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When Scientists Choose Motherhood:

A single factor goes a long way in explaining the dearth of women in math-intensive fields. How can we address it?

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> I have frequently been questioned, especially by women, of how I could reconcile family life with a scientific career. Well, it has not been easy.
>
> —Marie Curie, two-time Nobel Prize winner and mother of a daughter, Irène Joliot-Curie, who also won the Nobel Prize

Jennifer was an extremely talented undergraduate, majoring in mathematics and engineering. Her grades and test scores were nearly perfect; her professors saw a bright future for her as an engineering professor and encouraged her to pursue a doctorate. In graduate school, she continued to excel, accumulating high-quality publications, fellowships and awards. She landed a premier postdoctoral position and was headed for a first-tier professorship. But she never applied for a tenure-track academic job. As a 33-year-old postdoc, she could not imagine waiting to have children until after tenure at age 40, nor could she imagine how she would juggle caring for a young family with the omnipresent demands of an assistant professorship. The harried lives of the two tenured mothers in her department convinced her that such a path was not for her. Jennifer made the choice to have a family and teach mathematics part-time at a local community college.

Although it's not hard to find evidence of women professors' many successes in the academy, scenarios like Jennifer's are all too common. Women hold a substantial portion of professorships in the humanities and liberal arts, and they are well represented in the social sciences and some fields of natural science, such as biology. Overall, women make up 33 percent of faculty at doctoral-level institutions. They receive many teaching and service awards and do as well as men in winning grants. But women are in short supply in math-intensive fields, such as chemistry, physics, mathematics, engineering and computer science. For example, in the top 100 U.S. universities in 2007, women full professors in these fields numbered only 4.4 to 12.3 percent, and women were only 16 to 27 percent of assistant professors (*see* Figure 2).

What is going on here? Why are women who are talented and dedicated enough to graduate from college with degrees in mathematics not progressing through graduate school and ultimately earning full professorships? Where are these women going, and why do they leave their chosen field?

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Much has been written about the underrepresentation of women professors in math-intensive fields, particularly in upper-level positions. Despite the substantial amount of high-quality data on this issue, however, myths and misunderstandings prevail. Potentially addressable issues that limit women are often ignored, and efforts and resources are misdirected toward solving problems that no longer exist.

The usual explanations for the shortage of women focus squarely on sex discrimination at various life stages. As a result of such discrimination, the argument goes, girls and women drop out of math-based endeavors or change their focus. Some scholars have argued for the effects of early socialization practices that lead girls along a path that downplays math—pink versus blue attire for babies, Barbie dolls proclaiming "Math class is tough," middle-school math teachers calling on boys more than girls, high-school girls urged to be cheerleaders or writers instead of scientists. Others invoke gender stereotypes—sets of shared cultural expectations that suggest, for instance, that females are not gifted in math or that the responsibility for raising children belongs primarily or solely to women. Still others look further down the pipeline, at disenfranchisement of women once they enter academic-science careers, focusing on claims of "chilly climate"; unequal pay and promotion; devaluing of women's work styles and biased assessment of their efforts; and old-boys' clubs that isolate women. Researchers have also studied the role of sex differences at the extreme right tail of the math distribution—more boys than girls demonstrate extremely high levels of math ability on standardized tests such as the SAT. Still others suggest that women simply prefer to use their math and science skills to be veterinarians and biologists, for example, rather than engineers and computer scientists, and that the difference in the numbers can be explained by this freely determined preference.

We argue for the importance of another factor in women's underrepresentation: the choice to become a mother. To place the role of this choice in context, we consider its impact on women's careers relative to the impacts of other variables that may reduce women's participation in the sciences. Our own findings as well as research by others show that the effect of children on women's academic careers is so remarkable that it eclipses other factors in contributing to women's underrepresentation in academic science.

Unlikely Causes

Three major sets of factors have been offered to explain the dearth of women in math-intensive fields: ability differences; occupational and lifestyle preferences; and sex discrimination. Elsewhere we have extensively reviewed the evidence for several of these issues; here we provide a summary.

Ability differences

Scholars once thought sex differences that favored men on tests of quantitative ability were responsible for the shortage of women in math-based fields. Although there are no systematic sex differences in average scores on tests such as the SAT mathematics (SAT-M), many more men score in the very top range. For example, among the top 0.01 percent (1 in 10,000) of scorers in nonrandom samples, there are about 4 men for every woman. College admissions committees may admit more men because of their higher SAT-M scores, setting in motion a cycle of women's attrition.

Yet this cannot be the whole story or even a large part of it. Starting about two decades ago, women began gaining on men in math ability and participation. By 2005, men and women were almost equally represented among college math majors, and women tend to get better grades in math courses. But far fewer women than men enroll in math-based Ph.D. programs. The GRE-Quantitative scores of graduate students in math-intensive fields at our

own university are very high across the board. These students come from the top end of the ability distribution, and the test actually underestimates their ability due to ceiling problems (there are not enough very hard questions to distinguish the truly exceptional from the merely talented). So, since fewer women score in the top range on tests used for admission to Ph.D. programs, this fact may be responsible for some of the shortage of women in math-intensive careers.

As compelling as this argument seems, however, there are several problems with it. Females outperform males in math classes throughout schooling, including in college. Surely graduate-admissions decision makers take women's higher GPAs into account. Also, even if among the top 1 percent of scorers there were 2 males for every female, there should still be more women in math-based disciplines, because we do not see anything close to a 2-to-1 ratio of men to women in these careers. Recall that 12 percent or less of full professors in these fields are women. Something more than scoring at the right tail is responsible.

Some researchers argue that those who succeed in mathematical fields come from more rarefied strata than the top 1 percent. David Lubinski, Camilla Benbow and their associates at Vanderbilt University have shown that those in the top quarter of the top 1 percent of scorers outperform those in the bottom quarter of the top 1 percent in obtaining tenure-track jobs, publishing articles and patents, and other indicators of excellence and success. If extremely high math ability is important to success, and if many more men possess this extreme ability than do women, perhaps it is responsible for observed ratios of men to women in math-based fields. Although further investigation might show a correlation between success and scores in the far-right tail of the range, no one has demonstrated a causal relation between the two factors. We do know that math-talented women are less likely than equivalently math-talented men to enter mathematical professions. In other words, many fewer women than men choose mathematical fields—even when they have comparable math scores.

