Biological Clocks and Tenure Timetables: Restructuring the Academic Timeline

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ABSTRACT

Despite decades of progressive social change by an active women's movement, federal and state legislation, and adoption of academic affirmative action policies, women geoscientists have not reached a critical mass in higher education. Women comprise only 12.5% of geoscience faculty in U.S. colleges and universities, and only 10% at Ph.D.-granting institutions. Senior women faculty tend to be marginalized from the academic power structure. A combination of biological factors, lifestyle choices, dual career pressures, double standards for social and professional interactions, and gender-based discrimination creates an effective filter, reducing women in geoscience departments to a surprisingly low level. There are two rungs on the ladder where women proportionally leave the discipline at a higher rate than men. One is continuing on to obtain a Ph.D.; the other is prior to, or at tenure. The present time frame for achieving tenure and promotion was established by men, for men, decades ago. Such a time frame is incompatible with women's biologic reproductive constraints, and as such, puts an unequal level of pressure and stress on women relative to their male professional counterparts. Only a significant change in the culture of science, and its traditional pathways, will create a geoscience community that has a sound base of gender equity. Strong leadership from innovative and far-sighted administrators and colleagues is required to introduce and foster institutional change that will reduce the conditions that leave women disadvantaged.

THE ACADEMIC LADDER

The percentage of women in all U.S. academic geoscience departments is only 12.5% (professors, 2.2%; associate professors, 2.5%; assistant professors, 4.4%; and instructors and/or adjuncts, 3.4%) (Fig. 1, Table 1). A surprising 40% of geoscience departments have no women (Wolfe, 1999). Approximately 35% of B.Sc. and M.Sc. degrees in geology are awarded to female students, and ~25% go on to obtain Ph.D. degrees (Fig. 1) (Wolfe, 1999; Claudy, 1999). At present, ~22% of assistant professorships are held by women, indicating that women who complete Ph.D. degrees are successful in getting tenure-track positions. Although there are 22% women making up the assistant professor ranks, assistant professors comprise only 20.1% of all professors. Therefore, assistant women professors in the geosciences are only 4.4% of the total academic faculty. Similarly, 14% of associate professors are women, but since only 18.3% of all faculty, the total number of women in that rank is only 2.5%. Five percent of full professors are women, but because 44.1% of all academic faculty in the United States are at the rank of full

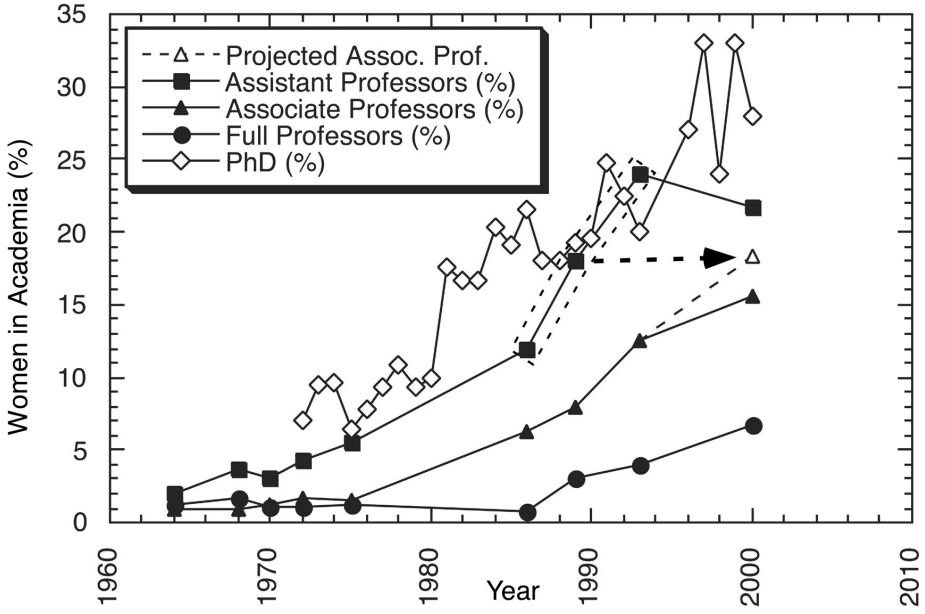

Figure 1. Data compiled from the American Geological Institute and Ongley et al. (1998) illustrating the percentage of women obtaining Ph.D. degrees and moving through academic ranks from 1965 to 2000. The dashed line to the unfilled triangle shows the percentage of female associate professors predicted by forward modeling assuming the tenure success rate for women is the same as that for men.

