Demystifying the Academic Research Enterprise

Becoming a Successful Scholar in a Complex and Competitive Environment

By: Kelvin K. Droegemeier

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By: Kelvin K. Droegemeier
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Perception and Reality: Public Attitudes, Understanding, and Use of Research

Chapter Overview and Learning Objectives

Although research and creative activity benefit society in a variety of ways, attitudes toward these endeavors, and use of their outcomes, vary among stakeholder groups—in some cases dramatically. This chapter describes how research is viewed by the general public as well as factors that can undermine public trust in research findings and the overall value of research. It also describes models of innovation and emphasizes the need to view research through a broad lens, to ultimately instill a culture of collaboration across multiple fields to advance knowledge and understanding. After reading this chapter, you should

- Understand the social compact between taxpayers and researchers in the context of fundamental research;
- Describe public attitudes toward research and its application, and the factors shaping those attitudes;
- Explain how progress in research must be balanced with belief systems and ethics and how such factors influence public policy;
- Describe how research results can be used, and misused, in policy;
- Explain how our current system of disciplines arose and the challenges such a system poses for research;
- Describe the linear and cyclic models of innovation; and
- Explain the roles of research and creative activity in society, particularly in serving as the foundation for innovations that improve economic and national security as well as quality of life.

3.1 Research and the Social Compact with the General Public

As described in chapter 1, research and creative activity span a wide spectrum of types, funders, and performers (table 1.1). At one end is curiosity-driven, fundamental or "basic" research, which involves studying the world in which we live simply because we want to understand more about it. It also involves creating works of art and culture that enrich the human experience. At the other end are applied research and development, which involves innovating basic research results to create products and services that provide practical benefits to society.

Fundamental research takes place mostly at universities, whereas applied research and development occur mostly in government laboratories and private companies (figure 2.4).[1] Applied research and development are funded (figure 2.1) mainly by the federal government, say for military applications (figure 3.1), and by private industry. Conversely, fundamental research is funded principally by the federal government (figure 2.1)—using taxpayer dollars—because the outcomes of such work are far too uncertain, and the associated risks of success usually are far beyond those a company is willing to accept. That is, companies must make money to survive, and uncertainty

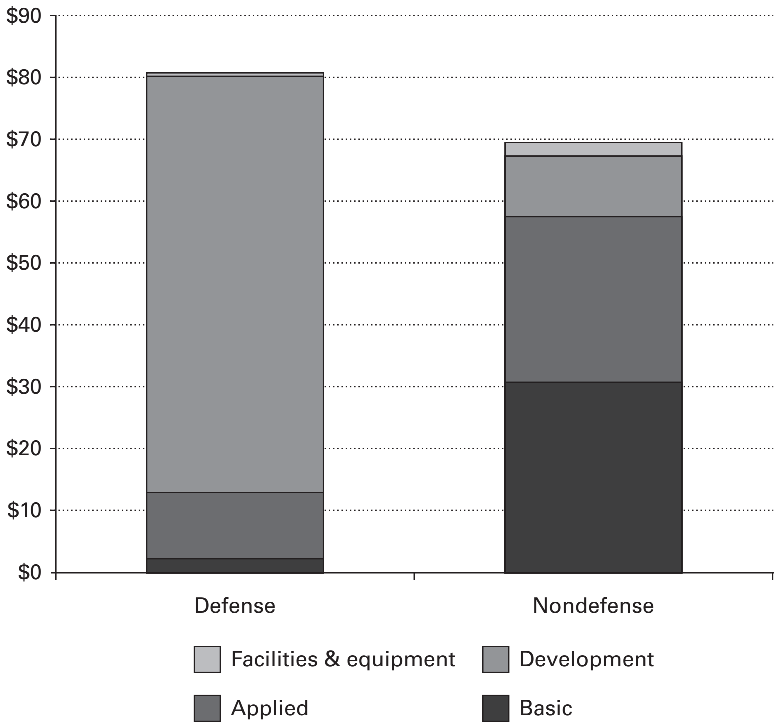

Figure 3.1
US FY 2017 base budget R&D by character. *Source*: Hourihan and Parkes (2016).

and risk are factors companies try to minimize. Yet fundamental research is critical to companies because its outcomes represent the "seed corn" or starting point from which private sector innovation flows.

Because taxpayer dollars support a great deal of fundamental research—to the tune of tens of billions of dollars per year—citizens who provide this funding, namely, the general public via taxation, must be assured the money is used as effectively as possible. In this spirit, an implicit "social compact" of trust, between the general public and those performing fundamental research, emerged after World War II. The compact holds researchers and federal funding agencies accountable as responsible and trustworthy stewards of these dollars.

The emergence of this social compact, and arguably the start of the modern research enterprise, were marked by a highly visionary treatise titled *Science: The Endless Frontier*. It was written by Dr. Vannevar Bush (Bush 1945), President Franklin D. Roosevelt's de facto science advisor and head of the Office of Scientific Research and Development. Recognizing the critical value of research in aiding the Allied war effort, President Roosevelt reasoned these same capabilities—which were organized principally within the highly secretive Manhattan Project—could provide tremendous benefits to civil society if transitioned into the open framework of academia. Consequently, the president charged Dr. Bush in 1944 with developing a plan for such a transition, and Bush underpinned it with three key foundational elements: the essential value of basic or discovery research in advancing national interests and the role of the federal government in supporting it; the importance of developing scientific talent for the future; and the need to remove as many restrictions as possible to promote the open exchange of scientific ideas, information and results.

