

# Booms, Busts, and the World of Ideas: Enrollment Pressures and the Challenge of Specialization

by *David Kaiser*\*

## ABSTRACT

Historians of recent science face a daunting challenge of scale. Local case studies—our principal means of interrogating past scientific practices—fail to capture the sweep and texture of some of the most dramatic changes in scientific life since World War II. During that period, most facets of research grew exponentially, from numbers of practitioners to numbers of research articles published in any given specialty. The explosive growth placed unprecedented pressure on the intellectual coherence of various disciplines. Drawing on examples from the postwar physics profession in the United States, I suggest that simple quantitative methods can aid in elucidating patterns that cut across isolated case studies, suggesting themes and questions that can guide close, archival research.

## CYCLES, PATTERNS, AND THE CHALLENGE OF SCALE

For some time, historians of science have recognized a mismatch between many of our most prized methodological approaches and whole classes of phenomena that demand scrutiny. The challenge seems especially acute for sciences of the past sixty years. There is a problem of scale. Close-focus case studies, deep archival excavations, microhistories, and comparable investigations inspired by the sociological and ethnographic experiments of the 1970s and 1980s have enlivened our understanding of the cultures and practices of science enormously. Never again should historians assume that knowledge claims or laboratory techniques traveled effortlessly from off-scale mind to off-scale mind through the ages; our eyes are rightly focused on the local and contingent. Yet these tools of inquiry seem to be no match for the brute fact of exponential growth—the extraordinary expansion of people, places, and papers that has marked the scientific life at least since World War II. To date, no deeply satis-

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My thanks to Robert Kohler, Kathryn Olesko, Bruno Strasser, and two anonymous referees for helpful suggestions on an earlier draft, and to Alex Wellerstein for preparing the figures. The following abbreviations are used for archival sources: AIP-EH—Elmer Hutchisson papers in NBL; AIP-EMD—Education and Manpower Division records in NBL; AIP-HAB—Henry A. Barton papers in NBL; CIT—California Institute of Technology archives, Pasadena; LIS—Leonard I. Schiff papers, Stanford University Archives, Palo Alto, Calif.; NBL—Niels Bohr Library, American Institute of Physics, College Park, Md.; PR-AR—*Physical Review* annual reports, in the editorial office of the American Physical Society, Ridge, N.Y.; UCB—Bancroft Library, University of California, Berkeley.

fying synthesis has emerged from averaging over dozens of small-scale studies; no clear synthesis has coagulated from the clutter of individual case units.<sup>1</sup>

The challenge of scale is hardly new. Decades ago, Lucien Febvre, Fernand Braudel, and their colleagues in the *Annales* school sought some means to capture the *longue durée*. Within the history of science, scholars like Derek Price pursued their own methods to fathom large-scale phenomena and long-term patterns. Unlike in their day, vast digital databases are now available, huge storehouses of information on dissertations filed, articles published, and grants received. The databases are no panacea—number crunching will never replace the careful sifting of meanings from subtle and dense sources. But let us not be afraid to count. Quantitative tools can complement historical analysis and help to direct it, opening up new questions, suggesting new patterns, and helping to spot those topics, people, or places on which close-focus scrutiny might yield the richest rewards. With their power to telescope between scales of activity, from the lab bench to the nation-state, these tools offer one way to try to piece together a new amalgamated account of scientific change.

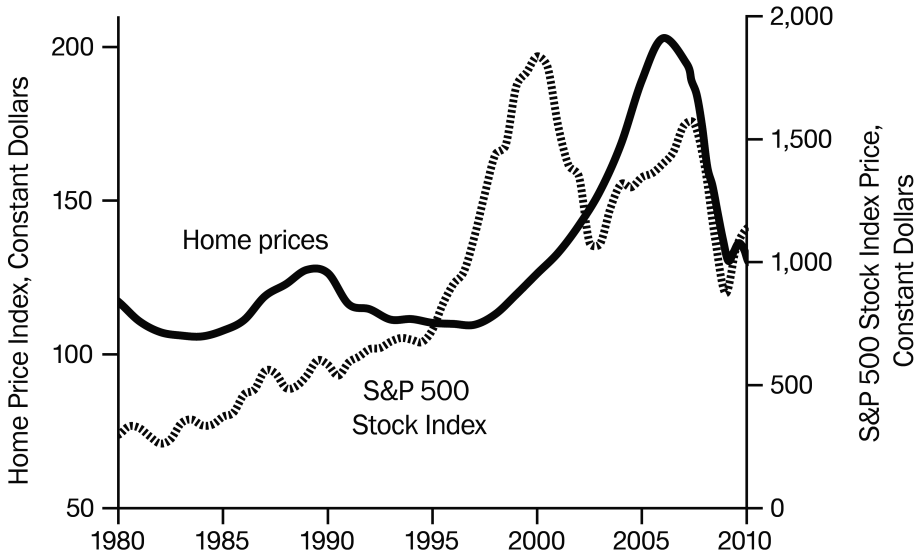
Back in the 1960s, Price found his favorite graph: the logistic (or S-shaped) curve. Whether measured in terms of numbers of authors or numbers of publications, many scientific fields began with a burst of exponential growth followed by saturation and an eventual steady state. The same pattern held for many other features of modern science, ranging from the number of known chemical elements at a given time to the energies achieved by particle accelerators. Price got a lot of mileage from his simple curve; he came to see it everywhere. The ubiquity of these logistic curves, and their repeated appearance from the age of Galileo and Newton to the present day, suggested to Price that there might exist some universal, underlying structures of science. Though the methods were distinct, Price's quest for universality was shared by other eager modelers of science from that time, including Thomas Kuhn.<sup>2</sup>

Price's model was focused mainly on stasis and equilibrium—long-term periods of relative stability—not unlike Kuhn's picture of normal science punctuated by the occasional revolution. Perhaps inevitably, given more recent world events, I have become interested in a rather different defining shape. When we start to count things from the postwar era, a stark pattern quickly emerges: the speculative bubble. The shape itself has become familiar to many of us. Choose your (least) favorite example: stock prices or real estate values in recent times, the fabled tulip craze that gripped Amsterdam in the 1630s, or the South Sea Bubble of 1720 that nearly bankrupted Isaac Newton (among many others).<sup>3</sup> Such bubbles share a common form. They are bid up by earnestness combined with runaway hype and hope and amplified by various feedback mechanisms until the whole house of cards comes tumbling down. Like Price's logistic curve, bubbles begin with an exponential climb. Unlike in Price's pet

<sup>1</sup> See, e.g., articles by Robert Kohler and others in the "Focus" section "The Generalist Vision in the History of Science," *Isis* 96 (2005): 224–51, and references therein. See also Lorraine Daston and Peter Galison, *Objectivity* (New York, 2007), 35–6, 47–50.

<sup>2</sup> Price, *Little Science, Big Science* (New York, 1963), chap. 1. See also Price, *Science since Babylon* (New Haven, Conn., 1961); Kuhn, *The Structure of Scientific Revolutions* (Chicago, 1962).

<sup>3</sup> On the early modern bubbles, see esp. Simon Schama, *The Embarrassment of Riches: An Interpretation of Dutch Culture in the Golden Age* (Berkeley and Los Angeles, 1988), chap. 5; Anne Goldgar, *Tulipmania: Money, Honor, and Knowledge in the Dutch Golden Age* (Chicago, 2007); Richard S. Westfall, *Never at Rest: A Biography of Isaac Newton* (New York, 1980), 861–2; Thomas Levenson, *Newton and the Counterfeiter: The Unknown Detective Career of the World's Greatest Scientist* (Boston, 2009), 244–5.

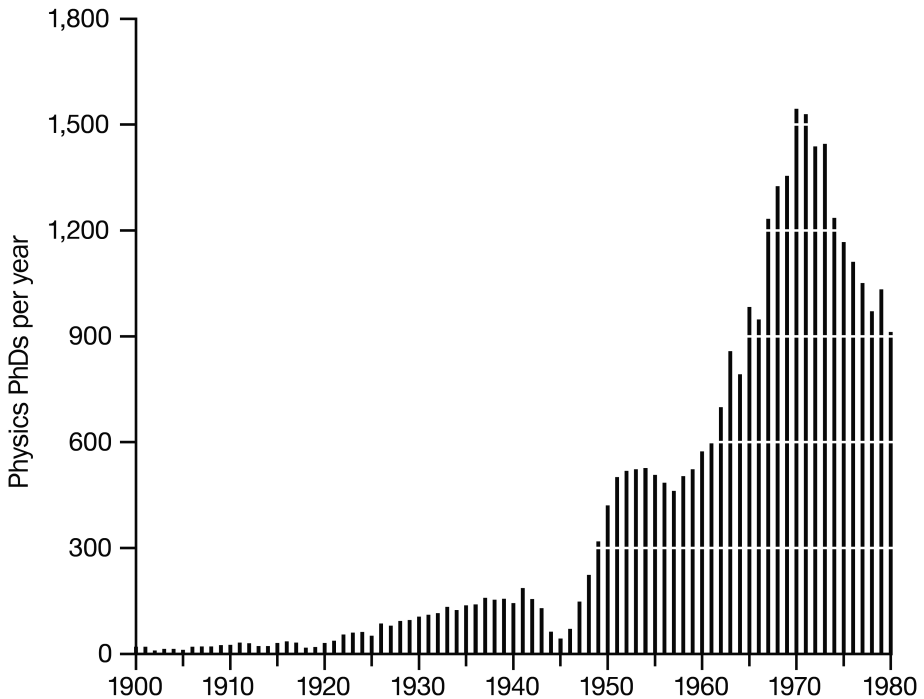


**Figure 1.** Recent examples of speculative bubbles, revealing their characteristic shape. The black line shows the inflation-adjusted US home price index, and the dashed gray line shows the inflation-adjusted Standard & Poor's 500 stock index. Based on data compiled by the Yale economist Robert Shiller, available at <http://www.econ.yale.edu/~shiller/data.htm> (accessed 2 January 2011).

graph, however, no sustainable stasis is achieved; the fall is as sharp as the rise (see fig. 1).

We all are painfully aware of speculative bubbles in the financial world these days. Though slower moving, similar processes have characterized academic life as well, especially (though not exclusively) in the United States since World War II. The pattern is particularly clear in the case of student enrollments. The classrooms of American colleges and universities bulged like never before following World War II. Several major changes, including the GI Bill, brought over two million veterans into the nation's institutions of higher education. Enrollments in nearly every field rose exponentially. Just as quickly, enrollments across nearly all disciplines in the United States faltered in the early 1970s, amid the earliest stirrings of stagflation, détente, and massive cuts in education and defense spending. As we will see in the following section, one case illustrated the general pattern in starkest form: graduate-level enrollments in physics. Physicists encountered the vast shifts first and most acutely—they experienced the extremes of what quickly became the norm. Their enrollments served as a bellwether in good times and bad. Rising fastest and falling sharpest, physicists' enrollment trends heralded systemic transitions throughout American intellectual life (fig. 2).

Simple time-series graphs like this one elicit several follow-up questions. Who wanted all these physics students, and why? As I discuss in the third section, the suggestive similarity in shape between figures 1 and 2 is no mere coincidence. The dynamics behind the physicists' enrollment curve bore all the classic features of a speculative bubble. The dramatic oscillations in student numbers, meanwhile, point beyond questions of policy and recruitment. What effects, if any, did these sharp



**Figure 2.** Number of physics PhDs granted by US institutions per year, 1900–80. Based on data available in National Research Council, *A Century of Doctorates: Data Analysis of Growth and Change* (Washington, D.C., 1978), 12; National Science Foundation, *Division of Science Resources Statistics, Science and Engineering Degrees, 1966–2001, report no. NSF 04–311* (Arlington, Va., 2004).

swings have on physics itself—on the intellectual landscape of the field? The fourth section of this article illustrates how the sudden pressure of numbers after the war threatened physicists’ own vision of their field. Abstract concerns over specialization collided with the practical requirements of processing and publishing the latest research findings; unprecedented pedagogical pressures reshaped physicists’ long-standing habits of communicating results and organizing knowledge. Finally, in the closing section, I note that the Cold War bubble of figure 2 was no isolated event. Rather, boom-and-bust cycles became a repeating phenomenon. The fact that most academic fields had enrollment curves similar to figure 2 suggests looking for comparable epistemic effects in other disciplines as well.