TABLE 1. PROPORTION OF WOMEN FACULTY BY RANK

Academic rank	% of U.S. faculty*	% of women in rank	% of women faculty
Professor	44.1%	5%	2.2%
Associate professor	18.3%	14%	2.5%
Assistant professor	20.1%	22%	4.4%
Instructors and/or adjuncts	17.4%	20%	3.4%

* Table 2, Claudy (1999)

professor, the actual percentage of full professors who are women is 2.2%. Instructors and adjunct professors make up the balance, according to a 1999 American Geological Institute report (Claudy, 1999). However, the number of women who continue on through the academic ranks appears to decline relative to the number of men who continue up the academic ladder (Fig. 1). Figure 1 shows that the number of female associate professors is below the projected level (dashed line to open triangle), assuming the same rate of gaining tenure as men. This indicates that either women are not being awarded tenure at the same rate as their male counterparts, or that women are choosing to leave the profession at a greater rate than men. National data indicate that women do receive tenure at approximately the same rate as men (National Science Foundation, 1996), or a slightly lower rate (Tomorrow's Professor Listserve, 2000). Therefore, we suggest that there are other factors contributing to the loss of women at the critical juncture between assistant and associate professor. The ~18% and ~6% of women in associate and full professor positions reflects a lag time between the early 1980s, when the percentage of women getting Ph.D.s in geology began to rise appreciably (Fig. 1). There is a minimum lag time of ~12 years for the first of that cohort to work its way through the ranks to achieve tenured status and higher (de Wet and de Wet, 1994). The objectives of this paper are to (1) reaffirm the need for gender equity; (2) examine contributing factors to the loss of women faculty; and (3) suggest alternative strategies to promote the full participation of women in geoscience higher education. Although we have used U.S. geoscience departments for our database, many of the issues discussed here are widely applicable across numerous disciplines where women are underrepresented.

GENDER EQUITY MAKES SENSE

Harding (1991, 1994) and Macfarlane and Luzzadder-Beach (1998) summarize the case for gender equity stating that fundamentally science is improved through diversity, and that women should have opportunities and access equal to those of men. Cecily Selby, chair of the 1998 National Science Foundation (NSF) Women in Science and Engineering Conference stated, "This situation is not so much a 'woman problem' as it is a problem for science and engineering; as long as women's talents and abilities are not fully used, our scientific and technical enterprises lose. Our economy is, in turn, diminished. In other words, the question now is not what universities and corporations may be willing or compelled to concede to women. It is, rather, what sort of work environments encourage 'the best and the brightest' human beings in our society, regardless of their gender (or any other extraneous-to-science characteristic), to contribute to the advancement of science."

Even the most cynical can view the loss of women out of the profession as a waste of resources. Each person who advances through the ranks of a discipline represents years of intellectual and financial input. The average cost of educating an undergraduate geoscience major through the four years is between $25,000 and $130,000 (university in-state tuition versus private liberal arts college). Field camp and research experiences (e.g., Keck Geology Consortium, NSF Research Experiences for Undergraduates Program) may add another ~$7,000. Adding expenses for a master's and doctorate degree gives a range of $50,000 to $100,000, depending on cost of fieldwork or ship time, and analyses. If the student does a one-year post-doc, another $30,000 may be invested in that individual as salary, plus or minus grant support.

So just to get an individual to the point where she or he is ready to contribute back to the discipline as a faculty member means that at least $200,000 has been invested. This astounding figure is only the financial investment. There is also the individual's time and effort, plus the time and effort of research supervisors, mentors, teachers, and peers who have contributed to the individual's success thus far. Clearly, educating geoscientists is an expensive business monetarily, but even more important, in terms of expertise and training. It is, therefore, not logical to be willing to lose a portion of those individuals every year. Such a waste of intellectual and financial resources has a significant impact on the discipline.

