Little Science: the Paradoxes of Research and Education in the Sciences at Swarthmore College, 1935-1965

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Much of the history of American sciences in the mid-twentieth century has focused on the triumph of "big science," based on the combination of federal funding, vast increases in the scale of instrumentation and experimentation, and the alliance of universities with agencies of government, particularly the military.[1] This approach documents the vast and clearly consequential changes in American sciences that are necessary for understanding the creation of what President Dwight Eisenhower called the "military-industrial complex," the space program, and the deep technological infrastructure that underpins most advanced science today. But it virtually ignores the education of the scientists themselves – without whom, after all, there would be no science.

We became interested in this historical problem through researching and writing a book on Courtney C. Smith, president of Swarthmore College, 1953-1969.[2] Though Smith himself, a former professor of English literature, did not have a strong interest in the sciences, our reading of his papers and our investigation of the years leading up to his presidency, convinced us that the sciences at Swarthmore, a small liberal arts college, were vital, important, and worth examining more closely. Moreover, we have looked at several other small liberal arts colleges, such as Juniata, Oberlin, and Reed, which have had reputations for strong science programs, to see whether what we have observed at Swarthmore is part of a bigger story.

In sum, we will argue that Swarthmore, and similar liberal arts colleges, provided an extremely high level of academic training for many of the generation of scientists who were central to the rise of "big science." As Donald Kennedy, editor-in-chief of *Science* magazine wrote recently, "Today, just as in the 1930s and the '50s, [liberal arts colleges] disproportionately supply the undergraduate talent that feeds the academic pipeline."[3] As we consider this phenomenon, we also will examine the kinds of curriculum that provided the training, the issues that the science faculties faced, and who were the science-educators on the liberal arts campuses.

Swarthmore College, founded in 1864 by a liberal branch of the Society of Friends, or Quakers, was a rather quiet small college a few miles southwest of Philadelphia, with a certain reputation for football, when a new president, Frank Aydelotte, took office in the early 1920s. He revolutionized the curriculum by introducing an intense honors program for selected juniors and seniors, and almost immediately made Swarthmore a nationwide magnet for students who desired in college a challenging intellectual experience. It was, as well, a magnet for professors who enjoyed teaching in such an environment.

A Rockefeller Foundation officer visiting Swarthmore in 1938 wrote these comments in his diary after visiting an embryology seminar:

> Swarthmore has very small classes and much informality in the teaching. This happened to be a group of six or seven pre-medic [sic] students sitting around a table discussing

> various problems in vertebrate embryology with [Professor Kille], and various ones going to the blackboard from time to time and drawing sketches of chick and pig embryos, particularly with reference to the fetal membranes.... One gets the impression of exceptionally fine teaching by these methods... [Kille] taught in the invertebrate course at Woods Hole several summers, now goes to the Tortugas Laboratory...[4]

The next year another Rockefeller Foundation officer, the head of the Natural Sciences Division, Warren Weaver, made these comments after meeting with Wolfgang Köhler, the great experimental psychologist who came to Swarthmore as part of the intellectual exodus from Nazi Germany:

> K[öhler] speaks of the fact that psychology being such a young subject is still essentially all “frontier,” so that he can bring undergraduates to research problems with but very little preliminary training. K[öhler] says that one of his undergraduates is now doing as good research in psychology as has ever been done under his direction. During the afternoon [I] had visited one of K[öhler]’s seminars, where a small group of Honors undergraduates was carrying on an exceedingly interesting research inquiry into the nature of memory.[5]

It was an era when Detlev Bronk, an early product of Aydelotte-era Swarthmore and a future mandarin of science, could write an optimistic essay on “Research at the Small College” that argued that:

> The growing size of our state universities is making it increasingly difficult for them to give that intimate contact between the mature and the developing scholar that has so important a function in the development of a nation’s best minds and characters.[6]

Bronk's kind of "intimate contact" remained the hallmark of Swarthmore's educational style throughout the decades we are considering today. Other small liberal arts colleges of the era that were similar to Swarthmore in providing an intense educational program, with or without an honors program, were described in similar ways. An assessment of Oberlin's science program in 1952 emphasized that its honors program "permits superior students to engage in some individual research or other study project in the senior year," and that "classes have remained fairly small, a condition made possible in part by the favorable student-faculty ratio of 11 to 1 that has obtained for the last two decades or longer."[7] (We found few outside descriptions or critiques of the sciences at other liberal arts colleges in the 1930s and 1940s.)[8]

The results of the liberal arts education fostered at these institutions was the focus of a very influential book published in 1953, *The Younger American Scholar: His Collegiate Origins.*[9] The authors sought "to discover which American undergraduate institutions are most fruitful in the present-day production" of "those individuals who show promise of future intellectual achievements of note."[10] Focusing on the years 1946-1950, they compiled a list of the undergraduate degrees held by those Americans who had earned a Ph.D. at one of 25 leading universities; had won a university fellowship from that same pool; had received a fellowship from one of nine foundations; or had been awarded a fellowship from the Public Health Service, the Atomic Energy Commission or the Fulbright Program. [11]

