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THE ECONOMICS OF SCIENCE
FUNDING FOR RESEARCH

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The Economics of Science

Funding for Research

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Abstract
Scientific research has properties of a public good; there are few monetary incentives for individuals to undertake basic research and the conventional wisdom is that the market, if left to its own devices, would under-invest in research in terms of social benefits relative to social costs. Thus research, especially of a basic nature, has traditionally been supported by either the government or philanthropic institutions. More recently, industry has also begun to support research conducted in nonprofit institutions. This paper explores the various sources of support for research in the university sector. Although the focus is on the United States, the paper discusses trends in other countries as well. The paper also examines mechanisms for distributing funds, including peer review and performance based distribution. The paper closes with a case study of the National Institutes of Health doubling during the period 1998-2002.

This paper is based on work for a book Stephan is currently writing, tentatively titled *The Economics of Science*, which is under contract at Harvard University Press. The material is presented here with the permission of Harvard University Press. The author thanks William Amis and Aldo Geuna for helpful comments.

Introduction:

Stanford University receives approximately $720 million a year in support of research[1]; the University of Virginia about $300 million; Northwestern University about $379 million[2] In the case of Stanford, this represents 23% of university revenues; it represents 24%[3] for Virginia and 25% for Northwestern. Where does the money come from? What criteria are used for allocating it? And why does a country agree to spend approximately .35% of its GDP in support of university research?

Why support university research?

Scientific research has properties of what economists call a public good. Research findings are not used up when shared and others cannot easily be excluded from using the results once they are made public (see Chapter 2). As noted in the earlier discussion, the market is not well suited for producing goods with such characteristics. Unlike the baker, whose customers must pay if they wish to eat his cake, or the symphony orchestra which can sell tickets to its concerts, the researcher has nothing to sell once her research has been made public and thus has no means of appropriating the benefits. It is particularly difficult to appropriate the benefits of basic research, which at best is years away from contributing to products the market may or may not value as well as to other fundamental upstream research. Thus, there are few monetary incentives for individuals to undertake basic research and the conventional wisdom is that the market, if left to its own devices, would under-invest in research in terms of social benefits relative to social costs.

Society, however, is more ingenious than the market (to use a phrase of Kenneth Arrow's), and the priority system has evolved in science to create a reward system that encourages the production and sharing of knowledge. Scientists, as discussed in Chapter 2, are motivated to do research by a desire to establish priority of discovery. To do so, they must share their findings with others because the only way to make the research their own, and thereby establish priority of discovery, is to give it away by publicly sharing it. Thus priority addresses the appropriability problem.[4]

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[1] The figure is for 2007/2008 and excludes funds for SLAC but includes indirect costs. See http://www.stanford.edu/dept/pres-provost/budget/plans/BudgetBookFY08.pdf.

[2] Figures are for FY 2008. See http://www.northwestern.edu/budget/documents/PDF.pdf.

[3] Data are for 2008-2009.
http://www.virginia.edu/budget/Docs/2008-2009%20Budget%20Summary%20All%20Divisions.pdf

[4] Priority is not the only way to address the appropriability problem. Patents have long provided an alternative route: in exchange for public disclosure of an idea the inventor is awarded a monopoly for a period of years. However, patents are generally not suitable for basic research; moreover the cost of taking out a patent ($30,000 or more) discourages their use.

Priority, of course, does not insure that efficient outcomes will be forthcoming or that society will strike the right balance in the production of knowledge. At least two additional factors encourage underinvestment and inefficient outcomes with regard to research. First, the uncertain nature of research discourages scientists from following certain risky lines of research with the potential of a high payoff. Second, as Chapter 5 demonstrates, research costs money. Priority may provide the incentive to do research, but it does not provide the where-with-all to do it.

Thus research, especially of a basic nature, has traditionally been supported by either the government or philanthropic institutions.[5] The government's rationale for supporting scientific research also rests on the importance of research and development to specific outcomes deemed socially desirable and not directly provided by the market, such as national defense and better health. It also rests on the desire to win the "Scientific Olympics."[6]

The relationship between research and economic growth provides another reason for government support of science and has been a particular rallying cry for more resources in recent years. In the summer of 2006, for example, the state of Texas decided to invest $2.5 billion in science teaching and research in the University of Texas system. A primary focus of the initiative is to build up the research capacity at campuses in San Antonio, El Paso and Arlington in an attempt to turn these cities into the next Austin, Texas, if not the next Silicon Valley. The National Academy of Science report, *Rising Above The Gathering Storm*, received considerable attention when it was issued the same year. The message: the U.S.'s competitive position in the world has begun to erode and will continue to decline unless more U.S. citizens are recruited into careers in science and engineering and the U.S. steps ups its investment in research.

This chapter examines sources and mechanisms for supporting research conducted in the public sector, especially at universities. The focus is primarily on the United States, although trends in other countries are briefly mentioned. The chapter begins with an overview of sources of funds and then focuses on mechanisms for the distribution of the funds. It continues with a discussion of the benefits vs. the costs of different mechanisms and concludes with a case study of funding for biomedical research in the United States.

Several themes emerge from the discussion. One is the tendency of most systems of support to experience stop and go periods. This has efficiency implications; it can also have considerable implications for careers. Scientists who have the bad fortune to enter the labor market during a "stop" period can feel the adverse effects for years. Another theme is the loss of efficiency that accompanies various mechanisms for funding science. By way of example, an investigator-initiated mechanism provides maximum freedom of intellectual inquiry and consequently may

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[5] A different type of logic explains why basic research is more likely to occur in the university, non-profit sector. See the discussion of P. Aghion, M Dewatripont, and J. Stein, "Academic Freedom, Private-sector Focus, and the Process of Innovation." *Rand Journal of Economics*, 39(3):617-635 in Chapter 1.

[6] Harry G. Johnson, 1972. Some Economic Aspects of Science. *Minerva* 10:10-18.

have the greatest intellectual pay-off. But it also comes at considerable cost. It requires time both on the proposing and reviewing end. It may also discourage risk taking. There is also the question of whether the national research portfolio is well balanced. This has been a particularly egregious issue in recent years in the U.S, when the Congress has found it considerably easier to vote to fund health research than to fund research in the physical and engineering sciences.

Sources of Funds

Federal funding

U.S. universities in 2008 spent almost $52 billion on research (in 2008 dollars). The largest contributor to research by far was the federal government (60.2%), followed by universities themselves (20.1%). Considerably less came from state and local governments (6.6%), industry (5.5%) and other sources (7.6%) such as private foundations.[7]

The composition and amount of funding for university research has changed considerably during the past 55 years, as can readily be seen in Figure 6.1.[8] Several trends emerge. First, the amount contributed by the federal government has gone through considerable fits and starts beginning in the mid-1950s. Prior to Sputnik, the Federal government, in 2008 dollars, was spending less than a billion a year on university research and contributing about 55% of the amount spent at universities and colleges on research. The role of the Federal government changed dramatically in response to the launch of Sputnik: in constant dollars, the amount the federal government spent on research at colleges and universities grew by a factor of 6 from 1955 to 1967. The proportion of funds coming from the federal government also dramatically increased, going from 56% to 73%. Funding for research was sufficiently plentiful to lead scientists to parody a well-known advertisement at the time for Grant's whisky: "While you're up (in Washington) get me a grant!"

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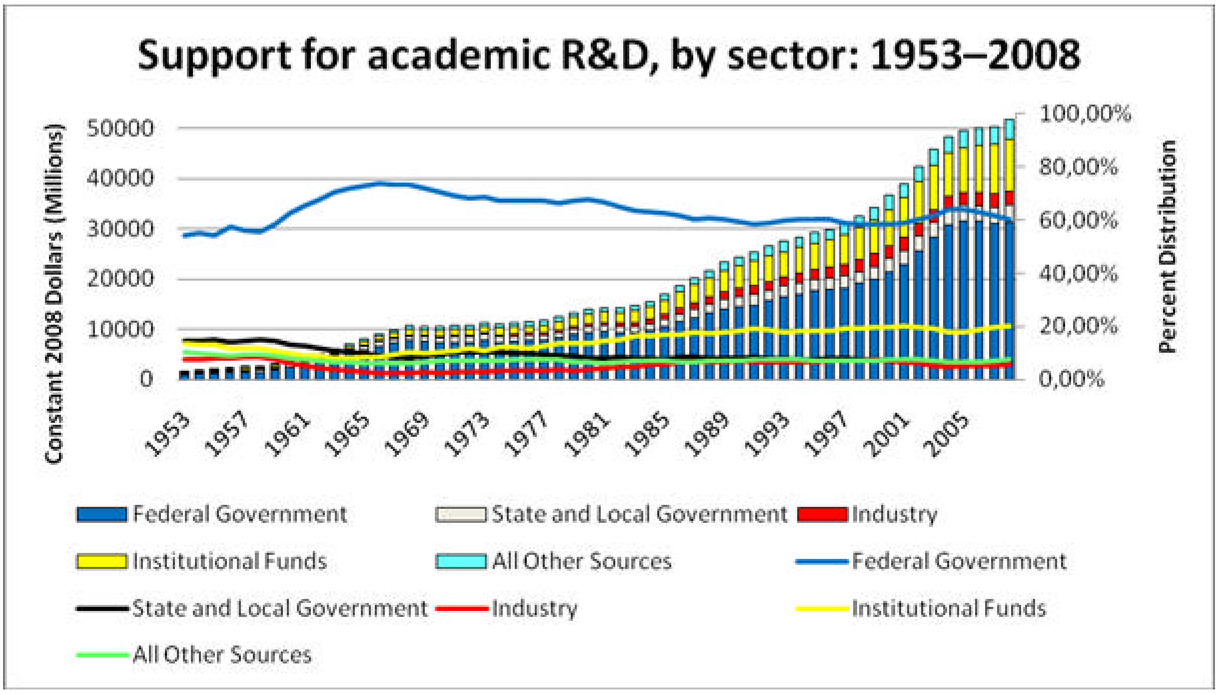
[7] http://www.nsf.gov/statistics/infbrief/nsf09318/?org=NSF#fig1.

[8] http://www.aaas.org/spp/rd/guiuniv.htm. 2008 data come from http://www.nsf.gov/statistics/infbrief/nsf09318/?org=NSF#fig1

Figure
6.1



The increase had profound effects on the practice of science at U.S. universities. Universities expanded and new universities were created. Not only were there more federal funds for research: the coming of age of baby boomers meant that increasing numbers of students headed to college. To meet the rising college enrollments and research demands, new universities were established, programs added, and faculties greatly expanded. Thus, for example, between the late 1950s and the early 1970's, the number of doctorate-granting institutions in the U.S. grew from 171 to 307. Over the same period, the number of doctoral programs in physics went from 112 to 194, the number in the earth sciences more than doubled, going from 59 to 121; and in the life sciences the increase was from 122 to 224.[9]

The Vietnam War brought the nation's love affair with science to a halt. The amount the federal government spent in real dollars on university research declined and remained stagnant until the late 1970s. University jobs, which had been plentiful in the late 1950s and most of the 1960s, became scarce; the percent that the federal government contributed to university research fell from 73% to approximately 66%. The roller coaster continued in the late 1970s and 1980s: dramatic increases followed by declines in real funding during the recession of the early 1980s,

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[9] Paula Stephan and Sharon Levin, 1992, *Striking the Mother Lode in Science: The Importance of Age, Place and Time*, Oxford University Press, New York, p. 95.

followed by increases. The fits and starts dissipated considerably during the next fifteen years, as federal contributions to university research continued to increase. Despite this increase, the federal share of university R&D continued to decline, and beginning in 1988, hovered around 60%. [10]

This all changed in 1998 with the commitment to double the NIH budget in a period of five years. The federal government's contribution to university research grew dramatically in the next five years, going from $17.7 billion to $26.9 (constant 2008 dollars)[11]; the federal share increased from 60% to over 64%. While many had assumed that the doubling would be followed by a period of "normal growth" in NIH's budget, such was not to be the case. The years after the doubling were followed by real decreases in the amount of funds allocated for NIH as well as to several other federal agencies that support university research. The federal contribution to university research, until the 2009 stimulus package arrived, remained flat.

