2018 ANNUAL REPORT OF RESEARCH ACTIVITY

OFFICE OF THE VICE PRESIDENT
FOR RESEARCH

PennState
Vice President for Research

Second straight year of record research expenditures

Penn State's research expenditures reached a record high for the second consecutive year in fiscal year 2017-2018. The $927 million total represents a **$64 million increase** over last year's figure, and includes a record **$562 million in federal funds** as well as **$365 million** from a combination of private funders, the Commonwealth, and University sources.

Two major factors in achieving the record total were a **14 percent increase** in defense-related funding and a **10 percent rise** in funding from industry, foundations, and other sponsors.

Our federal funding went from **$534 million to $562 million**, and while a $28 million increase from the Department of the Navy accounted for the bulk of that rise, we also enjoyed increased support from the National Institutes of Health, NASA, and the Department of Energy.

Highlighted here are a few notable examples of federally sponsored projects, including an **NSF grant** to establish and lead a multidisciplinary center to further understanding of the security risks associated with the use of machine learning, an **NIH-sponsored study** aimed at developing standardized mobile technologies for studying brain changes associated with aging, and a study funded by the **Department of Energy** to develop deep-rooted crops that can thrive in conditions of rising temperatures and drought.

NEIL SHARKEY
Vice President for Research

It should be noted that **$191 million**, almost 21 percent of total expenditures, is accounted for by the **University's own investment in research for the public good**, an integral part of our land grant mission. These investments, together with substantial new investments in new facilities and instrumentation, enable our investigators to be the best they can be, thus attracting highly competitive federal dollars.

In sum, our record funding level reflects the hard work and ingenuity of our world-class faculty, students, staff as well as a renewed enthusiasm in Washington for federally supported research and development.

CENTER FOR TRUSTWORTHY MACHINE LEARNING

PATRICK MCDANIEL

Patrick McDaniel, William L. Weiss Chair in Information and Communications Technology, has been awarded a National Science Foundation (NSF) Frontier grant to establish and lead the Center for Trustworthy Machine Learning. The five-year, $9.98 million grant will allow members of the multi-institution, multidisciplinary center to develop a rigorous understanding of the security risks of the use of machine learning and to devise the tools, metrics, and methods to manage and mitigate security vulnerabilities.

Machine learning is fundamentally changing the way everyone lives and works. From autonomous vehicles, to digital assistants like Amazon Alexa and Siri, to robotic manufacturing, computers are performing complex reasoning in ways considered science fiction just a decade ago. As more critical systems such as financial systems, self-driving cars, and network monitoring tools employ machine learning, it is of vital importance to develop the rigorous scientific techniques needed to make machine learning more robust against malicious attacks.

"We seek to develop a new science of safe machine learning that will provide a basis for applying intelligent algorithms in new domains," explained McDaniel. **"This science will ensure that these new technologies cannot be exploited in ways that will hurt the people who use them."**

MACHINE LEARNING IS FUNDAMENTALLY CHANGING THE WAY EVERYONE LIVES AND WORKS.

MOBILE COGNITIVE HEALTH

MARTIN SLIWINSKI

A $13.4 million National Institutes of Health (NIH) grant will allow a team led by Penn State's **Martin Sliwinski** to develop standardized mobile technologies for tracking small changes in the brain that may lead to neurological conditions later in life, information critical for developing prevention measures and improving quality of life for older adults and their families.

"Using these new technologies, we'll be able to obtain high-precision data about the mental and cognitive function of research study participants in the context of their everyday lives," said Sliwinski, Gregory H. Wolf Professor of Aging Studies and director of Penn State's Center for Healthy Aging.

For example, study participants could open a smartphone app, enter information about their stress levels, then play a brain game, allowing researchers to measure their cognition and study how stress affects brain function. The availability of the app would remove the need for participants to make multiple trips to a lab or clinic.

"If you need 1,000 participants for a study, it gets very expensive very quickly," Sliwinski explained. "By putting a lab on everyone's smartphone, we can make it affordable to do well-powered, strong biomedical science focused on cognitive and brain health."