Unlike Price, with his high hopes for his logistic curve, I do not believe that speculative bubbles have been lurking always and everywhere in the conduct of science. They are no silver bullet, unlocking hidden patterns in all places and eras. Their partial character is part of their appeal. I am fascinated precisely by the modest range of scales they seem to capture: patterns and cycles that unfolded over a few decades, rather than centuries; phenomena that seemed to affect many fields of inquiry but not all of them, in similar but not identical ways. On this point I draw particular inspiration from literary scholar Franco Moretti. As Moretti has emphasized, “cycles constitute *temporary structures within the historical flow*.” He continues: “The short span is all flow and no structure, the *longue durée* all structure and no flow, and cycles

are the—unstable—border country between them. Structures, because they introduce repetition in history, and hence regularity, order, pattern; and temporary, because they're short (ten, twenty, fifty years . . .)."<sup>4</sup> Much as Moretti has argued, one-dimensional plots like figure 2 will never be the last word in our efforts to understand the past. But they can be a productive starting point, prompting new questions as we aim to make sense of broad patterns in the recent history of intellectual life.

### THE POSTWAR POPULATION EXPLOSION

A well-known historiographical arc has traced the transition from the gentleman-amateurs of natural philosophy to professional scientists, with a convenient-enough pivot marked by William Whewell's invention of the term *scientist* in 1840. To this genealogy we may add a third phase: the mass-produced scientist. The new creature was at least as different from the nineteenth-century "man of science" as that idealized figure had been from the early modern philosopher-courtier. They differed in self-perception as well as means of production. Robert Kohler once likened graduate training in the United States during the late nineteenth century to a "PhD machine." Yet as Frederick Taylor and Henry Ford knew so well, not all machines operate on the same scale or with comparable efficiencies. During the 1950s, the mechanisms of graduate training evolved from cottage industry to factory-scaled production.<sup>5</sup>

The United States underwent a massive experiment in social engineering during the decades after World War II, in what might be called the credentialing of America. Higher education was booming. The proportion of twenty- to twenty-four-year-olds who received a bachelor's degree doubled between the early 1950s and the early 1970s, while the proportion of twenty-five- to twenty-nine-year-olds who received a PhD quadrupled. The increases were hardly distributed evenly across fields. Between 1950 and 1963, for example, the nation's population increased by 25 percent (from around 152 million to 190 million); its total labor force grew by just shy of 17 percent (from 65 million to 76 million workers); while its pool of PhD-trained scientists and engineers grew by a whopping 136 percent (from 45,000 to 106,000). That is, the PhD-level scientific and technical workforce grew eight times more quickly than the total labor force.<sup>6</sup>

<sup>4</sup> Moretti, *Graphs, Maps, Trees: Abstract Models for a Literary History* (New York, 2005), 14; emphasis in the original. My thanks to Michael Gordin for bringing Moretti's book to my attention.

<sup>5</sup> See esp. Kohler, "The Ph.D. Machine: Building on the Collegiate Base," *Isis* 81 (1990): 638–62; Steven Shapin, "The Image of the Man of Science," in *The Cambridge History of Science*, vol. 4, *Eighteenth-Century Science*, ed. Roy Porter (New York, 2003), 159–83; Shapin, *The Scientific Life: A Moral History of a Late Modern Vocation* (Chicago, 2008).

<sup>6</sup> On credentialing, see also Frank Newman, "The Era of Expertise: The Growth, the Spread, and Ultimately the Decline of the National Commitment to the Concept of the Highly Trained Expert, 1945 to 1970" (PhD diss., Stanford Univ., 1981). The statistics on degrees per age cohort were calculated from data in the following sources: on US bachelor's degrees, Douglas L. Adkins, *The Great American Degree Machine: An Economic Analysis of the Human Resource Output of Higher Education* (Berkeley, Calif., 1975), 190–4, with additional data supplied by Roman Czujko, director of the American Institute of Physics (AIP) Statistical Research Center, personal communication to the author, 19 January 2005; on US PhDs, National Research Council, *Century of Doctorates* (cit. fig. 2 caption), 7; on US population cohorts, Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, *World Population Prospects: The 2004 Revision*, available at [http://www.un.org/esa/population/publications/WPP2004/WPP2004\\_Volume3.htm](http://www.un.org/esa/population/publications/WPP2004/WPP2004_Volume3.htm) (accessed 30 January 2012), and *World Urbanization Prospects: The 2003 Revision*, available at <http://www.un.org/esa/population/publications/wup2003/WUP2003Report.pdf> (accessed 30 January 2012). On changes in the US labor force between 1950 and 1963, see *Impact of Federal Research and Develop-*

Within this constellation, physics grew fastest of all. According to data collected by the National Science Foundation's National Register of Scientific and Technical Personnel—a register created during the early 1950s to facilitate the federal government's mobilization of scientists in times of war—between 1954 and 1970 the number of professional physicists employed in the United States grew substantially faster than the numbers of all other scientific professionals: 210 percent faster than earth scientists, 34 percent faster than chemists, 22 percent faster than mathematicians, and so on.<sup>7</sup>

Physics had not always led the pack. Averaged over the period 1890–1941, the annual number of physics PhDs granted in the United States doubled every thirteen years—slower than chemistry and mathematics; slower, too, than history, English, and foreign languages. During the Depression years, the growth rate for physics slowed even further. On the eve of World War II, it would have taken eighteen years to double the annual output of physics PhDs in the United States, based on the pattern set during 1930–9. The situation changed immediately after the war. Between 1945 and 1951, the annual output of physics PhDs from US institutions doubled every 1.7 years—a tenfold increase in rate. No other field came close: physics grew nearly twice as quickly as chemistry, for example, and fully 12 percent faster than its nearest competitors, engineering and psychology. By the mid-1950s, American institutions required just two years to graduate as many physics PhD recipients as the entire country had produced between 1861 and 1929.<sup>8</sup>

The rapid rise in numbers of young physicists sprang from much more than simple demographics. From the bumps and wiggles in the running tally of new physicists one may read off the changing political economy of the postwar years: the flood of returning veterans from World War II, the impact of the Korean War, the hardening of the Cold War and the Sputnik surprise, and the dramatic reversal of national priorities years into the slog of Vietnam. At best, the baby boom—which first hit American colleges and universities in 1964, driving first-year undergraduate enrollments up by 37 percent from the previous year—played a supporting role in setting the pace of change (figs. 3 and 4).<sup>9</sup>

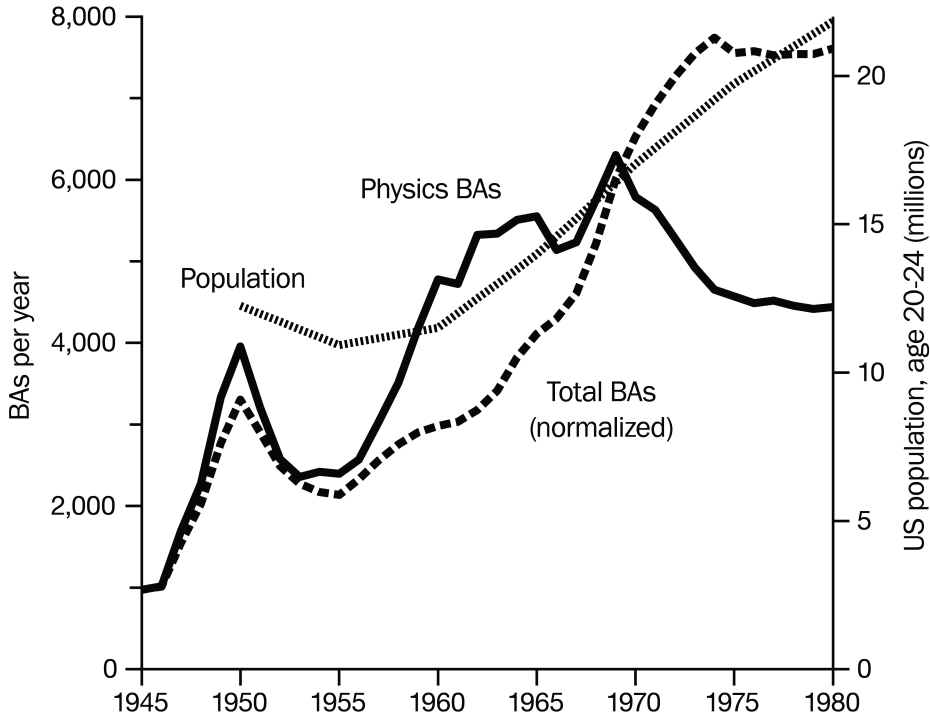
Developments in other countries help to put the American situation in context. Consider the United Kingdom and Canada, wartime allies of the United States and partners in the Manhattan Project to design and build nuclear weapons. By the postwar years, Britain and Canada also shared a system of higher education and advanced

*ment Policies on Scientific and Technical Manpower: Hearings Before the Subcomm. on Employment and Manpower of the S. Comm. on Labor and Public Welfare*, 89th Cong. 142 (1965) (testimony of Bowen C. Dees, associate dean of planning, National Science Foundation).

<sup>7</sup> Based on data in the series of National Science Foundation reports titled *American Science Manpower* (Washington, D.C., 1959–71). On the National Register, see the form letter from Henry A. Barton (director, AIP), 16 November 1950, a copy of which is in LIS, box 1, folder "Amer. Inst. of Physics (AIP), General"; "Scientific Manpower Studies," in *The Third Annual Report of the National Science Foundation* (1953), 26–33, available at <http://www.nsf.gov/pubs/1953/annualreports/start.htm> (accessed 18 January 2012).

<sup>8</sup> David Kaiser, "Cold War Requisitions, Scientific Manpower, and the Production of American Physicists after World War II," *Historical Studies in the Physical and Biological Sciences* 33 (2002): 131–59, on 134–6, 157–9. See also Spencer Weart, "The Physics Business in America, 1919–1940: A Statistical Reconnaissance," in *The Sciences in American Context: New Perspectives*, ed. Nathan Reingold (Washington, D.C., 1979), 295–358.

