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Testimony of Nancy Jackson, Ph.D.

Representing the American Chemical Society

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The Merit Review Process: Ensuring Limited Federal Resources are Invested in the Best Science

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American Chemical Society
1155 Sixteenth Street, N.W. Washington, D.C. 20036 T [202] 872 4386 F [202] 872 6206 www.acs.org

As president of the American Chemical Society, or ACS, it is my great pleasure to address the Subcommittee this morning on the topic of the merit review process of the National Science Foundation (NSF).

Founded in 1876, ACS has grown to be the world's largest scientific society with more than 163,000 members and one of the world's leading sources of authoritative scientific information. A nonprofit organization, ACS was chartered by the U.S. Congress in 1937 to advance chemistry in all its branches, promote scientific research and inquiry, and foster public welfare and education. ACS members work in industry, universities and colleges, and at national laboratories.

ACS is at the forefront of the evolving worldwide chemical enterprise. It is the premier professional home for chemists, chemical engineers and related professionals around the world as well as a global leader in chemical information. ACS publishes 41 world-class scientific journals and operates the Chemical Abstracts Service, which provides the most comprehensive databases of disclosed research in chemistry and related sciences.

Every year, ACS gives more than $11 million in grants for basic research in petroleum and related fields through the Petroleum Research Fund (PRF). Twenty-five researchers, who were recipients of these grants, later went on to become Nobel Laureates.

The Society also plays a leadership role in educating and communicating with public policy makers and the general public about the importance of chemistry in our lives. This includes identifying new solutions to global challenges, improving public health, protecting the environment, and contributing to the economy.

ACS has been a strong, long-time supporter of the National Science Foundation, which is of particular importance at this critical time in our nation's history. My testimony will concentrate on chemistry and NSF's impact on our science. While I think my observations and recommendations are broadly applicable, chemistry is my area of expertise.

Chemistry is the fundamental science that is at the heart of processes and products that meet our most fundamental needs for food, shelter, and health, as well as developments and materials that are vital to advances in biotechnology, computing, and telecommunications. It is a keystone of U.S. manufacturing and is essential to a range of industries.

America's $720-billion chemical industry is one of our nation's top exporters, with $171 billion in annual exports, which accounts for more than 10 cents of every dollar in total U.S. merchandise exports. Within the United States, the chemical industry employs 784,000 people and is a driver of innovation. The industry invests $55 billion in research and development annually, and one in five U.S. patents is chemistry related. In addition, the industry contributes to human and environmental health. Drug innovations, made possible through chemistry, have helped increase life expectancy in the United States by 30 years over the past century.

I mention this today because the success of the chemical enterprise is due largely to scientific and technological breakthroughs and advances made in industrial, academic, and government laboratories. Although much of the nation's chemical research is carried out by scientists, engineers, and technicians employed in industry and academia, the federal government is an important source of support, particularly for basic research conducted by our nation's universities and government laboratories. By

stimulating the roots of innovation, the federal government plays a fundamental role in ensuring the ability of the U.S. chemical industry to stay competitive in the long term. And because so many other industries depend on chemicals, the federal investment enhances the ability of the United States to compete globally by enabling a high-tech, competitive chemical industry to supply new products at prices that give our nation's producers an edge.

The NSF plays a unique role in the U.S. scientific enterprise. While other federal agencies have missions directed at advancing specific science and technology in health or energy, for example, the core mission of NSF is to foster a healthy scientific enterprise here in America. Supporting the best ideas and exploring new frontiers across research disciplines have been the hallmark of NSF and the backbone of the American research system.

NSF has played a pivotal role in paving the way for scientific discovery, in large part, by awarding grants to members of the scientific research community that have demonstrated outstanding merit. The Foundation accomplishes its mission by supporting fundamental research and education in science and engineering. From aircraft design, pioneering medical tools and robotics, to discovering how children can learn chemistry better, NSF has played a key role in funding discoveries that have driven the nation's economy, improved our quality of life, and enhanced national security. It also supports high-risk research and novel collaborations that could deliver exceptionally high rewards.