Another part of why gender equity matters is balance and diversity. Most departments seek balance in terms of number of senior versus junior staff and look for balance in subdisciplines and in the range of years of experience. Balance in gender promotes a positive climate for being inclusive, broadening scientific perspective, and increasing the department's overall intellectual vitality.

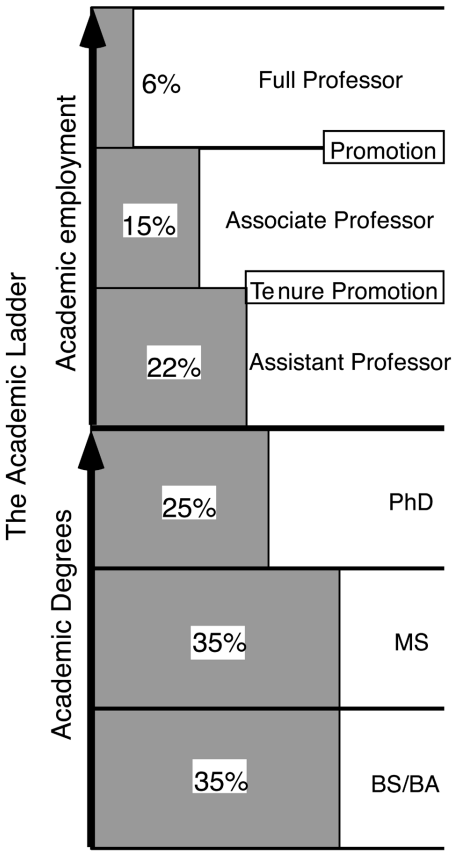

Figure 2. Percent of women in various ranks along the academic ladder.

WHY THE ATTRITION?

Both men and women leave the academic system to join the workforce or switch fields after each major step. But female students switch out of science majors to non-science majors at a rate of 70% (national samples) and 54% (highly selective institutions) compared to 61% and 39%, respectively, for men (Goldberg, 1998). The trend continues up the ladder (Goldberg, 1998; Macfarlane and Luzzadder-Beach, 1998; Holmes et al., 2002). But the loss of women at the Ph.D. level, and prior to or at tenure-time, is disturbing (Fig. 2), because these points reflect maximum input from both personal and professional resources. For a person to leave late in a career trajectory means that something serious is occurring. We emphasize that our observations concerning women in academic posts takes into

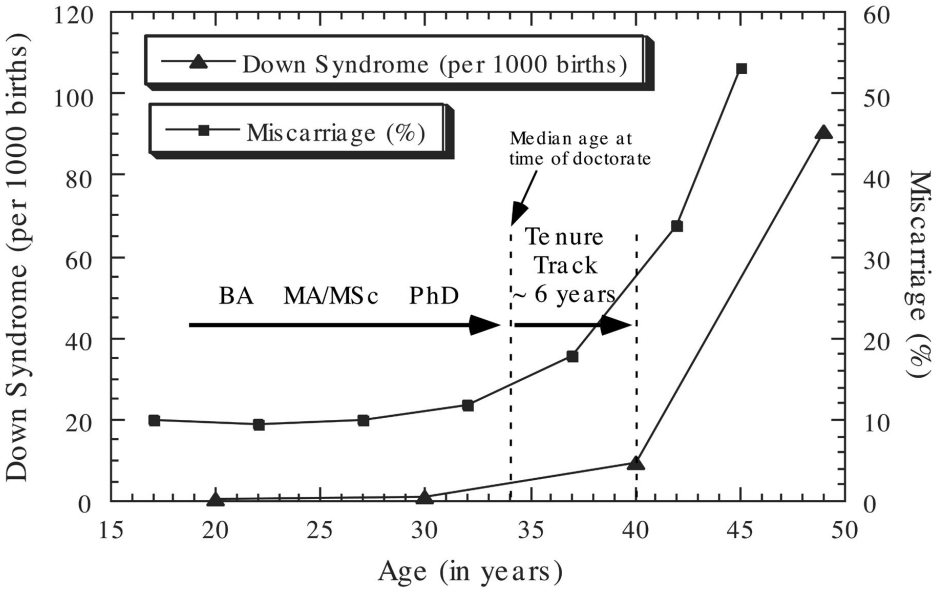

Figure 3. Correlation between a significant rise in the risk of Down syndrome and miscarriage with the pre-tenure years in an academic career.