The results of their research were presented simply, in two tables, ranking the fifty leading colleges and universities as sources of these Ph.D.s. and graduate awards. The first, listed the scholarly "productivity" of male or co-educational colleges: Swarthmore was ranked first by a considerable margin, with Reed, Chicago, Oberlin, Haverford, Cal Tech, Carleton, Princeton, Antioch, and Harvard rounding out the top ten. In the sciences Swarthmore was ranked second to Cal Tech, with Chicago, Reed, MIT, Augustana, Oberlin, Johns Hopkins, Antioch and Cooper Union the rest of the first decade. (The authors noted that there were also a number of highly-productive women's colleges, but did not include them in the tables.)[12] The authors argued, referring to the growing notion that specialized training was a necessary precondition for graduate school, that their study:

> strongly suggests that high achievements in the production of younger scholars of promise is a general rather than a specific matter, and that whatever influences explain high achievement may be invoked generally with respect to all fields of learning.[13]

They also noted that the majority of the institutions in the list of fifty were liberal arts colleges, that the top five were co-educational, and that "in the first 12 institutions the social fraternity system is either extremely weak, inactive, or nonexistent."[14]

One might dismiss these results as an artifact of the times, before the great explosion of undergraduate education had affected American higher education (although the late 1940s was the era of the G.I. Bill). However, studies over the years have come up with similar results.[15] The latest, *Science and Engineering Indicators 2000*, published by the National Science Board, has an appendix that measures productivity as a ratio of Ph.D.s. in science and engineering awarded to graduates of an institution to the number of undergraduate degrees awarded to that institution.[16] The similarities to the list published in 1953 are strong: In order, the top ten are: Cal Tech, Harvey Mudd, MIT, Reed, Swarthmore, Cooper Union, Chicago, Radcliffe, Rice, and Haverford. Missing from the top ten of 1953 are Carleton, now ranked 12th; Oberlin, now ranked 15th; Antioch, now ranked 16th; Princeton, now ranked 20th; and Harvard, now ranked 33rd.[17] If we allow for the year 2000 list's inclusion of engineering (which, by the way, favors Swarthmore, which maintains an undergraduate major in engineering), there would be few differences over a half-century. Another study, which focused solely on institutions that offer only baccalaureate degrees (essentially a list of small American liberal arts colleges), offers another comparison of productivity: the absolute number of science and engineering doctorates awarded to graduates in the years 1991-1995. Clustered at the top of the list, within a few percentages of each other, are (in order) Oberlin, Carleton and Swarthmore, followed by Wesleyan, Reed, St. Olaf, Williams, Smith, Bucknell, and Wellesley.[18]

The "productivity" of Swarthmore College can be made more specific by reference to the three Nobel science prizes won by graduates from the decades we are considering: Christian Anfinsen ('37), in Chemistry, 1972; Howard Temin ('55), in medicine or physiology, 1975; and David Baltimore ('60), in medicine or physiology, 1975.[19] Two others worth special note are Maxine Singer, a leading molecular biologist and head of the Carnegie Institution of Washington; and Ted Nelson, "who shaped the crucial concept of hypertext" for electronic dissemination of information.[20]

Clearly there is something going on at Swarthmore, and similar institutions, that is worth examining. Why do small liberal arts colleges continue to produce outstanding scientists disproportionately? What makes them different?

We now will look at what the sciences were like at Swarthmore and similar institutions during the three decades we are examining. In the process of considering what might have been the critical factors we will encounter some of the paradoxes and limits of "little science."

First, were future scientists produced because of great science?

At Swarthmore from the late 1930s into the 1960s there were two unusual and outstanding areas of scientific investigation: astronomy and experimental psychology. Astronomy had a program of research based on the Sproul Telescope (installed in 1911), a 24-

inch visual refractor with a 36-foot focal length. (In 1946 it was reportedly the third largest refracting telescope in the United States.)[21] The arrival of Peter van de Kamp at Swarthmore in 1937 marked a strong turn toward positional astronomy, which utilized the strengths of the telescope and minimized the defects of its location on the edge of a major urban-industrial area.[22] Van de Kamp's goal was to better understand double stars, some of which had invisible companions that were possibly planets. Although the Astronomy department had an undergraduate major, Van de Kamp's program drew graduate students to the Astronomy department, one of the two at the college that regularly awarded master's degrees.

