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BROKEN BEAKERS: FEDERAL SUPPORT FOR RESEARCH

HEARING

BEFORE THE

SUBCOMMITTEE ON FEDERAL SPENDING OVERSIGHT AND EMERGENCY MANAGEMENT

OF THE

COMMITTEE ON HOMELAND SECURITY AND GOVERNMENTAL AFFAIRS UNITED STATES SENATE

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WEDNESDAY, OCTOBER 18, 2017

U.S. SENATE,
SUBCOMMITTEE ON FEDERAL SPENDING,
OVERSIGHT AND EMERGENCY MANAGEMENT,
OF THE COMMITTEE ON HOMELAND SECURITY
AND GOVERNMENTAL AFFAIRS,
Washington, DC.

The Subcommittee met, pursuant to notice, at 2:20 p.m., in room SD–342, Dirksen Senate Office Building, Hon. Rand Paul, Chairman of the Subcommittee, presiding.

Present: Senators Paul, Lankford, Peters, Hassan, and Harris.

OPENING STATEMENT OF SENATOR PAUL[1]

Senator PAUL. The hearing will come to order, and I want to thank everybody for getting here sort of in a rush. We are going to have to go vote a little after 3:00 p.m., but we wanted to get as much done as possible because I think there are six votes and there may not be a resumption of the hearing. So we are going to be efficient and get to it and have a good discussion.

Today we are going to look at the Federal Government's role in funding research. I am concerned that the government system of supporting research is inefficient and often incentivizes the wrong things, which leads to bad science and wasted taxpayer dollars.

We have published examples, like this National Science Foundation (NSF) study, which had money being spent on Ugandan gambling habits. I just see no reason at all taxpayer money would go to that, period. And we do it year after year after year.

Senator Lankford found an National Institutes of Health (NIH) study, $2 million, investigating if kids do not like food that has been sneezed on. Are you more or less likely to eat the food in front of you in the buffet line if someone sneezes on it? That is absurd.

And who could forget the shrimp on a treadmill found by Senator Coburn?

So how does this happen? More accurately, how does this continue to happen? I remember as a kid in the 1970s seeing Senator William Proxmire describe waste such as this as he gave his Golden Fleece Awards, and here we are 40 years later still with the same kind of questions.

Part of the problem is the old adage, "Publish or perish." Researchers that publish are more likely to get Federal funding, and

[1] The prepared statement of Senator Paul appears in the Appendix on page 21.

unique research is more publishable. So how do unique projects get funded to begin with? At some agencies, grant applicants themselves can actually recommend who should review and make the recommendations on their grant. So the people getting the money can recommend who approves giving them the money. That is right. Researchers get to pick the people who approve their funding. It does not sound very objective.

Some grantsmanship books advise applicants to recommend reviewers who will be champions for your work, while agency guidelines suggest disqualifying those who have scientific disagreement with you. So we teach people how to get grants, and we say, "Find people who agree with you and get them on the committee. If you know anyone already disagrees with you, make sure you keep them off the committee."

This is baking in bias, and it is unacceptable. I have introduced legislation that will prohibit this practice and further require impartiality on grant review panels.

Another problem we found is downstream funding or taking original grant money and giving it to other researchers for projects that are often not consistent with the original grant. The Federal Government gives someone money to do research. That person then gives it to someone else, who even may give it to a third or a fourth party. None of this is published in public government databases.

One example of this problem was a study that its intent was what makes for the perfect first date. But this is the subject of the study: "What makes for a perfect first date?" The original grant, to study how scientists collaborate on scientific research. They were going to study collaboration on scientific research. They somehow got to what makes for a perfect first date.

It is difficult to discover how much these studies cost because they are cobbled together from multiple sub-grants. My bill would curtail this by requiring that all sub-grants, no matter how removed from the original grant, be fully reported, approved, and made public.

We also found that many grants are issued for rational but broad research subjects and then are used for ridiculous ancillary projects. For example, one researcher took money from NIH to study drug and alcohol abuse and then published a paper on how to select the best wines for your palate. I am not sure how this prevents alcoholism, but I am pretty sure it must have been interesting to the journal editors.

Our bill creates a special Inspector General (IG) to oversee this and make sure that we are spending our money wisely. Why should we do this? Well, we spend $700 billion more than we take in every year, and we have a $20 trillion debt. It is inexcusable just to keep shoveling good money after bad without paying attention to how we spend it.

In our bill we also ask for something called a "taxpayer advocate for research" that can look into these matters, provide rigorous oversight, and report to Congress about such follies.

Our bill also requires that committees reviewing grants have at least one researcher from a scientific field unrelated to the subject area to further remove personal bias. The idea is to have a scientist from important areas of research, such as cancer, diabetes, Alz-

heimer's, heart disease, sit in on review committees that would review grants for wine tasting. Maybe someone would say, "You know what? We really have a lot of people with Alzheimer's," or, "We really have a lot of people with heart disease." Maybe someone would say, "Maybe the shrimp on a treadmill is not something we have to study." Or maybe the money could be better spent somewhere else.

The last problem I will discuss is replicability. An increasing body of work shows that, in an effort to publish, a lot of research is not reproducible. This means that the study cannot be duplicated by other scientists to produce statistically similar results. That is a major problem, and it goes back to this issue of publishing. Journal readers and editors do not get excited about negative results, so the bias is toward funding studies that prove a premise versus studies that may disprove a premise.

My bill would seek to address this by creating greater transparency to the whole process so taxpayers can know exactly how their money is being used. This will allow the scientific community and the public at large to be able to collectively review and evaluate taxpayer-funded research. Hopefully, this will deter study manipulation to prove hypotheses.

Some will say that the general public does not understand science, but I do not think you need a Ph.D. to understand people are less likely to choose food that has been sneezed on, and they do not want that kind of research either.

With that, I would like to recognize our Ranking Member, Senator Peters, for his opening statement.

OPENING STATEMENT OF SENATOR PETERS[1]

Senator PETERS. Well, thank you, Chairman Paul, for holding this hearing today. I would like to join Chairman Paul in thanking our witnesses for taking the time to be with us here today. I look forward to hearing your testimony.

One of the essential tasks of this Subcommittee is to engage in honest evaluations of the public investments that we make as a Nation and whether or not these investments are indeed worthwhile. This is a responsibility to the taxpayer that I personally take very seriously, and I am grateful to have an opportunity to do so in a collaborative, bipartisan way.

We are here today to discuss Federal funding for scientific research, which I believe remains a necessary investment in our collective future. Scientific research is the seed corn of innovation and new discoveries, and Federal investments in research and development (R&D) have led to discoveries that have had profound impacts on public health, safety, and our quality of life. Federally funded research has resulted in widespread adoption of technologies as revolutionary as the Internet, global posititioning system (GPS) satellites, magnetic resonance imaging (MRI), and the Human Genome Project (HGP). This research results in economic growth in every State and leads to the creation of tens of thousands of jobs in entirely new sectors of the economy. It inspires the

[1] The prepared statement of Senator Peters appears in the Appendix on page 23.

next generation of Americans to believe that the sky is the limit and that no challenge is impossible.

Even as the share of Federal investment remains at a historic low as a percentage of overall gross domestic product (GDP), supporting federally funded research remains as important as ever to maintain America's competitive edge in an increasingly competitive global economy.

Targeted Federal investments in research can accelerate, catalyze, and encourage private sector innovation that may not have otherwise occurred.

We should recognize that the Federal and private contributions to the research and development enterprise are not perfect substitutes for one another, but instead work in tandem with each other, focusing on different stages in the R&D cycle.

Last year, I was proud to introduce bipartisan legislation with Senators Gardner, Thune, and Nelson known as the "American Innovation and Competitiveness Act," which was signed into law in January of this year. The bill was the product of a year-long effort that began with a series of roundtable discussions with representatives from science, from education, business, and economic development communities on how to improve the American research and innovation ecosystem.

Our legislation reauthorized a number of important programs that promote research and scientific inquiry, strengthen innovation and advance manufacturing, grow our skilled workforce, and enhance American competitiveness around the world.

The bill included a number of provisions that aim to reduce regulatory and administrative burdens on academic researchers so that they can spend more of their time on research and less on paperwork.

Our bill also reaffirmed the independent merit review process that guides NSF funding decisions and ensures that research proposals are judged independently on their merits by peers in the scientific community and without bias.

While certain basic research projects that receive Federal funding certainly have some very silly sounding titles, further examination may reveal the true scientific merit and potential broader impacts of that work.

Before a proposal gets one penny of funding, reviewers have to consider it based on criteria that include whether the proposal increases economic competitiveness, advances public health and welfare, or supports the national defense. It is worth noting that only one in five proposals receive NSF funding at all and that NSF is required to justify to the public why these proposals were lucky enough to receive funding.

Even as research begins with a clear question in mind, it can be hard to quantify or predict exactly where the science will lead. Rather than inject politics into this process, our discussion today should instead concentrate on how to safeguard the often unexpected process of discovery inherent in scientific inquiry while ensuring that Federal dollars spent on research remain completely and fully accountable to taxpayers.

Part of the solution may lie in breaking down barriers. Rather than remain ensconced in the ivory tower of academia, scientists

should be prepared to engage in a robust exchange of information with the general public about the goals and benefits of their research.

The discussion we are having today is an important one. Our country faces critical environmental, public health, and economic challenges in the years ahead, but we must not shy away from facing head on by leveraging the power of our research enterprise to create a better tomorrow for each and everyone.

Thank you again to our witnesses for your time today. I look forward to the discussion.

Senator PAUL. Thank you, Senator Peters.

With that, I will begin by introducing our first witness, Brian Nosek. Dr. Nosek is the co-founder and executive director of the Center for Open Science at the University of Virginia, which works to increase the openness, integrity, and reproducibility of scholarly research. Dr. Nosek holds a Ph.D. from Yale and is professor of psychology at the University of Virginia.

We are happy to have you here and to get your thoughts on these critical issues. Dr. Nosek.

TESTIMONY OF BRIAN A. NOSEK, PH.D.,[1] EXECUTIVE DIRECTOR, CENTER FOR OPEN SCIENCE, AND PROFESSOR, DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF VIRGINIA

Mr. NOSEK. Chairman Paul, Ranking Member Peters, Members of the Subcommittee, on behalf of myself and the Center for Open Science, thank you for the opportunity to discuss the funding of scientific research and the role of transparency and reproducibility to maximize the return on those investments.

Science may be humanity's most important long-term investment. The effort to accumulate knowledge has profound consequences for growing the economy, security, and well-being of American society. Some of the impact of scientific investments are directly anticipated in the project aims. But much of the impact is indirect. Research often leads to unexpected insights and applications that are only appreciated after the discovery, and these unexpected directions can produce returns that are many orders of magnitude larger than the original investment.

Simultaneously, there are opportunities to nudge the culture of incentives in science to be even better stewards of taxpayer support.

In 2002, I became a professor at the University of Virginia in the Department of Psychology. My group does fundamental research on implicit social cognition—thoughts and feelings that occur outside of conscious awareness or conscious control—and my lab has had Federal support from NIH and NSF.

Since 2013, I have been on extended leave from the university because a graduate student and I spun out a technology and culture change company from my lab called "The Center for Open Science." The center has a mission to increase openness, integrity, and reproducibility of research and has received support from NIH, NSF, Defense Advanced Research Projects Agency (DARPA), and Intelligence Advanced Research Projects Activity (IARPA).

[1] The prepared statement of Dr. Nosek appears in the Appendix on page 25.

Transparency and reproducibility are core values of science because they are how science advances knowledge. When I make a claim, you could believe it based my authority as an expert or how confident I seem making it. But these are not sufficient for scientific claims. For credibility of scientific claims, I need to show you how I arrived at the claim. By showing you my methodology, the data I collected, and how I analyzed and interpreted that data, you can make an independent assessment. You might recognize a flaw, think of an alternative interpretation, or have an idea about how to extend what I did to learn more. Moreover, by sharing how I arrived at that claim, I give you the opportunity to reproduce the evidence. If you can independently obtain similar results, then our confidence in the claim increases. The challenge, and the reason for the Center for Open Science's existence, is that the culture of incentives for scientists sometimes undercuts the core values of transparency and reproducibility.

The culture rewards novel, positive, clean results, and there are few incentives for being open or reproducible. As a consequence, we may be producing exciting results at the cost of credibility of those results. And some evidence suggests that the reproducibility of the published literature is lower than desirable or expected. Federal research funding agencies are aware of this problem and only have taken initial steps to address it. This can change. If transparency and reproducibility are incorporated into the policies and incentives shaping researchers' behavior, we may reduce waste and increase the pace and efficiency of discovery and ultimately earn even greater returns on investment of taxpayer dollars.

