The IMPACTS of investing

Times of crisis bring renewed demands for returns on publicly funded research, but this ignores the fact that scientific production follows complex and interconnected pathways

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PUBLISHED IN AUGUST 2016

In times of economic crisis, society often questions the use of public funds and would rather prioritize activities that offer visible and immediate returns. Fields in which outcomes are more elusive or less palpable are often viewed as being of low priority when allocating funds. When this phenomenon affects the research system, whose funding depends largely on the government—though this dependence varies from country to country—it is often expressed as a choice between basic and applied research, as if the two concepts were independent rather than deeply intertwined. Investing in research that immediately results in new products and technologies tends to be viewed as most important because it provides tangible returns to society. Funds targeted toward basic science, however, are sometimes considered an extravagance, as we saw emphasized in 1967 when the Republican governor-elect of California, Ronald Reagan, proposed, that taxpayers stop subsidizing "intellectual curiosity" in state university programs and courses as a way of resolving budgetary problems, . "We do believe that there are certain intellectual luxuries that perhaps we could do without," said Reagan, attracting criticism from all sides. In an editorial, *The Los Angeles Times* argued that, "If a university is not a place where intellectual curiosity is to be encouraged and subsidized, then it is nothing."

In the reality of 21st-century science, the debate calls for classifications that are far more complex than either of the two categories of basic and applied science. "The concepts of pure and applied research are useful in abstract discussions and can work in specific situations, but they do not adequately serve to categorize science," contends Graeme Reid, a science and research policy professor at University College London in the UK and author of the report, *Why should the taxpayer fund science and research*?, which was published in 2014. In the first place, he says, the common denominator for classifying science should be "excellence," without it neither basic nor applied sciences produce consistent results.

Reid cites the Higher Education Funding Council for England (HEFCE), a British agency that funds and regulates university teaching and research, as an exmaple. HEFCE allocates funds without reference to either category because the qual-

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EXAMPLES OF BASIC RESEARCH THAT HAVE RESULTED IN APPLICATIONS

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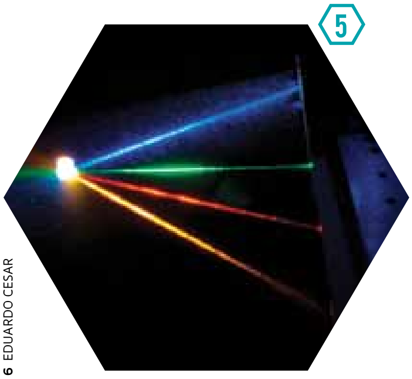

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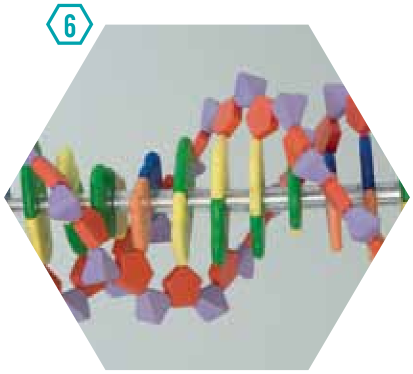


PHOTOS 1 LÉO RAMOS CHAVES 2 WIKIMEDIA COMMONS 3 ERIC GABA/WIKI MEDIACOMMONS 4 MARTI/JILA 5 RANDY MONTOYA 6 EDUARDO CESAR

ity of the research is what enables it to have an impact. The report mentions a document published in 2010 by the Council for Science and Technology, which is associated with the British Prime Minister, entitled, *A vision for UK research*. This document states that the importance of research is its ability to ask important questions; the insistence on distinguishing between pure and applied research creates more problems and divisiveness than solutions. Reid notes that the benefits of investing in research come in several forms that go well beyond the polarization between the advantages of better understanding phenomena on the one hand and the gains generated by technology development (such as university-generated start-ups that are capable of quickly transforming knowledge into wealth, the attraction of global investments in research and development (R&D) to universities and research centers, and the supply of highly specialized labor to companies and public agencies) on the other. "The research environment is a delicate ecosystem that delivers a multiplicity of benefits to society and the economy through complex and interconnected pathways," Reid says.