There is no direct evidence that men's math-score advantage explains this shortage of women. Forty-five percent of undergraduate degrees in mathematics go to women, as do 29 percent of Ph.D.s, suggesting that whatever these women's math skills, they are compatible with very high levels of achievement. Thus, we believe mathematical differences between the sexes are not primary factors in women's underrepresentation in math-heavy fields.

Career preferences and lifestyle differences

If cognitive differences cannot explain most of the shortage of women in these careers, what about sex differences in career preferences and lifestyle choices? Surveys have documented that females, starting at a young age, are more interested in careers that involve living things —such as medicine, biology, animal science and psychology—than fields such as computer science, mathematics, physics and engineering. Adolescent girls seldom name engineering and computer science as desired careers, whereas nearly a quarter of adolescent boys do. Unlike some researchers, we are not overly worried by these findings, because careers in biology, medicine and veterinary science seem as valuable and satisfying as those in math-based fields. It would be troubling if adolescents declined to try such professions on the basis of faulty information about what is possible, but as long as they are doing so to pursue careers they perceive as more rewarding, society still benefits from these young people's talents.

A related factor concerns life-course differences between the sexes. In surveys of graduate students, Lubinski, Benbow and their students found that female graduate students viewed a fulltime career as "important" or "extremely important" about as often as did their male counterparts (77 percent versus 81 percent, respectively). However, when it came to the

importance of temporarily having a part-time career, significant sex differences emerged (31 percent versus 9 percent, respectively), as well as for always having a part-time career (19 percent versus 9 percent, respectively).

Such life-course preferences can lead to differences in research productivity and hours spent at the office, reflecting differing priorities in optimal life-work balance. Lubinski studied the amount of time that nearly 2,000 33-year-olds, who were in the top 1 percent of quantitative ability during their adolescence, spent on career-related work. He found that roughly twice as many high-aptitude men as women reported working at their jobs more than 50 hours per week. Other surveys underscore this male advantage in working very long hours.

Sex discrimination in publishing, funding and hiring

A frequent claim is that women are derailed by sex discrimination in publishing their work, obtaining grant funding and being hired. However, although these forms of discrimination may have played important roles historically, none of these causes can explain today's underrepresentation. In an article in the *Proceedings of the National Academy of Sciences of the U.S.A.,* we reviewed the evidence and concluded that such discrimination is not responsible for the current dearth of women. Consider one example of the research we synthesized. In 2004 and 2005, a National Research Council committee surveyed U.S. university departments and faculty in a number of math-intensive fields about their interviewing, hiring and promotion records. It found that women applicants were actually more likely to be interviewed and offered tenure-track jobs than were their male competitors, and that there were no differences in tenure and promotion rates for women and men. A number of other analyses have reached the same conclusions. In mathematics, only 20 percent of applicants for tenure-track posts were women, but 28 percent of those invited to interview were women, as were 32 percent of those offered positions.

The picture is much the same for funding and publishing. Women scientists are as successful as men at publishing work and at earning grant funding, according to analyses of hundreds of thousands of grant applications submitted throughout the United States, Canada, the United Kingdom and Australia.

Thus, the shortage of women in mathematical fields is not the result of discriminatory hiring, publishing and funding, nor can it be explained away on the basis of ability differences. Some portion of the dearth of women in math fields can clearly be traced to differences between the sexes in career preferences. Women's greater desire for lifestyle flexibility, reflecting differing ideas about work-life balance and different expectations regarding responsibility for raising children and working in the home, also plays a role. This latter point leads to what we see as the single most important factor in explaining women's underrepresentation: a desire for children and family life.

The Perils of Motherhood

It is when academic scientists choose to be mothers that their real problems start. Women deal with all the other challenges of being academic scientists as well as men do. Childless women are paid, promoted and rewarded equivalently to their male peers (and in some analyses at even higher rates). Children completely change the landscape for women—but do not appear to have the same effect on the careers of men. What happens when children enter the equation, and why does this change seem to impact women's but not men's careers?

Answering this question requires knowledge about the typical course of an academic career. Most college students interested in becoming professors in the sciences graduate from

college and matriculate in graduate school soon thereafter. Earning a doctorate takes five to six years on average; it is common to work as a postdoctoral associate for several years after the doctorate. By the time students contemplate applying for tenure-track academic jobs, they are at least 27 years old, and on average 33. Landing a job means applying broadly and being willing to relocate, giving the search priority over the needs of partners or spouses. The next six years are spent in relentless efforts to accumulate an impressive portfolio of work—encompassing research, teaching, service and grants—until finally, at age 35 or older, a professor may be fortunate enough to earn tenure. Research by Jerry Jacobs and Sarah Winslow has shown that more than 60 percent of female untenured professors are over 40, and Mary Ann Mason and Mark Goulden showed the average age of tenure was already 39-plus by 2003.

Women's optimal fertility is between ages 18 and 31. By age 37, many will have difficulty conceiving. Waiting to have children has not only physical aspects but also emotional ones —some women want to have children when they are younger. For women, the tenure track presents a harsh reality that juxtaposes the most significant physical and emotional challenges of their lives with the most significant professional challenges. It's easy to see why the pretenure years might be off-putting for a woman who does not wish to delay having children until her late thirties—she must deal with pregnancy, childbirth and child care while simultaneously amassing a tenurable portfolio of work. This reality is too daunting for some women, and they either leave the tenure-track pipeline or give up on having children.

Surveys have shown that regrets plague women in the academy at a far greater rate than they do men. In a 2002–2003 survey of around 4,500 University of California faculty members by Mason, Angelica Stacy, and Goulden, 38 percent of women but only 18 percent of men stated that they "regret not having children" or "regret not having more children." In research by Elaine Ecklund and Anne Lincoln at Rice University and Southern Methodist University, nearly 40 percent of women graduate students said they had fewer children than they wanted because of the pressure of their careers (versus only 20 percent of men), as did 45 percent of women faculty in astronomy, biology and physics (versus only 25 percent of men). Often this regret is associated with leaving the academy.