account the lag time between the early 1980s, when female students began to enter Ph.D. programs in appreciable numbers, and the years it takes to move that cohort through the academic ranks (Fig. 1) (de Wet and de Wet, 1994). Taking into account the lag time, women associate professors should have been at ~18.4% of the total geoscience faculty by 2000. Calculations based on the most recent data (2000) from the American Geological Institute shows that women make up only 15.6% of associate professors (Giesler et al., 2001). We contend that the majority of women who leave geology during their Ph.D.s or early in their professional lives may do so because of their biological clocks and career timetables, along with a general lack of sensitivity and support from the academic infrastructure. This supports the conclusion of a National Research Council (NRC) panel, whose findings show that having children improves a man's chances of becoming a full professor, but hinders a woman's progress up the academic ladder (Mervis, 2001). The NRC report also notes that marriage and family issues are major factors that relate to men still having the edge over women in U.S. science careers (Mervis, 2001).

BIOLOGICAL FACTORS

Childbearing Years and Tenure Trajectory

Due to the inevitable tick of the biological clock, there is an unavoidable collision between a woman's optimum childbearing years and her career trajectory (Fig. 3). Although career and family issues affect both men and women, and many men are fully involved in family responsibilities, the point of this discussion is to recognize that there are issues unique to women who are starting a family. No one else will be faced with the difficult position of potentially compromising her career or her child's health (or even her own). For example, maternal mortality rates are substantially higher with increasing maternal age; mortality rates are four times higher among women 35 to 39 years old than those of ages 20 to 24 (Rochat et al., 1988). The babies of older women have substantially higher rates of mortality as well (Cunningham and Leveno, 1995). In women age 35 or older, there is a four-fold increase in serious fetal complications, including stillbirth (Prysak et al., 1995).

The most fundamental gender-specific issue is childbearing. Figure 3 illustrates the average time it takes to accomplish major professional goals—Ph.D., first job, tenure—versus reproductive risks represented by the increasing likelihood of Down syndrome or other chromosomal abnormalities with maternal age. Clearly, a woman faces a difficult choice: wait to have children until her professional life is secure, but risk serious health consequences for the child, or bear her children earlier, and risk her professional success (Cole and Zuckerman, 1987; Herbold, 1995; Katterman, 1995; Cunningham and Leveno, 1995). This kind of emotional dilemma is what may lead some women to leave the discipline. Those who stay in the profession experience tension that may seriously impact their quality of life, their careers (research productivity, field and lab work), and their ability to successfully compete for jobs and grants. The overlap in biological and professional imperatives lasts for only a minor portion of a woman's life, perhaps only 6 years out of a 35-year career.

There are three broad issues that face women who delay childbearing. The first issue is pregnancy outcome. The most widely publicized aspect of this is the positive correlation between maternal age and chromosomal abnormalities. Down syndrome is the most common chromosomal abnormality in live born children. The risk of giving birth to a child with Down syndrome at age 35 is ~1:270 (1:350 for 1988 data by Hook et al., but that compilation shows a 1:275 incidence of Down syndrome for age 36) (Fig. 3) (Hook et al., 1983, 1988; Brody, 2002). By age 40, this risk is 1:106 (1:100 Hook et al. [1988] data) (Brody, 2002). Lethal chromosomal abnormalities are also more common with advanced maternal age, and increased risk of miscarriage is a significant concern (Cunningham et al., 1997; Cunningham and Leveno, 1995). Only ~10% of woman under the age of 20 experience spontaneous abortion. By age 40, this risk has more than doubled, to almost 34% (Brody, 2002).

The second issue is the unavoidable decline in fertility with advancing age. Information about age and fertility comes from a study of the Hutterites, a religious sect in South Dakota with two characteristics that make the study of population fertility valid: (1) contraception is condemned, and (2) the Hutterites live communally, so there is no incentive to limit the size of a family due to economic reasons. The average age of the last pregnancy was 40.9 years. Eleven percent of the women had no children after age 34. By age 40, fully one-third of the women were naturally infertile, and 87% were infertile by age 45 (Thompson et al., 1991).