Psychology was the other department with a graduate program, because there were three outstanding figures in modern psychology on its staff: Solomon Asch, Wolfgang Köhler, and Hans Wallach. The latter two were pioneers in exploring human perception, although Wallach, at least, was interested in animal research as well.[23]

But neither of these departments had a substantial number of majors – the vast majority of science-trained students were in the traditional natural sciences departments whose research strengths were less obvious. William Elmore in Physics had connections with the Atomic Energy Commission and, along with another professor, Dennison Bancroft, was a consultant for the Los Alamos Laboratory.[24] In Biology the long-time chairman was Robert Enders, who had regular research visits to Panama, the Jackson Hole Wildlife Park, and the Rocky Mountain Biological Laboratory for his studies of speciation in mammals. Near the end of his career he was made an honorary fellow of the Association for Tropical Biology and Conservation.[25] The Chemistry department had three members who had active research programs or who had consulting relationships with industry.[26]

The faculty of the natural sciences also had some satisfaction that they were matching up well with other institutions. An internal Du Pont Company memorandum that reached President Smith in 1954 noted that "most of the chemistry graduates of Swarthmore who are employed by [du Pont] come to us as Ph.D. candidates from some of the major universities."[27] A 1965 review committee described the Biology department as "an excellent and extraordinarily successful operation" that sent its students to "first-rate graduate schools."[28] The Engineering department was pleased to find that, according to comparative SAT scores, it was competing on an even basis for students with MIT.[29]

But throughout the administration of President Smith, 1953-1969, there were increasing dilemmas and discontents in the science faculties. A leading issue was the matter of faculty replacement. Swarthmore found it a struggle to recruit and retain younger faculty. Elmore, the chairman of the physics department, described two days of recruiting for a faculty position at a meeting of the Physical Society:

> Two or three other physicists who looked me up at the recruiting table, either with Ph.D.s. or about to obtain them, bowed out when they learned what the teaching load is at Swarthmore, our lack of research facilities and the fact that we have no graduate program. A new Ph.D., with ability and ambition, is anxious to continue research, and is not willing to settle down to a heavy teaching load. There are too many competing institutions where the teaching load is 4-8 hours, graduate students to work with on research problems, and lots of exciting things happening at the frontiers of physics. And there is also the financial competition of government and industrial laboratories where starting salaries for a new Ph.D. are roughly at the associate professor level. For example, Los Alamos was actively recruiting at the ... meeting.[30]

Elmore knew whereof he spoke, because a few years earlier a candidate for a position at the college wrote a frank letter to him describing his recruitment to Los Alamos, and why he decided to go there, rather than take a position at Swarthmore.

> I was interviewed by several groups... One group is J division, which as you know is a test division[; it] had a rather attractive offer... they are concerned with fast scintillation detectors and fast timing problems and it sounded like an interesting position. Of course, it would mean going to the Pacific whenever there was a test but right now that seems more of an opportunity than a disadvantage. They made quite a good financial offer, about 50% more than Yale offered [$8500], and the five weeks vacation sounds good. I received the formal offer today and am going to accept it...[31]

Swarthmore's experience was not unusual: a contemporary *New York Times* article summarized a report by a committee of physics professors that stated that "the nation's four-year colleges are finding it increasingly difficult to ... [staff] their physics departments because of the intense competition of universities, industry and Government for the services of able physicists." The committee also stated that "the college physics teacher has a teaching load that averages twice as many hours as that of his university counterpart."[32]

This last was a constant complaint from the science departments, who argued that they had not only full schedules, but overloads, in part because they were overseeing required laboratory sections.[33] There were no teaching assistants to take on such non-lecture elements of courses. This left little time for personal research except in summers, which was the usual outlet for research-oriented professors at liberal arts colleges.[34]

Class overloads was one of the factors that led the scientists to feel that the president of Swarthmore was increasingly out of touch with their needs. We know that President Smith felt personally that science was moving increasingly in a direction at odds with the liberal arts tradition of discussion and debate that he encouraged. He told one of the physics professors that "scientists had compromised the poetic use of language by their insistence on precise definitions of words."[35] With these concerns, Smith exercised his presidential authority early in his tenure to appoint to the chemistry department a protégé of a Princeton University professor known for his "spectacular lecture demonstrations." He was never promoted, however, and when the department's chairmanship was open was told bluntly by other members of the department that he was unsuited for that role. The chairman of the department later told Smith directly that the appointment had been "a mistake" because neither his teaching nor his research were adequate.[36]

Another aspect of Smith's apparent distance from emerging science was his lack of interest in finding the funds for up-to-date instrumentation. In his remarks to outside groups he stated that Swarthmore should have excellent science instruction but without a cyclotron, a shorthand image for the facilities of "big science."[37] He did not demonstrate particular investment in or enthusiasm for purchasing a computer for the college either, a project that took three years (1961-1964) to bring to fruition. He apparently concurred with those who felt that the college should not create "a major computer center," even though a committee found that there was "a surprisingly strong need and a large number of [potential] uses."[38] Smith's resistance may have derived from the experience of being on the Princeton University faculty in the late 1940s when the off-campus Forrestal Research Center was established as a site for large-scale research enterprises, and the humanities faculty became "conscious of the shifting balance of campus power and the redistribution of resources, that appeared to threaten honored Princeton traditions and established principles."[39]