Men more often have stay-at-home spouses or spouses in flexible careers who bear and raise children while the men are free to focus on academic work. Women professors in heterosexual partnerships who want to bear children, by virtue of biology, can never achieve this same distance from childrearing, and male stay-at-home partners devoted to child care are rare. Mason and her colleagues found that mothers are 35 percent less likely to enter the tenure track and 38 percent less likely to achieve tenure than fathers, and twice as likely as fathers to work in part-time or non–tenuretrack positions. Only one in three women who accepts a fast-track university job before having a child ever becomes a mother. Among tenured scientists, only 50 percent of women are married with children, compared to 72 percent of men, and women married when beginning faculty careers are much more likely to divorce or separate than men. For women who want to have children and a career in science, the picture is not pretty.

If women's fears about the effects of having children on their careers were unfounded, we could simply educate young women scientists about what really happens and relieve them of their anxiety. But in fact, children represent a dramatic influence on women's life paths and work productivity. To complicate the situation further, in some cases children have a positive impact on men's productivity. Research by David Leslie has shown that the more children a woman has, the fewer hours per week she spends on her professional work, while the exact opposite is true for men.

Both for men and for women who have no children or plans to have them, the process of becoming a tenured professor in a scientific field depends on single-minded pursuit of academic goals. Whether measured in hours spent or in percentage of one's life energy devoted, the job demands devotion to the task at a level that is extraordinarily challenging for women who are mothers of young children. The tenure system was created at a time when few women worked outside the home and when raising children was assumed to be women's work, and thus it was designed for people without significant responsibilities in household work or child care. In fact, many early professors were unmarried men who were expected to live in residence at their universities. A lot has changed since then, but the tenure system itself has remained much the same.

The research by Mason, Stacy and Goulden found that childless women and childless men professors report working an average of 78 hours per week across all life domains (in the workplace and at home), and men with children work 88 hours per week. But women with children work 100-plus hours per week across all life domains. Among assistant professors with children, women spend nearly 4 hours fewer per week on their professional careers than do men (52.5 versus 56.3), according to Jacobs and Winslow. The impact of children on women is especially dramatic for the proportion working 60-plus hours per week—42 percent of married male assistant professors with children work 60-plus hours per week, compared to only 29 percent of married women with children. The reality of the lives of women professors with children may seem too stark for their younger colleagues, postdocs and students.

The role of children in women's versus men's decisions about whether to stay in a research-intensive career track or opt out of it can also be seen in research by Goulden, Karie Frasch and Mason. They show that once children—or even plans for children—exist, women become far more likely to move out of the research-professor pipeline. Women with no plans for children show decision making comparable to men, exhibiting about the same likelihood of opting out of research-professor careers.

This single factor of having or wanting children has great impact. In some analyses, females are twice as likely as males to decide not to pursue tenure-track careers as a result of this factor. Having children prior to working as a postdoctoral associate creates a 19 percent likelihood for men of opting out, versus 32 percent for women; having new children after beginning postdoctoral work creates a 20 percent versus 41 percent difference. No other factor can account for as much leakage of women from the research-professor pipeline. The percentage of women in the applicant pool at each of several key transition points shows this decline: From award of Ph.D., to application for tenure-track positions, to being invited to interview, to being offered a tenure-track job, to being promoted to associate and full professor, women's numbers diminish. The proportion of applications from women is significantly lower than the proportion of doctoral degrees awarded to women. This gap is more pronounced in some fields than in others; for example, the difference is quite substantial in chemistry and biology, two disciplines with relatively high proportions (32 percent and 46 percent, respectively) of recent Ph.D.s awarded to women. However, when women do apply for tenure-track positions, they are more likely to be interviewed and hired than their proportion in the applicant pool (as opposed to their proportion in the Ph.D. pool) would lead one to expect. These data, in sum, lead us to conclude that the dynamics of family formation in Western society—not biased hiring committees, journal reviewers and grant panelists—are the primary cause of the underrepresentation of women in academic science.

Do women in nonacademic careers face the same challenges? At least in some fields, the answer is yes. The economists Marianne Bertrand, Claudia Goldin and Lawrence Katz

surveyed nearly 2,500 University of Chicago M.B.A.s who graduated between 1990 and 2006. More women M.B.A.s dropped out of the full-time workforce with each added year following their degree. As their biological clocks ran down, significantly fewer remained in full-time and part-time employment. Although this situation is also seen among women in medicine and among Ph.D.s, it is exacerbated in business, particularly for those jobs associated with work weeks of more than 60 hours (investment banking, consulting) or close to 60 hours (venture capital, sales, trading). For the first few years following receipt of their M.B.A., men and women have similar labor-force participation, both at nearly 100 percent. However, 10 years after graduation, among women who have one or more children, only 52 percent work full-time and full year. Sex differences in labor-force participation widen as careers progress.

Women are not found in greater numbers in some fields, particularly math-intensive ones, due to a combination of factors. The two most significant reasons are that women are more likely than men to prefer other fields (such as medicine, biology, law and veterinary science, rather than mechanical and electrical engineering, computer science and physics), even when they have comparable mathematical ability, and that family-formation goals extinguish tenure-track aspirations in women more often than in men. The majority of child care, housework and household management is done by women, and women scientists are no exception in assuming this greater burden. Although this second factor affects women in all fields of science, not just math-intensive ones, the lower numbers of women entering graduate programs in math-based fields means that any factor that further reduces their number results in a dearth of tenure-track female faculty. At the top 100 universities in the 1996-to-2005 cohort, less than a third of Ph.D.s in math-intensive fields were women, and in three of those fields less than 15 percent of Ph.D.s were women. Fields such as biology, psychology, sociology and medicine, in which the majority of new Ph.D.s and M.D.s are now women, are able to retain a larger number of women in the tenure-track pipeline, even after family-driven attrition.

Policy Changes with Potential

If sex discrimination in interviewing and hiring, or in reviewing of women's work products, were responsible for the dearth of women professors in math-intensive fields, we would advocate interventions targeting these issues. But current data show that our society has moved past these types of blatant discrimination. Of course, more subtle forms of discrimination may operate today, and we await empirical data supporting their existence and illuminating optimal pathways to address them.