An important outcome of Bush's report was establishment in 1950 of NSF, an independent federal agency which today funds the bulk of our nation's nonclinical fundamental research.[2] NIH was formally established in 1948, though its origin dates back to 1887. As the name implies, NIH funds fundamental research and its translation into clinical practice in all areas of human health.

Within the arts and humanities, NEA was created in 1965 to support excellence in the arts, both new and established, along with bringing the arts to all Americans and providing leadership in arts education. In the same act of Congress, NEH was established to support research, education, preservation, and public programs in the humanities.

In the 1980s, the objectives of federal support for research, mostly in science fields, were expanded to include major efforts such as the Human Genome Project. Since then, the US research enterprise has continued to blossom, though with challenges to its reputation and value. These include researcher misconduct in fabricating or falsifying results (chapter 10), experimental design that sometimes leads to nonreproducible results (section 4.7), the long time (years to decades) often required for fundamental research to yield outcomes viewed as practical by society, the fact that many published studies are never cited, and violations of agency policy, especially failure to disclose affiliations that might impact national security (section 10.3).

Despite these and other challenges, the public tends to appreciate research having tangible impacts, such as in the medical and technology fields, though has less understanding of how research is performed or the manner in which research *and* teaching are intertwined in higher education. Surveys show that public trust in leaders of research is second only to that of the military (figure 3.2)—a trend that has persisted for approximately two decades. However, the COVID-19 pandemic has impacted public attitudes toward research in ways that are not yet entirely clear. Surveys also show Americans view research as generating opportunities for the next generation, and that the federal government should continue funding basic, discovery-type research.

One key to maintaining taxpayer trust in research and creative activity, among many factors, is anonymous peer/merit review (chapters 6 and 7), in which peers review each other's proposals, journal articles, or other works to ensure high quality and lack of bias (chapter 8). Not to be forgotten are the arts and humanities, which create life-changing introspective development, teach us to engage with ideas critically and independently, and equip us with

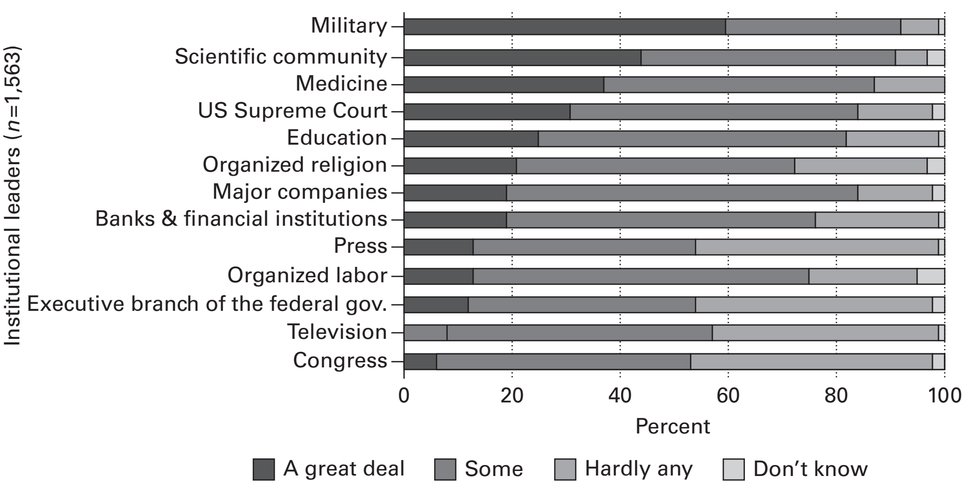

Figure 3.2
Public confidence in institutional leaders, by selected institution, in 2018. *Source*: National Science Board (2020g).

the skills necessary to understand how complex organizations operate and change. They also sustain and preserve the heart and soul of our civilization. Unfortunately, as noted elsewhere in this book, funding for the arts and humanities typically is not given a high priority, when in fact these disciplines reflect the core of our very existence.

Research also has impacts broader than the work itself (chapter 6). Such impacts include teaching and training in K–12 schools, broadening the participation of traditionally underrepresented groups, enhancing public understanding of research through mechanisms such as partnerships with museums and science centers, and commercializing research outcomes to benefit existing companies or start new ones (chapter 12).

3.2 Factors Shaping Public Understanding of Research

How do we develop understanding—about anything? We attend primary and secondary school for twelve years, then possibly go on to college, and then perhaps even earn an advanced degree (master's, doctorate, law degree, medical degree). Such *formal* education is wonderful, but in addition to preparing us for a career, it also prepares us to be lifelong and engaged learners. That is, to have the ability to understand on our own, gather facts and evidence from trusted sources and analyze them, gather opinions and analyze them as well, talk with others, add our own experiences and viewpoints to the mix, and ultimately develop our own assessments.