NSF is not just about research. It's also about developing and training tomorrow's scientific workforce. There is a symbiotic relationship between research and education. When a graduate student or a post-doctoral student works with a researcher funded by NSF, the student is honing skills and adding new scientific knowledge. In this way, the torch is passed from one generation of researchers to the next. To put it another way, this is how we keep pushing the edge of the envelope. If the United States is to continue to be a leader in science and technology, then we need to have the trained workforce working in that space.

NSF provides more than 20 percent of the federal support for basic research at academic institutions and supports roughly 10,000 new awards per year through the merit reviews of over 40,000 proposals received. Every year, an estimated 200,000 people, from undergraduates to senior faculty, participate directly in NSF research and education programs.

The NSF merit review process is the gold standard worldwide, and is one of the reasons why U.S. science has been as successful as it is. When other countries seek to set up their own national research efforts, they often look to the U.S. NSF as the role model to emulate.

At NSF, all proposals are evaluated for intellectual merit and broader impacts. NSF receives far more meritorious proposals than it could ever fund. While a proposal with weak intellectual merit has no hope of getting NSF funding, many proposals are rated "excellent" with strong intellectual merit and still do not get funded because of the stiff competition. The broader impacts criteria take into consideration which research is the most urgent or has the greatest relevance to improving the quality of life. This merit review process enables NSF to ensure that precious R&D money goes only to the most pressing R&D needs.

As anyone with a retirement fund has been told, managing a portfolio is critical to its long-term strength. Financial advisors stress that it's important to find the right balance between solid performing stocks and riskier investments that may provide higher returns. Managing a research portfolio is similar:

the research manager, whether working in industry or at NSF, strives to find the right balance between science that will deliver steady advances and ideas that are out of the box, but could result in game-changing developments. This point is especially important in times of restricted funding. It's human nature to make more conservative choices and be risk-aversive when times are tough. However, now more than ever, America needs pioneering research that will create economic renewal, produce jobs, and train the scientific workforce of the future. Extra efforts and attention must be paid to cultivating young researchers and game-changing ideas.

One of the reasons why the merit review process is so successful is because it draws from the collective wisdom of the scientific community. Many NSF personnel come directly from the scientific community and will return to their research institutions at the end of their two or three year rotations. Relying on rotating directors means the managers are up to date on the most recent scientific developments. The panels that perform the peer review of proposals are fellow researchers in the field, and as such, are also up to speed on the latest developments. This scientific community service, whether performed by grant proposal reviewers or NSF program officers, is an integral part of scientific culture. Many scientists dedicate their time in this way because it provides an opportunity to remain in touch with and influence the cutting edge, as well as because they understand that the system only works if everyone volunteers to play their part. In a way, it is the science community's way of "paying it forward."

The merit review process requires significant efforts by both NSF employees and scientist volunteers. To better understand how the process plays out, consider this example from the NSF chemistry division. The division receives about 1,800 proposals annually. Each program officer in the division manages about 100 proposals a year. These managers are responsible for picking peer reviewers, and they must do so with an eye for diversity across a large number of factors such as ensuring that the reviewers reflect a balanced group based on type of institution (e.g., small undergraduate colleges vs. large research universities), geography, and racial and gender characteristics.

Peer reviewers must also be experts within the proposal's subfield of chemistry. Generally, a program officer approaches three reviewers to find one who will accept the call to serve. Since each proposal requires three to five reviewers, this means the officers approach six to ten reviewers for each proposal. Therefore, on the average, the NSF chemistry division approaches between 10,000 to 18,000 researchers to serve as peer reviewers for the proposals submitted.

For every 100 grant proposals a program officer reviews, a small number (perhaps 10) will be of such high quality that it is obvious they should be funded. Another 50 proposals will be recognized as clearly not competitive; however, they still must be considered through the process. An agonizing choice must then be made over the 40 proposals in the middle. These include proposals that may be considered excellent or very good. In fiscal year 2010, the NSF award rate was 23 percent. In our analogy of 100 proposals, this would mean that 13 out of the remaining 40 would be funded.