Sometimes, however, resistance to new directions in science was rooted in the faculty themselves. A clear example is in biology, which into the 1960s was dominated by the "classical" tradition of research on organisms, with the cell being the basic unit of understanding. The chairman of the department, Robert Enders, was emotionally opposed to adopting any elements of the new molecular biology that was revolutionizing the field in the latter 1950s and early 1960s. This was obvious even to President Smith, who was put in the position of urging him (unsuccessfully) to take advantage of funding possibilities in biophysics and biochemistry.[40] Presumably it was this resistance to new directions that led David Baltimore to recall that Swarthmore had given him "a terrible biology education."[41]

The biology faculty as a whole wanted change. In 1964-1965 they exchanged a series of memoranda, which began by stating that "Molecular biology is enormously exciting... It is important that this new area of study be incorporated into undergraduate curricula as swiftly as possible."[42] Several months later one faculty member argued that "we must not endeavor to perpetuate a fixed and dated concept of the field by building bias and prejudice...into [our] students."[43] In the summer of 1965 President Smith finally brought in an external review committee, which recommended that the next appointment to the department be extended to someone in molecular or cell biology – a step taken with a new hire in the middle of the 1966-67 academic year.[44]

In sum, it does not appear that science students at Swarthmore were stimulated by cutting-edge science. Might it have been the facilities and opportunities for student research?

At Swarthmore the research facilities in the late 1930s were regarded as equal to those at major universities, although we should remember that even major universities before World War II often had minimal laboratory and research equipment. Two decades later conditions at

Swarthmore in all of the natural sciences departments had deteriorated considerably. Reports to the president by the faculty harped on overused classrooms and laboratories, limited instrumentation, and tight budgets. This situation seems to have been mirrored at other small liberal arts colleges. There was now a clear divide between “big science” and the “little science.”[45]

There were occasional and incremental improvements through small grants. Swarthmore received an annual grant of $2500 for chemistry directly from the DuPont Company, and obtained modest grants for physics and biology from the National Science Foundation and the National Institutes of Health. A grant to Biology from the Atomic Energy Commission for equipment to use radioisotope tracers in physiological studies is a good example.[46] The physics department had 16 grams of plutonium on long-term loan from the Atomic Energy Commission.[47] But none of these grants appear to have been related to substantial improvements in the facilities on campus.

One possibility for faculty was to utilize research facilities at nearby institutions – something that science professors at liberal arts colleges frequently did. In 1965 Swarthmore in fact became a member of the new University City Science Center, a consortium headed by the University of Pennsylvania that gave Swarthmore’s faculty and students access to advanced instrumentation.[48] The arrangement, however, ran afoul of the pacifist traditions of the Quaker college (and the increased sensitivities to the Vietnam War) when it became clear that the Science Center was taking on substantial defense contracts.[49]

President Smith knew from early in his administration that the college’s science facilities were outmoded, and in 1957 obtained a $1.8 million grant from the Longwood Foundation (a du Pont philanthropy) to construct a new science building.[50] Opened late in 1959, it had new facilities for physics, mathematics and chemistry, as well as space for a new science library. The new facility made a huge change. It had numerous small classrooms with demonstration facilities; others were specifically identified as "seminar rooms" that were "designed to accommodate about ten people" and having adjacent "small tea pantr[ies]." (Those familiar with small-college seminars will recognize the amenities.) Although the faculty preferred to have flexible research space, and most laboratory rooms were not dedicated to particular types of research, all faculty had offices with attached laboratories that were intended to be combined research-teaching facilities, and physics had rooms for construction of laboratory apparatus, an optics laboratory, and a spectrographic facility. As the published description of the new building had it, "this arrangement makes it easier for the faculty member to sandwich research into small amounts of free time, and to keep certain types of experiments going even while working in his office or supervising students in the teaching laboratory."[51]

It is worthwhile to note here that the post-Sputnik judgment on American science clearly gave a boost to science-building construction.[52] Oberlin College desperately needed new science facilities: a Rockefeller Foundation officer who visited in 1959 described the existing chemistry building as "very old" and "crowded"; the botany building as "completely impossible"; and the biology department (different from botany) as located in the bowling alley of the women's gymnasium. With funding from the Rockefeller and Kettering foundations, Oberlin opened Kettering Hall in 1961.[53] Juniata College (PA) planned on a new science building in 1958, received a Longwood Foundation challenge grant of $400,000 in 1962, and opened the $2.4 million Brumbaugh Science Center in 1965.[54] Colorado College had a $1.5 million grant from the Olin Hall of Science; Reed College completed a new biology building and an addition to its chemistry building in 1961; at Williams ground was broken in 1964 for the Bronfman Science Center, a $3.9 million undertaking.[55]