I will close with a specific suggestion that the Committee could pursue to help further the efficiency in scientific research, and that is to set the default to open for papers, data, and materials. In 2013, Federal agencies were asked by the White House to make a plan for improving the management and accessibility of data and materials for the research that they fund. Most agencies have completed this work. Congress could take the next logical step and require each Federal research funding agency to develop policies that require the research data and materials generated by Federal dollars to be made publicly accessible by default upon the publication of the findings or completion of the grant period. Changing the default from closed to open would alter cultural expectations and behavior. Instead of needing to generate reasons to share data, researchers would need to provide justification for delay or to not share at all due to proprietary or privacy concerns.

Public investment in science leads to solutions, cures, and entirely unexpected advancements that benefit American society. Changing the default to open for scientific research data would transform science, dramatically increase the return on investment (ROI) from publicly funded research, and accelerate progress. This is not a difficult proposition and concept, but it does require a mandate. This one action would dramatically increase the public benefit from our investments in science.

Thank you, Members of the Committee, for your continuing support of science and for the opportunity to speak with you today.

Senator PAUL. Thank you, Dr. Nosek.

Our next witness is Terence Kealey. He is a senior research fellow at the Cato Institute. Prior to joining Cato in 2014, he served as president of the University of Buckingham, the only university in Britain to be financially independent from the government. He has also lectured in clinical biochemistry at the University of Cambridge and is the author of "The Economic Laws of Scientific Research." Dr. Kealey holds an M.D. from the University of London and a Ph.D. in metabolic chemistry from Oxford. During his laboratory career, he focused on the study of inflammatory skin conditions.

Thank you for being here, and we look forward to your opening statement.

TESTIMONY OF TERENCE KEALEY, M.D., PH.D.,[1] SENIOR VISITING RESEARCH FELLOW, CATO INSTITUTE

Dr. KEALEY. Thank you very much for having invited me.

I am very glad to be speaking after Dr. Nosek because in a sense my five minutes is about addressing how we got to a situation where Brian Nosek's research became so important.

In my testimony I provide the evidence and, with great respect to Senator Peters, I have to say that there is, I am afraid, simply no evidence that economic growth or technological growth that leads into economic growth is in any way benefited by the Federal funding of science. It is widely believed that government should fund science. It is based on a model of what science is that I regret is unscientific, and in my testimony I hope I have shown pretty clearly that the government in this country and no other government needs fund science, at least for economic reasons.

Nonetheless, I am going to take the testimony as read. I am not going to revisit it. I am just going to accept that that is what governments do. They fund science. And what they do in consequence is they impose a particular model on science, which is called "the linear model," which actually has a history of 400 years. It was first described by Francis Bacon 400 years ago in England. And the model says, very much as Senator Peters suggested and very much as Dr. Nosek suggested, that what you need is you need a group of scientists doing pure research in universities and similar research institutions where they are free to follow their own curiosity and to follow where the science takes them. And then as a consequence of that, knowledge leaks out to the rest of the world and is then turned into technological and other forms of sociological advance.

That is not how science happens in the free market. In the market, scientists who are embedded within companies and industry are embedded very tightly with technologists, with other members of the company, even with marketing. They are part of a commercial enterprise. The result, therefore, is that there are two ways of judging scientists, and in industry, scientists are ultimately judged by their technology. How does a scientist's research ultimately lead to technology that is of benefit, of course, immediately to the company and to the stockholders but to society at large that way?

[1] The prepared statement of Dr. Kealey appears in the Appendix on page 30.

As Daniel Sarewitz of the University of Arizona said in a very influential essay last year, it is technology that keeps science honest. But the government funding of science makes scientists answerable not to technology, not to stockholders, but to fellow scientists. And that leads directly to the two problems that Senator Paul indicated.

First, the problem with peer review is that you end up with a group of people all agreeing with each other on which particular paradigm they wish to support, and often unconsciously—scientists are profoundly honest people, but, nonetheless, they have their own interests, and unconsciously supporting paradigms that, if they were tested against the technological market, would never have survived for nearly as long as they do survive in the academic world. Such an example might be the 40-year history of governments telling us not to eat fat, which was based on a group of scientists telling another group of scientists that they should not eat fat and all agreeing with each other. It was, of course, wrong.

But the other problem, again, as Dr. Nosek and Senator Paul indicated, is that scientists are not judged by what they achieve. They are judged by the numbers of papers they publish, at least in part, and they are judged by which journals they are published in. So to be savage about this, scientists are not judged by what they achieve; they are judged by what they write. The consequence of that is that scientists are encouraged to do the sort of things that Brian Nosek has picked up, such as produce papers that are not easily reproduced. The reason they produce such papers is the benchmark for success is having the paper accepted, not making an important advance for humanity.

So, to conclude, this country has engaged since 1950, when the NSF was created, in an interesting experiment of the Federal Government funding science. It has had no impact on fundamental rates of economic growth. What it has done, it has created a microclimate or a niche where scientific pathologies have proliferated, and the answer actually is to question anew whether government should be funding science at all.

Thank you.

Senator PETERS. Well, I have the great pleasure to introduce a fellow Michigander, Dr. Rebecca Cunningham, who is representing not only the State of Michigan but a great American university, the University of Michigan. Of course, we are blessed with a number of great universities in our State, but it is great to have Dr. Cunningham here. She is the Associate Vice President for Health Sciences Research for the University, Professor for the University of Michigan's Department of Emergency Medicine, and a Professor in Health Behavior and Health Education at the University of Michigan School of Public Health.

Dr. Cunningham has a very distinguished career in conducting clinical trials focused on public health interventions in health settings, such as the emergency department. Her past clinical trials have focused on interventions in the emergency room using technology to overcome barriers to reaching youth, to prevent alcohol and prescription opioid misuse. This is a matter, of course, of great interest to this Committee, and I applaud all of your efforts in that area.

Her federally funded research over the last 18 years has focused on improving the health of children and young adults and those seeking emergency health services. Also, notably, Dr. Cunningham started her career as an attending physician at Hurley Hospital in Flint, Michigan.

Thank you, Dr. Cunningham, for your service, and thank you for testifying here today and representing us all very well.

TESTIMONY OF REBECCA CUNNINGHAM, M.D.,[1] ASSOCIATE VICE PRESIDENT FOR RESEARCH—HEALTH SCIENCES, UNIVERSITY OF MICHIGAN OFFICE OF RESEARCH

Dr. CUNNINGHAM. Thank you for that introduction. Good afternoon, Chairman Paul, Ranking Member Peters, and Members of the Subcommittee. Thank you for inviting me to speak with you today about the value of federally funded research. I also want to give special thanks to Ranking Member Peters for his work on crafting and securing passage of the American Innovation and Competitiveness Act which serves to support the critical Federal research enterprise that I am here to talk with you about today.

Our great Nation is what it is today because of Federal investments in research. We are leaders in innovation because of these investments, our economy is strong because of these investments, and our top research institutions are the envy of the world because of these investments.

This investment has supported—and must continue to support—basic, curiosity-driven research alongside applied research and engineering. The knowledge that we derive from fundamental research is the seed to innovations like self-driving cars and life-saving drugs. Another example is the iPad; without Federal research investments to deepen our understanding of basic scientific principles across many agencies, engineers never would have been able to design the core software and components that made the iPad such a ground-breaking device. This is just one example of the possibilities that come out of fundamental research: innovations that our imaginations cannot always comprehend.

I have seen the benefits of these innovations firsthand. As an emergency physician, I have seen the success of drugs and new medical technologies that allow patients to walk out of the hospital today who would have died when I was a medical student. I have sat with the spouses, parents, and children of those who have fallen victim to the epidemic of opioid overdose in our Nation. Over the past 20 years, funded by the NIH and the Centers for Disease Control (CDC), I and our research team and lab have worked to develop interventions for the treatment of children impacted by substance abuse or trauma who flood our emergency rooms, and such research has prevented many more from needing our care.

For example, I am partnering with scientists and community leaders to address the opioid epidemic that is impacting every community across our Nation. Translating the underlying science of opioids into policy solutions relies on fundamental research. From synthetic chemistry funded by the NSF to basic neuroscience funded by the NIH, policies based on sound fundamental science and

[1] The prepared statement of Dr. Cunningham appears in the Appendix on page 37.

life-saving medical breakthroughs will ultimately lead to the solutions that we cannot yet imagine but need for the opioid crisis.

Federal support for research has been part of our country's fabric dating back to the start of the Republic in the 1700s. In the past 70 years alone, the role of funding in game-changing innovations has been tremendous. For example, the development of the GPS, supercomputing, the visible light-emitting diode (LED), the technology behind the MRI machine that aids many of my patients in diagnosis of brain disease daily, all have their roots in Federal investments in public sector researchers.

Federal investments in research also help drive our economy and train our future Science, Technology, Engineering and Math (STEM) workforce. At the University of Michigan, there were 444 new inventions last year and 12 startup companies launched based on technologies developed by our researchers. Federally funded research supports local economies all across the Nation by providing billions of dollars each year to vendors—from small businesses to biotech companies—who are making devices, software, and other equipment needed to perform research.

In the past 15 years, vendor spending to support research at the University of Michigan has created 221,000 manufacturing jobs and 641,000 health care jobs. This investment also supports thousands of employees working in laboratories and research institutions across the country, many of whom the largest recipients by far are our students. It is this next generation of students that will drive and support American innovation and competitiveness in the future and lead many of the industries that will take us to success.

Flat funding rates in Federal investments in research—and in many cases declining funding rates—over the last decade have already shown impacts on our scientific talent pipeline, driving away the next generation of leaders and innovators from careers in research. This decline is happening while other countries see the clear return on investment in government-sponsored research and are doubling down on their efforts to become global leaders. Indeed, several metrics related to innovation and scientific impact already show that the United States is losing ground to countries like China.

This trend will only continue at our current level of research investment, and the consequences will impact the American economy as well as our national security. For the United States to remain a global leader, we need to lead in innovation, science, and research. American industry leaders recognize that the Federal Government's investment in basic science is critical in driving innovation, productivity, and economic growth. For example, hundreds of business leaders signed the Innovation Imperative statement, which was a call to action for Federal funding increases in basic scientific research.

Thank you again for this opportunity to discuss the importance of Federal investments in research. I would be happy to answer any questions.

Senator PAUL. Thank you all for your testimony.

I was intrigued, Dr. Kealey, by your sort of compare and contrast of the way industry works versus how we judge science in univer-

sities. Tell me again, what was the name of the author of the paper you said that talked about technology keeps scientists honest?

Dr. KEALEY. Daniel Sarewitz, in a journal called "New Atlantis." It is a very good article.

Senator PAUL. OK. I was intrigued by the contrast between how technology keeps scientists honest because it basically has to work, and the stuff that works in rewarding the stuff that does not work, may sit around. But it is kind of interesting because people on the left will say, well, we will never get any basic science research, serendipity and all of these things where people put some mold in a dish and discover penicillin are never going to happen if it is just industry. But I was thinking of, even in my State, we have Corning, who has been famous for developing practical uses of science. They developed something back in the 1960s—they call it now "Gorilla Glass," but it was a technology for making this glass. They did not have a use for it for 50 years. But they kept it in their files. They patented it. And now it is the glass on your cell phone. And it is an amazing thing. I think it drives their whole industry. It drives their whole company now, what they make, the money they make off of this. So I think serendipity and things can come from industry as well.

But in contrasting that with the university where the reward is not whether your science is necessarily good or produces anything of value to society or economic growth, but whether or not it is published, how many times it is published, and in what journals.

I guess my question to you, though, would be: In looking at this contrast, what do you think of the other side's argument that says, well, we will not get basic science research, we will not get serendipity, we will not get all these clever little things that just happen to turn up from being curious if we had science led by technology and industry?

Dr. KEALEY. Well, it is a myth that industry does not support basic science. Industry is very generous toward basic science. Because, of course, industry needs basic science. But the real lesson is historical. Despite Dr. Cunningham's statement that the Federal Government has supported science throughout the history of the Republic, actually as recently as 1940 the Federal Government was funding only about 20 percent of American science or R&D. You became the richest country in the world in 1890 under a regime of complete laissez-faire, and you have only got to look at some of the Senate records of the Senate opposition even to taking the money for the Smithsonian Institution, which was opposed by a number of Senators, to realize how long the suspicion has been of American funding of science by the Federal Government.

The NSF was created as part of the Truman Doctrine. It was Truman deciding that he was going to forget George Washington's statement of no foreign entanglements. America was now going to get involved with foreign entanglements, which meant he needed defense research to support his defense initiatives.