One potentially promising way to increase women's representation is to focus efforts on the problems faced by mothers struggling to raise young families while building tenurable scholarly records. Accordingly, we advocate evaluation of an assortment of strategies (suggested by ourselves and by others, such as Mason and her colleagues) to determine which have promise. For instance, universities might educate women graduate students about the downsides of alternative career paths, following partners' career moves and taking time off. They could explore the use of part-time tenure-track positions for women having children that segue to full-time once children are older, and offer members of a couple the option to temporarily share a single full-time position. Further strategies include not penalizing older or nontraditional applicants for jobs; leveraging technology to enable parents to work from home while children are young or ill; providing parental leaves for primary caregivers of either gender and offering funding to foster successful reentry; and providing an academic role for women who have left professional positions to have children. Institutions could also try stopping tenure clocks for primary caregivers during family formation; adjusting the length of time allocated for work on grants to accommodate

childrearing; offering no-cost grant extensions; providing supplements to hire postdocs to maintain labs during family leave; reducing teaching loads for parents of newborns; providing grants for retooling after parental leave; hiring couples; offering child care during professional meetings; providing high-quality university-based child care and emergency backup care; and instructing hiring committees to ignore family-related gaps in curricula vitae. Ensuring that adolescent girls and boys have access to accurate career information is also important, so that misinformation does not lead young people to opt out of careers they might have found rewarding. Some of these strategies have been implemented at some universities; a range of adjustments to the tenure process will be necessary to ensure that women and men who want to have children and be primary caregivers will have equal opportunity.

Key factors that limit women today are still in need of solutions. It is time for our society to address them. The stresses faced when raising young families drive women out of careers for which they are trained and in which they would be as successful as men were they to make the choice not to have children. This critical constraint, which has both biological and cultural aspects, creates a sometimes grim and seemingly unfair reality for women that men simply do not face. Modern universities must create policies to target this real issue, which is supported by extensive empirical data, and which lies at the heart of the current problem.

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Figure 1.

Industrial engineer Lillian Gilbreth was a rare and early career scientist and mother of 12. Above, Gilbreth and some of her children gather at the family's home office in Rhode Island in 1916. At left is a view of one of Gilbreth's projects, The Kitchen Practical, designed to save time at home by reducing the need for excess motion. The space could be customized to fit individual women's bodies, and it included an alcove with a small desk.

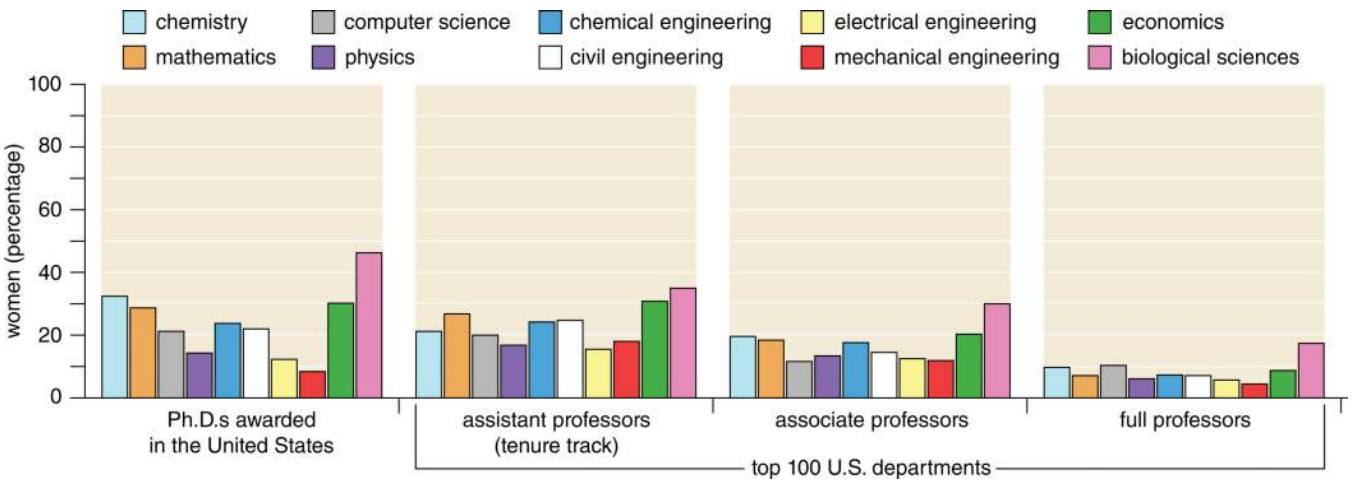

Figure 2.

Women are in the minority in nearly all fields of science, especially in math-based fields. Assistant professors are more numerous than associates, who are more numerous than full professors, as shown above for 2007. Women appear to be hired as assistant professors at rates close to their representation among Ph.D.s. However, fewer women apply for tenure-track jobs than their numbers in the Ph.D. pool suggest, according to a 2009 report by the National Research Council. Thus women applicants are more likely than men to be offered tenure track jobs, when they apply—and they are more likely to be hired than their numbers among assistant professors indicate. (Graphs based on data from D. Nelson and C. Brammer, 2010.)