1 FROM GRADIENTS TO RESONANCE EXAMS
In 1954, U.S. physicists Hermann Carr (1924-2008) and Edward Purcell (1912-1997) described the use of magnetic field gradients to relate nuclear magnetic resonance frequencies to spatial positions. The initial developers of magnetic resonance had no idea that their work would create a diagnostic imaging technology that is currently widely used in medicine.

2 FROM MAXWELL'S EQUATIONS TO MARCONI'S RADIO
The development of a receiving device called a coherer allowed the Italian Guglielmo Marconi (1874-1937) to invent the radio. Marconi's accomplishment, however, would not have occurred without the contributions of the Scottish physicist and mathematician James Clerk Maxwell (1831-1879), whose abstract equations drove studies in the field of magnetism and electricity, and of the German physicist Heinrich Hertz (1857-1894), who later demonstrated the existence of electromagnetic waves.

3 FROM MAGNETORESISTANCE TO HARD DISK MINIATURIZATION
In 1988, German physicist Peter Grünberg and French physicist Albert Fert discovered giant magnetoresistance (GMR), a quantum effect observed in thin films composed of alternate layers of ferromagnetic and non-magnetic metal. The finding made it possible for the later dramatic miniaturization of hard disks, which expanded their data storage capacity and helped to popularize microcomputers and portable mp3 devices.

4 FROM THE ATOMIC CLOCK TO GPS
To test Einstein's general theory of relativity and determine whether time in fact is slower in an intense gravity field, physicists proposed placing ultra-precise atomic clocks into orbit aboard artificial satellites. This led MIT physicist Daniel Kleppner to create a new type of atomic clock in the 1950s that performed an important role in facilitating the development of the global positioning system (GPS).

5 FROM THE FIRST LASER TO FIBER OPTIC COMMUNICATION
The first laser was built in 1960 by US physicist Theodore Maiman (1927-2007) based on an idea from atomic physics (in particular, the effects of stimulated emission, which were predicted decades before by Einstein). With the development of gas lasers, these sources of light permitted holographic and interferometry studies. The most important applications came from the development of solid state lasers and their use in fiber-optic communication. Today, lasers are used in medicine, electronic equipment and in scanning and printing technology.

6 FROM THE STRUCTURE OF DNA TO THE BIOTECHNOLOGY INDUSTRY
In 1953, Francis Crick (1916-2004) from England and James Watson (1928-) from the United States discovered the molecular structure of deoxyribonucleic acid, DNA, and uncovered basic elements of genetic heritage and protein production. The work, which sought to expand our understanding of nature, formed the basis of genetic engineering and led to the development of diagnostic exams, new treatments and creation of the billion-dollar biotechnology industry.

Each country's balance

Destination of public R&D funding according to a study by the University of Sussex, United Kingdom.

UNITED STATES
Federal defense budget investments decreased from 57.7% of the total in 2007 to 53% of the total in 2013. Resources targeting health research, however, increased from 21.9% to 24.3%. A third of all investments in R&D go to basic science.

EUROPEAN UNION
The Horizon 2020 program, which has a €80 billion budget for the period from 2014 to 2020, allocates funds in three equal portions: basic science projects, research of interest to companies and research that addresses society's greatest challenges.

NORWAY
Basic research receives 40% of public R&D funds, and applied research and development receives 60%. Universities receive 60% of the funds, and research institutes receive 40% of the funds.

DENMARK
Universities receive 90% of public R&D funds. Of the total, 44% is invested in basic research, and 56% is invested in applied research and development.

CHINA
Applied research accounts for 73% of R&D investments made by the central government. Basic research receives about a fifth of the total, at 22%.