All that happened as a consequence of that was crowding out. What people forget is the phenomenon of crowding out. When the State funds something, the private sector withdraws. Dr. Cunningham points out that companies like private—the government funding science. Of course they do. Companies are very fond

of corporate welfare. Crowding out in the phenomenon that explains why there is no evidence anywhere that the government funding of science has ever stimulated economic growth or, indeed, the amount of pure science. Industry cannot survive without pure science, and it funds it very generously.

Senator PAUL. Senator Peters.

Senator PETERS. Thank you, Mr. Chairman.

Dr. Cunningham, I would like you to expound a little bit on some of the points that you made. First I want to say that we know the scientific enterprise and the ability to advance scientific knowledge is a complex ecosystem, and it is not mutually exclusive. It is not just private industry. It is not just in academia. It is about the interaction between all of these entities working together and churning the innovation that comes out of the scientific enterprise. So in my mind, there is a role for Federal research. Certainly private industry is a big part of it. In fact, most investment in research is done with private industry today.

But I would like you to speak a little bit just from your own experience. Can you provide an example of research that you have done over the many years that you believe just simply would not have been done if it was not for Federal investment?

Dr. CUNNINGHAM. Sure. Thank you. A lot of the work that we have done has been on looking at ways that we can get adolescents and teenagers who are at risk for substance use and opioid misuse to make safer decisions and to be safer after leaving the emergency department. That is not the type of research that typically would be of interest to industry, would have an immediate economic gain to industry. It is of tremendous help and benefit to the greater public health, and that type of prevention work is critical to our public safety, public health, and eventually hopefully to the opioid epidemic that we face.

Senator PETERS. So it is not something you would see pharmaceutical companies doing?

Dr. CUNNINGHAM. That type of prevention work is not done by pharmaceutical companies.

Senator PETERS. I also know that the University of Michigan, just from my own personal experience, is an incredible engine of economic growth in our State. I think it is in no small part because of the tremendous research that is being done at the University of Michigan as well as our other research universities that have created intellectual hubs that spread out throughout the economy, throughout the business sector.

Considering your role in the Office of Research, could you provide some examples of basic research at the University of Michigan that you believe has led to significant economic growth?

Dr. CUNNINGHAM. Yes, thank you. The University of Michigan is a tremendous—there is tremendous spillover throughout the State. First of all, I can say, as I mentioned, the 444 new inventions last year and the 12 new startup companies in technologies based on our researchers. A new startup happens about every four weeks out of the university research alone. Recently, a company, Neurable, was created by University of Michigan scientists who were studying foundational questions around brain waves. They have then gone on to develop a cap that can help you think about making

things move just by wearing the cap. That will likely go on to have great economic benefits down the road. That is really in its early stages right now, but came from foundational research and foundational science.

I think also the spillover effect in terms of training cannot be overlooked. For example, a researcher that did foundational work on semiconductors that went on to being part of Samsung screens came out of the University of Michigan, has had big implications for cheaper and more efficient solar cells, which have impacted our economy, also influenced national security. And really importantly to think about is while that researcher was doing that federally funded research, they also trained 27 post-docs and 52 Ph.D. students, many of whom went on to be faculty and leaders and eventually leaders of companies and leaders of industry. They were trained with this foundational research. That type of spillover effect is really critical.

Also, when we talk about benefits to the economy, it is important to think about that type of linear model has been rethought more recently by many scholars in terms of an innovation ecosystem. Really, we do not see it anymore as a linear model of pure science happening at the institutional level that eventually trickles down in a linear way to industry and to the economy. Instead, we really see much more of what we call "tire track model" where there is a lot of interaction back and forth even at early levels between basic scientists and industry and basic scientists and the public sector. Those inform each other, and they train each other. In the end we wind up with an innovation ecosystem that is a lot stronger.

I think the university as well as other academics have also come to see that we can do better in moving this pipeline faster down the road, and some federally funded programs have helped that. For example, the University of Michigan has what is called the Clinical and Translational Science Awards (CSTSA) program, which is designed specifically to take early stage work and help investigators move it quicker down a pipeline by connecting basic scientists who often cannot speak outside of their field because they are very much experts in a particular field with folks who have applied and practiced in industry work, to be able to have that interaction happen faster and really be synergistic.

Senator PETERS. Partially in response to criticism from Members of Congress about silly sounding research grants—we heard some examples of those here earlier today—the NSF issued guidance in 2013 to researchers on how to write titles and abstracts in a way that enhances public understanding of scientific research. It encourages researchers to explain the significance of their projects in a non-technical manner. This change may seem insignificant, but I think it really underscores the importance of building connections between the scientific community and the general public, while certainly reminding Americans that scientific innovation and research benefits the whole country in many ways.

I am curious about the panel's thoughts on what scientists can do to better communicate the importance of their research to the public and to dispel some of these misconceptions about silly sounding research. I will start with you, Dr. Cunningham, and then I

think we will only have time for Dr. Nosek. If you would follow up, I would appreciate it. Dr. Cunningham.

Dr. CUNNINGHAM. I think we all have a responsibility to communicate our science better. I think although silly sounding science to non-scientists may be difficult to understand the ultimate meaning behind, we are responsible for communicating better. There are a number of ways that that can happen. Our CDC center that I currently direct takes each of our science publications that comes out and works with communications staff, specifically pairing scientists with non-scientists in that realm to help create one-page sheets that can be easily understood for the public on exactly what it is we are doing and how that might inform our public practice and health. I think that is one manner.

There are a number of other programs that are like that at the American Association for the Advancement of Science, the Center for Public Engagement in Technology, a Science Policy Fellows Program that is working to engage scientists in communicating that information better to the public.

Senator PAUL. Thank you.

We are going to go to Senator Harris, and I apologize, but we are going to do five minutes so we can try to get through everybody, because we are getting ready to have to go vote. Senator Harris.

OPENING STATEMENT OF SENATOR HARRIS

Senator HARRIS. Thank you, Mr. Chairman.

I will tell you, this issue is very personal to me. My mother was a scientist, an endocrinologist. She advised NIH. She did her research at a number of places, but most recently before passing, at UC-Berkeley she maintained a lab for years. In fact, my first job was cleaning pipettes in my mother's lab. I was awful. She fired me. But there you go.

Being from California, we take a certain level of pride, perhaps—and please forgive any bravado—but Google's search engine, its foundational tool, came from federally funded research at Stanford; the nicotine patch that has helped millions of people quit smoking came from federally funded research at UCLA; augmented reality, military training, from federally funded research at USC; the hepatitis B vaccine, from federally funded research at UCSF; and image sensory technology, which is in our cell phones, from federally funded research at CalTech. So I add that list to the list of those discoveries that you, Dr. Cunningham, have outlined.

My question then is: As we recognize all of that, can you also talk a bit about the concern that many of us have that were it not for federally funded research, the research that would be conducted would be motivated by what is profitable and not necessarily what impacts the largest number of people? In particular, my concern is for cures that we need for rare diseases as an example, those diseases that may impact a few number of people, and so the benefit will be to a few number of people and, therefore, will not necessarily be capable of being marketed and purchased by a lot of people. What can you say about that concern? And I will use as examples of those kinds of diseases that also impact specific racial or ethnic groups, and that can be anything from lupus to sickle cell to Tay-Sachs. What is your perspective on that?

Dr. CUNNINGHAM. Thank you for asking that question. It is really important that the research that is funded by the Federal Government often has a long timeline to show a result. So that shorter timeline, which is really important to industry and to industry-funded studies is not going to be profitable, as you say, for these rare diseases or for diseases that are prevention-focused or really focused on a greater public good necessarily, but will not show an immediate return on investment. These are the types of long-term investments that we need to make at the Federal level. That is the kind of investment that Federal research has shown to be able to do to invest in things that may be curiosity-driven at this time but might lead to an end result, which is a cure for a rare disease.

I like the example of the honeybees, which is a silly sounding science study that was done by NSF, where scientists were looking into how honeybees found their nectar in a hive and why that would be relevant, and that was funded many years ago. Later on, that went on to give the answers to how to do Web algorithms for the Internet. So the kind of basic science research that might be funded now might be what gives the cure for your rare disease in 15 or 20 years from now, and that is not an investment that anyone could know in the room up front would cure that disease and is in the greater public good to take care of looking into that curiosity to understand the basic science.

Senator HARRIS. You mentioned return on investment. So there are a lot of experts that I have read who talk about every dollar invested in biomedical research funding, for every dollar the economy gains roughly $2. And it is even greater for certain projects. For example, the United States invested $3.8 billion in the Human Genome Project, which resulted in nearly $1 trillion in economic growth, which if you do the math on that is a 178:1 return on investment. So these types of Federal R&D investments certainly do help support the economy and jobs. In California, 38,000 Californians have benefited from the Genome Project that I mentioned.

Can you explain why the private sector might not be willing to put an investment in biomedical research on projects that the government has funded? The concern that we have is nationwide Federal funding of NIH alone supports almost 380,000 jobs and generates about $65 billion in economic activity across the United States. I see my time is running short, and we have to take a vote. So perhaps we can talk about that in the continuing conversation. I will yield to my colleagues.

Senator PAUL. Senator Lankford.

OPENING STATEMENT OF SENATOR LANKFORD

Senator LANKFORD. Thank you, and thanks to all of you for being here and being a part of the dialogue on it.

As we go through some of the research, I am not opposed to research, and I am grateful every time I pick up my cell phone or visit a doctor's office for research in the past. The question is: federally funded research, should the information be transparent and available to everyone else? How quickly does that get out? How does that get out? The diversity of the selection teams, if that ends up being the same teams selecting over and over again and directing funds, and then the national benefit of that. And when I get

to the national benefit of it, as Senator Peters mentioned, there are times that I will look at some studies, as has already been mentioned, studies about people sneezing on a child's food and are they more or less likely to be able to take that. But I can go to other studies that I have had the opportunity to be able to look at. NSF funded a study on the connection between religion and politics and cemeteries in Iceland. NSF also did a study on 500-year-old fish bones to study social structures in Tanzania. There was a study done on senior dating habits, on how likely seniors are to date and what their preferences are in dating.

Now, again, senior dating may be fascinating research, but I am not necessarily assured that it is federally necessary. Match.com may be very interested in that and lots of other folks may as a way to be able to partner up seniors, but is that a national priority?

So the questions that I have circle around how we are doing selections of this: Who is doing the selection of the funding? What is fundamental research and what really should be applied research? Is the Federal Government really focusing in on fundamental research?

My first question really deals with this issue of who is making the decision when these grants come? A quick comment on it, then I want to open this up.

I have talked to researchers at universities that say, "For the exact same research, I write it one way to apply to NIH; I write it another way to try to get a grant from NSF. I really do not care where I get the funding from, but I write the grant in a way that they want me to write it, trying to figure out who is going to be able to give me the dollars for it. Then I will target my research based on whoever will give me the dollars for it." That to me is a red flag. I understand if you get an NIH grant, you have to tell NSF that you have it. But if you are applying for both simultaneously, they do not know what the other one is getting, and I have gone back to be able to verify that.

Let us start with the basics. The decision of how a grant is done, these decisionmaking boards, is there diversity in the boards? Do those boards transition and change over? Or is it basically the same people doing approvals consistently? And then what follow up happens from there? So anybody can take that if they choose to.

Mr. NOSEK. Thank you, Senator Lankford, for the question. I cannot speak to the details of how reviews happen across the various agencies, except for having been myself on both sides of it, having been a reviewer of grants and having been a submitter of grants. In the context of that experience, agreeing to be a reviewer of a grant, the first step that I go through is to assess from the initial information that they provide whether I have the qualifications to review it at all. If I were to make a wild guess, I would to say if I were to look at the breadth of NSF-funded grants, probably 90 percent of them I would not feel like I had the competence to review myself. There is just too much information that is depth information that I do not have in insight for how it is to evaluate that.

The second challenge, I think, of the points that you were mentioning relating to how the grants are characterized—and Senator Paul mentioned this as well—I think is a critical one, which is it

is easy to see the title of a grant as indicating something absurd, like scientists wanted to study shrimp on a treadmill? What were they thinking in deciding that that was a reasonable research question. The challenge—and I think Dr. Cunningham was correct—is the translation challenge that researchers need to do better at, which is it starts with a theoretical question, an interest of principles. How is it that this particular thing works? I do not know this shrimp example, but I imagine, just guessing, that it was researchers interested in biomechanics. How is it that biomechanics work in some way? So they had to come up with how is it that we test it. How do we operationalize that theoretical question into something that is meaningful to test? It is the operationalization that is often very apparent and very easy to sort of misunderstand as something silly when it is actually testing something deeper. That deeper question, the theoretical question, I think researchers need to do a much better job of surfacing as the point of the research so that taxpayers can recognize what the value is of——

Senator LANKFORD. All right. Let me make just a quick comment on this, because I would love to be able to work in a bipartisan way on this, because I think there is a lot of common agreement on it. Science that is paid for by the Federal tax dollars should not be then retained by individuals saying, "I am going to hang onto that." If it was done for the public good, it needs to be publicly available as that science. I think that should be a given. That is not always so at this point.

