Chapter 3
Gender, Science, and Occupational Sex Segregation

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Over the past 20 years, policy makers have been increasingly connecting science and technology to innovation and economic growth. Many nations have made increased public investments in science and technology, as reflected in GDP (National Science Foundation 2012). Simultaneously, the role of diversity within the innovation process, in general, and the potential contributions of women, in particular, to national science and technology enterprises, has received much attention in many nations and international organizations (see, for example, efforts by UNESCO, APEC, the European Union and OECD).

As part of a larger volume, this chapter is meant to provide general audiences that include advocates of women's participation in science, individuals with science backgrounds, and social scientists who study these areas, with a description of the methods, tools, and approaches of occupational sex segregation as applied to understanding issues for women in science. The larger volume within which this chapter appears focuses attention on four science disciplines: chemical sciences, computing, mathematics, and statistics; hence we have attempted to incorporate examples from these specific disciplines, when possible (Fig. 3.1).

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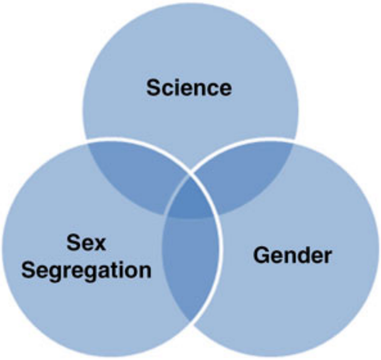


Fig. 3.1 Three research literatures

The attention to four specific disciplines is important within a larger framework of occupational analysis. Many treatments generalize across science, which is problematic because women's representation varies across science fields, the local and global labor markets in science fields varies, and the very nature of the work (material conditions of production) that scientists do varies within and across fields.

This chapter brings together three concepts that have often been pairwise connected but which we propose to integrate. To date, little work on the representation of women in science has deployed the tools of segregation analysis. The most recent edition of *She Figures* (European Commission 2013), though, includes a discussion of the D, the index of dissimilarity, which we will discuss in this chapter. By tools, we mean both the measurement methods and the theoretical models that enable us to understand the processes of sex segregation and allow us to make comparisons across units, such as nations, as might be of interest to those who wish to understand the status of women in international chemistry, computer science, and mathematics and statistics. By using segregation measures, we are able to effectively normalize data within a specific context—for example, nations—so that valid cross-national comparisons are possible. Such comparisons could offer useful insight about the extent to which science disciplines are gendered and how this shapes the larger context for women in science. Further, if we are interested in examining trends over time in the level of segregation within a particular context (e.g., within a nation over time or across disciplines, Frehill 2006), segregation measures permit such analysis.

This chapter will provide an overview of occupational sex segregation in science at three levels of analysis. The first section looks broadly at the concepts and tools of occupational sex segregation analysis at the macro or labor market level. Next, we discuss how the institutional processes of qualification, training, recruitment, and retention within scientific careers are impacted by the social institution of gender. At this level the emphasis is on how social relations are gendered and how social processes are deeply influenced by gender, as well as race and generation, resulting in very different positions for men and women in the scientific world (Galerand and Kergoat 2013). Finally, at the individual level, we discuss the concept of "choice." To what extent do differences in the occupational structures and careers reflect choices made by active agents and to what extent are choices constrained by gender as a social institution? How do individuals navigate through scientific careers within these larger contexts?

We use Brazil as a case to illustrate gender differences in science because as one of the BRIC nations, which also include Russia, India, and China, it has one of the largest and strongest scientific and technological systems in Latin America. Brazil is also spends more than 1% GDP on science and technology (S&T) and has a consolidated graduate program in the majority of S&T areas, with a systematic and overall evaluation process in place. The participation of women in the educational and capacity building sectors is also impressive and detailed figures are available.

3.1 Science Labor Markets and Measuring Occupational Sex Segregation

To date, literature that implements an occupational sex segregation framework to understand the structure of scientific labor markets has been relatively sparse. There is much literature at the intersection of science and gender and another robust literature at the intersection of gender and segregation, including an extensive literature on the sociology of work, which, in the past quarter century, has had more content related to gender and work (Maruani 2013). There is also quite a bit of work that examines segregation of occupations or educational fields in cross-national perspective (Chang 2004; Charles 1992; Charles and Bradley 2002; European Commission 2009; McDaniel 2010), without explicit focus on science. The literature on science and gender includes many anecdotal accounts (i.e., usually first-person narratives) along with standard social science using both qualitative and quantitative approaches. The literature on gender and segregation has a long research tradition. Demographers' tools and techniques originally developed to understand spatial segregation patterns (e.g., Duncan and Duncan 1955, and Massey and Denton 1993) have been applied to measuring occupational segregation by race/ethnicity (e.g., Frehill 1996; King 1992) and occupational sex segregation (e.g., Anker 1998; Blackburn et al. 2000; Charles and Grusky 2004; Melkas and Anker 2001).

Literature that connects all three areas—science, gender, and sex segregation—has been less common. To some extent this is due to differences in data availability and cross-national variation in educational structures and labor markets. To another extent, science, as an enterprise, tends to represent a proportionately small segment of the overall labor force within a nation. In the United States, for example, approximately 5–6% of the workforce is classified as scientists or engineers, 24% of which is women (Author's analysis of U.S. Bureau of Labor Statistics 2013). In the European Union, it has become more common to refer to "knowledge intensive activities" (KIA); 35% of workers in the EU-27 across the EU are in KIA jobs of which about one-third are women. In other international reports, such as data on science and technology indicators produced by the Organisation for Economic Development and Cooperation, data are provided on the number of researchers such as the number of researchers per 1,000 members of the economy's workforce. In 2011, the highest ratio was in Finland, where there were 14.8 researchers per 1,000 workers and the lowest was in Mexico at 0.9. The European Commission's most recent edition of *She Figures* reports that in 2009, researchers represented about one-third of the EU-27 workforce, with women's representation varying from 21% in Luxembourg and 52% in Latvia (European Commission 2013).

These occupations are important to study because these jobs are often advantaged and respected, commanding (usually) decent salaries and providing a modicum of career satisfaction and, within many contexts, job security. From a policy perspective, too, many nations have embraced the notion that science is an engine of economic development and advancement particularly for "knowledge economies:" so it is imperative to ensure that the field taps all potential human resources, including women.

What does it mean to say that an occupation is segregated by gender? The term and measures are derived from the US racial residential segregation literature; therefore, it is common for some see "segregation" as implying "intentionality." But such a view conflates measurement and explanation. We argue that the observed differences in the distributions of women and men into different occupations reflect the outcomes of many social forces, operating at the social, institutional/organizational, individual levels, some of which may have intentionally sought to disadvantage women, while others result in different treatment patterned by gender as unintended consequences. As such, we use the term "segregation" simply as macro-level measurement of the difference in women's and men's occupational distributions. The intentionality of the social forces that lead to segregation is a matter of much debate, to which we are encouraged to attend once we engage in the comparative analyses associated with the metrics.

Segregation refers to the tendency for members of different socially defined groups to be in different types of jobs. Segregation can be described along both horizontal and vertical dimensions. Figure 3.2 gives an example of horizontal

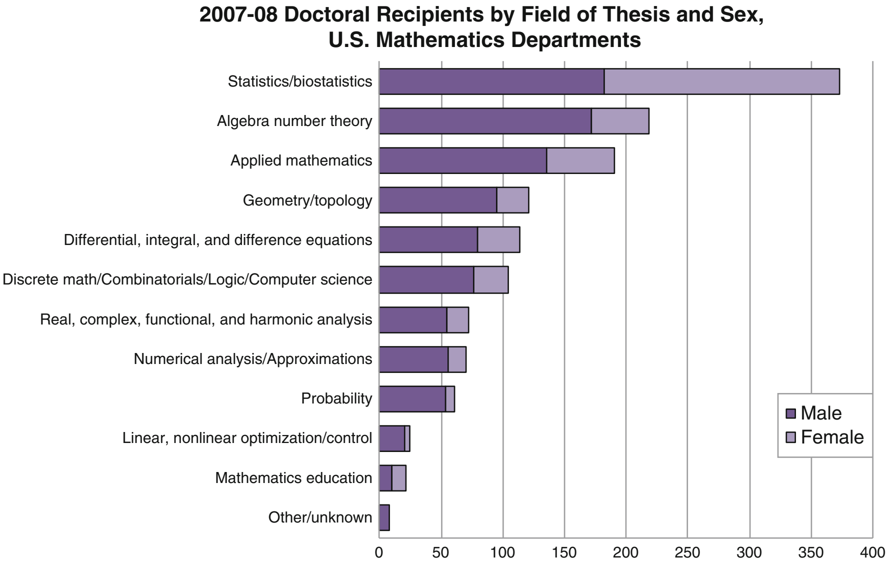


Fig. 3.2 Illustration: horizontal segregation

segregation, drawn from data published annually by the American Mathematical Society based on that organization's survey of departments of mathematics in the United States. These data show how women and men are distributed across various subfields within mathematics. Women accounted for just over half of all doctorates awarded to mathematicians who specialized in statistics or biostatistics. Women also accounted for half of those who specialized in mathematics education, although, as shown in the graph, this was a far smaller subfield than statistics/biostatistics was. Women were least represented in probability (12%) and in linear, nonlinear optimization/control (17%).

A customary way to describe horizontal segregation is to compare the extent to which groups of interest are concentrated in a specific set of fields. Here, for example, we would find that 44% of the 435 women who earned doctoral degrees in US mathematics departments specialized in statistics/biostatistics. While about one-in-five men who earned doctoral degrees also specialized in this area, it is noteworthy that men are much more "spread" across subfields than are women. Women's concentration in the statistics/biostatistics area raises a number of questions associated with the larger relationship between sex/gender and mathematics. For example, how do the subfields in mathematics vary in status, visibility, and resources such as positions grant funding, salaries etc.? To what extent are those who specialize in statistics/biostatistics advantaged or disadvantaged within mathematics? Are rewards such as earnings and prestige similar in this versus other fields? As has occurred in other fields (see, for example, Reskin and Roos 1990), will statistics/biostatistics "tip" and become even more female-dominated within mathematics and what are the implications of this change?

Vertical segregation looks at a particular occupation, or set of occupations, to see how people from different social groups occupy different levels within that occupation. For example, in most fields of science, women are often more highly represented among those at lower educational and occupational levels, with men more highly represented at higher levels. The So-called scissors diagrams, such as the one shown in Fig. 3.3, show women's representation along stages of science careers, is a common way to illustrate vertical segregation.