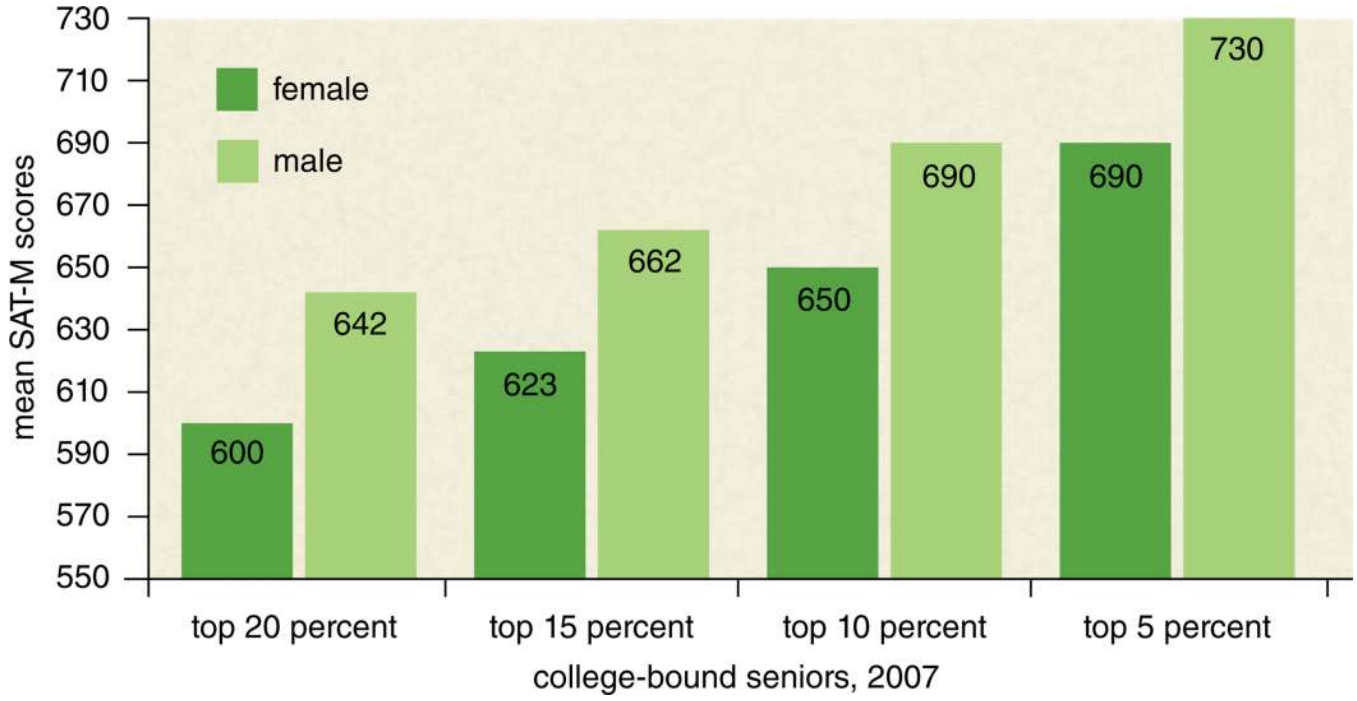

Figure 3.
Women in the United States do less well than men in the upper percentages of standardized-test score ranges. Mean SAT mathematics scores from 2007 show differences in the top 20, 15, 10 and 5 percent. A score of 690, for example, places a woman in the top 5 percent of women, but the same score places a man in the top 10 percent of men. Men's advantage does not extend into all areas, however: For instance, women get higher grades in math classes throughout schooling. (Graph based on data from the College Board, "2007 College-bound Seniors Total Group Report," http://professionals.collegeboard.com/data-reports-research/sat/cb-seniors-2007.)

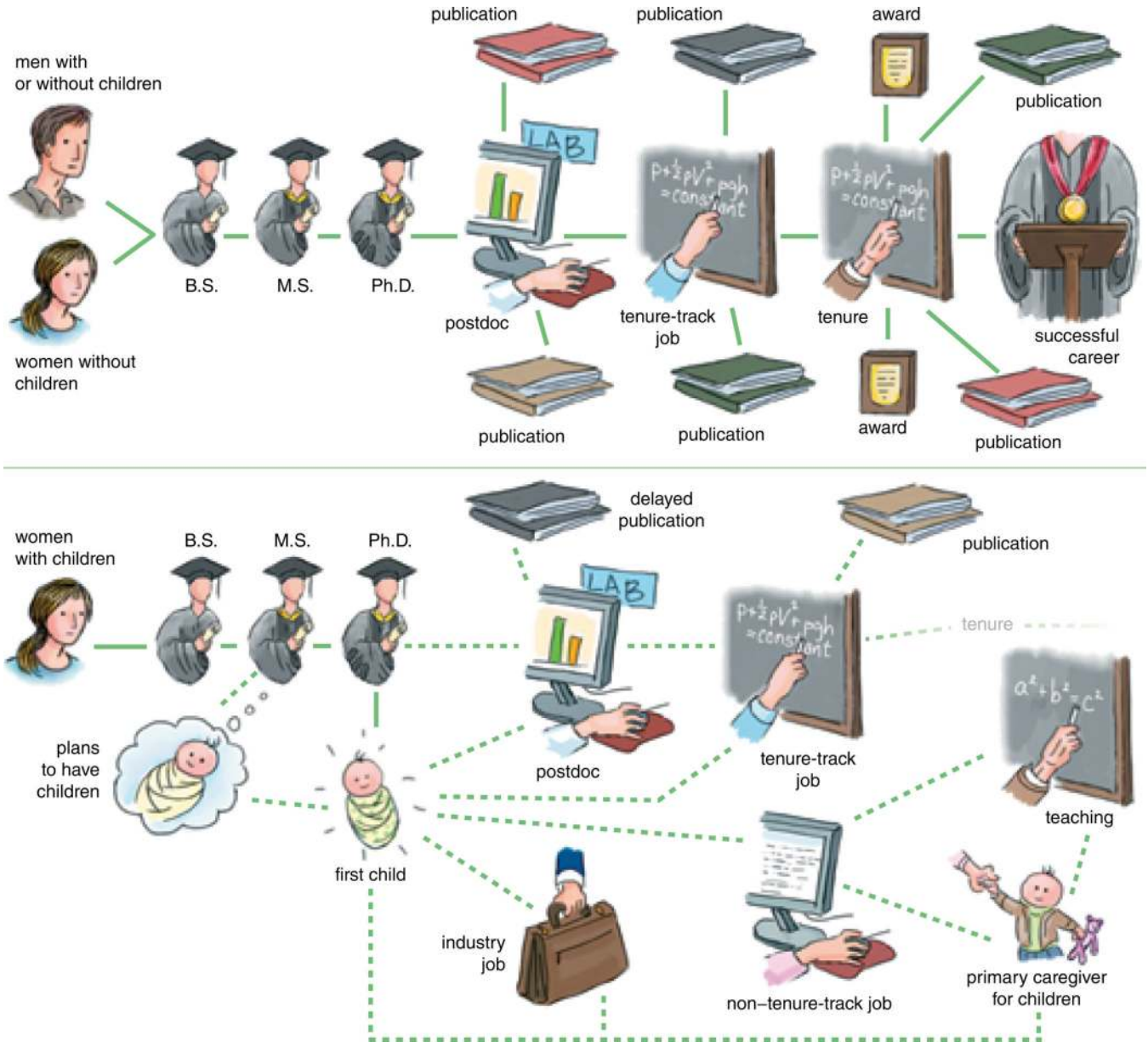

Figure 4.

The path to becoming a successful scientist looks much the same for women without children and for men with or without children: a straightforward, if long and arduous, track from undergraduate degree through postdoctoral and tenure-track positions. For women who have children, or even just plans to have them, the road is fraught with obstacles. Women who choose to have a first child are usually in the thick of the most difficult parts of their career. Even after the early, physically intensive months of childbirth and childrearing, women typically do more of the work of child care and household management than do male partners, at the cost of productivity at work. As a result, they may choose to take industry or non–tenure-track jobs with less demanding hours, or they may leave the workforce entirely.