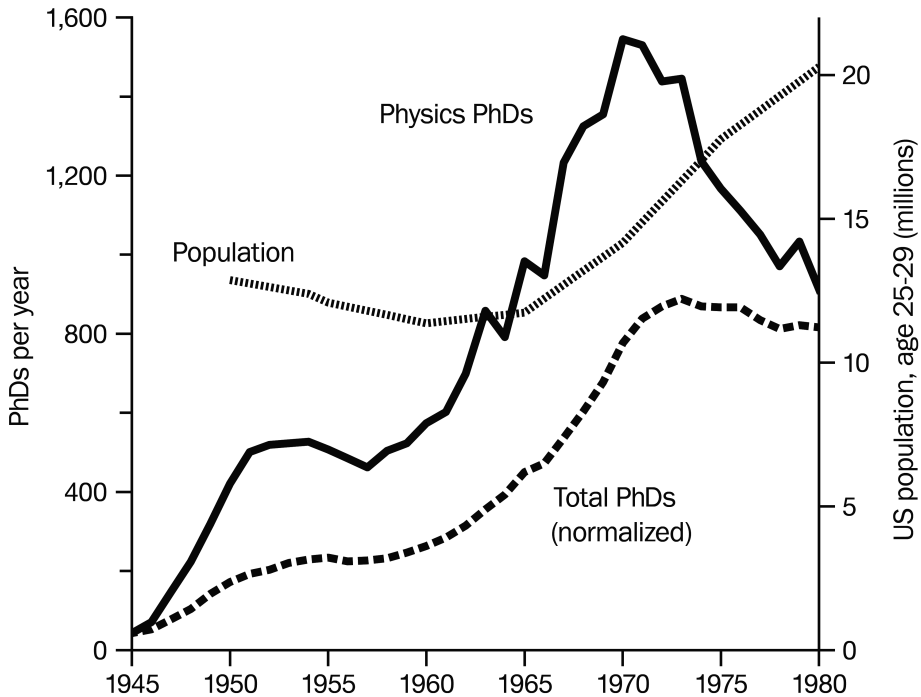
<sup>9</sup> On the baby boom, see Todd Gitlin, *The Sixties: Years of Hope, Days of Rage*, rev. ed. (New York, 1993), 11–21, 164.



**Figure 3.** Number of physics bachelor's degrees granted by US institutions per year, 1945–80. Also shown are the total number of US bachelor's degrees granted in all fields per year, normalized to the number of physics degrees in 1945 (to show relative rates of change), and the portion of the US population between the ages of twenty and twenty-four. To convert the normalized BAs to total BAs, multiply by 122. The data come from Adkins, *Great American Degree Machine, 190–4*; Czujko, personal communication; and United Nations Secretariat, *World Population Prospects* (All cit. n. 6).

degrees broadly similar to that of the United States, with the PhD degree increasingly seen as a necessary prerequisite for professional scientific employment.<sup>10</sup> As in the United States, those countries likewise saw very rapid growth in the numbers of new physics PhDs granted immediately after the war; there, too, the pace set by physics exceeded that of most other fields. Yet unlike in the United States, physics quickly settled into the pattern set by higher education more generally. In Britain, for example, the number of physics PhDs granted each year doubled at precisely the same rate as for all fields combined during the decade after Sputnik; the Soviet satellite elicited no new burst in physicist training. In Canada, meanwhile, the doubling rate for physics PhDs slipped to nearly 20 percent slower than the rate for all fields combined during the same time interval. In other nations with similar Anglo-American education systems, such as Australia, the growth in advanced physics training re-

<sup>10</sup> Burton R. Clark, *Places of Inquiry: Research and Advanced Education in Modern Universities* (Berkeley and Los Angeles, 1995); Yves Gingras, *Physics and the Rise of Scientific Research in Canada*, trans. Peter Keating (Montreal, 1991). See also Clark, ed., *The Research Foundations of Graduate Education: Germany, Britain, France, United States, Japan* (Berkeley and Los Angeles, 1993), pt. 2; Jean Babcock et al., "American Influence on British Higher Education: Science, Technology, and the Problem of University Expansion, 1945–1963," *Minerva* 41 (2003): 327–46.



**Figure 4.** Number of physics PhDs granted by US institutions per year, 1945–80. Also shown are the total number of US PhDs granted per year in all fields, normalized to the number of physics degrees in 1945 (to show relative rates of change), and the portion of the US population between the ages of twenty-five and twenty-nine. To convert the normalized PhDs to total PhDs, multiply by 38. The data come from National Research Council, *Century of Doctorates*, 7, 12; National Science Foundation, *Science and Engineering Degrees* (Both cit. fig. 2 caption); United Nations Secretariat, *World Population Prospects* (cit. n. 6). See also the AIP graduate student surveys, 1961–75, available in AIP-EMD; additional data supplied by Roman Czujko, personal communication to the author, 11 April 2002.

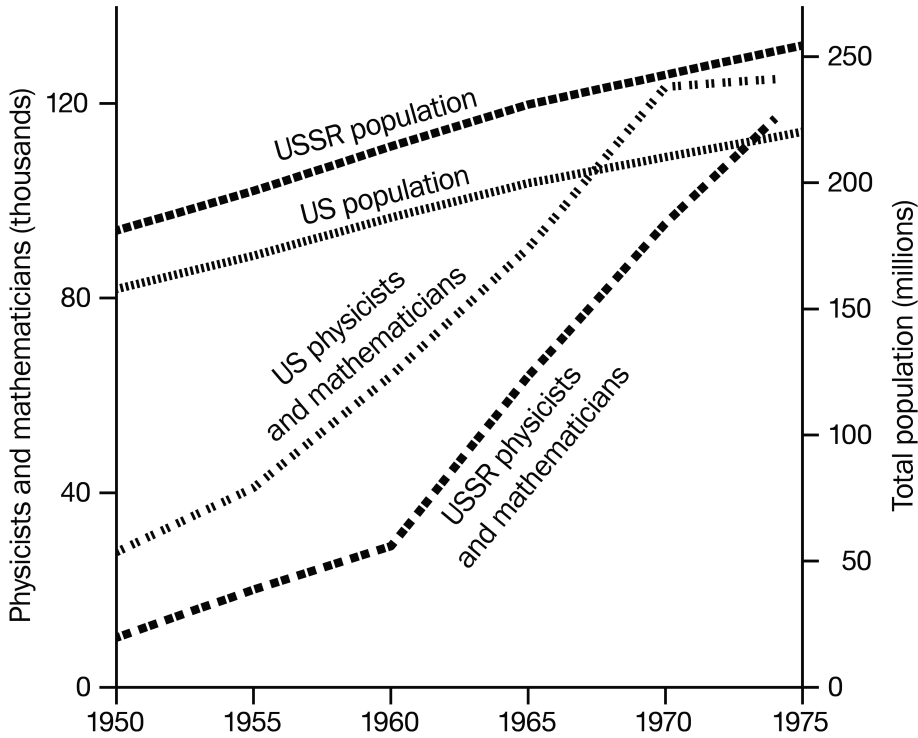
mained a largely demographic effect, mirroring overall population growth—even after Australia inaugurated its own nuclear power program in the mid-1950s.<sup>11</sup>

The country with the pattern closest to that of the United States proved to be the Soviet Union. In both countries, physics grew faster than any other field. In the Soviet Union, new physicists entered the labor force at an average annual growth rate of 10.7 percent between 1951 and 1974: more than one-and-a-half times faster than the pace for all scientists combined, and fully 15 percent faster than the growth rate for engineers. In fact, the stocks of professional physicists and mathematicians in both Cold War superpowers grew at nearly the same steep pace for a quarter century, far exceeding rates of overall population growth (fig. 5).

All told, between 1945 and 1975, 124,000 individuals completed undergraduate degrees in physics in the United States, while 24,000 completed PhDs in the subject.

<sup>11</sup> Based on data in Roger Bilboul, ed., *Retrospective Index to Theses of Great Britain and Ireland, 1716–1950* (Santa Barbara, Calif., 1975); Geoffrey M. Paterson and Joan E. Hardy, *Index to Theses Accepted for Higher Degrees by the Universities of Great Britain and Ireland and the Council for National Academic Awards* (London, 1951–); Gingras, *Physics and the Rise* (cit. n. 10), appendixes; *The Union List of Higher Degree Theses in Australian University Libraries* (Hobart, 1961–91).





**Figure 5.** Total number of physicists and mathematicians in the United States and Soviet Union, 1950–74. (The Soviets did not distinguish between physicists and mathematicians for such accounting; all were graduates of the physico-mathematical faculties in the Soviet universities. Hence, both groups have been included in the American tally as well.) Also shown are the total populations of both countries. The data on physicists and mathematicians are from Catherine P. Ailes and Francis W. Rushing, *The Science Race: Training and Utilization of Scientists and Engineers, US and USSR* (New York, 1982), 107; the population data are from United Nations Secretariat, *World Population Prospects and World Urbanization Prospects* (cit. n. 6). Ailes and Rushing used US Bureau of Labor Statistics data for the US case.

More and more of the nation's universities retooled, adding graduate education in physics to their roster of offerings. In 1950, 52 institutions in the United States conferred PhDs in physics. In 1960 the number had risen to 78; by 1970, it was 148.<sup>12</sup> Ultimately, such runaway growth could not be sustained; or, as physicists might say, for every action there must be an equal and opposite reaction. And so there was. Physics PhDs in the United States peaked in 1971, then fell precipitously.

A painful conjunction triggered the fall. Internal audits at the Department of Defense began to question whether the postwar policy of funding basic research on university campuses—which had underwritten the education of nearly all physics graduate students since the war—had produced an adequate return on investment. As the Vietnam War raged, campus protesters grew equally dissatisfied with the Penta-

<sup>12</sup> The numbers of US institutions granting physics PhDs were computed from data in the ProQuest Dissertations and Theses Database, accessed via <http://www.proquest.com.libproxy.mit.edu/en-US/products/dissertations/> and available from <http://www.proquest.com>.

gon's presence on campus and often targeted physicists' facilities. To supply troops for the escalation of fighting, meanwhile, military planners began to revoke draft deferments—first for undergraduates in 1967, then for graduate students two years later—reversing a twenty-year policy that had kept science students in their classrooms. Détente with the Soviets and the onset of stagflation in the early 1970s exacerbated the situation, as each induced substantial cuts in federal spending for defense and education.<sup>13</sup>

The fast-moving changes affected nearly every field across the universities, but none more severely than physics. While annual conferrals of PhDs across all fields slid by a modest 8 percent between their peak in the early 1970s and 1980, physics PhDs plummeted by fully 47 percent. Several fields experienced sharp downturns—mathematics went down by 42 percent, history 39 percent, chemistry 31 percent, engineering 30 percent, and political science 20 percent from their early 1970s highs—but physics led the way.<sup>14</sup> Demand for young physicists vanished even more quickly. Whereas more employers than student applicants had registered with the Placement Service of the American Institute of Physics (AIP) throughout the 1950s and into the mid-1960s, by 1968 young physicists looking for jobs outnumbered advertised positions by nearly four to one. Three years later, the gap had widened much further: 1,053 physicist job seekers registered, competing for just 53 jobs.<sup>15</sup>

#### SPECULATIVE BUBBLES

Economists have developed sophisticated models to try to understand such vacillations in the scientific labor market. The most prominent has been nicknamed the “cobweb” model, based on the pattern sketched out on a graph of wages versus workforce. Increase demand for specialists in a particular field, and wages for those workers should rise as well. The upturn in wages will encourage more students to flock to the discipline, increasing the labor pool available, which will ultimately overshoot demand. The glut in supply will in turn lead to lower wages, discouraging some students in the next cohort from pursuing that line of work, and so on, keeping the pattern oscillating, cobweb-like, around an idealized market equilibrium. Fancier models have replaced present-day wages (at the time a student needs to decide on a course of study) by projected (future) wages, to take into account the long delays incurred during the training process itself, and other bells and whistles have been added to the basic cobweb model to try to improve its accuracy.<sup>16</sup>

<sup>13</sup> See esp. Daniel Kevles, *The Physicists: The History of a Scientific Community in Modern America*, 3rd ed. (Cambridge, 1995), chap. 25; Stuart W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at M.I.T. and Stanford* (New York, 1993), chap. 9; Roger Geiger, *Research and Relevant Knowledge: American Research Universities since World War II* (New York, 1993), chaps. 8–9; Kelly Moore, *Disrupting Science: Social Movements, American Scientists, and the Politics of the Military, 1945–1975* (Princeton, N.J., 2008), chaps. 5–6.

<sup>14</sup> Calculated from data in National Science Foundation, *Science and Engineering Degrees* (cit. fig. 2 caption).