Historically, once individuals finished their formal education, the bulk of their knowledge and understanding about events shaping their lives came from organized media outlets (radio, newspapers, television), weekly or special publications (e.g., *Time*, *Newsweek*, *US News and World Report*, *Life Magazine*), and conversations with peers. In the late 1980s, the emergence of twenty-four-hour cable news, and later the explosive growth of the Internet and devices that utilize it, transformed the public's ability to gather information, including streaming videos and images.

Numerous studies have been conducted to evaluate the impact of this transformation on public understanding and awareness of national and international affairs, as well as how new "news" elements such as blogs, social media posts, and tweets, have impacted our ability to distinguish between opinion and evidence-supported fact. In the realm of research, leading newspapers once had entire sections dedicated to topics in science, technology, and the arts. Today, science journalism has all but vanished, though one is able to find on the Internet a vast array of resources for learning as much about scholarly activity as one wishes. However, much of this new framework requires *intent* on the part of the reader, and thus only those who already have an interest in or understanding of research and creative activity tend to seek information about them.

Politics and personal ethics also shape public understanding of research, especially for topics such as climate change, genetically modified organisms, and stem cells (discussed further in the next section and in chapter 10). Deeply held beliefs come into play, as do alignments with political platforms and ideologies. Shrinking federal spending on research (figure 2.2), and decreasing funding at the local level, tend to make the arts, fine arts, and humanities targets for funding cuts because they are not seen by many as delivering practical benefits to society.

Consequently, we as researchers must learn how to communicate the results of our work in understandable and relatable ways, and with the proper background and context, to the general public (chapter 11). It also is important to find mechanisms—such as civic organizations, church groups, chambers of commerce, and town councils, to name a few—in which to explain our work and show the importance of it. We need to bring the excitement and substance of our work to the public, not require the public to seek us out.

But in doing so, we should never view our communication as "dumbing down" the work we do, for even experts in one field need clear, straightforward explanations of concepts from another discipline. Far too frequently, researchers become frustrated when others do not appreciate their work, yet they do little to engage them. This is especially true with regard to Congress and others in organizations that determine the course of research itself via the authority they possess to fund it. Our local and national leaders *want* to hear from us, but often we come forward only when it is in our best interest to do so. That is a mistake. Continuous communication is the key.

Many excellent resources exist to help you, as a researcher, communicate your scholarly activities to nonexperts. Doing so can be extremely fulfilling but also exceptionally valuable, and we examine this topic in greater detail in chapter 11.

3.3 Balancing Progress in Research with Belief Systems and Ethics

Should stem cells from human embryos be used in research that might one day cure cancer, blindness, or Alzheimer's disease? Should genetic engineering be used to modify plants and animals, thereby producing organisms more resistant to disease and less expensive for human consumption? Should artificial intelligence and facial recognition technology be used, in the context of a criminal investigation, to identify individuals whose images are captured on public surveillance cameras? Should taxpayer funds be used to study esoteric languages, support the creation of works of art, or study political views on sensitive topics that might endanger funding for the social sciences? How does one reconcile competing views regarding the age of the earth, how humans came to exist, and the possibility of life on other planets?

Because public tax dollars fund the bulk of fundamental research and creative activity via grants awarded by federal agencies, the public, and by virtue of it the Congress, have a lot to say about which areas of research represent national priorities. This is true not only in science, engineering, and medicine, but also in the arts, fine arts, and humanities. Indeed, Congress has the formal role of both authorizing (that is, setting dollar targets) for funding federal agencies that sponsor research, as well as appropriating (that is, actually providing) the money (chapter 2).

With that responsibility comes significant challenges, among them the issue of balancing progress in research with acknowledgment of and respect for belief systems and ethical views held by the public. In that context, two factors are particularly important.

The first concerns fundamental religious, cultural, and personally held beliefs. Stem cell research is a good example of the former, in which some oppose the use of aborted fetuses in research. With regard to cultural beliefs, Native Americans and other people groups sometimes oppose for research purposes the use of lands determined by them to be sacred. Other examples include opposition to the siting of large telescopes or the building of pipelines on certain lands owing to religious or environmental concerns. Questions, such as whether live animals should be used in research, or even euthanized and then used, continue to challenge some sectors of society. In deciding which sorts of research are allowable or ethical—that is, adhere to moral standards established by society—one has to weigh the benefits to be gained against other issues.

The second major factor to be considered concerns political views, which often are intertwined with belief systems. For example, one political party tends to favor fossil energy development while another supports renewable energy and research into public attitudes of our political system. One party may value funding for the arts and culture while the other feels public funding should be directed mostly toward endeavors that lead to outcomes having "much greater" practical benefits for society. These views can have profound impacts on how funding is allocated for research and creative activity. Yet, in the end, progress must be balanced with respect for belief systems and the realization that research does not exist in a vacuum, but rather is part of society itself.

Consequently, as a researcher, it is very important to avoid categorizing a given individual, group, or organization as having one belief versus another because, in reality, a spectrum of belief systems and views exists. Such is the nature of a diverse society. Research rarely identifies immutable truths or contains absolutes in its outcomes. Rather, it builds upon results successively via the continuous gathering, analysis, and refinement of data and evidence—sometimes challenging and even overturning established paradigms—in a continual process of advancing knowledge and understanding.