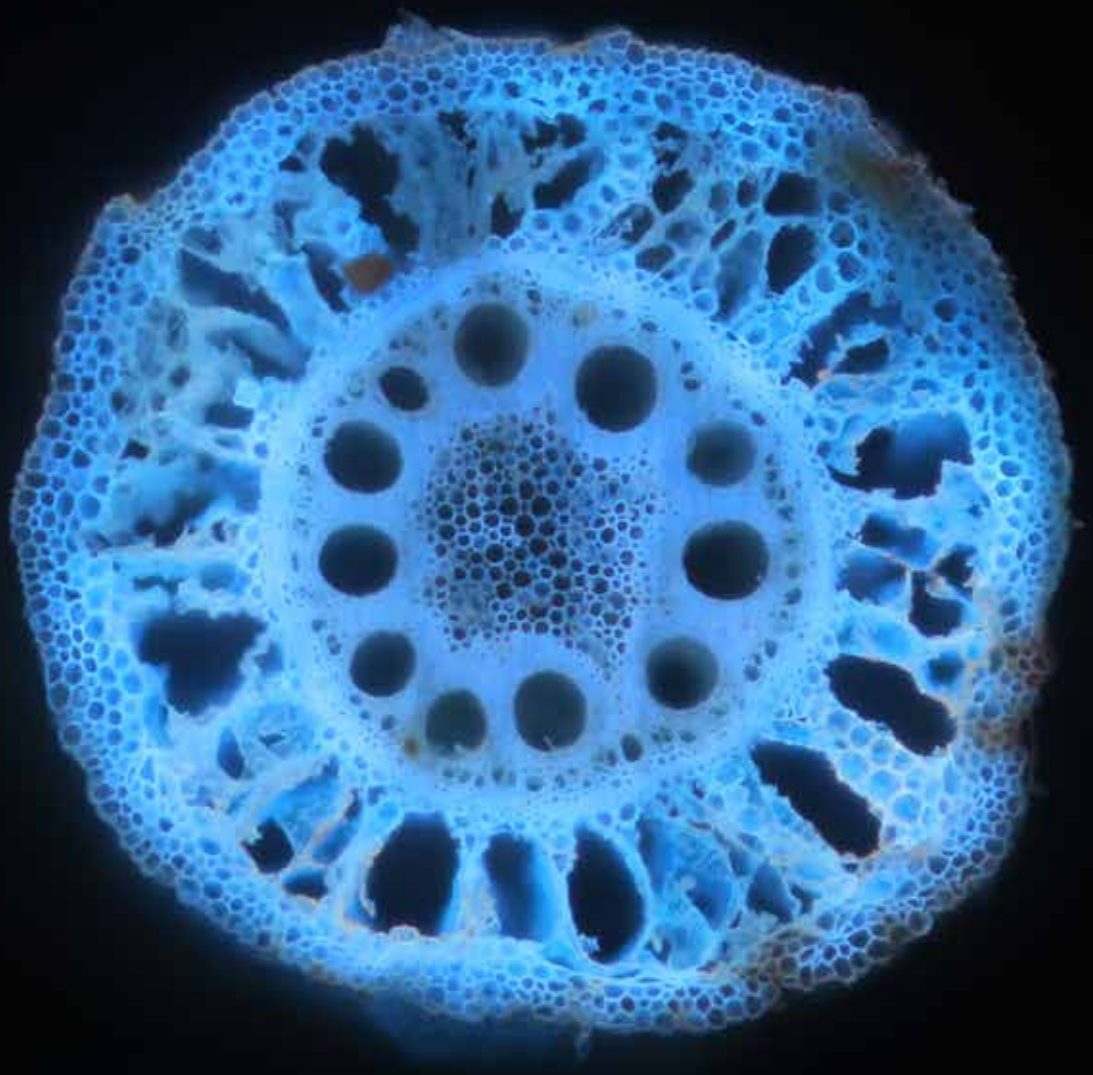
While some researchers are already using mobile technologies to gather data, Sliwinski noted, there's currently no standardized software or set of best practices. Under the new grant, he and his team will work with Sage Bionetworks, a company helmed by Penn State alumna Lara Mangravite, to build this infrastructure.