<sup>15</sup> “Placement Register, Statistical Comparison, APS-AAPT Annual Joint Meeting, 1963 to 1969,” n.d., ca. 1970, and “Summary: Placement Service Register, the American Physical Society Meeting, Washington, D.C.,” 3 June 1971, both in AIP-EMD, box 13, folder “Placement Literature”; “Supply and Demand,” October 1970, in AIP-EMD, box 13, folder “Placement Service Advisory Committee.” See also Kaiser, “Cold War Requisitions” (cit. n. 8), 151–2.

<sup>16</sup> See esp. Kenneth J. Arrow and William M. Capron, “Dynamic Shortages and Price Rises: The Engineer-Scientist Case,” *Quarterly Journal of Economics* 73 (1959): 292–308; Richard B. Freeman, *The Market for College-Trained Manpower: A Study in the Economics of Career Choice* (Cambridge,

A fine model, it has been applied successfully to many sectors of the labor market. Despite decades of concerted effort, however, neither the model nor its many variants have *ever* produced accurate predictions of the bulk flows of supply and demand for scientists and engineers in the United States. An expert panel of economists, statisticians, and public-policy specialists convened by the National Research Council recently concluded:

Interest in predicting demand and supply for doctoral scientists and engineers began in the 1950s, and since that time there have been repeated efforts to forecast impending shortages or surpluses. As the importance of science and engineering has increased in relation to the American economy, so has the need for indicators of the adequacy of future demand and supply for scientific and engineering personnel. This need, however, has not been met by data-based forecasting models, and accurate forecasts have not been produced.<sup>17</sup>

Even dressed in the restrained language of a blue-ribbon technical report, this is a striking admission of failure.

The tremendous surges in American physics enrollments suggest a different economic metaphor: a speculative bubble. Economist Robert Shiller defines a speculative bubble as “a situation in which temporarily high prices are sustained largely by investors’ enthusiasm rather than by consistent estimation of real value.”<sup>18</sup> Shiller emphasizes the roles of hype, amplification, and feedback loops in driving the dynamics of such bubbles. Consumers’ enthusiasm for a particular item—be it a hot new tech stock or a hip loft near Central Park—can attract further attention to that item. Increased media attention, in turn, can elicit additional consumer investment, and the rise in demand will drive up prices. The price increase will become a self-fulfilling prophecy, drawing still more fawning from commentators and investment from consumers. “As prices continue to rise, the level of exuberance is enhanced by the price rise itself,” as Shiller explains. Shiller likens the process to naturally occurring Ponzi schemes, which can sharply boost prices—if only for a while—even in the absence of outright fraud or deliberate deception. Donald MacKenzie likewise emphasizes the feedback dynamics of performativity: the fact that financial models act back on the very markets they are meant to simulate can increase financial markets’ susceptibility to boom-and-bust cycles.<sup>19</sup>

As with stock prices or the housing market, so with graduate training. The Cold War bubble in physics enrollments was fed by earnest decisions based on incomplete or imperfect information, intermixed with hope and hype that had little discernible grounding in fact. Feedback loops between scientists, policy makers, and journalists kept the market for American physicists (and specialists in related fields) artificially inflated. Faulty assumptions that could easily have been checked assumed a seeming

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1971); Glen G. Cain, Freeman, and W. Lee Hansen, *Labor Market Analysis of Engineers and Technical Workers* (Baltimore, 1973); Larry R. Leslie and Ronald L. Oaxaca, “Scientist and Engineer Supply and Demand,” in *Higher Education: Handbook of Theory and Research*, vol. 9, ed. John Smart (New York, 1993), 154–211; National Research Council, *Forecasting Demand and Supply of Doctoral Scientists and Engineers: Report of a Workshop on Methodology* (Washington, D.C., 2000), chap. 2.

<sup>17</sup> National Research Council, *Forecasting Demand and Supply* (cit. n. 16), 1.

<sup>18</sup> Shiller, *Irrational Exuberance*, 2nd ed. (Princeton, N.J., 2005), xvii.

<sup>19</sup> *Ibid.*, chap. 4, quotation on 81; MacKenzie, *An Engine, Not a Camera: How Financial Models Shape Markets* (Cambridge, 2006), chap. 7.

naturalness, hardened by prevailing geopolitical conditions. When those conditions changed abruptly, physics had nowhere to go but down.

Though hardly unique for the time period, my favorite example of the hype-amplification-feedback process concerns a series of reports that were commissioned during the 1950s on Soviet advances in training scientists and engineers. Three major reports were released between 1955 and 1961 to assess the Soviet threat: Nicholas DeWitt's *Soviet Professional Manpower*, Alexander Korol's *Soviet Education for Science and Technology*, and DeWitt's *Education and Professional Employment in the USSR*. Both DeWitt and Korol were Russian expatriates who had relocated to Cambridge, Massachusetts: DeWitt to the new Russian Research Center at Harvard, and Korol to the equally new Center for International Studies at MIT. As we now know, both centers were secretly funded by the CIA.<sup>20</sup>

DeWitt and Korol each urged caution in the interpretation of statistics like annual Soviet degree conferrals—in part because of basic definitional mismatches between types of academic degrees in the Soviet Union and the United States, in part because of serious questions about academic standards at some of the Soviet training centers, and most of all because the Soviet rolls were bloated by correspondence-school students. The latter earned their degrees in science and engineering by sending homework assignments through the mail to overworked instructors, with no benefit of laboratory work or face-to-face instruction. Indeed, the potential for mistaken impressions seemed so serious that Korol refused to tabulate enrollment data from the Soviet and American tallies side by side, in order to avoid “unwarranted implications.”<sup>21</sup> DeWitt printed such comparative tables only after emphasizing all the caveats at length, and even affixing a lengthy appendix on what he called the “perplexities and pitfalls” of interpreting Soviet education statistics. Nonetheless, when he counted up annual degrees in the two countries, it appeared that the Soviets were graduating two to three times more students per year in science and engineering than were American institutions.<sup>22</sup>

That ratio—“two to three times”—quickly took on a life of its own. DeWitt's and Korol's reports had been careful, lengthy, serious affairs. The journalistic coverage, on the other hand, leaned toward the sensationalistic. “Russia Is Overtaking U.S. in Training of Technicians,” announced a typical front-page headline in the *New York Times*; “Red Technical Graduates Are Double Those in U.S.,” echoed the *Washington Post*. Leading spokespeople from the CIA, the Department of Defense, the Joint Congressional Committee on Atomic Energy, and the Atomic Energy Commission routinely trotted out the same stripped-down number (“two to three times”) in public speeches and congressional testimony, with no trace of DeWitt's caveats or cautions. Each proclamation elicited further hand-wringing in the newspapers—all before the

<sup>20</sup> DeWitt, *Soviet Professional Manpower: Its Education, Training, and Supply* (Washington, D.C., 1955); Korol, *Soviet Education for Science and Technology* (Cambridge, 1957); DeWitt, *Education and Professional Employment in the USSR* (Washington, D.C., 1961). On the composition of the reports, see also David Kaiser, “The Physics of Spin: Sputnik Politics and American Physicists in the 1950s,” *Soc. Res.* 73 (2006): 1227–9. For other examples of hype over “scientific manpower” and its effects on enrollments during the Cold War, see Kaiser, “Cold War Requisitions” (cit. n. 8), 142–51.

<sup>21</sup> Korol, *Soviet Education* (cit. n. 20), 407–8.

<sup>22</sup> DeWitt, *Soviet Professional Manpower*, viii, xxvi–xxxviii, 259–61; DeWitt, *Education and Professional Employment*, xxxix, 549–53; Kaiser, “Physics of Spin,” 1229–30 (All cit. n. 20).

surprise launch of the Sputnik satellite in October 1957.<sup>23</sup> Here, in raw form, was the first step in Shiller's model: hype.

Next came amplification. Sputnik helped here; as luck would have it, Korol's long report appeared just two weeks after the Soviet launch. Enterprising physicists leaped on the unforeseen opportunity, flogging DeWitt's number everywhere from emergency meetings with the president to syndicated radio programs and beyond. I. I. Rabi, who had known President Dwight Eisenhower at Columbia University, urged Eisenhower to use Sputnik as a pretext to spur further scientific training in the United States. Elmer Hutchisson, director of the AIP, encouraged his peers to use the "almost unprecedented opportunity" presented by Sputnik to "influence public opinion greatly." Hans Bethe, past president of the American Physical Society (APS), found himself repeating DeWitt's ratio of "two to three times" to journalists and in radio addresses without knowing (as his handwritten notes on typewritten speeches indicate) whence the number had come or how it had been computed. Eager journalists soaked it all up.<sup>24</sup>

Most significant of all, lawmakers and their physicist consultants used the launch of Sputnik and the purported "manpower gap" in science and engineering training to push through the massive National Defense Education Act, signed into law in September 1958. The act unleashed about \$1 billion in federal spending on education (nearly \$8 billion in 2011 dollars), restricted to critical "defense" fields such as science, mathematics, engineering, and area studies. The act represented the first significant federal aid to education in a century: not since the Morrill Land-Grant Colleges Act of 1862 had the federal government intervened so directly in educational matters, which had traditionally been considered the prerogative of state and local governments. One close observer of the legislative wrangling behind the National Defense Education Act concluded that opportunistic policy makers had used the Sputnik scare as a "Trojan horse": the act's proponents had been "willing to strain the evidence to establish a new policy."<sup>25</sup>

Passing legislation is usually a messy affair. The effects, in this case, were crystal clear. During its first four years, the National Defense Education Act supported 7,000 new graduate fellowships, or about 1,750 per year. On the eve of the bill's passage, American institutions had been producing only 2,500 PhDs per year across all of engineering, mathematics, and the physical sciences. The huge federal outlay, in other words, amounted to an overnight increase of 70 percent in the nation's funding capacity to train graduate students in the physical sciences. During that same period,

<sup>23</sup> Benjamin Fine, "Russia Is Overtaking U.S. in Training of Technicians," *New York Times*, November 7, 1954; "Red Technical Graduates Are Double Those in U.S.," *Washington Post*, November 14, 1955. The *New York Times* article responded to a preview of DeWitt's first book-length report: DeWitt, "Professional and Scientific Personnel in the U.S.S.R.," *Science* 120, no. 3105 (1954): 1–4. On further repetition of the "two to three times" claim by public officials and journalists, see Kaiser, "Physics of Spin" (cit. n. 20), 1231–3.

<sup>24</sup> Hutchisson, memorandum to American Institute of Physics Advisory Committee on Education, 4 December 1957, in AIP-EH 3:3; Bethe, "Notes for a Talk on Science Education," n.d., ca. April 1958, in Hans A. Bethe Papers, box 5, folder 4, Division of Rare and Manuscript Collections, Cornell University, Ithaca, N.Y. On Rabi's meeting with Eisenhower on October 15, 1957, see Barbara Barksdale Clowse, *Brainpower for the Cold War: The Sputnik Crisis and the National Defense Education Act of 1958* (Westport, Conn., 1981), 11; Robert Divine, *The Sputnik Challenge: Eisenhower's Response to the Soviet Satellite* (New York, 1993), 12–3; Zuoyue Wang, *In Sputnik's Shadow: The President's Science Advisory Committee and Cold War America* (New Brunswick, N.J., 2008), 75–7.

<sup>25</sup> Clowse, *Brainpower for the Cold War* (cit. n. 24), 91, 87.

the act funded half a million undergraduate fellowships as well as block grants to institutions and added incentives to states to increase science enrollments.<sup>26</sup> Hence the final element in Shiller's model: feedback.

