# Changes in the Gardens of Science, Wrought by Women

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Not long ago, in a symposium held here by the New York Academy of Sciences on The Flight from Science and Reason, I gave a paper titled "Imaginary Gardens with Real Toads." What I have to say in this paper might be called "Creeping Toward Inclusivity in Science, Despite Persistent Toads." By means of some stories—chiefly personal experiences—and a few statistics, I want to offer homage to intrepid activists who catalyzed remarkable changes. Within a single generation, these changes have greatly enhanced opportunities for women in many professions, especially science. Although optimistic about future prospects, I must also point out some daunting toads and serpents lurking in the gardens of science. These challenge the rising generation of young scientists to be no less intrepid.

Much that is unthinkable today was almost unquestioned 25 or 30 years ago. Here are some examples that impressed me back then. All pertain to curious practices that persisted until the late 1960s or early 1970s.

On a visit to Oberlin, my hosts proudly told me that it was the first college in the United States to offer coeducation. However, I was amazed to learn that a laundry service was provided for men students but not for women students.

Closer to home, Harvard did not allow Radcliffe women to study in Lamont library, which is specifically for undergraduate use, on grounds that women would distract the men from scholarly pursuits. That policy was abruptly abandoned when Radcliffe built Hilles Library, bigger and better.

Closer yet to home, I remember that Bell Labs offered jobs to two newly minted Ph.D.s from the same research group in the Harvard Chemistry Department. This dismayed everyone who knew of it, because Bell did not want to hire the more promising of the two, a woman, as a staff scientist but only as a librarian.

Of course, in the wider world such things were also pervasive. For instance, the Boston Symphony Orchestra, like other major orchestras, had hardly any women musicians. Now there are many, but that did not come about until the practice developed of having final auditions behind a screen. Even then, the women finalists had to learn not to enter wearing distinctly audible shoes.

## WOMEN ON THE HARVARD FACULTY

In 1970, two women assistant professors went to the Dean of the Faculty of Arts and Sciences (FAS) at Harvard and pointed out what nowadays would be

called a glaring "gender disparity." The FAS professorial ranks (full, associate, and assistant) then numbered about 675, but included only thirteen women. Of those, eleven were assistant professors and one a full professor newly appointed to an endowed chair that specified its holder must be a woman. The Dean responded in traditional fashion, by appointing a committee to study the status of women on the faculty. I was one of the six faculty members appointed to this committee, three men and three women. At our first meeting, attended by the Dean, we had to take him to task for a strange aspect of his appointment letter; it included a list of the committee members, with "Dr." before the names of the men and "Mrs." before those of the women.

It was an earnest, diligent committee, very ably co-chaired by Caroline Bynum (one of the assistant professors who had prodded the Dean, now a distinguished scholar and Vice President of Columbia) and Michael Walzer (now at the Princeton Institute for Advanced Study). Because our mandate invited us to study the "status and problems of women graduate students as well as faculty members," we recruited as consultants five women graduate students. During the fall of 1970 we held a series of seven open hearings at which over fifty people testified on a great variety of topics relevant to the status of women at Harvard. We addressed detailed inquiries to all FAS department chairmen and received ample responses from most of them. We interviewed most of the women holding any sort of academic appointment and consulted at length with administrative officials. We also obtained information about the experience, achievements, and career expectations of women graduate students, by means of a questionnaire sent to all women then enrolled in the graduate school (and to one-third of the men), as well as to all members, female and male, of the entering graduate classes of 1950, 1957, and 1964. Our findings were published in a 96-page report[1] with a crimson cover; our committee and a few fans liked to refer to it as our "manifesto."

At a special faculty meeting in May, 1971, which drew the largest attendance of the year, the committee report was presented and four proposals advanced in it were approved by lopsided voice votes.[2] In brief, these specified: (1) that the faculty endorse our major conclusion: "the number of women on the faculty must be increased" and appoint a standing committee to assist in the process; (2) that part-time appointments to any of the professorial ranks be permitted; (3) that any non-tenured professor who becomes pregnant during her appointment shall be allowed an extension of one year for each pregnancy, not to exceed a total of two years; (4) that graduate students in all departments be permitted to work on a part-time basis while retaining proportional scholarship assistance, working at not less than a two-course load per term.