The Fig. 3.3 example is based on data from the European Union's *She Figures 2012*. In this particular case, the slight overrepresentation of women at the lower levels of tertiary study leading to academic careers and men's increasing overrepresentation at higher levels result in lines that cross like a pair of scissors. The extent to which the scissors widen reflects the extent to which men are more advantaged at higher levels. In some national or occupational settings, such as in many African nations, the lines do not cross, because girls/women have not reached parity even at the lower levels of education. Segregation indices, which we discuss next, provide a way of measuring this gap to permit systematic analysis that goes beyond looking at graphs and to enable more rigorous comparative analysis within and across contexts.

The stacked bar chart in Fig. 3.4 shows another illustration of vertical segregation. As with Fig. 3.2, this example is drawn from US mathematics, in this case, showing the representation of women and men at different academic levels. Derived

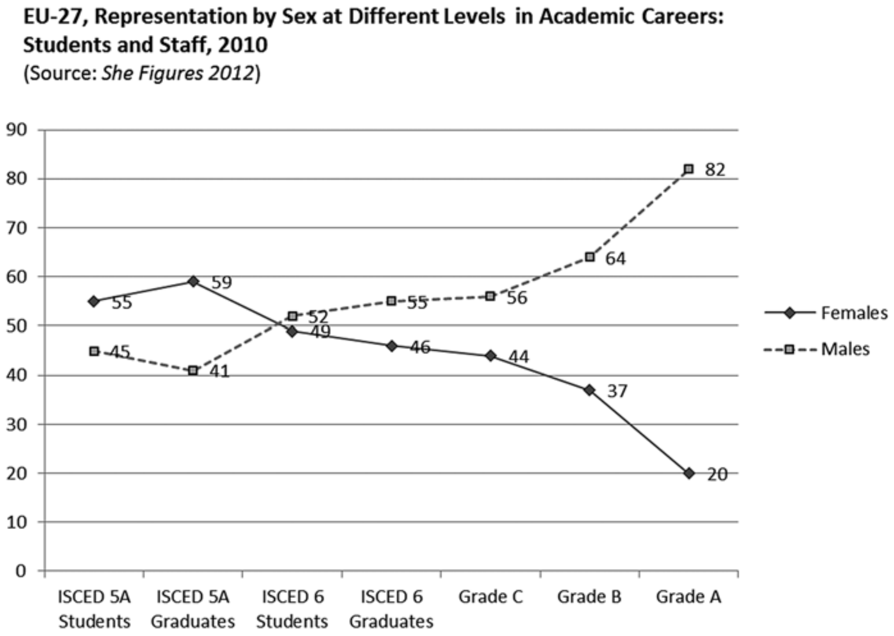
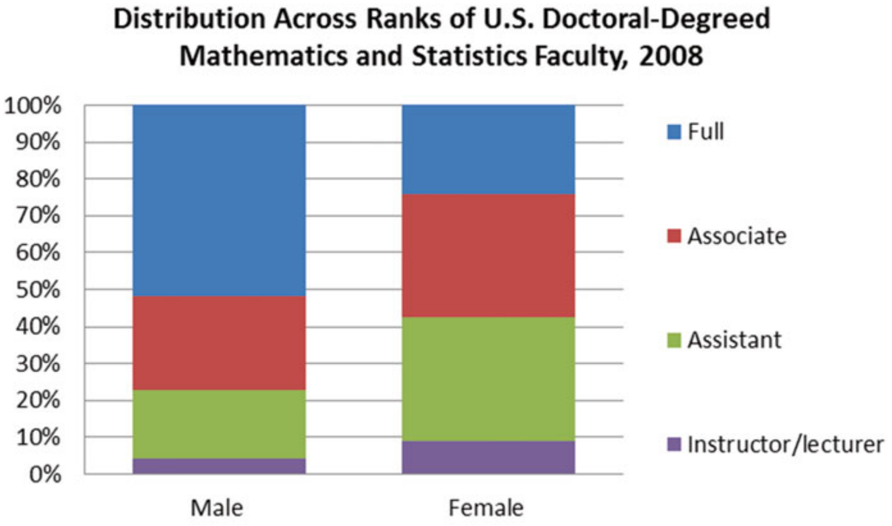


Fig. 3.3 Example scissors diagram: European Union Academic Pipeline. *Source*: Frehill, Lisa M., analysis of data from European Commission. 2013. *She Figures 2012*



Source: author's analysis of data in National Science Foundation. 2012. *Characteristics of Doctoral Scientists and Engineersin the United States, 2008, Detailed Statistical Tables*, NSF13-302.

Fig. 3.4 Illustration: vertical segregation from data from the National Science Foundation's Survey of Doctorate Recipients, each stratus in the stacked bar chart shows the within-sex proportion of faculty in each of four academic ranks for doctoral-degreed mathematicians.[1] The figure shows, what is now, common knowledge: women are far less likely than men to be in the highest rank (i.e., full professor) and are more likely than men to be in the more marginalized rank of instructor/lecturer, which is generally untenured and often lacking in job security and prestige within US academia.

The occupational sex segregation literature provides metrics and theoretical models with which to understand differences in women's and men's participation in science and enable disaggregation of science into more specific fields. The framework suggests a need to look at factors associated with both men and women, with the various ways in which gender is constructed with respect to these fields in different places at different times, and the benefits that accrue to men and women who conform to these societal norms. The role of power is critical here. All-too-often the literature to date on gender and science—with the exception of the clearly feminist research in this area—has been devoid of any meaningful power analysis.

3.1.1 Measures of Segregation

The most common segregation measure is the Index of Occupational Dissimilarity, originally developed by Duncan and Duncan (1955) to describe residential segregation. This relatively simple measure ranges from 0 to 1, with 0 indicating perfect equality of two occupational distributions and 1 indicating complete inequality. The computed ratio is interpreted as the percentage of workers who would have to change jobs in order for the distributions of the two groups into jobs to be the same.

$$D = \frac{1}{2}\sum_{j=1}^{J}\left|\frac{F_j}{F} - \frac{M_j}{M}\right| \times 100$$

The difference in the within-gender percentage of women and men in each of the J occupations forms the basis for D. As Frehill (2006) explains: "The D-score enables comparisons of the structure of occupations over time (Bertaux 1991; Frehill 1996; Jacobs 1989, 1995) across different race by gender groups (Frehill 1996; King 1992; Semyonov et al. 2000), and across different labor markets, such as those in different nations (Chang 2004; Charles and Bradley 2002, 2009)"

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[1] The U.S. Survey of Doctorate Recipients (SDR) population is drawn from the Doctoral Records File, which includes information about all recipients of doctoral degrees conferred by the US colleges and universities. This means that estimates based on the SDR exclude consideration of individuals who earned doctoral degrees at the non-US institutions.

Frehill (2006: 346).[2] For example, the D-score associated with the data shown in Fig. 3.4 is 0.24, which is slightly lower than the D-score of 0.27, which was computed for those same data in 2006. These D-scores suggest that between 24 and 27% of doctoral-degreed academically employed mathematicians/statisticians would need to change ranks in order for women and men to be evenly distributed by academic rank at US 4-year colleges and universities.

Concentration is another important dimension of segregation. Massey and Denton (1989) proposed this as one of five dimensions of racial residential segregation in their formulation of hyper segregation as an explanation for the continued significance of race as a determinant of class outcomes for African Americans in US major metropolitan areas. Concentration is generally computed in a straight-forward way as a percentage, but then additional interpretation is necessary to determine at what percentage level one might say that "concentration" exists or not. In the international occupational segregation literature, Anker (1998) has proposed:

> Female-concentrated occupations are thus defined as those having more than 1.5 times the mean percentage female, while "female-underrepresented" occupations are those having less than 0.5 times the mean percentage female. (Anker 1998: 87)

As illustrated in Figs. 3.2, 3.3, and 3.4, it is critical to explore both the vertical and horizontal dimensions of occupational segregation within science. Each analysis calls attention to different issues within and across fields and suggest different kinds of questions. The distribution of advantage described by vertical segregation reveals how sex is reflected in the structure of a specific occupation or discipline. The definitions, content and processes of advancement in each national context greatly vary.

Figure 3.4 reflects the US system in which full professors are at the top of academia, holding positions of greatest power and prestige within this economic sector. In other sectors, such as government or industry, these positions would be senior research scientists with large budges, spans-of-control, and decision-making authority about the scientific work that will be undertaken. Full professors in academic settings and senior research scientists in others are "gatekeepers" who make decisions about whether new entrants will be admitted (i.e., hiring decisions) and how and when individuals will advance in the field (i.e., tenure and promotion decisions). They make and enforce the rules within their field via their control of discipline-based professional organizations.

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[2] See also Frehill (2006 pp. 346–347): "In recent years, the D-score has been critiqued as a measure of occupational segregation. Charles and Grusky (1995) developed a new measure, A, which is based on logistic regression modeling of occupational distributions. A has been proposed as a superior measure because it is truly marginal independent, unlike D or another version of D known as the standardized (D Charles and Grusky 1995; Grusky and Charles 1998). That is, A provides a measure that better accounts for the relative sizes of the male and female labor forces (e.g., women's participation in academic science and engineering is quite a bit lower than that of men's) as well as the relative sizes of the different occupational groupings (e.g., there are fewer industrial engineers employed in academia than there are mathematicians)."

At the other end of the academic spectrum are those who hold doctoral degrees but are in instructor or lecturer positions, which tend to be nontenure track. Tenured and tenure track faculty are advantaged in academic settings, while those who are not on the tenure track are disadvantaged with respect to power, privilege, and access to resources. Likewise, scientists in government and industrial settings who lack a doctoral degree are often relegated to lower-level positions, which carry less discretionary decision-making authority and control.

3.2 Theories of Occupational Segregation and Levels of Analysis

The previous section discusses the macro-level measurement of sex segregation. While there are a number of decisions about measurement that reflect theoretical points of view, theories to explain the observed differences in men's and women's distribution into the occupational structure attempt to determine the causes and meaning behind the patterns noted using these quantitative, macro-level measures. There are many excellent discussions of the theories of occupational segregation (see, for example, Charles and Grusky 2004; Anker 1998; Reskin and Hartmann 1986). One way of summarizing this vast literature is via the concepts of supply-side and demand-side factors and with attention to the level of analysis.

On the supply-side, individual level decisions that men and women make about occupations result in the sorting of workers into occupations based on gender. The logic associated with these choices may vary: individuals, for example, may focus on the human capital investments necessary to pursue specific careers or they may focus on the extent to which they view careers as suitable or unsuitable within the context of the other constraints within their lives, which may be associated with gender.