There should be diverse selection teams. If it is the same team selecting the same type, they are going to select the same type of research year after year from the same universities year after year. If you are one of those universities that benefits from that, you will always want that to stay status quo. But I think it is not how we get diverse backgrounds on it, and I think we need to make sure it actually has national benefit and is fundamental research, not something that does not have national benefit. I think we can find agreement on that, and I would love to be able to finish that work.

Senator PAUL. A quick comment. There is a possibility these studies are not silly and we need better titles so they are not silly, or there is a possibility they are silly. Tasting wine and studying alcoholism. Silly. Sneezing on food, should we eat it? It is not the problem with the title or translating good research into a bad title. Maybe the research should not be done. Senator Hassan.

OPENING STATEMENT OF SENATOR HASSAN

Senator HASSAN. Thank you very much, Mr. Chair, and to our Ranking Member as well. And thank you, witnesses, for being here. I apologize because as soon as I get done asking questions, I think we are all going to bolt, and I apologize for that, but we have a vote.

I will just make a quick comment as well. I still remember one of the early public health challenges I dealt with in public life was the onset of Triple E, which is a kind of mosquito-borne illness that is rare but happened to occur in my portion of my State of New Hampshire when I was in the State Senate. There was not any private sector interest in developing a vaccination for Triple E because it is so rare that the investment in doing it would not be paid back

in any way given the rarity of the disease. So I watched constituents deeply debilitated by this disease and who lost their lives to this disease, in part because there was no economic incentive for developing the kind of treatment. So I think it is really important to remember the public purpose.

I did to that point want to ask Dr. Cunningham a question based on your testimony. You discussed your personal experiences dealing with the heroin, fentanyl, and opioid crisis, an epidemic which is having a truly devastating impact on communities in New Hampshire and across the country. I would like to highlight the important connection you made in your testimony between addressing the epidemic and federally funded research.

Another example comes once again from my home State of New Hampshire. In order to fight this epidemic, it is critical that we understand the current trends of the crisis across the United States. The National Drug Early Warning System is an important system that helps us monitor emerging drug trends to enable health experts, researchers, and concerned citizens across the country to respond quickly to potential outbreaks. This surveillance system is supported by grants from the National Institute on Drug Abuse (NIDA).

Last year, the National Drug Early Warning System released a critical report based on research conducted by Dr. Lisa Marsch at Dartmouth, as well as New Hampshire public health experts at High Intensity Drug Trafficking Area (HIDTA), and the State Office of the Chief Medical Examiner. This report brings us closer to understanding the patterns, causes, and effect of heroin, fentanyl, and opioid misuse in our communities, and it is my understanding that NIH and the National Institute on Drug Abuse are expanding their funding for additional research in New Hampshire to continue to help improve our response to this epidemic.

Dr. Cunningham, do you agree that this kind of Federal funding is critical to help public health researchers such as yourself determine how we can best respond to the ongoing substance misuse crisis?

Dr. CUNNINGHAM. Thank you for the question. The Federal research is completely critical. We have a horrific epidemic on our hands with opioid and heroin overdose. Before we throw and waste Federal dollars at programs that may or may not work, we need to understand which programs are actually going to make a difference and decrease and save lives. We will do that by rigorous behavioral research being done by NIDA and the CDC and National Institute on Alcohol Abuse and Alcoholism (NIAAA), that are well designed, well reviewed by our peers, with very diverse panels of people from all across the country to try to understand how those are going to be the best solutions so that eventually, when we then go to implement the solutions into local communities with local values, we know that they will work and we will know that those solutions that we are throwing out there will not actually do harm because they have not been rigorously tested by scientists. Thank you.

Senator HASSAN. Well, thank you very much. In the interest of getting us to our vote, I will conclude. Thanks. Thank you again, witnesses.

Senator PAUL. Thank you.

Senator Peters, do you have a statement that you would like to make?

Senator PETERS. I think we are ready to vote.

Senator PAUL. OK. Well, thanks, everybody, for appearing. I apologize a little bit for the rushed schedule, but we never know when we are going to vote until about 20 minutes before we vote, and we have a series of votes coming up.

I think the testimony was good. From my point of view, I would just say that we do have a problem, and we need to admit we have a problem. It is not that we do not have silly research going on. We do have silly research going on. It is not just the title, and cleverly changing the title to obscure the silliness of the project will not make it any less silly. What we need to do is have less silly research so we take our precious dollars that we have and they are spent more wisely.

I think if we look at the way they are approved, I think we ought to consider that you should not get to pick the people approving your money. That makes obvious sense to me. I cannot imagine how anybody would think that the person applying for a grant should get to pick the people on the committee or have any influence on the people on the committee.

I also personally think that there should be people on the committee who have nothing to do with that subject, who are well intentioned, people educated enough to understand a scientific project being explained to them, but that have no dog in that fight. They are not going to have to turn around next week and ask for approval from the same people in these committees. It is a circle back and forth, and, I think really we need some people independent. I would put a taxpayer advocate on the committees. I would put a scientist who is not involved with that research on the committee. So there are a lot of things we could do.

But the bottom line is what William Proxmire pointed out in the 1970s, the Golden Fleece Awards for this crazy research, sneezing on food, senior dating, gambling in Uganda, just bizarre stuff that everybody agrees that government should not fund. Let us not say that it is not silly. It is silly. Let us quit doing it and let us fix it, because I tell you, the danger is if you do not fix it and you are part of the receiving folks in this branch of government, this fourth branch of government, there is going to be a day on which people are going to get made and there is not going to be any more money. People are going to get mad and finally say enough is enough.

So if you like the gravy train, I would recommend that we fix it so we are not funding really crummy research. I think it is still out there. It may be the exception rather than the rule, but there is enough of it that every year we come up with dozens of them. I would suggest that the scientific community needs to get together and admit we have a problem and fix it.

Thank you all.

[Whereupon, at 3:19 p.m., the Subcommittee was adjourned.]

APPENDIX

I call this hearing of the Federal Spending Oversight Subcommittee to order.

Today we're looking at the federal government's role in funding research.

I'm concerned the federal government's system of supporting research is inefficient and incentivizes the wrong things, which leads to bad science and wasted taxpayer dollars.

We've published examples like an NSF study into Ugandan gambling habits. Senator Lankford found NIH spent $2 million investigating if kids don't like food that has been sneezed on. And who could forget the shrimp on a treadmill found by former Senator Coburn?

So, how does this happen? More accurately, how does this continue to happen. I remember as a kid in the 1970's hearing Senator William Proxmire describe waste such as this that he gave his Golden Fleece Award to.

Part of the problem is the old adage, "publish or perish." Researchers that publish are more likely to get federal funding, and unique research is more publishable.

So, how do unique projects get funded to begin with?

At some agencies, grant applicants themselves can actually recommend who should and shouldn't review and make recommendation about their grant.

That's right – researchers get to pick the people who approve the federal spending.

Some "grantsmanship" books advise applicants to recommend reviewers who will be "champions" for your work, while agency guidelines suggest disqualifying those who have scientific disagreement with you.

That is baking in bias, and it is unacceptable. So I've introduced legislation that will prohibit this practice and further require impartiality on grant review panels.

Another problem is downstream funding or taking original grant money and giving it to other researchers for projects that are often not consistent with the original grant. The federal government gives someone money to do research, that person then gives it off to someone else, who may even give it off to a third or fourth person, none of this is published on public government databases.

One examples of this problem is the study of, "what makes for the perfect first date," the original grant was to study how scientists collaborate on scientific research.

It is difficult to discover how much these studies cost because they are cobbled together from multiple subgrants.

So, my bill would curtail this by requiring that all subgrants, no matter how removed from the original grant be fully reported, approved, and made public.

We also found that many grants are issued for rational but broad research topics, and then are used for ridiculous projects. For example one researcher took money from NIH to study drug and alcohol abuse and then published a paper on how to select the best wine for your pallet. I'm not sure how that prevents alcoholism but I'm sure it was interesting for journal editors.

So, our bill creates a Special Inspector General and Taxpayer Advocate for Research that can look into these matters, provide rigorous oversight, and report to Congress about such follies.

Our bill also requires that committees reviewing grants have at least one researcher from a scientific field unrelated to the subject area to further remove personal biases.

The idea is to have scientist from important areas of research such as cancer, diabetes, Alzheimer's, heart disease, sit on review committees that would review grants for "wine tasting."

The last problem I'll discuss is replicability. An increasing body of work shows that in an effort to publish, a lot of research is not reproducible.

This means the study cannot be duplicated by other scientists to produce statistically similar results. That is a major problem, and it goes back to this issue of publishing; journal readers and editors don't get excited about negative results. So the bias is toward funding studies that prove a premise versus studies that disprove a premise.

My bill will seek to address this by creating greater transparency through the whole process so taxpayers can know exactly how their money is being used.

This will allow the scientific community and the public at-large to be able to collectively review and evaluate taxpayer funded research. Hopefully this will deter study manipulation to prove hypotheses.

Some will say the general public doesn't understand the science; but I don't think you need a PhD to understand people are less likely to choose food that has been sneezed on. And they don't want that kind of research either.

With that, I'll recognize the Ranking Member Peters for his opening statement.

Thank you, Chairman Paul, for holding this hearing on such an important topic, and thank you to our witnesses for taking the time to be here today. I look forward to hearing your testimony.

One of the essential tasks of this subcommittee is to engage in honest evaluations of the public investments we make as a nation and whether these investments are indeed worthwhile. This is a responsibility to the taxpayer I personally take very seriously, and I'm grateful for the opportunity to do so in a collaborative, bipartisan way.

We are here today to discuss federal funding for scientific research, which I believe remains a necessary investment in our collective future. Scientific research is the seed corn of innovation and new discoveries, and federal investments in research and development have led to discoveries that have had profound impacts on public health, safety, and our quality of life.

Federally-funded research has resulted in widespread adoption of technologies as revolutionary as the Internet, GPS satellites, MRI imaging, and the Human Genome Project. This research results in economic growth in every state and leads to the creation of tens of thousands of jobs in entirely new sectors of the economy. It inspires the next generation of Americans to believe that the sky is the limit and that no challenge is impossible.

Even as the share of federal investment remains at a historic low as a percentage of overall gross domestic product, supporting federally-funded research remains as important as ever to maintain America's competitive edge in an increasingly competitive global economy. Targeted federal investments in research can accelerate, catalyze, or encourage private-sector innovation that may not have otherwise occurred.

We should recognize that the federal and private contributions to the research and development enterprise are not perfect substitutes for one another, but instead work in tandem with each other focusing on different stages in the R&D cycle.

Last year, I was proud to introduce bipartisan legislation with Senators Gardner, Thune, and Nelson known as the American Innovation and Competitiveness Act, which was signed into law in January of this year.

The bill was the product of a year-long effort that began with a series of roundtable discussions with representatives from science, from education, business, and economic development communities on how to improve the American research and innovation ecosystem.

Our legislation reauthorized a number of important programs that promote research and scientific inquiry, strengthen innovation and advanced manufacturing, grow our skilled workforce, and enhance American competitiveness around the world.

The bill included a number of provisions that aim to reduce regulatory and administrative burdens on academic researchers so they can spend more of their time on their research and less on paperwork. Our bill also reaffirmed the independent merit review process that guides NSF funding decisions and ensures that research proposals are judged independently on the merits, by peers in scientific community, and without bias.

While certain basic research projects that receive federal funding certainly have silly-sounding titles, further examination may reveal the true scientific merit and potential broader impacts of the work.

Before a proposal gets one penny of funding, reviewers have to consider it based on criteria that include whether the proposal increases economic competitiveness, advances public health and welfare, or supports the national defense. It's worth noting that only 1 in 5 proposals receive NSF funding at all, and that NSF is required to justify to the public why these proposals were lucky enough to receive funding.

Even as research begins with a clear question in mind, it can be hard to quantify or predict exactly where the science will lead. Rather than inject politics into this process, our discussion today should instead concentrate on how to safeguard the often unexpected process of discovery inherent in scientific inquiry, while ensuring that federal dollars spent on research remains completely and fully accountable taxpayers.

Part of this solution may lie in breaking down barriers. Rather than remain ensconced in the ivory tower of academia, scientists should prepare to engage in a robust exchange of information with the general public about the goals and benefits of their research.

The discussion we are having today is an important one. Our country faces critical environmental, public health, and economic challenges in the years ahead, but we must not shy away from facing them head-on and leveraging the power of our research enterprise to create a better tomorrow for everyone.