"We'll be designing a suite of tools that is ready for scientists to begin using, with no programming or technical knowledge needed," Sliwinski said. **"But it will also be a code base that can be built upon**

"WE'LL BE DESIGNING A SUITE OF TOOLS THAT IS READY FOR SCIENTISTS TO BEGIN USING, WITH NO PROGRAMMING OR TECHNICAL KNOWLEDGE NEEDED..."

if a researcher needed to customize and tailor it to fit their work. We want other labs to be able to innovate it and make it their own."

Penn State faculty from five departments will join the mobile cognitive health team, along with researchers from Mclean Hospital, Washington University in St. Louis, the Oregon Health Sciences University, the University of Victoria, the National Institutes of Health, and Sage Bionetworks.



DEVELOPING DEEPER ROOTS

Researchers in Penn State's College of Agricultural Sciences have received a $7 million grant from the U.S. Department of Energy's Advanced Research Projects Agency-Energy, or ARPA-E, to design a low-cost, integrated system that can identify and screen for high-yielding, deeper-rooted crops.

The interdisciplinary team, led by **Jonathan Lynch**, distinguished professor of plant nutrition, will combine a suite of technologies designed to identify phenotypes and genes related to desirable root traits, with the goal of enhancing the breeding of crop varieties better adapted for nitrogen and water acquisition and carbon sequestration.

Cross-section of a maize root segment showing its internal structure. Credit: Jonathan Lynch

JONATHAN LYNCH

The project is part of ARPA-E's Rhizosphere Observations Optimizing Terrestrial Sequestration, or ROOTS, program, which is aimed at developing crops that enable a 50 percent increase in carbon deposition depth and accumulation, while also reducing nitrous oxide emissions by 50 percent and increasing water productivity by 25 percent.

The ROOTS program website explains that while advances in technology have resulted in a tenfold increase in crop productivity over the past century, soil quality has declined, leading to a soil carbon debt equivalent to 65 parts per million of atmospheric carbon dioxide. This soil carbon debt increases the need for costly nitrogen fertilizer, which has become the primary source of emissions of nitrous oxide, a greenhouse gas. The soil carbon debt also impacts crop water use, increasing susceptibility to drought stress, which threatens future productivity.

Given the scale of domestic and global agriculture, there is tremendous potential to reverse these trends by harnessing the photosynthetic bridge between atmospheric carbon, plants, microbes, and soil. Advanced root systems that increase soil organic matter can improve soil structure, fertilizer use efficiency, water productivity, crop yield, and climate resilience, while mitigating topsoil erosion — all of which provide near-term and sustained economic value.

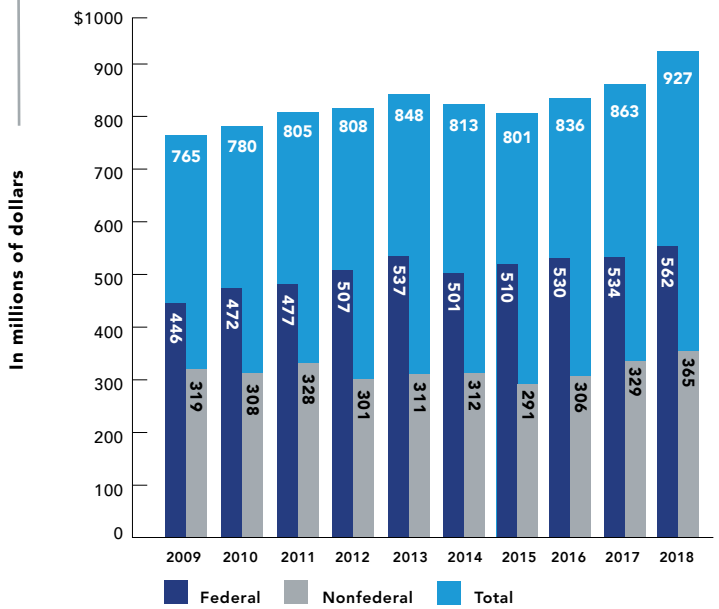
"THE SOIL CARBON DEBT INCREASES THE NEED FOR COSTLY NITROGEN FERTILIZER, WHICH HAS BECOME THE PRIMARY SOURCE OF EMISSIONS OF NITROUS OXIDE, A GREENHOUSE GAS."