The lopsided votes came as a pleasant surprise. It was only two years since the student takeover of University Hall had split the faculty into politically contentious factions, and tensions lingered. Rumors preceding the meeting indicated that item (1) would draw vigorous objections, but that didn't happen. When presenting it, Caroline Bynum took care to note that, according to the Oxford English Dictionary, "must" is "an expression of firm resolve." In an eloquent seconding speech, Emily Vermeule quoted a passage in Greek, rendered as "She is a virgin from the neck up—a woman below." Emily added: "It is only the qualities of women from the neck up that should concern us here." An amendment to item (3) was proposed by

a male assistant professor, suggesting paternity leave for fathers, on grounds that child care should be shared equally. That was supported by a senior professor; he said that our committee, "In an effort to ingratiate themselves with the Neaderthals on the faculty, . . . had put sexist implications" into the legislation. The amendment was voted down, but item (3) passed unanimously.

The "must" did take effect. Already by 1975, there were twelve women full professors, or about 3%; these were chiefly appointments of recognized scholars who had long been at Harvard in "off-ladder" positions. There were ten women associate professors (11%) and forty-two women assistant professors (25%). Now, in 1998, about 11% of the full professors are women and 31% of the junior faculty (nontenured, associate or assistant professors). For the past 5 years, women have received about 25% of the tenured appointments at Harvard. That is close to the fraction of Ph.D.s earned by women fifteen years ago. On the other hand, the fraction of tenured women faculty has not increased appreciably above 11% in recent years. That is largely because many of the new appointments are replacing women now retiring from tenured positions that had not opened up for them until rather late in their careers.

## THAT WAS THEN, THIS IS NOW

Likewise heartening, if only in the Gilbert and Sullivan sense of "modified rapture," are other changes I have observed over the years; I'll mention a few pertaining to science.

### *Two Scenes in Philadelphia*

As a result of serving on the Bynum-Walzer committee, I was invited in late 1971 to take part in a symposium titled "Women in Academia: Evolving Policies Toward Equal Opportunities," held in Philadelphia at a meeting of the American Association for the Advancement of Science.[3] The presenters included seven women and four men; the audience about 300, with only one man. In the front row was the President of the National Organization of Women, attired in overalls. She delivered caustic commentary on the remarks of each of the male speakers. More compelling, however, were the opening remarks by Mary ("Polly") Bunting, then President of Radcliffe College. Standing at the podium, before a huge painting of a group of bewigged men signing the Declaration of Independence, she urged that women focus on "doing your best work; that will make the difference." She also said, "if you want to get somewhere, don't wait for the rain to stop."

In February, 1998, I was again in Philadelphia at an AAAS meeting. There I learned that the last four presidents of AAAS have been women (the first in its 150-year history) and that the Board of Directors has for years had 50% or more women. How did that come about? The bylaws require that there be at least two candidates for the elective offices; it has turned out that whenever one of the candidates is a woman, she usually wins the election, even though most AAAS members are men.

Women likewise had a prominent role in many symposia. At the meeting, President Clinton announced that he had nominated Rita Colwell, a former AAAS president, to be the next Director of the National Science Foundation. These striking contrasts with the 1971 scene were capped by an exuberant luncheon given by the Association for Women in Science, celebrating its 25th anniversary. Philadelphia had become the city of sisterly love.