The third issue for women is that the natural incidence of chronic illnesses that complicate pregnancy increases with

maternal age. Common conditions such as diabetes and chronic hypertension increase both maternal and fetal risks (Speroff et al., 1994; Cunningham and Leveno, 1995). Potentially serious bleeding complications of pregnancy such as abruptio placentae and placenta previa are more frequent among older women (Cunningham et al., 1997; Cunningham and Leveno, 1995). The occurrence of cesarean delivery is at least twice as high in women over age 35 (Cunningham and Leveno, 1995). These conditions can affect functioning at work and make pregnancy and childbirth more difficult.

BIOLOGICAL IMPERATIVES

Biological differences do matter. Pregnancy and the desire to nurture young are deeply rooted biological processes that affect women. Pregnancy, possible complications, nursing, children's illnesses, and emotional commitment are all factors that sap women's energy and time (Fort, 1993). However, these issues affect women disproportionaly for a relatively short part of their professional lives.

Other biological issues may be more difficult to pin down, but may nonetheless have a nontrivial impact on whether a woman decides to leave the academic system. For example, men's and women's different approaches to sexual attraction may impact mentoring and supervisory roles (Fig. 4) (Herbold, 1995). It may make working in research groups difficult. Women may not be taken as seriously as their male counterparts (Zuckerman et al., 1991; Fort, 1993). Hormonal differences have consequences that may affect women's competitiveness and assertiveness (Silver, 1998).

LIFESTYLE CHOICES

As people move through academic ranks, they make decisions based on lifestyle choices. A significant number of female students and junior faculty leave academia because they perceive that (1) conditions in the workplace are frequently incompatible with their needs and priorities (Cole, 1981; Fort, 1993); and (2) the work itself is based on a model that implicitly or explicitly identifies characteristically male ways of doing things as the "scientific way" and denigrates other styles as unscientific (Cole, 1981; Fort, 1993; Goldberg, 1998).

Female and male scientists organize

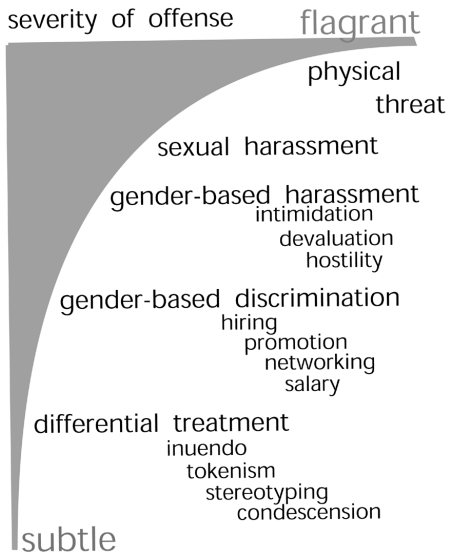

Figure 4. Gender bias in the academic environment ranges in the severity of the offence from subtle differential social treatment to verbal or physical harassment. Discrimination in hiring, promotion and salary inequities are gradually being elimination by legal action (often class action suites). Differential treatment such as stereotyping, tokenism, condescension and sexual innuendos may undermine women's ability to work productively and compete effectively with male peers (after Yentsch and Sindermann, 1992).

lifestyle priorities differently (Fig. 5). Goldberg (1998) notes that women tend to regard collaborative effort, supportive workplace, quality of life, and a better balance between professional and personal life as rewarding. These are rarely included in the traditional academic roster of benefits and rewards. The rewards typically offered by university-based geoscience careers, such as higher salary, prestige, elevated status, and increasing power, do not reflect what many women deem most necessary or value most highly (Goldberg, 1998). Women indicate that measuring personal success comes from assessing all aspects of life, including career satisfaction, family, and personal life over a lifetime (Goldberg, 1998).

The first few years in academia are notoriously difficult. The new faculty member is designing courses, writing lectures, learning how to teach effectively, and establishing a research program while simultaneously being evaluated by student evaluations, third-year review processes, or the like. There are few rewards during those early years. Salary increases are small, publications come out slowly on new material, and citations and awards are typically given to senior or established scientists. For women, adding the additional emotional and physical issues of pregnancy, childbearing, and infant care, the load becomes staggering, and a satisfying career may seem unattainable.