INDIA
Three-quarters of all R&D investment by the central government goes to applied research and new products. One-quarter goes to basic science. Resources spent on defense accounted for 24.5% of all funds in 2010, followed by agriculture at 17.7%.

SOURCE: COMPARATIVE STUDY ON RESEARCH POLICY – SPRU/ UNIVERSITY OF SUSSEX, OCTOBER 2015.

Instead of distinguishing between the benefits of basic and applied science, decision-makers and institutions that support science have established new ways to classify research objectives that revolve around a single key concept: the potential impact of the investment. "Impact is a very broad concept and it has several dimensions, namely, intellectual, economic and social," said Carlos Henrique de Brito Cruz, FAPESP's scientific director, in the chapter he wrote for *University priorities and constraints* (Economica, 2016), a book which comprises contributions by 23 leaders of the world's most distinguished research universities at the Glion Colloquium Forum in Switzerland in June 2015.

Some studies have benefited society by inspiring or backing public policies in virtually every sphere. A broad example is the contribution made by various disciplines to the understanding of phenomena associated with climate. Another example of particular interest is the role of the Biota-FAPESP program's findings in influencing legislative actions. Established in 1999 to map the biodiversity of São Paulo State, the program has generated knowledge that has been published in scientific articles, books, atlases and maps that have been used as reference materials for the drafting of six government decrees and 13 environmental resolutions.

In a 2005 study funded by the Department of Research, Science and Technology of Quebec, Canada, political scientists Benoît Godin and Christian Doré attempted to map the various types of impact generated by research and developed a list of 11 items. Some are well known, such as the scientific, technological and economic impacts. Others are less studied, such as the cultural impact, which is understood as changes in habits and attitudes of individuals that are caused by the broader understanding of natural phenomena, or the organizational impact, in which new knowledge helps organizations to improve management (*see the table on page 9*). "Although economic impact should not be ignored, it represents only a fraction of a whole that extends into the social, cultural and organizational realms of society," Godin and Doré explained in the study.

SCIENCE FOR THE SAKE OF SCIENCE

A major antagonist in these discussions is what is referred to as research conducted for curiosity's sake, a phrase often understood as being synonymous with basic research. This means the scientist chooses the topic on which to work instead of being prompted to research a particular theme or topic; such research may take on an abstract or applied character or a combination of both. Although not intentionally, this path has led to remarkable contributions in the field of lasers, atomic physics, and biotechnology. One classic case occurred in 1983 when two teams of researchers in different countries discovered that a retrovirus, later named HIV, was the cause of a recently discovered disease: acquired immunodeficiency syndrome (AIDS). The US team, led by Robert Gallo, and the French team, led by Luc Montagnier were successful due to years of retrovirus research, driven by the scientists' curiosity, since no one could have imagined its relevance to human health (*see more examples on page 5*).

Research that has an intellectual impact can also have an economic or social impact, but part of this research will serve simply to expand the frontiers of knowledge and have no immediate tangible return. "There is not always an endpoint to be reached through basic research," said Harvard University professor and biochemist Stephen Buratowski, in an interview for the Harvard Medical School website. His laboratory is currently studying the mechanisms of gene expression in eukaryotes. "Many of the subjects studied on the basis of a scientist's curiosity are attempting to answer fundamental questions about biology. Their understanding allows us to move forward and face actual clinical problems."

Transformative research is an example of a new category of production of knowledge that is heavily based on curiosity-driven research. It involves ideas and discoveries that have the potential to radically change our understanding of scientific concepts and create new paradigms. The term, adopted in the second half of the past decade by the National Science Foundation (NSF), the leading US government funding agency for fundamental research, and by the UK's Engineering and Physical Sciences Research Council (EPSRC), is defined as research that involves creativity and high risk, as well as research that has the potential to lead to radically new technologies—along with the possibility of tremendous returns. However, to achieve these results, it must be remembered that truly revolutionary ideas often take a long time to develop, can require substantial investment, and might not yield the desired results. This is simply the nature of science.