On the other hand, demand-side explanations focus on employers' actions. Employers may engage in discrimination based on group membership (where groups are defined by gender or a host of other dimensions salient in a given society). In the more benign formulations, employers merely reflect the values of a society in which they are located. In less benign formulations, competition from the less powerful group threatens the advantages of those currently at the top of occupational hierarchies, who implement subtle and covert strategies that exploit institutional structures to prevent the encroachment by the newcomers. This institutional analytical level suggests it is important to understand how scientists' careers are structured within a larger disciplinary context, which is often defined by work organizations and disciplinary associations. In some contexts, disciplinary associations are private, in others they are part of the state apparatuses, and in others there are honorary societies that bestow status and privilege upon "chosen" scientists. Institutional processes, therefore, can be highly resistant to changes that may be perceived as threatening the hegemony of science, reflecting the interests of an entrenched group.

3.2.1 Understanding Occupational Segregation: The Gendering of Social Relations in Science

Key to understanding how sex segregation works to funnel women and men into different scientific occupations are the institutional processes of qualification, recruitment, retention and advancement. In the last 40 years, extensive social science research has clarified the role that these processes play in limiting women's access to science careers and, especially, to leadership positions in science. A global effort to address these issues has been underway with numerous synthesizing reports produced by international organizations in the first decade of the twenty-first century (European Commission 2002; Organization of Iberoamerican States—OEI 2004; Organization of American States—OAS 2005; Inter Academy Council 2006; OECD 2006; Third World Organization for Women in Science (TWOWS) 2007; UNESCO 2007; European Commission 2008; European Commission 2009a, 2009b; Caprile et al. 2012). These multiregional findings consistently point to a range of factors to explain the persistent underrepresentation of women, emphasizing the role of specific institutional and national contexts.

In this section we look at the underlying complex, institutional processes associated with horizontal and vertical segregation. A gendered perspective is essential to understand the complex social processes that shape scientists' careers, which have been metaphorically referred to as the "leaky pipeline," the "crystal labyrinth," and the "glass ceiling" for women. The processes of qualification and training, recruitment, retention, and advancement all occur within various scientific workplaces and educational settings, the institutional sites that shape large-scale segregation outcomes.

3.3 Qualification and Training

One of the most important issues related to women in science is how to attract girls and young women to scientific disciplines. While there has been much progress made in girls' education in many parts of the world, there are still some important differences within and across nations in terms of the likelihood that girls and women will stay on academic pathways that will lead to successful careers in science.

While women now constitute a majority of university students in many regions, including North and South America and Europe, sex segregation across fields of study is persistent. Women's representation is higher in the social and biological sciences; women's participation lags that of men in other areas of science and varies across levels for those who work in science occupations (see Figs. 3.2–3.4 for examples). Among the four disciplines we are focused on, women's representation in the chemical sciences has seen an important increase in many nations and there have been modest increases in women's participation in mathematics and statistics. Computer science, however, remains elusive for women in many countries, yet, as

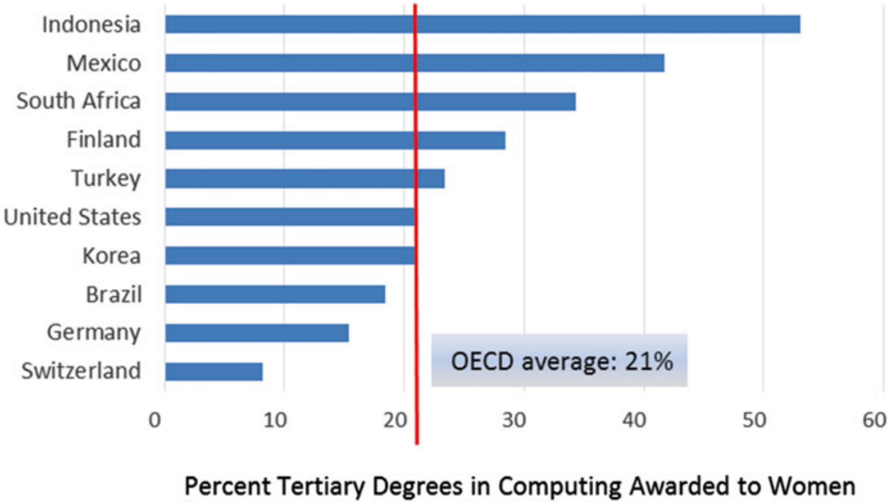

Fig. 3.5 Women as a percent of computing tertiary degrees, selected countries. *Note*: Tertiary includes both A level and advanced research programs. *Source*: Frehill, Lisa M. analysis of OECD. 2012. "Indicators of Gender Equity in Education, 2012" Gender Data Portal, online at www.oecd/els/gender

shown in Fig. 3.5, women's representation varies greatly cross-nationally. The lowest level of representation was in Switzerland at 8%, while in Mexico women account for 42% and in Indonesia, just over half (53%) of tertiary degrees in computing were awarded to women in 2010. The substantial cross-national variation suggests that essentialism offers an inadequate explanation for the observed gender differences of these fields.

Of course, in some other parts of the world attaining a university education remains a significant barrier for women who aspire to careers in science. In areas such as parts of Asia, Africa, and the Arab countries, women often lack access to careers in science, which generally require university training and, quite often, post-baccalaureate training as well.

There are many pivotal moments that influence the participation of women and girls along the scientific career trajectory, including some that parallel the life course processes of childbearing and rearing. Such issues have long been viewed as key in attempting to understand placement and success in science careers. For example, in some fields, a bachelor's (hereafter, B.S.) or a master's degree (hereafter, M.Sc.) is a suitable qualification for occupational entry, while in others the Ph.D. continues to be the requisite entry credential, with a concomitant devaluation of the B.S. and M.Sc. Likewise, in some science fields, the M.Sc. is a stepping stone along the pathway to a Ph.D., providing a useful set of career/life balance options.

While many reports point to the challenges associated with the lengthy career training process this simply is not a robust explanation. In spite of lengthy training, in many countries—not only the developed countries—there has been a notable increase in recent years in the presence of women among Ph.D. graduates and in some countries they are the majority (see Vignette 1.1: *Focus on Brazil*). In other disciplines with long and arduous training time, such as medicine, women now predominate. The increased prevalence and advancement of women in some careers suggests that it is *possible* for institutions to adapt to women's life course needs. The many organizations that constitute scientific discipline establish and enforce normative behavior for those who wish to be considered members. Many work organizations have implemented policies to enable employees to attend to family matters. Women continue to bear a larger share of responsibility for family care giving, but recent research indicates that younger men are also interested in workplaces that enable employees to balance work and family life. The burden of adaptation, however, appears to continue to fall upon individuals. The key question, though, is what actions do organizations take—or do not take—that enable women to manage advancement into and through science careers within the context of life course plans? Which opportunities do they create for women, in general, to counter disadvantage in their careers independently of family responsibilities?

3.4 Recruitment, Retention, and Advancement: Leaky Pipelines and Crystal Labyrinths

Institutional processes associated with recruitment, retention, and advancement often vary from country to country and within different economic sectors. Recruitment systems and specific criteria for advancement vary, although some indicators of productivity, such as publications and research funding for doctoral-degreed scientists, are prevalent in most contexts. Expectations for performance within these systems vary as do the extent to which scientists' careers are influenced by state policies that may or may not provide supports or resources for scientists. Transparency in these processes can produce more equitable outcomes, but the level of transparency varies across institutional contexts.

3.4.1 Recruitment

As Rees (2004: 115) summarizes the ETAN report (Osborn et al. 2000): [W]hatever the country […], whatever the discipline, and whatever the proportion of women among the undergraduate population […], men are selected disproportionately to their numbers in the recruitment pool at every stage on the career ladder. Many reasons have been given for this persistent state of affairs. Although the majority of Western countries now have equal employment laws that attempt to block overt discrimination, "covert or perceived discrimination that discourages women" (OECD 2006) is persistent.

Narrow job advertisements are one issue in recruitment, which may have a disparate gender impact. Women are unlikely to apply for positions for which they do not see an immediate match to their qualifications, but in some contexts, men are more likely to apply regardless of their qualifications (NRC 2010). Further, the narrower the job advertisement, the narrower the potential pool of recruits; with the rapid changes in science, such restrictions seem to be inefficient.

Even when women apply for positions, the many incremental subjective judgments embedded within selection processes may disadvantage women. Again, many institutions, led by those that had ADVANCE awards from the U.S. National Science Foundation, have implemented institutional policies to improve search processes via: (1) wider and more open advertisement of positions; (2) articulation of criteria for new hires and careful assessment of all candidates on all of these criteria; (3) training of department chairs and faculty about unconscious bias; and (4) oversight of hiring processes. Such interventions often had a positive impact on the likelihood that women would be hired (Bilimoria and Liang 2012).

In other countries, where the entry point in the scientific career might be by other forms of recruitment, such as public competition for example, networks are nevertheless still important in the subsequent steps of the career ladder. Women's limited access to networks continues to disadvantage them relative to their male colleagues within the hiring process. A study by the US National Research Council (2010) found that women were less likely than men to apply for academic positions, particularly in fields in which women are underrepresented. Further, as shown by Wenneräs and Wold (1997) women are held to higher performance standards than are men: they must work twice as hard to gain half the recognition of equivalent male colleagues. Advocates for women in science often refer to these higher standards for women as "raising the bar" for women candidates (Moody 2005).

3.4.2 Retention and Advancement: Leaky Pipelines and Crystal Labyrinths

Advancement in science is another process that has been a challenge for women. As bluntly put by Caprile et al. (2012) "the existence of a "'glass ceiling'" or "'sticky floor'" for women trying to progress to senior positions is well documented and affects all occupational sectors," regardless of the level of women's representation. Christine Williams (1992) documents that even in occupations that are numerically dominated by women such as nursing, gender privilege for men translates into a "glass escalator," suggesting that larger numbers of women, alone, are unlikely to alter the likelihood of achieving top positions in a field. While the glass ceiling is problematic for women in all sectors, it appears to be more pronounced in science (EC 2006; OECD 2006). According to a 2006 OECD report, institutional factors play an important role in women's career advancement. First, women's professional networks differ from those of men. Second, the workplace culture and organizational structures associated with promotion practices and the selection and allocation of research funding disadvantage women (OECD 2006: 11–12).

Professional networks are important for career advancement; they are a source of information for workers and provide access to the informal work culture, in general, and a key means by which scientists form collaborative relationships within and across work settings. Sveva Avveduto's (2015) discussion of women's participation in science in Italy suggests that such networks, "relationship-building tools for encouraging exchanges," have been instrumental in the increase in women's participation. In addition, networks provide newly minted scientists with access to mentors and guides who can assist with navigating the often-difficult path to tenure in academic settings and to career advancement in government and private industry. The lack of transparency associated with these career paths and the differential access to mentors has produced a crystal labyrinth for many women scientists (Eagly and Carli 2007).

