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Sexual discrimination

Athena unbound: barriers to women in academic science and engineering

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This looks at why there are so few women scientists: it focuses on the experiences of women in PhD programs and as faculty members. Science is largely organized on the basis of a male role model and women feel excluded and undervalued. This is the conclusion of the survey conducted for this research. The gender dimensions of science must be deconstructed, and a science policy for women implemented in order to transcend the masculine and feminine scientific roles and practices.

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WHY ARE THERE SO FEW women scientists? This is a question as relevant today as a quarter-century ago when it was posed as an equity issue (Rossi, 1965). Women have entered professions such as law and medicine in significant numbers in recent decades, albeit unevenly distributed into high and low status subspecialties. They have gone into science at much lower rates and, due to too few Americans pursuing scientific careers, this deficit has become a national policy issue (Pearson and Fechter, 1992).

The persistence of the sexual separation of labor (Etzkowitz, 1971), gender-linked work roles (Frank-Fox and Hesse-Bieber, 1984) and the continuing low rate of participation of women in many scientific disciplines appears to invalidate the norm of universalism that scientific careers are open to all who have talent (Merton, 1942). This anomaly has made women in science a strategic research site for proponents of the Mertonian paradigm in the sociology of science (Zuckerman *et al*, 1991).

Feminist scholars have raised fundamental questions about the constitution of science as a male cultural domain (Keller, 1985, 1991; Harding, 1983, 1991). They have gone beyond 'pipeline' issues of the number of women embarking on scientific careers to analyze the negative effects on women of a masculinized epistemology and exclusionary scientific institutions (Harding and Huntikka, 1986).

These analysts have raised cognitive issues questioning the lack of acceptability of 'holistic' approaches to science and engineering problems as

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well as social issues involving not only the relative proportion of women at various levels of the scientific enterprise but also the nature of their experience. For example, the question is not only one of retention in doctoral study but the more subtle one of whether women have a graduate experience that is of as high a quality as that of men in terms of technical research training, mentorship, first job placement, and care taken for their introduction into an academic career. From this perspective, until science is demasculinized, or feminized, women's participation will continue to be limited.

Questions of sex and science have come into the foreground in sociological theory, feminist research and human resource policy. This article focuses on the experiences of women in PhD programs and as faculty members. Rather than examining threshold effects that might keep women out of graduate programs or glass ceiling effects that might keep women with high-quality training from progressing to the peak of academic careers, we investigated the conditions under which women are at a disadvantage during their doctoral training and early stages of their academic careers.

Academic practices, presumed to be meritocratic and gender-free, often work against women's professional success. Their deleterious effects on most women are sometimes hidden behind a neutral or even positive façade erected on the highly publicized achievements of a few exceptional women, some of whom deny the existence of obstacles in their path (*Science*, 1992).

Gender and science puzzle

The 'genderization of science' denotes that the scientific enterprise is infused with ideological elements that shape what we know, how we know and who becomes the knower. This social character of science does not presume that the physical universe or biological organisms are 'socially constructed' (although sciences of the artificial are increasingly important), merely that our relationship to them is often shaped by forces that we have created and of which we are often unaware. These social arrangements can both impede and enhance our ability to understand natural phenomena and are in any event inevitable in some form given that science is a human endeavor.

The interaction between gender and science takes place in three dimensions and affects:

- the nature of scientific knowledge (representations of reality);
- the relationship between the scientist and the topic of investigation (modes of knowing); and
- how science is organized as a human activity and its inter-connection with the larger society (social structure of science).

Each of the gendered dimensions of science affects the participation of women in science in ways that have only recently become the focus of investigation. Most fundamental and most difficult to see is how gender differences imbue the scientific depiction of reality. Some theorists have identified alternative female and male modes of doing science (intuitive, interactional and relational rather than mono-causal, reductionist and falsifiable) that are, of course, in principle open to all scientists to pursue in tandem.

Keller offers the example of the reception of the pacemaker concept from her own career in mathematical biology. She shows how an attractive thesis of a simple and single cause, rather than a model of a complex interactive process, was widely accepted for a time due to its congruency with masculine modes of scientific conceptualization. This occurred despite a paucity of, or at best ambiguous, empirical evidence that could well have supported either interpretation (1985).

The relationship between the knower and known has also been genderized as one of distance and separation. Thus, McClintock's observational studies of the genetic characteristics of maize, in contrast to experimental investigations at the molecular level, took much longer to be accepted for its scientific worth due to the presumption of lesser validity of her scientific method (Keller, 1983).

Finally, the traditional social structure of academic science emphasizes hierarchically-organized and highly-competitive research groups. Despite the predominance of patriarchy, egalitarian and collegial models of research organization have been found to be effective for both women and men scientists (Kemelgor, 1989). Often the scale of experimentation and the requirements for passing knowledge down through succcesssive student generations mandate co-operative styles of research (Etzkowitz, 1992). New center arrangements comprising several research groups within the same university or among several academic institutions also appear to be leading to increased co-operation between groups. Indeed, intense competitiveness, often viewed as a motive force of scientific progress, may well be producing an increased rate of scientific fraud as a byproduct.

Supposed natural masculine and feminine characteristics are not isomorphic to the sexes. Rosalind Franklin's biographer notes the obsession of her subject with "hard facts" in contrast to the intuitive flair of her male detractor. When a feminine characteristic is found in a man it can be accepted as a sign of exceptional brilliance but even when a woman exemplifies the male model of 'good science' it may not be enough to gain her recognition and reward. Indeed, her prowess may even be turned against her by male peers who interpret it as a sign of inappropriate sex role behavior (Watson, 1968).

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It can now be asked of such historical instances as the race to decipher the biochemical code of heredity, whether the competitiveness that accompanied the development of the double helix model was a help or hindrance? Was it useful to fostering scientific progress or merely individual aggrandizement? Would not more co-operative arrangements between the Kings College and Cambridge groups have sped research, making subterfuge to obtain research results unnecessary? Perhaps a collegial relationship between the US and UK research groups would have advanced understanding in what became a domain marked by intense competition and denigration of women scientists (Sayre, 1975).

Harding (1986) argues that the sexual division of labor in science replicates that of the larger society and, along with the gender symbolism of science, is responsible for the small number of women in science. On its face, this is a strong challenge to claims of scientific universalism in theory and in practice. Karl Mannheim had excluded science from the domain of the sociology of knowledge on the grounds that it was not socially determined. Based on rational principles, science was "...largely detachable from the historical-social perspective of the investigator" (Mannheim, 1936, page 290).

The conclusion that science was different from other forms of knowledge paved the way for the development of a sociology of science, independent of the sociology of knowledge. However, the emergent sociology of science was based on the premise of the existence of particular historical social structures that supported the growth of rationality as an independent domain (Merton, 1933). Science was held to be bounded off from the rest of society by its distinctive structure and norms. Indeed the first phase of the sociology of science, orginated by Robert K Merton, was devoted to elucidating the norms of science, including universalism (Merton, 1973).

Universalism posits openness of science to all with talent but the social structure of science is not gender-neutral. Beginning in the mid-1960s, a series of conferences on women in science have uncovered successive layers of overt and covert discrimination against women in male-dominated scientific professions, much of it embedded in traditional assumptions about work and sex roles and the contradictions between them (Haas, 1984). Constructed in accordance with the traditional male role, the scientific role was also predicated on the existence of a traditional female role that allowed men to concentrate on work because of the presence of domestic support structures. The incorporation of science into academia during the 19th century further reinforced traditional male scientific roles by binding them to similarly biased academic roles.

An unconscious assumption of a traditional male scientific role has been built into academia, with obvious deleterious consequences for women who attempt to follow their own path. The received masculine culture and social structure of science and academia works against women who can, only with great difficulty, accommodate to the requirements of male roles.

Academia at the graduate research level tends to be hierarchical and patriarchal. This is due, in part, to its origin in apprenticeship practices and a heritage of discipleship in which master scientists create successors in their own image as a form of asexual reproduction. A recent international reunion of several generations of former students of a distinguished medical research professor, who self-identified themselves by his surname as 'Storcks', illustrates this process. In the traditional European model a single professor represents a field, with junior researchers holding higher degrees dependent upon the professor for direction and resources. In the more democratic American model, where junior faculty members control their own research direction and seek research support independently, graduate students exist in a dependent relationship to faculty members for funding support and approval of their work. In the context of these patron-client relationships, invidious sex role distinctions are an overlay on a substrate that is already permeated by inequalities.

The taken-for-granted practices of the PhD training system are widely assumed to be an inevitable feature of academic life. In one department that we studied, the link between funding support and discipleship in a particular professor's research group had been eliminated and replaced by a system of department-wide support. But this now-traditional feature of graduate training in the sciences was reinstituted in the face of financial stringency and decline of research support.

