homeland Security

UW–Madison Space Science and Engineering Center

New Tool to Assist Emergency Managers: For emergency managers, anticipating damage from a tornado can be as important as responding to the damages left in its wake. Until recently, a publicly available tornado model that could create or model a tornado path did not exist. To fill the gap, our Cooperative Institute for Meteorological Satellite Studies (CIMSS) scientists have combined multiple types of data to develop a tornado model that simulates tornado paths and estimates damage. The CIMSS Tornado Model is an important addition to the suite of tools available to the Department of Homeland Security, National Weather Service, local first responders, and emergency managers as they improve and manage emergency preparedness.

ENERGY AND NATURAL RESOURCES

UW–Madison received $66 million in federal research awards from the U.S. Department of Energy (2014–15).

United States Department of Energy

UW–Madison College of Engineering

Increasing Efficiency and Reliability in the Nation's Power Grid: UW–Madison researchers are working to develop the mathematical tools that help power-grid operators increase efficiency and reliability. Historically, a problem with implementing transmission switching in power grids is that finding the right lines to turn off has been too computationally demanding. In real power grids, there is an astronomical number of possible combinations of lines that may be switched off, and each possibility affects the overall efficiency of the system. Researchers are developing new mathematical tools that will help solve this switch-optimization issue. Operational efficiencies like these will translate into big savings for utilities and their customers.

Another challenge facing power grid operators is the expanding use of renewable energy. Because the output from renewable energy sources like wind and solar power cannot be perfectly predicted, its use adds uncertainty to planning for future transmission systems and will affect the placement of power lines and the construction of power plants. However, most tools currently

The Wisconsin Energy Institute at the UW–Madison College of Engineering serves as a center for energy-related research and education. Advances in power-grid technology currently under investigation at UW–Madison can greatly enhance the use of renewable energy such as wind and solar power.

in use in power systems planning ignore this uncertainty, potentially leading to inefficient or unreliable plans. UW–Madison researchers are working to create mathematical tools to solve the planning problems and ultimately allow utilities to deliver energy more efficiently and reliably.

Wisconsin Energy Institute

Advancing Nuclear Energy and Electricity Innovations: Generating clean, efficient, and reliable electricity is critical to creating a secure energy future. UW–Madison scientists and engineers are working on ways to better test nuclear reactors, develop high performance materials, and improve our scientific infrastructure. These efforts will help our nation's energy security, reduce pollution, and ensure the safe and efficient use of nuclear energy for our future. Researchers in engineering physics are also harnessing the extraordinary powers of a fluid called supercritical carbon dioxide to replace the steam turbines traditionally used to generate electricity. This innovation could increase power generation efficiency by 50 percent or more.

Wisconsin Energy Institute

Developing Advanced Sources of Energy: Housed in the Wisconsin Energy Institute, the Great Lakes Bioenergy and Research Center (GLBRC) is one of three bioenergy research centers established by the Department of Energy. Since its inception in 2007, Great Lakes Bioenergy has reported findings in over 800 papers, produced knowledge that led to filing for more than 120 patents and more than thirty licenses, and the formation of several start-up companies. GLBRC performs the basic research that generates technology to convert lignocellulosic biomass of plants to fuels and chemicals. GLBRC researchers are working to meet the nation's need for a comprehensive suite of clean energy technologies, including next-generation and drop-in fuels that can be used in today's engines. GLBRC's research supports the development of a robust pipeline from biomass production through pretreatment and final conversion to products, with sustainability providing a unifying theme. The Center fosters collaboration in the bioenergy research community as evidenced by jointly reported data with over 150 institutions across 32 states and 24 countries over the last 12 Months.

National Science Foundation

UW–Madison College of Agricultural and Life Sciences

Understanding Our Atmosphere: Each year, the carbon dioxide absorbed by plants in the spring and summer as they convert solar energy into food goes back into the atmosphere in autumn and winter. Over the last five decades, the magnitude of this rise and fall has grown nearly 50 percent in the Northern Hemisphere, as the amount of the greenhouse gas taken in and released has increased. UW–Madison researchers have shown that a significant increase in the productivity of crops grown for food accounts for as much as 25 percent of the increase in carbon dioxide (CO_2) seasonality. However, it is not that crops are adding more CO_2 to the atmosphere; instead, if crops essentially absorb CO_2, the amount that can be absorbed has increased and can hold and release more of the gas. With food productivity around the world expected to double over the next 50 years, researchers may use these results to enhance climate models and contribute to our understanding of the atmospheric CO_2 buffering capacity of ecosystems.

A sea of flowering prairie dock, purple gayfeather, and rattlesnake master plants at the Curtis Prairie at the University of Wisconsin-Madison Arboretum.