Subtle gender biases and societal norms that regulate interactions between men and women impact the extent to which women can access the right networks to ensure successful career transitions. For men, it is almost "natural" that a more experienced scientist takes a new male scientist under his wing to ensure that he makes all the proper acquaintances. Women, however, do not seem to have the same opportunities. The general lack of women in leadership positions, and the scarcity of a mentoring culture in many countries have led to a relative scarcity of opportunities for women students. In the United States and in the European Union more formal mentoring structures are now seeking to address this inequality in both universities and professional associations, but in other countries mentoring is still in its infancy.

Access to key resources—research funding, materials, students or junior researchers, and space—is critical to scientists' career success. Such resources are more crucial in capital-intensive science (e.g., bench sciences like the chemical sciences) than in areas that are less capital-intensive (e.g., mathematics). A report of the European Commission (2009) on the "gender challenge in research funding" confirms that access to research funds by men and women scientists can show an important disparity, but also emphasized the situation varied much between the European countries under analysis. A number of innovative national policies which affect research funding were noted. Such policies include, for example: establishing targets for the proportion of women funded; giving preference to women in the case of candidates assessed to have equal merit; implementing programs and policies to address career phases or groups of researchers; and facilitating work/life balance for researchers (Husu and de Cheveigné 2010). In addition, a few aim at institutional transformation in a dialogue with universities (EC 2009: 25–27; Bilimoria and Liang 2012).

Other research has shown that women tend to have smaller funds and projects. In a study of the U.S. National Institutes of Health (NIH) US women represented 25% of the awards in 2004, and their awards remained at about 80% of the size of men's research grants (Hosek et al. 2005). In the UK, Blake and La Valle (2000) found that "not only women apply for fewer grants than men, but they are less likely to apply as the principal applicant, generally apply for grants of shorter duration and for lower levels of funding." (p. 51). Funding structures could contribute to both horizontal and vertical sex segregation. If women have less access to funding, overall, the result might be that women will be more likely to be in fields that require less funding (horizontal). A study of the German Research Foundation showed that women's rate of success in winning grants was higher in male-dominated fields than in fields with higher percentages of women (Hinz, Findeisen, and Auspurg 2008).

How resources are made available, the ways that scientists obtain these resources, and the role of gender within these processes is key in understanding the persistent difficulties that women face with the glass ceiling or the sticky floor. In general, too, the extent to which these processes are transparent and involve universalistic criteria versus the extent to which they are organized as pre-bureaucratic forms or in which particularistic criteria continue to operate as a means by which resources would be allocated. In general, then, two inter-related gendered mechanisms tend to disadvantage women and advantage men in resource allocations: the assessment of excellence in science settings and negotiation as a means of obtaining resources.

Assessing Excellence: The mechanisms for the construction of excellence in science, critical for advancement to the highest positions in the system, involves numerous "gatekeepers": full professors or senior research scientists, members of national science and technology councils, members of evaluation committees and panels, external reviewers, science editors, and many others. The research evidence is clear that, in most countries, power, decision-making, and other gatekeeping activities continue to be dominated by men, in many cases, overwhelmingly so. According to Feller (2004), in the analysis of gender bias in scientific excellence it is important to distinguish conceptually between: (1) The ways in which scientific excellence is defined and measured and (2) The specific procedures for assessing scientific excellence. The definition of scientific excellence and the measurement of scientific production have both been shown to be constructed on models that are still clearly masculine. "This meritocratic system strengthens unequal starting points and has particularly damaging results for many women and some men who do not meet the model of success defined as standard" (Caprile et al. 2008, cited by EU Seventh Framework Programme 2008: 19; Bailyn 2003; Knights and Richards 2003; Valian 1998).

On the other hand the increasing dependence on bibliometric measures of scientific production has been debated, including within a gender framework. Women scientists have often been considered less productive than men because they published fewer papers. Evidence shows, however, that "productivity is not an independent characteristic of individuals but rather a reflection of their positions in the academic hierarchy and the access to resources that those positions make possible. When academic position, available resources, type of institution, and other personal and institutional factors are held constant, men and women scientists are equally productive." (NRC 2007: 113)

Negotiation: The extent to which adversarial negotiation processes are used to obtain institutional resources plays an important role in gender differences in advancement. In those national contexts and institutional settings where negotiation is the principal method by which space, students, salaries, travel funds, and other resources essential to the conduct and dissemination of scientific research, women are likely to be disadvantaged relative to men. As discussed by Babcock and Laschever (2009), women are less likely to demand the same resources as men. But merely asking does not, necessarily, improve women's success, as being demanding is stereotypically a male trait in many cultures; so when women violate this gendered norm, administrators respond to their request differently, hence women risk being negatively evaluated. Instead, the processes by which individuals secure resources must be made more transparent and less particularistic in order to provide a level playing field for all.

3.5 The Pay Gap: Economic Resources over the Life Course

The pay gap persists between women and men; in all countries where this information is available, women earn less than men. Historically, men have been concerned when women start to move into "their" fields for fear that women's entrance will erode the status and prestige of the field as well as the pay. The specter of diminishing pay—and potentially concurrent decreases in status and prestige of a field—represents a key interest that entrenched majorities would seek to preserve by barring entry to women.

Similar to the mechanisms that produce disparate career advancement outcomes for women in science, segregation is related to pay along both the vertical and horizontal dimensions, which can make the gendered social forces that produce the pay gap more difficult to reveal. Along the horizontal segregation, different areas of science have different pay rates. Women have often been observed to be more highly represented in the lower-paid fields while men are more highly represented in the higher paying fields. For example, biologists often earn far less than computer scientists or engineers; women are more highly represented in biology than in CS or engineering. Employment sector is another dimension of horizontal sex segregation: pay is often far higher in private industry than in academia. As Etzkowitz et al. explain, in some fields like computer science women tend to work in universities while men take better paying positions in industry (2000: 204).

In addition, vertical segregation also has important implications for the pay gap; as one gains more seniority and/or moves up positions in the status hierarchy, one expects increased earnings over the life course. The glass ceiling, therefore, imposes differential rates of access to higher-status jobs and this accounts for women's lower average earnings relative to men's. However, there is also evidence that women in positions equivalent to male peers also earn less than men, especially those that lack transparency and expect allow individuals to negotiate. In pay systems with less room for negotiation, however, gender differences are likely to be smaller since position (including rank in academic settings), experience, etc. will be more of an objective measure. Government systems or those in which labor unions play an important role, for example, can diminish wage inequality when compared to more *laissez faire* systems. These processes that lead to horizontal and vertical segregation funnel more men but less women into higher-status and higher-paid jobs, so that over the career-course, the pay gap widens.

3.6 The Cloister Culture of Science

When examining the work content of science, the traditional scientific career model was more accurately a "two-person career" that assumed that family and non-work issues were taken care of by someone else, traditionally a wife, allowing the male scientist to have a total commitment to work, with long hours. Such highly dedicated men could also be expected—within this social context—to be highly mobile in pursuing career opportunities, often in multiple countries. This model is increasingly untenable for both men and women; calling into question the traditional structures that guided scientific career paths. The extent to which family responsibilities may be a factor in women's career disadvantage in science varies across countries. The availability of childcare varies from publically funded to inexpensive childcare and household labor that allows parents to "outsource" these tasks. National and local contexts for childcare, therefore, provide different tools with which dual-career families may balance childcare, producing different patterns of career attainment. In countries with little (institutional) supports for childcare, the dynamics of work/life balance are intensified for scientists with children. For many women, childcare responsibilities have led to career breaks, which can hinder career success (CATALYST studies, Etzkowitz et al. 2000; Gupta et al. 2004; Kemelgor and Etzkowitz 2001; Osborn et al. 2000). Such studies have pointed to the need for "on-ramping" programming for women who may have had such breaks to re-integrate into their careers.

Of course, children will not always have a negative impact on careers. Some researchers have challenged the notion that women's advancement in science is thwarted by childcare and family responsibilities. Mary Frank Fox (2005) has shown that US women with children who stay in academia are more productive than their counterparts without children. Frehill and Zippel (2011) find that the presence of children did not affect US-based women's participation in international collaboration. Work by the European Commission, however, indicates that childcare responsibilities continue to limit women's career outcomes in the highest levels of science (<>*She Figures* 2012).

3.7 Institutional Processes

In this section, we have reviewed a number of processes within the institutions that comprise the presumed meritocratic objectivity of scientific communities, including the workplaces within which scientists work, that lead to patterned differences in the career outcomes for men and women. Women experience barriers to advancement in science both within educational institutions and scientific workplaces. The scissors diagrams, which have become an omnipresent visualization tool, are clear in showing women's declining representation at higher levels of science education and occupations and men's concurrent increasing representation, especially women's rarity in top leadership positions in science.

The so-called "blind" processes of peer review, in which faith has been grounded as an efficient and fair means of evaluating the merits of scientific research, have been shown time and again and across national contexts to be fraught with some persistent bias against women. While women might benefit overall from "blind" evaluation processes, the persistence of gender biases, even if they are not as overt as previously, can hinder women's access to and advancement in science. The accumulation of small disadvantages produces disparate outcomes over the course of individuals' careers (Valian 1998).

Finally, particularistic institutional processes that treat individuals differently, which reward men for gender-appropriate aggressive behavior and may punish women for gender-inappropriate behavior (i.e., aggressiveness) disadvantage women, who are placed in an untenable, no-win situation necessary to access resources that are critical to career success. The subtle ways in which gender is woven into these processes provides institutions with a way to deflect attention away from institutional actions and, instead, to women's own behaviors as the reason for persistent gender disparities in resource allocation, advancement, and pay.

3.7.1 The Calculus of "Choice": The Individual Level

In this section, we move further down into the social world to the level of individuals. At this level we are particularly interested in the calculus of choice. Here we reach a dilemma; to paraphrase Karl Marx, people make their own history, but they do so under circumstances directly encountered, given, and transmitted from the past. While individuals may be viewed as active agents of their own lives, especially in Western cultures, the extent to which individuals encounter opportunities and constraints, which can be patterned by a number of characteristics, which can serve to channeled individuals into some areas or block them out of others. Further, evidence from non-Western cultures suggests that individualism is less important in determining career outcomes. Rather, in these cultures (notably Indian and China), students' early performance on tests in mathematics and science and family wishes play a far larger role in the career selection process. In this volume, the ways in which the institution of gender shapes individuals' choices, even though they may believe that these are freely made, results in the macro-level patterns of the sex segregation.

Norms, values, policies, and practices are patterned by gender channel individuals towards choices in relatively predictable ways. In addition, the information that individuals possess and the specific situations in which they find themselves also impact choices. The personal comments by Diane Wilcox (2015) about advancing in South African academic science provide an illustration of personal choices as they are embedded and constructed in a larger set of gendered practices.

Many researchers on gender and science today agree that there are multiple factors associated with variations in women's representation in science. In general, both women and men select themselves out of and into sex segregated fields and believe that these are freely chosen pathways. Yet, we will show here, cross-national differences in how young women and men embark on studies and careers in science reveal the significance of context for these choices. Indeed, that these gender differences in career interests are not fixed, but vary greatly cross-nationally, reflects the influence of complex social forces in social, organizational, institutional settings, and cultural beliefs that shape individuals' choices.