As Shiller is quick to note, speculative bubbles can take hold even without outright chicanery. Such was the case here. The influential physicists who used Sputnik to argue for increased graduate training were not acting inappropriately: it was their job to lobby on behalf of the profession. Increased funding for higher education, moreover, is hardly an evil thing. Yet the cycle of hype, amplification, and feedback quickly came unmoored from any reasonable assessment of the underlying situation. Careful readers of DeWitt's massive reports would have noticed that his data only supported the rallying cry of "two to three times" if one lumped together degrees in engineering, agriculture, and health—leaving out science and mathematics altogether, and ignoring all the important stipulations about different types of degrees, uneven quality, and the predominance of correspondence students. If one dropped agriculture and health and included science and mathematics, the Soviets' numerical advantage fell by a factor of ten. Moreover, if one looked squarely at degrees in physics—the field usually hailed as most important, rightly or wrongly, amid the hue and cry over "scientific manpower"—then DeWitt's tables indicated that the United States held a two-to-one *lead* over its rival, rather than a deficit. (Later assessments confirmed that ratio.) None of those points were buried in classified reports; all were as plain on the page as the "two to three times" data.<sup>27</sup> Yet physicists, policy makers, and journalists traded sober analysis for the giddy flights of a speculative bubble—and all trundled along just fine until the bottom fell out.

#### THE CENTER WILL NOT HOLD

Speculative bubbles like the physics enrollment curve interest me not only because of the changes they induce in who enters the field, what they seek in a physics career, and what jobs they receive after graduation. Other questions follow as well. Did the brute-force demography on display in figure 2 shape the intellectual history of the discipline—that is, did the sudden changes in educational infrastructure affect physics itself?<sup>28</sup>

Consider specialization. Before World War II, physics departments across the United States had commonly held doctoral students responsible for "a good general knowledge of the entire field of physics," as a Berkeley memorandum explained in 1928.<sup>29</sup> A few years later, after completing his qualifying examination at Caltech, a graduate student mused about the "certain satisfaction" he had attained from "knowing

<sup>26</sup> On grants and fellowships funded by the act, see *ibid.*, 151–5, 162–7; Divine, *Sputnik Challenge* (cit. n. 24), 164–6; Geiger, *Research and Relevant Knowledge* (cit. n. 13), chap. 6. The data on PhDs in physical sciences and engineering come from National Research Council, *Century of Doctorates* (cit. fig. 2 caption), 12.

<sup>27</sup> Kaiser, "Physics of Spin" (cit. n. 20), 1237–9.

<sup>28</sup> On employment patterns and changing personae, see David Kaiser, "The Postwar Suburbanization of American Physics," *Amer. Quart.* 56 (2004): 851–88. On epistemic effects of the bubble, see Kaiser, "Whose Mass Is It Anyway? Particle Cosmology and the Objects of Theory," *Soc. Stud. Sci.* 36 (2006): 533–64; Kaiser, "Turning Physicists into Quantum Mechanics," *Phys. World* 20 (May 2007): 28–33; Kaiser, *How the Hippies Saved Physics: Science, Counterculture, and the Quantum Revival* (New York, 2011).

<sup>29</sup> Unsigned memorandum, "Requirements for the Degree of Doctor of Philosophy, Department of Physics, August 1928," in Department of Physics records, 4:22, in UCB.

all of physics at one time.”<sup>30</sup> Soon after the war, however, few departments retained the language of “the entire field of physics.” Indeed, faculty across the country debated just what physics students should be expected to know. The old quest for comprehensive coverage (even on “comprehensive” exams) struck many physicists as unworkable. As early as 1951, Karl K. Darrow, long-time executive secretary of the APS, lamented that no one could fulfill the task he had been assigned as keynote speaker for the upcoming meeting: to address “the whole of physics.”<sup>31</sup>

Trends like these seem obvious enough to understand in the abstract. Scholars have long noted the general process by which specialization unfolds. As the number of practitioners goes up, so too does the volume of research output, making it necessary for individuals to narrow their focus—to “know everything about nothing.” Where once there was natural philosophy, by the nineteenth century a patchwork had emerged of physics, chemistry, biology, geology, and so on. With continued growth, these fields, too, underwent their own internal divisions, a kind of mitosis of the scholarly mind. Looking back over the span of centuries, the process can seem unavoidable—nothing more than “natural evolution,” as Samuel Goudsmit, the long-time editor of the *Physical Review*, noted in the early 1970s.<sup>32</sup>

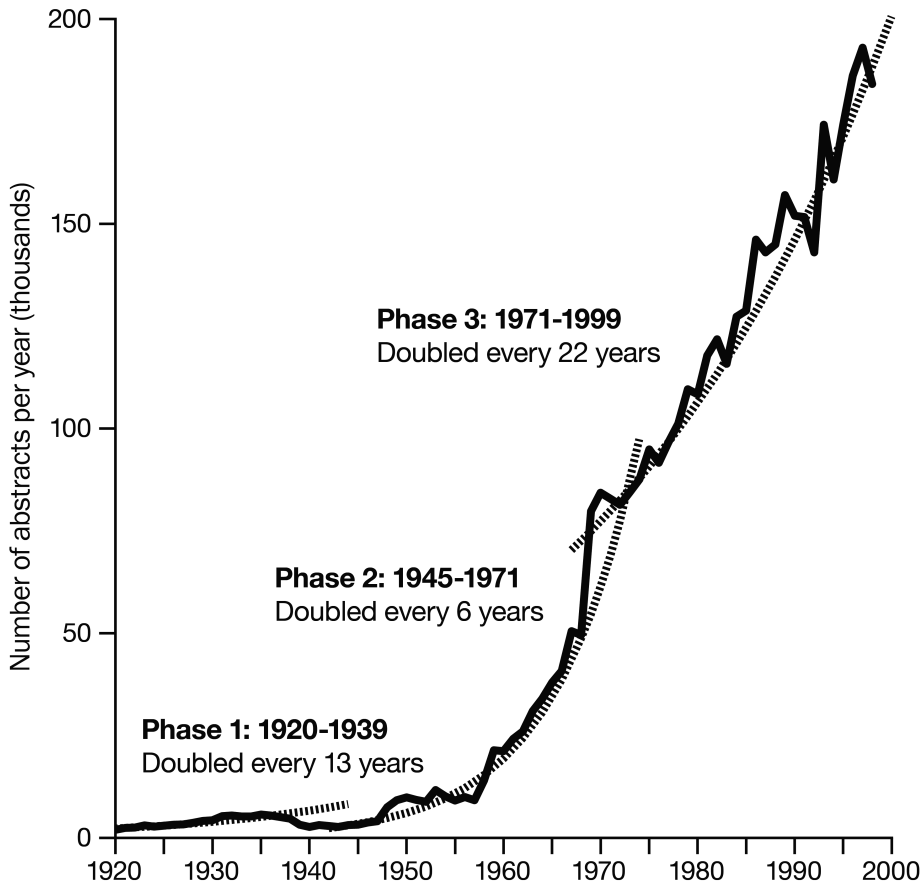
If the process was obvious in outline, however, its pace caught many physicists off guard after the war and sent them scrambling for some means of redress. *Physics Abstracts* illustrates the trend. The London Physical Society and the British Institution of Electrical Engineers established *Physics Abstracts* in 1898; by 1903, the APS and most European groups aided in the endeavor. From the start, a full-time staff of physicists made regular surveys of the world’s physics journals—over one hundred journals in 1900, two hundred by 1940, and nearly five hundred by 1965—collecting and publishing abstracts of the articles in monthly installments of *Physics Abstracts*. Although the number of abstracts had grown steadily during the 1920s and 1930s, the floodgates opened soon after the end of World War II. The number of abstracts published in 1949 (7,500), for example, was nearly twice that published in 1948 (4,090). The numbers continued to climb more than twice as quickly as during the interwar period. *Physics Abstracts* published more than 10,000 abstracts per year for the first time in 1954; in 1971, the journal printed more than 84,000 abstracts. Just as quickly, after the Cold War bubble burst, the rate of growth slouched by nearly a factor of four (fig. 6).

The worldwide acceleration of physics publications was especially marked in the United States. In fact, half of all entries published in *Physics Abstracts* during the

<sup>30</sup> Martin Summerfield, entry of 10 March 1939, in Caltech “Bone Books,” box 1, 3:60, in CIT.

<sup>31</sup> Darrow, “Physics as a Science and an Art,” *Phys. Today* 4 (November 1951): 6–11, on 6. On changing comprehensive exams, see also P. C. Martin et al., “Proposed Changes in Oral Examination Procedures,” 10 November 1959, in Department of Physics records, “Correspondence: 1958–60,” box A-P, folder “1959–1960 agenda, dept. luncheon,” Harvard University Archives, Cambridge, Mass.; Charles Zemach to Burton Moyer, 29 July 1963, in Department of Physics records, 4:22, in UCB; correspondence and exams from 1948–9 in LIS box 9, folder “Misc. problems”; comprehensive exams from 1962 in Felix Bloch papers, 10:19, Stanford University Archives, Palo Alto, Calif., and in W. C. Kelly, “Survey of Education in Physics in Universities of the United States,” unpublished report, 1 December 1962, app. 19, available in AIP-EMD, box 9.

<sup>32</sup> Goudsmit, 1972 annual report, in PR-AR. See also Price, *Science since Babylon* (cit. n. 2), chap. 5; Diana Crane, *Invisible Colleges: Diffusion of Knowledge in Scientific Communities* (Chicago, 1972); John Ziman, *Knowing Everything about Nothing: Specialization and Change in Research Careers* (New York, 1987); Tony Becher, *Academic Tribes and Territories: Intellectual Enquiry and the Cultures of Disciplines* (Bristol, 1989).



**Figure 6.** Number of abstracts published annually in *Physics Abstracts*. Dashed lines show best-fit exponential growth curves for each period.

1950s and 1960s stemmed from journals published in the United States and the Soviet Union, the countries with the fastest-growing ranks of professional physicists. Even though staffers at *Physics Abstracts* scrutinized comparable numbers of journals from each of the Cold War superpowers, American journals accounted for nearly twice as many entries as their Soviet counterparts (consistent with the two-to-one American lead in new physics degrees granted per year). During this period, the single largest source of entries in *Physics Abstracts* was the American workhorse of a journal, the *Physical Review*, published by the APS.<sup>33</sup>

The *Physical Review* swelled like no other journal after the war. The cause seemed

<sup>33</sup> Stella Keenan and Pauline Atherton, *The Journal Literature of Physics: A Comprehensive Study Based on "Physics Abstracts,"* report no. AIP-DRP PA1 (New York, 1964); Keenan and F. G. Brickwedde, *Journal Literature Covered by "Physics Abstracts" in 1965,* report no. ID 68-1 (New York, 1968); L. J. Anthony, H. East, and M. J. Slater, "The Growth of the Literature of Physics," *Reports on Progress in Physics* 32 (1969): 709-67. In 1965, *Physics Abstracts* included complete coverage of 82 journals, of which 17 were published in the United States and 13 in the Soviet Union; the remaining 413 journals scanned by the *Physics Abstracts* staff contributed less than 23 percent of all the abstracts published that year. See Keenan and Brickwedde, *Journal Literature*, 6, and app. 4, on 22.



clear, even at the time. “Graduate school enrollment should be watched as basis for prediction of size of future issues” of the *Physical Review*, concluded the APS Advisory Committee on Publication Policy in the mid-1950s.<sup>34</sup> Goudsmit agreed. In his annual reports he took to graphing the number of articles published in the journal alongside the growing membership of the APS, driven up each year by the new crop of PhDs. During his first year as editor, in 1951, the *Review* published fewer than five thousand pages. During his final year as editor, in 1974, the journal published more than thirty thousand pages.<sup>35</sup>

The lightning-fast expansion affected every aspect of the journal. Shortages of paper and labor—especially of skilled operators who could handle the journal’s sophisticated mathematical typesetting requirements—continued to hamper its production well into the late 1950s.<sup>36</sup> Staffing the editorial office also became a challenge. When Goudsmit became editor of the *Review* in 1951, his position was part-time, so he could continue research at Brookhaven National Laboratory. Other than Goudsmit, the editorial office included two secretaries and one full-time assistant. By the time Goudsmit retired in the early 1970s, the editorial staff had swelled to thirty people: ten PhD physicists working as full-time editors, two more assisting as part-time editors, plus eighteen people working in full-time clerical and administrative capacities. All those hands were kept busy. Virtually every year between 1951 and 1969, Goudsmit reported an increase over the previous year in the number of submissions received, articles published, and pages printed. Whereas the journal processed 1,379 article submissions in 1955—averaging 115 new submissions each month—the number had doubled by 1965 and nearly tripled by 1968. Given the number of transactions, Goudsmit explained to a colleague in 1966, the journal “is no longer similar to the neighborhood grocery store where old customers get personal attention.” Instead it had become “more like a supermarket where the manager is hidden in an office on the top floor. As a result, lots of things are just done by routine rather than by human judgment.” He meant it literally: by that time, the office was experimenting with a new punch-card computer system to mechanize the process of matching referees with submissions and to track the progress of referee reports received, responses sent to authors, and so on.<sup>37</sup>

Physicists could not fail to notice the effects of all those efficiencies. Goudsmit himself noted in the mid-1950s that each issue of the journal had become “almost too bulky to carry.”<sup>38</sup> One physicist working at the National Bureau of Standards complained to Goudsmit on behalf of “the poor over-burdened members” of the

<sup>34</sup> Minutes of Advisory Committee on Publication Policy of the American Physical Society, 6 January 1956, in AIP-HAB 57:7.