In December 1960, soon after the opening of Swarthmore's science building for physics and chemistry, President Smith met with National Science Foundation officials regarding plans for a facility that would serve the needs of both Biology and the experimental psychologists.[56] The Biology Department wanted new facilities in the form of a new Animal House to hold experimental animals. As plans proceeded the biologists complained that it would provide research facilities but no new office and classroom space.[57]

At Swarthmore, whatever the facilities, there does not seem to have been a consistent tradition (as there seems to have been at Oberlin and Reed, for example) of involving students in research in the science departments. Robert Enders was known to take students on his research trips to Panama, and a review of the Engineering Department reported that

> The unusual combination of a very small number of students and highly-flexible courses permits the staff to inject research into the regular undergraduate academic program. Accordingly, the students develop a high degree of original thinking and ability to analyze rather complicated problems.[58]

However, when President Smith suggested to the chemistry faculty that they apply to the Petroleum Research Fund to support undergraduate research, the chairman replied that "undergraduate research usually means that the instructor does the research with undergraduate help. Nobody seems to believe that time can be found to carry on such type of work."[59]

In our view neither the state of science research nor the facilities at Swarthmore College were outstanding (let alone comparable to big science settings) and can account for the college's output of future scientists. There is a remaining factor, rather subjective, which seems to explain the difference – the quality and style of the educational process. Not just the honors program, but the entire pedagogical system at Swarthmore was oriented toward small classes verging on the tutorial, which at once encouraged student-professor and student-student dialogue, and provided an atmosphere of exploration of ideas.

President Smith believed strongly in the importance of faculty interaction with students, arguing that:

> the student-faculty dialogue comes best when there is substance – when it starts, for example, with an intellectual question the student wishes to carry further, or when it involves a problem the student has a reason to believe the faculty member could help with.[60]

To maintain this dialogue, and the kind of faculty who would work with students who had "intellectual questions" they wished "to carry further," Smith personally interviewed every candidate for a faculty position, and encouraged departments to select as new members those who would maintain the college's traditions of free inquiry.[61]

Personal accounts sustain the reality of Smith's goal. Even David Baltimore, who denigrated the level of biology education at Swarthmore, found that the student-faculty Biology Club and a microbiology honors seminar were his sources of information about molecular biology, along with the opportunity and encouragement for independent reading that the college environment provided.[62] An earlier student in the biology department, Vivianne Nachmias, who graduated in 1952 before molecular biology had become a tidal force, recalled the "charismatic chairman, Robert Enders, who was always ready for conversation and questions. On Sunday evenings he had gatherings at his house for students who would sit around the fire... and discuss science, adventure and philosophy." Nonetheless, when she found that the department lacked a commitment to biochemistry, she joined fellow student Maxine Singer in developing their own on-campus seminar.[63]

In this context it is interesting to read the 1954 review of the introductory science portion of the new curriculum installed at Amherst College several years before:

> Throughout the freshman course every effort is made to focus the attention of the students on the *ideas* which are involved – the language, the concepts, and the inferences. It is explicitly pointed out that the problems are simply the *means* to an end, not ends in themselves... [In the laboratory the student] is required to state his problem and then to investigate it. Virtually no specific instructions as to procedure are given.[64]

A description of chemistry education at Oberlin is similar:

> Oberlin chemistry students have the personal attention and freedom usually reserved in large departments for the graduate students. In the informal atmosphere possible in a college laboratory the students are in contact with experienced teachers who can guide the students as individuals both in the laboratory and in the library.[65]

It is useful to recall here as well the Harriet Zuckerman's research into the making of Nobel Prize winners. She came to the conclusion that the common element was the experience of being personally mentored in a style of learning that was critical to intellectual trajectory, rather than the assimilation of a particular body of knowledge.[66]

The central paradox of "little science" at a college like Swarthmore is that it violates, or perhaps it is better to say, rectifies our usual focus on experiment and publication as the measure of the creation of science. We are brought back to the recognition that there is no science without the generation of scientists, and that – if the productivity of the liberal arts colleges is to be reckoned with -- they are generated out of encounters with ideas – and encouragement to play with those ideas – at least as much as encounters with the things of science.[67]

ENDNOTES:

[1] See the recent six-part definition of "big physics" in Jean-Paul Gaudilliére, "Paris-New York roundtrip: Transatlantic Crossings and the Reconstruction of the Biological Sciences in Post-war France." *Stud. Hist. Phil. Biol. & Biomed. Sci.* 33 (2002) pp. 394-95. A useful access point to discussions of this topic is: Peter Galison and Bruce Hevly, editors, *Big Science: The Growth of Large-Scale Research.* Stanford, California: Stanford University Press, 1992.