3.8 Gender Stereotypes

The Institutional Context of Mathematics Choice and Sex Segregation

Mathematics is the basis of many fields of science. Imagine the difference between growing up in a country in which in secondary school around the age of 13–14, individuals are asked, do you want to continue taking advanced math classes? And compare this situational "choice" to that in another educational system where the option for continued mathematics education is delayed until college. If mathematics is believed to be connected to gender, then those of the gender viewed as inferior at mathematics might be permitted to opt out of mathematics in the first situation, making it more difficult to pursue math-intensive majors later in college. This example illustrates how the educational systems' context can have profound influences on gendered achievements and potentially closing the gender gap in math.

The social construction of gender varies cross-nationally, across cultural groups within a nation, across time, and across the individual's life course. Gender stereotypes are cultural beliefs about what it means to be a male or a female: these are learned from the moment of birth. In general, stereotypes of any kind are embedded in a society and influence individuals' behaviors. Counter examples do not upset the conceptual framework of stereotypes, as these are viewed as "exceptions to the rule," therefore, stereotypes can prove difficult to change.

Beliefs, for example, such as "girls are not good at mathematics," despite the weight of evidence against this proposition, are commonly asserted as fact because stereotypes need no evidence to be taken at face value. Given the foundational role of mathematics in science, this particular stereotype is particularly problematic in those nations that hold this stereotype.

Spencer et al. (1999) explored stereotype threat as a factor affecting women's mathematics performance. The original concept of stereotype threat had been developed by Claude Steele and Joshua Aronson (1995) to understand why African American youth performed poorly on standardized tests in the United States. Steele found that under conditions of stereotype threat—a situation in which subjects were told that a test measured ability—African Americans performed substantially worse than Whites, while in a non-stereotype threat condition, African American scores were slightly higher than Whites. Many psychologically oriented researchers and engineering and mathematics educators have taken the phenomenon of stereotype threat seriously, and have devised testing protocols (i.e., specific sets of instructions) that serve to create a non-stereotype threat environment in testing contexts (Steele 1997).

At the heart of the matter, the United States, along with other Western-European cultures, frames mathematics as an innate ability, with an uneven gender distribution of talent (i.e., girls are viewed as less likely than boys to be "good at math"). In Asian cultures, however, mathematics is culturally defined as a skill, which, like any other skill, requires practice to master. Therefore, the concept of stereotype threat, while salient in those nations where mathematics is a gendered ability, may be less relevant in those nations where mathematics is conceptualized as a skill.

Another way in which stereotypes affect the calculus of choice is the subtle biases that creep into decision processes. Peer review and evaluation, the most prevalent system of assessment and widely believed to be the most effective and efficient means of maintaining highest standards, does not completely preclude social prejudices, such as gender stereotypes, which disadvantage women and advantage men. The earlier-cited works by Wenneräs and Wold (1997) for Sweden and Cotta et al. (2009) for the case of Brazil make it clear that peer evaluations can be biased. Further, social psychological studies point to the persistence of implicit bias against women in science which can seep into the evaluation of their work (Nosek and Riskind 2012) and that often these biases are held by both men and women as they are inextricably woven into the fabric of social life.

3.9 Gendered Norms

In the case of stereotypes, solutions can be developed that pull back the curtain to reveal the fallacy of the belief. New instructions can be devised for testing and more careful methods of review can be implemented to ensure that women and men are treated equitably in peer review processes. More difficult, however, are gendered norms, which are merely expectations for behavior based on gender. As indicated, above, these vary cross-nationally, over time, and cross-culturally (e.g., by ethnicity, religion, social class) within a nation. Norms guide behavior in predictable ways as an element of social order. Enforcement of norms tends to be informal: those who violate appropriate rules of behavior associated with their gender might be punished, while those who conform may be rewarded, as was the case with negotiation, discussed in the previous section. But these punishments and rewards are not always codified nor are the sanctions. In addition, the punishments and rewards associated with violating or conforming to norms may not be consequential to a given individual. Hence, the calculus of choice within the context of gendered norms is rather complicated even as these norms do channel individuals into "gender-appropriate" fields.

Norms and Major Choice: When girls and boys make individual choices in school to major in specific subjects, later in university and finally for their career choices, gender norms affect their choices. As discussed above, stereotypes can serve as strong signals to girls and boys about the appropriateness of fields and careers. But the operation of gendered norms can often be more subtle.

For example, students now in the United States may refer to biology as an intuitive, "soft" and easy field because of the preponderance of women in this major over the past 30 years. This means that biology as a field is more accessible to women, since women can fit in without creating dissonance between their self-image and that of a scientist. By contrast, mathematics and physics are constructed as difficult, "hard" sciences, which are more consistent with masculine norms, which attract men. Within the hegemonic construction of masculinity (Connell 1995), men shun fields associated with women/femininity and seek fields in which their sense of themselves as men can find expression.

Gender and the Life Course: Gendered norms are particularly important in defining appropriate behaviors within family structures: wives and husbands, sons and daughters, and mothers and fathers. In China and India, for example, there has been a strong male-child preference because of beliefs about the roles of sons and daughters. In these countries, daughters are expected to marry into another family, with sons remaining and viewed as carrying on the family name and family responsibilities, which become more onerous as parents age.

Family obligations and the gendered expectations associated with these obligations pose different consequences for women and men along the science career pathway. Employment choices are gendered, with long lasting influence of careers paths including pay and status, and, again contribute to observed gender segregation in labor markets. Consider the situation of a German woman with young twins who went back to get a master's degree in computer science. She started a job in an almost all-male IT start-up company with little flexibility and high demands for working overtime. She did not feel that this was a good "fit" for her. Instead, she chose teaching at a local high school and has been satisfied for the past several years.

While the woman might believe that she has made a "free choice" between two career paths, when we look at the institutionalized features of the positions, "gendered" organizational features become visible. The high school offered her a gender-mixed environment of colleagues and students, in contrast to the almost all-male (IT) one she left. The working hours at school matched her children's school and vacation schedule, hence enabling her to maximize time with her children. For her, this flexibility was particularly important because her husband had a job with high time demands and little flexibility, much like positions in start-up companies.

Hence, her "choice" between these two careers needs to be contextualized by the features of these two positions, the gendered workplace culture of the jobs as well as the availability of childcare beyond limited school hours in the German system.

If we carry this example a step further, we can also see a way in which individual-level choices, driven by organizational contexts, result in the macro-level pay gap. In this case, teaching pays less than IT work for those with the same education. But the work context in the IT start-up leaves little time for a worker to pursue much life outside the workplace. Teaching, however, is very consistent with work/life balance—at least on the surface—so it is not surprising that this woman was funneled into teaching and away from IT. Over time, her husband will see increases in his pay and could continue to reap the financial rewards that come from long hours of paid employment. The woman is likely to work more hours than her husband, but will split her time between the lower-paid teaching job and the unpaid work of caring for her family. In addition, she will also now have an IT career discontinuity that she would have to explain—if she is even given a chance to do so—making it rather difficult for her to move back into a full-time IT job even when her children are older.

Gender, *the Life Course*, *and Science Careers*: The decision to get an advanced degree in science and the choice of a work setting can be shaped by how individuals make choices within the context of the culture of science disciplines that are patterned by gender. As illustrated by the example, above, individuals make choices within the context of their family situations and beliefs about appropriate behavior within the family setting. The German woman, above, who opted for a lower-paying job that provided her with more time to spend enacting the gendered role of "mother" might not have had that same freedom of choice if she did not have a partner who was not well employed. Likewise, if her husband had wished to spend more time with the children and less in the paid labor force, would his "choice" to take a lower-paying job be seen as acceptable?

Advanced science degrees, especially at the doctoral level, prepare students for academic careers and open doors in industry and government for professional careers with high status and leadership opportunities. When we compare disciplines and countries we easily see how these decisions are not just shaped by personal motives, but also by a whole set of complicated factors. The availability of work for people in labor markets varies by degree field level and individuals' careers may not match their level of formal education. For example, a US individual who holds a B.S. in chemistry but progresses within her/his career as a result of on-the-job training to positions of higher level research responsibility may find that without a formal educational credential it would not be possible to be hired to do the same work at another US firm or at a laboratory in another country (e.g., Germany). Particular subfields in the German chemistry workforce are deemed more open to women such as food-chemistry, which has less status and pay than other chemistry subfields (Kahlert 2012).

In addition, regulations and practices of workplace protections that people take for granted can further constrain women's career choices. For example, in Germany pregnant women are not allowed to work in laboratories that might expose them to "dangerous" substances, which has obvious implications for women's ability to work in fields like the chemical sciences. Hence, women who intend to have children in Germany may avoid chemistry jobs with such restrictions and take jobs in other areas of chemistry. Gendered policies that most individuals take for granted further obscure the role of gender in shaping career choices.

3.10 Individual-Level Choices

Individuals are active agents but they are not atomistic. They are connected to significant others and, as members of cultures, sensitive to the norms that regulate social behavior. Gendered norms are woven throughout cultures, often in subtle ways, so that individuals may believe that the pathway choices they make are entirely independent of gendered considerations when, indeed, gendered factors have shaped these choices all along the way to produce the macro-level separation of women and men into different occupations. Individuals who choose to challenge, ignore, or violate the gendered norms within their culture run the risk of being evaluated negatively or, in extreme cases, of being targeted by gunmen as was Malala Yousafzai, the 14-year-old Pakistani girl who advocated for girls' access to education. On the other hand, conforming to gendered norms may produce rewards, such as when men can choose to accept opportunities for advancement because someone else is responsible for taking care of their children.

3.11 Conclusion

In this chapter, the horizontal and vertical dimensions of occupational segregation were discussed. Women and men often pursue different areas within the sciences (horizontal segregation). The role of education in preparing individuals for careers in science and the mechanisms by which entry is patterned by gender, therefore, produce differences in women's and men's entry to different fields of science. Further women are less likely to be at the pinnacle of scientific careers in positions of power and are more likely to be concentrated in lower-level positions (vertical segregation). The large cross-national variation in women's representation across fields reveals the importance of social factors—versus innate biology—as the reason for gender variation. The social institution of gender, itself, plays a pivotal role in women's representation both across different fields of science and in advancement within science. Gender as an integrated set of social norms, values, roles, expectations, and practices, shapes behavior and patterns opportunities in subtle ways, so that the average individual typically fails to acknowledge the role of gender in producing educational and occupational outcomes.

