G-SCIENCE ACADEMIES STATEMENT 2020

Basic Research

EXECUTIVE SUMMARY

Expanding fundamental knowledge has made enormous contributions to solving global challenges and sustaining healthy and prosperous societies. Investment by the public in basic research creates essential human and intellectual capital and enriches society in unexpected ways, including new treatments and technologies that spawn new industries, elevating the global standard of living.

Yet, there are many current cases of inadequate or decreasing investment in basic research. And investments and policies for education, capacity building, cooperation and openness are necessary to realize the benefits of basic research and to distribute them throughout society.

- **Our central recommendation is to restore and sustain long-term public funding of basic research, pursuing new frontiers of knowledge, providing the basic fuel for successfully meeting current and future challenges**

It is also important to:

- **Strengthen investment in cultivating inquiry and innovation through early and ongoing science, technology, engineering, and mathematics (STEM) education, integrated with the humanities and arts**

- **Foster global cooperation and information sharing to accelerate discovery and spread benefits and to reduce knowledge-based inequities**

- **Support interdisciplinary collaboration among and between fields, including engineering and social sciences**

- **Openly publish research, to increase scientific knowledge, foster curiosity, and benefit all publics**

BACKGROUND

"Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science. Today, it is truer than ever that basic research is the pacemaker of technological progress."

—Vannevar Bush, (*Science, The Endless Frontier*, 1945)

Seventy-five years ago, Vannevar Bush laid out the case for government support of basic research—that is, research pursued for the advancement of fundamental knowledge without preconceived application in mind. His report drew the connection between the pursuit of fundamental knowledge and technological progress, elucidated by several examples from his time—from the discovery of penicillin and use of vaccines to the development of synthetic materials and radio communications. In cases of such leaps in scientific understanding, the benefits to the global community have been enormous. Advances in biomedicine have enhanced and saved untold numbers of lives. Scientific breakthroughs have created new industries and jobs, and advances in agriculture freed billions of people from hunger.

The challenges of the present are daunting—including the need to address climate change and mitigate the impact of natural disasters, fight new and re-emerging agents that cause disease, address chronic health issues, provide robust technological systems and cybersecurity, reverse environmental degradation, and provide sustainable sources of energy, food, and water. Basic research is more important now than at any stage in human history, a crucial, long-term investment in the future to meet these challenges and produce game-changing ideas essential to the progress and endurance of society.

WHY BASIC RESEARCH?

It is a paradox of science that the road to revolutionary breakthrough is often an indirect, inquiry-driven approach that yields increased understanding of the natural world and ourselves, and enables transformative discoveries for real-world challenges. For example, cancer could not seriously be addressed before fundamental breakthroughs were made in genetics and molecular biology.

Basic research across disciplines is necessary for responding to our common challenges. Human activity has a large impact on the planet, its resources and its climate, and accelerating technological developments provide unanticipated social and ethical implications. These challenges inequitably affect the most vulnerable populations in society. Thus, it is essential to understand human decisions, behavior, culture, political processes, migration, and conflict. These questions can be addressed by basic research in fields including engineering, social sciences, and humanities. Science is intrinsically an international endeavor beyond national borders and cultures, and its benefits should be distributed equitably and globally. It can contribute to cross-cultural dialogues, international understanding, and to peace.

Basic research is an essential complement to mission-oriented research and development, which target specific problems or commercial objectives. Applied activities supply advanced tools needed for basic research, and those tools provide other direct benefits to society. Young scientists and scholars are drawn to the deep intellectual challenges of inquiry-driven basic research and are trained in, or create, new questions and ways of thinking. As these skills are applied to societal priorities, they can have transformative effects, enabling the growth of R&D-intensive industries and formation of start-ups.

While the rate of return on investments in basic research is difficult to estimate, historical experience and specific examples indicate that it is very high. Economists have estimated the social rate of return for all research and development investments to range up to as much as 100 percent. Continued contribution of basic research to global well-being depends on adequate, steady, long-term public funding. Public funding promotes the scientific values of objectivity, honesty, fairness, and accountability, thereby fostering science of the highest quality, rigor, and transparency.

BASIC RESEARCH, ITS APPLICATION AND BENEFITS

Apart from the immediate scientific results, basic research often generates indirect benefits. Most of modern technology is a consequence of basic research. Some illuminating examples:

Most modern electronic devices including microprocessors, lasers, and nanotechnology are dependent on classical and quantum theory, first conceived in 1900 by physicist Max Planck, resulting in almost a third of the gross national product of leading economies. With the advent of quantum computers, the quantum internet, and quantum sensors, this percentage may increase.