[2] Darwin H. Stapleton and Donna H. Stapleton, *Dignity, Discourse, and Destiny: The Life of Courtney C. Smith.* Cranbury, New Jersey: Associated University Presses for the University of Delaware Press, 2004.

[4] Frank B. Hanson diary, 1 March 1938, excerpt, folder 1929, box 157, series 200D, Record Group (RG) 1.1, Rockefeller Foundation Archives (hereafter RFA), Rockefeller Archive Center, Sleepy Hollow, New York.

[5] Warren Weaver diary, 14 March 1939, box 68, RG 12.1, RFA.

[6] Detlev Bronk, "Research and the Small College," unpublished manuscript, c. 1930, folder 25, box 82, Detlev Bronk Papers, Rockefeller Archive Center, Sleepy Hollow, NY.

[7] Excerpt from Robert H. Knapp and H.B. Goodrich, *Origins of American Scientists* (1952), published as R.H. Knapp and H.B. Goodrich, "Origins of American Scientists." *Oberlin Alumni Magazine,* March 1955, pp. 8-9.

[8] Our inquiries sent to the archives of over a dozen leading liberal arts colleges in the summer of 2003 regarding the history of sciences at their institutions were met in all but a couple of cases with the response that they had little historical material, archival or published, specifically on the sciences. Our reading of histories of liberal arts colleges, admittedly eclectic, has led us to the conclusion that the authors of such histories had little interest in the sciences at their institutions and a fondness for the "presidential synthesis" as a means of exposition: Richard J. Walton, *Swarthmore College: An Informal History*. Swarthmore, Pennsylvania: Swarthmore College, 1986; David M. Stameshkin, *The Strength of the Hills: Middlebury College, 1915-1990*. Hanover, New Hamphire: University Press of New England, 1996; Earl C. Kaylor, Jr., *Juniata College: Uncommon Vision, Uncommon Loyalty.* Huntingdon, Pennsylvania: Juniata College Press, 2001; Jean Glasscock, editors, *Wellesley College, 1875-1975: A Century of Women.* Wellesley, Massachusetts: Wellesley College, 1975; Robert D. Loevy, *Colorado College: A Place of Learning, 1874-1999.* Colorado Springs, Colorado: Colorado College, 1999; F. Wilbur Gingrich and Eugene H. Barth, *A History of Albright College, 1856-1956.* Reading, Pennsylvania: Albright College, 1956; Gail Kennedy, editor, *Education at Amherst: The New Program.* New York: Harper & Brothers, 1955.

[9] Robert H. Knapp and Joseph J. Greenbaum, *The Younger American Scholar: His Collegiate Origins.* Middletown, Connecticut and Chicago, Illinois: University of Chicago Press and Wesleyan University Press, 1953.

[10] Ibid., p. 1.

[11] Ibid., p. 8.

[12] Ibid., pp. 16-17. Reportedly, a study of five leading women's colleges in the early 1950s found that they produced "three times as many physics majors" as a group of select co-educational universities: "Electrific Major," *Mademoiselle,* March 1955, unpaginated copy in "Physics Dept 1953-57" folder, box 62, CCSPP.

[13] Ibid., p. 17.

[14] Ibid., p. 17.

[15] See Thomas R. Cech, "Science at the Liberal Arts Colleges: A Better Education?" *Daedalus* 128 (Winter 1999) pp. 195-216.

[16] National Science Board, *Science & Engineering Indicators 2000.* NSB-00-1. Arlington, Virginia: National Science Foundation, 2000. Our copy was downloaded from the National Science Foundation's web site.

[17] Ibid., Appendix B, "Productivity Ratios for the Leading 100 Undergraduate Sources of Science and Engineering Ph.D.s," pp. 252-255. This may also be found at: http://www.wws.princeton.edu/cgi-bin/byeserv.prl/~ota/disk1/1989/8919/891908.PDF.

[18] *Undergraduate Origins of Recent (1991-95) Science and Engineering Doctorate Recipients,* Appendix B, table B-8, "Top 25 'baccalaureate colleges' that were baccalaureate-origin institutions of 1991-95 science and engineering (S&E) doctorate recipients, ranked according to total S/E doctorate by field of doctorate," http://www.nsf.gov/sbe/srs/nsf96334/append.htm.

[19] See biographies at www.nobel.se/chemistry/laureates/1972/anfinsen-bio.html; www.nobel.se/medicine/laureates/1975/temin-autobio.html; www.nobel.se/medicine/laureates/1975/baltimore-autobio.html.

[20] Brief biography of Maxine Singer at http://carnegieinstitution.org/singer/default.html; Owen Edwards, "Ted Nelson," *Forbes,* 25 August 1997, at www.forbes.com/asap/1997/0825/134.html.

