President's Remarks to
U.S. House of Representatives Science, Space, and Technology Committee

Presented by
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Thank you, Mr. Chairman, Ranking Member, distinguished Members of the Committee. It is a pleasure to be here today to talk to you about the status of the research and development enterprise in the United States.

I am President of the nation's oldest private technological research university, Rensselaer Polytechnic Institute. Our graduates have been an integral part of America's promise, through discovery and innovation, since the university was founded in 1824. America's health and prosperity, our security, and the availability of good jobs depend upon our leadership in science and technology. As a nation, we have invested in education and scientific research. These investments have made a difference in people's lives.

Let me illustrate **how** with a true-life **story.** The New York Times reported that, in October 2004 in Afghanistan, a mortar exploded, and a US Marine Corporal (Isaias Hernandez) was nearly ripped apart by shrapnel, which tore away seventy percent of the muscle in his right thigh, and fractured his femur. Corporal Hernandez endured four years of surgeries and physical therapy – to little affect; **until** he met a doctor (Stephen Badylak) of the McGowan Institute of Regenerative Medicine at the University of Pittsburgh, who cut open (once again) the Corporal's thigh, and applied what is known as the **extracellular matrix** – derived from pig bladders.

The **extracellular matrix** fills the space around the body's cells. It contains hormones, structural proteins, and other molecules that maintain cell function and health, mediate inter-cellular communication, and, importantly, guide tissue growth. **Miraculously**, after about six weeks, the implanted gel mixture spurred the growth of muscle tissue, tendons, and vasculature, and, with it, restored physical strength to the marine's thigh.

Dr. Badylak does **not** really know how the extracellular matrix works. But, what **is** known is this: it becomes part of the **existing** tissue, it draws **stem cells** to the implant location, it changes the body's immune response from **rejection** to **reconstruction**. By recruiting the body's **own** stem cells and putting them to work, the extracellular matrix **obviates** the need for controversial and difficult stem cell implants. Think of it as a kind of biological **catalyst**. The work I have described is part of a ($70 million) government-supported regenerative medicine research program.

This is the kind of work that researchers at Rensselaer are engaged in – deriving breakthroughs in the use of **adult** stem cells, understanding the role of the **extracellular matrix** in cell signaling and tissue regeneration, developing **enzyme-based** coatings that kill antibiotic-resistant bacteria (MRSA) on contact, bioengineering **synthetic heparin**, and much more.

Heparin-like molecules are key components of the extracellular matrix, serving to mediate the exquisite control of signals that enables the extracellular matrix to serve as a highly tuned niche for cell function.

Interestingly, heparin also serves as the most widely used intravenous anticoagulant drug with more than 100 tons produced annually worldwide. Heparin was discovered in 1916 and entered early clinical trials as the first “biologic” drug during the 1930s, before the establishment of US Food and Drug Administration. Heparin is produced today much like in the early years of the last century. The raw material is isolated from pig intestines in a large number of small factories in countries with little quality control.

This largely unregulated raw heparin is then converted into the actual drug within well-controlled and regulated processing facilities here in the U.S. Nevertheless, this lack of regulation opened the door for the purposeful contamination of several raw heparin batches, which resulted in the purified drug also being contaminated, and further resulting in nearly **100 deaths** in the U.S. This contamination served as a wake-up call to the pharmaceutical industry and the FDA, as well as other regulatory agencies worldwide, which led to a major multidisciplinary effort, spearheaded by **Robert Linhardt at Rensselaer Polytechnic Institute**, to develop a non-animal sourced, **bioengineered heparin.**

The large-scale production of **bioengineered heparin** involves the use of enzymes, nature’s catalysts, which place key chemical moieties onto the heparin backbone, thereby endowing the molecule with its well-known anticoagulant properties. By immobilizing (or attaching) these enzymes onto finely tuned materials, these enzymes are stabilized to enable economically viable, large-scale production of bioengineered heparin. While heparin is medically important, bioengineered heparin is built on the intersection of chemistry, biology, materials science, and data and computational science largely supported by the National Science Foundation and the various agencies within the Department of Defense.

Immobilized enzymes have other uses too, including those that can impact long-term space missions. Nature uses enzymes in many ways, including protection from pathogens. An enzyme in our tears, lysozyme, acts as a disinfectant by killing bacteria that enter the eye. Similarly, some bacteria produce enzymes that kill other bacteria that encroach on their environment. By putting these enzymes into surface coatings, researchers at Rensselaer Polytechnic Institute led by **Jonathan Dordick** have developed a paint that kills **methicillin-resistant *Staphylococcus aureus* (MRSA)** on contact, yet does not harm human cells.

In fact, this **enzyme-containing paint** was used on the final mission of the **Space Shuttle Atlantis** and was just as effective in space as here on earth. This has important implications for long-term space flights, whether on the **International Space Station** or a **mission to Mars**, where pathogen-free environments are critical to the health and well being of the crew.

The extracellular matrix-based therapy described, as well as the bioengineered heparin breakthrough, comes not just from one discipline, but from research results based in the life sciences, chemical and biological engineering, nanotechnology and materials science, industrial engineering, space science, and earth and environmental sciences. So, once again, the confluence of fundamental science and real-world applications is built on the shoulders of federal funding of basic and applied research.