Thank you again to all the witnesses for your time today, and I look forward to our discussion.

Testimony of

Brian A. Nosek, Ph.D.

Executive Director
Center for Open Science

Professor
Department of Psychology
University of Virginia

Before the

Senate Committee on Homeland Security and Governmental Affairs
Federal Spending Oversight Subcommittee
U.S. Senate

October 18, 2017

"Broken Beakers: Federal Support for Research"

Chairman Paul, Ranking Member Peters, and Members of the Subcommittee, on behalf of myself and the Center for Open Science, thank you for the opportunity to discuss the funding of scientific research and the role of transparency and reproducibility to maximize the return on those investments.

Science may be humanity's most important long-term investment. The effort to accumulate knowledge has profound consequences for growing the economy, security, and well-being of American society. Some of the impact of scientific investments are the direct aims of the project. But, much of the impact is indirect. Research often leads to unexpected insights and applications that are only appreciated after the discovery and produce many orders of magnitude return on investments. Examples include the creation of the Internet and the core search insights that led to the founding of Google. Science is a long-term investment strategy for the continuing vitality of society, and we can do an even better job with this investment. Today, I will discuss how promoting a culture of transparency and reproducibility will improve the speed and efficiency of scientific discovery.

In 2002, I became a professor at the University of Virginia in the Department of Psychology. My research group does fundamental research on implicit social cognition -- thoughts and feelings that occur outside of conscious awareness or conscious control. Our interest is interested in why behavior does not always align with values and intentions. For example, a citizen may want to be objective in evaluating evidence for public policies, but may nevertheless be

influenced by the party identity of the proposer independent of the policy itself. My team's research has been supported by federal grants from NIH and NSF.

Since 2013, I have been on extended leave from my faculty position because a graduate student and I started a technology and culture change company called the Center for Open Science based on two projects from my laboratory. The Center for Open Science has a mission to increase openness, integrity, and reproducibility of research. To meet that mission, the Center conducts research on the causes of irreproducibility in science; builds free, open-source software to help researchers manage, archive, and share the materials and data underlying their research; and works with stakeholders across the research community (funders, publishers, societies, institutions) to shift the incentives for researchers to reward transparency and reproducibility.

Transparency and reproducibility are core values of science because they are how science advances knowledge. When I make a claim, you could believe it based my authority as an expert, or how confident I seem making it. These are not sufficient for scientific claims. For credibility of scientific claims, I need to show how I arrived at the claim. By showing you my methodology, the data I collected, and how I analyzed and interpreted that data, you can make an independent assessment. You might recognize a flaw, think of an alternative approach, or have an idea about how to extend what I did to learn more about the phenomenon. Moreover, by sharing how I arrived at the claim, I give you the opportunity to reproduce the evidence. If you can independently obtain similar results, then our confidence in the claim increases. The challenge, and the reason for the Center for Open Science's existence, is that the culture of incentives for scientists sometimes undercuts those core values of transparency and reproducibility.

The currency of academic science is the publication. Researchers earn jobs, grants, tenure, and acclaim by publishing frequently and in prestigious journals. In the present culture, novel results are more publishable than replications or additional evidence for existing claims. Positive results--finding a relationship between things or that an intervention did impact an outcome--are more publishable than negative results--finding no relationship or effectiveness. And, tidy results are more publishable than results with exceptions or loose ends. Novel, positive, tidy results are the best kind of results, but achieving them is difficult. Scientists are studying things that they do not yet understand. Progress is slow and uncertain, often with many dead-ends. But, because I am rewarded for publishability, I might make decisions--perhaps without even realizing it--that maximize publishability at the cost of accuracy. For example, we run many experiments, but we might only select to publish the ones that make the best story and rationalize ignoring the others as having flawed methodology. Also, there are many ways to analyze a dataset to decide what has been learned. I could use that discretion and convince myself that the analysis strategy yielding the most publishable analysis strategy is also the correct analysis strategy. If these behaviors occur, then the findings in my published papers will be less credible than they appear.

The solution to these human behavior challenges are transparency and reproducibility. Science is done by scientists. Even with the best of intentions, scientists' behavior is shaped by their culture and incentive systems. Unintended biases permeate decision-making and are insidious because they are so difficult to identify in ourselves. Transparency is a mechanism for identifying bias. If you knew about the other studies and analyses I conducted but did not report, then you would be able to adjust your impression of the credibility of my findings. Also, with transparency, you could examine my methodology and data and try to independently reproduce the findings yourself. If you don't know how I arrived at my claims, then there is no way for you to properly assess their credibility. If others cannot reproduce my claims independently, then either I haven't communicated sufficiently how to obtain the results, or the results are not sufficiently reproducible to be credible. Science relies on transparency and reproducibility for the open, unregulated marketplace of ideas to function efficiently.

By and large, scientists endorse the values of transparency and reproducibility. But, the culture rewards novel, positive, clean results; there are few incentives for being open or transparent or reproducible. Federal research funding agencies are aware of this problem and have only taken initial steps to address it. As a consequence, openness is rare, and reproducibility appears to be lower than is desirable. This can change. If transparency and reproducibility are incorporated into the policies and incentives shaping the culture and researchers' behavior, we may reduce waste and increase the pace and efficiency of discovery and ultimately earn even greater return on investment of taxpayer dollars.

Moreover, with transparency, we can improve the credibility and understanding of how science works to the taxpaying public. For example, it is easy for the public to understand the value of research investment on applied questions such as "Will this drug reduce cancer?", "Will this battery store more energy for more time?", and "Will this cognitive therapy reduce the symptoms of PTSD?" The direct outcome of interest for such investigations is justification enough for supporting the research.

Transparency can help the public also see the benefits of investments in fundamental science questions. Fundamental, or basic, science is the breeding ground for identifying opportunities to answer those applied questions. How can we know what drugs to try for cancer? We need to know more about the biology of cells. How can we know what materials might lead to longer battery life? We need to know more about how materials store electrical energy as chemical energy. How can we know what cognitive techniques are best for PTSD? We need to know more about human reasoning and emotion and the relationship between thoughts and actions.

Fundamental science is a patient, long-term, high-reward investment strategy. If we understand the core of how something works, then it may have immediate impact on known implications. But, it can also have massive impact on entirely unexpected applications. The emergence of Google out of federal grants for advancing digital libraries is a dramatic example. A more modest example is my own experience.

The products and services provided by the Center for Open Science to improve research efficiency is an unexpected outcome of an R01 grant to my lab from the National Institute of Mental Health. I was studying thoughts and feelings outside of conscious awareness and conscious control. We were trying to figure out why people's social values such as "I want to treat people fairly regardless of their race or gender." did not always translate into their behavior. While studying that, we learned how cultures and social circumstances can influence behavior, sometimes even leading people to behave contrary to their own values without recognizing it. Over years, we came to realized that these general principles of decision-making could be applied to how scientific culture shape scientists' behaviors. This was not anticipated in the R01 application. It is only with the benefit of hindsight that we can see how investigating those fundamental questions led to ideas that spawned the Center for Open Science, its products and services, and its progress on the mission to increase openness, integrity, and reproducibility of research.

Because we don't yet know what we will learn, there is little chance of anticipating which fundamental science investigations will lead to the massive returns on investment. If we knew that, then it would be easy to decide what to study and what to fund. Without a crystal ball, science relies on the next best thing--peer review. I write grants proposing to study what I believe are the next most important questions in my field. Others with similar expertise evaluate my proposals for their merit and anticipated impact. Their prediction of impact is necessarily limited to the ability to imagine what will be learned and how that knowledge could be used. Nevertheless, independent domain experts are best positioned to make those judgments because they possess depth insight on both what we know and what we don't know, and thus have some idea of the implications of filling the knowledge gaps.

Some parts of the peer review process are transparent and other parts are privacy protected. As a representative for the Center for Open Science, I believe that there is room to improve transparency of the peer review process and still protect the interests motivating privacy protections. The benefits of greater transparency in peer review would be to demonstrate the credibility and integrity of the process to the taxpaying public to whom science funding decisions can feel daunting, distant, and obscure.

I will close with a specific suggestion that the committee could pursue to help further improve the return on investment in scientific research: **Set the default to open for papers, data, and materials**. In 2013, federal agencies were asked by the White House to make a plan for improving the management and accessibility of data and materials for research that they fund. Most agencies have completed this work. Congress could take the next logical step and require each Federal research funding agency to develop policies that require the research data and materials generated by federal dollars be made publicly accessible by default upon publication of the findings or completion of the grant period. Changing the default from closed to open for research created with public dollars would alter cultural expectations and behavior. Instead of needing to generate reasons to share data, researchers would need to provide justification for delay or not sharing at all due to proprietary or privacy concerns.

Public investment in science leads to solutions, cures, and entirely unexpected advancements that benefit American society. Making open the default for scientific research data would transform science, dramatically increase the return on investment from publicly funded research, and accelerate progress. This is not a very expensive or difficult proposition, but it does require a mandate. This one action would dramatically increase the public benefit from our investments in science.

Thank you members of the committee for your continuing support of science and for the opportunity to speak with you today.

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Governments need not fund science (at least, not for economic reasons)

by

Terence Kealey

Senior Visiting Research Fellow, The Cato Institute

Introduction The years 1776 and 1947, the years of the Declaration of Independence and the promulgation of the Truman Doctrine, are existentially important in the history of the US. Less obviously, they are the two most important dates in the history of science funding.

1776-1947 1776 was not only the year of the Declaration of Independence, it was also the year Adam Smith wrote his *Wealth of Nations*, where he showed that economic or technological growth did not require governments to fund science: by 1776, industrialization was well-established in Britain (the flying shuttle had been patented as early as 1733) and experience had shown that the demand for new technology was being met within the workshops of industrialists:

> If we go into the workhouse of any manufacturer ... and enquire concerning the machines, they will tell you that such and such an one was invented by some common workman.
>
> Adam Smith, 1776, *Wealth of Nations*

Smith, moreover, specifically denied that industrial technology flowed from academic research: indeed, the opposite was true, it was academic science that flowed from industrial technology:

> The improvements which, in modern times, have been made in several different branches of philosophy [i.e., pure science] have not, the greater part, been made in universities [i.e., they were made in industry].

Between 1776 and 1947 Adam Smith's observations were repeatedly confirmed by those economists who actually *observed* the industrial scene. Thus observers as various as Karl Marx and Joseph Schumpeter reiterated that science was, in the jargon, endogenous: markets produced all they needed.

> The bourgeoisie, during its rule of scarce one hundred years, has created more massive and more colossal productive forces than have all the preceding generations together. Subjections of Nature's forces to man, machinery, application of chemistry to industry and agriculture, steam-navigation, railways, electric telegraphs, clearing of whole continents for cultivation, canalisation of rivers, whole populations conjured out of the ground – what earlier century had even a presentiment that such productive forces slumbered in the lap of social labour?
>
> Karl Marx & Friedrich Engels, *Communist Party Manifesto* (1848)

> Industrial mutation incessantly revolutionizes the economic structure *from within*. [Schumpeter's italics].
>
> Joseph Schumpeter *Capitalism, Socialism and Democracy* (1942)

Not only does the history of the UK confirm those observations (the British Industrial Revolution of the 19th century, like the British Agricultural Revolution of the 18th century, was *laissez faire* in science) so also does the history of the US. The US was *laissez faire* in science between 1776 and 1940, yet by 1890 it had overtaken the UK to become the richest industrialized country in the world. Meanwhile those European countries – including France and the German states – whose governments invested most in science failed to converge on the UK or the US, let alone overtake them.[i]

Opposition to the federal government funding of science was fueled not only by Adam Smith's writings but also by a Constitution that empowered the states. That opposition was so strong that in 1839, when James Smithson left Congress some $500,000 to found the Smithsonian Institution, its acceptance was opposed by the defenders of states' rights. Senator John C Calhoun from South Carolina said the money "must be returned to the heirs," while Senator William Campbell Preston, also from South Carolina, asserted that if Smithson's money were accepted, "every whippersnapper vagabond ... might think it proper to have his name distinguished in the same way." Meanwhile, defenders of taxpayers' rights such as Andrew Johnson of Tennessee, the future president who was then in the House of

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[i] It is commonly asserted that Germany overtook the UK during the 19th century, but Angus Maddison is one of many economic historians to have shown that is not true (*The World Economy* 2007, OECD). 19th century Germany excelled in certain areas of technology such as chemicals, but in other areas such as agriculture it so lagged that, overall, its economic performance was mediocre. It can be compared to the Soviet Union: by 1957, with the launch of *Sputnik*, the USSR was clearly the world's leading space power; it was also dirt poor.

Representatives, denounced any federal support for the Institution as picking the "pockets of the people".