These conditions necessitated tighter linkages between graduate student research output and faculty research support. The need to produce large quantities of research to gain tenure or sustain funding support reproduces traditional hierarchical relations, by inducing students to contribute to existing research programs rather than to consider developing their own, even in fields where this is not necessitated by the large scale of re-

search projects.

Production pressures encourage practices such as faculty co-authoring by virtue of status rather than intellectual contribution, often accepted by students and professors alike as a legitimate price for the degree (Etzkowitz, 1992). Women entering PhD programs in the sciences must conform to a structure, many of whose underlying principles are nowhere stated in official degree requirements, and knowledge of these expectations is expected to be acquired through informal socialization.

Against women in science

There are many forces working against women's participation in science, including a masculine image of the scientific role that has already taken hold by primary school, and deterrence of women from mathematics in secondary school. Virtually every science and engineering discipline displays a common pattern of declining female participation as one moves up the academic and then the career ladder.

While women comprise 37% of the students taking physics in high school, only 22% of those taking the calculus-based introductory physics course in college are women (AIP, 1988, 1991). Women's presence is reduced to 15% of those receiving the bachelors degreee in physics and then to 10% of the share of PhDs. The decline continues in the shift from education to academic employment, with women comprising 7% of assistant professors of physics and only about 3% of full professors.

In France, there is a decreasing proportion of women physicists at the higher levels of government-sponsored research institutes (CNRS); at the lower levels 42% of the best qualified research assistants are women, although they represent only 16.8% of the class (Couture-Cherki, 1976). Thus, womens' careers develop more slowly than those of men and require more qualifications for promotion.

In the UK there is also a paucity of women in high-level scientific positions. The footnote identifying the author of a preface to a recent volume on the condition of women in science and engineering noted that Professor Jackson was the first and only woman professor of physics in the country (Haas and Perucci, 1984). She is since deceased but there are now two female physics professors in British universities (Healey, 1992). Nevertheless, the continuing depressed level of participation at higher career levels is a virtually universal cross-national phenomenon despite a history of improvement at the lower levels.

Similar patterns can be found in virtually all the physical sciences and engineering in the USA, while the life sciences show somewhat higher representation of women at all levels. For all the physical sciences, women earn 28% of the bachelors degrees, 16% of the doctorates, and constitute less than 7% of all employed scientistists with PhDs. While 13% of the assistant professors are women, the percentage declines to 9% for associate professors and 3% for full professors (NSF, 1988, Tables 24-25). For engineers the figures start from a smaller base and the decline is even more precipitious.

Some of the explanation for this rapid drop as we move up the careeer ladder may relate to recent gains in the proportion of women at the lower levels. Nevertheless, the decreasing participation of women has remained remarkably stable over time.

Yet some women overcome the barriers. Despite the difficulties a large number of women major in science in college and a significant percentage of women receive BA degrees. An increasing number have entered graduate school in the sciences and engineering in recent years, with enrollment rising from 94,800 in 1980 to almost 135,000 in 1990.

Women's participation in scientific careers, as PhD-holding scientists, has improved in recent years from 9.7% in 1976 to 17.2% in 1989 (NSF, 1991). This is primarily due to the greater presence of women in the life and social sciences in contrast to the physical sciences and engineering.

Much has been achieved but even more remains to be done, especially about the highly unequal conditions in many fields that suggest the continuing presence of a sexual division of scientific labor.

Sexual economy of science

The barriers to entry just described create a division of scientific labor that is tied into the broader sexual political economy of science. The Mertonian theoretical framework of the sociology of science assumes that scientists are free actors unimpeded by organizational constraints (Merton, 1942). For example, the norm of universalism is based on an implicit economic model of a free market without barriers to new competition.

Institutional economists, on the other hand, view the actual market structures of particular industries as consisting of a set of firms that place higher or lower barriers in the way of new firms entering that industry (Bain, 1956). New firms may accumulate sufficient resources to break through the barriers to entry into an industry or, under certain conditions, the industry may lower its barriers to make the conditions of entry easier. Public policy has emphasized access to resources, such as subsidies and procurement contracts, and changing the industrial structure, through anti-trust measures and revising the regulatory environment, as alternative approaches to opening up an indus-

try to new competitors.

Similarly, academic departments within a particular discipline can be viewed as establishing the conditions for entry into a field, through their requirements for degrees and setting the conditions for achievement. Four conditions of entry to an industry have been identified (Bain, 1956, page 274) that can be extended to academia:

- blockaded entry or total exclusion when women were not admitted to graduate school in the sciences (see Rossiter, 1982);
- effectively impeded entry or tokenism when an occasional woman is allowed in (the Marie Curie Phenomenon);
- ineffectively impeded entry when some entry takes place despite barriers, but a price is paid in marginal disadvantages;
- easy entry (no barriers to entry), universalism prevails.

To arrive at this latter state requires more than a lowering of barriers to the admission of new entrants; the internal structure of an industrial or academic system will likely have to be transformed.

Graduate training in the sciences is a full-time commitment and the culture of the research laboratory has engendered expectations of all-consuming involvement. In addition, expectations about geographical mobility have been built into the training and job recruitment process. Academic science presumes a taken-for-granted male model of social organization that takes little or no account of non-work related roles or social relationships. This academic structure and culture thus generates a continuing series of barriers to women at each level of the academic ladder within and after graduate school, including such 'hidden' obstacles as the traditional length of the tenure process, expectations of switching schools between academic training stages, and more overt processes of discrimination such as the sexual separation of labor and importation of sex-role stereotypes into adviser-advisee relationships.

The state of the economy also affects conditions of entry and retention. Barriers to entry in industry and academia fall most easily under conditions of expansion and prove more intractable under conditions of recession. In the United States, Finland and Portugal women gained an increased proportion of R&D positions during the post-war expansion of the sciences (Ruivo, 1987). On the other hand, Terttu Luukkonen-Gronow found that when the expansionary period ended in Finland in 1983 it became more difficult for women, relative to men, to obtain posts in academic science. During such periods of increased competition she expects that "...informal discriminatory practices and attitudes..." will take hold with renewed strength (Luukonen-Gronow, 1987, page 196).

Beatriz Ruivo, in her analysis of women's representation in scientific labor markets, suggests that this likely outcome can be avoided only if sufficient women are in decision-making positions in science and technology by the time a downturn occurs. Otherwise "...women will lose their positions... unless preventive measures are devised" (Ruivo, 1987, page 390). Some differential outcomes are hidden by inaproppriate comparisons between men and women.

Fallacy of the matched sample

Harriet Zuckerman has identified the key substantive and methodological problem of research on women in science. She states that,

> "Research which centers on differential outcomes and neglects the processes which bring them about is apt therefore to produce erroneous conclusions about the extent of discrimination in a given case" (Zuckerman *et al* 1991, page 19).

Such research assumes that discrimination only manifests itslf in unsuccessful cases and ignores discrimination that was overcome by women who achieved a successful outcome. It is much more reasonable to assume that discrimination is an obstacle that virtually all prospective women scientists face and that only a few overcome.

Thus, a social theory of women in science should account for both women who enter scientific careers and those who are excluded. Women are progressively alienated from science during the early stages of the life course, from pre-school through college (Koballa, 1988; Ware and Lee, 1988; Mulkey, 1988; Vetter, forthcoming). Sex-role typing of scientists, discouragement from mathematics and assaults on self-confidence represent cumulative disadvantages that remove most potential females from the so-called human resource pipeline at early academic levels (Moen, 1988).

Some of these cumulative disadvantages carry over and affect women who enter graduate school in science disciplines. For example, impaired self-confidence affects women's approach to research in graduate school. In addition to the effects of cumulative disadvantages that at one and the same time narrow the pipeline and hinder women's scientific careers, we have identified a series of 'marginal disadvantages' that are part of the academic structure and culture, at the highest levels and impact women after they have passed though the barriers of 'cumulative disadvantage' and entered graduate training in the sciences. Marginal disadvantages are like lead weights attached to the feet of superior runners to bring them down to the level of average achievement (Vonnegut, 1963).

Sociologists investigating scientific productivity

The effects of gender on scientific careers will be masked if studies continue to utilize matched samples, because this does not take into account the fact that women are progressively alienated from science

have accumulated a body of research on the effects of gender on scientific careers (Cole and Zuckerman, 1987). Matched samples of women and men scientists with the same academic background have been compared, with mixed results. These studies have produced varied findings on the effects of marriage and children on the research productivity of women, with some researchers finding a positive effect, others a negative effect and still others no effect (Long, 1990). We call these contradictory findings the "conundrum of women in science". Even if this were resolved it would not change the reason why matched samples are used in such studies: the small number of women in most fields of engineering and science. Such studies cannot help but ignore the most glaring issue which is the paucity of women in science and therefore tend not to offer solutions to this problem.