### *Women Chemists at Research Universities*

In 1976 a guest editorial appeared in *Chemical and Engineering News*, a magazine received by all members of the American Chemical Society. The editorial, written by a Dean at Princeton, vigorously criticized numerical goals for affirmative action.[4] I was then on sabbatical at Caltech, associated with a group that had two women graduate students. Together we sent a response pointing out that the forthright way to abolish such goals was to fulfill them.[5] As evidence that it should be feasible, we described what had happened at Harvard in the previous five years. We also discussed the acute problem of the very low hiring rate for women faculty in the sciences, especially physics and chemistry. At that time, only 3% of new Ph.D.s in physics and 9% in chemistry were women. There was not a single woman at any ladder professorial rank in chemistry at twenty of the top twenty-five research universities in chemistry.[6] There were only six women chemists, all assistant professors, at the other five universities; four of them had been appointed just in the previous two years and all but one were biochemists. These twenty-five major chemistry departments had a total of 770 professors, so the six women were 0.8%. At least 165 of these faculty (mostly assistant professors) had been hired within the previous five years. During that time, the twenty-five universities turned out about 270 women Ph.D. chemists. If women had been hired during those five years at the 9% Ph.D. production rate, about fifteen rather than six of those positions would have gone to women, particularly in fields other than biochemistry. If women had been hired at only a 5% rate for the previous twenty-five years, those chemistry departments would have had about twenty-five women full professors and fifteen associate or assistant professors; so the total of forty would have been 5.2% of the faculty.

Two decades later, in 1997 these twenty-five chemistry departments[7] had a total of 754 professors, fifty-three of them women, or 7.0%. Of the tenured professors, thirty were women (4.6%), and of the assistant professors twenty-three were women (21%). Thus, at these twenty- five major universities, the percentage of tenured women chemists now on the faculty represents about half of the Ph.D. production rate 20 years ago (9%), whereas nontenured women faculty are being appointed at about three-fourths of the current Ph.D. production rate (27%).

The distribution of women faculty among subfields of chemistry is revealing. Among the fifty-three, there are six organic chemists, fifteen biochemists, eighteen physical chemists, ten inorganic chemists, three analytical chemists, and one nuclear chemist. It is striking that there are so few women faculty in organic chemistry, the subfield that has the most graduate students and postdoctoral fellows. (Biochemistry is not fairly represented here, since some of the twenty-five

departments include it but many do not.) The distribution of women among these chemistry faculties is also curious. UCLA has seven, Michigan has five, Ohio State and Berkeley each have four, Caltech has three; none of the other twenty universities has more than two women chemists and one has none. As yet eleven have no women full professors in chemistry and only five have more than one.

At least in chemistry, the "leaky pipeline" between high school and the Ph.D. has now become appreciably less porus.[8] In 1975, women received about 22% of B.S. degrees and 9% of Ph.D.s in chemistry; twenty years later, about 43% of B.S. degrees and 27% of Ph.D.s. These upswings should accelerate substantially the appointment of women faculty.

### *Women Elected to Honorary Academies*

Before 1970, the percentage of women members of the National Academy of Sciences (founded in 1863) had remained in the range 0.3–0.7% for the previous half-century. It then began to grow slowly but steadily, reaching 1.9% in 1975, 3.1% in 1985, and is now 5.8%: There are 110 women among the 1,880 current active and emeritus members.[9] Despite the low percentages achieved as yet, it is encouraging that the upward curve is in fact tracking in parallel the increasing numbers of women Ph.D. scientists and faculty members.

Other honorary societies have also elected increasing numbers of women. Up to 1980, the American Academy of Arts and Sciences (founded in 1780) had only elected about 70 women.[10] In the next decade, it elected another fifty-five, but thus far during the 1990s it has elected nearly 300. That climb is actually steeper than the latest bull market in stocks. Women now comprise 11% of the fellows, only about 4% of fellows in the physical sciences, but 14% in biological sciences, 11% in social sciences, and 16% in the humanities. These numbers are quite similar to the percentages of women full professors now found in leading American universities. That is interesting, since the Academy Fellows are a more distinguished category than the full professors.

### *Young Women in Science*

When I began teaching large freshman chemistry classes about fifteen years ago, very few women students chose to sit in the first three or four rows; in recent years, more women than men occupy those rows. Over that span, the fraction of women in the course has grown only modestly, from about 40% to 50%, but the number majoring in chemistry has increased markedly, from typically eight to about twenty per year; women are now nearly 40% of chemistry majors at Harvard. Moreover, back when there were few women in the front rows, the top ten students in terms of performance were nearly always only men. That is no longer so; this year three of the top four (A+'s) and six of the top ten were women. We do not really know why such changes have happened. My impression, reinforced by many conversations and also by experience with graduate students, is that young women now feel much more confident of their abilities and prospects as scientists.