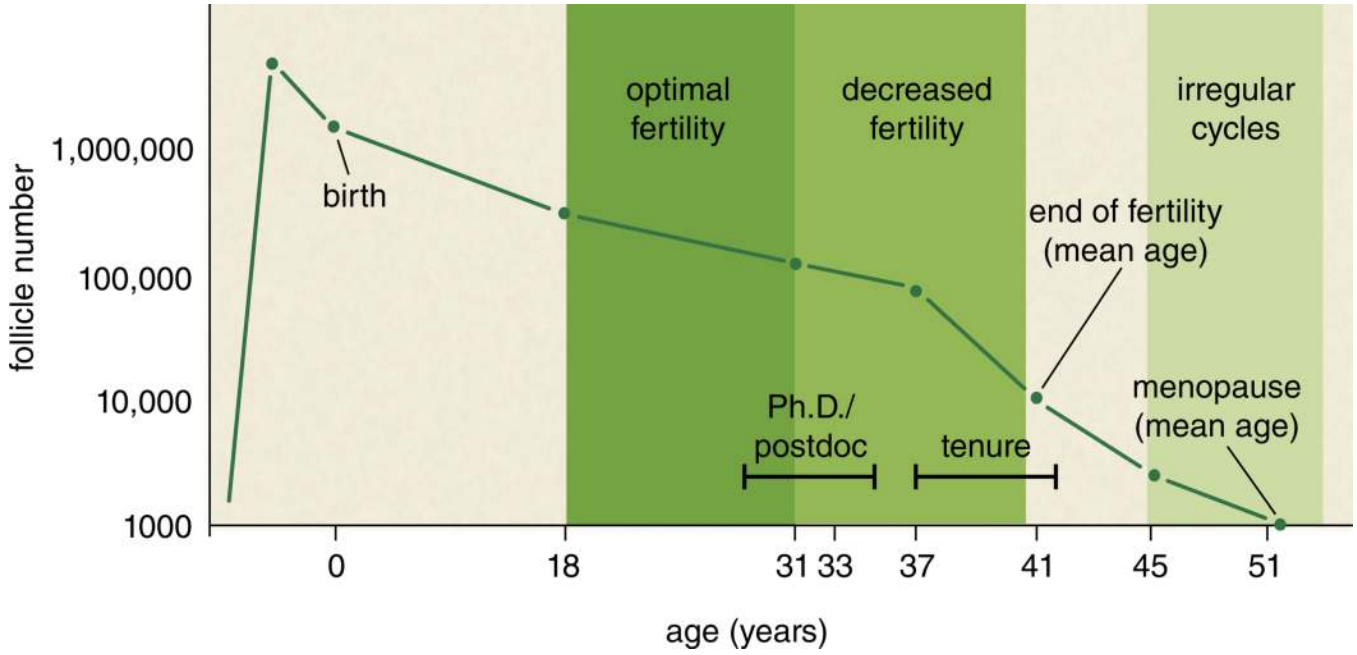

Figure 5.

The years in which a scientist is forging her career are the same years in which her fertility *(represented by number of ovarian follicles, green line)* reaches its peak and begins to decline. A scientist might optimistically expect to earn tenure around age 37, well past her peak fertility. Women scientists who want to become mothers are faced with a conundrum: Should they risk their careers for the sake of having children earlier, or risk lower fertility and birth complications for the sake of their careers? (Fertility data from E. R. te Velde and P. L. Pearson. 2002. "The variability of female reproductive ageing,"*Human Reproduction Update* 8(2):141–154.)