The effects of gender on scientific careers will be masked if studies continue to utilize matched samples. In fact matched samples may contribute to the conundrum. They imply that those few women who have achieved status within the academy reflect the larger number who enter graduate school. However, we know that "women drop out of career lines more frequently than men after receiving their bachelors degrees and during graduate school" (Moen, 1988, page 2).

If women who enter a field are a relatively small proportion of a larger group of women who face barriers to entry, it is probable that those few women who do overcome the barriers have different characteristics (such as greater native ability, adaptability, ability to emulate the male model) than men who do not encounter these barriers.

Thus, comparisons between members of the two ostensibly matched groups can mask the effects of an additional set of barriers faced after entry into the field, since the greater ability level may wash out the effects of discrimination. Indeed, matching presumes that individual actors can be removed from their contextual environments for research purposes and be meaningfully compared.

The study

The data traditionally relied upon to gauge the relative standing of women in science and engineering programs measures educational outcomes using simple attainment rates at different rungs on the academic ladder.[1] In absolute figures, the drop was from 230,000 women taking high school physics to less than 1000 earning physics bachelors degrees to less than 100 earning physics PhDs in 1987. For men, the drop was from 390,000 men taking high school physics, to 4,400 earning bachelors degrees, to 1,000 earning PhDs. The kind of data that might help to explain why women disappear from one rung measurement to the next (such as tracking representative samples of women students over time to highlight critical points of attrition, evaluation of particular aspects of academic programs in terms of their impact on retention of women students, and so forth) and describe what happens to them beyond the simple fact of their disappearance (for example, specific reasons for leaving, and final academic and career destinations), have rarely been collected, due largely to an historical lack of interest and the need to conduct case studies, an unfashionable methodology (Mitchell, 1983).

The initial research site is classified as a Carnegie I research university (Boyer, 1987). Four science and engineering departments were selected for examination, including two basic sciences, physics and chemistry; an engineering discipline, electrical engineering; and a hybrid discipline, computer science,[2] to determine the receptivity of their cultures to women graduate students and faculty members.

Three hundred and fifty current students and 76 dropouts were identified in the four departments, along with 198 students who received their doctorates within the past five years. There are 117 faculty members including five women: two each in computer science and physics, and one in chemistry. At the time faculty data were collected, there was one tenured woman in the four departments. During the course of the study, another was granted tenure, she was apparently the first to be accorded permanent status in the engineering school.[3]

We collected data from departmental academic records on advisers and advisees and interviewed female and male faculty members, female graduate students and academic administrators. The quantitative data consists of a listing of current graduate students, along with PhD recipients over the last five years, paired with their main faculty advisers, although from one of the departments, Electrical Engineering, data on PhD recipients only spans the past two years.

Supplementing this, data were also gathered for students who dropped out of their programs prior to earning their doctorate. In the Computer Science and Physics departments, drop-out information was obtained for the previous five years, while in Chemistry it spans three years, and in Electrical Engineering only one. (However, since Physics students are not assigned a faculty adviser

until after they have completed two years, adviser data were missing for those who dropped out of the program before this point. In Electrical Engineering, drop-out data were provided only for the prior year and it also did not include students who left after failing a qualifying exam administered after their first few months in the program.)

The qualitative data consists of 46 interviews with faculty, graduate student and adminstrator informants. Twenty five interviews were conducted with currently-attending and recently-graduated female PhD students within the physics, chemistry, electrical engineering and computer science departments. All five female faculty members were interviewed. Two recent former women faculty members, who are currently faculty members at other universities, were also interviewed.

Interviews were conducted with eight male faculty members who had been identified by chairs or graduate students as having either particularly good or poor relations with female graduate students. Chairs were interviewed to ascertain any special departmental policies concerning the recruitment of women (there were none). In addition, interviews were conducted with the administrators in the engineering and graduate schools.

Women's experience as faculty members and graduate students was studied in the same four disciplines at a public research university. A department of molecular biology with a critical mass of women faculty was studied at a third university to give a total of nine departments. This article primarily reports on the qualitative findings from the initial site.

Barriers to entry

Barriers against professional women have been framed in two different ways, emphasizing two stages at which obstacles might occur:

- a threshold 'beyond which gender no longer matters'. Women encounter difficulties advancing in a field but the obstacles fall away once a certain status is attained;
- a 'glass ceiling of gender-specific obstacles to advancement into top positions'. There is a particular career level women may attain at which point a blockage occurs to further advancement, for instance women are handicapped in attaining full professorship in science departments at leading universities (Sonnert, 1990).

The 'threshold effect' presumes that women only face barriers in the early stages of their career while the 'glass ceiling' presumes barriers only at the higher levels of careers.

We find that at all stages of the academic ladder women face barriers to entry and achievement. We have identified a series of mechanisms that mitigate against the progress of women in academic careers in science and engineering. First, the normal working of everyday features of academic science, such as advising patterns, have the unintended consequence of excluding women. Secondly, the negative effects of these academic norms are amplified by such extra-academic factors as the differential socialization of men and women. Thirdly, there are sources of subtle and not-so subtle bias derived from the taken-for-granted male model of doing science that also discourage women from full participation.

Needless to say these characteristics are often intertwined and a phenomenon discussed in one category of analysis will also overlap into another. We discuss examples of each of these three types of barriers to entry into scientific careers and offer suggestions as to how they can be eliminated or at least lowered.

Advisor-advisee relationships

In graduate school, students are expected to develop a close working with their faculty adviser, a relationship that lasts several years and is crucial to the progress of the student through the program and out into the professional world. Previous researchers have identified negative interactional patterns in male advisers' relationships with their female graduate students that "...lessens their opportunity for advancement" (Frank-Fox, 1989, page 226). We also found a series of gender-related blockages to successful advisement. At best, there was an attempt at equal treatment based upon the faulty assumption that women had been socialized and educated the same as men. At worst, women graduate students were sterotyped as less capable, uncompetitive and were viewed as non-scientists. Such advisers simply could not take women seriously as graduate students.

Barriers to women deriving from the structure of the academic system are reinforced by 'cumulative disadvantage' factors that excluded other women from science but also carry over and affect the academic careers of women. These include the differential socialization of men and women, impaired self-confidence and expectations regarding the impact of children on women's academic careers.

The roots of this problem lie in the different gender experiences of boys and girls. As young girls and women, females are socialized to seek help and be help givers rather than be self-reliant, function autonomously or competitively, as are boys. Girls are encouraged to be good students in so far as they expect to be given a task, complete it well and then receive a reward from an authority figure. In graduate school, behavior is expected to be independent, strategic and void of interpersonal support.

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was a nice guy. That's when I feel it: I'm out there on my own." In another instance:

> "If I didn't know the answer to something, [my adviser said], 'Just do the experiment, don't do the theory'. Do this, do that, 'I can't believe you're so stupid'. It had a very bad effect on my self-confidence. You're a piece of shit. Go win one for the team. I think guys tend to respond to this, like being on a football team."

In another instance: "[My adviser] told me to pretend I was in my kitchen at my counter... 'Listen, honey, you should be this, you should be that'."

Attempts to find an analogy to the traditional female role for women in the laboratory are in accord with the thesis that academia is a 'male milieu' in which women's presence is viewed as disruptive and threatening. These 'degradation ceremonies' may be followed up by subtle and not-so-subtle attempts to eliminate the unwanted presence. For example, one woman commented:

> "When I was trying to get something to work, [my adviser] would come up to me and say, 'did you see it yet? Did you see it yet?' Everyday he would say, 'did you see it?' I should have stopped it, but sometimes it takes a long time to see what's going on. It was very humiliating."

In the following instance a presumption of failure was established at the outset:

> "There was this woman who joined this group and [her adviser] sat her down and said, 'look, if you're going to join my group I don't want to know that you're going to leave in six months'. Of course this woman ended up leaving."

It is not only male advisers' treatment of female students that affects their situation but also how male advisers instruct their male students to act toward women. A female graduate student said:

> "I hear rumors about myself...being involved with somebody. [I heard that] a faculty member was advising his students that it might be interesting to have an affair with me".

These frequent negative instances are complemented by occasions when men have served as successful advisers to women. A sensitive male adviser helped a student make future decisions based on the reality of being a woman within the field:

> "His attitude toward women is very understanding, very supportive, without being condescending. He doesn't say 'I understand what's going on' which is offensive because it's hard for a man to understand what's going on. He doesn't bring these issues up, I bring them up. He is very politically aware. He'll say, 'don't talk to —— because he's Greek'. Sometimes [his advice] was because of sexism and sometimes because this person was an arrogant son of a bitch and sometimes because this is a good person, but is just not comfortable with women."