UW–Madison College of Agricultural and Life Sciences

Understanding Water Dynamics: Water dynamics are central in urbanizing agricultural watersheds where changing climate, human demands, agricultural practices, land use, and other policies interact. UW–Madison researchers are working to better understand how ecosystem services vary and how they can be sustained in regional watersheds as climate, land use, land cover, the built environment, and human demands change. They are addressing this question through a coordinated program of integrated scenarios, model experiments to assess effects of changing drivers on a broad set of ecosystem services, evaluations of governance and leverage points, outreach and public engagement, and information management. Their focus is the Yahara Watershed of Wisconsin, which is an exemplar of water-related issues in the Upper Midwest. Integrated scenarios will synthesize the research and also provide a focus for public education, outreach, and dialog with decision-makers about future pathways that the watershed might take.

UW–Madison Aquatic Sciences Center

Water Contaminant Becomes a Water Cleanser: Clean drinking water is something many Americans take for granted. Yet, there are a host of naturally occurring as well as human-introduced contaminants that threaten the quality of what flows from water taps every day. Through this study, which is funded by both NSF and the U.S. Geological Survey, researchers from our Civil and Environmental Engineering program recently discovered that manganese, a natural element found in the rocky aquifers that supply water to much of southern Wisconsin, could be a useful water cleanser after it is removed as part of a municipal water treatment system. These manganese solids could provide the means to naturally degrade hazardous compounds like heavy metals of bisphenol A (BPA). Manganese is found in groundwater throughout southern Wisconsin and its use in treating hazardous compounds could prove beneficial to human health across the nation.

A thin layer of ice forms on Lake Mendota on the UW–Madison campus. Lake Mendota is an integral part of the Yahara Watershed which UW researchers are studying to better understand how water dynamics are affected by climate change and human activity.

COURTESY OF BIBLIOTECA APOSTOLICA VATICANA

The world map of Pirrus de Noha, circa 1414, illustrates the cover of *The History of Cartography, Volume 1, Cartography in Prehistoric, Ancient, and Medieval Europe and the Mediterranean.*

HUMANITIES AND ART

National Endowment for the Humanities (NEH)

UW–Madison College of Letters & Science

The History of Cartography Project: Initiated by UW–Madison faculty, this is a research, editorial, and publishing venture that is in the process of compiling the multi-volume *History of Cartography* series. Organized by region and time period, *The History of Cartography* looks at maps in the context of the societies that made and used them. Its interdisciplinary approach brings together scholars in the arts, sciences, and humanities. The volumes integrate existing scholarship with new research, examining an unprecedented range of artifacts from local maps to those of the cosmos. The books are extensively illustrated and contain detailed footnotes, appendixes, and reference maps. Chapters from the first three volumes, which are freely available online, have been downloaded more than a million times. The project also receives support from NSF.

EDUCATION

UW–Madison received $6.8 million in federal research awards from the U.S. Department of Education (2014–15).

United States Department of Education

UW–Madison School of Education

Tackling Education Reform: Founded at the University of Wisconsin–Madison in 1988, Families and Schools Together (FAST) is a targeted approach to education reform that reduces behavioral problems in children and improves their academic performance. In 2013, representatives from many of the 46 U.S. states and 13 countries in which FAST has a presence made the trip to Madison for a conference celebrating FAST's 25th anniversary. In 2013, Wisconsin Center for Education Research received a grant to expand the FAST program to 60 schools in Philadelphia.

UW–Madison School of Education

Testing the Promise — A Randomized Trial of a Promise College Scholarship for Urban Public School Students: This research project assesses the efficacy of The Degree Project (TDP), a *promise program* that seeks to increase college preparation, enrollment, and degree completion among low-income, urban high school students by promising ninth-grade students a scholarship if they engage in college-preparation activities during high school. Promise programs are widely used (73 programs nationally) and are feasible alternatives to traditional "late commitment" grant and loan programs (e.g., Pell grants) that wait to inform students until after they leave high school — when many are already off track. This study, the first U.S.–based randomized trial of a promise program, evaluates the impact of TDP on college enrollment and persistence for students in Milwaukee Public Schools.

UW–Madison School of Education

Working to Reduce Gaps in Opportunity and Achievement: Over the next four years, education researchers at Wisconsin's Department of Instruction and the Wisconsin Center for Education Research (WCER) at UW–Madison will analyze data from all state public schools. Their goal is to identify proven practices teachers use to narrow gaps in student opportunity and achievement levels across all racial and ethnic backgrounds and family income levels. The cornerstone of this project is to identify those schools in Wisconsin where racial and economic achievement gaps are narrowing and then identify effective practices that other districts can replicate.

Sources: University of Wisconsin's *Budget in Brief*, the College of Agricultural and Life Sciences' *Grow Magazine*, and the Office of University Communications

All images by the Office of University Communications unless otherwise noted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