Additionally, it important that you have a broad view of the academic enterprise and understand inequities that exist regarding public funding for research and creative activity across it. As an example, nearly 50 percent of NSF funding for competitive research grants goes to fifty universities in America (National Science Board 2020b). The remaining hundreds of other colleges and universities, including MSIs (which include HBCUs, TCUs, HSIs, and Asian American, Native American, and Pacific Islander Serving Institutions), as well as ERIs, historically have not been as competitive.

Specific programs have been created to address these challenges and to improve equity within multiple federal agencies, including EPSCoR. Additionally, significant new funding, with strong bipartisan support in Congress, is being proposed for MSIs and ERIs, not only to support research itself, but also to help create the administrative infrastructures required to deal with the associated funding. Only in this manner will all of America's talent have an opportunity to participate in research and creative activity and thus bring benefits to society.

It is axiomatic that research always will have an uneasy coexistence with public belief systems and ethics. Such has been the case for centuries, and the positive value of this construct cannot be overstated. Only if we attempt to eliminate or greatly devalue one or the other will we, as a society, pay a heavy price.

3.4 The Use and Misuse of Research Results in Policy

Each of us has been exposed to policies throughout our lives, sometimes without even noticing. Your parents most likely applied numerous rules and policies as you were growing up, some of which you even followed! How late you could stay out, at what age you could have your own phone or car, when you could take your first job, and when you could begin dating. What guided the creation of their policies? Most likely, practical experience and perhaps a book or two, though ultimately, the desire to *protect* you.

Public policy is very similar. It draws upon the collective wisdom of a diverse array of resources—people, data, and history—to reach a common public goal. It does not involve the creation of new knowledge—which is what we refer to as research and creative activity, but it does involve the wise use of research outcomes. For example, policy governing the storage of nuclear waste, the amount of carbon dioxide that should be released by coal plants, acceptable levels of heavy metals in drinking water, and the manner in which foreign nationals are evaluated for immigration to the US. In these and numerous other examples, research is an extremely important factor in crafting public policy.

Two key points are worth noting about federal government policy, both of which apply to policy concerning research. First, policy is not necessarily law, and in many cases consists of procedures, rules, and processes, promulgated by cabinet departments and their associated federal agencies, which must be followed to avoid negative consequences (chapters 9 and 10). Exceptions include presidential policies such as executive orders, presidential memoranda, and national security presidential memoranda, which have the effect of law for federal agencies. And of course, policy contained in laws passed by Congress and signed by the president indeed are formal laws and carry legal penalties if not followed.

Second, policy is a statement of intent or guidance that is carried out via a series of actions, many of which are outlined in the policy itself but some of which are left ambiguous. A good example is the famous speech by President John F. Kennedy regarding the Cuban missile crisis of October 1962. He said, "It shall be the policy of this nation to regard any nuclear missile launched from Cuba against any nation in the Western Hemisphere as an attack by the Soviet Union on the United States requiring a full retaliatory response upon the Soviet Union" (John F. Kennedy Library n.d.). That policy statement was unambiguous in its intent but, understandably in that situation, conveyed nothing about how the action would be carried out.

OSTP was established by Congress in 1976 (note the combination of science and technology in the title), with a broad mandate to advise the president on the effects of science and technology on domestic and international affairs. It issues policy guidance to federal agencies in the form of memoranda, sometimes in conjunction with other White House organizations such as OMB. OSTP also frames topics and their associated policy implications via reports issued by NSTC and the President's Council of Advisors on Science and Technology (PCAST). Note that numerous federal policies directly impact the academic research enterprise, such as those governing open access to scholarly publications and data (section 11.2), as well as research compliance (chapter 10).

Some cabinet departments in the US government have chief scientists to advise on policy matters (e.g., NASA, NOAA, and even the secretary of state), and many agencies within them do as well. Congress uses the Congressional Research Service (CRS) to provide input on matters of policy and legal issues, and NASEM, the Government Accountability Office, and NSB all support policy creation as well.

Although research is a vitally important ingredient for creating public policy, the research community has, for decades, been extremely careful to avoid being influenced by politics, personal prejudices, or external pressures in performing its work. Academic tenure in fact was created to protect researchers from external political pressures or other factors that could lead to bias (chapter 8) or inappropriate influence in their studies.

The roles played by each sector of society in creating public policy are clear and must be well understood and respected. Scientists discover and communicate evidence and uncertainties in their findings. Policy analysts consider these results in light of values held by various sectors, and they frame the problems to be addressed as well as recommend possible courses of action. Policymakers and lawmakers then make judgments to determine how the information should be applied, and then ultimately create policy. Policy is enforced in a variety of ways, ranging from congressional oversight and federal agency inspectors general to numerous legal mechanisms available to the law enforcement community.

Research has become somewhat of a battleground in the context of policy for topics such as climate change, energy, genetic engineering and gene drives, stem cell research, hydraulic fracturing, and the fundamental value of the arts and humanities. A good example is climate change research. Some wish to see deep funding cuts for research on this topic, despite overwhelming evidence that such work is essential for guiding key areas of society such as food production, construction in coastal zones, and human health. In this manner, research outcomes are not being used effectively, or are being misused and misinterpreted. This is often referred to as the "politicization of science," or "spinning" research outcomes.