Nationwide, the participation and performance of high school girls in science fairs has likewise grown quite substantially. The International Science and Engineering Fair (ISEF), now sponsored by Intel Corporation, has been held each May in a different city for the past forty-eight years. It has expanded to more than 1000 participants, over 90% from the United States, selected as winners of hundreds of local, state, and regional fairs in which about a million other high school students take part. Twenty-five years ago girls were about 25% of the ISEF finalists, but they are 47% now.[11] Likewise, in recent years girls have received nearly half of the top prizes.

## TOADS AND SERPENTS

In contrast to the many recent trends that offer encouragement to young women pursuing careers in science, particularly academic careers, there are now at least two major factors that have become increasingly daunting. One is the tight job market and funding situation. The other, perhaps more recalcitrant, is the expansion of the time to complete a Ph.D. degree. Even in the sciences, six or seven years has become the norm. Furthermore, for those who seek faculty positions, postdoctoral experience is now expected. With the job shortage of recent times, the typical postdoctoral stint has become a holding pattern, often extending to three years or more. Thus, assistant professors now start out several years older than usual years ago. What should have been an invigorating, adventurous jaunt on the way to an independent position has, for far too many, stretched into a grueling marathon.

That shift of several years makes it all the more difficult to cope with responsibilities to a spouse and/or children while trying to prove mettle in research and teaching.[12] The tenure decision also comes at a later age, so becomes more stressful. For women, the biological clock exacerbates the impact of such an expansion of the early career era. Other professions also demand much of young people; but the route to law or medicine is now much shorter than for academic science. Reducing the "apprenticeship" period between a bachelor's degree and appointment as an assistant professor to five or six years, as used to be typical, would of course benefit both young men and women scientists. Moreover, enabling them to launch independent careers at a younger age would surely foster new, enterprising ideas and efforts, so vital to the vigor of science.[13]

In my opinion, the way academic science has come to be funded is a major toadish factor stretching out the apprenticeship. The funding is given for particular research projects, not for people. Most graduate students and postdoctoral fellows therefore are supported chiefly by serving as hired hands on a project. This imposes a great burden on the professorial research advisor, especially since nowadays in fields such as chemistry a typical grant supports only one or two students and seldom extends for more than three years. Because veteran graduate students or postdoctoral fellows are most useful in obtaining results to justify a renewal, the vital need to get grants renewed tends to extend the apprenticeship. Another factor often operates in the same direction. When funding is tight, the peer review system induces cautious, mainstream proposals likely to be endorsed

by reviewers who hope to get support for similar work from the same agency. Usually, the less novel or distinctive the work, however, the thicker a respectable Ph.D. thesis must be, and the longer the time required to complete it.

Despite the significant gains in inclusivity achieved in just one generation, women in science as in other professions still often encounter bias, subtle or blatant. Feudal aspects of universities and corporations are remarkably persistent. For instance, as yet Harvard has made very little progress with "affirmative action for portraits," even though appeals for it have been made repeatedly. Faculty appointments or promotions that seem attributable to affirmative action do arouse resentment. Yet there is much that could be done to benefit women that would benefit men as well.

Certainly that is so for shortening the time to the Ph.D. For a student entering graduate school with decent preparation, four years should be enough. In the sciences, that can be achieved if both faculty advisors and students recognize it as a key priority. Uncoupling the support of graduate students from project grants should also help them break loose. If support of students (and preferably also postdoctorals) on grants to individual professors were abolished, the same money could be put into expanding greatly both the number of fellowships that students can win for themselves and block training grants to university science departments. Winning a fellowship profoundly influences a student's outlook and approach to research work; they are certified as a national resource rather than hired hands. Both the fellowships and training grants should be tenable for no more than five years. A fellowship winner completing the Ph.D. in four years should be rewarded by receiving a postdoctoral stipend for a year to work at a laboratory of his or her choice.

