for example, how physicians will use genetic data for diagnosis and treatment, and whether individuals will welcome or fear knowledge of what their genomes hold for the future.

Such social change will follow, I believe, when useful applications of genomic information become available. They might tell us how to alter our lifestyles to improve our health, or distinguish which drugs will be of benefit or have serious side effects, or may guide the development of new drugs. But this will take time. We are only at the beginning of interpreting the sequence and understanding what variants mean for the individual.

Drawing the Map of Life is one of many books that have been written about the HGP. The volume does not add much to earlier descriptions of the project's genesis, such as *Genome* by Jerry Bishop and Michael Waldholz (Simon and Schuster, 1990) and *The Gene Wars* by Robert Cook-Deegan (W. W. Norton, 1994). In *Cracking the Genome* (Free Press, 2001), Kevin Davies brought us up to the completion of the draft sequences. More recently, protagonists John Sulston and Venter have told their contrasting personal stories, while James Shreeve has written a detailed study of Venter's contributions.

All of these books are valuable; what is now needed is a scholarly history of the HGP. *Drawing the Map of Life* is not that book, but it offers an enjoyable account of the project from origin to conclusion and beyond. ■

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In Retrospect: *Science — The Endless Frontier*

Vannevar Bush's pivotal report that marked the beginning of modern science policy catapulted the phrase 'basic research' into popular usage, explains **Roger Pielke Jr**.

Science — The Endless Frontier. A Report to the President on a Program for Postwar Scientific Research
by Vannevar Bush
National Science Foundation: 1960 (reprint). First published 1945.


H. WALKER/TIME LIFE PICTURES/GETTY

Engineer Vannevar Bush's proposals led to the creation of the National Science Foundation in 1950.

The US government's landmark report *Science — The Endless Frontier* was published 65 years ago last month. Commissioned by President Franklin D. Roosevelt and prepared by electrical engineer Vannevar Bush, who directed US government research during the Second World War, the document distilled the lessons of wartime into proposals for subsequent federal support of science. Although its bold recommendations were only partly implemented, the document is ripe for reappraisal today: it marked the beginning of modern science policy.

Bush's report called for a centralized approach to government-sponsored science, largely shielded from political accountability. The creation of the National Science Foundation in 1950, a small agency with a limited mandate, was far from the sweeping reform set out in the 30-page report and its appendices. However, its publication ushered in a new era in which science was viewed as vital for progress towards national goals in health, defence and the economy. Government funding for research and development consequently increased by more than a factor of ten from the 1940s to the 1960s.

The influence of *Science —The Endless Frontier* stems largely from its timing, coming at the tail end of a war in which science-based technology had been crucial. The development of the atomic bomb, radar and penicillin meant that Bush's declaration that "scientific progress is essential" to public welfare found a receptive audience. Bush also adopted innovative language that capitalized on this new-found government credulity.

In particular, he broadened the meaning of the phrase 'basic research'. In using it to refer simultaneously to the demands of policy-makers for practical innovation and to the interests of scientists in curiosity-driven enquiry, he satisfied both sectors.

Before the report, pleas by scientists to expand government support for research had met with only limited success. Prominent calls along similar lines were made to no avail in 1924 by the UK National Union of Scientific Workers (NUSW) and in 1929 by US agriculture secretary Arthur Hyde. The poor response might have been due to the confused messages offered to protect the integrity of pure research. In a 1921 essay, for example, the NUSW president declared that scientific research has "no industrial bearing at all" but later stated that it is "the foundation of progress in industry". Not surprisingly, most policy-makers shrugged.

Some political leaders did champion government support for basic research before 1945. Prior to Hyde's appointment, US agriculture secretary Henry C. Wallace had argued in

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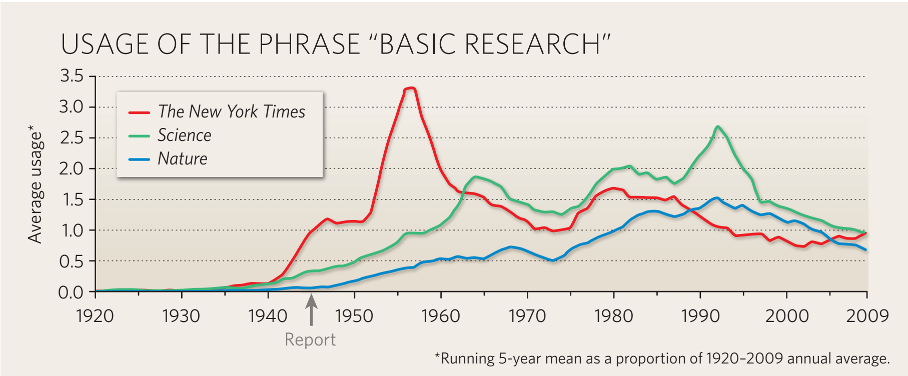

The fluid meaning of "basic research" galvanized science-policy discussions in the mid-twentieth century.

the early 1920s (one of the first narrow uses of the phrase) that the agency should fund more "basic research" to enhance agricultural productivity. At the time, Wallace's call for investment was counter-intuitive because US agriculture was suffering from being too efficient; a surfeit of production depressed prices and caused hardship for farmers. But he reasoned presciently that consumption would catch up in the longer term. Wallace did not live to see his vision realized, but his son, Henry A. Wallace, picked up the baton, first as agriculture secretary under Roosevelt (1933–40) and then as Roosevelt's vice-president (1941–45). During the war, the younger Wallace served as liaison between Roosevelt and Bush.