Such has been the case in the COVID-19 pandemic, during which the general public became acutely aware that understanding of the novel coronavirus evolved considerably over time, as did the guidance about it provided by public health officials. This, along with poor coordination of messaging, led to considerable confusion regarding actions to be taken by states, communities, and even individuals, with debates about competing ideas and theories—some grounded in science and others not—playing out in the press, on social media, in Congress, and at other venues. The phrase "follow the science" was frequently heard, even though scientific understanding gained through research was unable to provide the desired final answers, and in fact sometimes contained opposing results. This led to the understandable question: "Which science should be followed?" The research enterprise was performing in extraordinary ways, yet the general public had never before been exposed in this manner to its winding paths, intense debates, uncertainties, and stepwise advances.

In addition, a presumption exists on the part of many, not only in the general public but also in the scholarly community, that no daylight should exist between policy prescriptions and scientific findings. However, in reality, science is but one of numerous inputs to policy, as I saw firsthand during my two years at the White House. Other inputs include implications regarding national security, economics, international relations, health and welfare of citizens, demographics, existing laws and policies—and of course, politics. Policymakers must weigh very carefully these and other considerations, thus resulting in policy outcomes that sometimes run counter to expectations of those who view policy through a narrow lens.

An important lesson learned from the pandemic, and one which has long been recognized, is that researchers must stay "pure" in their efforts and not let politics or other similar factors influence the manner in which they perform their work (see chapters 4 and 9). They also must do their best to educate policymakers and lawmakers about research—about how it contains assumptions and uncertainties, how it rarely produces definitive answers to complex questions, and about how freedom to explore ideas using robust techniques always will be in the best interest of society.

OSTP issued a report (National Science and Technology Council 2022b) on the topic of protecting the integrity of government science, and particularly the use of scientific results in policy. It addressed issues not only regarding the scientific process, but also the communication of results and how they are used. Although the report did not formally define the term "government science," it generally is meant to describe scientific research performed by federal government employees. However, the concepts described are equally applicable to research performed in any organization, public or private.

Finally, many researchers are interested in policy, either so they can play a more active and effective role in its formulation and execution, or because a deeper understanding will assist their ability to explain and follow it. I frequently am asked for advice regarding options to engage in federal research policy, and many exist. First, taking one or more courses in public policy lays an excellent foundation. Even if you already are conducting research, say as a postdoctoral scholar or faculty member, you still can sit in on such courses or read books to gain insight into policy.

Second, as a student or practicing scholar, you can volunteer your services to members of Congress, either in their state or district offices or in their Washington, DC offices. You also can seek similar opportunities within staff offices of congressional committees (section 2.2), though I would suggest this route mostly for nonstudents.

Third, numerous professional societies offer policy fellowships, many of which are immersive and involve spending time in Washington, DC, meeting with various federal officials. Examples include the AAAS Policy Fellowship program (http://www.aaas.org/programs/science-technology-policy-fellowships) and American Academy of Arts and Sciences Humanities Policy Fellows program (http://www.amacad.org/about/fellowships).

Finally, the federal government operates a number of policy programs, one of the most prestigious of which is the White House Fellows Program (http://whff.org) for emerging leaders at all stages of their professional career.

3.5 All Academic Disciplines Created Equal?

The various academic departments and programs we are familiar with today—from chemical engineering and architecture to history, English, and atmospheric science—are a relatively new construct in higher education. The University of Paris, which was one of the first educational institutions established outside the church, in 1231 consisted of four so-called faculties: Theology, Medicine, Canon Law and Arts. Educational institutions originally used the term "discipline" to catalog and archive the new and expanding body of information produced by the scientific community.

Most academic disciplines have their roots in the mid- to late nineteenth-century secularization of universities, especially in Germany, when the traditional curricula were supplemented with nonclassical languages and literatures, social sciences, economics, and technology disciplines such as engineering. In the early twentieth century, new academic disciplines, such as education and psychology, were added. Then, in the 1970s and 1980s, an explosion of new academic disciplines occurred, focusing on specific themes such as media studies, women's studies, and African studies. Interdisciplinary scientific fields of study, such as biochemistry and biomedical engineering, gained prominence as well.

At its core, research and creative activity involve the creation and dissemination of new knowledge and understanding for improving the world around us. Nowhere is this better seen than in public and private academic institutions, where dozens of disciplines coexist and interact to both study the world's most interesting and challenging problems as well as create and study works of beauty and culture to enrich the human experience.

Because all such activity requires money (chapters 2 and 6), funding is extremely important to academic disciplines, and to the institutions housing them. During the past few decades, public funding for public research universities has dropped precipitously (though improving recently), with the costs offset by substantial increases in tuition and fees (figure 3.3). Even endowments for private universities have become problematic. Yet, the value of higher education remains mostly undisputed, not only in terms of much greater lifetime earnings for degree earners, but also in creating an educated citizenry that is foundational to our democratic republic.

Government funding for research is, however, extremely varied across disciplines (figure 2.10), reflecting, in part, the perceived "value" of those disciplines but to a larger degree the different costs of actually performing research and creative activity within them. For example, funding for biomedical research dwarfs the nearest discipline (engineering) by a factor of two. Other life sciences and the physical sciences are a factor of two less than engineering, followed by environmental science and computer science. Social science and psychology are smaller yet, with the arts, fine arts, and humanities essentially at the noise level. However, many philanthropic organizations also fund these latter activities, with private companies, overall, funding nearly three-fourths of all research and development in the US, mostly in applied areas (chapter 2).