"Development of new root-focused plant cultivars could dramatically and economically reduce atmospheric CO2 concentrations while improving productivity, resilience and sustainability," Lynch said. **"With ARPA-E's support, we plan to create DEEPER, a revolutionary phenotyping platform for deeper-rooted crops, which will integrate breakthroughs in nondestructive field phenotyping of rooting depth, root modeling, robotics, high-throughput 3-D imaging of root architecture and anatomy, gene discovery, and genomic selection modeling."**

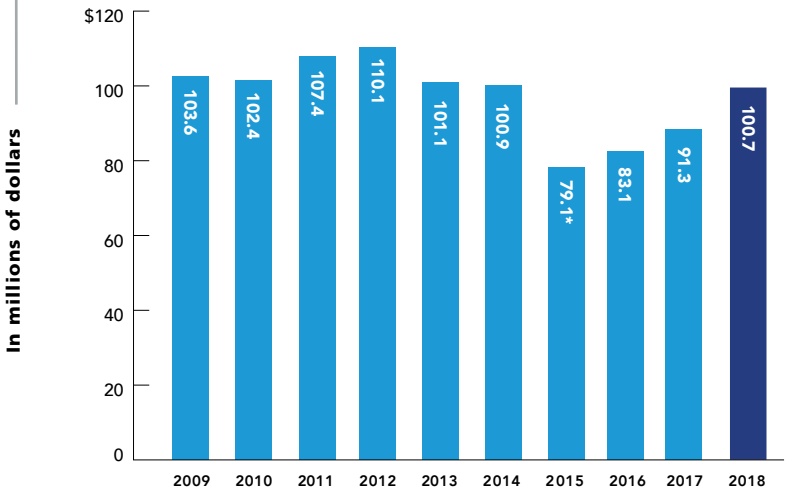
Root crown of a freshly dug maize plant.
Credit: Jonathan Lynch

TOTAL RESEARCH EXPENDITURES, 2009–2018

(Federal and Nonfederal)



RESEARCH SPONSORED BY INDUSTRY, FOUNDATIONS, AND OTHER SPONSORS, 2008–2017



SOURCES OF RESEARCH FUNDING

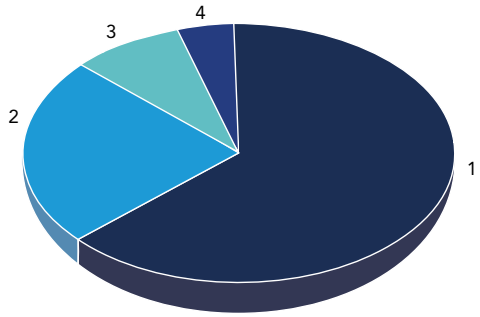
1 **Federal $561,858,000**

2 **University $191,194,000**

3 **Industry and other $100,700,000**

4 **Commonwealth of Pennsylvania $72,824,000**

Total $926,576,000



** Starting in FY15, federal flow-through dollars were removed from industry awards and allocated back to the prime federal sponsor.*