The start button was pushed again with the passage of the American Recovery and Reinvestment Act of 2009, which provided $21 billion for science and engineering research and infrastructure support, much of which was targeted for universities. The act was revolutionary in the sense that it was the first time that funding for research had been specifically provided as a countercyclical measure. Moreover, heretofore, research funding had been pro-cyclical. Witness the substantial declines in federal funding for university research during the recessions of 1973 and 1981.[12]

The majority of stimulus funds were directed to individual research projects. Some of the stimulus funds, however, were used to support large-scale projects put on hold the previous year when the funding stream slowed down. The stimulus package, for example, added $400 million to NSF's major facilities account, which supports such large scale projects as telescopes and supercomputers. NSF chose to use the funds to support the Alaska Region Research Vessel, the Advanced Technology Solar Telescope and the Ocean Observatories Initiative.[13] While the scientific community welcomed the increase, they almost immediately began to wring their hands over what would happen when the stimulus money disappeared and funding went back to its pre-2009 level.

Support from Industry

The ups and downs in federal funding have led universities to seek alternative sources for funding research. One such source is industry. It is not uncommon for faculty to receive funding from industry for specific products or for the further development of proofs of concept licensed by the firm. For example, Philip Leder's research which developed the genetically

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[10] National Science Board, Science and Engineering Indicators 2000, Appendix, Table 6.

[11] http://www.aaas.org/spp/rd/fduniv05t.pdf

[12] The exception is the recession of 2001. Because of the commitment to double the NIH budget, federal funds for university research continued to grow.

[13] Jeffrey Mervis, "The Money to Meet the President's Priorities," *Science*, 29 May 2009, vol. 324, pp. 1128-1129.

modified oncomouse as a model for studying cancer was supported by a grant from DuPont. He is not alone. By the mid-1990s more than 25% of life-science faculty reported receiving support from industry through grants and contracts.[14]

Sometimes faculty-industry research arrangements come with strings attached, as was the case in Leder's agreement with DuPont which allowed DuPont to have an exclusive license on the ensuing mouse that he invented and Harvard patented. Sometimes agreements require company review of research findings prior to publication. But sometimes there are no obvious strings. The $200,000 in research funds that Magdalena Balazinska, at the University of Washington, gets from Microsoft Research are a case in point. According to Balazinska, "Microsoft never tried to "control what we do nor [did they] expect us to do something specific."[15]

The importance of industrial support for university research grew during the 1980s and 1990s. There were several contributing factors. First, growth in university patenting and licensing (see Chapter 3) meant that faculty had more opportunities to work with industry. Second, the increasing number of freshly-minted PhD students who went to work in industry provided growing opportunities for faculty to work with colleagues in industry. Third, faculty became increasingly involved with industry as a result of faculty start-ups, a number of which are noted in Chapter 3.

Finally, in an effort to find alternative sources of funding, universities aggressively sought out research alliances with industry. Examples include Monsanto's research alliance with Washington University School of Medicine, established in 1982 and MIT's 1997 collaborative agreement with Merck. In the case of Washington University, the alliance initially provided $6 million in research funds for faculty to engage in "exploratory and specialty" research. In exchange, the university agreed to a 30-day publishing delay while Monsanto patent attorneys reviewed research.[16] Merck's 1997 collaborative agreement with MIT provided for up to $15 million in funding over a five-year period. In exchange, Merck received certain patent and license rights to developments resulting from the collaboration.[17]

By far the most controversial of these agreements was struck between the Department of Plant and Microbial Biology at Berkeley and Novartis in 1998. In exchange for up to $25 million in

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[14] Elisabeth Pain, "Playing Well with Industry." *Science*, 14 March 2008, Vol. 319, 1548-1551. The 25% comes from a survey done by Eric Campbell in 1995 and is discussed by Pain.

[15] Elisabeth Pain, "Playing Well with Industry." *Science*, 14 March 2008, Vol. 319, 1548-1551. Even if there are no specific strings attached, it can be in the researcher's own self interest to please the company that supports the research and develop the relationship. Frank Dellaert, a faculty member at the Georgia Institute of Technology in Atlanta, who also receives support from Microsoft, reports that "it is in my own self-interest to use the money [as proposed] to build that relationship up." p. 1549 of cited article.

[16] See Steve Olson, Biotechnology: An Industry Comes of Age, National Academy of Science, 1986.

[17] Merck, MIT announces collaboration, Kenneth D. Campbell, March 19, 1997. http://web.mit.edu/newsoffice/1997/merck-0319.html

research support over a five year period and access to Novartis' gene-sequencing technology and DNA database on plant genomics, Novartis was given first rights to negotiate licenses to patents on a proportion of the discoveries made in the department. The agreement was highly controversial. While industrial grants to individual researchers or research teams had occurred in the past, as well as strategic alliances with universities, this was the first time that an entire department had been funded by one firm and gave "the impression that the whole department has been bought—that the university is a captive of the funding agency."[18]

Industrial support for university research in the U.S. reached its peak in the late 1990s when industry contributed approximately 7.4% of all university research funding.[19] Since then, the proportion of university research supported by industry has declined and the amount, in constant dollar terms has remained fairly flat—a victim of the 2001 recession as well as the large number of corporate mergers in the new century, which resulted in the consolidation of R&D efforts among companies that merged.[20] Any chance for a revival in funding in the short run was snuffed out by the financial meltdown of 2008.

Non-profit foundations

Non-profit foundations are another source of funds for university research. Indeed, long before either the federal government or industry became a ready source of funds for university research, the Rockefeller Foundation and the Gugenheim Foundation were funding scientific research. The Sarah Mellon Scaife Foundation provided the funds to renovate Jonas Salk's laboratory when he moved to the University of Pittsburg in 1948 and the National Institute of Infantile Paralysis supported his research.[21] Although the federal government does not track funding from non-profit foundations as a separate category, funding from non-profits represents the largest component of the "other source" shown in Figure 6.1. The figure suggests that the amount of support coming to universities from non-profits has increased in recent years.

Some non-profit foundations support a wide-range of initiatives, research (including university research), being but one of them. Currently the largest of these is the Bill and Melinda Gates Foundation. Its net worth, which was over $29 billion in 2006, was significantly increased that

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[18] Lawrence Busch, University Distinguished Professor of Sociology at Michigan State University and principal investigator in a study commissioned by the faculty senate at UC Berkeley to examine the relationship. See "MSU group reviews Berkeley venture into brave new science funding world.", August 02, 2004, Michigan State University. http://news.msu.edu/story/413/

[19] In the early 1950s industry support reached 8.5% at a time when federal support for university research was minimal. Since then, industrial support for university research has been between 2.5 to 7.4 percent.

[20] The "greedy" attitude of universities may also be contributing to the decline. In an effort to increase licensing revenues, universities have become more aggressive in protecting intellectual property arising from industry-funded projects, and negotiations between firms and universities have become more difficult. "Even if we come in with the ideas and the money, we are expected to pay a licensing fee for the product of research that we already paid for," says Stanley Williams, a computer scientist at Hewlett-Packard Laboratories in Palo Alto, California. "Then we get into a negotiating dance that can take 2 years, by which time the idea is no longer viable." *Science*, vol. 312, 5 May 2006, "Industry Shrinks Academic Support," Yudhijit Bhattacharjee, p. 671.

[21] http://www.bookrags.com/research/jonas-edward-salk-scit-071234/

year when Warren Buffet signed a letter of intent pledging $31 billion to the foundation in Berkshire Hathaway shares.[22]

Many non-profit foundations focus on a specific area, such as global warming, or, as in the above case, infantile paralysis. Other examples that readily come to mind are the Cystic Fibrosis Foundation, the American Cancer Foundation, the American Heart Association and the Ellison Medical Foundation, (with its focus on aging).[23] In addition to creating public awareness for their cause and lobbying Congress for funds, such foundations also support university research. Some non-profits have a quite narrow focus, such as the Kirsch Foundation, which currently is focused almost exclusively on finding a treatment for Waldenström macroglobulinemia (WM), which affects about 1500 people a year in the U.S.

There are even foundations that are devoted to establishing a new area or field. The Whitaker Foundation, for example, devoted its entire resources to transforming biomedical engineering from a barely recognized discipline into a firmly established field. During its 30 years of existence the Foundation gave away more than $800 million to help create departments of bioengineering at universities, and provide support for graduate student training and faculty research.[24]

Although it is difficult to find an exact accounting, casual empiricism suggests that target-specific foundations have been on the rise in recent years, as a growing population of individuals find themselves in possession of great wealth and either face a health threat or have a loved one who does. Examples include the Prostate Cancer Foundation, funded by Michael Milken after he was diagnosed with prostate cancer, the Michael J. Fox Foundation for Parkinson's Research, established by the actor after he was diagnosed with Parkinson's disease, and the Kirsch Foundation, which changed its focus from social issues to WM after its co-founder Stephen Kirsch was diagnosed with WM.[25]

Perhaps no other non-profit organization has had as powerful an impact on academic research in the United States as the Howard Hughes Medical Institute (HHMI). Established in 1953 by the late aviator and highly eccentric engineer, industrialist and movie producer Howard Hughes, the Institute acquired a stronger footing when it sold the Hughes Aircraft Company to General

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[22] A list of its grants, a number of which have been made to universities, can be found at http://www.gatesfoundation.org/grants/Pages/search.aspx.

[23] The foundation was established by Lawrence Ellison, the founder of Oracle. In 2007 it had plans to make $30,000,000 in grants. http://philanthropy.com/free/articles/v19/i12/12000701.htm.

[24] David Grimm, "Spending Itself Out of Existence, Whitaker Brings a Field to Life." 3 February 2006, vol 311, *Science*, pp. 600-601. Unlike most foundations, the Whitaker foundation was not set up to last forever. Its founder, U.A. Whitaker, had a disdain for bureaucracy, and hoped the foundation would fold within 40 years of his death in 1975.

[25] *Science* 14 December 2007, p. 1703. No title and no author.