Often overlooked in disciplinary research funding profiles, and discussions regarding disciplines, is education. This is rather ironic because research and education are inextricably linked. Specifically, research conducted in the

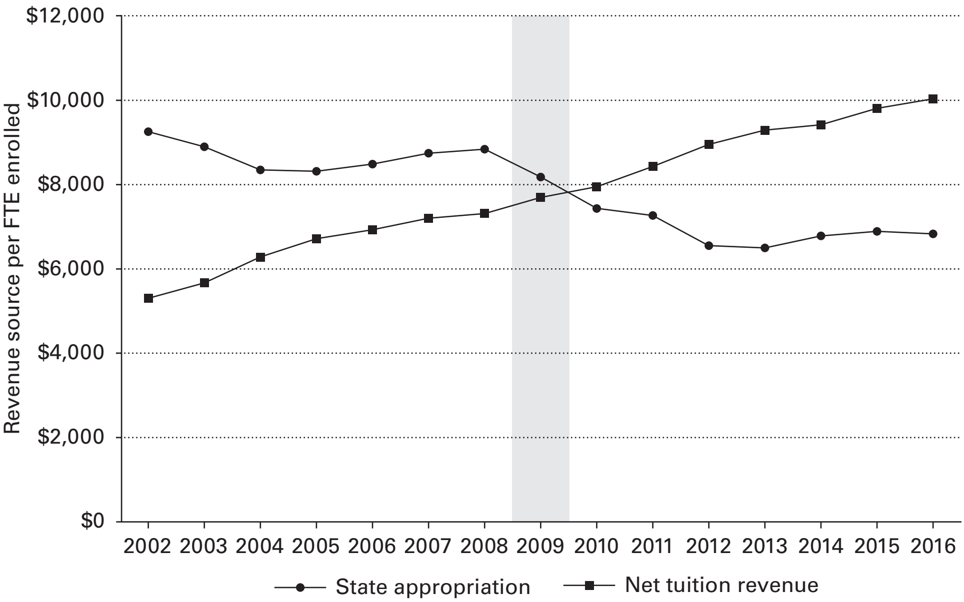

Figure 3.3
Recent trends in state appropriations and net tuition revenue in 2016 dollars per full-time equivalent (FTE) student at public institutions. *Source*: Comrie (2021). Used with permission of Creative Commons License (CC BY 4.0; https://creativecommons.org/licenses/by/4.0/).

discipline of education is foundational to education as a process of learning. Education research results underpin our understanding of how individuals learn. They guide us toward effective pedagogical methodologies and discipline-specific approaches to learning. And they inform education delivery tools (e.g., virtual learning management systems) and analyses describing education progress and factors affecting it (chapter 14).

Conversely, education as a process of learning is foundational to the creation and dissemination of knowledge (i.e., research and creative activity). Next-generation researchers are educated in a wide variety of ways, ranging from standard classroom lectures to active learning environments, individual mentoring by research advisors, independent study, topical-reading and journal clubs, and of course by the research they perform.

Unfortunately, to many, education as a discipline is mistakenly presumed to encompass solely the training of future teachers. In reality, the US government invests considerable funding in education research, mostly through the NSF Directorate for STEM Education (approximately $1 billion per year) and the US Department of Education Institute for Education Sciences (approximately $0.75 billion per year). Numerous other federal agencies also support education research programs, as do private nonprofit foundations.

Society benefits when knowledge advances via research, not only in STEM disciplines but also in the arts, fine arts, and humanities (STEAM, where A represents the arts). It has been said that, during World War II, United Kingdom prime minister Winston Churchill was asked to cut federal funding for the arts in order to direct all possible resources to the war effort. And that Churchill responded, "Then what are we fighting for?" Although the veracity of the attribution is generally accepted as untrue, the response would have been quite appropriate.

3.6 Research and Creative Activity as the Foundation of Innovation

In the early 1950s, when the social compact described in section 3.1 emerged, it was thought fundamental research would yield outcomes for further advancement via applied research, followed by development, followed by commercialization to yield products and services that benefit society. This is known as the "linear model of innovation" for obvious reasons, and it has served very well. In its simplest form, shown in figure 3.4 in the context of academic research, taxes collected by the US Treasury are appropriated by Congress (section 2.2) to federal R&D agencies. These agencies fund both fundamental research as well as applied research and development, in the case of academia usually in response to grant proposals (chapter 6). (Note that other sectors,