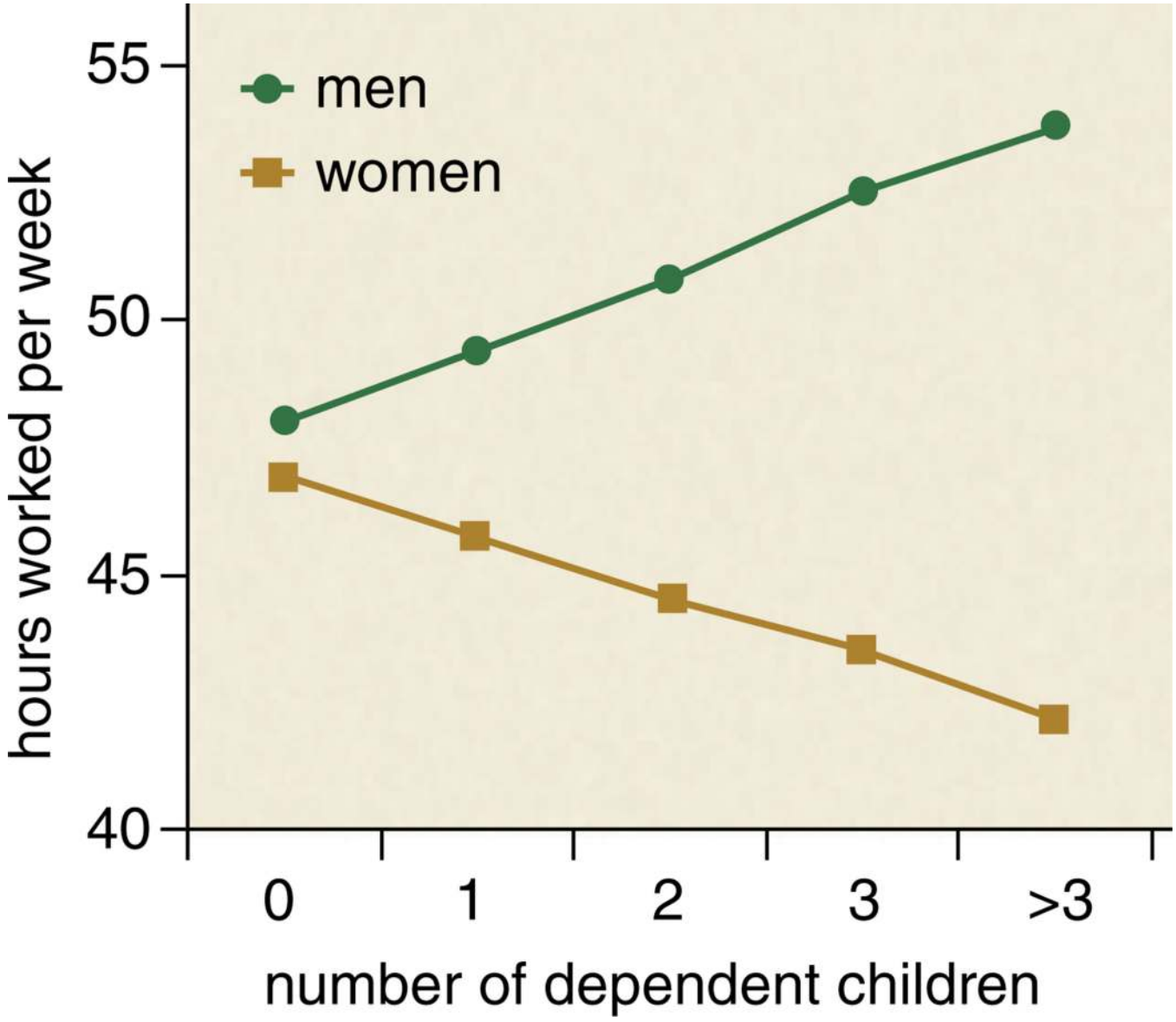

Figure 6.
Women with children spend fewer hours per week on career-related work the more children they have *(gold)*. But for men, the picture is almost the reverse: The more children they have, the more time they spend per week on their careers *(green)*. A penalty for women in building a scientific career is, at least in this data set, an asset for men. (Graph based on data from D. W. Leslie, 2007.)

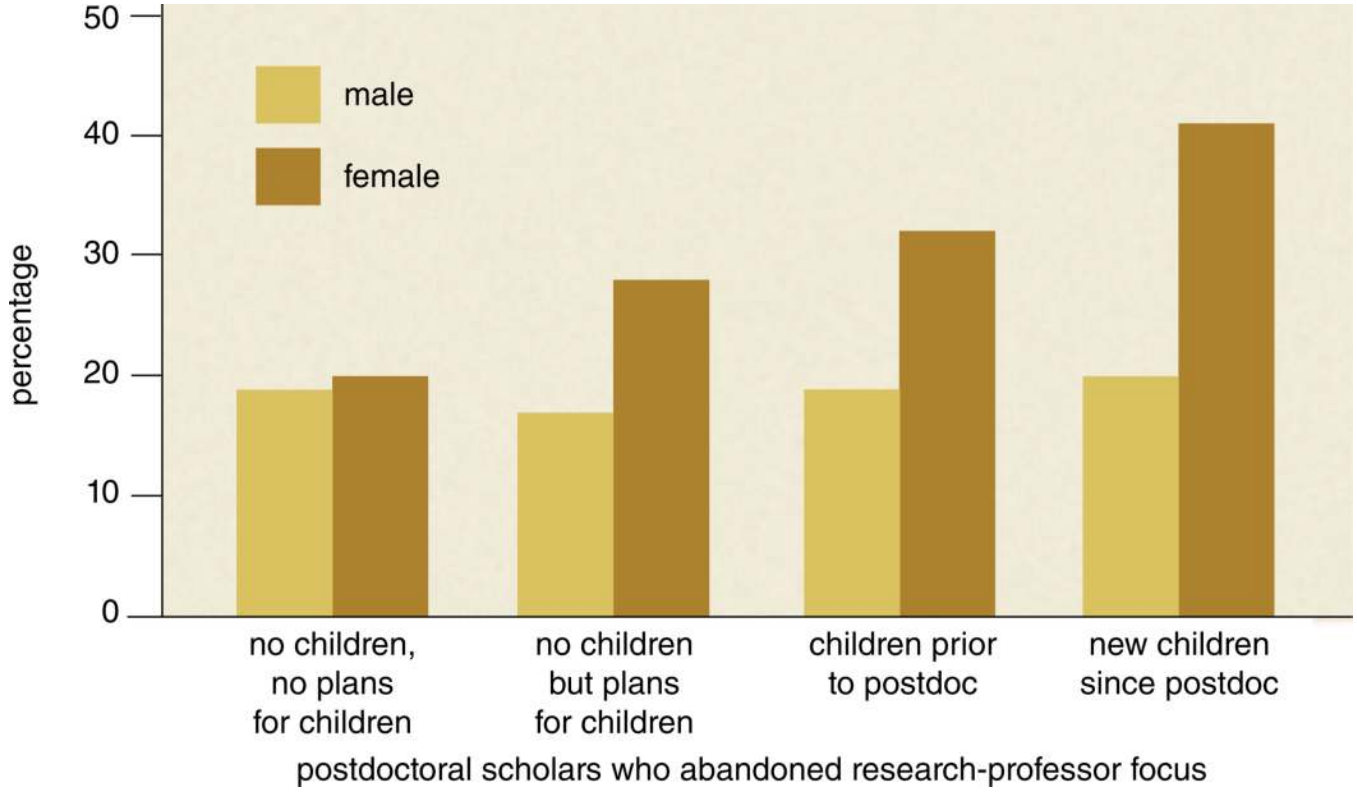

Figure 7.

Children, or plans to have them, exert a greater influence on women's careers *(brown)* than they do on men's *(gold).* In a 2008 survey of University of California postdoctoral scholars, about 20 percent of men moved out of the research-professor career track, regardless of whether they had children. Percentages of women who left that path vary, with the most significant attrition, 41 percent, occurring for women who had new children after beginning a postdoctoral position. (Chart based on data from M. Goulden, K. Frasch, and M. Mason, 2008, "University of California Postdoctoral Scholar Career and Life Survey.")