Women report that the best advisers are encouraging, give you concrete directions and show you the ropes. As an older physics student said: "I enjoy being around people who can work the system because I don't understand the system". Women's relative lack of knowledge of how to negotiate the academic system was called attention to by a woman faculty member who explained that many women lacked a strategy to deal with the admissions process:

> "What you're supposed to do is get a hold of the brochure and if you want to get in at least say that's what you want. The women don't seem to have grasped that...the men go down the list and say, I want to work with this professor for this reason, that professor for that reason...the females give me no indication that they have even looked at the brochure."

Without an adviser who is willing to encourage and be directive, women are often unable to puzzle out the strategies necessary to get through graduate school. Most women are not socialized to understand the political strategies necessary to advance within the academic system. As one woman put it:

> "Part of the game of getting through graduate school is perceiving what the game rules are. One is not presented a list of the rules, it's up to one to divine the rules. The people from the same culture, background and sex seem to do better figuring out the rules."

These and other culture conflicts result in the discouragement of many women graduate students and young faculty members from pursuing careers at the highest academic levels.

Impact of family

It is no surprise that pregnancy and child-bearing still have negative consequences for women in the world of work in the United States (Gerson, 1985). However, the impacts appear to be especially strong in academic science, given its structural features that mandate virtually exclusive attention to research achievement during the years that co-

incide with fertility. Realization of what lies ahead sometimes deflects women from pursuing the PhD.

A woman engineer speaking to a colloquium at a private research university organized to encourage women students to pursue engineering careers advised them to seek jobs in industry after the BA. She said that once they were established in their group, industry would accommodate part-time work or work at home during child-bearing and early child-rearing years. She said that she had chosen not to pursue a PhD because she wanted to have her children before she was 30.

Marriage and children negatively impact women's careers in academic science at three key time periods: having a child during graduate school, marriage at the point of seeking a job, and pregnancy prior to tenure. In addition, we found some disparagement of marriage during the graduate student career. Women, but not men, are sometimes thought to be less than serious about their science if they do not stay single while in graduate school. As a female graduate student recalled:

> "When I first interviewed to come here, I was single. On my first day of walking into this department I had an engagement ring on my finger. [My adviser's] attitude was 'families and graduate programs don't go together very well'.. First he was worried I was going to blow my first year planning my wedding. I got a lot of flack about that and so did other women...teasing. 'So and so's not going to get much work done this semester because she'll be planning her wedding'. [sarcastically] The guys' don't plan weddings."

Earlier in the century, marriage was grounds for a woman's expected retirement from a faculty position. The mutual exclusion of academic and family life has a long history. Until well into the 19th century, Oxbridge male academics were also expected to choose between academic career and marriage. Nevertheless, there have been few, if any, residual carry-overs from the male academic celibate role. Even when a choice between academic career and family is no longer an official requirement, the presumption that each role requires a woman's total attention still survives. It next surfaces when children are contemplated or arrive.

Women graduate students expect that they will be penalized for having children. One informant visualized her adviser's and the department's reaction:

> "If I had walked into ——'s office and said I was pregnant, they would have been happy for me as a woman, but in their list of priorities as to who to get out of the program and who to support I would have plummeted to the bottom of the list."

These concerns arise because the existing academic structure is ill equipped to deal with pregnancy. Pregnancy is discouraged and graduate women who have children are encouraged to take leave of absence that tends to become permanent withdrawal. In one department an informant reported that: "The only one left is —— [of the students who has a child]. Two women PhDs who got pregnant were strongly encouraged to take leaves of absence. One did and one did not come back". In another department a female graduate student reported that:

> "One person took a leave of absence to get married and asked her adviser if she had a child would she be able to work part-time and he told her, 'Absolutely not. No way'. What if I should want to do something like that? Is it the end of my career in ——? Was it just the adviser? What am I going to do with my life? People say they're not going to have children until they're 40 and have tenure. I can't think like that. Thinking about [these] details is what scares me. That's when I think I should drop out."

Graduate student women were caught in a bind, wanting to have children and, while doing so, wanting to show that they could keep up with the pace of graduate work. A female faculty member reported that:

> "I had one student who was having her child in the middle of the semester and was to take and pass her qualifiers at the end of the semester. She wanted to do it. I said, 'don't do it'...because of the emotional state you are in and the physical state after having a baby. We discussed this at length at one of our meetings...she ended up not doing it."

One department had taken child-bearing into account to a limited extent:

> "During evaluations, If a PhD [student] has a child she will be given some leeway for that

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semester... I think that's pretty funny...it's such a small amount of time. I think the women should get more leeway, you're physically out of it. It should be longer...at least a year. What's the big deal. [In one case, a student]... had the baby in November and had until the end of the semester. It was partly her fault as well; she did not want to say she could do less. The faculty gave her a choice of doing a part time thing or keeping up to pace. She chose to be put to the same standard as everyone else."

A peer had a somewhat different view of the faculty's action and described an unusual instance of solidarity among women graduate students:

"She decided not to take a leave [when she had the child] and made the decision at the end of the semester when we are all evaluated. She got a particularly harsh letter, [the faculty] essentially threatened to cut her support. They gave her requirements that would not be achievable for anybody...even without a baby. Two people had left the department earlier in the semester. One was a new mother, the other was a man who was very involved with his family. We got the feeling this was being done to discourage her and tell her to go away. She was encouraged by her husband and a number of us to renegotiate this because it was clearly off base and came out of the blue."

The expectation that women students will succumb to the pressures of child-bearing and child-rearing makes some male and female faculty wary of taking on women students in the first place, especially since funding is tight and every place must be made to count. Another female faculty member stated that,

"If a student had a baby with her, I wouldn't have her. Students who have babies here get no work done. It's not that I wouldn't take a woman with a child in the first place, but the first sign of trouble, I would just tell them to go away. If my students fail it looks bad for me."

Women who survive the strain of lack of support for child bearing and rearing in academia and complete their degrees at the highest levels of achievement may nevertheless find that their career will not survive the next hurdle of the academic career path. Two shifts in work site: from PhD program to post-doctoral position in a different university and from post-doctoral to yet another work site are expected. The highest climbers on the academic ladder of success are able to accept the most promising and prestigious post-doctoral and faculty positions without regard to any other consideration. The rule of intellectual exogamy has disastrous career consequences for many women who are unable or unwilling to make individualistic locational decisions. As one observer put it (Rosenfeld, 1984, page 99):

"The academic market is a national one. Those who do not accommodate their choice of geographical location and willingness to move to their careers may lose out."

The next impediment is at the point of the job search. When a married woman is about to attain the PhD, the 'two body' problem comes into play, typically deflecting women's careers from their highest potential. A male faculty member discussed the situation of:

"Another woman I encouraged incredibly, she's a good example of where the problem can be. She was an NSF fellow. She married a male student here who was also an NSF fellow. The two of them went on the job market at the same time and they were around looking for jobs, but it turned out that most places liked one of them and not the other: it was not always the same one that they liked and nobody wanted to offer her a job and say well he can just take his chances. There was a place that offered him a job and said well she can just take her chances and they eventually decided to do that.

...he took an academic job and she went into a company which is not a bad job but I think it's not as good a job as she should have had. But it was considered, both by the school that made the offer and to some extent by them, [that] it was OK for her to make a compromise on the career but they would never have asked him to do it so she ended up the victim on this: a clear double standard."

Marriage and children are generally viewed by male faculty members as impediments to a scientific career for women. Even those most supportive of women note that:

"I've had some disappointments with very good women who settled for jobs that are less than an equivalent man would do. You have some extremely good people you think are going to go out and make a mark and then somehow or other they marry somebody and spend their time in a bad career. For a man to decide not to take his career seriously is like admitting he takes drugs. For a woman to say she puts her family ahead of her career is considered a virtue; the pressures are all in that direction. The women are told, 'Isn't this wonderful. You are giving up your career to

semester... I think that's pretty funny...it's such a small amount of time. I think the women should get more leeway, you're physically out of it. It should be longer...at least a year. What's the big deal. [In one case, a student]... had the baby in November and had until the end of the semester. It was partly her fault as well; she did not want to say she could do less. The faculty gave her a choice of doing a part time thing or keeping up to pace. She chose to be put to the same standard as everyone else."

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something. If the baby hadn't shown up, I would have pushed for an early decision. Now I will wait."