There are on-the-job conflicts that primarily affect women more than men. As shown in Figure 6, many of these conflicts seem to come down to either/or situations that have lifelong consequences. For example, does a woman chose to have healthy babies or publish during her early-to-middle thirties? Does a woman preserve her marriage to her science professional spouse when both seek employment (statistically, the woman's career rarely takes precedence)? And, does a woman put up with subtle or overt bias and discrimination so as to not jeopardize her chances of getting tenure? Most women in senior faculty roles today either had no female mentors or role models, or had ones whose survival skills were to "be quietly competent and not make

DIFFERENT LIFESTYLE CHOICES

Female scientist	Male scientist
(1) Parent	(1) Science professional
(2) Partner	(2) Self
(3) Science professional	(3) Partner
(4) Humanist	(4) Parent
(5) Naturalist	(5) Naturalist
(6) Self	(6) Humanist

Figure 5. Female and male scientists' responses to how they view themselves relative to six aspects of their lives. The significant differences in perspective reflect on how women and men view their careers, families, and role in society. The male perspective closely reflects traditional perceptions about priorities for a successful career in science. This ranking is based on interview questions from *The Woman Scientist,* 1992, Plenum Press (Yentsch and Sindermann, 1992).

THE FILTERING PROCESS—ON-THE-JOB CONFLICTS

(1) Babies or publish?
- Prime reproductive years coincide with early career development.
- Concerns (such as Down syndrome) increase after 35 years.

(2) Two-career relationships.
- Sharing one academic position or negotiating two positions at same institution.
- Woman's career rarely takes priority.

(3) Gender bias and discrimination.
- Subtle (and not-so-subtle) bias occurs at all levels.
- Senior faculty tend to get marginalized from the power structure.

(4) Old Boys' Network
- Lack of experience at networking, negotiation, and bargaining often put women behind when obtaining a position, start-up packages, promotions, merit increases, and dealing with outside offers.

Figure 6. Issues that have a disproportionately large affect on women's career success in science. One or more of these issues may have a dramatic impact on a woman's progress up the academic ladder but are unlikely to hamper men's career success.

waves," hardly the role models needed to be successful in today's "squeaky wheel" culture (Muller, 1999). Women often lack experience at networking, negotiation, and bargaining, and are not as successful as their male counterparts in obtaining start-up packages, promotions, and merit increases, and in handling outside offers.

CHANGING THE TONE AND TEMPO OF SCIENCE

The scheme (timing, rate, and magnitude of accomplishments) for awarding tenure and promotion—critical steps on the academic ladder—was designed by men and for men long before there was a trickle of women in the academic pipeline (Harding, 1986). Historically, it made sense for men to devote themselves to the pursuit of science at a young age. Now, however, both men and women live longer productive lives, and the pressing need for maximum accomplishment between ages 20 and 35 has lessened. But the scientific tradition has deep roots, and the community today operates on the same time frame that it did 100 years ago. Today, there is no logical reason why maximum professional productivity must coincide with optimum childbearing years, except to say, "it has always been that way." We suggest that it is time to seriously reconsider the tone and tempo of the academic system.

How can the geoscience discipline change itself to squarely address these challenges? Women must be present in high enough numbers to reach a critical mass. This is discussed in Macfarlane and Luzzadder-Beach (1998), and according to Osborn (1994) once a minority group reaches 15% they have enough "critical mass" to begin to change the system. In terms of faculty positions, it is not only a question of the ratio of female to male colleagues, but also the generation of women. Etzkowitz et al. (1994) noted that older women in academic departments were most similar to older men in thinking and style (i.e., survivors of the male designed tenure and promotion system). These women are, therefore, not serving as mentors or role models outside of the status quo for younger women faculty. Continued hiring of women faculty remains important (Fig. 7).

Industry outpaces academia in progressive approaches to the retention of women. Thanks to a combination of self-interest (competition for talent) and government legislation (20 years of civil rights legislation), the private sector and government agencies have made significant strides in gender equity (Wilson, 2002). According to Goldberg (1998), however, elite colleges and research universities have been almost stagnant, or even resistant to change. Only the recent lawsuits at the Massachusetts Institute of Technology and the University of South Florida have spurred many institutions to examine their role in female faculty concerns (Muller, 1999).