Difficulties in understanding the limitations of science often leads to tension. In February 2016, the US House of Representatives approved a bill proposing changes to the NSF's project evaluation process. The bill, still awaiting Senate approval, requires that all research projects presented to the NSF be accompanied by a justification describing not only how the project "promotes the progress of science in the United States" but also how it might serve "national interests." "Many of the criteria mentioned for determining whether a project is in the national interest do not apply to basic science," said John Holdren, the White House Office of Science and Technology director, proposing a veto of the law if it passes. "The authors of the law are questioning whether research will increase economic competitiveness, improve health and well-being and strengthen national defense. That is the concern of applied research. Is it possible that they do not understand that basic research involves the search for scientific understanding without anticipating any particular benefit?" he asked. This type of pressure in Congress is not new to the NSF. In 2013, the agency suspended the annual selection of projects within the field of political science after Congress passed a law preventing the funding of research studies in that field if they could not be guaranteed to benefit national security or to be of economic interest. During budget negotiations, Republican Senator Tom Coburn referred to this as a "waste of federal funds on political science projects."

KNOWLEDGE AND DEVELOPMENT

Discussions of the public funding of research have existed since several countries decided to set up national science and technology research systems. These began after the end of World War II, when the application of a series of scientific developments, such as the development of radar and plastic, and the expansion of nutrition science, had a tremendous impact, thus solidifying the perception that knowledge leads to development and justifying public funding. The model establishing State support for basic and applied research was designed by American engineer Vannevar Bush. Bush headed the US Office of Scientific Research and Development (OSRD), a US government agency through which nearly all R&D efforts were carried out during the war. By government order, in 1945, Bush wrote a document entitled *Science, the endless frontier,* in which he proposed that basic research be carried out without considering its practical ends. The resulting general knowledge would provide the means to address a large number of important practical problems, even if it did not provide complete specific answers to any one of them; it would fall upon applied research to provide these solutions. "The simplest and most effective way for the government to strengthen corporate research is by supporting basic research and developing scientific talent," Bush wrote.

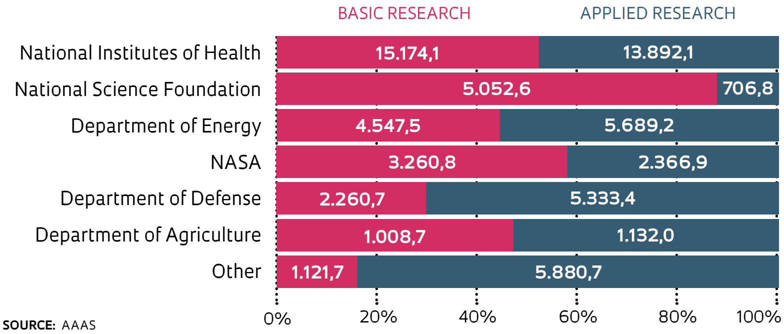
In an article published in the *Revista Brasileira de Inovação* journal, in 2014, Carlos Henrique de Brito Cruz recalls that Bush, at the time, thought the US was producing an insufficient volume of basic research, so much so that many applications developed in the US were based on fundamental knowledge discovered in European universities. The report provoked different reactions in the United States, as Brito Cruz wrote: "The *New York Times* criticized him for thinking the report proposed insufficient government in supporting research; the *Wall Street Journal* criticized him while advocating that industry could do everything that was proposed as long as it received further tax breaks via incentives. And Budget Director Harold Smith found defense of public-funded research

In 1967, California governor Ronald Reagan faced protests against his plan to cut $64 million from state university budgets; in his view, funding "intellectual curiosity" was unnecessary.

BETTMANN / GETTY IMAGES

Budget break-down

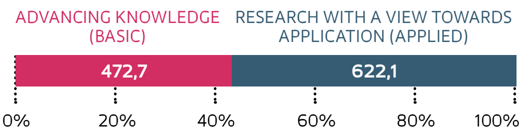
Amounts (in millions of US$) and percentages of US funding agency budgets allocated to basic and applied research in fiscal year 2015.