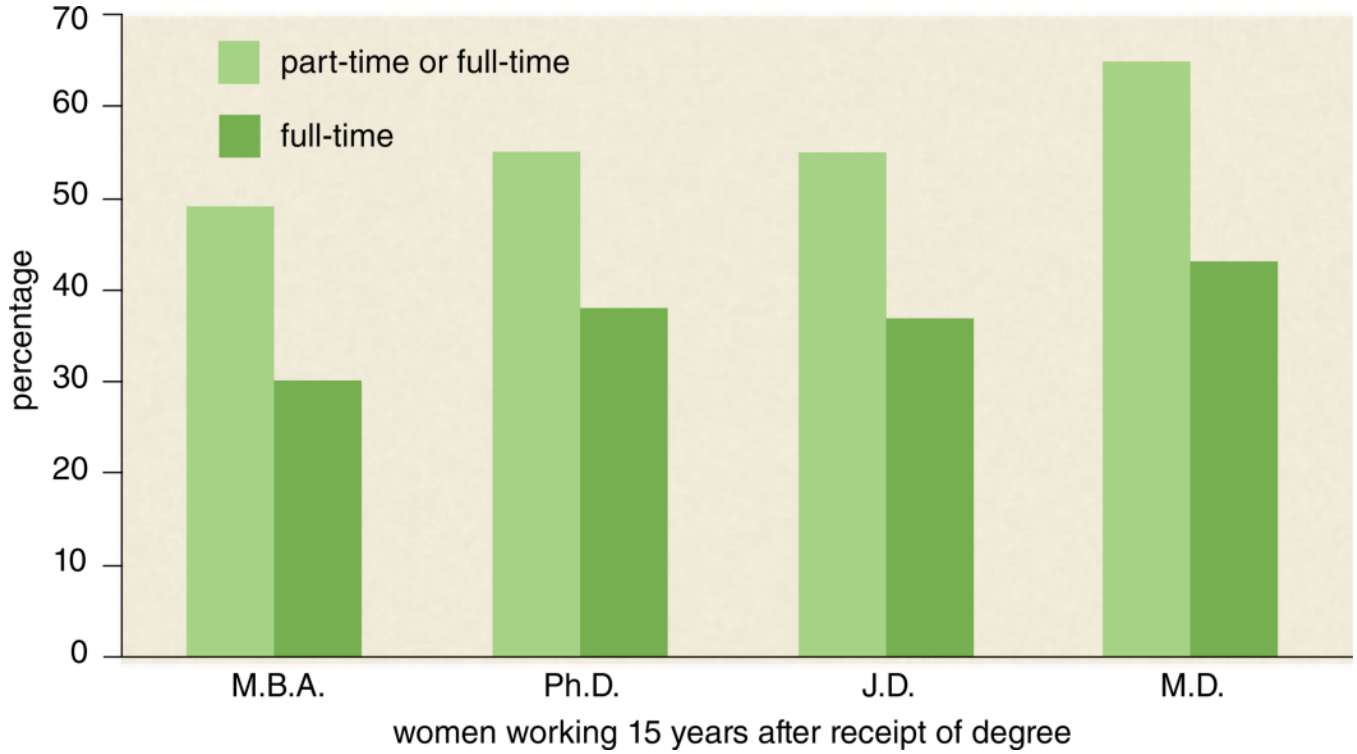

Figure 8.
Women's representation in math-intensive fields of science declines with children; this trend appears to hold for other fields as well. Shown above are the percentages of mothers who are still working in their fields, part-time or full-time, 15 years after receiving Ph.D.s or terminal degrees in business, law or medicine. (Graph based on data from M. Bertrand et al., 2010.)

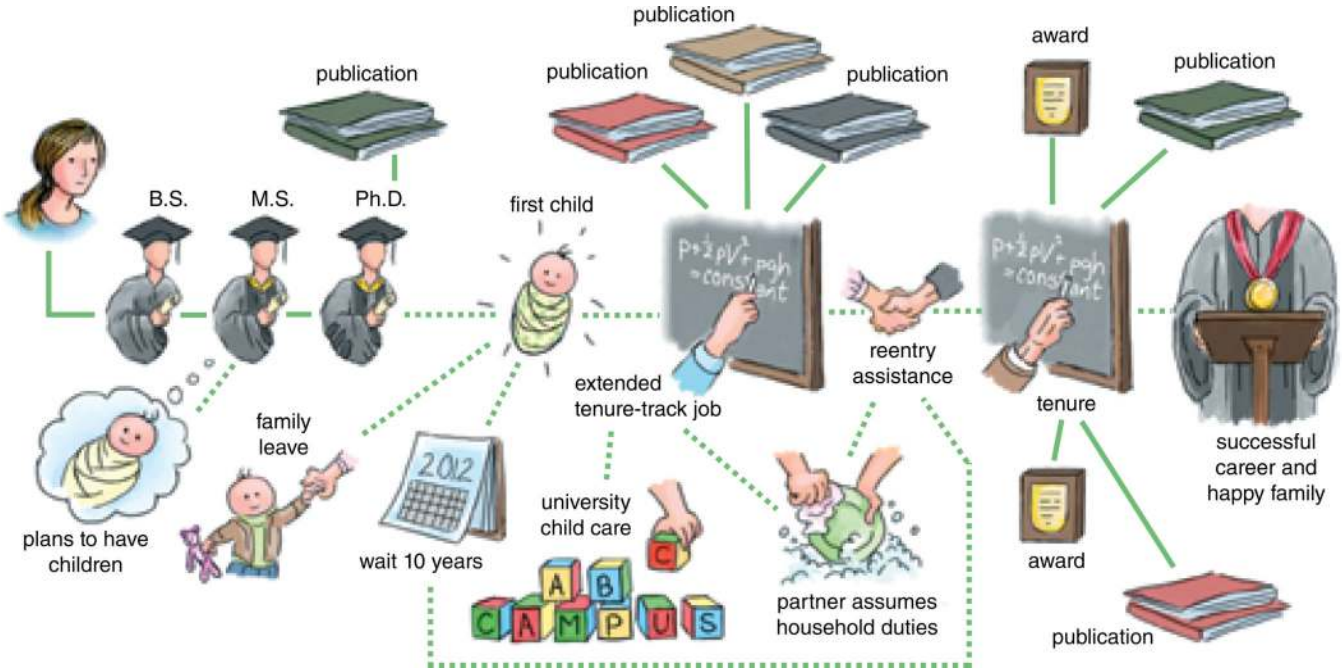

Figure 9.

Research has just begun on the effectiveness of various policy changes that could help universities keep more women in the tenure track. A variety of strategies show promise in bringing greater gender equality to math-intensive fields as well as other disciplines. A woman who wishes to have a child might be offered family leave, for instance, followed by a tenure-track job with a longer assumed timeline. Alternately, she might take time off from work and be offered assistance in reentering her field. These options represent a more winding path than the traditional route to tenure, which assumes scientists will take on few family responsibilities. But they may offer better chances of success across life realms. In combination, they could effect positive changes for women as well as men.