Motors in 1985, thus establishing the Institute's endowment at $5 billion.[26] In 2008 its endowment was valued at close to $18 billion. By law HHMI is required to distribute 3.5% of its assets each year. It has done so by supporting between 300 and 350 HHMI investigators at research universities, funding a number of training programs, and establishing the "farm." (To be more precise, the Janelia Farm Research Campus, in Ashburn, Virginia, that opened in 2006 with the goal of bringing 25 interdisciplinary teams together to study neural circuits and imaging.)[27]

HHMI's largest outlay by far is in support of investigators. In 2008, for example, HHMI supported 335 investigators at 66 universities and medical centers and spent approximately $700 million doing so.[28] The process of selection begins when a university nominates a candidate. After an extensive mail review of the candidates' materials, reviewers come to HHMI headquarters and discuss in depth the candidates who have fared the best in the mail review. Investigators are not granted tenure at HHMI. They are, however, considered for reappointment. Reappointment decisions are based in part on a report, which can be no more than five pages in length, describing his/her research accomplishments during the period of the HHMI appointment as well as future research plans. Investigators also submit up to five of what they consider to be their best articles, as well as an updated cv and bibliography. Investigators then come to HHMI and make a 50-minute presentation to a panel of experts in the field. The review panel then votes either to continue or to phase out the investigator's appointment.

Non-profit-foundation support for research suffers from the same ups and downs related to the business cycle as does government funding and industrial support. Foundations that rely on donations can be particularly hard hit during a recession. Moreover, foundations that fund grants out of their endowment can experience severe problems when the stock market takes a deep dive, as it did in 2001 and again in 2008. During the 2001 downturn, for example, the HHMI endowment plummeted by $3 billion in two years. The timing was poor: the downturn came just when the Foundation had started to build the $500 million Janila Farm facility. In order to continue with construction, the foundation chose to cover the shortfall partly by cutting investigator grants by 10% for one year.[29]

More recently, several foundations found their balance sheet at close to zero, a result of investing their assets almost exclusively with Bernard Madoff. For example, the Picower Foundation, which reported assets of almost $1 billion in 2007, announced in late 2008 that it would "cease all grant making effective immediately." Investigators supported by the foundation received e-

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[26] http://www.hhmi.org/about/growth.html
[27] Jocelyn Kaiser, HHMI's Cech Signs Off on His Biggest Experiment," *Science*, 11 April 2008, vol. 320 p. 164.
[28] http://www.hhmi.org/about/financials/scientific.html. Note that the $700 million does not show up in the government's accounting since officially the faculty members who are investigators are employees of HHMI, as are their support staff. Investigators are permitted to spend 25% of their time in teaching, administration or other activities that benefit the "host" institution.
[29] Jocelyn Kaiser, HHMI's Cech Signs Off on His Biggest Experiment," *Science*, 11 April 2008, vol. 320 p. 164

mails from Barbara Picower, a cofounder of the foundation, informing them that their funding was terminated.[30]

Self-funding

Universities also have looked to themselves for the funds to support research and to smooth out the peaks and valleys of federal funding. While in the mid-1950s universities contributed only about 14%, their share declined considerably during the 1960s when the Federal government's contribution was growing at a fast pace. By 1963, only about 8% of research expenditures were "self-funded" by universities. This did not last: as the federal budget for research deteriorated, universities directed increasing amounts of their own funds to research. By 2008, 20% of the funds for research, or approximately $10.5 billion, were coming from universities themselves.

At least two other factors have contributed to universities picking up a larger share of research funding.[31] First, there is the issue of indirect cost recovery. Historically, external funding agencies have funded much of the infrastructure of universities, as well as the cost of administering research, by paying indirect costs on grants. This means that a university marks up its direct cost request for research (for example, for graduate students, postdocs, equipment and faculty salaries) by a multiple, known as the indirect rate. Government auditors, however, began to take a much harder look at the rate, after a much publicized case involving Stanford University in the early 1990s and caps were put on expenses that universities could claim in a number of areas. The end result was that the average indirect rate at private research and doctoral universities, which was over 60% in 1983, fell to about 55% in 1997 and has remained fairly constant since.[32]

Another reason universities are picking up more of the cost for research relates to start-up packages. As we have already discussed, in recent years it has become the norm for universities to provide start-up packages to new faculty. Not only are start-up packages important in recruiting top talent; they are an investment in newly-minted faculty who require some period of time before they can begin to bring in their own research funds. Start-up packages are designed to provide the where-with-all for them to do this.

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[30] Jennifer Couzin, "For Many Scientists, the Madoff Scandal Suddenly Hits Home." *Science*, vol. 323, 2 January 2009, p. 25.

[31] The actual share that universities contribute to research declined in the early 2000s due to the tremendous increase in NIH funding. Since 2003, however, it has risen again.

[32] A web-based search by Martha Lair Sale and R. Samuel Sale of the policies of 31 private doctoral/research universities in 2004 found the average indirect rate to be 54.4%. Their work was presented at the 2009 Academic and Business Research Institute in Orlando (http://www.aabri.com/OConference.html). The situation is somewhat different for public universities, which typically have had lower indirect rates due to their reliance on state governments to build research facilities. However, in recent years, with declining state support for operating budgets of universities, public universities have paid more scrutiny to indirect rates and their average rate has actually slightly increased.

Who pays for the increased costs of research that universities are contributing? More to the point, do students? This is a question that Ron Ehrenberg, Michael Rizzo and George Jakubson investigate for 228 research and doctoral universities for the twenty-year period spanning the late 1970s to the late 1990s.[33] They try to determine whether increases in internal funding for faculty research is associated with increased student-faculty ratios and increased tuition payments. The findings suggest that students bear some of the cost, especially at private institutions, where the student-faculty ratio grows as internal funding for research grows, and where tuition levels increase as internal funding for research grows. The first effect is smaller at public institutions; the tuition effect is non-discernable for public institutions. The authors also find that institutions that increase the size of their graduate student enrollments compensate by increasing tuition. This is true for both public and private institutions.

Their work suggests that although students may benefit from being in close proximity to great researchers, they pay for this proximity—in terms of higher student-faculty ratios and, in private institutions, somewhat higher tuition levels. Moreover, creating or expanding graduate programs raises tuition. The effects, however, are not very large. Increased internal research expenditures have led the student-faculty ratio to increase by about .5 during the period at privates: by about .3 at the publics. Tuition has increased by less than 1% at privates in response to increased expenditures for research and by another 2% in response to increased graduate programs. Public university students have ended up paying about $50 more to pay for growth in graduate programs.[34]

Other Countries

Trends in the support of university research in nine European countries and in Japan are given in Table 6.1. The classification scheme builds on that developed by the OECD, splitting sources into seven categories: Government funds are subdivided into direct government funds (DGF), such as contracts and earmarks, and general university funds (GUF), which come in the form of block grants, distributed either incrementally or on a formula basis. Additional categories include funds from business, funds from abroad (including contracts for research with foreign companies), private-non-profits (NPO) and higher education's own funds (HE). For some countries, data are only available through 1995 or are not available for all categories.

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[33] Ronald G. Ehrenberg, Michael J. Rizzo, and George H. Jakubson, "Who Bears the Growing Cost of Science at Universities?" in *Science and the University*, edited by Paula E. Stephan and Ronald G. Ehrenberg, University of Wisconsin Press, Madison, 2007.

[34] Their work also helps explain the changing "mix" of faculty. In other work, Ehrenberg and Zhang (2005) have shown that the high price of start-up packages affects the willingness of universities to hire at the tenure rank; it also encourages universities to replace full professors with assistant professors. (Ronald Ehrenberg and L. Zhang, "The Changing Nature of Faculty Employment." In *Recruitment, Retention, and Retirement in Higher Education: Building and Managing the Faculty of the Future*, ed. R. Clark and J. Ma, pp. 32-52, Northampton, MA, Edward Elgar Publishers.)

The country patterns mirror, in many ways, those of the U.S. That is to say that in most countries there has been a decrease in the share of research funds coming from the government—and an increase in research funds coming from business, non profits and higher education itself. With the exception of France, the decrease in government support has come from a decline in unrestricted block grants (GUF).

But there are substantial differences by countries. In the U.K., for example, the amount of funds coming from government grants and contracts has grown considerably. The same pattern is observed for Spain, Ireland, and Denmark, for the earlier period for which comparable data are available. The growth in business support for university research has occurred primarily in Germany although business support for research has also increased in Spain, The Netherlands and Belgium. All countries have experienced a substantial increase in funding coming from abroad, some of which is from foreign companies.

The increasing role of non-profits has been particularly important in the UK. Non-profits also play an increasing role in the Netherlands and Denmark. The largest non-profit in Europe is the Wellcome Trust, which in 2008 had assets of approximately £15.1 billion and gave away (2007/2008) approximately £620 million to support research, both within the U.K. and internationally. Like other foundations it was hit hard by the financial crisis, losing an estimated £2 billion and, accordingly cut its support for research in 2009.[35] Specific non-profits play a minor but growing role in support of research in other countries, as well. For example, L'Association Française Contre les Myopathies (AFM) raises over 100€ million a year through a telethon and spends approximately 60% of it on research on rare neuromuscular diseases.[36] And in Italy, bank foundations, established by law during the restructuring of the mutual savings banks in 1990, regularly support research at Italian universities.

Table 6.1

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[35] See http://www.the-scientist.com/blog/print/55417/

[36] See "A Season of Generosity…and Jeremiads." *Science*, Vol. 314, 8 December 2006, p. 1525. Martin Enserink.

Funding for Research in Higher Education[37]

		Belgium	Denmark	France	Germany	Ireland	Italy	Japan	Netherlands	Spain	UK
Gov	1981			98	98		96	58			81
	1995			91	91		93	52			68
	2006			88	82		94	51			69
DGF	1981	39.4	10.9	45		14.9		16	5.7	13.0	15
	1995	38.0	22.9	46	20	20.0		10	6.3	30.1	30
	2006			36	23		18	12			35
GUF	1981	43.4	85.6	53		67.6		42	91.1	87.0	65
	1995	34.9	66.8	45	70	42.0		42	79.3	40.3	38
	2006			53	58		76	39			34
Business	1981	8.7	1.0	1	2	7.1	3	1	.3	0	3
	1995	10.6	1.8	3	8	6.9	5	2	4.0	8.3	6
	2006			2	14		1	3			5
NPO	1981	0	1.6	.1	?	2.6	?	0	2.3	0	5
	1995	1.0	4.5	.5	?	2.5	?	0	6.5	.5	14
	2006			.6	?		1	1			14
HE	1981	2.9	0	1	?	.4	0	41	.3	0	9
	1995	6.8	0	4	?	4.5	?	41	.3	13.7	4
	2006			7	?		?	45			4
Abroad	1981	1.8	1.3	0	..	7.3	1	0	.3	.1	2
	1995	8.7	4.2	2	1	24.0	2	0	3.5	7.0	8
	2006			3	4		4	0			8

Funding patterns in Japan are somewhat similar, although the changes are more muted. Direct funding from the government has declined, funding from business has increased, as has the contribution from higher education. Japan was the only country that joined the U.S. in making scientific research a component of its 2009 stimulus plan. The sums were not trivial. Indeed almost 10% of the $141-billion supplemental appropriation was science-related. Most of that was allocated to upgrading facilities and equipment but it also includes $2.7 billion to support a small number of research teams.[38]

Focus of Research

Not all science is created equal when it comes to funding. Moreover, what is favored during one period may lose favor in another and the research focus often depends on who's paying. When state funding was the major source of resource support, for example, universities directed their research to topics of interest to the state. Wisconsin focused on dairy products, Iowa on corn,

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[37] Source: Aldo Geuna class slides and The Changing Rationale For European Research Funding: Are There Negative Unintended Consequences? Aldo Geuna, *Journal of Economic Issues*, September 200 1, XXXV, no. 3, pp. 607-632.