SOURCE: AAAS

FAPESP disbursements by funding objective in 2015, in billions of R$*

*Does not include disbursements for research infrastructure, which totaled R$93,813,340.



SOURCE: FAPESP

freedom inappropriate. He facetiously suggested that the report change its title to 'Science: the final expense'."

"Bush advocated freedom of research and investment in science as disconnected from any possible interest in its applications," says political scientist Elizabeth Balbachevsky of the School of Philosophy, Literature and Human Sciences at the University of São Paulo (FFLCH-USP). For Bush, science was an inexhaustible source of knowledge and developments that fostered innovation. Bush's Science, the endless frontier inspired the establishment of the NSF in 1950 and served as a guideline for establishing research funding agencies in several countries, including Brazil, which were interested in setting up their own systems of science and technology.

This worked relatively well into the 1970s, when the world experienced its first post-war economic crisis, which affected the major industrialized countries and consequently harmed many less-industrialized countries. Governments began seeking faster returns on public investments in science. "The growing cost of research also generated pressure on government and research funding budgets and added to their overriding interest in impact and short-term results," Brito Cruz explains. According to data from the Tufts Center for the Study of Drug Development, the cost of pre-clinical and clinical trials for new medications increased fifteenfold between 1970 and 2010— the was an increase of 145% in the past decade alone. At the same time, this was accompanied by attempts to expand and better understand the relationship between universities, industry and government. "The boom in startups that began in the 1980s made it clear to taxpayers and their representatives that the opportunity was ripe for creating wealth from knowledge at a much faster pace than ever before," says Brito Cruz.

In 1980, the Bayh-Dole Act (US legislation dealing with intellectual property resulting from federal government-funded research) was enacted. Until then, the government did not have a unified policy regarding patents. Research financing agreements signed by government agencies with research institutes, companies and non-profit organizations now began to include clauses that allowed the government to relinquish ownership of inventions. An important dimension of the new legislation consisted of expanding the categories of patentable subject matter to include knowledge and methods that were not directly associated with a given application.

The targets of funding agencies, universities and research institutions consequently became university-industry partnerships, programs that supported small business research and the licensing of intellectual property produced by researchers. The frequency of interaction between universities and industry can be measured in terms of the relative share of industry funds that are used to support research. In the United States, this percentage has fluctuated between 5% and 7% in recent years. In most of the Organization for Economic Development and Cooperation (OECD) member countries, the private sector participation in university research funding varies from 2% to 10%. One outlier is Germany, where industry funds 14% of research.

Such interactions generally benefit both industry and universities. Industry relies on universities to share the risks of research and obtains access to skilled scientists, suitable facilities and a cadre of researchers and students who can reinforce their research capacity. Universities tend to view collaboration as an opportunity to secure research funds and gain access to the challenges of science and technology that are encountered in industry. According to Carlos Américo Pacheco, a professor at Unicamp's Institute of Economics, international experience shows that producing patents at universities and licensing intellectual property to companies play an important yet complementary role in business interests. "The sources of information for technological innovation in companies come more from the chain of suppliers and customers than from universities. It is through science that companies can enable their developmental efforts, but they are guided more by market demands than by what the university has to offer," he says. Pacheco observes that the most sophisticated and efficient way to bring academia and the private sector together is to set up start-up companies. "This has strengthened certain regional clusters around universities, attracting company laboratories and investors, which then become stimulating microcosms," notes Pacheco, who served as executive secretary at the Ministry of Science and Technology from 1999 to 2002.