Modern biomedical applications are based on discoveries in molecular biology, starting with the structure of DNA by Crick, Watson, and Wilkins. In the 1960s, microbiologist Hamilton Smith and colleagues showed how an enzyme is capable of slicing DNA at specific sites, which in turn sparked the growth of the biotechnology industry. Basic research beginning in 1987 by Ishino Yoshizumi discovered unique repetitive DNA sequences in bacteria, the function of which was later elucidated in 1989 by Francisco Mojica, whose work led to tools for gene editing. These gene-editing tools are being applied in agriculture and have the potential to revolutionize medicine.

While studying ultra-cold temperatures, physicist Heike Onnes discovered the phenomenon of superconductivity that can be used to create powerful magnets. This knowledge has been applied in contexts from maglev transport to magnetic resonance imaging (MRI) in healthcare, but later basic research also benefited from these advances. The CERN particle accelerator used superconductivity to confirm the existence of the Higgs particle. Further, the development of functional magnetic resonance imaging (MRI) provides new opportunity for understanding the brain's role in human behavior, fostering breakthroughs in basic research by social scientists in economics, sociology, anthropology, psychology, and communication.

Basic research may require significant time for advancements to be applied. An example is the many fields researching artificial intelligence (AI). The first attempt at a computerized neural network was built by Minsky in 1951. Then neural networks were written off for decades. Recently, the incredible yield of basic research on AI was driven by the information explosion, with mass storage of data and extraordinary improvement in computing capacity. Continued research on AI and its ethical and social challenges is essential.

The common thread among these (and numerous other) breakthroughs is that basic research provides enduring potential for long-term and evolving applications. Basic research can lead to paradigm shifts, opening up entirely new fields of industry, technology, and understanding of the human condition. Public investment in basic research often encourages important private sector research and innovation.

CHALLENGES

Because of the exploratory nature of basic research, and the need for healthy and stable funding, government is the key funding source in the advancement of new knowledge. Since much of the knowledge developed by basic research is publicly accessible and benefits global society as a whole, it is a public good that cannot easily be owned or restricted by individuals, institutions, or nations. Of course, not every basic research project will develop into immediately practical applications, yet those that do have a vast impact on humanity.

In many countries, however, public funding for basic sciences is inadequate, has stagnated, or is declining. Economic and political uncertainties, along with a research climate driven by short-term results and the hunt for scarce funding, have undermined investment in transformative ideas. Yet, now more than ever, the scale and complexity of global challenges demands revitalized investment in basic research to leverage the full spectrum of human ingenuity in devising insight and solutions.

The chief concerns of government include full employment, public health and national security, whereas businesses are inherently focused on shareholder returns. Corporate and philanthropic funding of basic research is valuable and reaffirms the importance of cultivating new knowledge, yet its incentives remain different and do not provide a stable substitute for public funding of basic research. Public funding is unique in that it is more apt to ensure both open, creative inquiry and resource stability, as is needed for effective basic research.

RECOMMENDATIONS

1) Most importantly, restore and sustain long-term public funding of basic research

Governments have proven to be the most natural and reliable funder of basic research. Investment in basic research, including in engineering and social science, provides the knowledge basis on which applied research can build to address major current and long-term challenges.

2) Build capacity via STEM education

It is vital to cultivate student creativity, imagination, and a scientific approach from the earliest stages of education, through robust investment in STEM education, integrated with humanistic, social, and artistic perspectives. Funding of scholarships for undergraduate and postgraduate studies is also essential. Special effort and support for education and basic research in less-developed countries and regions is of particular urgency to harness intellectual potential and address urgent needs while improving access to the benefits of science.

3) Cooperate globally

Open cooperation is key to the pursuit of new knowledge on the fundamental laws of nature. It is essential for governments to support scholarly exchange and visa programs. Basic research, when pursued with integrity in open cooperation among a global community, additionally serves to enhance international relations and mutual trust. Ensuring that basic research data, opportunities to present and partake in cutting-edge research, and scholarly publications are globally accessible is essential to scientific advancement and an equitable world.

4) Collaborate across disciplines

Investment in basic science must take into account all research disciplines, including engineering, social sciences, and humanities. All should be pursued to engage in understanding the social, cultural, and ethical implications of advancing technologies.

5) Openly publish research results

Results of research funded by the public should be made available and accessible to the public at no further cost. This requires innovative science communication and publishing models.

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