Academic institutions need a "sea change" in their approach to retaining and promoting women faculty (Fig. 7). One of the most important changes would be institutional recognition of time problems by granting extended leave time (beyond the federally mandated time), stopping the tenure clock, or allowing women to work part time on a monthly or yearly basis (de Wet and de Wet, 1995, 1997; Wilson, 2002). The Statement of Principles on Family Responsibilities and Academic Work (American Association of University Professors, 2001) outlines specific steps that institutions can take to change the tone and tempo of science on their campuses. For example, family leaves, modified teaching schedules, stopping the tenure clock, and institutional assistance for family responsibilities are suggested. Many of the suggestions could be instituted based on individual needs, subject to revision when those needs change. The benefits that six months off, or a year at half time, would afford a woman who is starting a family would be repaid in increased productivity and contentment as her time crunch lessened (Fig. 7) (Wilson, 2002).

Another strategy is for women to work in collaborative research groups that foster cooperation and support, rather than

SOLUTIONS—INSTITUTIONAL ASSISTANCE WITH FAMILY RESPONSIBILITIES

- Continued hiring of women
- Stopping or slowing the tenure clock
- Time off—to be repaid later
- Collaborative research groups
- Modifies teaching schedules
- Half-time tenure track positions

Figure 7. Possible strategies for institutions and departments to pursue towards the goal of full participation by women in the geosciences.

competition (Fig. 7). If one member of the group needs to reduce her commitment for a given time period, the other members of the group can take up the slack, knowing that they may need that flexibility in the future. The reduced commitment need not be only for childbearing, but for elder care, or for some other serious issue that requires considerable time, but only for a finite period. The group approach would enable the researcher to continue to publish, but her main contribution might come later. Tenure and promotion criteria could be modified from being based on the number of publications and the size of grants, to include quality of science, creativity, long-term projects and collaborative efforts. Such a new paradigm requires that deans, provosts, and others who evaluate scholarship be receptive to a changing system.

Our discussion has focused on women in higher education, and proposed changes specifically aimed at improving the climate for women in academia because this is where the pool of future female professionals will come from. The academic system needs to be the pacesetter, but unfortunately, it has so far lagged behind the private sector and government. We urge administrators and department heads to become creative, forward-thinking leaders in changing the tone and tempo of science. Changing institutional policies may be easier than changing institutional cultures, but unless effort is made on all fronts, women will continue to disproportionately leave academia.

CONCLUSIONS

Attrition from the geosciences is higher for women than men at two critical points: (1) after the M.Sc. degree, and (2) between assistant and associate professor. Due to the inevitable tick of the biological clock, there is an unavoidable collision between a woman's optimum childbearing years and her career trajectory (Fig. 3). Assuming that gender equity in science makes sense in terms of resources, diversified types of study, and balance, then causes for the rate of women's attrition must be sought.

Human biology dictates that the responsibility of human reproduction falls to women, even though many men are active participants in family issues. Biological realities should be acknowledged if we are to attain a critical mass of women in the geosciences. Early career conflicts that place unequal pressure on women can be ameliorated by changing the traditional time frame for progression up the academic ladder. Stopping the tenure clock, allowing part-time work for given time periods, and encouraging split positions are policies that already exist in some institutions. More responsive, flexible schemes for integrating work and family are essential to ensure women's full participation in higher education. At one time, it was considered impossible for female students to go on field excursions because of a lack of facilities. This "impossible situation" has been overcome, and there is no reason to doubt that the issues we have described can also be overcome.

Changing the tone of the geosciences to recognize the different priorities and goals of many women scientists may be the most difficult task. The subtle ways that the academic community undervalues what women value highly, such as family commitment, spousal satisfaction, and other lifestyle choices, means that women will continue to feel marginalized and choose to leave in higher numbers than their male counterparts.

Only by the retention and advancement of women can critical mass be achieved, after which women can begin to fill positions of power and influence. Women then can serve as role models for the next generation of scientists, encouraging more of them to enter and stay in science. This pool will then form the teaching basis for both academia and industry, and will potentially lead to a generation of managers and department heads who will be part of the ongoing transformation of the sciences. Only strong leadership today, by both administrators and faculty, can change the academic culture of priorities, workloads, reward structure and values to more closely reflect all of its constituencies and begin such a transformation.

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