<sup>35</sup> Goudsmit, 1951–74 annual reports, in PR-AR.

<sup>36</sup> R. P. Rohrer (president of Lancaster Press) to Henry Barton, 27 May 1949, in AIP-HAB 79:13; Elmer Hutchisson, memorandum of 20 September 1957, and unsigned memorandum, “Study of the Physics Publishing Problem,” 18 February 1958, both in AIP-EH 14:3; R. E. Maizell, “Minutes of AIP Committee to Study Physics Publishing Problems,” 18 April 1959, in AIP-EH 14:2.

<sup>37</sup> The quotations are from Goudsmit to Leonard Schiff, 2 September 1966, in LIS box 4, folder “Physical Review.” The data on numbers of submissions and pages published come from PR-AR. On staffing, see E. L. Hill (editor of *Physical Review*) to Karl K. Darrow (secretary of the APS), 14 October 1950, in AIP-HAB 32:6; Goudsmit, 1973 annual report, in PR-AR; APS Council meeting minutes of 27 November 1953 and 26 November 1954, in AIP-HAB 79:1. See also Simon Pasternack (assistant editor, *Physical Review*) to Leonard Schiff, 22 January 1958 and 27 June 1963, in LIS box 4, folder “Physical Review.”

<sup>38</sup> Goudsmit, 1956 annual report, in PR-AR.

APS “whose book-shelves and closets are beginning to burst with the vast amount of paper that you are helping to distribute every year”; American physicists now needed to “cope with scientific literature by the ton.”<sup>39</sup> A senior physicist at Berkeley lodged a similar complaint:

Having been a subscriber of the *Physical Review* from 1913 on, I had to sell my back numbers up to 1947, simply because I had no space to store them. Even today, with the limited space in a comfortable, but small 8 room house, I am already finding that the growing files of journals take up so much space that I am just at my wit’s end as to what to do. My own office, which is sufficiently commodious in the new building, can no longer house the journal either.<sup>40</sup>

Goudsmit found such complaints a bit silly. Given the rapid pace of research in physics, he reasoned, the journal’s contents became obsolete relatively quickly. “There is really little reason to keep more than about ‘six feet’ of *The Physical Review* at home,” he explained in his 1955 annual report. To the physicist from the National Bureau of Standards, Goudsmit recommended an even more direct method for keeping the journal’s bulk in check: physicists should stop being “overly sentimental” and simply rip out those articles they wanted upon each issue’s arrival, throwing away the rest. His correspondent was not impressed by the suggestion. “One revolts against such destruction of the printed word, even if bound in nothing more than paper, and moreover if one throws away something one later needs it cannot possibly be replaced.” Yet ten years later, a Caltech physicist reported to Goudsmit on his own efforts to do just as Goudsmit had recommended. He reduced the two feet of shelf space taken up by his copies of the 1963 *Physical Review* to a few inches by ripping each issue apart, throwing away those articles of no interest to him, and stapling the rest back together. The arts-and-crafts project had worked, but it had not been easy. Perhaps, the physicist suggested, the journal could be bound with a different kind of glue, to better facilitate such scan-and-tear operations.<sup>41</sup>

Goudsmit, too, wondered what was keeping the journal together, literally and figuratively. In 1962 he reported with exasperation that the journal was bumping up against the printer’s limit: the press could only bind individual issues that contained fewer than five hundred pages. “We are rapidly reaching this technical limit,” Goudsmit noted, “but have already long ago passed the psychological limit above which the subscriber is overwhelmed by the bulk and looks only at the few articles in his own narrow field.” Not long after that he inserted an editorial into the journal, entitled simply “Obscurantism.” Most articles struck him as having been written for “a few specialists only,” or, even worse, as a kind of “memorandum to [the author] himself or merely for the benefit of a close collaborator.”<sup>42</sup>

<sup>39</sup> W. B. Mann to Goudsmit, 11 January 1955, in AIP-HAB 79:14.

<sup>40</sup> Leonard B. Loeb (Berkeley) to Goudsmit, 19 April 1955, in Raymond Thayer Birge papers, box 19, folder “Loeb, Leonard Benedict,” in UCB.

<sup>41</sup> Goudsmit, 1955 annual report, in PR-AR; Mann to Goudsmit, 11 January 1955 (cit. n. 39); Thomas Lauritsen to Goudsmit, 27 December 1968, in Thomas Lauritsen papers, 12:14, in CIT. Goudsmit’s recommendations were remarkably similar to those of sixteenth-century scholars Conrad Gesner and Girolamo Cardano; see Ann Blair, “Reading Strategies for Coping with Information Overload ca. 1550–1700,” *J. Hist. Ideas* 64 (2003): 11–28, on 25–7; Blair, *Too Much to Know: Managing Scholarly Information before the Modern Age* (New Haven, Conn., 2010).

<sup>42</sup> Goudsmit, 1962 annual report, in PR-AR; Goudsmit, “Obscurantism,” *Physical Review Letters* 13, no. 17 (1964): 519–20.

As research journals like the *Physical Review* grew fatter and fatter, and editors like Goudsmit recommended that readers conquer the heft with scissors and glue, others began to offer even more brazen suggestions about the future of scientific publishing. Some proclaimed that the entire system of scientific journals would need to be scrapped and replaced by some radical alternative. As early as June 1949, physicists debated the publication problem at an annual meeting. One idea that emerged was to stop printing journals like the *Physical Review* altogether and to replace them with a weekly newspaper that would contain the titles and abstracts of all physics articles received. Subscribers could then write directly to the APS editorial office to request only those articles in which they were interested; photo-offset copies of specific articles could then be printed and mailed on demand. Although Henry Barton, the director of the AIP, remained skeptical of the idea—he suggested that the finances and logistics of such a plan be thoroughly analyzed “before it gains too much headway in the minds of our members”—the London Physical Society in fact converted to this system for several years during the early 1950s before concluding that it was too expensive, and the idea kept resurfacing among American physicists well into the 1960s.<sup>43</sup>

One leading physicist offered a different suggestion a few years later. The *Physical Review* should become a kind of “greatest hits” journal, surrounded by several smaller, specialized journals catering only to narrow subfields. The *Review* would then consist entirely of reprints of specially selected articles deemed most important or most interesting in the specialist literature. Photo-offset printing (rather than retypesetting each article) could keep the costs low, and the *Review*’s size could be strictly controlled to allow the average physicist to be able to read or skim the best work from the whole of physics. Still others suggested converting the *Review* into a *Reader’s Digest* of physics, publishing specially commissioned, short and accessible versions of specialized articles that appeared elsewhere.<sup>44</sup>

Yet the dream of sampling the best work from the whole of physics faded fast. The subject index to *Physics Abstracts* illustrated the problem. Throughout the 1950s, physicists representing the APS and the AIP negotiated with counterparts in Britain over the length and arrangement of the index. Both groups agreed that the index required constant revision, with new levels of detail added to keep up with the fast pace of specialization.<sup>45</sup> In 1930, the index featured eight main categories—general physics; meteorology, geophysics, and astrophysics; light; radioactivity; heat; sound; electricity and magnetism; and chemical physics and electrochemistry—only one of

<sup>43</sup> Barton to John T. Tate (editor, *Physical Review*), 20 June 1949, in AIP-HAB 79:13; Mann to Goudsmit, 11 January 1955 (cit. n. 39); Goudsmit, 1955 annual report, in PR-AR. In fact, the idea had been advanced in the early 1930s and resurfaced after the war. See Ralph H. Phelps and John P. Herlin, “Alternatives to the Scientific Periodical: A Report and Bibliography,” *UNESCO Bulletin for Libraries* 14 (March–April 1960): 61–75; my thanks to Michael Gordin for bringing this reference to my attention. The 1949 suggestion eventually became the operating principle behind the first electronic physics preprint system during the early 1990s, now available at <http://www.arXiv.org>.

<sup>44</sup> H. A. Barton, “Thoughts on the Physics Publication Problem,” unpublished memorandum, 7 March 1956, in AIP-EH 14:1; Goudsmit, “Editorial: The Future of Physics Publications; A Proposal,” *Physical Review Letters* 10, no. 2 (1963): 41–2.

<sup>45</sup> E. Hutchisson, “Report of the Joint APS-AIP Committee on Science Abstracts,” n.d., ca. March 1951; W. K. Brasher (secretary, British Institution of Electrical Engineers) to Hutchisson, 29 March 1951; S. Whitehead (deputy chair, Committee on Management, British Institution of Electrical Engineers) to Hutchisson, 29 March 1951, all in AIP-EH 15:1. See also the other correspondence in AIP-EH 15:1 and 15:3.

which, electricity and magnetism, required a further division into four subcategories. By 1955, major fields like nuclear physics, separated into six subcategories, had been added to the list. Ten years later, nuclear physics had been carved up into thirty-five distinct subcategories, and solid-state physics into thirty-eight.

The subdivisions and rearrangements continued but did not converge. The 1960 subject index featured eighty-four subject headings in all (major and minor); simply reading through the list of topics had become a chore. By 1967, the AIP experimented by printing separate lists of subfields by specialty in its own indexes; it was no longer able to fit all the categories and subject headings into a single unified list.<sup>46</sup> Scanning abstracts had long since become infeasible, so physicists tried an even sharper condensation. For a brief time in the late 1960s, the publishers of *Physics Abstracts*, in conjunction with the AIP, printed *Current Papers in Physics*, a biweekly newsletter arranged in tabloid-newspaper format that simply listed author names and article titles, by subject category, for items that were due to appear in forthcoming issues of *Physics Abstracts*.<sup>47</sup>

Several physicists feared that the baroque complexity of the subject index would carry pedagogical ramifications. The joint committee of the APS and AIP on *Physics Abstracts* suggested that all competing index schemes should be judged by how effectively graduate students could use them. The AIP actually conducted tests of “index efficiency” in January 1960 by running thirty-six graduate-student volunteers through time trials. “The attempt was made to simulate a real life situation in information retrieval,” the report began. Groups of students were assigned one of five indexes: some used the experimental indexes based on permutations of keywords from titles, while others used the existing subject indexes in the *Physical Review*, *Physics Abstracts*, *Nuclear Science Abstracts*, or *Chemical Abstracts*. Each student received copies of the first page of fifteen different articles with title and author lines blacked out. Using only their assigned index, they had to identify each article and find at least one subject heading under which it was classified. The report then listed the average number of articles located (of the original fifteen) by students in each group, the average time taken per article (ranging from 1.4 to 6.2 minutes), and the average number of false leads (from 10 to 18.2).<sup>48</sup>

The physicists’ journals did not just swell from the enrollment pressures; they cracked. As early as 1949, Berkeley physics professor Emilio Segrè suggested that the *Physical Review* should be split into two journals, one aimed at experimentalists

<sup>46</sup>Dwight E. Gray, minutes on meeting of joint APS-AIP Abstracting Committee, 24 November 1958, in AIP-EH 15:3; A. A. Strassenburg (director, AIP’s Office of Education and Manpower) to Robert B. Leighton, 12 July 1967, in Robert B. Leighton papers, 1:12, in CIT. See also Simon Pasterack to Leonard Schiff, 27 June 1963, in LIS box 4, folder “Physical Review.”