We already are seeing how genomics, transplanted organs and limbs, artificial organs, embedded sensors, and expert systems are transforming medical care and treatment. Undoubtedly, there will be **even more breakthroughs** that will surprise us, and continue to change lives.

An **important** point is that these breakthroughs come from a **spectrum** of basic research funded by the federal government – across a broad disciplinary front **and** at the intersection of disciplines.

Life changing, job creating, security sustaining scientific discoveries and technological innovations in the United States have long been driven by a strong collaboration among business, government, and academe. This three-way partnership has created an “innovation ecosystem” that has driven our economy, our prosperity, and our well being for decades.

Federal investments in scientific research and development built the **foundations f**or a broad range of industries such as information technology, communications, and advanced materials. Many leading U.S.-based global companies including **Genentech, Google, and Cisco Systems** all can trace their roots to federal research investments.

> The roots of **Genentech** lie in breakthroughs from government supported research that led to the discovery of DNA and the ability to manipulate it.
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> **Google’s** business rides on the backbone of the **Internet**, the Global Positioning Satellite System **(GPS),** and breakthroughs in computer science – all derived from research and infra-structure supported or built by the Federal government, often for mission driven purposes, but later opened up for commercial use.
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> **Cisco**, likewise, has benefitted from government sponsored research and infrastructure.

Along with the research support was linked federal support for the people -- the scientists and engineers who did the work – often, including students.

The successes of the innovation ecosystem in the United States have not gone unnoticed. China, India, and other nations have studied our approaches to collaborative support – including government support – for education, research, and development, and they are emulating our model by making concomitant investments so they can gain the same benefits for their citizens. If the U.S. is to remain globally competitive, we must sustain and enhance the U.S. innovation ecosystem. We must be positioned to apply science to address the key global challenges of access to clean water, food security, energy security, health security, and disease mitigation, and the corresponding risks of climate change and resource allocation. Research in the areas of nanotechnology, big data, biotechnology, and smart systems hold great promise for producing new products and processes and changing our lives.

But what is the **special brew** that will help us to strengthen the U.S. innovation ecosystem? Our system rests on the three-legged stool of industry, academia, and government, and collaboration among them. Each sector has its role to play, and each must participate effectively and cooperatively.

An innovation ecosystem requires four things:

First is **strategic focus**. Among a world of possibilities, we must choose important and promising areas to explore and develop, and these must match the talent, resources, and opportunities we have or can attract.

Second is **idea generation**. Game-changing ideas tend to arise out of basic research, which pushes the boundaries of human knowledge. Universities are critical players here, because basic research dovetails magnificently with our educational mission.

The **third** element requires **translational pathways** that bring discoveries into commercial, or societal, use. The protection, regulation, and exploitation of intellectual property are the front-end of translation. Support for start-ups, business incubators, specialized industry collaborations, and public/private partnerships are all key in this process.

The **fourth element** of a robust innovation ecosystem is the **financial, infrastructural, and human capital** to support the development and exploitation of promising new technologies.

We clearly need a new financial model that can overcome the so-called “valley of death,” for entrepreneurial, technology-based start-ups -- between venture funding and full-blown major investment -- when no financing is obtainable.

Equally important is the **physical capital** that allows new technologies to be improved and scaled for the marketplace — facilities for applied research – including shared infrastructure -- for the prototyping and testing of new technologies, for the development of advanced manufacturing processes for modeling and simulation.

Good examples exist. The **Computational Center for Nanotechnology Innovations (CCNI)** is a joint project of **IBM**, **New York State**, and **Rensselaer**. It not only hosts one of the world’s most powerful university-based supercomputers, used for research by our faculty, it also allows companies of all sizes to perform research, and to tap the expertise of Rensselaer scientists. The **CCNI** has **800** discrete users, and **25** corporate partners.

The **most crucial** of capital required for our ecosystem is **human capital**.

We must draw more young Americans into science, technology, engineering and mathematics, and educate them well. We must address what I have called the the “Quiet Crisis” of a looming loss of STEM talent due to pending and actual retirements of today’s scientists and engineers , without enough young people in the pipeline being prepared to enter these fields. We must improve mathematics and science education from the very beginning of our children’s educational careers. And, if we want to remain competitive, we must sustain our commitment to these students throughout their academic careers. Retaining high caliber talent from abroad is equally important, especially those obtaining advanced degrees in science and engineering from American universities.

Clearly, the skilled labor demands of advanced manufacturing require that we make comprehensive education and retraining efforts a priority if the U.S. is to remain competitive.

Retaining technological leadership is not a given. We still experience the benefits of our system, but, as many recent reports have pointed out, its health is in decline. Perhaps most pressing for you, as Members of the Congress, funding for research in these austere times is facing significant challenges.

Those nations that educate the next generations, invest in research, and make commitments to building effective innovation ecosystems are poised to become the global leaders of tomorrow. There should be no disagreement about the wisdom of educating our children in science and technology, without compromise. And our commitment, in terms of investment, rhetoric, and vision should be unmistakable and unshakable.

Mr. Chairman, thank you for the opportunity to submit this testimony today.