Even under the best of circumstances the academic structure is resistant to accommodating family needs. A female faculty member in one department was able to arrange a modest reduced percentage of official time commitment involving a reduced teaching load. She reported that in her department: "The faculty have been very supportive of me having children. After my review I've had people say, 'How can you do that and have children too?'" This professor adopted the strategy of reducing her work load and lengthening the time period before the tenure decision. She said that:

> "The university policy allows you to work part-time to have children...that part-time work stops the tenure clock for the percentage of time you are not working. Because of tenure, I didn't want to cut my [research] back by 50%, so I made an arrangement to work 70% and cut the teaching load. I could have done it [full time] with children, but I wouldn't have enjoyed it...appreciated it. However, everybody assumed, including the chairman, that this time off would not count for tenure. A year before I was supposed to come up for tenure the chairman brought it up to the provost because [it was found that] the clock was still running. If it had stopped, I should have had an extra year before I was up for tenure so I would have more time to publish and get my research done. I decided not to fight it because I was concerned how going through a fight would affect the tenure decision. I was quite worried when the case went before the engineering school who are all older men who were looking at me not having worked full time."

In this instance, the outcome was favorable but the anxiety level, normally high about tenure prospects, had been raised even further by the difficulties that the academic structure had in recognizing the presence of children in her life. A few years later she was involved in an effort in the Senate of her university to make reduction in work load for women with children an official option. Some of the responses reported during the debate on the issue, that it should be among a list of limited choices in fringe benefits or equally available to men and therefore too costly to be made available at all, suggests that the academic system is still resistant to accommodating women's needs.

What is the response of women to the strictures of academic life? A majority of women graduate students in all departments studied, reported that they intended to pursue an industrial, rather than an academic, career since it was more compatible with family life. As an informant, comparing the two scenes, concluded:

> "Women will go in to industry. It's 9 to 5. It's more flexible. They have day-care and child-care. There are federal rules they have to abide by in terms of maternity leave, whereas in academia you're on your own, and where there are rules to protect you, you are not protected by your peers who are saying, 'she hasn't been here in six months, she's not current with the literature'. The support systems exist [in industry] and it's the only way you can [have a family]."

Of those who aspired to academia, most were interested in jobs in small teaching colleges rather than research universities because as one woman summed it up: "Science isn't everything". In recent years, two women had resigned their positions to take appointments at teaching colleges where they felt they could be respected as individuals and not have to confront a discriminatory environment. Given that the total number of women faculty in these departments was so small, even two women constitute a significant proportion of the total number.

Differential treatment

As part of the cumulative thwarting of a female professional identity, devaluation of women's scientific contributions has been found to be widespread (Benjamin, 1991). It takes many forms including crediting the male partner in scientific collaborations and ignoring the work of women (Scott, 1990). At our primary research site, despite a formal and even at times a strongly-stated commitment to non-discriminatory treatment of women, discrimination was manifested informally. For example, a female graduate student reported differential treatment of men's and women's contributions: "In group meetings I get the sense that if a woman says something, 'OK' and that's the end of that". On the other hand, male contributions were exaggerated:

> "When I joined the group there was one man. When there were more men, it seemed that the women's statements weren't entirely ignored, but if a man said something, even completely off the wall and even stupid, [the professor] would find some way to twist it into something good. He would make this great effort for the men. Our immediate reaction was complete shock...and annoyance."

Sometimes women are devalued by not being included in events. A female graduate student reported that invisibility was imposed when: "If you have a visitor to the lab, the professor introduces

the male students, but does not you". Another reported self-imposed invisibility in reaction to expectations that her contributions would not be valued:

> "[In lab meetings] you feel very self conscious saying what you think and I think it's because you are a woman. They would just as soon you would sit back and be quiet and when they ask you if it turned red or green, [you say] 'it turned red,' rather than saying 'it turned red and this is what we're going to do next'."

Women found it too difficult to be taken seriously as professionals outside the department as well. One said that: "If I go to conferences, if I ask a question, the answer gets addressed to a man in the room. It's worse in physics than in other fields". A female graduate student reported her response to being ignored: "It's always a thing where being invisible, you don't exist...It was a sense I didn't exist".

Other times, women are made to feel different by being given excessive visibility. A female graduate student reported that a professor was: "...addressing the class, 'Gentlemen'...and then made a big pause and looked at me and added, 'and lady'. I was different. Other people noticed it..."

Still other times women are patronized. A female graduate student told how: "I was sitting at this table and he kept referring to us as 'my girls'. In that context I didn't like it. He was thinking of us differently. He didn't say, 'my boys'". At the public university, many graduate women felt that they were treated as 'one of the boys' but this was an unsatisfactory resolution as well, since differences between men and women with respect to child-bearing were not taken into account.

Alternative role models

Essentially, women are expected to follow a 'male model' of academic success involving a total time commitment to scientific work and aggressive competitive relations with peers. There are two contrasting 'ideal typical' responses to this situation by women graduate students and faculty members. We have identified two types of responses from women scientists to gender issues:

- women who follow the male model and expect other women to also; and
- women who attempt to delineate an alternative model, allowing for a balance between work and private spheres.

A relatively few women are willing to adapt to the male model of academic science, involving an aggressive, competitive stance and an unconditional devotion to work at least until tenure. Instead, most attempt to define a women's academic model, balancing work and non-work roles, with an emphasis by faculty members on co-operation at the work site among members of their research group (Kemelgor, 1989). This has resulted in two distinctive female scientist roles: 'instrumentals' and 'balancers'. Even when these models are in conflict with each other, they offer women students a range of possibilities to choose among.

Instrumentals are able to act independently and strategically. A female faculty member described her strategy for getting through graduate school:

> "When I went to grad school I specifically chose the chair as my adviser because I wanted to graduate...he had a reputation for graduating all his students. I knew I was doing well when I picked that guy. [His research] didn't matter so much. The research I wanted to do, I could do after I graduated."

Instrumentals typically viewed the system as favorable to women and regard the status of women as a non-issue. A female graduate student who believed in doing "the politically right thing" said:

> "When you get to graduate school [physics is] incredibly biased in favor of women. They work much harder to keep the female students and there is good reason. Most of them don't come in with adequate preparation. There are women who talk themselves out of taking the qualifying exams."

Moreover, this individual was outwardly hostile toward women, favoring the men whom she emulated:

> "I worked all through my undergraduate career all by myself. I don't see the need to work with others. The women don't have enough intelligence to work things out for themselves".

However, she also noted the debilitating effects of traditional socialization on women:

> "The guys have more of an idea about mechanical things and are self-confident. Women end up getting help, and then they end up in graduate schools they wouldn't normally get into and they're stuck because it is built into them to get help, assistance."

Instrumentals were willing to put in night and weekend work hours, making the lab the center of their social as well as work life. One such woman faculty member said:

> "It never occurs to the males that they could come in at 9 and leave at 5, five days a week

> and get a PhD They're here at 3 am, weekends. You never see a woman here off hours. You see all the males. The males are socialized that they have to do their work and it always pissed me off because I always worked as hard as the men and so did the women who went to school when I did."

Instrumentals were typically unmarried or divorced and without responsibilites for child rearing. An informant noted that:

> "A common pattern is that women who are successful are single or divorced and really dedicate most of their energy to their career".

They are often ambivalent toward women students who are not as directed as they are. A female faculty member said:

> "Males come to me immediately with a problem. Women muddle off. I try cajoling them, pleading with them, yelling at them. I would rather have men...I guess I don't really mean that."

In contrast to the instrumentals who emulate the male model, balancers find the highly competitive nature of academic science to be problematic, since it conflicts with their own preference for co-operation as described by this student:

> "Given the competitiveness that goes on around here, it is a lot harder to be open, honest and supportive because you don't know if you are going to get turned on."

Balancers are aware of their difficulties in functioning strategically. Anxiety and confusion over the desire to balance multiple roles, at times, overwhelmed students. One student expressed her fear of future strains:

> "I can't think like that [about how to balance]. Thinking about [these] details is what scares me."

The current constrained funding climate further exacerbates women's unstable position, causing professors, fearful of productivity losses, to be less willing to tolerate deviation from the traditional male model of doing science.

Nevertheless, despite these obstacles a new scientific work role is emerging as women and men struggle to restructure traditional family and work roles (Gerson, 1985). To treat the lab strictly as a work site is a necessary strategy for women (and some men) who want both to be highly productive as scientists yet maintain an outside life. These faculty members had a commitment to raising of equal importance to their work commitment.

The balancers wished to pursue muliple roles, typically family and work, seeking a reasonable division between the two spheres. Perhaps ironically, multiple roles have recently become accepted for high status males in science who wish to combine participation in entrepreneurial ventures with the professorial role (Etzkowitz, 1989). However, combining the professorial role with serious attention to family obligations is seldom an acceptable stance for a high level career in academic science or other professions (Frank-Fox and Hesse-Bieber, 1984).

Informal activities outside of the department are also often linked to traditional sex role activities and venues. In one department in a related study, a regular pick-up basketball game was a site for exchange of informal comments on research activities along with visits to a male-oriented local bar. A female faculty member felt inevitably excluded from 'the club' (Kemelgor, 1989).