<sup>47</sup>Maizell, “Physics Abstracting Services,” unpublished report, 15 February 1960, in AIP-EH 15:3; Van Zandt Williams, Elmer Hutchisson, and Hugh C. Wolfe, “Consideration of a Physics Information System,” *Phys. Today* 19 (January 1966): 45–52; Franz L. Alt and Arthur Herschman, *Plans for a National Physics Information System*, report no. ID 68–6 (March 1968), in LIS box 1, folder “AIP Information Program”; see also the questionnaire dated 15 November 1968 from the AIP Information Division in the same folder and the correspondence in AIP-EH 15:3, 16:10.

<sup>48</sup>R. E. Maizell, minutes from meeting of APS-AIP Committee on Science Abstracts, 27 April 1960, in AIP-EH 15:3; unsigned report, “Investigation of Index Efficiency as Based on Tests with Graduate Physics Students,” 19 January 1960, in AIP-EH 16:10. See also Philip Morse, *Library Effectiveness: A Systems Approach* (Cambridge, 1968); Erik P. Rau, “Managing the Machine in the Stacks: Operations Research, Bibliographic Control, and Library Computerization, 1950–2000,” *Library History* 23 (June 2007): 151–68.

and the other at theorists. Others thought that the *Review* should be split along subject lines, one *Review* for each topical division of the APS. Goudsmit dismissed the idea as uneconomical: such divisions would needlessly duplicate editorial office effort, requiring the maintenance of separate subscription lists and mailing labels, and so on. To officers of the AIP, the problem ran deeper than economics. They feared such splitting “would be dangerous,” furthering an intellectual balkanization that the institute had been founded to fight.<sup>49</sup>

As a compromise, Goudsmit agreed to begin arranging the articles within each issue of the *Review* by topic early in 1953, “without any general announcement” that he was doing so. Yet with submissions to the *Review* growing by as much as a third in a single year—as they did between 1952 and 1953—Goudsmit felt compelled to return to the idea of splitting the journal. He included a ballot on the back cover of the APS *Bulletin*, mailed out to members in advance of the society’s January 1955 meeting in New York, asking them to vote on whether the *Review* should be split into two journals, one catering to solid-state physics and the other to nuclear and high-energy physics. Within weeks hundreds of ballots poured in, most of them favoring the split—although, Goudsmit was quick to note, most of those in favor had come from solid-state physicists, who thought that their specialty was unduly crowded by nuclear topics in the *Review*.<sup>50</sup>

Beyond the ballots, impassioned letters began to circulate; the question of whether or not to split the *Review* had clearly touched a nerve. Norman Ramsey, for example, Harvard physicist and member of the APS Executive Council, wrote to his fellow council members to reiterate his “personal preference” for “no splitting of the Physical Review whatsoever”: such a split presented too many “evils,” and “compartmentalization in physics should be discouraged.” Views like Ramsey’s on the council carried the day. As the society’s Advisory Committee on Publication Policy noted, the decision not to split the *Review* was taken “for ideological rather than other reasons. Influential Council members deplored any tendency to compartmentalize physics.”<sup>51</sup>

But the matter would not go away. In 1962 the editorial office suggested a compromise. The *Review* could be split into four separate sections, covering nuclear physics, high-energy physics, solid-state physics, and atomic physics. Each section would come out biweekly and still be sent to all subscribers; individual physicists could then keep their preferred sections and give away (or toss away) the others. Half of the plan soon went into action. Beginning in 1963, the *Physical Review* was printed in two sections, *A* on solid-state and atomic physics and *B* on nuclear and high-energy physics—but, to appease those who had argued against splitting, the two sections were paginated continuously (so libraries could bind them together as a single vol-

<sup>49</sup> Segrè to Henry A. Barton, 14 February 1949, in AIP-HAB 28:5; Goudsmit, 1952 annual report, in PR-AR; Elmer Hutchisson to Barton, 14 February 1951, in AIP-EH 15:1. On the founding of the AIP and the issue of fragmentation, see Spencer Weart, “The Solid Community,” in *Out of the Crystal Maze: Chapters from the History of Solid-State Physics*, ed. Lillian Hoddeson et al. (New York, 1992), 617–69.

<sup>50</sup> Goudsmit, 1952–4 annual reports, in PR-AR; John C. Slater to Clyde A. Hutchison Jr., 4 February 1953, and Slater, meeting minutes of APS Committee on Publication Policy, 15 April 1953, in AIP-HAB 57:7; Karl K. Darrow, APS Council meeting minutes, 26 January 1955, in AIP-HAB 79:1.

<sup>51</sup> Ramsey to APS Council members, 6 June 1956, in AIP-HAB 79:14; minutes of Advisory Committee on Publication Policy, APS (cit. n. 34). See also Leonard Loeb to Raymond Birge, 27 October 1954, and Loeb to Goudsmit, 19 April 1955, in Raymond Thayer Birge papers, box 19, folder “Loeb, Leonard Benedict,” in UCB; Birge to Goudsmit, 5 April 1955 in Birge papers, box 40, folder “Letters written by Birge, January–April 1955,” in UCB; Mann to Goudsmit, 11 January 1955 (cit. n. 39).

ume) and covered by a single index. Two years later, members were given the option of only subscribing to one half or the other, and only 45 percent chose to continue receiving both sections. The uproar against the evils of specialization that had erupted among council members a decade earlier had faded, no longer much of a match against the journal's exponential growth.<sup>52</sup>

Even these changes rapidly proved insufficient. With the editors again citing the need for "drastic changes" if the journal were to remain of any use to researchers, the inexorable divisions continued. In 1966, the *A* and *B* sections were themselves each divided in half—atomic and molecular physics separated from the rest of solid-state physics; nuclear physics separated from high-energy particle physics—and the following year the editors introduced a five-part division. Yet even with the latest splits, the size of individual issues remained unmanageable. Finally the realities of operating a journal that received more than ten new submissions every day of the year overwhelmed those advocates who had hoped to stem the tide of specialization. In 1970 the *Physical Review* was divided into four separate biweekly journals, each paginated and indexed independently. Both *Physical Review B* (on solid-state physics) and *Physical Review D* (on particle physics) were themselves further subdivided, those issues appearing on the first of each month catering to a different set of topics than the issues appearing two weeks later. In their annual report, the editors noted that a sizable proportion of subscribers to *Physical Review B* were so specialized that they chose to subscribe only to one or the other of these subsections, and the same held true among subscribers to *Physical Review D*—a trend that continued throughout the 1970s.<sup>53</sup> Similar pressures affected other leading journals. Elsevier divided both its *Nuclear Physics* and *Physics Letters* into separate *A* and *B* sections in 1967, and the *Zeitschrift für Physik* split into three separate journals in 1970.

Ironically, after wrestling with the issue of how to balance ballooning size with intellectual coherence for twenty years, the *Physical Review* split into separate journals just as its massive growth ground to a halt. When plans were laid to divide the journal back in 1968 and 1969, the increases still seemed unstoppable—after growing by an average of 280 submissions per year for each of the previous seven years, receipts leapt by an additional 420 submissions in 1968 alone. Yet by 1970, when the journal finally split, the growth had definitely stopped: the total number of submissions actually fell by 115 that year, and it remained flat for the remainder of the decade. The centrifugal pressures had mounted during the feverish rise of the Cold War bubble, but the *Physical Review* split just when it might have finally achieved some stability.<sup>54</sup>

To Goudsmit and others, the great challenges facing scientific publishing were at root pedagogical, both in cause and effect. All those graduate students needed to publish their work somewhere, and the journals had ballooned in response. In turn, the bulge affected what got published, and in what manner. No student (nor any practitioner) could engage the full range of research on, say, nuclear physics if several hundred dissertations and articles on the topic had been filed the previous year, with several hundred also filed the year before that, and so on. Of course the *Physical Review* had outstripped all previous growth rates and the *Physics Abstracts* subject index had

<sup>52</sup> Goudsmit, 1962–5 annual reports, in PR-AR.

<sup>53</sup> 1966–79 annual reports (by Goudsmit and others), in PR-AR. See also S. Pasternack and A. Herschman, "Editorial: A Proposal for Changing the *Physical Review*," *Physical Review* 137, no. 7AB (1965): AB1.

<sup>54</sup> 1961–79 annual reports (by Goudsmit and others), in PR-AR.

become so unwieldy—how else to make room for all those new dissertations? Along the way, the physics landscape itself had changed, its internal divisions and units of currency (research articles, dissertations) arrayed in a dramatically different fashion than what had seemed natural just a few decades earlier.

#### OTHER BUBBLES

The physicists' bubble, so sharply pronounced between 1945 and 1975, was not a one-shot deal. In fact, graduate-level physics enrollments rebounded during the 1980s in the United States, bid higher and higher by many of the same mechanisms that had inflated the first bubble. A resurgence of defense-related spending under the Reagan administration—including the sprawling Strategic Defense Initiative, or “Star Wars”—combined with new fears of economic competition from Japan drove enrollments in physics and neighboring fields up exponentially once more, nearly matching the late-1960s peak. They fell sharply a decade later with the end of the Cold War. Just as during the early 1970s, shared conditions across fields led to an overall decline in graduate-level enrollments.<sup>55</sup> By the time PhD conferrals bottomed out in 2002, annual PhDs across all fields had fallen by more than 6 percent from their 1990s peak; annual PhDs in science and engineering had fallen by 10 percent; while annual PhDs in physics had plummeted by 26 percent. Once again, dire predictions of shortfalls in the scientific labor supply had been stupendously mistaken; once again, physics marked the extremes of a general pattern throughout American universities (fig. 7).<sup>56</sup>