PASTEUR'S QUADRANT

A breakthrough in the debate on the distinction between basic and applied science came with the publication of *Pasteur's Quadrant: Basic Science and Technological Innovation* (Editora Unicamp, 2005), a book written by Princeton University political scientist Donald Stokes, who proposed a new classification. In addition to basic research studies (best exemplified by the work of the Danish physicist Niels Bohr on atomic structure and quantum physics in the first half of the 20th century) and studies of technology development (as symbolized by Thomas Edison's electric light bulb), Stokes identified another category: research that could contribute to the advancement of knowledge while offering the potential for high-impact practical use (*see the table on page 11*). Studies conducted in France by Louis Pasteur in the field of microbiology, which contributed to the advancement of knowledge and yielded economic benefits are examples of this category, in addition to inspiring the title of the book.

"Stokes showed that the Vannevar Bush model worked in the United States differently than in other countries because the US government invested huge sums in basic scientific fields but still sought to answer practical questions in the medium- and long-terms," says Balbachevsky. "It is also the case with agencies like the National Institutes of Health (NIH)—which has more resources than the NSF—and the Department of Defense." The United States has always maintained a dual system, which is both concerned with advancing knowledge and focusing on potential uses, and each funding agency allocates resources towards both avenues (*see box on page 10*). The perception that this type of investment had increased the US capacity for innovation mobilized Europe in the 1990s. "European countries had followed the Bush model in producing high-quality science but did not develop the same interface with the manufacturing sector," Balbachevsky adds. In the past two decades, we have seen an effort by Europe to create interfaces with industry. "In the European Community, practically all of today's programs are attempting to form networks in which governments

The types of impacts on science

Research conducted in Canada mapped according to 11 types of impacts generated by the production of knowledge. Information was obtained from interviews with researchers and organizations that benefit from scientific knowledge.

SCIENTIFIC IMPACT
Research, the results of which promote progress in knowledge, produces new models and theories, and develops fields and disciplines.

POLITICAL IMPACT
Effects generated by new scientific knowledge in the sphere of law, jurisprudence and ethics in formulating public policy or mobilizing citizens.

ORGANIZATIONAL IMPACT
The influence of research findings on business administration and institutions, on the organization of work, and on human resources.

TECHNOLOGICAL IMPACT
Innovations in products, services and processes and the development of technical know-how that are generated by scientific activities.

ECONOMIC IMPACT
This category refers to impacts that generate wealth, such as innovation marketing, return on investment in professional training and the development of new markets.

IMPACT ON HEALTH
This refers to the effects of research on increases in the life expectancy of people and on the prevention and treatment of diseases or on reducing healthcare costs.

CULTURAL IMPACT
Changes in the abilities and attitudes of individuals that are generated by an expanded understanding of the phenomena of nature and the use of new technologies.

IMPACT ON THE ENVIRONMENT
This impact is associated with studies that underpin biodiversity conservation and pollution management or expand the understanding of climate phenomena.

SYMBOLIC IMPACT
Companies often gain credibility by investing in R&D and associating with university researchers on joint projects.

SOCIAL IMPACT
This is related to the outcomes of research that improves well-being and quality of life for individuals or that changes society's discourse and conceptions.

EDUCATIONAL IMPACT
This refers to the creation of new curricula and teaching tools at universities and to increases in students' ability to conduct research or respond to demands from the labor market.

SOURCE: MEASURING THE IMPACTS OF SCIENCE: BEYOND THE ECONOMIC DIMENSION, BY BENOÎT GODIN AND CHRISTIAN DORÉ.

and companies come in with a portion of the funding."

In Horizon 2020, the European Union's framework program for research and development, which has a budget of €80 billion for the period between 2014 and 2020, funds are divided into three portions. One portion is earmarked for basic research, which funds curiosity-driven projects and topics that propose to focus on new technologies. The second portion is earmarked for industry research that makes funds and credit available to small-, medium- and large -sized companies, including programs whose returns are considered high-risk. Finally, the third portion is earmarked for projects that attempt to address "challenges to society" in the form of interdisciplinary topics, such as population aging, energy efficiency and food security.