Some women were able to work out an accommodation with the demands of a career at a research university by strictly budgeting their work time and making every minute of it count. For these women the university was a work site, not a social environment as well. For many males the time put in in the lab is not all work related, but being in the lab extremely long hours is part of the accepted persona of the successful academic scientist. A single male professor in a related study (Etzkowitz, 1989) reported that:

> "A lab, in a sense, is a little bit like a country club. You have your friends here... I don't stay here because its competitive. I stay here because who wants to go home... It's what I see most of the people here doing, too. They get the newspapers, they talk to their friends, this is the place. It's a club."

Despite recognition of the non-work related nature of some of this presence on the job, in the culture of academic science, time spent in the lab is still viewed as an independent indicator of strength of commitment to science.

The balancing stance is not solely a female response to academia. Some male faculty adopted this position to a limited extent but typically admitted that their participation in domestic life and child-rearing was less than their spouses. Moreover, not all women who wished to balance the demands of an academic research career and family were able to achieve this goal. Graduate students who were encouraged to take leaves after a pregnancy often did not return.

PhDs interested in academic research careers often decided to accept industry positions, either to give their husband first preference in a job search and/or to have a work role that was explicitly

members abandoned research careers to accept positions in teaching colleges.

Thus, at present, the strategy of balancing career and family is contrary to the culture of high status research universities and is difficult to arrange and sustain. Neverthless, this is the option that most women in our sample wished to pursue. Few had the support of their institutions or persons available whose example they could follow.

Relevant role models

Role modelling has been identified as an effective socialization mechanism in work life. Modelling oneself on an older person has been found to be a good way of creating a pathway into a career, making for likely early success. A younger person can take on the characteristics of an older person in a professional role while serving in a junior capacity. The closer the modeler is to the person modeled, the easier is it for the transformation process to occur. Conversely, the more differences that exist, whether in the behavior directly being modeled or in associated personal characteristics, the more difficult it is for the socialization process to work.

Previous research has indentified the characteristics of successful women role models who integrated, "...professional and personal concerns" (Mokros *et al*, 1980, page 11). Beyond strictly professional issues, women mentees are concerned with the interpersonal quality of the relationship and seek a sympathetic mentor (Dowdall, 1978).

In the sciences, male senior researchers have traditionally served as role models for their junior colleagues. As women entered scientific careers they were expected to follow a male model, accept a distinctly subordinate status, the scientific equivalent of the traditional female role (research associate) or leave the profession.

More recently, some women have attempted to carve out a new status and professional identity for themselves in the world of academic science (Kemelgor, 1989). This involves a different relationship to work and students, in which work life is pared down to professional elements and limited in time so that a private life may be constructed and compartmentalized apart from the professional role. This is not dissimilar from a 9-5 job with little carry-over from work to home and vice-versa in terms of socializing, professional relationship and effect. Indeed it represents a formalization of the work role and an attempt to remove sexualizing and other personal elements that may interfere with work.

Recently, some women have attempted to carve out a new status and professional identity for themselves in the world of academic science, involving a different relationship to work and students, and allowing time for private life

Women graduate students prefer to have a range of models of female behaviors in science available to emulate. At present, the numbers of female faculty are usually so small that there are often few, or even no, choices of role models to emulate. A junior female faculty member described her role model in graduate school:

> "Another woman did quite well...many things I didn't like about her, but it showed it was possible. There were a number of women in my field who were well known as I was going through, most of them were single and remained single".

Most women graduate students made a sharp distinction between women faculty whom they viewed as relevant or irrelevant as role models. Women faculty who were perceived to be instrumentals, emulating an aggressive male scientist role and attempting to become 'one of the boys', were often not viewed as viable models. As a female graduate student said:

> "That's a real problem. There are no real good role models to follow. The women a generation ahead of us had it so difficult that they are by and large a very aggressive group. [They had to be so aggressive] and that's who got ahead. You have trouble looking at them and saying, 'I want to be like that'. You don't."

On the other hand, a woman faculty member who was successfully balancing career and family was looked to as a model by several women in her department, even though she was somewhat less available due to time constraints. A female graduate student said that:

> "—— is a role model precisely because she can balance the two. She definitely finds time for the things on both sides. It can be hard on her students. When you do find the time to finally meet with her, you do have her attention. Everyone feels the same way: Frustrated that it's tough to get her, but that they really have her when they do."

However, for most female students anxiety about the present and the future is exacerbated, because there is no model to demonstrate how to deal with problems or issues. "Women are dropping out because there are no role models to show you how 'you get there'." This is related to the ability of men to identify culturally with male advisers and en-

hance their self- confidence, leaving women with no one to 'pave the way'.

The need for women faculty to show how professional and family responsibilites could both be met was expressed by a student who said:

> "I think it would be interesting to see [the female professor] get pregnant, so we could see how someone else deals with the situation. I have no clue whatsoever. I don't know what it's like in academics. I'm scared about that".

Thus, for the most part, students are left to feel they must be pioneers. In some instances, this situation was resented. The few who felt they did have role models, identified them as being from high school, undergraduate school, from industry or were their mothers.

Most importantly, the role model women wanted was the woman who could concretely explain the necessary strategies and steps to be taken to succeed in graduate school. This conclusion derives from the reality that: 1) rules are made by men, 2) young men are socialized to those rules and further socialized in graduate school: they have learned the strategies, 3) most women have not been socialized to be autonomous, therefore are not strategists and have difficulty figuring out the rules, 4) because of bias or lack of sensitivity to women's situation, most male advisers do not concretely and directly teach women the strategies necessary to succeed.

Of course, this finding does not hold for those very few graduate women who excluded other interests in favor of their career. The absence of viable female role models in most of the departments studied, creates anxiety among women graduate students and is believed by them to contribute to the rate of attrition. Nevertheless, women graduate students report successful and unsuccessful experiences with both men and women advisers. Men can be sensitive and women can be relevant role models, but few men and women faculty currently meet the needs of most women graduate students.[4] Women graduate students seek out women faculty members as advisers in hopes of finding a sympathetic mentor, while male graduate students sign up with a woman only after she has achieved a distinguished position in the field.

Policy implications

In response to these problems of women in science, the intersection of gender and science has become a focus of feminist theorizing, sociological investigation and human resource programs. Opening scientific careers to a broader range of women than those who are willing and able to adhere to the traditional male model is the key to solving the policy dilemma of women in science. To accomplish this end, the structure of the academic workplace must be changed.

Opening scientific careers to a broader range of women than those who are willing and able to adhere to the traditional male model is the key to solving the policy dilemma of women in science

Structural changes in academia going well beyond improved recruitment measures will be required to achieve universalism, viewed as a desired value or goal rather than as an existing norm or unwritten rule. Reforms proposed range from changes in the larger society to remove cultural barriers to young women thinking of mathematics and science as an appropriate activity, to changes within the structure of academic science to take account of women's needs rather than presuming that women must fit into an existing structure designed implicitly to meet male needs. Two basic strategies for changing the conditions of entry into academia have been identified:

- the provision of resources through offering fellowships or providing set up costs, such as the United States' National Science Foundation Visiting Professorships for Women and Presidential Young Investigator Awards programs; and
- revising the academic structure, to eliminate gender-related obstacles to entry or retention, for example, the Israel Institute of Technology's extension of the time period before tenure review for women with children (Mannheim, 1990).

Without waiting for necessary changes in the larger society, we hold that significant steps can be taken to adapt the social structure of science to accommodate women, and improve their rate of participation and performance.

Creating appropriate academic atmosphere

Administrative actions, engendered from above or below, even if they do not change attitudes, can affect behavior. A female graduate dean at another university reported on the efficacy at her institution of administrative leadership to remind people of gender and minority issues at every step of the academic process. "We had a graduate program director who took this issue up as a personal cause." She reported that it was most important to be stringent on sexual harassment so that everyone

knew that it is morally and legally wrong, officially and unofficially.

The affirmative action officer at the primary research site, a female attorney, reported that she received virtually no complaints from women in the science and engineering departments, while there were many from the humanities and social sciences. She presumed that the universalistic spirit of science was responsible for the paucity of complaints rather than an environment that suppresses the expression of gender differences.

In one instance, a woman graduate student contemplated making a complaint against a male faculty member who was discussing pornographic images on a computer screen with his male graduate student. The incident took place in her presence in an office that she shared with the graduate student. She drew back from making an official complaint, fearful of endangering her degree. However, the matter attained sufficient visibility within the department that the chair sent out a strongly-worded message condemning the practice as unnacceptable and warning against its repetition.