[21] "College to Add to Observatory," *The Swarthmorean.* Swarthmore, Pennsylvania, 14 June 1963; Peter van de Kamp to John W. Nason, February 7, 1941, folder 1926, box 157, series 200, RG 1.1, RFA; Rockefeller Foundation, *Annual Report 1946.* New York: Rockefeller Foundation, 1947, pp. 164-65.

[22] "The Research Program of the Sproul Observatory." (August 22, 1946), folder 1927, box 157, series 200, RG 1.1, RFA.

[23] "Death of Solomon Asch," University of Pennsylvania Almanac, 42 (5 March 1996), at www.upenn.edu/almanac/v42/n23/asch.html; Ulric Neisser, "Wolfgang Köhler, 1887-1967." National Academy of Sciences, *Biographical Memoirs*, 81 (2002) pp. 3-13; "Hans Wallach, 93, Scientist Who Helped Explain Hearing." *New York Times*, 15 February 1998, p. 44; "Notes on Animal House Committee Meeting." 25 November 1959, and "Notes on Animal House Conference." 19 December 1960, "Animal Laboratory" folder, box 6, Courtney C. Smith Presidential Papers (hereafter CCSPP), Friends Historical Library, Swarthmore College, Swarthmore, Pennsylvania.

[24] Courtney C. Smith to A.E. Dyhre, 28 April 1958, "Physics Dept. 1958-61" folder, box 62, CCSPP.

[25] Anne Matthews Rawson, "History of Biology at Swarthmore College," 1989, unpublished, copy in authors' files, which has biographical information on other department members, as well. On Enders being elected an Honorary Fellow of the ATBC, see: www.atbio.org/fellows.htm.

[26] L.A. Wetlaufer to E.F. du Pont, 17 March 1954, "Chemistry Dept. 1953-59" folder, box 24, CCSPP.

[27] Ibid.

[29] John R. Dixon to Courtney C. Smith, 29 June 1965, "Admissions 1965" folder, box 2, CCSPP.

[30] William Elmore to Courtney C. Smith, 19 February 1961, "Physics Dept 1958-1961" folder, box 62, CCSPP.

[31] Charles Fenstermacher to William Elmore, 13 March 1957, "Physics Dept 1953-57" folder, box 62, CCSPP.

[32] Robert H. Terte, "Run of Physicists Plagues Colleges," *New York Times*, 7 May 1964, p. 34. William Elmore was a member of the committee: see press release, "Nations Colleges Face Serious Problems in Physics Teaching." 6 May 1964, copy in "Physics Dept 1962-1968" folder, box 62, CCSPP.

[34] Biology Department chairman Robert Enders wrote to one candidate for a faculty position that the department had "teaching schedules in which some of us have taught as much as 26 hours per week. Schedules like this do not allow time for research... The amount of money coming from the college [for research] is negligible." Robert K. Enders to Lionel Jaffe, 5 May 1955, "Biology Dept. 1953-59" folder, box 10, CCSPP.

[35] Irving E. Dayton to Donna and Darwin Stapleton, 10 June 1992, in author's files.

[36] Ibid.; “Memorandum of a conversation with ** on 24 October 1957,” “Chemistry - Ad Hoc Committee 1958" folder, box 24, CCSPP; “Notes on Ad Hoc Chemistry Committee Meeting,” 14 December 1957, “Chemistry - Ad Hoc Committee 1958" folder, box24, CCSPP. Name of individual withheld for privacy reasons.

[37] E.g., Courtney C. Smith, remarks to Association of Independent Schools of Greater Washington, 16 October 1956, box A, Courtney C. Smith Personal Papers (hereafter CCS Personal Papers), in possession of Elizabeth Smith Ingram, Chevy Chase, MD. Smith used this image in a Voice of America lecture, published as: Courtney C. Smith, *The Liberal Arts College, The Voice of America Forum Lectures.* Educational Series, 5 Washington, D.C.: Voice of America, 1960, p. 7.

[38] “New Emphasis on Computers Planned.” *Swarthmore Data Sheet* (newsletter of the Division of Engineering, Swarthmore College), May 1962, pp. 1, 3, copy in “Computer 1962-63,” box 29, CCSPP; Norman Meinkoth to Courtney Smith, (26 March 1964), “Computer 1964-1968" folder, box 29, CCSPP.

[39] Amy Sue Bix, “‘Backing into Sponsored Research’: Physics and Engineering at Princeton University, 1945-1970.” *History of Higher Education Annual*. 13 (1993) p. 13.

[40] Courtney C. Smith, memorandum of conversation with Robert Enders, 3 February 1961, “Biology Dept. 1960-63" folder, box 10, CCSPP.

[41] Shane Crotty, *Ahead of the Curve: David Baltimore’s Life in Science* Berkeley, California: University of California Press, 2001, pp. 21, 31, quote on p. 31.

[42] William C. Denison, “Molecular Biology and Classical Botany-Zoology,” 20 July 1964, “Biology Dept. 1964-66" folder, box 10, CCSPP.