[38] Dennis Normile, "Science Windfall Stimulates High Hopes—and Political Maneuvering." *Science*, Vol. 324, 12 June 2009, p. 1375.

Colorado and other Western states on mining, North Carolina and Kentucky on tobacco, Illinois and Indiana on railroad technology, and Oklahoma and Texas on oil exploration and refining.[39]

Defense-related funding from the federal government altered the focus of university research beginning with World War II. It also contributed to the expansion of several universities, including the Massachusetts Institute of Technology and the California Institute of Technology. Other universities were quick to learn from their sister institutions and used postwar defense contracts to propel themselves into the all-star league. Stanford was an early example of this; more recently the Georgia Institute of Technology and Carnegie Mellon have benefited from defense-related research.[40]

More recently, the tremendous growth in biomedical research funds has contributed to the growth of universities with a heavy focus on medical research, such as the University of California-San Francisco, Johns Hopkins University and Emory University. It has also played a major role in the strategic plans of universities. By way of example, membership in the American Association of Universities (AAU) is viewed as highly prestigious within the university community. The organization currently has but 63 members. Membership is by invitation only. A key criterion is research performance, one metric of which is money. The dominant role that funding for medical research plays means that those outside the AAU club have a much greater chance of admittance if they have a strong program in the biomedical sciences. Such logic was a major factor leading the University of Georgia to adopt plans in 2007 to develop a medical school.[41]

Funding data for university research by field is given in Figure 6.2 for the entire period 1975-2006 and for the later period, 1995-2006. The decline of the physical and engineering sciences and the growth of the biomedical sciences are abundantly clear. Over the entire period, only three areas of research have experienced an increase in share: computer science, engineering, and the life sciences. The share of funds going to the physical, environmental and social sciences, psychology and math has declined. In the most recent period, the share going to the life sciences has increased at the expense of the share going to all other fields of research.

The U.S. love affair with funding for the life sciences, especially the biomedical sciences is not difficult to understand. It is far easier for Congress to support research that the public perceives

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[39] Claudia Goldin and Larry Katz, "The Origin of State-level Differences in the Public Provision of Higher Education: 1890-1940," *The American Economic Review* 88:303-308, 1998; "The Shaping of Higher Education: The Formative Years in the United States, 1890 to 1940," *Journal of Economic Perspectives* 13:37-62. 1999. Also see Nathan Rosenberg and Richard R. Nelson "American Universities and Technical Advances in Industry." *Research Policy* 23(3):323-48, 1994.

[40] S. Leslie 1993, p. 12. *The Cold War and American Science: The Military-Industrial Academic Complex at MIT and Stanford*. New York: Columbia University Press.

[41] The school programs will be developed jointly by the University of Georgia and the Medical College of Georgia. See http://www.uga.edu/news/artman/publish/01-17_UGA_Navy_School_Proposal.shtml.

as benefiting their well being. Moreover, a large number of interest groups constantly remind Congress of the importance of medical research for “their” disease. The age distribution of Congress does not hurt. The average member of the House of Representatives in 2009 was 56.0; the average senator was 61.7.[42] Both houses are considerably older than they were at their “youngest” in 1981 when the average member of the House was 48.4 and the average Senator was 52.5.[43] Certain senators are particularly focused on biomedical research. Senator Arlen Specter (born in 1930), for example, has long been a champion of NIH funding and almost single- handedly increased the amount that NIH got out of 2009 stimulus funds from a “modest” $3.9 billion to $10.4 billion. He is also a three-time survivor of cancer.

The widespread appeal of biomedical research is sufficiently strong that a rationale for funding the physical sciences is often made on behalf of its contribution to health research or in the guise of health research. The nanotech funding initiative, for example, in some respects was a Trojan horse. The small scale of nano research made Congress think “health applications.” In reality, a good deal of the funds went to research in engineering and the physical sciences.[44] Moreover, NIH leaders have from time to time gone to Congress to make the case that progress in medical research is critically tied to research in the physical sciences. For example, the MRI and the laser, both important technologies for biomedical research and health care, came out of research in the physical sciences.

The focus of research has also changed over time in other countries but the shift is far harder to document since--unlike the United States-- no database tracts university funding by field over time. It is safe, however, to say, that although there has been an increase in funding for biomedical research at universities outside the U.S., it has not been as dramatic as it has been in the United States.[45] . This is partly because many countries have made considerable commitments to support large scale projects such as the LHC at CERN, the Extremely Large Telescope, and ITER, the International Thermonuclear Experimental Reactor.

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[42] http://www.centeroncongress.org/learn_about/feature/qa_members.html#age

[43] Guide to Congress, 6th edition, Washington, D.C.:CQ Press, c2008., 2 v. (xx 1606, 54 p.)

[44] The initiative started in 2001 with $.464 billion in federal funding. By 2008, approximately $1.5 billion in federal funds was allocated to it. See http://www.nano.gov/html/facts/faqs.html.

[45] The U.s. also has traditionally spent a larger percent of its research budget on health.

Figure 6.2

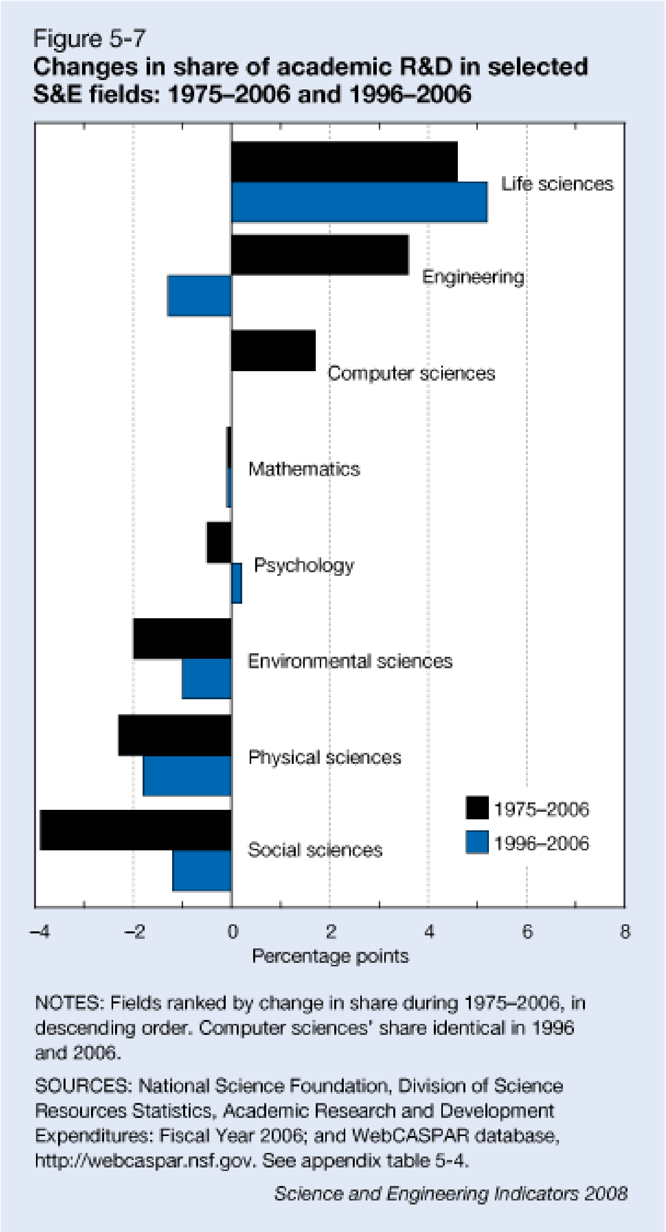

Figure 5-7

Changes in share of academic R&D in selected S&E fields: 1975–2006 and 1996–2006

NOTES: Fields ranked by change in share during 1975–2006, in descending order. Computer sciences' share identical in 1996 and 2006.

SOURCES: National Science Foundation, Division of Science Resources Statistics, Academic Research and Development Expenditures: Fiscal Year 2006; and WebCASPAR database, http://webcaspar.nsf.gov. See appendix table 5-4.

Science and Engineering Indicators 2008

Mechanisms for Allocating Funds

Traditionally university research has been funded out of resources the university received from the state or, in the case of private institutions, from tuition and private donations. In many European countries, research universities have a long tradition of receiving general funds from the state in the form of block grants, a portion of which have been used in support of research (see Table 6.1). In some countries, research in the public sector has been primarily conducted at government run institutes that operate independent of the university system, such as CNRS and INSERM in France and Max Planck in Germany. Researchers could also teach and hold an appointment at a university. But the funds for research came primarily through the institute. By 2008, approximately 80% of research in France was done in these so called "mixed units," many of the labs for which are physically located at a university or other host institution.[46] Such funding arrangements meant that the responsibility for research resources did not rest with the faculty member. Neither, in many cases, did it rest with the institution. Moreover, there was generally no tradition of evaluating the research outcomes produced as a result of funding. More to the point, funds were often provided independent of results.

More recently, as documented in Table 6.1, researchers in Europe increasingly are being supported by competitive grants. The Engineering and Physical Science Research Council (EPSRC) in the UK, for example, funds research in engineering and physical sciences; the Research Council in Norway funds all types of research in the university, as does the Flemish Science Foundation. Competitive grants are particularly important for university researchers hired in soft money positions.

Since the 1950s resources for research at U.S. universities, including the funds to buy out part of their own time, increasingly have become the responsibility of faculty members.[47] The university, as we have noted, provides start up funds but thereafter faculty are responsible for raising their own funds through the submission of proposals to funding agencies, be they non-profit, federal, or in some cases, state or local. The majority of these funds come from just four federal agencies: The National Institutes of Health, the National Science Foundation, the Department of Defense and the Department of Energy, in that order. In addition, the U.S. Department of Agriculture and NASA provide over a $1 billion a year in support of university research.

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[46] Marin Enserink, "After Initial Reforms, French Minister Promises More Changes." *Science*, 11 January 2008, vol. 319, p.152.

[47] Faculty in "hard-money positions" can use grant funds to buy out part or all of their teaching time and cover their summer salary. Faculty in "soft-money" positions are expected to get grants to cover part if not all of their salary.

NIH and NSF evaluate proposals through a process of peer review, with some agency variation. The Department of Defense and Department of Energy are much more likely to base their funding decisions on in-house evaluation, as are The Department of Agriculture and NASA. Given the size of NIH and NSF relative to other federal agencies, this means that over 75% of federal funds coming to U.S. universities in support of research are distributed through the process of peer review.[48]

Peer Review

Peer review begins at NIH when a proposal is assigned to a "study section." Study section members review proposals in advance of the meeting. When the study section meets, a process of triage occurs which results in approximately half the proposals not being formally discussed, or, in the language of NIH, "not scored." While investigators whose proposals are triaged receive the initial reviewer's statements, they do not receive a summary report from the study section. Non-triaged proposals are discussed in some detail and scored to one decimal point by members of the study section on a 1 to 5 scale, 1 representing the most favorable review and 5 representing the least favorable. An average (rounded to two decimal points) is then computed and multiplied by 100.[49] Scores are standardized by pooling them with those given in other recent meetings. This resulting priority score and accompanying written review is forwarded to the specific institute (there are 27 institutes and centers at NIH) and reviewed by the institute's national advisory committee. Percentile cutoffs are important in determining who gets funded, although NIH does fund PIs whose proposals fall below the payline. NIH, in an interest in distributing the wealth, singles out for special scrutiny proposals that would place the PI over $750K. Investigators whose proposals are turned down have the right to resubmit two additional times. Most do. It is particularly challenging to resubmit if one's proposal is not scored for then there are no written comments to address. This is a particularly serious problem for new, unestablished investigators.