The years 1776-1947, therefore, saw the US fall into a fixed pattern: in peacetime, science was left to the private sector. Only in wartime did the federal government commission science, but – when peace returned – science reverted to *laissez faire*. So – to develop new military technologies such as iron-clad warships – the Civil War saw the federal government found the National Academy of Sciences and the Permanent Commission of the Navy Department, but after 1865 the National Academy was left to fund itself and the Commission was dissolved. During the Spanish-American War, the US Army funded the Smithsonian's research into heavier-than-air aircraft (though it was the privately-funded Wright brothers who made that advance). And during the First World War the National Research Council was created, but after 1919 its funding progressively ceased. Equally, 1941 saw the creation of the Office of Scientific Research and Development (which oversaw the Manhattan project *et alia*) but after 1946 it was progressively defunded.

The only significant federal funding for science in peacetime was launched in 1862, for agricultural research within the land grant colleges, but that was to address the problem of *overproduction*. Virgin land was so cheap (and food was so cheap) that farmers were slashing-and-burning, so the land-grant colleges were founded to promulgate soil conservation: the market in agriculture had been working only too well.

Consequently, by 1940 the federal government was funding less than a quarter of US science or R&D, yet – as shown by the successes of the Wright brothers, Thomas Edison and Nikola Tesla, to say nothing of the great industries of Pittsburgh and Detroit – US science, technology and industry flourished. [ii]

The Truman Doctrine Curiously, the federal government has not, since 1947, abandoned its policy of funding science only in wartime, because since 1947 the US has been at permanent war.

In 1945 the director of the Office of Scientific Research and Development, Vannevar Bush, alarmed at the prospect of the peace-time demobilisation of his Office,

[ii] The federal and state governments were spending $81 million pa compared to the private sector's $265 million, which included $31 million for university and foundation research (T Kealey, 1996, *The Economic Laws of Scientific Research*, Macmillan, p 151). Almost all the governments' research was for agriculture (which was economically irrelevant) or defense (defense research has only about 10 per cent of the economic value of civil research; Advisory Council On Science and Technology, 1990 *Developments in Biotechnology* HMSO, London).

published his *Science, the Endless Frontier* to advocate the creation of a federally-funded National Science Foundation. Initially his initiative floundered, and when in 1947 Congress passed a bill to create a NSF, it was vetoed by President Truman:

> This bill contains provisions which represent such a marked departure from sound principles for the administration of public affairs that I cannot give it my approval.

But that was soon to change. In his leaving address George Washington had warned against "permanent alliances," and against "excessive partiality for one foreign nation, and excessive dislike for another" (often summarised as his warning against "foreign entanglements") but in 1947, in his Doctrine, President Truman reversed that non-interventionism: and having committed the US to the Cold War, he then sought, as all war-time presidents have sought, to bolster his nation's defense by bolstering its science, and in 1950 he compromised with Congress and signed a new bill establishing the NSF.

In his 1947 veto Truman had complained that the bill would "vest the determination of vital national policies, the expenditure of large public funds, and the administration of important government functions in a group of individuals who would essentially be private citizens" but in the 1950 compromise it was agreed that the NSF's director would be appointed by, and would report to, the President.

Truman had intended the NSF to be primarily a defense initiative (and contrary to myth, Vannevar Bush's *Science, the Endless Frontier* – though it did address advances in health and the growth of the economy – was primarily a defense-orientated book) but – as Truman had feared – the NSF was subsequently captured by the scientists and their so-called 'linear model':

> Government funding → pure science → applied science → technological growth

The linear model This model was first proposed by the English lawyer Francis Bacon in his 1605 book *The Advancement of Learning* ("If any man think philosophy and universality to be idle studies, he doth not consider that all professions are from thence served and supplied"). Bacon supposed science was a public good, calling it "a universality" whose benefits could not be monopolized by the funder ("the benefits inventors confer extend to the whole human race"). Consequently, he argued that the market would not fund it ("there is no ready money") and governments, therefore, had to pay for it ("there is not any part of good government more worthy than the further endowment of the world with sound and fruitful knowledge").

But Bacon had no experience of an industrial revolution, and his thinking was purely theoretical. Nonetheless other theoreticians including Friedrich List (*National System of Political Economy*, published in German in 1841) and John Stuart Mill (*Principles of Political Economy*, 1848) agreed with him, culminating in a curious episode of American intellectual thought.

To promote his ideas, in 1945 Vannevar Bush joined the US Air Force and the McDonnell Douglas Corporation in helping create Project RAND (now the RAND Corporation; Research And Development Corporation) one of whose missions was to lobby for the federal funding of science. Consequently RAND funded the two most influential papers in the modern economics of science, those of Richard Nelson and Kenneth Arrow, where they echoed Francis Bacon.[1] Nelson and Arrow asserted that because science is, in the jargon, "non-rivalrous" (an idea, unlike an object, can be used by an infinite number of people) and "non-excludable" (no idea remains secret for very long)[iii] no private funder can retain the benefits of their funding, so no private entity will fund science.

And economists like Paul Romer[2] or Partha Dasgupta & Paul David,[3] who have subsequently promoted ideas of "endogenous growth," still describe science as a "merit good," requiring significant public funding.

Yet the empirical evidence still shows them to be wrong – and that evidence has been collected by governments. Thus in 2003 the OECD, on studying the growth rates of the 21 leading world economies between 1971 and 1998, found "a significant effect of R&D activity on the growth process," but it is only:

> Business-performed R&D that ... drives the positive association between total R&D intensity and output growth ... [4]

Equally, in 2007 Leo Sveikauskas of the US Bureau of Labor Statistics, using a different methodology, concluded:

> The overall rate of return to R&D (research and development) is very large ... However, these returns apply only to privately financed R&D in industry [Sveikauskas's underline].[5]

[iii] In an 1813 letter Thomas Jefferson expressed these concepts colorfully: "He who receives an idea from me, receives instruction himself without lessening mine; he who lights his taper at mine, receives light without darkening me." Jefferson, though, invoked those concepts not to argue for the government funding of science but for the abolition of patents.

Ronald Reagan once described an economist as someone who, when they see something working in practice, wonders if it will work in theory, and in 2014 Martin Ricketts and I provided the theory. We showed that, contrary to myth, science is not publicly-available (how many readers of this document can read Einstein's papers, even though those papers are over a century old?) Rather, science is open only to fellow scientists – who pay for their access by the papers they themselves contribute. And when science is modeled as a "contribution good," the need for government funding disappears.[6]

One more, longitudinal, piece of American evidence shows governments need not fund science. Whereas before 1940 almost all American pure science was funded privately, today the private sector (in the shape of industry, foundations and universities) funds only half of it: the other half is funded by federal agencies including the NSF and the National Institutes of Health. And whereas before 1940 almost all US R&D was funded privately, by 1989 the federal government was funding two thirds of it (today it is only a third). Yet since 1830 the long-term rates of GDP *per capita* and TFP (total factor productivity) growth in the US have been steady (with GDP *per capita*, for example, growing at just under 2% per annum) and the inauguration of the federal funding for science had the following effect on long-term rates of GDP per *capita* and TFP growth: none.

Conclusion The evidence that governments need not fund science for economic reasons is overwhelming, and it is ignored only because of self-interest: the scientists like public funding because it frees them to follow their own interests, companies like it because it provides them with corporate welfare, and politicians like it because it promotes them as patrons of the public good (witness Bill Clinton's leading the celebrations over the mapping of the human genome.) So the empirical evidence is ignored in favor of abstract theories.

There are, of course, non-economic reasons, such as defense or the study of pollution, why a government might want to fund science (and a democratic polity, moreover, might not wish to be dependent only on private entities for its expertise in science) but in this document I cannot pronounce on these non-economic justifications for the government funding of research: only democratically-elected representatives have that competence. Here I can make only the technical argument that there is no credible evidence that governments need fund science for economic reasons.

But we can nonetheless note that in his own farewell address (known for its regrets for the "industrial-military" complex and for the "three and half million men and women directly engaged in the defense establishment") Truman's immediate successor as President lamented the effects of the federal government's funding for science. He lamented the effects on the universities:

> In the free university, historically the fountainhead of free ideas and scientific discovery ... a government contact becomes virtually a substitute for intellectual curiosity.
>
> The prospect of domination of the nation's scholars by federal employment ... is gravely to be regarded.

And he also lamented the effects on the federal government itself:

> We should be alert to the ... danger that public policy could itself become captive of a scientific-technological elite.

Acknowledgements I thank my two collaborators, Professor Martin Ricketts of the University of Buckingham, UK, and Dr. Pat Michaels of the Cato Institute, DC, for their input into this work.

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[1] Nelson, Richard, R. 1959. The Simple Economics of Basic Scientific Research. *Journal of Political Economy* 67: 297-306. Arrow, K. J., (1962). Economic Welfare and the Allocation of Resources for Invention, in *The Rate and Direction of Inventive Activity: Economic and Social Factors*. Princeton: Princeton U. Press 609–25.

[2] Romer, Paul. 1990. Endogenous Technical Change. *Journal of Political Economy* 98: S71-S102.

[3] Partha Dasgupta and Paul David (1994) Toward a new economics of science. *Research Policy*. 23: 487-521.

[4] OECD, 2003, *The Sources of Economic Growth in OECD Countries*. OECD. Paris.

[5] L Sveikauskas (2007) *R&D and Productivity Growth: A Review of the Literature*. Bureau of Labor Statistics. Washington, D.C. www.bis.gov/osmr/pdf/ec070070.pdf

[6] T Kealey, M Ricketts (2014) Modelling science as a contribution good. *Research Policy* 43: 1014-1024.

U.S Senate Homeland Security and

Governmental Affairs Committee

Subcommittee on Federal Spending Oversight

Broken Beakers: Federal Support for Research

Expert Testimony by

Rebecca Cunningham, M.D.

Associate Vice President for Research - Health Sciences,

Office of Research

Professor, Emergency Medicine

Professor, Health Behavior and Health Education

Director, U-M Injury Center

University of Michigan

October 18, 2017

Good afternoon Chairman Paul, Ranking Member Peters, and members of the Subcommittee. Thank you for inviting me to speak with you today about the value of federally funded research. I also want to give special thanks to Ranking Member Peters for his work on crafting and securing passage of the American Innovation and Competitiveness Act which serves to support the critical federal research enterprise that I am here to talk with you about today.

Our great nation is what it is today because of federal investments in research. We are leaders in innovation because of these investments, our economy is strong because of these investments, and our top research institutions are the envy of the world because of these investments.

This investment has supported—and must continue to support—basic, curiosity-driven research alongside applied research and engineering. The knowledge that we derive from fundamental research is the seed to innovations like self-driving

cars and life-saving drugs. Another example is the iPad; without federal investments to deepen our understanding of basic scientific principles from agencies like DARPA, Department of Energy, NASA, NSF, and DoD, engineers would never have been able to design the core software and components that made the iPad such a ground-breaking device. This is just one example of the unknown possibilities that come out of fundamental research: innovations that our imaginations cannot always comprehend.

I have seen the benefits of these innovations first hand. As an Emergency Physician, I have seen the success of drugs and new medical technologies that allow patients to walk out of the hospital today when they would have died when I was a medical student. I have also sat with the spouses, parents and children of those who fell victim to the epidemic of opioid overdose in our nation. Over the past 20 years, funded by NIH and CDC, I have worked to develop interventions for the treatment of children impacted by substance abuse or trauma who flood through our Emergency

Rooms and have prevented many more from needing our care. I have worked with scientists and community leaders in Flint, Michigan to improve health outcomes in the wake of their water crisis, and continue to partner with our law enforcement and health department partners to translate the underlying science of opioids into policy solutions that address the opioid epidemic that is impacting every community across the nation. This reliance on fundamental research—from synthetic chemistry funded by NSF to basic neuroscience funded by NIH—helps develop policies based on sound science and life-saving medical breakthroughs that will ultimately lead to solutions that we cannot yet imagine for the opioid crisis.

Federal support for research has been part of our country's fabric dating back to the start of the republic in the 1700's. In the past 70 years alone, the role of federal funding in "game-changing" innovations has been tremendous. For example, the development of GPS, supercomputing, the visible LED, and the technology

behind the MRI machine that aids many of my patients in diagnosis of brain disease daily, all have their roots in federal investments to public sector researchers.

Federal investments in research also help drive our economy and train our future STEM workforce. Federally funded research supports local economies all across the nation by providing billions of dollars each year to vendors—from small businesses to biotech companies – who are making devices, software, and other equipment needed to perform research. Over the last 15 years, vendor spending at U-M alone has created 221,000 manufacturing jobs and 641,000 healthcare jobs. This investment also supports thousands of employees working in laboratories and research institutions across the country—of whom the largest recipients by far are students. It is this next generation that will drive and support American innovation and competitiveness in the future.