EXPENDITURES FROM FEDERAL AGENCIES

1 **Department of Defense $242,028,000**

2 **Department of Health and Human Services $127,231,000**

3 **National Science Foundation $72,931,000**

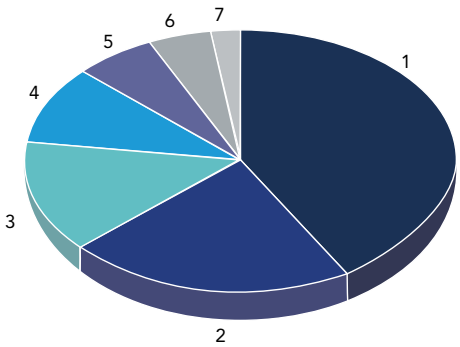
4 **Other $49,501,000**
- Commerce $2,706,000
- Education $5,587,000
- EPA $716,000
- Interior $1,683,000
- Transportation $5,791,000
- Other Federal $33,018,000

5 **USDA $30,870,000**

6 **DOE $26,409,000**

7 **NASA $12,888,000**

Total $561,858,000



EXPENDITURES BY PERFORMING UNIT

1 **Agricultural Sciences $125,094,000**

2 **Defense Related Research Units $242,251,000**

3 **Earth and Mineral Sciences $67,491,000**

4 **Eberly College of Science $127,530,000**

5 **Education $7,968,000**

6 **Engineering $131,791,000**

7 **Health and Human Development $50,298,000**

8 **Information Sciences and Technology $8,269,000**

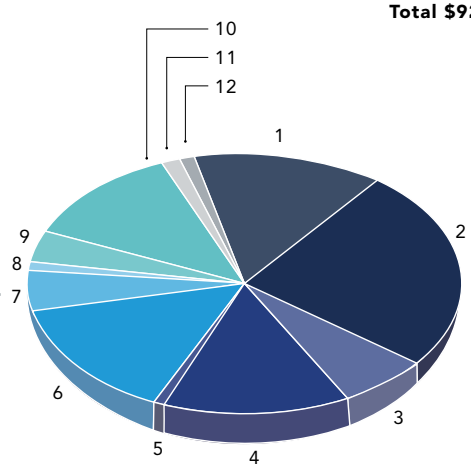
9 **Liberal Arts $36,750,000**

10 **Medicine $106,399,000**

11 **Other Campuses $10,355,000**
- Altoona College $1,038,000
- Behrend College $3,262,000
- Berks College $734,000
- Capital College $2,399,000
- Great Valley $417,000
- Other Commonwealth Campuses $2,505,000

12 **Other Colleges $11,674,000**
- Arts and Architecture $1,890,000
- Communications $562,000
- Dickinson School of Law $706,000
- International Programs $861,000
- Nursing $4,654,000
- Penn State Law $696,000
- Smeal College of Business $3,011,000

Total $926,576,000



PENN STATE TECHNOLOGY TRANSFER AT A GLANCE

Total revenue: $2 million

158
INVENTION DISCLOSURES **RECEIVED**

64
U.S. PATENTS ISSUED

8
START-UP COMPANIES **FORMED**

31
LICENSES AND OPTIONS EXECUTED

Technology transfer data are for the period January–December 2017.

A SAMPLING OF MAJOR AWARDS

BOVINE TUBERCULOSIS
The Bill and Melinda Gates Foundation awarded $5.55M to Penn State researchers to accelerate control of bovine tuberculosis in developing countries, targeting a reduction in the estimated $300B in global economic losses and stemming transmission from cattle to humans.

BRAIN DISORDERS
Two separate awards, from the National Institute of Mental Health ($3.68M) and the National Institute of Neurological Disorders and Stroke ($2.27M) will advance research intended to reveal how special MRI techniques can be used in tandem with routine clinical tests to aid in the non-invasive diagnosis of a variety of brain disorders.

SEA-LEVEL RISE
A $2.3M award from the National Science Foundation will support a joint initiative to substantially improve decadal and longer-term projections of ice loss and sea-level rise originating from Thwaites Glacier in West Antarctica.

LUNG CANCER DIAGNOSIS
The National Cancer Institute awarded $1.98M over 5 years to advance the development of an image-guided bronchoscopy system for more effective lung-cancer diagnosis and staging.