Expectations for performance within these systems vary and scientists' careers can be influenced by state policies that may or may not provide supports or resources for scientists. Transparency in these processes can produce more equitable outcomes, but the level of transparency varies across institutional contexts. The extent to which individuals negotiate within these systems and the extent to which negotiation is gendered hold further implications for women's advancement in science.

A number of processes within the institutions that comprise the presumed meritocratic objectivity of scientific communities were reviewed. The omnipresent scissors diagrams clearly illustrate women's lower representation at higher levels of science education and occupations and men's concurrent higher representation, especially women's rarity in top leadership positions in science. Such stratification holds implications for women's access to key resources in science and maintains men's control of scientific organizations, thereby replicating the gendered status quo.

Second, the so-called "blind" processes of peer review have been shown to be fraught with bias (Wenneräs and Wold 1997). The accumulation of small disadvantages produces disparate outcomes over the course of individuals' careers (Valian 1998). Further, particularistic institutional processes that reward men for gender-appropriate aggressive behavior in the allocation of resources disadvantage women, who are placed in an untenable, no-win situation where aggressive behavior may result in sanctions.

Much more research is needed to understand how these processes vary between countries. The cross-national variation is a potentially rich source of "natural experiments" to examine the way gender operates to impact education and career outcomes. The D-scores that quantify the level of segregation—both horizontal and vertical—are one metric that can aid in these analyses; these metrics are also useful for the analysis of the segregation of science within a nation over time. Robust analyses should drill down to better document the institutional and institutional-level processes by which gender is salient in the careers of scientists. Within national contexts, it would be useful to examine if these processes impact women differently based on the level of women's participation in science. For example, are women more or less likely to advance in male or female-dominated fields? Some evidence suggests that that even in fields in which women account for the majority of occupants, men are privileged and "ride the glass escalator" to higher positions of authority (Williams 1992).

There are a number of other research avenues in which attention to the horizontal and vertical dimensions of segregation and the social, organizational, and individual-level mechanisms could prove fruitful. First, the recent worldwide economic crisis increased competition for jobs across labor markets in most nations. To what extent were women in science likely to suffer adverse career impacts, either because of men's assertion of gender privilege or due to "last in-first out" processes?

Second, intersectionality also bears more careful scrutiny. In this chapter, we focused almost exclusively on deploying the tools and analytical strategies of sex segregation to understand the relative status of women in four science fields in international perspective. Other bases of differentiation, including birth cohort (or generational effects), race/ethnicity, immigration status, sexual orientation, etc. have been increasingly incorporated into more nuanced analyses of gender differences to provide a richer understanding of the segregation outcomes and cross-national differences that might be observed. Scientists are an internationally mobile workforce; so, for example, to what extent does gender and national origin (i.e., immigrant/nonimmigrant) impact individuals' science careers?

Additional research on women's science careers outside of academic settings in cross-national perspective is also needed. There are vast differences across nations in the level and quality of data about workforce participation. Data on women in industrial and government science workplaces is often very difficult to obtain, despite the efforts by international organizations like OECD to standardize occupations and industrial classification systems.

Much of the international effort focused on improving the status of women (e.g., UNESCO) often focuses on such basic needs for health and sanitation, that increasing women's participation in science seems remote in comparison. That is, as illustrated by recent events, the need to address outright violence against women when they attempt to go to school or work may be a more pressing priority versus opening doors to women to what is generally a small segment of the larger labor force (i.e., science).

In closing, the relationship between scientific credentials, careers, and larger social and economic forces must attend to gender as an often subtle factor that affects all of these processes. The social organization of science and the ways this might vary across national contexts should also find a place on social scientists' research agenda. The worldwide discourse that suggests that science is critical for economic development and continued technological advancement implies that women have an important stake in being full participants in science.

Chapter References

Anker, Richard. 1998. *Gender and Jobs: Sex Segregation of Occupations in the World*. Geneva: International Labour Office.

Aaveduto, Sveva. 2015. Greetings from Italy: What Is Changing for Women and Science and Research Careers. In *Advancing Women in Science: An International Perspective*, ed. W. Pearson Jr., L.M. Frehill, and C.L. McNeely. New York: Springer.

Babcock, Linda, and Sara Laschever. 2009. *Women Don't Ask: Negotiation and the Gender Divide*. Princeton, NJ: Princeton University Press.

Bailyn, Lotte. 2003. Academic Careers and Gender Equity: Lessons Learned from MIT. *Gender, Work & Organization* 10: 137–153.

Bertaux, Nancy E. 1991. The Roots of Today's "Women's Jobs" and "Men's Jobs": Using the Index of Dissimilarity to Measure Occupational Segregation by Gender. *Explorations in Economic History* 28: 433–459.

Bilimoria, Diana, and Xiangfen Liang. 2012. *Gender Equity in Science and Engineering: Advancing Change in Higher Education*, vol. 15. New York: Routledge.

Blackburn, R.M., Jennifer Jarman, and Bradley Brooks. 2000. The Puzzle of Gender Segregation and Inequality: A Cross-National Analysis. *European Sociological Review* 16: 119–135.

Blake, Margaret, and Ivana La Valle. 2000. *Who Applies for Research Funding?: Key Factors Shaping Funding Application Behaviour Among Women and Men in British Higher Education Institutions*. London: National Centre for Social Research.

Caprile, Maria, ed., B. Sánchez, N. Vallès, A Gómez, J Potrony, E Sixto, D Herrera, M Oleaga, M. Amate, and I. Isasa. 2008. *Monitoring Progress Towards Gender Equality in the Sixth Framework Programme*. European Commission, Directorate for Research.

Caprile, Maria, coord., Elisabetta Addis, Cecilia Castaño, Ineke Klinge, Marina Larios, Danièle Meulders, Jörg Müller, O'Darchoai, Robert Alain Plasman, Seppo Roivas, Felizitas Sagebiel, Londa Schiebinger, Nuria Vallès, and Susana Vazquez-Cupeiro. 2012. *Meta-Analysis Gender and Science Research: Synthesis Report*. Bruxelles: ULB—Universite Libre de Bruxelles.

Chang, Mariko Lin. 2004. Growing Pains: Cross-National Variation in Sex Segregation in Sixteen Developing Countries. *American Sociological Review* 69: 114–137.

Charles, Maria. 1992. Cross-National Variation in Occupational Sex Segregation. *American Sociological Review* 57: 483–502.

Charles, Maria, and Karen Bradley. 2002. Equal but Separate? A Cross-National Study of Sex Segregation in Higher Education. *American Sociological Review* 67: 573–599.

_____. 2004. *Occupational Ghettos: The Worldwide Segregation of Women and Men*. Stanford: Stanford University Press.

Charles, Maria, and David B. Grusky. 2004. *Occupational Ghettos: The Worldwide Segregation of Women and Men*. Stanford: Stanford University Press.

CNPq. 2013. *Diretório dos grupos de pesquisa no Brasil. Censos a partir de 2000 e base corrente* (Directory of Research Groups of Brazil. Census from Year 2000 and Current Base).

Connell, R.W. 1995. *Masculinities*. Oakland: University of California Press.

Correll, Shelley J., Stephen Benard, and In Paik. 2007. Getting a job: Is There a Motherhood Penalty? *American Journal of Sociology* 112: 1297–1338.

Cotta, Monica Alonso, Marília J. Caldas, and Marcia C. Barbosa. 2009. Climbing the Academy Ladder in Brazil: Physics. *AIP Conference Proceedings* 1119: 87.

Duncan, Otis Dudley, and Beverly Duncan. 1955. A Methodological Analysis of Segregation Indexes. *American Sociological Review* 20: 210–217.

Eagly, Alice H., and Linda Lorene Carli. 2007. *Through the Labyrinth: The Truth About How Women Become Leaders*. Boston, MA: Harvard Business School Press.

Etzkowitz, Henry, Carol Kemelgor, and Brian Uzzi, eds. 2000. International Comparisons. In *Athena Unbound: the Advancement of Women in Science and Technology*. Cambridge: Cambridge University Press, 203–224.

European Commission. 2002. *National Policies on Women and Science in Europe: A Report About Women in and Science in 30 Countries by Professor Teresa Rees*. Brussels: EC.

_____. 2006. *She Figures 2006*. Brussels: EC.

_____. 2008. *Mapping the Maze: Getting More Women to the Top in Research.* Luxembourg: Office for Official Publications of the European Communities.

_____. 2009. *The Gender Challenge in Research Funding: Assessing the European National Scenes*. Brussels: EC.

_____. 2013. *She Figures 2012. Gender in Research and Innovation. Statistics and Indicators. Office for Official Publications of the European Communities.* Brussels: EC.

European Commission, Directorate-General for Research Science, Economy and Society, ed. 2009b. *Women in Science and Technology: Creating Sustainable Careers*. Luxembourg: EUR-OP.

European Science Foundation (ESF). 2009. *Research Careers in Europe. Landscape and Horizons. A Report by the ESF Member Organisation Forum on Research Careers*. Strasbourg: ESF.

European Union Seventh Framework Programme. 2008. *Meta-Analysis of Gender and Science Research*. CIREM.

Feller, Irwin. 2004. Measurement of Scientific Performance and Gender Bias. *Gender and Excellence in the Making* 35.

Fiske, Susan T. 1998. Stereotyping, Prejudice, and Discrimination. In *The Handbook of Social Psychology*, ed. D.T.F. Gilbert, T. Susan, and G. Lindzey, 367–411. New York: McGraw-Hill.

Fiske, Susan T., J.C. Amy, Peter Glick Cuddy, and Xu. Jun. 2002. A Model of (Often Mixed) Stereotype Content: Competence and Warmth Respectively Follow from Perceived Status and Competition. *Journal of Personality and Social Psychology* 82: 878–902.

Fox, Mary Frank. 2005. Gender, Family Characteristics, and Publication Productivity Among Scientists. *Social Studies of Science* 35: 131–150.

Frehill, Lisa M. 1996. Occupational Segmentation in Kansas and Nebraska, 1890-1900. *Great Plains Research* 6: 213–244.

Frehill, L.M., and K. Zippel. 2011. Gender and International Collaborations of Academic Scientists and Engineers: Findings from the Survey of Doctorate Recipients, 2006. *Journal of the Washington Academy of Sciences* 97(1): 49–69.

_____. Measuring Occupational Sex Segregation of Academic Science and Engineering. *The Journal of Technology Transfer* 31: 345–354.

Galerand, Elsa, and Danièle Kergoat. 2013. Le travail comme enjeu des rapport sociaux (de sexe). In *Travail et genre dans le monde L'état des savoirs*, coord. Margaret Maruani, 44–51. Paris: La Découverte.

Grusky, David B., and Maria Charles. 1998. The Past, Present, and Future of Sex Segregation Methodology. *Demography* 35: 497–504.