[43] Launce J. Flemister to the Biology Department, 19 March 1965, “Biology Department 1964-66" folder, box 10, CCSPP.

[44] Rawson, “History of Biology at Swarthmore College.”

[45] On this subject see: Robert Finn, “Scientists at Four-Year Colleges Strive for Research Qualit.” *The Scientist,* October 27, 1997, pp. 13-14.

[46] National Science Foundation grant application, 26 December 1962, Atomic Energy Commission grant application, 22 December 1962, both in “Biology Dept. 1960-63" folder, box 10, CCSPP. Acknowledgements of the awards of the grants are in the same folder.

[47] Edward K. Cratsley to Charles G. Manly, 9 February 1960, “Physics Dept. 1958-1961" folder, box 62, CCSPP; Edward K. Cratsley to John C. Cera, 28 June 1961, “Physics Dept. 1962-1968" folder, box 62, CCSPP.

[48] *Come to Where the Knowledge Is*. (Philadelphia, 1965), in "University City Science Center, 1962-64" folder, box 78, CCSPP; Edward K. Cratsley to Jean Paul Mather, 12 October 1965, "University City Science Center 1965-66" folder, box 78, CCSPP.

[49] Courtney C. Smith to Paul J. Cupp, draft, 26 June 1967, "University City Science Center 1967" folder, box 78, CCSPP.

[51] Irving E. Dayton, "The Pierre S. du Pont Science Building, Swarthmore College." *American Journal of Physics* 29 (November 1961) pp. 753-763, quote on p. 759.

[53] JEM diary, 3-7 May 1959, excerpt in folder 1935, box 205, series 200D, RG 1.2, RFA; grant action of the Rockefeller Foundation Board of Trustees, 24 June 1960, folder 1935, box 205, series 200D, RG 1.2, RFA; Thurston E. Manning to J. George Harrar, 19 June 1961, folder 1935, box 205, series 200D, RG 1.2., RFA.

[54] Kaylor, *Juniata College*, p. 207.

[55] Loevy, *Colorado College,* p. 147; grant action, Rockefeller Foundation Board of Trustees, 19 June 1959, and Gwen L. Taylor to John H. Greenfieldt, 24 March 1961, folder 2045, box 215, series 200D, RG 1.2, RFA; "Science at Williams: the first 200 Years," (Williamstown, MA: Williams College, 2002), chapter 4, part 4, online at www.williams.edu/go/sciencecenter/center/histscipub.html.

[56] Courtney C. Smith appointment diary, 23 December 1960, box F, Personal Papers; "Notes on Animal House Committee Meeting," 25 November 1959, and "Notes on Animal House Conference," 19 December 1960, both in "Animal Laboratory" folder, box 6, CCSPP. Note that in the fall of 1959 there were plans to erect a temporary shelter on the roof of the Biology Department building "to house the mink colony of a project being run by Professor Enders": Andrew Simpson to E.K. Cratsley, 28 October 1959, "Animal Laboratory" folder, box 6, CCSPP.

[57] "Analysis of Space Requirements, Present and Future, for the Department of Biology," 30 March 1962, "Biology Dept. 1960-63" folder, box 10, CCSPP.

[58] Ralph A. Morgen to Courtney C. Smith, 7 November 1963, with attached report, "Engineering Department Apr 1964-65" folder, box 36, CCSPP.

[59] Edward Cox to Courtney C. Smith, 6 December 1957, "Chemistry Dept. 1953-59" folder, box 24, CCSPP.

[60] Courtney C. Smith, "The Dialogue." *Swarthmore College Bulletin* 60 (May 1963) p. 6.

[61] See chapter 10, "Faculty." in Stapleton and Stapleton, *Dignity, Discourse and Destiny,* note 2 above.

[62] Crotty, *Ahead of the Curve*, pp. 23-27.

[63] "Vivianne Nachmias: ASCB Profile," at www.ascb.org/news/vol22no1/profile.htm. Maxine Singer recalled that "when I was in college, biology was still observational, phenomenological. I actually didn't like it": "Dr. Maxine Singer," About Biotech, 1992 interview at www.accessexcellence.org/AB/CC/singer.html.

[64] Gail Kennedy, editor, *Education at Amherst*, pp. 211-212. Italics in the original.

[65] Luke E. Steiner, "Chemical Education in American Institutions: Oberlin College." *Journal of Chemical Education* 25 (October 1948) p. 529.

[66] Harriet Zuckerman, *Scientific Elite: Nobel Laureates in the United States* New York: Free Press, 1977, pp. 122-123.

[67] For a more general argument on higher education as places of knowledge, not just "education," see: Sverker Sörlin, "Cultivating the Places of Knowledge." working paper 2002-2009, Swedish Institute for Studies of Education and Research, www. sister.nu. The paper later appeared in *Studies in Philosophy and Education: An International Quarterly*.