The review process puts considerable weight on past accomplishments, which are enumerated on a standardized NIH biosketch form. Results from the previous grant (if there was one) also play an important role in evaluation. The presence of demonstrated expertise and strong preliminary data play an especially key role in the review process. "No crystal, no grant." A major reason that universities provide start up funds is to permit the newly hired faculty member time to continue the process of collecting preliminary data for an NIH proposal. The "lineage" of the scientist is often noted, in terms of where the scientist trained and in whose lab the scientist did his or her postdoc work. Researchers must also demonstrate that they have adequate space at their university in which to conduct the research.

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[48] This is for obligations and comes from Appendix, Table 5.7 of National Science Board, *Science and Engineering Indicators 2008*.

[49] http://www.niaid.nih.gov/ncn/newsletters/2008/1217.htm#n01

Historically anywhere between 10 and 40% of applications have been funded. Success obviously depends on the number of applications, the cost of the proposals being considered and the availability of funding. It is also institute specific. For example, in 2008, the highest success rate was for applications reviewed by the National Eye Institute (29.5%); the lowest was for proposals reviewed at National Institutes of Child Health and Human Development (16.8).[50] In 2001, during the doubling, several institutes had success rates above 35% and many more had success rates above 30%.[51]

The R01 grant, the "bread and butter" for university investigators, typically lasts for three to five years. Researchers can apply to renew their grant. This is the norm, not the exception. It is greatly encouraged by the fact that renewals do much better in the review process than new proposals. It is not unknown for researchers to be supported on the same grant for forty-plus years. Or even fifty-plus. Harold Scheraga (Cornell University) has had the same NIH grant to study protein folding for 52 years.[52] In rare instances, a university can nominate a new investigator to take the place of an investigator who is stepping down and the same grant is passed on to a new generation.

NSF peer review follows a slightly different process. Investigators submit proposals to programs, which are generally organized around fields of study. Programs vary as to whether they use mail reviews exclusively or panel reviews supplemented by mail reviews to evaluate proposals.[53] Reviewers rank proposals on a five-point scale that goes from Excellent to Poor. Reviewing is voluntary: Of the 60,400 requests made in fiscal year 2008, NSF got almost 37,000 reviews (61%).[54] Unlike the case of NIH, program officers have considerable discretion in making funding decisions, especially with regard to proposals that fall between a "clearly fund" and a "clearly do not fund." There is not a tradition of continuing a grant at NSF, as there is at NIH, although researchers can and do submit proposals for follow-on research.

NSF has the appearance of putting less emphasis on reputation than does NIH and limits the number of publications the researcher can list to a maximum of ten. Anywhere between 20 and

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[50] See http://report.nih.gov/award/success/Success_ByIC.cfm. Excluded from the discussion are institutes that received fewer than 500 proposals and the NCCAM National Center for Complementary and Alternative Medicine.

[51] http://report.nih.gov/award/success/Success_ByIC.cfm.

[52] Scheraga, who was born in 1921, may be the oldest NIH investigator. In March of 2009 he wound down another NIH grant for experimental work and in the process freed up lab space for a new faculty member. See Jocelyn Kaiser, "The Graying of NIH Research." *Science*, 7 November 2008, vol. 322, p. 848.

[53] Approximately 10% of proposals are reviewed exclusively by mail. The use of mail only review has declined considerably. See Figure 21 in National Science Board 09-43, Report to the National Science Board on National Science Foundation's Merit Review Process, Fiscal Year 2008.
http://www.nsf.gov/nsb/publications/2009/nsb0943_merit_review_2008.pdf

[54] National Science Board 09-43, Report to the National Science Board on National Science Foundation's Merit Review Process, Fiscal Year 2008, p. 27.
http://www.nsf.gov/nsb/publications/2009/nsb0943_merit_review_2008.pdf

37% of NSF research proposals are funded.[55] As in the case of NIH, the rate depends upon the number of applications and the availability of funding. It also depends on NSF policies with regard to size of award and length of award. In an effort to "increase productivity by minimizing the time PIs spent writing multiple proposals and managing administrative tasks" NSF tried to extend the length of the average grant and increase the size of the grant. Between 2000 and 2005 the average size of an award increased by 41%; the average length of an award stayed approximately the same, at almost exactly three years. Success rates plummeted as more proposals chased fewer grants.[56] Not only was there an increase in the number of applicants; there was also an increase in the number of proposals per applicant. Both effects were no doubt due in part to the increased dollar value of an award, although part of the increase was undoubtedly due to increased ease of submitting through the NSF fast-track system, and the pressure universities brought to bear on faculty to engage in grantsmanship.[57]

Peer review also plays a role in allocating resources for university research outside the U.S. It is used, for example, by all research councils in the U.K., as well as by the Wellcome Trust. It is the basis for decisions made by the Flemish Science Foundation (FWO) and the Norwegian Research Council. The European Union, which has long supported research through the "Framework Program," now in its seventh form (Seventh Framework Program (EP7), has always used peer review to distribute resources. In an effort to encourage "cutting-edge" basic research, the European Research Council (ERC) was established in 2007. [58] Again, decisions are based on peer review. Likewise, the FIRB, which was established in Italy in 2005, makes decisions by peer review, as does the Agence nationale de la recherché (ANR) in France, which made its first grants in 2005.

Other mechanisms

There are at least three other mechanisms, in addition to block grants and peer review, for allocating research funds. One is a variant of the block grant approach and distributes funds through an assessment of the strength of the department. This method has become increasingly important in recent years outside the U.S. For example, in the U.K. the Research Assessment Exercise, which in 2009 distributed £1.57 billion funding in support of university research, includes quality of publications as one of the measures for evaluating departments.[59]

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[55] The figure excludes proposals for centers, facilities, equipment and instrumentation and are for the period 2001-3008. National Science Board 09-43, Report to the National Science Board on National Science Foundation's Merit Review Process, Fiscal Year 2008., Figure 6.

[56] P. 5 in "Impact of Proposal and Award Management Mechanisms," Final Report, August 1, 2007, National Science Foundation, August 1, 2007, National Science Foundation. http://www.nsf.gov/pubs/2007/nsf0745/nsf0745.pdf.

[57] See discussion by Richard Freeman and John Van Reenen, "What If Congress Doubled R/D Spending on the Physical Sciences?" in *Innovation Policy and the Economy 2008*, edited by Josh Lerner and Scott Stern, National Bureau of Economic Research Innovation Policy and the Economy, 2009, p. 24.

[58] Gretchen Vogel. 2006. Basic Science Agency Gets a Tag-Team Leadership. *Science* 313:1371.

[59] Approximately 25% of university research funds are distributed through the RAE. Katz, S. and Hicks, D. 2008. "Excellence vs. Equity: Performance and Resource Allocation in Publicly Funded Research." Prepared for

Publications also play a role in the distribution of research funds to Norwegian universities, as they do in Australia, New Zeeland and in Flanders, where 30% of university research funds are distributed based on bibliometric measures.

Earmarks, the money schools love to hate

In 1978 the president of Tufts University, Jean Mayer, hired two lobbyists to press the University's case to obtain funds from the Department of Agriculture to build a nutrition center at the university. Their efforts were successful: Tufts received $32 million toward the building of a nutrition center which, not surprisingly, is today known as the Jean Mayer USDA Human Nutrition Research Center on Aging.[60] "Once the genie was out of the bottle, nothing could put it back."[61] Money for earmarks for university research has grown in leaps and bounds ever since. In 2008 earmarks equaled $4.5 billion or 14% of all federal funding for research.[62]

Politicians often justify earmarks on the rationale that the peer review system concentrates research funding among a few elite universities. Without earmarks, research at second string institutions would never get a chance to develop. The proclivity of peer review to be risk averse is also sometimes used as a rationale for providing funds to universities through earmarks.

Occasionally universities and colleges get earmarks without asking for them. Marywood College, for example, once received earmarked funds from the Department of Defense that they had not asked for, thanks to John Murtha (D-PA).[63] But most universities that receive funds hire lobbyists to make their case on the Hill. Moreover, it is not only the second string who lobby. Despite the public distain that most elite universities hold for earmarks, they also engage in the practice. In fiscal year 2003, 90 percent of AAU institutions accepted at least one earmark and received a total of $336 million in earmarks.[64] Despite their efforts, earmarking redistributes funds away from top research universities towards lower-ranked institutions.

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presentation DIME-BRICK Workshop "The Economics and Policy of Academic Research", 14-15 July 2008, Collegio Carlo Alberto, Moncalieri (Torino), Italy. Also see Daniel Clery, "England Spreads Its Funds Widely, Sparking Debate," *Science*, Vol. 323, 13 March 2009. Also see "Changing Incentives to Publish and the Consequences for Submission Patterns," Chiara Franzoni, Giuseppi Scellato, and Paula Stephan. 14-15 July 2008, Collegio Carlo Alberto, Moncalieri (Torino), Italy.

[60] John M. De Figueiredo and Brian S.Silverman, How Does the Government (Want to) Fund Science? In *Science and the University*, edited by Paula Stephan and Ronald Ehrenberg, University of Wisconsin Press, Madison, WI, 2007, p. 52 and Jeffrey Mervis, "Building a Scientific Legacy on a Controversial Foundation," *Science* 25 July 2008, pp. 480-483.

[61] Robert Rosenzweig, former president of AAU. Quoted p. 480 in Jeffrey Mervis, "Building a Scientific Legacy on a Controversial Foundation," *Science* 25 July 2008, pp. 480-483.

[62] Jeffrey Mervis, "Building a Scientific Legacy on a Controversal Foundation," *Science* 25 July 2008, pp. 480-483.

[63] John M. De Figueiredo and Brian S. Silverman, "How Does the Government (Want to) Fund Science?" *in Science and the University*, edited by Paula Stephan and Ronald Ehrenberg, University of Wisconsin Press: Madison, 2007, p. 40.

[64] John M. De Figueiredo and Brian S. Silverman, "How Does the Government (Want to) Fund Science?" *in Science and the University*, edited by Paula Stephan and Ronald Ehrenberg, University of Wisconsin Press: Madison, 2007, p. 43.

