INNOVATION

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Diversity Should Power Science

More Money Is Not the Only Answer

By Scott Page

WHETHER PUT FORTH by Vannevar Bush, one of the godfathers of the military-industrial complex, or Richard C. Atkinson, the long-serving head of the National Science Foundation, the case for the funding of basic science remains largely the same *even after 50 years*—investment in basic research produces the knowledge that drives innovation and, in turn, human progress.

The sources and causes of innovation remain mysterious (and will always be so), which in turn requires new thinking about how best to finance innovation. This faith in government funding of basic research rests (first of all) on the proven shortcomings of profit-driven science. The demands of the marketplace obviously create incentives to explore many scientific pursuits, most often practical problems such as how to build faster computer chips, safer allergy medications, and more fuel-efficient cars. One fact should be obvious, businesses won't set out to make the world a better place unless they can make money at it.

That leaves many fundamental questions related to the causes of disease, the forces that create an affluent society, and the maintenance of the earth's ecosystems in need of funding from governments. Finding solutions to existing problems is reason enough to support science research, yet government investment in basic science also encourages unguided exploration, which can result in solutions in search of problems, such as the laser. As odd as this sounds, science often finds answers to problems we didn't even know we had.

So why would I argue that the current science funding model is clearly inadequate to the needs of scientific inquiry? Why is this model antiquated? Because the sources and causes of innovation

remain mysterious (and will always be so), which in turn requires new thinking about how best to finance innovation.

SOURCES OF INNOVATION

Innovation, in economic terms, resides inside the heads of people. People possess different ways of seeing problems and solutions—oftentimes different perspectives depending on the kinds of people viewing particular problems and solutions. People's perspectives are accompanied by ways of searching for solutions to problems, something scientists call heuristics. When confronted with a problem, people encode their (often quite different) perspectives and then apply their particular heuristics to locate new, possibly better, solutions.

Individuals who perform best obviously possess good perspectives and heuristics (think Thomas Edison and his multiplicity of inventions), yet 30 copies of Edison working as a team may be no better than one. In contrast, a diverse team of individual innovators may on average know fewer heuristics each but collectively know more. When a diverse team applies those diverse heuristics, the effects can be superadditive. James Watson plus Francis Crick were far more impressive than either working alone.

On a far larger scale, one reason for Silicon Valley's success is surely its abundance of bright engineers from different academic disciplines and from almost every corner of the globe. Collectively, they out-innovate other technology hotspots with equal brainpower but less diversity.

Government funding of science must take this diversity calculation into account when allocating budgets. Government spending on science today is in effect a giant hedge fund. Despite the huge potential payoffs, this hedge fund won't emerge from the private sector because too often the payoffs aren't appropriable. The Naismith family made little from the invention of basketball, for example, but the world gained immeasurably.

As with any hedge fund, effective government funding of science requires that lots of money gets tossed around. Some investments will yield little, while others will produce enormous dividends. This "portfolio" metaphor for scientific funding leads to an intuition that diversity has value—that basic scientific research should be allocated to diverse research projects. And that intuition is correct—diversity does provide portfolio insurance—yet the value of diversity goes far beyond mere portfolio effects. Diversity can produce superadditive effects.

A breakthrough in one domain can be combined with a breakthrough in another to produce even deeper knowledge. Research on disease transmission by epidemiologists helps us understand the spread of disease. Research by computational social scientists on how to construct large-scale simulations of societies helps us understand how markets work and how economies collapse. When we combine just these two breakthroughs, we're able to construct a third, in the form of high fidelity computational models of disease spread that enable us to learn when and how to intervene.

In short, the mathematics of innovation shows that one plus one often equals three.

DEVELOPING SCIENTIFIC DIVERSITY

The government can encourage scientific diversity in four ways. First, they can encourage interdisciplinary research through programs such as the National Science Foundation's Integrated Graduate Education Research Traineeship initiative, or IGERT, which funds Ph.D. students in novel, interdisciplinary programs. The diversity of study of the IGERT program breaks through the current incentive structures of the modern academy, which reward progress within disciplines. Well-placed (and sufficiently large) IGERT carrots can provide incentives for scholars to step out of the comfort of their home departments to work with interdisciplinary teams.

Second, the government can continue to support scholars from underrepresented groups. Fewer

than two in 100 Ph.D.'s in physics are African American, and fewer than two in 10 are women. Yet, we know from biology, psychology, and economics that the inclusion of women and minorities not only changes the questions being asked within a discipline, but also changes how those questions are answered.

Third, funding must loosen up, and not just the purse strings. Government grants, be they from the National Science Foundation or the National Institutes of Health, often require perfect scores from multiple referees. This tends to bias awards in favor of safer, more conservative grants. Fear of failure, which is unavoidable given that future prospects depend on past successes, exacerbates the tendency toward more mainstream research. Innovation won't be produced by tinkering on the margins of existing approaches.

Aiming big implies failure. That's okay. In its golden era of innovation, Bell Labs demanded a certain failure rate. Too much success signified a lack of experimentation. Breakthroughs in science come from someone seeing a problem in a new way. Government needs to fund the space, resources, and opportunity for scientists to step outside of their usual boxes and fail. That's impossible if grant renewals require success at every step.

Fourth, the government can make commitments to big problems—finding a clean source of energy, colonizing Mars, curing cancer, eradicating poverty and disease. Big problems create diversity by shifting attention away from techniques and toward solutions. Thus, they spawn multiple approaches.

Big problems almost always unpack into lots of smaller problems, each of which requires diverse ways of thinking. And big problems, such as the space program, make science focal and fun, encouraging more people, and more diverse people, to choose science as a career.

INNOVATION FOR THE COMMON GOOD

Many of the problems we face today are complex. They consist of diverse, dynamically interconnected parts. Certainly climate change, epidemics, terrorism, and poverty fit into that category.

Other problems are just plain difficult: finding a workable form of fusion, understanding protein folding, and curing diseases. We won't solve these problems, the difficult or the complex ones, with current modest levels of funding for well-established routes of inquiry. We need more funding and more ways of thinking.

The aim of governmental scientific funding is the production of innovation that improves the lives of everyone, and the seeds of innovation lie in seeing problems in new ways. The funding of science should reflect that by rewarding diverse thinkers, funding interdisciplinary research, broadening the pool of scholars, and focusing attention on big problems. sp

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Scott E. Page is Professor of Complex Systems, Political Science, and Economics at the University of Michigan and external faculty at the Santa Fe Institute. He is author of The Difference: How the Power of Diversity Creates Better Groups, Teams, Schools, and Societies.