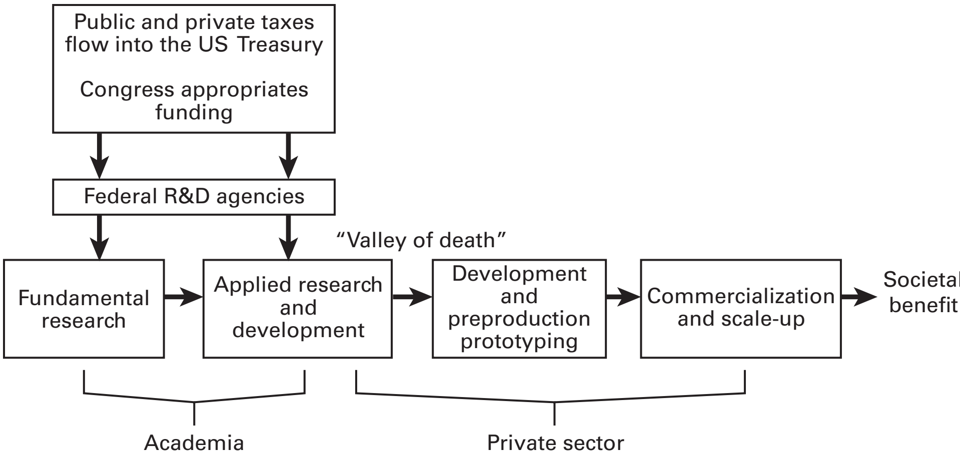

Figure 3.4
Traditional academic linear model of innovation.

including federal agencies, perform applied R&D as well.) Private companies, sometimes in partnership with academia, innovate on these outcomes to commercialize products and services at scale, which yield benefits to society. Sometimes academic institutions have difficulty moving research outcomes from fundamental and applied R&D to the development stage, and in many cases, useful outcomes are never commercialized. This transition therefore is known as the "valley of death" (figure 3.4), with speculative funding in it provided by angel investors, venture capitalists, and other sources (section 12.4).

In reality, the transition from fundamental research to practicable products and services is far more complex, as shown in figure 3.5. Specifically, "innovation" consists not of a set of sequential steps but rather embodies an ecosystem containing multiple, interconnected elements composing an iterative process. Additionally, the starting point often is not fundamental research, but rather innovation itself, namely, the concept behind an interesting idea that requires an integration of multiple components to become reality, including things that already exist. Even when research fails to provide the answer, innovation can fill the gap to make a product, service or public good a reality.

Most public and private colleges and universities are today viewed as engines of innovation and economic development, and most of them have offices to help license inventions to private companies or support faculty who wish to start their own companies (chapters 1 and 12). Students have tremendous opportunities to innovate in so-called maker spaces, where they can rapidly prototype ideas and find support to further develop and even market them. Also,

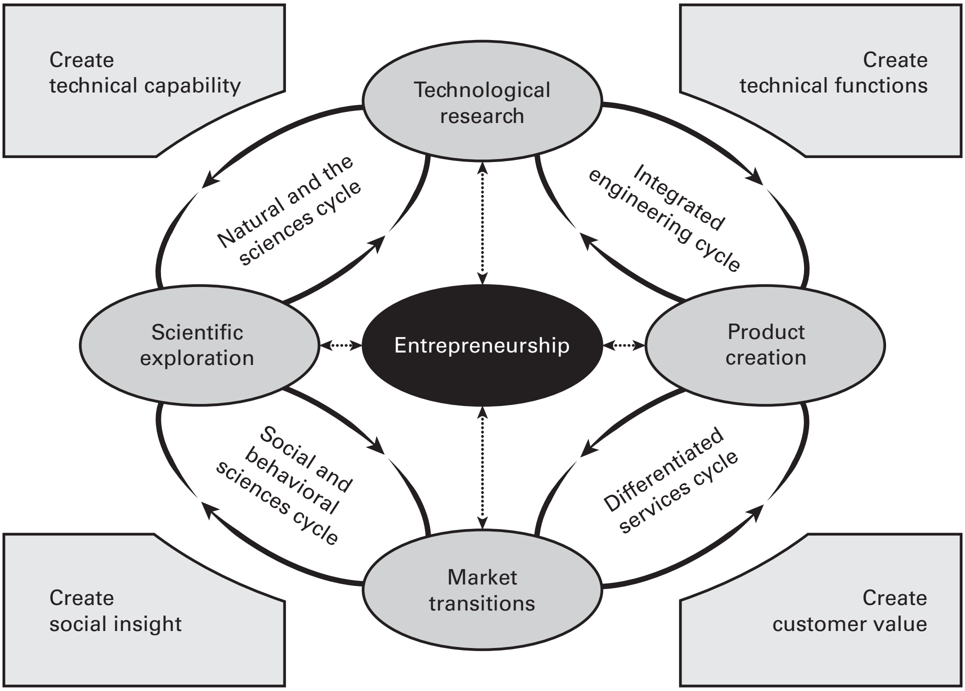

Figure 3.5
Cyclic model of innovation. *Source*: Spill and Mason (2014).

entrepreneurship programs, often housed in colleges of business but engaging all disciplines, including the arts, fine arts, and humanities, have exploded in number and quality and are helping students and faculty be more creative and find ways to make their research ideas and outcomes of practical use to the public.

Some of the more prominent examples of academic innovation include Gatorade, which was invented at the University of Florida, and Warfarin, which is a blood-thinning medicine developed at the University of Wisconsin. You may not have heard of the medicine, but I am certain you've heard of Gatorade. Did you realize it was invented at a research university?