Gupta, Namrata, Carol Kemelgor, Stephan Fuchs, and Henry Etzkowitz. 2004. The 'Triple Burden': A Cross-Cultural Analysis of the Consequences of Discrimination for Women in Science. In *Gender and Excellence in the Making*, ed. European Commission, 41–50. Luxembourg: Office for Official Publications of the European Communities.

Hanson, Sandra L., Maryellen Schaub, and David P. Baker. 1996. Gender Stratification in the Science Pipeline: A Comparative Analysis of Seven Countries. *Gender & Society* 10: 271–190.

Hinz, Thomas, Ina Findeisen, and Katrin Auspurg. 2008. *Wissenschaftlerinnen in der DFG. Förderprogramme, Förderchancen, Funktionen (1991–2004)*. Weinheim: Wiley-Verlag.

Hosek, Susan D., Amy G. Cox, Bonnie Ghosh-Dastidar, Aaron Kofner, Nishal Ramphal, Jon Scott, and Sandra H. Berry. 2005. *Is There Gender Bias in Federal Grant Programs?* Santa Monica, CA: RAND.

Husu, Liisa, and Suzanne Cheveigné. 2010. Gender and Gatekeeping of Excellence in Research Funding: European Perspectives. In *Gender Change in Academia*, ed. B. Riegraf, B. Aulenbacher, E. Kirsch-Auwärter, and U. Müller, 43–59. Wiesbaden: VS Verlag für Sozialwissenschaften.

Inter Academy Council. 2006. *Women for Science. An Advisory Report*.

Jacobs, Jerry A. 1989. Long-Term Trends in Occupational Segregation by Sex. *The American Journal of Sociology* 95: 160–173.

_____. 1995. Gender and Academic Specialties: Trends Among Recipients of College Degrees in the 1980s. *Sociology of Education*, 68: 81–98.

Kahlert, Heike. 2012. Was kommt nach der Promotion? Karriereorientierungen und -pläne des wissenschaftlichen Nachwuchses im Fächer- und Geschlechtervergleich. In *Einfach Spitze? Neue Geschlechterperspektiven auf Karrieren in der Wissenschaft*, ed. S. Beaufaÿs, A. Engels, and H. Kahlert. Campus: Frankfurt am Main [u.a.].

Kemelgor, Carol, and Harry Etzkowitz. 2001. Overcoming Isolation: Women's Dilemmas in American Academic Science. *Minerva* 39: 153–174.

King, M.C. 1992. Occupational Segregation by Race and Sex, 1940-88. *Monthly Labor Review* 115: 30–38.

Knights, David, and Wendy Richards. 2003. Sex Discrimination in UK Academia. *Gender, Work & Organization* 10: 213–238.

Maruani, Margaret, coord. 2013. Travail et genre dans le monde. L'état des savoirs. Paris: La Découverte.

Massey, Douglas S., and Nancy A. Denton. 1989. Hypersegregation in U.S. Metropolitan Areas: Black and Hispanic Segregation Along Five Dimensions. *Demography* 26(3): 373–91.

Massey, Douglas S., and Nancy A. Denton. 1993. *American Apartheid: Segregation and the Making of the Underclass*. Cambridge, MA: Harvard University Press.

McDaniel, Anne. 2010. Cross-National Gender Gaps in Educational Expectations: The Influence of National-Level Gender Ideology and Educational Systems. *Comparative Education Review* 54(1): 27–50.

Melkas, Helina, and Richard Anker. 2001. Occupational Segregation by Sex in Nordic Countries: An Empirical Investigation. In *Women, Gender and Work: What Is Equality and How Do We Get There?* ed. M.F. Loutfi, 189–213. Geneva: International Labour Office.

Moody, Joann. 2005. Rising above Cognitive Errors: Guidelines to Improve Faculty Searches, Evaluations, and Decision-Making.

National Science Foundation. 2012. *Science and Engineering Indicators*. Arlington, VA: National Science Board.

Nosek, Brian A., and Rachel G. Riskind. 2012. Policy Implications of Implicit Social Cognition. *Social Issues and Policy Review* 6: 113–147.

National Research Council (NRC). 2007. *Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering*. Washington, DC: The National Academies Press.

_____. 2010. *Gender Differences at Critical Transitions in the Careers of Science, Engineering and Mathematics Faculty*. Washington, DC: National Academies Press.

Organization of American States (OAS). 2005. Gender Equity and Equality in Science and Technology. *Policy Proposals for the Americas*. Washington, DC.

Organisation for Economic Cooperation and Development. 2006. *Women in Scientific Careers: Unleashing the Potential*. Paris: OECD.

OEI—Organización de los Estados Iberoamericanos y UNESCO SAP. 2004. *Proyecto Iberoamericano de Ciencia, Tecnología y Género—GENTEC—UNESCO*. Informe comparativo regional e informes nacionales de Argentina, Brasil, Costa Rica, España, México, Paraguay, Uruguay y Venezuela.

Osborn, M., T. Rees, M. Bosch, C. Hermann, J. Hilden, J. Mason, A. McLaren, R. Palomba, L. Peltonen, C. Vela, D. Weis, A. Wold, and C. Wennerås. 2000. *Science Policies in the European Union: Promoting Excellence Through Mainstreaming Gender Equality*. Luxembourg: Office for Official Publications of the European Communities, European Commission.

Rees, Teresa. 2004. Measuring Excellence in Scientific Research: The UK Research Assessment Exercise. In *Gender and Excellence in the Making*. Luxembourg: Office for Official Publications of the European Communities, 115–120.

Reskin, Barbara, and Heidi I. Hartmann. 1986. *Women's Work, Men's Work: Sex Segregation on the Job*. Washington, DC: National Academy Press.

Reskin, Barbara, and Patricia A. Roos. 1990. *Job Queues, Gender Queues: Explaining Women's Inroads into Male Occupations*. Philadelphia: Temple University Press.

Semyonov, Moshe, Yitchak Haberfield, Yinon Cohen, and Noah Lewin-Epstein. 2000. Racial Composition and Occupational Segregation and Inequality Across American Cities. *Social Science Research* 29: 175–187.

Spencer, Steven J., Claude M. Steele, and Diane M. Steele. 1999. Stereotype Threat and Women's Math Performance. *Journal of Experimental Social Psychology* 35: 4–28.

Steele, Claude M. 1997. A Threat in the Air: How Stereotypes Shape Intellectual Identity and Performance. *American Psychologist* 52: 613–629.

Steele, Claude M., and Joshua Aronson. 1995. Stereotype Threat and the Intellectual Test Performance of African Americans. *Journal of Personality and Social Psychology* 69: 797–811.

Third World Organization for Women (TWOWS). 2007. Proceedings of the International Conference on Women's Impact on Science & Technology in the New Millennium. In *International Conference on Women's Impact on Science & Technology in the New Millennium*, ed. V. Krishnan. Bangalore: Institute of Science.

UNESCO Institute for Statistics. 2007. *Science, Technology and Gender: An International Report*. Montreal: UNESCO.

U.S. Bureau of Labor Statistics. 2013. *CPS Tables, Annual Averages,* http://www.bls.gov/cps/tables.htm#annual (accessed 12 December 2013).

Valian, Virginia. 1998. *Why so Slow?: The Advancement of Women*. Cambridge, MA: MIT Press.

Wenneräs, Christine, and Agnes Wold. 1997. Nepotism and Sexism in Peer-Review. *Nature* 387: 341–343.

Wilcox, Diane. 2015. A Personal Reflection on Advancing in South African Science. In *Advancing Women in Science: An International Perspective*, ed. W. Pearson Jr., L.M. Frehill, and C.L. McNeely. New York: Springer.

Williams, Christine L. 1992. The Glass Escalator: Hidden Advantages for Men in the “Female” Professions. *Social Problems* 39: 253–267.

Vignette 3.1

Focus on Brazil

Alice Abreu

The case of Brazil is worth looking at in more detail, since at first glance women appear to have made important progress in the scientific system. Figures 3.6 and 3.7 show the percentage of M.Sc. and Ph.D. graduates by sex for the period from 1996 to 2009.

Women have been the majority of M.Sc. graduates since 1998 and the majority of Ph.D. graduates since 2004, making the famous scissors diagram change direction. As discussed in Vignette 10.3, this was the result of a consistent universal policy of support for graduate training. In 2008 women accounted for 53.9 M.Sc. graduates and 51% of Ph.D. graduates.

Between 1996 and 2008 there were 87,000 Ph.D.s graduated in all scientific areas CGEE (2010). The number of Ph.D.s conferred increased 278% between 1996 and 2008, a yearly rate of 11.9%. The large majority of the Ph.D.s graduated from public universities, either from the state system of São Paulo, or the Federal Universities. In fact, five universities, including three of São Paulo, accounted for about 60% of total Ph.D.s conferred in Brazil between 1996 and 2008. Having women as the majority of Ph.D.s graduates puts Brazil among the very few countries, which includes Portugal and Italy, where women represent the majority at this level of training. Across the EU, women earn, on average, 46% of Ph.D.s European Commission (2013) and in the United States women earned 49% of Ph.D.s in 2011.

In Brazil, as in other countries, there are considerable differences in women's participation between the scientific disciplines. In 2008 women represented a very strong majority of Ph.D. graduates in Health Science (59%) and Biological Sciences (63%), which is similar to the high rates of participation in these areas in the United States and many European nations. However, unlike the United States and some

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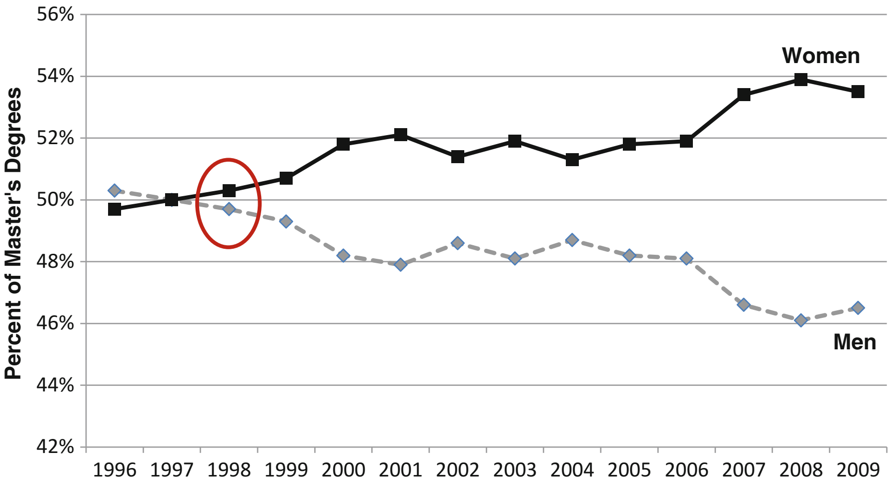