Flat funding rates in federal investments in research—and in many cases declining funding rates—over the last decade have already shown impacts on the scientific talent pipeline, driving away the next generation of leaders and innovators from careers in research. This is happening while other countries see the clear return on investment in government-sponsored research and are doubling down on their efforts to become global leaders. Indeed, several metrics related to innovation and scientific impact already show that the U.S. is losing ground to countries like China. This trend will only continue at our current levels of investment, and the consequences will impact the American economy and our national security. For the U.S. to remain a global leader, we need to lead in innovation, science, and research. American industry leaders recognize that the federal government's investment in basic science is critical in driving innovation, productivity, and economic growth. For example, hundreds of business leaders signed the "Innovation Imperative" statement, which was a call to

action for steady federal funding increases in basic scientific research.

At the same time, the research community is constantly examining ways to improve efficiency and maximize these federal investments. However, federal regulations related to research continue to increase and add new complexity for researchers. While the U.S. research enterprise is by far considered the gold standard, there are always ways to improve the grant-making process and related reporting requirements. Examples might include streamlining proposal requirements and developing a common federal portal for grants submission, progress and financial reporting, as well as the adoption of common research terms and conditions, across research funding agencies like NIH, NSF, and DoD. Finally, in part due to leadership from researchers like Dr. Nosek, the scientific community is committed to improving the reproducibility of its work, in many cases learning

from—and collaborating with—partners in government and industry.

Thank you again for this opportunity to discuss the importance of federal investments in research. I would be happy to answer any questions.

October 19, 2017

The Honorable Rand Paul, Chairman
The Honorable Gary C. Peters, Ranking Member
Federal Spending Oversight and Emergency Management Subcommittee
Homeland Security and Governmental Affairs, United States Senate
340 Dirksen Senate Office Building
Washington, DC, 20510

RE: Subcommittee Hearing Entitled "Broken Beakers: Federal Support for Research"

Dear Chairman Paul and Ranking Member Peters:

The Water Environment & Reuse Foundation (WE&RF) and the Water Research Foundation respectfully request submission of this letter for the record of the hearing entitled "Broken Beakers: Federal Support for Research". We are nonprofit (501c3) research collaboratives for the water and wastewater industry. Together, the Foundations serve more than 1200 water organizations, representing more than 90% of the watered and sewered population in the United States. In collaboration with subscribing members, the Foundations conduct peer-reviewed, applied research to treat water and wastewater and recover beneficial materials from wastewater, stormwater, and seawater including water, nutrients, energy, and biosolids.

As recipients of federal research funds, our experience demonstrates that federally funded research best serves our Nation through industry-driven research partnerships with non-federal research foundations. These research partnerships ensure that more federal dollars are spent to target real-world problems, facilitate knowledge transfer from academe to practice, and leverage federal funds with industry support.

Through this letter, we would like to highlight two highly-successful federal research partnerships that continue to provide leveraged, industry-relevant, applied research to help manage our Nation's important, yet scarce, water resources more efficiently and effectively.

Research Partnerships with the Bureau of Reclamation
Since 2000, the Foundations been providing leadership through a long-standing collaboration with the Bureau of Reclamation on a broad spectrum of water reuse and desalination issues. This public-private

partnership sets an applied research agenda, provides funding for research projects, provides technical support to federal and municipal staff, and disseminates research results.

This partnership has funded 122 research projects over the last 18 years. Through five cooperative agreements (2000-2016) and five competitive grants (2015-current) Reclamation funds (**$17,826,405**)

were matched by the Foundations (**$34,812,063.54**) at a ratio of 2:1, well above the required 1:1. Among the numerous funding partners contributing to these projects were the State Water Resources Control Board (CA), Department of Water Resources (CA), Pentair Foundation, and water and wastewater agencies throughout the U.S.

The entire research portfolio valued at $200M, includes research on chemical contaminants, microbiological agents, treatment technologies, salinity management, public perception, economics, and public engagement. With input from Reclamation, the Foundations hold periodic research needs assessment workshops that are specifically designed to generate priority research projects and produce substantial benefits for communities and help meet the needs of urban, industrial, and agricultural water users. In addition, the Foundations provide technical support on Reclamation projects, advising on the launch of the recent Prize competition and serving on peer review committees.

As a result of this partnership, 119 final reports (3 pending) have been published and more than 20 accompanying databases/publications, and dozens of workshops have been used by thousands of water professionals.

National Priorities Water Research Grants Program
Since 2011, the Foundations have worked with Congress to create and fund the National Priorities Water Research Grant Program (Program). Since FY 2012, this competitive grant program has funded research on issues of national significance and of importance to the water sector. The Program, informed by the Nation's water and wastewater utilities, was specifically designed to address the country's highest priority drinking water, wastewater, water reuse, and stormwater research needs through targeted applied research projects. The Program requires that grant funding be cost shared with at least a 25% matching contribution to leverage more research through partnerships. This research has already produced valuable information and tools to help meet today's water needs nationwide.

Since 2012, the Program has invested more than $20 million into research projects of critical importance to the water sector. These funds are leveraged through partnerships with utilities and academics, resulting in an additional $5 million of research value. National Priorities research has resulted in 198 publications in professional conference proceedings and peer-reviewed trade journals.

The Program covers four primary topics:

- Impacts of Water Conservation on Water Quality in Premise Plumbing and Water Distribution Systems
- Life Cycle Costs of Water Infrastructure Alternatives
- Systems-Based Strategies to Improve The Nation's Ability to Plan And Respond to Water Scarcity and Drought
- Centers for Water Research on National Priorities Related to a Systems View of Nutrient Management

Many of these research projects rely on strong partnerships with local water utilities who provide data, serve as test sites, and use the results to help improve their decision-making.

The realized and anticipated results of the Program include:

- Data and predictive models to assess the impacts of household plumbing types, water age, disinfectant type, and flow rates on drinking water quality at the faucet.
- Tools to evaluate the costs and benefits of green and gray infrastructure with the goal of supporting integrated planning and creating more livable communities while protecting water quality.
- Improved understanding of how extreme weather events affect drinking water quality and quantity that can result in improved water management and drought response.
- Practical solutions for the management and recovery of nitrogen and phosphorus from municipal and agricultural wastewater.

In conclusion, the Foundations, along with our many federal and non-federal partners, believe that federal research dollars are many times best spent through partnerships on industry-driven applied research projects. Our partnership leverages limited federal funding with industry-backed dollars, and delivers applied research relevant to today's toughest challenges in delivering and managing one of our most precious natural resources – water.

Sincerely,

Melissa L. Meeker
Chief Executive Officer
Water Environment & Reuse Foundation

Robert C. Renner PE BCEE
Chief Executive Officer
Water Research Foundation

Post-Hearing Questions for the Record
Submitted to Brian Nosek, Ph.D.
Executive Director, Center for Open Science
University of Virginia
From Senator Gary Peters
Broken Beakers: Federal Support for Research
Wednesday, October 18, 2017

1. In your testimony, you emphasized the importance of a culture of openness in the scientific community. Specifically, you support keeping taxpayer-funded datasets available to the public. Entrepreneurs rely on a range of publicly available datasets to launch or grow their companies, and scientists use data created by taxpayer-funded research to conduct follow-on studies. Unfortunately, in this Administration, there has been a startling trend of federal agencies removing taxpayer-funded datasets from public view because they don't support a particular agenda. I introduced bipartisan legislation called the Preserving Data in Government Act to require that federal agencies keep these taxpayer-funded datasets open and available to the public. **What are the benefits of ensuring that federally-funded data remains open and accessible to other scientists? Do you support the Preserving Data in Government Act?**

Nosek response: Openness of data, materials, and outcomes of research maximizes its potential return on investment. There are at least three ways transparency and openness of research content provide significant benefits to the American taxpayer and, ultimately, the speed and efficiency of finding cures, solutions, and knowledge:

First, transparency is a key mechanism for accountability. Researchers often have a conflict-of-interest with their research findings – some results are more publishable than others. Publication is the means of career advancement in academic research. As a consequence, practicing researchers are incentivized to find publishable results, not necessary accurate results. There are many behaviors that can occur intentionally or unintentionally that reduce the accuracy of published results. Most of these behaviors involve discretion of the researcher in what studies, analyses, and outcomes are ultimately reported in a paper. If I conduct 100 studies and only report to you 10 of those studies, and only report the analyses and outcomes of those 10 studies that are most interesting, then you may get a very biased view of the evidence that I actually accumulated. Transparency and openness provide accountability. If others can review all of my studies, data, and materials, then it is possible to evaluate the discretion that I employed in characterizing my findings—either to confirm that it was sensible and defensible, or to identify limitations and alternate approaches.

Second, transparency and openness are essential for accumulating accurate evidence. Most estimates find a strong bias for publishing positive results (evidence of effectiveness or a relationship between variables) over negative results (finding no relationship). This leads to a bias in the published literature that exaggerates the evidence for effects and the potential magnitude of their impact. To get accurate estimates of the actual evidence, it must be possible to discover both the positive and negative results. Requirements to register studies and make data and materials more accessible are essential for accumulating an accurate evidence base.

Third, transparency and openness facilitates reuse of data and materials for other purposes. There is substantial waste in research because of unnecessary repetition of studies, or failures to accurately implement protocols because the original materials are unknown or unavailable. Sharing of data and materials facilitates reanalysis and reuse of data for purposes beyond the original investigation. At scale, this would provide a significant cost savings by avoiding unnecessary redundancy.

The Preserving Data in Government Act appears to be a practical step for improving policy about open government data, and particularly, the steps for reasonable removal of access to open data. Open data is not free. Sensible guidelines for the announcement and ultimate removal of public data will ensure that data that is perceived of high value in the public have opportunity to identify alternative solutions for data that will be deleted or otherwise removed from public access.

2. Partially in response to congressional criticism about silly-sounding research grants, the National Science Foundation issued guidance in 2013 to researchers on how to write titles and abstracts in a way that enhances public understanding of scientific research. The guidance encouraged researchers to explain the significance of their projects in a non-technical manner. Although this change may seem insignificant, it underscores the importance of building connections between the scientific community and the general public and reminding Americans that scientific research and innovation benefits the country at large. **What can scientists and researchers do to better communicate the importance of their research to the public and dispel some of the misconceptions about silly-sounding science?**

Nosek response: This is an important issue. There are two steps that I believe are essential to address this:

First, it is not likely that scientists themselves will all become effective communicators with the general public. Translating hard, esoteric problems for public consumption is a specialized skill. In many cases, the scientists producing the research will (and should) stay focused on their expertise in doing the important research. But, we can improve the ongoing efforts of translation of the value of research to the taxpaying public. There are many possible approaches, but a few of particular value include: (a) training and fellowship programs for scientists that do show translation capacity to do that work at a university, funding agency, professional society, or as training to becoming a science journalist, (b) retrospective stories to show how a modern solution was made possible by a cumulative body of research evidence that may have begun in investigations of something completely different, and (c) training for grant applicants to avoid obvious problems in how they present their work. For example, the grant applicant is rarely thinking of the taxpaying public when writing titles or abstracts. Sometimes applicants will employ cute titles or phrases to provide levity to otherwise serious content. But, to an outsider, such statements can lead to significant misunderstanding of the purpose of the research.

Second, a reality of science is that we don't know quite where it will lead us until after we have done the research. Scientists are asked to venture out into the unknown and discover what we can learn that could someday be useful for solving problems that humanity faces. Because there is so much unknown, our conceptions of what we will learn at the beginning are very different than what we do learn at the end. I believe the public is prepared to understand this already, but the research community can do a better job of justifying the taxpayer investment by telling the story of how the investments make a

difference. It is difficult to provide that justification prospectively – what the research will deliver. It is much easier, and clearer, to provide that justification retrospectively – what the research did deliver. We need systematic reviews and strong narrative stories showing how technologies, solutions, and cures came to be. The road to discovery is winding and unpredictable, but it is also one that yields benefits many times the investment made into it.