X-RAY ROCKETS
The National Aeronautics and Space Administration provided $4.12M to support studies on the use of rockets for extended-source soft X-ray spectroscopy to provide information about the evolution of large-scale structures in the universe.

SAFER FUEL RODS
A $2.5M award from the US Department of Energy will support studies aimed at ensuring the stability of cladding materials designed to provide for safe transport and storage of spent nuclear fuel rods.

SUMMARY OF RESEARCH PROPOSALS AND AWARDS

$2.79B
TOTAL AMOUNT OF PROPOSALS

$730M
TOTAL AMOUNT OF AWARDS

4,799
PROPOSALS SUBMITTED

3,346
AWARDS RECEIVED

1,885
NEW & COMPETING CONTINUATION AWARDS RECEIVED

1,994
INVESTIGATORS RECEIVING AWARDS

967
SPONSORS

CONTACTS:

Neil A. Sharkey
Vice President for Research
304 Old Main
University Park, PA 16802
814-865-6332
nas9@psu.edu

Stephen P. Brawley
President and CEO Ben Franklin Technology Center of Central and Northern Pennsylvania, Inc.
150 Technology Center
814-865-8669
stevebrawley@psu.edu

James L. Delattre
Assistant Vice President for Research and Director, Office of Entrepreneurship and Commercialization
101 Technology Center
814-865-1751
jld141@psu.edu

Jeffrey B. Fortin
Associate Vice President for Research and Director, Office of Industrial Partnerships
304 Old Main
814-865-6042
jbf17@psu.edu

John W. Hanold
Associate Vice President for Research and Director, Office of Sponsored Programs
110 Technology Center
814-863-0768
jhh6@psu.edu

Mary J. Kennett
Director, Animal Resource Program
101 Centralized Biological Lab
814-865-1495
mjk26@psu.edu

Leslie J. Parent
Associate Vice President for Health Sciences Research, Vice Dean for Research and Graduate Studies, College of Medicine
H175, Hershey Medical Center
Hershey, PA 17033
717-531-7199
lparent@psu.edu

Shashank Priya
Associate Vice President for Research, Director of Strategic Initiatives
304 Old Main
814-863-9657
sup103@psu.edu

James L. Taylor
Director, Office of Research Information Systems
Suite 105, The 330 Building
814-865-0681
jlt41@psu.edu

Harl R. Tolbert
Assistant Vice President for Research and Director, Office of Technology Management
113 Technology Center
814-865-6277
hrt26@psu.edu

Candice A. Yekel
Associate Vice President for Research and Director, Office for Research Protections
Suite 205, The 330 Building
814-865-1775
cay3@psu.edu

Interdisciplinary Research

Jenni Evans
Director, Institute for CyberScience
224 Computer Building
814-865-3240
Jenni.Evans@psu.edu

Raymond J. Hohl
Director, Penn State Cancer Institute
717-531-4034
rjh35@psu.edu

Peter J. Hudson
Director, The Dorothy Foehr and J. Lloyd Huck Institutes of the Life Sciences
201 Life Sciences Building
814-865-6057
pjh18@psu.edu

Susan McHale
Director, Social Science Research Institute
114 Henderson Building
814-865-2663
mchale@psu.edu

Clive Randall
Director, Materials Research Institute
N221 Millennium Science Complex
814-863-1328
car4@psu.edu

Thomas L. Richard
Director, Institutes of Energy and the Environment
Land and Water Research Building
814-863-0291
tlr20@psu.edu

Lawrence Sinoway
Director, Clinical and Translational Science Institute
717-531-6853
lsinoway@psu.edu

Defense-Related Research

Paul E. Sullivan
Executive Director, Defense-Related Research Units and Director, Applied Research Lab (ARL)
814-865-6343
pes16@psu.edu

FOR MORE INFORMATION, VISIT OUR WEBSITE:

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Credit: Mark Golaszewski

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