Not all lobbying meets with equal success. It helps considerably to be from a state having a member on the Senate Appropriations Committee (SAC). Universities with representation on SAC receive, for example, $56 for every $1 spent on lobbying, almost four times more than universities without representation received for every $1 spent lobbying. Membership on the House Appropriations Committee (HAC) was not nearly as lucrative.[65]

Set-asides are another way Congress affects the allocation of resources for research. In this case, funds are provided for pet projects, often projects in which a state may have a considerable advantage. For example, buried in the federal spending measure adopted in the spring of 2009 was a $3 million directive for NSF "to establish a mathematical institute devoted to the identification and development of mathematical talent." The directive was backed by Harry Reid, the Senate Majority Leader (D-NV). It is not a surprise that a Nevada researcher is a co-PI on a proposal that had just been submitted to NSF to meet the needs of exceptionally gifted prospective mathematicians and that the University of Nevada, Reno, supports the Davidson Academy, a public school for exceptionally gifted students.[66]

Congressional representation also affects NIH allocations and (indirectly) the distribution of grants. Powerful congressmen, for example, can provide guidance on the allocation and disbursement of appropriated funds, direct reallocations among various NIH institutes and support funds for specific diseases. In recent years having an additional member on the appropriate subcommittee of the House Appropriations Committee that deals with the NIH budget increased NIH funding to public universities in the member's state by 8.8%. [67]

Prizes

In recent years there has also been considerable interest in stimulating research and development by offering inducement prizes. The idea is not new: The British Government, for example, created a prize in 1714 for a method to solve the longitude problem. More recently, the Ansari X Prize was established in 1996 for the first private manned flight to the cusp of space. The $10 million was awarded eight years later to Burt Rutan. More recently, the X Prize Foundation announced that it will pay $10 million to the first privately financed group to sequence 100 human genomes in 10 days. The winner will get another $1 million to decode the genomes of 100 additional people selected by the X Prize Foundation.[68] There are also prizes for dogs and

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[65] John M. De Figueiredo and Brian S. Silverman, "How Does the Government (Want to) Fund Science?" *in Science and the University,* edited by Paula Stephan and Ronald Ehrenberg, University of Wisconsin Press: Madison, 2007, p. 43.

[66] The details of the proposal were not available at the time of this writing. Jeffrey Mervis, "Senate Majority Leader Hands NSF a Gift to Serve the Exceptionally Gifted." *Science*, 20 March 2009, vol. 323, p. 1548.

[67] Deepak Hegde and David C. Mowery, "Politics and Funding in the U.S. Public Biomedical R/D System." *Science*, 19 December 2008, pp. 1797-1798., vol. 322.

[68] Elizabeth Pennisi, "On Your Mark. Get Set. Sequence!" *Science*, 13 Oct. 2006, p. 232. The Canadian company Archon Minerals donated the money for the prize. Craig Venter is on the board of the X Prize Foundation. 454 Life

cats: the Michelson Prize in Reproductive Biology, for example, will be awarded to the first entity to provide a non-surgical sterilant that is "safe, effective and practical for use in cats and dogs."[69]

Congressional interest in prizes has been on the increase in recent years. A talking point of John McCain's 2008 presidential campaign was a $300 million prize to stimulate the invention of a battery to "leapfrog" the abilities of current hybrid and electric cars.[70] Representative Frank Wolf (R-VA) proposed that NSF create a series of large prizes to stimulate innovative research. His opinion carried substantial weight: when he made the proposal in 2005 he was chair of the House spending panel that oversees NSF. At his request NSF asked the National Academies to write a report on the use of prizes.[71]

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The Pros and Cons of Different Allocation Systems

Earmarked projects are virtually never peer reviewed and it is therefore impossible to know what was given up in order to fund them. This, in and of itself, makes them the bête noir of the research community. But they do have some pluses. They are not subject to stop and go, providing a steady stream of funding. Stability encourages a long term horizon and, theoretically, increases risk taking.

Prizes have much to recommend them: they invite alternative approaches to a problem, not being committed to a specific methodology. They are awarded only in instances of success; the incentive to exaggerate is eliminated. In addition, prizes attract participation from groups and individuals who might otherwise not participate.

But there are serious downsides. Like the priority system, prizes encourage multiples. They are not well suited for research that has unknown outcomes--the desired outcome must be known and carefully specified. There is also the temptation of the awarding agency to raise the bar after a solution is proposed. But the greatest barrier for the use of prizes as a way to encourage academic research is that funding is only awarded after completion: entrants are on their own to find the funds needed to compete. This means that prizes are only suitable for academic research if partnerships can be built with industry. Scientists at Carnegie Mellon University and the

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Sciences was an early entrant. Steven Hawking and Larry King are already on the list of the 100 additional individuals.

[69] Advertisement by FoundAnimals, *Science*, 7 November 2008.

[70] http://edition.cnn.com/2008/POLITICS/06/23/campaign.wrap/

[71] The National Academy report was issued in January of 2007. The report suggests that NSF experiment with prizes before adopting a full scale prize program. Sums of between $200,000 to $2 million, for example, were mentioned, with the possibility of raising the payout to as much as $30 million if the concept proves successful. Representative Wolf lost chairmanship of the subcommittee when the Republicans lost the majority in 2006 and the prize is no longer a top priority. See Jeffrey Mervis, "Report Backs NSF Prize to Spur Innovation," *Science*, 26 January 2007, vol. 315, p. 446.

University of Arizona are doing precisely this. They are collaborating with Raytheon to compete in the $30 million Google Lunar X Prize, which will award $20 million to the first team to "safely land a robot on the surface of the Moon, travel 500 meters over the lunar surface, and send images and data back to the Earth." The second team to do so will receive $5 million and another $5 million will be awarded "in bonus prizes."[72]

Both direct government funding through a system of block grants and funding through peer review have benefits. Both also have downsides, or costs. The block-grant approach to funding insures that scientists can follow a research agenda with an uncertain outcome over a substantial period of time. It also exempts scientists from devoting long hours to seeking resources, or reviewers from spending hours evaluating proposals. These are non-trivial.

But block grants with "no strings attached" have costs. There is no built-in incentive for faculty to remain productive throughout their research career when neither funding nor salary depend on performance. Moreover, the research agenda is often set by the director of the lab or by full professors in the university. As a result, younger faculty may be constrained from following leads they consider promising and must wait for their senior colleagues to retire prior to leading a research effort.

Perhaps most important, the no-strings-attached approach fails to meet the criterion of accountability. In recent years, this has proven to be the Achilles heel of such a system, as the public, especially in Europe where the system had flourished, demanded to know what they were getting for their investment in research--both in terms of the quality of the research and its contribution to economic development. Like it or not, countries have moved away from using unrestricted funds in supporting research to a system that allocates university resources on the basis of past performance or through peer review. Several examples of such systems operating in Europe and Australia were provided above. In France, the call for reform has been a bit different and a bit later in coming. But a rationale is lack of quality, as Elias Zerhouni, who chaired the panel making recommendations for reform of life science research in France, made clear when he stated that although there are numerous exceptions "the large bulk [of journal articles] is published in lower-tier journals."[73]

Allocating resources on the basis of past performance invites universities to "game" the system. For example, in the UK there have been numerous instances of "just-in-time" hires where universities hire highly-cited researchers just before the cut-off for the next evaluation period in

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[72] http://www.googlelunarxprize.org/lunar/about-the-prize. The Carnegie Mellon group is participating through a university spin-off created by faculty member Reid Whittaker, Astrobiotic Technology, Inc. http://www.googlelunarxprize.org/lunar/teams/astrobotic

[73] Martin Enserink, "Will French Science Swallow Zerhouni's Strong Medicine?" *Science*, vol. 322, 28 November 2008, p. 1312. The panel also expressed concerns regarding the amount of paperwork that French researchers must cope with as well as problems related to the diffusion of responsibility and authority. The panel recommended setting up a unified agency to fund all of the life sciences.

order to boost their performance.[74] In some instances, the faculty who are hired are not full time, and retain a position at another university. This has proved to be a common practice in China, where performance affects resource allocation, and where a number of highly-cited U.S. Chinese-faculty have been granted jiangzuo, or lecture-chair positions that require them to spend at most three months a year in China.[75]

The criteria used for evaluation can also affect the quality of the research. For example, the formula used in Australia initially focused on publication counts in ISI journals. Not surprisingly, the largest increase in publications was in bottom quality quartile journals, with the exception of medical and health sciences, where the largest growth was in the bottom two quartiles.[76]

The peer review system also has its benefits. It provides for freedom of intellectual inquiry and encourages scientists to remain productive throughout their careers. To the extent that success in the grants system is not completely determined by past success, the system provides some opportunity for last year's losers to become this year's winners. Peer review arguably promotes quality and the sharing of information. The system also, as we have noted in Chapter 3, encourages entrepreneurship among scientists. Getting money from a venture capitalist is not very different from getting money from a funding agency. Both require making a strong "pitch."

Just as some of the benefits of a competitive grants system are costs of the unrestricted grant approach, so, too, some of the benefits of the latter are costs of the former. First is the question of time: Grant applications and administration divert scientists from spending time doing research. A 2006 survey found that U.S. scientists spend 42 percent of their research time filling out forms and in meetings; tasks split almost evenly between pre-grant (22%) and post-grant work (20%). Reviewing the proposals of others takes additional time: Antonio Scarpa, director of the NIH Center for Scientific Review, estimates that each proposal requires three reviewers working on average 12 hours apiece, or 36 hours of research time.[77] It is not surprising that in recent years concern has been raised at NIH and at NSF that it has become increasingly difficult to attract experienced reviewers and that the quality of the reviews has declined.[78]

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[74] Hicks reports that between 2002 and 2006 the number of British faculty earning more than £l00,000 grew by 169% . Diana Hicks, 2008, "Evolving Regimes of Multi-university Research Evaluation," mimeo.

[75] Normile, 2006. "Frustrations Mount Over China's High-Priced Hunt for Trophy Professors. *Science*, 313:1721-1723.

[76] L. Butler, 2004. "What Happens When Funding is Linked to Publication Counts?" *Handbook of Quantitative Science and Technology Research. The Use of Publication and Patent Statistics in Studies of S&T Systems*", Springer, The Netherlands

[77] Paul Basken, June 9, 2009, NIH is Deluged with 21,000 Grant Applications for Stimulus Funds." *Chronicle of Higher Education.*

[78] P. vi in "Impact of Proposal and Award Management Mechanisms," National Science Foundation, August 1, 2007.

A competitive funding system can also discourage risk taking. Grants are often scored on their "doability." To quote the Nobel laureate Roger Kornberg, "If the work that you propose to do isn't virtually certain of success, then it won't be funded." [79] There is a perception among older scientists that peer review, at least at NIH, used to be a different game, with reviewers focused on "ideas, not preliminary data."[80] The problem is compounded when funding is difficult to come by. The American Academy of Arts and Sciences' recently released ARISE report (Advancing Research in Science and Engineering) concluded that in tight times "reviewers and program officers have a natural tendency to give highest priority to projects they deem most likely to produce short-term, low-risk, and measureable results."[81]

The underlying incentive system encourages risk aversion on the part of the PI: Failure is not rewarded. Future funding clearly depends on obtaining successful outcomes during the current grant period. The system particularly discourages risk taking when one's own salary is at stake, as is often the case for researchers at medical institutions and always the case for summer support. The rubric for today's faculty has gone from publish or perish to "funding or famine," to use a phrase coined by Stephen Quake.[82] The most painful of appeals come from scientists whose labs will have to close and whose careers as an independent investigator will come to an end if their grant is not renewed.