A new system is also needed for launching young science faculty, women and men. Over the past fifteen years or so, a paradoxical situation has developed. While the postdoctoral holding pattern has built up, the number of assistant professors has declined, particularly at the major research universities. In chemistry, for example, it used to be that 25% or more of the faculty would be assistant professors; now 10% is typical. In many cases, this is not due to a lack of slots for beginning faculty. Rather, a major inhibiting factor is the high cost of providing, from university resources, both equipment and support for research students and postdoctoral fellows for the first two or three years, until the new professor can be expected to obtain outside funding. These costs are now so high that to sell a Dean on appointing an assistant professor, a department has to present a candidate deemed to be extraordinary. In a given recruitment season, such claims can likely be made for only one or two candidates in any given subfield. Those candidates often get offers from several universities, but other worthy candidates may get no offers while many universities are left with empty slots. This syndrome, in combination with the recent abolishment of mandatory retirement, is accelerating the greying (and balding) of science faculties.

In view of this demographic disequilibrium, it would be sensible to simply give block grants to active research centers for usual start-up costs of beginning faculty, so that they need apply to funding agencies chiefly for special equipment. If support of students and postdoctorals were uncoupled from project grants, the budgets for typical project proposals from professors, both junior and senior,

would be much smaller. As well as removing the burden of large start-up costs from the universities, which presumably would then welcome more young faculty, these reforms would enable students to choose faculty advisors without concern for funding and should also enhance departmental collegiality.

If such broad reforms are to happen, many institutions and agencies will have to become involved. Inertia and fear of change are immense obstacles, but there are now many groping efforts to fashion a new national science policy. The vigorous commitment of organizations such as the Association for Women in Science (AWIS) and Women in Science and Technology Alliance (WiSTA) can play a vital catalyzing role. Emphasizing that most of what would help young women scientists would also help men should enhance that role.

At present there is much concern that the gains made during the past twenty-five years may not be extended or perhaps even sustained by the coming generation of women scientists. Certainly it is hard to see how that can be achieved unless there are far-reaching institutional changes. While not confident that will happen, I am optimistic. More compelling than legal and political pressures are attitudinal changes. Even long overdue institutional changes can occur quickly when a new consensus emerges. A pertinent example is the abrupt abandonment in the early 1970s of the deeply rooted notion that college men and women must reside in separate dormitories. After another twenty years, there will be virtually no active male scientists left who had matured in that bygone era, when it was also presumed that hardly any women would become professional scientists.

What happens in the coming era will depend above all on the commitment and fortitude of the new generation of women scientists. When thinking about a title for this paper, I had in mind all the patient, persistent efforts required in gardening: planting, pruning, watering, combating weeds and pests. However, inevitably I thought also of Eden. The usual interpretation of that story has always struck me as odd. Actually, Adam comes across as a wimp, while to me Eve's eagerness to partake of the fruit of the tree of knowledge was admirable, indeed courageous since she had to defy Jehovah and deal with a serpent. May Eve's daughters continue to be as eager and brave.

## A TALE OF TWO FROGS

It seems apt to conclude with another story, a fable emphasizing the advice given by Polly Bunting. This tale appears in the autobiography of Emilio Segre,[14] a distinguished physicist, who said he got it from a Quaker lady in Philadelphia. For the version given here, Gertrude Elion has provided a trenchant improvement.

Two young frogs were frolicking in a rainy garden when they spied a curious, gleaming object. They jumped right in and found themselves in a pail of milk. It was wonderfully novel, far more exciting than a puddle of water. For a while they enjoyed splashing around. But then they began to feel tired and looked about for some solid perch on which they could rest. Much to their dismay, they discovered that there was no such perch. They became panicky and tried desperately to jump out of the pail, but the walls were too high and too slick. They fell back again and again.

At last one of the frogs gave up; it decided there was clearly no hope, collapsed and drowned. The other frog, no less terrified but much more stubborn, continued jumping. Over and over that frog leapt up and fell back. Finally, the second frog was exhausted and resigned to sinking into the milk.

But then the frog suddenly felt something solid under its feet. A little island of butter was forming. Buoyed by a surge of hope and adrenaline, the frog managed a few more jumps and in doing so churned a chunk of butter big enough to provide a resting place. It later served as a launching pad that allowed the frog to spring out of the pail and hop away, weary but wiser.

Gertrude Elion pointed out that "the second frog must have been female!"

## NOTES AND REFERENCES

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