Perhaps the most compelling example of our time is how fundamental research allowed the US and the world to rapidly develop vaccines for COVID-19. Investments in fundamental research made decades ago, which led to rapid genomic sequencing, the utilization of messenger RNA for vaccines, the Internet, and personal computers (which were indispensable for remote learning and work), supercomputers (which proved vitally important for understanding the virus and developing therapeutics and vaccines to combat it), and advanced manufacturing technologies all combined to facilitate an unprecedented response to a global crisis.

Yet, as noted previously and throughout this book, not all academic institutions have sufficient resources to participate in research and creative activity, and thus contribute to innovation and the development of their local and regional communities. In response, creative multi-institutional partnerships and regional hubs of innovation are emerging as partial solutions, along with national programs directing federal funding to specific types of institutions.

Ultimately, research is the "seed corn" of our future—the future of feeding the world, moving people around, communicating with one another, sharing information, remaining secure and healthy, understanding ourselves and our history, and creating beauty that reflects the very best about the human spirit. To compromise support for, and not ensure clear public recognition of the inestimable value of research and creative activity, is to place unnecessary and harmful constraints on our future and that of our children and grandchildren. We, as researchers, own the responsibility of telling the story. Not as we would in some technical journal, but in everyday language, with a context that shows why the work is important, and with humility and gratitude for the public funding that enables it. And we, as researchers, must continue advocating for research funding to the broad array of academic institutions in America so all can contribute and help every student and scholar realize their full potential.

Assess Your Comprehension

1. What is the "social compact" between researchers and taxpayers?
2. Who was Vannevar Bush and what role did he play in shaping America's research enterprise?
3. What factors are key to maintaining trust in America's research enterprise?
4. Describe public confidence in leaders of the scientific community relative to other institutions and sectors in the US.
5. List key factors in shaping public understanding of research and creative activity.
6. Describe the two most important factors in balancing research progress with belief systems and ethical views held by the public.
7. What problems can arise when researchers categorize a given individual or organization in the context of sharing research results?

8. Describe the mission of the Office of Science and Technology Policy (OSTP).
9. List the different roles in setting public policy played by scientists, policy analysts, lobbyists, and lawmakers.
10. In what ways can research outcomes be misused or politicized, and what actions can be taken to prevent this from occurring?
11. Provide a brief timeline of the evolution of academic disciplines.
12. Describe recent trends in state funding for higher education compared to tuition revenues and the reasons for them.
13. Describe the linear model of innovation and its limitations.
14. Describe the cyclic model of innovation and compare it to the linear model.

Exercises to Deepen Your Understanding

Exercise 1: Our views on topics, especially those of a controversial nature, are shaped by a number of factors. Select one or two topics in research and creative activity about which you have clear opinions and describe how your opinions developed over time. What factors or individuals influenced your thinking, including belief systems and ethics, and have your views changed with time? Why or why not? Now explore the views of others on the same topic, either by speaking with individuals or via information from Internet sources and compare and contrast them with your own. Do you see value in examining opposing views? To what extent do politics, belief systems, ethics, religion, race, culture, or other factors impact your answer regarding the views held by others?

Exercise 2: Research results play an important role in the development of policy at the local, regional, and national levels. For this exercise, select a policy issue of personal interest and use the Internet to gather information for evaluating the roles played by research in setting the policy. Examples you may wish to consider include genetically modified foods and plants, immigration, gun control, climate change, safe drinking water, community expansion, poverty, racism, crime, and urban development. You need not draw from this list—the examples are provided merely to stimulate your thinking.

Exercise 3: Research and creative activity are foundational to our health, economic and national security, global competitiveness, and quality of life. Yet, funding is quite varied as a function of discipline, partly because of the associated intrinsic costs, and partly because of the value attached by society and funding organizations to the nature of the work itself. In light of existing relative funding levels, provide a series of arguments for increasing funding in science, health and engineering disciplines at the expense of the arts, fine arts, and humanities, and then perform the reverse exercise. Provide justification and data for your arguments and consider also how funds might be utilized if they are removed from the research enterprise altogether and, for example, redirected to public assistance programs.

Exercise 4: This chapter lists a number of organizations, both public and private, that advise the federal government on research policy. Select three of them, spanning a broad space, and compare and contrast their missions, approaches, political alignments (as are relevant), and positions taken, especially in the form of reports to Congress or the White House. To what extent are these activities grounded in facts and supported by data or hard evidence, and are the facts and data presented in an unbiased, objective manner or grounded more in ideology and perception? Do you find evidence for common ground, and if so, how would you go about persuading the organizations to collaborate productively?

Exercise 5: Tenure is an important feature in most colleges and universities and was established to protect faculty pursuit of research, creative activity, and other scholarly and educational endeavors from undue external influences and pressures. This "academic freedom" ensures that scholars can pursue especially controversial topics without fear of retribution, provided they adhere to principles of honesty, integrity, fairness, objectivity, and so on. Those who secure tenure at an academic institution can only be terminated for cause, and for especially egregious activities as outlined in institutional rules and regulations. Tenure has long been a controversial topic, viewed by some as guaranteeing a job for life and inviting underperformance while viewed by others as essential to the conduct of scholarship. Conduct a review of the origin of academic freedom and tenure and outline arguments for retaining tenure, eliminating it, and modifying it. To what extent do you believe tenure is important for ensuring that research itself remains "pure," as discussed in this chapter? What consequences do you feel might arise if tenure is eliminated?

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