The way funding is structured, at least that of NIH, also discourages scientists from taking up new research agendas during the course of their career. Because renewals have a much higher chance of receiving a thumbs up, researchers stay with a known course and specialize in a line of research over their career. An established scientist once told me of the disdain he held for his colleagues who kept the same grant going for years, seeing it as a sign of lack of creativity. He is clearly in the minority: the current system encourages such behavior. He also has greater flexibility in choosing his research agenda: he is an HHMI Investigator.[83]

Neither has the competitive grants system proved to be friendly to the young. In recent years, for example, the number of new investigators funded by NIH has remained almost constant while the number of experienced investigators increased (more to follow).[84] And success, when it

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[79] C. Lee. 28 May 2007. "Slump in NIH Funding is Taking Toll on Research," p. A06, Washington Post, Washington, D.C. Kornburg continued by saying "And of course, the kind of work that we would most like to see take place, which is groundbreaking and innovative, lies at the other extreme."

[80] Jocelyn Kaiser, "The Graying of NIH Research." *Science*, 7 November 2008, vol. 322, pp. 848-849.

[81] American Academy of Arts and Sciences, ARISE. Advancing Research in Science and Engineering, 2008, p. 27.

[82] Stephen Quake "Letting Scientists Off the Leash" February 10, 2009, A *New York Times* Blog.

[83] Research suggests that the HHMI system encourages creativity and, by implication, greater risk taking than does the NIH system. Three things recommend it over the process used by NIH: it evaluates people, not projects; it funds individuals for a longer period of time than NIH grants typically do; and it is reasonably forgiving of "failure," at least the first time the individual comes up for review. See Pierre Azoulay, Joshua S. Graff Zivin, and Gustavo Manso, "Incentives and Creativity: Evidence from the Academic Life Sciences," NBER Working Paper 15466.

[84] Young investigators have also experienced difficulties at NSF. For example, the funding rate for established investigators decreased from 36 percent in 2000 to 26 percent in 2006. During the same period, funding rates for

comes, increasingly comes to older scientists. The average age at which one receives first independent funding increased from 37.2 to 42.4 between 1985 and 2006.[85] At least three factors contribute to this outcome: First, the need for preliminary results biases funding decisions towards more established researchers and delays the submission of grants by investigators just starting out. Second, more than 70% of new investigators must resubmit their proposals before receiving funding; thirty years ago over 85% of all new investigators received funding on their first submission. Resubmission can easily add an additional year to the process. Third, people increasingly are older at the time that they get a tenure-track position.[86]

The grants system comes up particularly short when the odds of receiving funding are extremely low. It is inefficient in terms of the time and resources expended in submitting and evaluating proposals that have an extremely low probability of being funding. It reduces morale. Moreover, decisions at the margin become increasingly random when reviewers must choose among a limited number of top-quality proposals. Only the finest of lines may distinguish the top nine projects from the top ten.

There is also the problem that the system provides incentives to secure as much funding as possible for one's work, irrespective of whether an increase in funding leads to a proportionate increase in productivity. Money can become an end, not a means, and the amount of funding a measure of productivity.[87]

Granting agencies are aware of many of these problems. For example, NIH has repeatedly made efforts to increase the number of young investigators it funds. A recent initiative, for example, created "Kangaroo" grants to help investigators transition from postdoc positions to new faculty positions. Reviewers are made aware of whether the proposal comes from a new investigator and the "payline" is generally raised for new investigators. Moreover, new investigators now routinely receive an additional one year of funding without asking. One of Elias Zerhouni's last actions before stepping down as the Director of NIH in the fall of 2008 was to make room for new investigators by declaring it formal NIH policy to "support new investigators at success rates comparable to those for established investigators submitting new applications." In 2009 this would mean at least 1650 awards for R01's, a substantial increase over the 1354 awarded in 2006.[88]

In an effort to increase risk taking, NIH created Pioneer and Eureka Awards. The former are "designed to support individual scientists of exceptional creativity who propose pioneering—and

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new investigators decreased from 22 percent to 15 percent. American Academy of Arts and Sciences, ARISE. Advancing Research in Science and Engineering, 2008, p. 14.

[85] American Academy of Arts and Sciences, ARISE. Advancing Research in Science and Engineering, 2008, p. 11.

[86] American Academy of Arts and Sciences, ARISE, Advancing Research in Science and Engineering, 2008, p. 12.

[87] Rui Sousa, "Research Funding: Less Should be More," letter in *Science* 28 November 2008, pp. 1324-1325.

[88] Jocelyn Kaiser, "Zerhouni's Parting Message: Make Room for Young Scientists." *Science*, 7 November 2008, vol. 322, p. 834-835.

possibly transforming approaches—to major challenges in biomedical and behavioral research."[89] The latter are designed "to help investigators test novel, often unconventional hypotheses or tackle major methodological or technical challenges."[90] Laudable as these efforts are, the numbers are miniscule. In 2009, for example, NIH made 18 Pioneer awards, the most ever. But the odds are less than one percent: over 2300 applications were received for the multi-million five-year award.[91]

NSF also undertook a new, foundation-wide initiative to encourage "transformative research" in 2007. Among other things, the agency expanded its merit-review criteria to explicitly include "review of the extent to which a proposal also suggests and explores potentially transformative concepts."[92]

NIH also recently made major modifications in its peer review system in an effort to address various concerns. To wit, it has restricted the length of the proposal (cutting it from 25 to 12 pages beginning in January of 2010), and streamlined the quantity and format of written comments expected from reviewers. In an effort to ease the reviewer burden, members of study sections can now serve out their 12 meetings over a six-year period rather than a four-year period. Those who go for the long haul are to be rewarded: after participating in 18 study section meetings they will receive a grant extension of up to $250,000, or about 9 months of funding. And those with three or more grants must serve as a reviewer if asked. NIH also modified the scoring system, resulting in a two-digit score rather than a three-digit score, and instituted a policy to score and rank all proposals, thereby effectively abolishing triage.

It is too early to know if the revisions will prove beneficial, and their review will be complicated by the fact that their implementation inadvertently coincided with the 2010 stimulus package that elicited an enormous response on the part of the scientific community, dumping a huge volume of proposals into the system.

The NIH Doubling: A Cautionary Tale

It's tempting to assume that money is the answer to many of the problems plaguing peer review and, more generally, the university research enterprise. Additional funds should translate into higher success rates, which in turn should encourage increased risk taking. More money should also mean more jobs and grants for young researchers.

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[89] http://nihroadmap.nih.gov/pioneer/

[90] http://www.nih.gov/news/health/sep2008/nigms-03.htm

[91] http://www.nih.gov/news/health/sep2009/od-24.htm. See http://www.news-medical.net/news/20090924/La-Jolla-Institute-scientist-Hilde-Cheroutre-earns-the-2009-NIH-Directors-Pioneer-Award.aspx for number of applicants.

[92] http://www.nsf.gov/nsb/news/news_summ.jsp?cntn_id=109853&org=NSF

But anyone who thinks so should be careful what they wish for. The doubling of the NIH budget between 1998 and 2002 ushered in a host of problems. By the time it was over, success rates were no higher than they had been before the doubling. By 2009, and in part because of the real decreases that NIH experienced in the intervening years, success rates were considerably lower than they had been before the doubling. Faculty were spending more time submitting and reviewing grants. The percent of proposals funded on the first submission fell from over 60% in the early 2000's to 30%. [93] Over one-third of all funded R01 proposals were not approved until their last and final review. This not only took time and delayed careers; the perception was that these "last chance" proposals were favored over others, creating a system that, according to Elias Zerhouni, awarded "persistence over brilliance sometimes."[94] Moreover, and jumping ahead to chapter 7, there is little evidence that the increase translated into permanent jobs for new PhDs, as had been the case in the 1950s and 1960s when government support for research expanded.

It's also not clear that the doubling resulted in the U.S. being relatively more productive, at least as measured by publications. Frederick Sacks' study of U.S. publications in biomedical fields found no "upward jump" in U.S. publications relative to those from labs outside the U.S. where funding did not double.[95]

A major cause of this seeming paradox was the response of universities to the doubling. Some universities saw the doubling as an opportunity to move into a new "league" and establish a program of "excellence." Others saw it as an opportunity to augment the strength they already had. For others expansion of their existing programs was simply necessary if they were to remain a player in biomedical research. Regardless, the end result was that the majority of research universities went on an unprecedented building binge. Recruiting senior faculty—with their large grants and capacity to generate still larger grants-- required space. Lots of it. Deborah Powell, dean of the Medical School at the University of Minnesota, put it bluntly: "The problem in recruiting senior professors is that they want lots of space. . . Getting a group of four or five neuroscientists means that you have to look at thousands of square feet of space and lots of money."[96]

Universities used philanthropic, local, and state resources, as well as debt to finance the expansion. They hired additional faculty and research scientists, many in soft-money positions. Universities also encouraged faculty who had heretofore not applied for grants from NIH, to "go where the money is." And they encouraged those who had grants to get more: not one grant or

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[93] Comes from PowerPoint "Update on NIH Peer Review," distributed to Council, National Institutes of General Medicine.

[94] Jocelyn Kaiser, "NIH Urged to Focus on New Ideas, New Applicants." *Science*, Vol. 319, 29 February 2008, p. 1169.

[95] Frederick Sacks, "Why Hasn't More Funding Meant More Publications?" *The Scientist*, 19 November 2007.

[96] http://www.minnesotamedicine.com/PastIssues/February2007/PulseBiomedicalFebruary2007/tabid/1705/Default.aspx

two grants but three became the expectation at many research institutions. New buildings with larger labs required more resources to support them.

Not surprisingly, the number of applications for new and competing research projects grew. In 1998, NIH received slightly over 20,000 applications for R01 awards; by 2003 it received 24,634 and by 2008, long after the doubling had ended, it received 26,648. Success rates, which initially grew, declined, going from 32% to 23%.[97]

One reason for the decline in success rates was the substantial growth in budgets accompanying the proposed research: in 1997 the average first-year budget of the typical grant was $217K; by 2003 it had grown to $351K.[98] Several factors contributed to the increase: First, more faculty were on "soft" money positions and thus writing off a larger proportion of their salary on grants. Second, the cost of equipment and supplies grew considerably during the period. Mice and MRI's are expensive! The Biomedical Research and Development Price Index went from 100 to 129 between 2000 and 2007.[99] Third, tuition for graduate students (which is included in grants) was increasing. It was an easy way for universities to get more federal funds.

Another factor contributing to the decline in success rates was that NIH had less money with which to support R01 grants. Not only did the NIH budget decline in real terms after the doubling, but commitments made during the doubling to fund grants having a duration of four-to five-years meant that fewer resources were available as the doubling ended. In 2003 NIH had $2.4 billion for competing R01 grants; by 2006 it had $2.1 to spend on R01s.[100]

Some of the new grants went to researchers who had heretofore not received NIH funds. But the vast majority of new grants went to established researchers: the percent of investigators who had more than one R01 grant grew by one-third during the doubling, going from 22% to 29%.[101] The number of first time investigators grew by no more than 10%.[102]

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[97] See Research Portfolio Online Reporting Tool RePORT). http://report.nih.gov/NIHDatabook/Charts/SlideGen.aspx?chartId=126&catId=1

[98] During the doubling period, the percent of the NIH budget going to R01 and equivalent grants also decreased, from 60 to 52%. See Geoff Davis, "NIH Budget Doubling: Side Effects and Solutions." Presentation made at Harvard University, March 2007, for information regarding the percent allocated to R01 grants and for information on average size of the award.