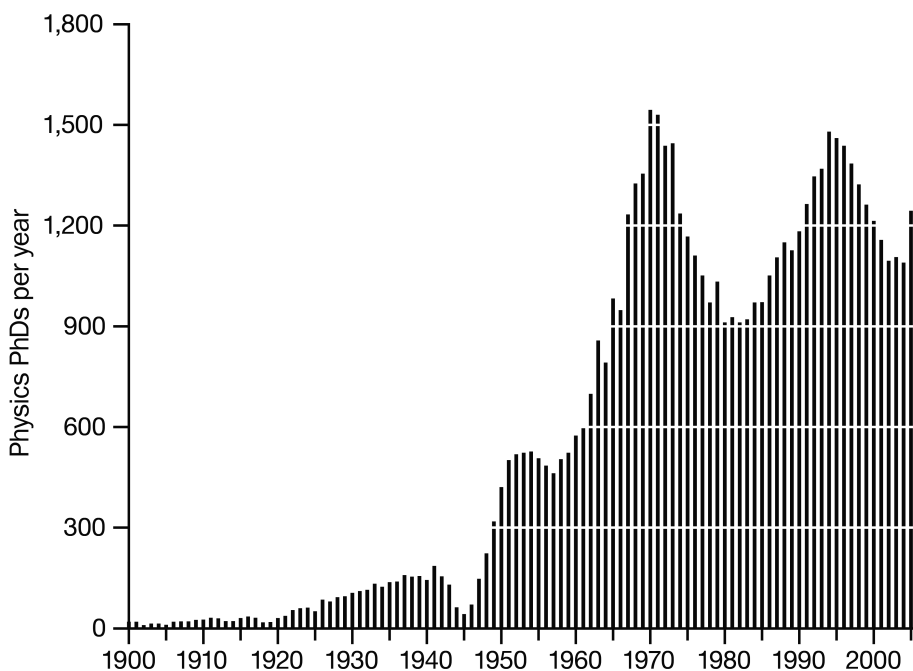
The dynamics behind the second bubble were remarkably similar to the earlier example. Beginning in 1986, the director of the National Science Foundation and colleagues sounded the alarm again that the United States would soon face a devastating shortage of scientists and engineers. Foundation projections indicated that there would be 675,000 too few scientists and engineers in the United States by the year 2010. Just as in response to the DeWitt and Korol studies from the 1950s—especially the stripped-down ratio of two to three times more science and engineering graduates per year in the Soviet Union than in the United States—the dramatic projections of shortages helped to unleash generous federal spending.<sup>57</sup>

Unlike the DeWitt and Korol studies, the 1980s study by the National Science Foundation did not impress many close observers. In keeping with broader economic modeling during the Reagan administration, the study had neglected to consider demand at all, sticking with only supply-side variables. Yet few skeptics came forward until the early 1990s, after the Soviet Union dissolved and the Cold War ground to an

<sup>55</sup> See, e.g., Juan Lucena, *Defending the Nation: U.S. Policymaking to Create Scientists and Engineers from Sputnik to the “War against Terrorism”* (New York, 2005), chap. 4.

<sup>56</sup> The declines in annual PhD conferrals across each category were calculated from data tabulated in the annual National Science Foundation reports titled “Science and Engineering Doctorate Awards,” 1994–2006, available at <http://www.nsf.gov/statistics/doctorates> (accessed 10 January 2011).

<sup>57</sup> David Berliner and Bruce Biddle, *The Manufactured Crisis: Myths, Fraud, and the Attack on America's Public Schools* (New York, 1995), 95–102; Daniel Greenberg, *Science, Money, and Politics: Political Triumph and Ethical Erosion* (Chicago, 2001), chaps. 8–9; Eric Weinstein, “How and Why Government, Universities, and Industry Create Domestic Labor Shortages of Scientists and High-tech Workers” (unpublished working paper), available at <http://www.nber.org/~peat/Papers/Folder/Papers/SG/NSF.html> (accessed 10 January 2011); Lucena, *Defending the Nation* (cit. n. 55), 104–12, 133.



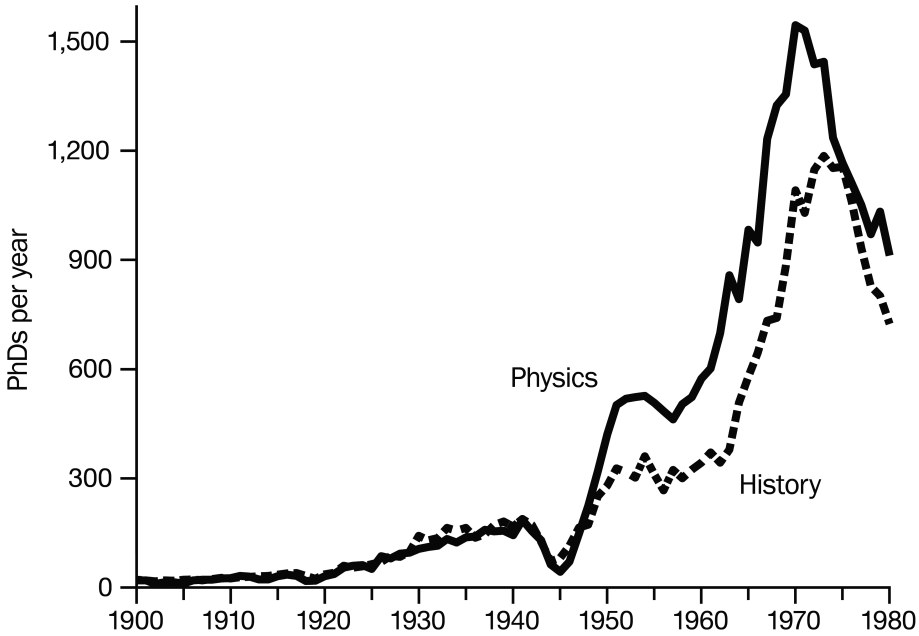
**Figure 7.** Number of physics PhDs granted by US institutions, 1900–2005. Based on data from the AIP Statistical Research Center, available at <http://www.aip.org/statistics> (accessed 10 January 2011).

unexpected halt. Just as in the earlier era, reality checks that could easily have been tried were not, while the scarcity talk looped from hype to amplification to feedback all over again. And just as in the early 1970s, the second bubble burst, triggering double-digit unemployment among PhD-level scientists and mathematicians. The glut of freshly minted scholars—many of whom had been lured to graduate school with federally funded fellowships and promises of plentiful academic jobs to come—occasioned testy hearings in Congress. The push-back led ultimately to the dismantling of the Policy Research and Analysis Division within the National Science Foundation, which had developed the faulty supply projections.<sup>58</sup>

So much for repeating bubbles over time. What about comparable effects on other disciplines, which like physics were caught up in boom-and-bust cycles after the war? Consider the field of history. Unlike for physics, few calls had rung out to boost annual production of history PhDs to help prosecute the Cold War. Yet the field (like most others) had been buoyed by the general expansion of the infrastructure of American higher education, a side effect of the speculative bubble and the harried calls for increased “scientific manpower” before and after Sputnik. As a result, PhDs in history grew rapidly during the 1960s, only to peak in the early 1970s and fall sharply—the pattern should by now be familiar (fig. 8).

<sup>58</sup> See esp. Berliner and Biddle, *Manufactured Crisis*; Greenberg, *Science, Money, and Politics*; Weinstein, “How and Why Government” (All cit. n. 57); Lucena, *Defending the Nation* (cit. n. 55), and references therein.





**Figure 8.** Number of PhDs granted by US institutions per year in physics and history, 1900–1980. Based on data from National Research Council, *Century of Doctorates*, 13, and National Science Foundation, *Science and Engineering Degrees* (Both cit. fig. 2 caption).

Just as for the physicists, years of overproduction were met by a crushing contraction. Physicists seeking jobs had outnumbered positions posted with the AIP by a factor of twenty to one in 1971. The ratio for young historians competing for interviews at the American Historical Association meeting around that time was only marginally better: 2,481 applicants for 188 positions, or about thirteen to one. Intellectual fragmentation, and not just job-market prospects, elicited impassioned concern from leading historians throughout the 1970s and 1980s, echoes of the physicists' losing battle against specialization.<sup>59</sup>

Equipped with time-series graphs like figure 8, we may return to a question raised thirty years ago by Robert Darnton. Darnton had noted a remarkable trend among history dissertations completed in the United States. Once-dominant specialties like political history and intellectual history had fallen consistently in terms of their share of all history dissertations. By Darnton's reckoning, political history had accounted for 34.3 percent of all history dissertations in 1958, 33.4 percent in 1968, and 23.7 percent in 1978. During that same interval, intellectual history had fallen from 10.5 to 9.5 to 8.8 percent. Meanwhile, social history grew by leaps and bounds, from just 6.8 percent of all dissertations in the field in 1958, to 10.4 percent in 1968, and 27.1 percent in 1978—a fourfold increase in just two decades.<sup>60</sup>

<sup>59</sup> Peter Novick, *That Noble Dream: The "Objectivity Question" and the American Historical Profession* (New York, 1988), 574 (on historians' job market), 577–92 (on specialization and fragmentation).

<sup>60</sup> Darnton, "Intellectual and Cultural History" (1980), repr. in Darnton, *The Kiss of Lamourette: Reflections in Cultural History* (New York, 1991), 191–218, on 202.

Darnton gestured toward the likely suspects to try to account for the dramatic trends. Clearly the social movements of the 1960s and 1970s, from civil rights to the women's movement and gay liberation, had left their mark on the discipline, encouraging the study of peoples and events that had barely rated notice during earlier time periods. But in the end Darnton threw up his hands. No matter how riveting those social and political movements had been, no clear causal arrows seemed to connect the swirling *Zeitgeist* with graduate curricula. For such trends, Darnton had to conclude, "their origin remains a mystery."<sup>61</sup>

As Darnton surmised, we need not downplay the impact that broader social and political conditions likely had on the intellectual direction of the history profession. Yet graphs like figure 8 suggest a plausible means to begin filling in the gears that Darnton feared were missing from such explanations. Just as for the physicists, broad changes in method and "acceptable" topics to study coincided with steep changes in enrollments. No discipline can sustain itself by pumping out five hundred dissertations each year reanalyzing Descartes's *Meditations* or the military strategies of World War I. Faced with record-breaking numbers of dissertations to advise—and certainly against a backdrop of broader social movements—historians may well have welcomed social history not just as a new set of methods, but as a limitless source of new topics. That would certainly help account for the timing and acceleration inherent in Darnton's numbers. Social history had made only modest inroads by the end of the turbulent 1960s. On the other hand, students who completed their dissertations in 1978 would have entered graduate school (on the average) five or six years earlier—right at the peak of the historians' curve in figure 8.

Obviously simple correlations like these do not guarantee cause. Rather, they spur further close-up inquiry. Just as figure 2 inspired questions of how physicists struggled to manage the contours and content of their discipline, we might ask comparable questions about how historians handled the massive expansion in their own ranks. Likewise, Charles Newman and Russell Jacoby may have glimpsed an important truth when they sneered that postmodern literary theory served as "an infinitely expendable currency, the ultimate inflation hedge."<sup>62</sup> The enrollment curve for PhDs in English literature in the United States looks remarkably similar to that of history in figure 8.<sup>63</sup> Might the heat and light behind the debates over multiculturalism and the broadening of the Western literary canon during the 1980s have owed something to the same kinds of enrollment pressures?

My interest is not to develop a hydraulic theory of scholarly production, some one-dimensional account of institutional pushes and pulls that might determine thought patterns or research trends. Many ingredients shape the contours of intellectual life, from budget lines to political exigencies, cultural cues, and shifting enrollments. Not all are independent of each other, nor are their interactions simple to disentangle. From their combination, however, certain patterns often emerge. The physicists' bubble has the potential to illuminate comparable shifts in other fields across the natural sciences, social sciences, and humanities. Disciplines as varied as chemistry,

<sup>61</sup> *Ibid.*, 205.

<sup>62</sup> Newman, "The Post-modern Aura: The Age of Fiction in an Age of Inflation" (1984), as quoted in Jacoby, *The Last Intellectuals: American Culture in the Age of Academe*, 2nd ed. (New York, 2000), 173.

<sup>63</sup> The enrollment curve for English departments in the United States may be produced from data in the sources listed in the fig. 2 caption.

biology, computer science, psychology, literature, and history each went through boom-and-bust cycles during the postwar decades. None was a carbon copy of the physicists' example; they all occurred later in time and remained smaller in magnitude. But each suggests how attending carefully to the ebb and flow of student numbers can help us understand the rhythms of disciplinary change. They might even point the way back to a robust mesoscopic account of scholarly life, informed by the finest local case studies but not limited to them.