One department studied had undergone significant change with respect to its treatment of women. Among its leadership were several middle-aged males who had simultaneously been in therapy in a community where the local culture had been strongly influenced by feminist values. In this context, one of them pointed out to the others that they were being unconsciously dismissive of the work of a female faculty member up for tenure. They accepted the validity of the charge, reviewed their behavior and decided to change their attitudes and practices.[5]

They also revised the departmental structure to emphasize collegiality and gender-blind decision making. For example, graduate student admission decisions are made by a committee with equal representation of faculty and students. Two students are elected each year to review and interview applicants. A male and a female had served in the previous year and two females in the current year. Applicants stay with other students when they come to campus to be interviewed. Once the incoming class has been picked, they are invited to a social event involving the entire department, with a picnic and sports.

All women students and faculty interviewed reported joining this department, rather than other prestigious institutions, based on their perception of a collaborative, co-operative, and collegial milieu. They were attracted by the warm interpersonal interactions that they experienced when they interviewed and by a sense of personal concern by faculty and students for the candidate. They were also impressed by the happiness and well-being of members of the department. Most had been disturbed by the demoralization of students at other departments where they had interviewed, having heard stories of exploitative advisers and anonymity in large research groups.

Since almost all had previously worked in laboratories as undergraduates or as technicians in academia or industry, they had a clear idea of the laboratory evironment that they wished to find as well as what they wanted to avoid. Several had suffered isolation in sexist, autocratically-run, competitive laboratories in which their status as female technicians promoted loneliness and professional stagnation.

They had relocated to laboratories in which laboratory heads and post-doctoral fellows had enhanced their self-confidence through direct teaching, generosity in time for communication and responding to questions without derison. In each of these instances, the informant came away feeling capable and competent to undertake graduate work, having experienced empathy and understanding from a mentor figure, whether female or male.

While the science being done in the department or by a faculty member often initiated a candidate's interest in the school, the emotional gratification of the interview process together with a preference for a collegial research environment influenced the candidate's final decision. Thus, selecting this particular department was a means of recapturing a signficant maturational experience that had promoted self-confidence and emergence of a scientific self-identity.

In this department a female academic model based on inter-personal relationships, affiliation and nurturance had become acccepted as legitimate and had even become the departmental norm. This was in strong contrast to another research site where the expression by women of a need for these characteristics in the laboratory environment was derided as a desire for dependence and emotionality by the adherents of the patriarchal system that was in place.

It is not women or men in the position, by itself, but the ability to meet female relational needs that is essential for a successful mentor of women. Women professors who follow the male model, in fact, often heighten performance anxiety among their female students by expecting more of themselves and their women students than do males. Patriarchal institutional roles, whether enacted by men or women, result in female behaviors being misinterpreted as inferior rather than different. for example, when women express a preference for a collegial rather than a competitive working environment.

Moreover, most women students reject an academic life style in which non-scientific relationships and activities, and the possibility of significant involvement in raising children are excluded. These conclusions necessitate additional changes in the academic system, beyond creating a supportive, non-sexist working environment.

Resolving time conflicts

There is an incompatibility between the seven-year race for tenure with the biological clock for child-bearing, with obvious negative consequences for women's participation in high-powered academic science. A female faculty member said of this conflict that:

> "There is definitely the pressure to continue to produce and to show that you can do both. Sometimes I feel like I'm setting women back. The women who are having children don't want to say they can do less. But they haven't had one yet and they don't know. They feel they have to show they can do it [maintain productivity]."

This professor has spoken up in faculty meetings, on behalf of extending the time before tenure review for women with children. However, she sees it as a double-edged sword. Pressure for reduced demands upon women with children might jeopardize their status by supporting the notion that women with children cannot be productive. Of course, the extension could be made gender-neutral, with the same provisions offered to men with extensive responsibilities for child-rearing. Nevertheless, in practice, it would likely be seen as a measure to accommodate women.

In addition, departmental and university-wide efforts to make workplace child-care facilities more widely available would help. An infant care center in a neigboring education school, discovered by a third world female graduate student, made an important difference to the ability of several women with children, in one of the departments studied, to carry on their graduate work virtually without interruption.

A male faculty member told us that, if women would wait until after 35 to have children, there would be no problem. They would be able to pursue tenure single-mindedly without intereference from other obligations. He recognized that most women were unwilling to delay having children that long and thus saw no answer to this dilemma. A graduate, now a professor at another university, reflected upon the relationship between the biological and tenure clocks. In discussing her plans for children she said:

> "I take every day as it comes. It would be outrageously difficult. I would feel much more confidence if I had tenure but I would be 38 and I don't choose to have a child that late."

If the objective is to significantly increase the number of women pursuing high-powered scientific careers, institutional accommodations will have to be made for women who wish to combine family with career. To achieve equality it is not just a matter of opening up opportunities but of changing the structure of the academic system. Women who wish to pursue traditional female roles along with a scientific career must be accommodated by allowing a longer time span before the tenure decision. This had been promised to one faculty member in our sample, although in the end it was not allowed.

This is not a call for a 'mommy track', with different and lower expectations of achievement and rewards, but a serious effort to accommodate the significant number of women who are not willing to forego family and children prior to tenure. It is unrealistic to expect significant numbers of women to follow the male model. If the goal is to substantially increase the participation of women in high-level academic science, a female model will have to be legitimated. Acceptance of an alternative career model is crucial both to placing more women in faculty slots in the immediate short term and to providing relevant role models for a broader range of female graduate students.

Conflicts of time will have to be accommodated for women faculty members with children. This currently happens for faculty members, typically men, who found firms or centers. However these time conflicts usually occur after tenure while for women involved with family responsibilities they tend to occur earlier in their career trajectory, placing them at risk. While time conflicts at later career stages may affect colleagues' views of a department member, they seldom, if ever, have deleterious career consequences. Simply put, women are more vulnerable than men prior to tenure.

Overcoming locational immobility

The limited geographical mobility of many women restricts both their choice of graduate school and job. A highly successful female scientist interviewed in another study explained the impact of location on her career, given existing norms of hiring. As a research associate her advance in rank was limited, as was her exposure to students and the experience of raising her own funds. She felt that these consequences of having to accept a position of lesser status had delayed her professional maturation.

> "I was married — I'm still married — and I didn't have the flexibility of moving around. That's one of the best ways to achieve a permanent position and to increase one's standing; to have the lever or the threat of saying, well, I'm going to leave. And to mean it. You can't do it as an empty threat. You have to be ready to leave, and people are. I was never in that position, so I could never use that threat." (Dupree, 1991, page 117).

A typical scenario that has been identified is marrying a man in the same field who completes his graduate work before his wife. He finds the best job he can without geographical constraints. When the woman finishes, she finds what job she can in a circumscribed region (Max, 1982). Women who are already married often select their graduate school based on what is available in a region and choose a job with similar considerations in mind. In many instances, second rank research universities attract higher quality candidates than they might otherwise, because of women's geographical restrictions.

The limited geographical mobility that many women face can be addressed in at least three ways:

- making women's careers equal in importance to men's careers, allowing women a greater latitude in job choice, and
- hiring both husband and wife, even in the same department, taking account of the fact that graduate students in the same discipline and department often marry.
- relaxing formal and/or informal prohibitions against hiring one's own graduates.

The highest achieving woman scientist in our sample was hired by her graduate department after a stint at a local college. This practice is especially significant for women who are geographically immobile in a region with few or even only one research university.

Achieving critical mass

The succession of impediments to the entry of women into scientific careers that narrrows the stream to an extremely small flow at the stage of graduate training has been conceptualized as cumulative disadvantage. However, even given these disadvantages a significant number of women receive degrees in science at the BA and even the PhD levels. Nevertheless, fewer pursue careers in science and there are few senior women professors (Moen, 1988).

The disadvantages that cumulate to narrow the flow into the science career pipeline are supplemented by additional disadvantages, at the margin, that discourage even the most highly motivated women who have taken steps to pursue scientific and engineering careers at the doctoral level. It is expected that removal of some or all of these barriers at the doctoral, junior and senior faculty levels could have an effect, in the short term, in increasing women's participation in science and engineering.

Taking such steps could also provide a critical increment of role models to assist in long-term efforts to lower barriers at the early stages of the life course, thereby increasing the flow into the science career pipeline. Thus, the importance of focusing policy intervention at the later stages is two-fold:

- to encourage the creation of a critical mass of women faculty in academic science and engineering departments that, in and of itself, has an effect in changing academic cultures and, by implication, lowering barriers for future generations; and
- to revise the image of high-level careers in science and engineering for women from an anomalous to a 'normal' role, thereby providing the incentive of widespread examples of achievement to encourage younger women to break through the barriers prevalent at early stages of the life course.

Focusing policy intervention at the later stages of the life course will encourage the creation of a critical mass of women faculty and revise the image of high-level careers for women in science and engineering

These graduate students and professors, after successfully negotiating the numerous barriers to entry that exclude so many other women, often pursue less demanding careers than their male peers. These are not women lost to science. Rather they are women who, with a few exceptions, are excluded from positions in the top academic departments in their field. Many pursue research careers in industry. Others have taken appointments down the academic ladder in teaching colleges.