[99] http://officeofbudget.od.nih.gov/pdfs/FY09/BRDPI%20Table%20of%20Annual%20Values_02_01_2009_2014.pdf

[100] Howard H. Garrison, Kimberly I. McGuire, Robert E. Palazzo. "Why Funding Cuts at the National Institutes of Health Are So Painful." *The Physiologist*, vol. 50, no. 4, August 2007. By 2008, there had been a slight increase, and NIH had $2.3 billion for competing R01 grants (private correspondence with Howard Garrison.)

[101] Geoff Davis, "NIH Budget Doubling: Side Effects and Solutions." Presentation made at Harvard University, March 2007.

[102] The number of first-time investigators who received R01 (or equivalent funds) from NIH went from 1439 in 1998 to 1559 in 2003. NIH, Office of Extramural Research, data prepared for AIRI. There was a considerable increase, however, in the number of R03 and R21 awards made to new investigators. Both are small in terms of funding (the R03 is for $50,000 for two years; the R21 is for two years and cannot exceed $275,000 in direct costs.

Young researchers were at a disadvantage competing against more seasoned researchers who had better preliminary data and more grantsmanship expertise; at every submission stage the success rates of new investigators was lower than for established researchers submitting a proposal for a new line of research.[103] The increased number of grants for experienced investigators and minimal growth in grants for first time investigators resulted in a dramatic change in the age distribution of PI's. In 1998 only a third of awardees were over 51: almost 25% were under 40. By 2003 42.3% were over 51 while less than 17% were under 40. Fully a quarter were over 55. (See Figure 6.3).

One response of the biomedical community was to lobby (unsuccessfully) for more funds. There was even a move to generate another "storm," given the perception that the earlier "Gathering Storm" report had proved helpful to the physical sciences, the primary source of its focus (since it was written right after the NIH doubling).[104] A similar report, focusing on the biomedical sciences, might be the way to attract Congress's attention.

No one expected that "help" would come in the form of a stimulus bill brokered in the middle of the night. But when the biomedical community woke up on the morning of February 4, 2009, they found themselves to be the recipients of more than $10 billion in stimulus funds *to be spent in two years.*

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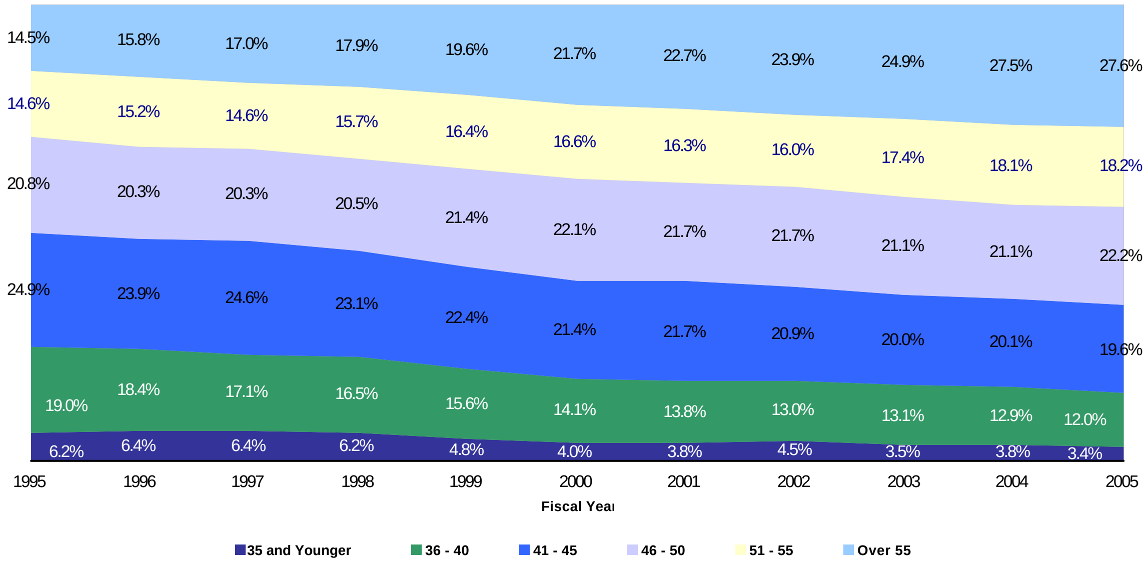
[103] Comes from PowerPoint "Update on NIH Peer Review," distributed to NIGMS Council.

[104] See Eliot Marshall, "Biosummit Seeks to Draw Obama's Attention to the Life Sciences." *Science*, 12 December 2008, *Science*, vol. 322, p. 1623.

Figure 6.3

NIH Competing R01 Equivalent Award



If it were difficult to have a smooth landing after a doubling, what would happen after an infusion of $10 billion, scheduled to disappear after two years? NIH sought to soften the landing by proposing to use only a small part on "new" grants, allocating instead most of the funds to supplement existing grants. But universities, hungry for indirect costs and with faculty whose grants had not been renewed, put on a full court press. The call for the newly (and quickly) designed Challenge grants was issued in early March 2009. In less than ten weeks, more than 21,000 proposals were submitted for the award, which could fund up to $1M of direct costs over the two-year period. The University of Minnesota, which submitted 224, accounted for 1% of these;[105] as did the University of California, Irvine, which submitted approximately the same number.[106] Deans at some universities reportedly told faculty members that they would be judged on the number of applications they submitted.[107]

When all was said and done, NIH funded 840 Challenge grants; the success rate was slightly less than 4%.[108] Not to worry; the majority are likely to be resubmitted as R01's. The marginal cost (from the PI's perspective) is virtually zero. The format of the Challenge grant (12 pages) is a perfect fit for the format of the new streamlined R01 proposal. If R01success rates were low in 2009, they will assuredly be lower in 2010. The supplemental funds may help many researchers

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[105] http://www.research.umn.edu/communications/publications/rno/5-8-09.html

[106] Jocelyn Kaiser, "NIH Stimulus Plan Triggers Flood of Applications—And Anxiety." *Science*, 17 April 2009, vol. 324, pp. 318-319.

[107] Paul Bsken, "NIH Is Delgued with 21,000 Grant Applications for Stimulus Funds," *Chronicle of Higher Education*, Tuesday, June 9, 2009.

[108] http://report.nih.gov/UploadDocs/Final_NIH_ARRA_FY2009_Funding.pdf

and universities through a difficult period, but they are not a "fix." Moreover, they pose an excessive burden on reviewers as well as the NIH staff, who worked long hours during the late summer and early fall of 2009 to get the grants out.

Conclusion

Research is an expensive business. Because of the characteristics of basic research and the motives of individuals who are drawn to doing it, and partly by historic accident, in many countries scientific research is performed in the university. It is paid for by a coalition of forces, with the government, regardless of country, picking up the largest part of the tab. Other contributors include industry, private foundations, and universities themselves. In recent years the trend has been for universities to pick up an increasing portion and for the proportion supported by the government to decline. But these patterns vary by country.

Increasingly, the criterion for the support of university research is performance: No output, no funding. While this may seem to be a straightforward proposition, it has not always been so, especially in Europe. Moreover, increasingly it has become the responsibility of faculty to generate the resources to support research, either indirectly by building reputation or directly by submitting grants. The U.S. is the extreme case of this: The university's direct support of a faculty member's research practically disappears after a couple of years. In addition, faculty are increasingly expected to raise the funds to pay for their own salary. This is especially the case at medical institutions, and not only for non-tenure track research faculty, but also for faculty holding "tenure."

At the same time, the resources to support research, as measured by success rates, have become more "scarce." This is in part because funds for research, especially in recent years, were practically flat. But it is also because the size of the university research enterprise—and the expectations of universities—expanded.

Such a system has led faculty, and the government agencies that support faculty, to be risk averse. "Sure bets" are preferred over research agendas with uncertain outcomes. It is not only the peer review system that fosters risk aversion. The Defense Advanced Research Projects Agency (DARPA), which once boasted that "it took on impossible problems and wasn't interested in the merely difficult" has increasingly shifted to the NIH model, funding research that is more near-term and less risky.[109] Playing it safe may generate research, but it is, to quote Don Ingber, "not science in its truest sense because science is the process by which we define the unknown."[110]

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[109] David Ignatius, "The Ideas Engine Needs a Tuneup," *Washington Post*, June 3, 2007, Page B07.

[110] Email to Paula Stephan, 2-24-09 . Draft of comments for March 1, DC conference.

The system, at least in the U.S., has particularly failed young investigators. It's no wonder: they have fewer preliminary results and less grant expertise than their grey-haired colleagues. But failure to adequately support young faculty is a recipe for more problems now and down the road. Exceptional contributions are more likely to be made by the young.[111] Future discoveries depend on building up a base of new investigators, as does the education of future generations of scientists. Moreover, supporting early-career scientists makes careers in science and engineering more appealing to younger people who are in the process of choosing careers.[112]

Many of the problems that confront the funding of science are scale related. A system that worked relatively well when the research community was small does not work nearly as well when the enterprise grows by a factor of ten, as the U.S. enterprise has done in the past forty-five years. As the system becomes larger, there is a need to codify the rules and allocation mechanisms. This can discourage risk taking. A larger system also makes it more difficult for scientists to engage in intensive peer review. The process used by the Howard Hughes Medical Institute to appoint investigators would be difficult to replicate on a significantly larger scale.

Other problems with the current system of support for university research relate to its proclivity to experience periods of stop and go. Stop and go funding is harmful for careers; it also makes it difficult for agencies to engage in long term planning. NIH assumed that its budget would grow at a "normal" rate after the doubling. Universities assumed that the manna would continue. While NIH might have behaved differently had it known that its budget would decline in real terms, it is not clear that universities would have. There was too much at stake. If the university did not expand, it would be left behind. It was a bit like going to a football game. The first person who stands up can see better, as can the second and third. But by the time everyone stands up, no one sees better. And everyone is colder standing up.

In one sense, U.S. universities behave like high-end shopping malls. They are in the business of building state-of-the art facilities and a reputation that attracts good students and faculty. They then turn around and "rent" the facilities to faculty in the form of indirect costs on grants and the buy-out of salary. Faculty, in turn, create research programs, staffing them with graduate students and postdocs, who contribute to the research enterprise by their labor and the fresh ideas that they bring, but who can also be easily downsized, if and when times get tough. Universities leverage these outcomes into reputation. The amount of funding universities receive, as well as

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[111] See Paula Stephan and Sharon Levin, *Striking the Mother Lode in Science: The Importance of Age, Place and Time,"* Oxford University Press, 1992. Paula Stephan and Sharon Levin, "Age and the Nobel Prize Revisited." *Scientometrics*, vol. 28, no. 3, pp. 387-99, 1993.

[112] Richard B. Freeman and John Van Reenen, "Be Careful What you Wish For: A Cautionary Tale About Budget Doubling." *Issues in Science and Technology*, Fall 2008. The authors also point out that research support not only produces knowledge but also contributes to the human capital of the people doing the research. This is another reason for supporting young researchers.

the citations and prizes awarded to their faculty, determine their peer group—the club to which they belong. They also attract donations and students and affect the university’s ranking.

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