3. I have heard that researchers can face difficulties complying with various administrative requirements that accompany federal research grants, with one estimate finding that researchers spend 42% of their time on paperwork. We should work to achieve the right balance between ensuring taxpayer accountability and not overburdening researchers with red tape. The American Innovation and Competitiveness Act required the Office of Management and Budget and the Office of Science and Technology Policy to set up a working group to figure out how to reduce these administrative burdens. **What recommendations do you have to reduce administrative burdens on researchers while maintaining taxpayer accountability? What can we do to simplify the grant application process and cultivate the marketplace of ideas by encouraging more researchers to apply for funding?**

Nosek response: There are approximately zero scientists that would complain about reducing the administrative burden on applying for grants, conducting research, and reporting the outcomes. In my view, the best solutions are relatively simple. If researchers were required to register and share the data, materials, and outcomes of their federally-funded research, then that transparency would provide substantial accountability. Additional reporting mechanisms are not essential. Scientists' most valued assets are their reputations. The scientific community operates by continuous skepticism and critique of each other's claims. That marketplace of ideas operates best when scientists can see the basis of each other's claims. As long as the research is openly available, the scientific community's mechanisms of self-correction will address the reputations, advancement, and consequences for individual scientists who are performing well and who are not meeting the standards of community practice. Also, technologies that streamline the process registration and sharing will be of substantial benefit to researchers by lowering the administrative burden and by improving rather than interfering with their workflow. The Center for Open Science's open source solution, the OSF (http://osf.io/), for example, is a free project management environment that makes it easy for researchers to register their studies and share their materials and data. Support for public goods infrastructure like this will provide value to researchers for managing their own work, and value to consumers of that work whether it is other researchers, policy makers, or the public at large.

Answers to Post-Hearing Questions for the Record
"Broken Beakers: Federal Support for Research"
Provided by
Rebecca Cunningham, M.D
Associate Vice President for Research-Health Sciences
University of Michigan Office of Research

On October 18, 2017, Rebecca Cunningham, M.D., provided witness testimony before the U.S. Senate Committee on Homeland Security and Governmental Affairs, Subcommittee on Federal Spending Oversight and Emergency Management, at a hearing entitled, "Broken Beakers: Federal Support for Research." The following questions for the record were submitted by Chairman Rand Paul and Ranking Member Gary Peters.

Chairman Rand Paul

Question: In response to questioning at our hearing, you discussed treatments and cures for orphan diseases (those that treat rare conditions) as an area of market failure with regard to scientific research. Many others have made the similar assessments; the logic follows that because there is a small customer base for orphan drugs, the private market would not have an incentive to pursue their development.

However, in his book *Get Rich Carefully,* noted stock picker and market analyst Jim Cramer says:

I prefer to recommend the stocks of companies that make orphan drugs – drugs targeted for a smaller population that the federal government gives special incentives for [mostly in the form of fast track FDA approval and exemptions from ACA price regulations] and insurers often pay hundreds of thousands of dollars a year for – because otherwise the cost of maintaining the patient without the drug could vastly exceed the cost of the drugs themselves. (Page 100)

Moreover Statista reports that the Orphan Drug industry generated $23 billion in revenue for 2016 and is projected to reach $209 billion by 2022, a growth of more than 800 percent in just 6 years.

o Could you discuss why there seems to be disagreement between the academic the financial community about private sector incentives and capacity to address rare diseases?

Answer:
I do not believe there is a disagreement. In my opinion, it is two stages of the same process. Investments must be made in in the fundamental science that may lead to a cure or treatment for

a disease, and additional investments must be made further downstream when emerging developments show market potential. Public investment in university research plays a critical role in developing the fundamental biological and chemical knowledge that lays the foundation for new drugs - this process takes a significant amount of time and the rewards are often uncertain. As a result, drug companies tend to invest at a much later stage to aggressively develop drug candidates. This is especially true for orphan drugs, despite the potential lucrative payouts, because the fundamental research is quite limited due to the narrow scope of the public health impact of the more rare diseases. As an example, after decades of federally supported research, University of Michigan Professor Jim Shayman and his colleagues identified a compound that could potentially be used to treat a rare but devastating congenital disorder known as Gaucher disease. Professor Shayman licensed the drug to a major biotechnology company which saw the commercial potential of the compound. The journey from creating the strategy to treat Gaucher disease to receiving FDA approval for a treatment spanned across 40 years. Without significant long term federal support, followed by the private development, patients for this rare disease may still be left without hope.

Question: According to NSF data, the University of Michigan spent over $1.3 billion on research in 2015, Columbia University spent $868 million, and Texas A&M spent $866 million. Of that, Michigan received nearly $650 million (50 percent) in federal research funding in that same year, Columbia University received $515 million (59.3 percent), and Texas A&M received $175 million (20.2 percent).

All three institutions have similar endowments between $9.0 and $9.8 billion and together hold the seventh through ninth ranking of largest endowments of U.S. universities according to U.S. News and World Report.

o Given that these three institutions are similarly endowed what accounts for the valence of their reliance on federal support to conduct research?

o How is Michigan able to spend nearly 50 percent more on research than Columbia while only receiving 26 percent more in federal support?

o What my explain why Texas A&M is able to rely so little on federal support while similarly endowed universities rely two and half, to three times as much on federal support?

Answer:
I cannot comment on how other institutions use their endowments or, the federal support they receive for research, so I will limit my response to the University of Michigan. Similar to most university endowments, the University of Michigan's endowment is a collection of more than 10,000 separate funds, most of which have been restricted by donors to provide sustained

support for targeted purposes such as scholarships, educational programs, or professorships. Only around four percent of the funds are designated for research. Therefore, the size of a University's endowment is not typically indicative of its research activity. Total expenditures are a more accurate measure for the overall research activity at a university. As you note, the University of Michigan receives considerable federal funds to support its research activities. The funds received under these contracts are used to cover the costs of specific research tasks outlined in grant proposal budgets and cannot be used to support or reimburse non-research related activities. The volume of federally supported research at U-M is an indicator of the size and quality or our faculty, and their ability to win awards in a highly competitive environment. It is also important to note that the total research expenditures at universities are a combination of many sources beyond federal grants, including funds from the state, industry, foundations, and philanthropic gifts, and other sources (e.g., revenue from university-affiliated hospital operations). Because we strongly believe in the value of research and its close relationship to our educational mission, the University of Michigan itself also invests considerably in research by supporting faculty and student research projects and the infrastructure needed to support it. However, none of these other sources could replace the value of federal investments and its role in discovering cures for diseases or ensuring the nation's security interests.

Ranking Member Gary Peters

Question: While universities throughout the country are conducting cutting-edge basic research, it can still remain a challenge to realize the full economic potential of promising new research and to commercialize innovative products. The scientific community refers to this part of the R&D cycle as the "valley of death." **In your experience, what happens at the end of a typical basic research project? Do university researchers have the skills they need to identify research with potential commercial value? How can we cultivate and encourage these skills, and how can we offer cost-effective federal support for follow-on research or commercialization of promising new innovations?**

Answer:
A typical basic, or fundamental, research project funded by most federal agencies yields two primary deliverables. First are publications of the research results in peer-reviewed scientific journals, which allow the results to be publicly shared across the scientific community and encourage further progress. Second are the students who have gained expertise in their fields by working on the project, and go on to apply that expertise in industry, government, academia, and non-profit organizations across the nation. The thousands of students that we graduate each year are the primary means by which our nation's universities have transformed our economic health and quality of life. University technology transfer offices actively seek out technologies that emerge on campus that have potential commercial value, and facilitate the patent process. At that point, they may work to license the technology to existing industry partners, or they may work

with faculty to develop a new company. In some cases, the commercial potential of their work may not be clear to faculty, or they may not be familiar with the steps required to take it to the marketplace. The NSF has been a leader in recognizing this gap and developing programs to address these issues, such as the I-Corps program, which teaches researchers the basics of innovation while they are exploring the commercial potential of their science by engaging with industry experts. If a viable commercial application is identified, follow-on NSF programs such as the Small Business Innovation Research (SBIR) program and the Accelerating Innovation Research - Technology Translation (NSF AIR:TT) program can provide the translational research funding to begin the necessary de-risking before private industry or investors are willing to put their own capital at risk. All of the programs mentioned above are highly cost-effective methods of developing science results into commercial opportunities. As specified in the American Innovation and Competitiveness Act, having other federal agencies follow NSF's example would be an excellent start. In fact, the NIH is now launching their own version of an I-Corps program due to its success.

Question: As reaffirmed in the American Innovation and Competitiveness Act, independent merit review by peers in the scientific community is considered the gold standard. During the peer review process, proposals hoping to receive NSF funding are judged based on their "intellectual merit" and potential "broader impacts." Currently, only one in five proposals receives any NSF funding. Additional efforts to evaluate proposals based on ideas about "taxpayer value" will add additional layers of bureaucracy and could have a chilling effect on the open nature of scientific inquiry. **Can you explain the difficulty of applying for a federal research grant? Do you believe that the current peer review process can adequately evaluate the integrity and value of a research proposal? Should taxpayers be concerned that research proposals do not receive thorough consideration before receiving federal funding? In what ways can the peer review process be improved? What can we do to ensure a diverse pool of high-quality peer reviewers?**

Answer:
The peer review system is widely regarded as extremely successful, leading to research that has transformed nearly every aspect of our lives through countless treatments and cures for disease, the development of the internet, smaller and more powerful computers and hand-held devices, new and more efficient energy sources, advances in telecommunications, and safer automobiles. That said, applying for a federal research grant is a very laborious and competitive process, with only the most highly meritorious proposals receiving recommendations for funding. I believe that the peer review system we have in place is the best system available to judge the potential value and integrity of scientific research. The process involves multiple rounds of review by a diverse pool of disciplinary experts and review panels—including experts from academia, industry, and government—to identify the most competitive proposals with the potential to have the greatest impact and an extensive process in which current conflicts of interest are identified.

However, there are ways to improve the peer review system. There are ongoing programs and initiatives across several agencies that aim to make the process as fair and transparent as possible, including topics such as how best to recognize implicit biases, how to identify and declare potential conflicts of interest, and providing more training for reviewers and panelists on assessment criteria. Moreover, agencies are doubling down on efforts to broaden the diversity of those involved in the peer review process, recognizing the importance of including representation from underrepresented minorities, smaller research institutions, non-academic researchers, and a range of experience levels.

Question: I have heard that researchers can face difficulties complying with various administrative requirements that accompany federal research grants, with one estimate finding that researchers spend 42% of their time on paperwork. We should work to achieve the right balance between ensuring taxpayer accountability and not overburdening researchers with red tape. The American Innovation and Competitiveness Act required the Office of Management and Budget and the Office of Science and Technology Policy to set up a working group to figure out how to reduce these administrative burdens. **Considering that you have received funding from multiple federal science agencies, what recommendations do you have to reduce administrative burdens on researchers while maintaining taxpayer accountability? What can we do to simplify the grant application process and cultivate the marketplace of ideas by encouraging more researchers to apply for funding?**

Answer:
My recommendations to address this problem would be consistent with those of the National Science Board's 2014 report *Reducing Investigators' Administrative Workload for Federally Funded Research*, which recommended changes for federal agencies as well as universities. As a researcher who receives support from multiple agencies, I think harmonization across agencies can dramatically reduce the amount of time that researchers and universities spend on administrative work. For example, having common research terms and conditions, definitions for conflicts of interest and clinical trials, and common federal portals for submission and reporting across all federal agencies would be beneficial in reducing burden while encouraging more researchers to apply. Agencies could also fully develop and make use of a centralized database for biosketches, curriculum vitae, licenses and other required documentation with standard formatting requirements across agencies.

Also in the NSB's report, and included for consideration by a federal interagency working group under the American Innovation and Competitiveness Act, agencies could modify proposal requirements to only include those essential to evaluating the merit of the proposal and making a funding determination. This can be achieved through use of simplified budget requirements (e.g., NIH could increase the threshold for a modular budget), requiring more materials "just in time"

when a proposal is likely to be funded, and possibly through use of preliminary proposals and other mechanisms.

Question: In your testimony, you talked about how other countries are doubling down on their efforts to become global leaders in innovation and research. As you stated, the U.S. is losing ground to China and other competitors in these fields. Much of this lost ground comes from research on artificial intelligence and aerospace technology. I recently spoke with the CEO of a leading American company, one that has benefitted immensely from federally-funded research, and he emphasized the importance of ensuring the United States remains the global leader in science and innovation. **Why is it so important that American institutions lead the world in innovation? What role does federal funding play in our dwindling innovation advantage?**

Answer:
One of the key reasons that other nations are investing so heavily in innovation and research is because they have seen how U.S. investments in research at universities have made our nation the global leader in science and innovation. Our university system--which generates the pipeline of ideas and expertise that has fueled our economic vitality, strengthened our national security, and enhanced our quality of life--is the envy of the world. It has never been more important for us to sustain, and expand, our commitment to this resource if we hope to remain a superpower against growing global competition. It is understandable that the CEO you mentioned would endorse this view. Our universities provide the pool of talent that goes on to work in industry, develop new products, new services, new processes, new companies, and entirely new industries. More broadly, the Council on Competitiveness—whose nonpartisan membership consists of CEOs, university presidents, labor leaders, and national lab directors— routinely calls for bipartisan solutions to economic prosperity that involve strengthening our research infrastructure, which is the cornerstone of our innovation infrastructure.

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