Bush was selected by his friend and neighbour Vice-President Wallace to draft *Science — The Endless Frontier*. As director of the Office of Scientific Research and Development, Bush had credibility and good connections within both the science and policy camps. This meant that when the report was released — less than two weeks before the Hiroshima atomic bomb was detonated — it was well positioned to influence. When Wallace's political fortunes fell, leadership in science policy completed its switch from the agriculturists to the physicists, and the language of science policy changed too.

With its inherent inscrutability, Bush's 'basic' research descriptor helped to secure a pragmatic compromise between scientists and politicians. The concepts of 'pure' and 'fundamental' research had long presented a narrow view of science in terms of benefits only to scientists. By contrast, basic research could be carried out for curiosity's sake — satisfying scientists — and could meet national needs, pleasing the politicians. Bush later recalled how the phrase made it easy to convey that "work that had been regarded by many as interesting but hardly of real impact on a practical existence, had been basic to the production of a bomb that had ended a war."

The publication of *Science — The Endless Frontier* entrenched the concept of government patronage of scientific research in policy discourse. The setting up of the National Science Foundation and countless other policy reports cemented it. "Institutions and statistics are what gave stability to the fuzzy concept of basic research," wrote science-policy scholar Benoît Godin in 2000. The speed with which science and society discussions were reframed is demonstrated by usage of the phrase in *The New York Times*, which rose rapidly from 4 mentions in 1944 to a peak of 159 mentions in 1957 (see 'Usage of the phrase "basic research"').

In recent decades, science policy has shifted its focus towards conferring measurable benefits to society. The fuzzy concept of basic research no longer seems to fit — nebulous descriptions of benefit are insufficient in today's competitive environment for public funds. Consequently, use of the phrase has declined since the early 1990s, as indicated by mentions in *Science* and *Nature* (see 'Usage of the phrase "basic research"'). Other terms, such as 'transformative research', have sprung up to fill the gap; even 'fundamental research' has made an ironic return. And science policy itself has been renamed by scholars of science studies: as collaborative assurance, socially robust science, use-inspired basic research and other monikers that have meanings largely known only to that community.

Words alone cannot bridge the gap between the different interests of scientists and politicians in pursuing research: governments demand relevance; scientists desire freedom. The so-far futile search for a language that is relevant today both reflects and reinforces the unsettled nature of science policy. In the six decades since *Science — The Endless Frontier* was written, research and policy have been transformed. Our framework for discussing both needs to catch up. ■

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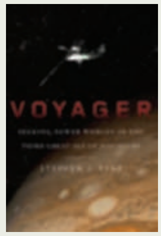
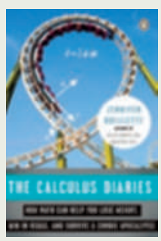
BOOKS IN BRIEF



Launched in 1977, the twin Voyager probes are true explorers. Among the earliest spacecraft to visit the neighbourhoods of Jupiter and Saturn, they will soon exit the Solar System and witness interstellar space. Environmental historian Stephen Pyne sets these missions within the wider arc of human exploration in *Voyager* (Viking, 2010). He examines the origins of the planetary exploration programme in cold war politics, and looks to modern frontiers of discovery, such as journeys to the ocean floor or beneath Antarctica's ice sheets.

Pythagoras held that the Universe is rational, and that there is order and unity to all things. In *Pythagoras* (Icon, 2010), science writer Kitty Ferguson pieces together the life story of the ancient Greek philosopher and his followers. She asks how his interest in mathematics arose and how his convictions developed. She unravels how Pythagoras's influence has spread across the ages, to underpin the work of great scientists such as Nicolaus Copernicus, Johannes Kepler and Isaac Newton, together with modern figures such as Stephen Hawking.



Mathematics fills some people with fear. In *The Calculus Diaries* (Penguin, 2010), science writer Jennifer Ouellette makes maths palatable using a mix of humour, anecdote and enticing facts. She describes how she overcame her own phobia of numbers and how maths forms the basis of modern life. Using everyday examples, such as petrol mileage and fairground rides, Ouellette makes even complex ideas such as calculus and probability appealing.