The notion of societal challenges has become ubiquitous in the research budgets of many countries, according to a report published in October 2015 by a group of researchers at the Science Policy Research Unit of the University of Sussex. The report, which compared public investment in R&D by the Nordic countries (Sweden, Norway, Denmark and Finland) with some of the BRIC nations (Brazil, India and China) and the United States, showed that this last category has been emphasized in the strategies of all the surveyed nations and that investments have been made in fields such as energy, climate and health. The outlier, according to the report, is the United States, where government R&D allocations are mostly directed towards defense (53% of the total in 2013) and health (ranked second at 24.3% of the total). The study concludes that there is no standard regarding the ideal portion of investment to be dedicated to basic and applied research. The trend among Nordic countries is to spend close to 40% of public funds on basic research. In China and India, however, that proportion is much lower, approximately 20% to 25% (*see box on page 6*). The study found no consolidated data regarding the breakdown of investments in Brazil.

THE ENTREPRENEURIAL STATE

After all, should or shouldn't the government invest in research? According to Italian economist Mariana Mazzucato, a professor at the University of Sussex, the public funding of science plays a crucial role in the production of knowledge, especially when this process involves high costs and risks, which companies tend to avoid. This is one of the taglines of her book, *The Entrepreneurial State*, which states that even in highly innovative fields such as pharmaceuticals, renewable energy or information technology, the private sector only joins the game after public funding has made considerable investments in research during phases in which outcomes were completely uncertain. "In biotechnology, nanotechnology and the Internet, risk capital arrived 15 to 20 years after the most important investments had already been made using public sector funds," Mazzucato wrote. "The State is behind most technological revolutions and extended periods of growth. That is why an 'entrepreneurial State' is necessary to assume risk and create a new vision, instead of simply correcting market defects." In her talks, the author uses smartphones as an example to show that a considerable part of the technology they contain resulted from public investment by the US Department of Defense at a time when no one could have imagined theri potential reach, which later included the Internet, GPS navigational systems and touch screens.

The defense of public funding of so-called basic research has recently gained the support from a country that , in relative terms, invests the most in R&D—equivalent to 4% of its Gross Domestic Product—and which traditionally spends less than 20% of this total on basic science: South Korea. The strategy that paved the way towards its economic development, which was based on improving and lowering the cost of technologies developed by other countries, focused on basic research. In the city of Daejeon, an experiment is being carried out to detect the existence of the axion, a hypothetical elementary particle of dark matter, which makes up a substantial part of the Universe but is invisible. This project is a very high-risk initiative that symbolizes the country's ambition to become a leader in basic research. If successful, the project, which is costing the country US$7.6 million a year, could give South Korea the Nobel prize it has long dreamed of. In May 2016, South Korean President Park Geun-hye announced that she would increase basic research funding by 36%. "Basic research starts with intellectual curiosity among scientists and technicians, but it could be a source of new technologies and industries," Park said, as reported in *Nature*.

The functions of research

As defined by the National Science Foundation.

BASIC RESEARCH

Systematic study that is directed towards acquiring knowledge or a deeper understanding of fundamental aspects of observable phenomena and facts without having any specific applications in mind with respect to processes or products.

APPLIED RESEARCH

Systematic study that is conducted to obtain knowledge or the understanding needed to determine the means through which a specific and recognized need can be met.

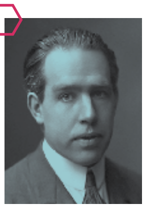
DEVELOPMENT

A systematic use of knowledge and understanding that is obtained through research that is directed towards the production of materials, devices and useful systems or methods, including the design and development of prototypes and new processes. This category excludes quality assurance, routine product testing and production.

Pasteur's Quadrant

Political scientist Donald Stokes classified research projects by proposing categories that go beyond the limits of basic and applied science and that are divided into four quadrants.

QUEST FOR FUNDAMENTAL UNDERSTANDING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NIELS BOHR (1885-1962)

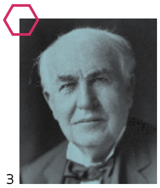
Work by the Danish physicist has contributed to our understanding of the structure of atoms and quantum physics.