The broader impacts criteria include considerations about whether the research proposal would broaden underrepresented minorities' participation in science, strengthen U.S. infrastructure, improve national security, or foster innovation. Some of these impacts are the result of language in the America COMPETES bill enacted last year. The broader impacts criteria take into consideration which research is the most urgent or has the greatest relevance to improving the quality of life. The broader impacts criteria enables NSF to choose between meritorious and even more meritorious proposals, and is a way to ensure that precious R&D money goes to the most pressing R&D needs.

It should be added that the number of grant proposals submitted to the NSF chemistry division steadily increases each year, more than doubling from levels 10 years ago. And while the number of proposals has doubled, the size of the NSF chemistry division staff has remained the same. NSF is challenged to continue to perform its job of supporting the best science, even as the sheer number of proposals competing for funding has ballooned.

I mentioned in my introduction that ACS is responsible for the management and administration of the ACS Petroleum Research Fund (PRF), which was established in 1944 by seven oil companies as a perpetual trust to advance science education and fundamental research in the petroleum field. In 2010, the Fund provided $11.4 million for research grants.

Although PRF is a small research fund, like the NSF, it has seen the number of submitted grant proposals skyrocket in recent years. Perhaps some insights gleaned from PRF would be useful in considering how to strengthen the NSF merit review process.

Several years ago, to relieve the growing peer review burden on the science community and to lighten the administrative load on the PRF staff, a policy was implemented to withdraw proposals from consideration that were deemed to be "poor" from the get go: this includes those that are poorly written, use bad science, or do not address the specific scientific areas that were eligible for funding. In practice, this means that the managers now triage approximately 20 percent of the grants that come their way. These managers err on the side of caution: if there is any doubt that a proposal may have some merit, it is forwarded to the peer review panels for consideration and ranking. The result has been that, while some "poor" proposals are removed from the evaluation process, more time and energy is freed up for PRF staff and the volunteer peer reviewers to focus on selecting the right balance of research from the strongest proposals.

Currently, NSF does not have the freedom to remove any proposals from the very bottom of the pile from consideration. Empowering NSF research managers to do so—provided that specific criteria are taken into consideration— would be a simple step to help NSF maintain excellence in its merit review process. If the average acceptance rate for an NSF proposal is about 23 percent, this means that 77 percent of funding proposals will be turned away. Enabling managers to remove the lowest 20 percent of those that would normally be rejected from consideration is highly unlikely to result in a potentially great proposal not getting its due consideration. Instead, this approach may be a practical step to balancing a steadily increasing NSF workload.

I have mentioned the important role the broader impacts criteria play in the NSR merit review process. NSF promotes broadening participation of underrepresented minorities and women, and persons with disabilities. This also includes increasing diversity in the NSF portfolio with respect to types of institutions supported and the geographic regions represented. Broadening participation is one way to address the broader impacts criteria; however, other activities are also appropriate.

The importance of NSF efforts to broaden participation of underrepresented minorities in science and engineering is well understood and supported by the scientific community. We know that if the scientific work force doesn't reflect the demographics of our country, we risk missing out on bringing the best minds and talents from every community to work on the scientific challenges that will impact all of our lives.

In spite of NSF efforts in the broader impact criteria areas, we could use better tools to measure how effective these NSF efforts have been. One difficulty of measuring the long-term impact of the broader impact criteria is that it's easier to measure the inputs than the outputs. Measuring how many fellowships or grants are funded is easy. Measuring increased national innovation, improved national security, or broadening participating is complex and must take place over a longer time scale. These differences make it difficult to single out how one individual effort has impacted a complex collection of national priorities.

As a scientist, I want these efforts to be successful. As a senior administrator, I recognize that it's nearly impossible to measure success if you can't measure long-term outputs. In industry, we understand that finding the right metrics is very difficult, but it's worthwhile to try. I do not know how to resolve this issue, but I do believe that empowering NSF to more easily gather the data needed to measure the success of the broader impacts criteria would be a necessary step to ensuring those efforts achieve their desired effect to the maximum extent possible.

Chairman Brooks, I thank you for the opportunity to testify today and to share these thoughts with you. ACS believes the NSF is the cornerstone of the U.S. scientific enterprise, and we stand ready to assist you efforts to strengthen the agency for the benefit of the scientific community and the entire nation.