Whether these scientists are excluded from high-level academic careers, through discrimination by academic departments unwilling to accept women as equals, or confer upon them an authentic professional identity or by choice, through their unwillingness to conform to an academic system that makes little accommodation for non-work roles and obligations, the result is the same. There is a pool of women scientists working in industry and lower down the academic ladder whom their advisers, usually men, agree are the equal of their male peers who are pursuing research careers at the highest academic levels.

If lines were made available, qualified women scientists could be recruited to create a critical mass of at least three women in each leading academic department. This would provide the range of female role models necessary to bring forth an enlarged next generation of women scientists.

Women who have avoided the effects of cumulative disadvantage, even accumulating some ad-

vantages that should propel their career forward, nevertheless suffer a marginal disadvantage at the graduate and junior faculty stages that significantly reduces the entry of women into research careers in academic science. While the causes of cumulative disadvantage are largely beyond the control of academic departments, the causes of marginal disadvantage such as advisement, role modeling and hiring practices are part of the academic enterprise, and departments can influence how they take place.

While culture is generally believed to be highly resistant to change we believe that our findings suggest a few key points of intervention. Specific steps could be undertaken to mitigate the negative effects of the male scientific ethos on the recruitment of women to science and engineering. The rigidity of the existing academic structure and male faculty misperceptions of women scientists constitute formidable barriers to the entry and retention of women at the highest levels of academic science. However, the fact that qualified women who would be interested in academic research careers are now in industry or teaching colleges suggests that, should these final barriers be lowered or removed, a pool of women scientists already exists that is available to pursue careers at the highest levels of academic science.

Conclusion

What can be done to implement these proposals? A first step is to become more self-conscious about the social organization of human scientific endeavors and that is, after all, a practical contribution that the social studies of science is expected to make to the conduct of the natural sciences. Deconstructing the taken-for-granted gendered dimensions of science allows science to be expanded in at least as many ways at it is currently limited. By accepting as universal various parochial ways of conceptualizing, investigating and organizing the conduct of science, significant sectors of the population have been excluded from full participation and alternative cognitive perspectives and organizational styles have been repressed.

As we become aware of such factors as masculine models of gender as the basis for many modes of doing science, a policy space is opened up where change can take place. Social movements and support groups organized by excluded groups, changes in departmental practices and university policies taken at the initiative of faculty and administrators, and governmental affirmative action policies and funding programs are all part of the emerging picture of science open to all talent in fact as well as by precept.

Science policy for women in science (Abir-Am, 1991) is the second step toward transcending masculine and feminine scientific roles and practices — the de-genderization of science and society. In self-exemplifying fashion the sociology of gender and science itself has moved beyond comparing men and women scientists according to implicitly masculine criteria such as number of publications, with article counts accepted as a primary indicator of productivity and achievement. On the other hand, women publish less, but their publications are more highly cited (Long, 1990). This finding may indicate different gender styles of scientific work. Perhaps women work more intensively on a subject before making their work public while men are more willing to go into print and try out their ideas with less evidence.

There is much to be said for and against each of these styles of scientific work. By viewing scientific practices from a perspective that relativizes both traditional male and female gendered perspectives and integrates them into a broader non-sexist framework in which alternative modes of doing science would be acceptable for both men and women, experimentation and verification of knowledge would be freed from the exclusionary oppositions in which that which is defined as feminine is automatically perceived as antithetical to 'good science' (Keller, 1980). Under these conditions universalism would be realized as a normative, as well as an ideological, component of the social structure of science. Then Athena, as well as Prometheus, will realize her full potential.

Notes

1. In physics, for example, the sharp decline in the proportion of women as the educational level rises has been reported for years (see following discussion).
2. At this university the Computer Science Department is located jointly in the Engineering School and the Faculty of Arts and Sciences.
3. The physics department previously had two tenured women, one now emeritus and the other deceased.
4. 22% of the female students in the four departments at private research university, as against only 4% of the male students, have female faculty advisers. While the proportion of female and male students entering subfields where female faculty advisers are available is fairly similar (32% and 24%, respectively), the proportion actually signing up with those female professors differs by a factor of four (68% to 17%).
5. In another instance the change did not come voluntarily but only after a female faculty member threatened to resign when a sexist male faculty member was about to be named permanent chair. This action received nationwide publicity, forcing university officials to do something about the sexist environment of the department. They prescribed a year of gender sensitivity training for the acting chair who resigned the position. See *Chronicle of Higher Education*, 1 April 1992, page A 14.

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1. A B Smith, C D Jones and E F Schwarzbaum, "Science policy and oranges in east Bolivia", Journal of Policy and Restaurant Anecdotes, 5(3), June 1988, pages 23-29.

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3. A B Smith, "Science policy and fresh fruit juice in Bolivia", in I Weissbaum (editor), Science Policy and Oranges (La Paz, Bolivian Press, 1988).

4. See Smith, reference 1. It is important to note that the same author has written nothing else on this theme.

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Main articles in this issue

Full summaries: see individual articles

Internationalising research and development in Japan
Jon Sigurdson (University of Lund, Sweden)

The science and technology system in Japan is undergoing continuous and dramatic changes. The country's globalising firms are establishing technological bridgeheads and tapping into the scientific potential in many parts of the world. Similarly, American and European companies have made considerable investments in R&D facilities in Japan. The Japanese government has been pressured to open up its R&D system and to make large contributions to basic research. The initiatives to organise international research programmes in the TRIAD have so far met with limited success. However, Japan is systematically expanding its support for basic research which may result in several new centres of excellence, which might be followed by Nobel prizes before the end of the century.

Europe's IT strategy moves closer to the users: the Open Microprocessor Systems Initiative (OMI)
Alfonso H Molina (University of Edinburgh, UK)

The Open Microprocessor Systems Initiative (OMI) is an emerging sociotechnical constituency bringing together a panoply of technologies and institutions from almost every country of the European Community with a view to building up a targeted microprocessors capability. Its two main features are that it is application-driven, and that it is open both in technical terms and institutionally (not restricted to European-owned firms). It is targeted to generating a complete and competitive technological capability in a critical area in IT, and seeks to integrate the creation, production and diffusion moments of the technology.

Athena unbound: barriers to women in academic science and engineering
Henry Etzkowitz (University of New York at Purchase, USA), Carol Kemelgor (New York University), Michael Neuschatz (American Institute of Physics) and Brian Uzzi (State University of New York at Stony Brook)

This looks at why there are so few women scientists: it focuses on the experiences of women in PhD programs and as faculty members. Science is largely organized on the basis of a male role model and women feel excluded and undervalued. This is the conclusion of the survey conducted for this research. The gender dimensions of science must be deconstructed, and a science policy for women implemented in order to transcend the masculine and feminine scientific roles and practices.

Accounting for the costs of research: some policy rethinking
Daryl E Chubin and Elizabeth M Robinson (Office of Technology Assessment, USA)

The research system in the USA is under stress after a period of relative growth and expansion. The demand for funds exceeds Federal funding increases. It may not be appropriate to simply increase Federal expenditures on research: the government could encourage research universities to consider the funding environment and adjust their research agendas accordingly.

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High technology is there: policy for nano-technology, neural network computing, superconductivity and electronics are all recent topics.

Such topics are important to the poorer world too. Recent papers have come from China, India, Poland, Nigeria and elsewhere.

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The Chinese government's support for S&T, Wang Boa-chen (Shanghai Institute for Science of Sciences), August 1991, 225-234; one of three papers on China in recent issues.

Canada's national system of innovation Jorge Niosi (University of Quebec), April 1991, 83-92; one of many papers on innovation policies..

Dilemmas of innovation policy in Poland's shift to a market economy, by A Jasinski (Inst for Science Policy, Warsaw), April 1991, 131-134.

Potential for sharing research equipment, by Susan Hinder *et al* (University of Manchester, UK), April 1990, 103-108.

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The evolution of UK S&T policy, by Philip Gummett (Manchester University, UK), February 1991, 31-37.

Problems in commercialisation of scientific research results in Nigeria, by F E Ogbimi (Obafemi Awolowo University), Dec 1990, 373-379.

Recent trends in the output and impact of British science [compared with US, Japan, France, Germany, Netherlands], Ben Martin, John Irvine (SPRU), Francis Narin (CHI, USA) *et al*, Feb 1990, 14-26.

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Technology development in Japan and the US: lessons from the high temperature super-conductivity race, Michael Crow (Iowa State University), December 1989, 322-344.

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S&T policy in the USSR, the papers from the [former] US planned for 1992.

Social responsibility of scientis papers by Reimar Lüst (Director eral, European Space Agency, Pari Stig Strömholm (V-C, Uppsala University), *et al*, April 1990.

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