2

LOUIS PASTEUR (1822-1895)

Studies by this Frenchman attempted to understand microbiological processes based on their practical impacts, such as the prevention of product deterioration.

Stokes intended this quadrant for research addressing particular facts that have no foreseeable application and that do not present general explanations about phenomena. He provided as examples the research by American ornithologist Roger Tory Peterson, author of the Field Guide to the Birds of Eastern and Central North America.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THOMAS EDISON (1847-1931)

This US inventor and businessman filed more than 2,000 patents. Among other things, he invented the phonograph and the electric light bulb.

CONSIDERATION OF USE

Even while achieving consensus with regard to the government's need to invest in research because of the tangible and intangible fruits it yields, discussion remains about how to distribute the available resources in order to achieve society's expectations in the short and long term. The questions posed to politicians and those who manage the public system of science and technology consist of determining how much should be allocated to each research category and their degree of interference when allocating said funds and in determining what scientists should be researching. The search for a balance is important so that public research institutions can obtain high-impact results for society while also producing a consistent stock of basic knowledge. When everyone moves to one side of the boat, it ends up sinking, said Francis Collins, NIH director, while defending the importance of preserving that agency's expenditures in basic research in a 2012 article in the journal *Science*. However, it is also up to the researchers to keep society informed about what they are doing and on the impact that the knowledge that they produce is having, as Collins stated in an editorial published in *Nature* in late July 2016, celebrating the results of a European Research Council pilot study that funded 199 basic research studies. The study showed that three fourths of the projects generated significant scientific advances, and at least one quarter had an impact on the economy or society or on the formulation of policies.

The usefulness of the notion of "useful knowledge" can be summarized by the conversation between US educator Abraham Flexner, founder of the Institute for Advanced Study at Princeton University, and businessman George Eastman, who popularized the use of roll film in photography, as related in an article published by Flexner in *Harpers* magazine in 1939 (library.ias.edu/files/UsefulnessHarpers.pdf). Eastman was considering dedicating his vast fortune to promoting education on useful topics. Flexner asked the businessman who he considered to be the "most useful worker in science in the world." He promptly heard in response, Guglielmo Marconi, the Italian inventor of the radio. Flexner then surprised his listener by stating that, aside from the usefulness of the radio, the Italian's contribution to science was practically negligible. He explained that Marconi would not have accomplished anything were it not for the contributions of Scottish scientist James Clerk Maxwell, whose abstract equations drove investigations in the field of magnetism and electricity, and German physicist Heinrich Hertz, who later demonstrated the existence of electromagnetic waves. "Neither Maxwell nor Hertz had any concern about the utility of their work; no such thought ever entered their minds. They had no practical objective. Obviously, the inventor, in the legal sense, was Marconi, but what did Marconi invent? Merely the last technical detail, the now obsolete receiving device called a coherer, almost universally discarded," said Flexner. Hertz and Maxwell invented nothing, but it was their apparently "useless theoretical work" that was seized upon by a clever technician to create new means of communication, utility and amusement, the educator wrote. "Who were the fundamentally useful men? Not Marconi, but Clerk Maxwell and Heinrich Hertz. Hertz and Maxwell were geniuses without thought of use. Marconi was a clever inventor with no thought but use." ■

References

BRITO CRUZ, C. H. "University research comes in many shapes", p. 131-42 in University priorities and constraints, Weber, Luc E. and Duderstadt, James J. (eds.). **Glion Colloquium Series**. No. 9 (Economica London, Paris, Geneva, 2016).

MAZZUCATO, M. The Entrepreneurial State. São Paulo: Companhia das Letras, 2014.

BUSH, V. Science: The endless frontier. Reproduced in **Revista Brasileira de Inovação**. V. 13, No.. 2 July/Dec. 2014.

PHOTOS 1 AB LAGRELIUS & WESTPHAL 2 FÉLIX NADAR 3 LOUIS BACHRACH