Fig. 3.6 Percent of M.Sc. degrees awarded in Brazil by sex, 1996–2009. *Source*: *Frehill*, *Lisa M. 2013. Analysis of data from CGEE 2012*

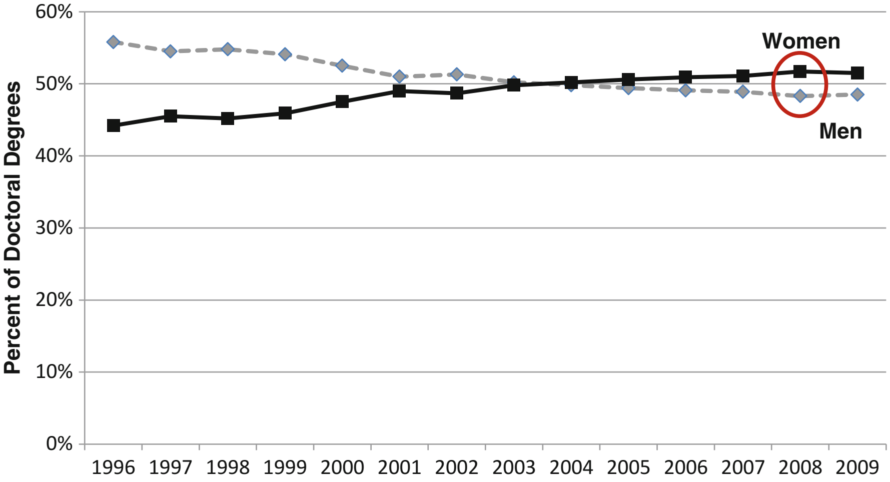

Fig. 3.7 Percent of Ph.D. degrees awarded in Brazil by sex, 1996–2009. *Source*: *Frehill*, *Lisa M. 2013. Analysis of data from CGEE 2010*

European nations, Brazilian women are more highly represented in Engineering (33%) and Exact Sciences (38%).

Looking in more detail at the three scientific areas focused by this book, mathematics, computer science, and chemical sciences, Fig. 3.8 shows that there are important differences among the Ph.D. graduates according to the subareas of those fields. In Probability and Statistics and Chemistry, women earned 50% of the Ph.D.s in 2008, with even greater representation but in Biochemistry, within the

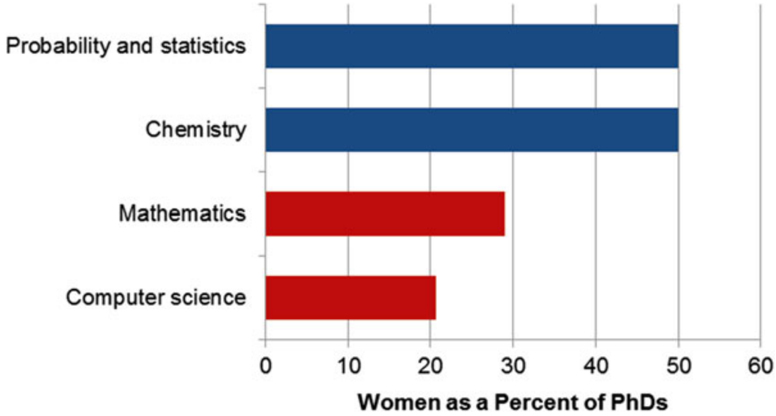

Fig. 3.8 Women as a percent of Ph.D.s in specific fields of science in Brazil, 2008. *Source*: *Frehill, Lisa M. 2013. Analysis of data from CGEE 2012*

Life Sciences, in which women accounted for 65% of Ph.D. graduates (this subfield is not shown in the chart). In Mathematics and Computer Science, however, the situation is very different; women earned only 20% of Ph.D.s graduates in 2008 in Computer Science, and just under 30% in Mathematics.

This enormous effort to qualify Brazilian scientists has had some important consequences for the S&T system in general; the overall participation of women researchers in active research groups increased from 39% in 1997 to 50% in 2010 (CNPq, Census of Research Groups 2013).

The increased number of women in the lower levels of the scientific and technological system, or even at the Ph.D. level as in Brazil, however, has not translated into increased numbers in the positions of higher prestige. For example, while women account for 50% of researchers overall, they represent just 44% of research group leaders. In engineering, even with women representing a third of new graduates a year, just 22% of research group leaders in Engineering are women (CNPq 2013).

Unlike the emphasis on tenure within US academia, tenure is not relevant to the scientific career of a Brazilian scientist. The access to the state and federal system is via public competition, which grants stability from the beginning of the work contract as a lecturer. The scientist then has to progress by merit to the different levels of the career ladder. At the highest level of the Full Professorship, another public competition is held.

Data to evaluate the position of women in the Brazilian University system as a whole are difficult to obtain, but there are some specific case studies that can shed light on this. A recent study of one of the large State universities of São Paulo, UNICAMP, shows that in 2006 women represented 34% of the total number of lecturers. They represented 42% of lecturers holding a Ph.D., but only 23.2% of Full Professors. This is however a substantial increase from the situation in 1994, when only 10.3% of Full Professors were women (Vasconcelos *e* Brisolla 2009).

Another indicator showing women's difficulty in reaching the higher positions in the system is related to the prestigious Senior Research Scholarships, a program of scholarships that supports the best researchers in the country. A very competitive process, researchers propose a 5 year project, is evaluated and reviewed at each renewal, with important expectations for resultant high level publications from the project. With five levels of excellence, women have represented only 22–23% of grantees in the highest level, with no upward trend in the last decade. So one of the big challenges for the Brazilian S&T system is to make sure that these highly trained women scientists participate fully and are involved in the highest decision-making positions of the system.

References

CGEE. 2010. *Doutores 2010: estudos da demografia da base técnico-científica brasileira (Ph.D.s 2010: Study of the Demography of the Brazilian Techno-Scientific Base).* Brasilia: Centro de Gestão e Estudos Estratégicos.

_____. 2012. *Mestres 2012: estudos da demografia da base técnico-científica brasileira (M.Sc.s 2012: Studies of the Demography of the Brazilian Techno-Scientific Base).* Brasilia: Centro de Gestão e Estudos Estratégicos.

CNPq. 2013. *Diretório dos grupos de pesquisa no Brasil.* Censos a partir de 2000 e base corrente (Directory of Research Groups of Brazil. Census from year 2000 and current base).

European Commission. 2013. *She Figures 2012. Gender in Research and Innovation. Statistics and Indicators*. Brussels: Office for Official Publications of the European Communities.

Vasconcelos, E.C.C. and S.N. Brisolla. 2009. Presença feminina no estudo e no trabalho da ciência na UNICAMP (The feminine presence in scientific study and work at the University of Campinas). *Cadernos PAGU* 32.

Vignette 3.2

Greetings from Italy: What Is Changing for Women and Science and Research Careers

Sveva Avveduto

According to OECD data, the Italian female employment rate is 48% OECD (2013), one of the lowest of the OECD area as well as of all Western countries. If we consider that so few women work in Italy, much is left to the imagination about the situation of women working in scientific and academic research, areas dominated by men. When in the 1990s, I started working with data and interpretation on women's condition in scientific careers in Italy, I had to face a complete underrepresentation of women in science, the relevance of gender stereotypes in any step of female scientists and researchers careers, a lack of gendered career paths and of role models. The entire academic and research systems seemed to be based on a masculine oriented model of work: heavy workload (as much as 60 h per week), exclusive dedication to research and study, selection made out of scientific affiliations preferring, in any case, men over women. Apart from the state of research and science workplace, female scientists and researchers had to face impressive family burden, due to a remarkable lack of social services for working women. In this sense, women in research and development (R&D) had to face an authentic martyr role in university classes and research labs, instead of being just a part of a scientific community building up knowledge and development.

My research and analyses focused on: (1) (unequal) access to scientific and research careers; (2) (unequal) career paths and access to career development opportunities; and (3) gender differences in the management of work/life balance. Nor did the situation prove to be better when I moved my analyses from a qualitative point of view to a quantitative one: in the European Commission 2003 *She Figures* reports the percentage of female researchers over the total workforce in R&D in Italy was 26.8%, compared to a percentage of 50.8% female graduates. The loss of human

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capital and human potential is clear if we consider that half of the female population graduating did not consider (or did not have access to) a scientific or research career. Resilient prejudice (and sometimes self imposed prejudice) about women's abilities in science and research, barriers in hiring and promoting female scientists from the "the old boys networks", difficulties experienced in managing family and workloads within an inadequate social welfare policy system played their part in the unfair and limited representation of women in R&D.

What can we say about the current situation of women in science and research in Italy? According to the data European Commission (2013) and to the analysis, although the general framework has not changed a lot, nevertheless, the situation for women in science and research has improved. From a quantitative point of view, we can notice from the most recent *She Figures* (2012), that female scientists and researchers in Italy reached the rate of 34% of the scientific workforce in universities and labs, with an increase of 7.2% in 10 years. This fact is interesting if we compare it with the 52% representation of female Ph.D.s (all fields) in 2010 and the 50.7% of female Ph.D.s in STEM. What happened to justify this quantitative improvement in the female presence in scientific careers? Do these data reflect also a qualitative improvement in career paths and management of work/life balance? Did Italian welfare system policies for working women improved significantly in this decade?

I find that, even if in the background context only minor changes occurred, two significant trends are emerging in the R&D system. First, the Europeanization of the research system brings with it rules and procedures regarding gender equal representation. Second, there are new relationship-building tools for encouraging exchanges between experienced and young female scholars.

Regarding the first trend: the introduction of *The European Charter of Researchers and the Code of Conduct for Recruitment* European Commission (2005) represents a turning point for better gender representation. According to the principle of nondiscrimination and the principle of gender balance, quality of research and competence of researchers were matched with an equal opportunity policy for recruiting and for further career paths. The salience of the European document is such that norms for foreseeing gender quotas European Commission (2011) in the hiring and evaluation commissions were first inserted in the procedures of Italian Public Research Institutions and then extended to all hiring commissions in the Public Administration.

The Europeanization of the Research Area with the ERA acted also as a catalyst for young female scholars, who had the chance to open their research and science horizons to a wider European scenario, comparing with different research and scientific systems where female underrepresentation has provided for different policy and cultural solutions (e.g., Scandinavia, with adequate welfare policy solutions for working women and even in countries from the former USSR block, where gender equal opportunity was tied to the concept of socialist equality). The Europeanization of the Italian research and science sector is a long-term process and it is still in a complex implementation phase, but I have to recognize that it was truly significant to give impetus to gender equal opportunities in scientific careers within the national R&D system.

But what I find really interesting, as a sociologist is the path to commonly shared social practices in female mentoring. Our scientific community finally managed to ensure (albeit still few) scientists key positions in public research institutes, universities, and laboratories, and these experienced researchers showed an uncommon ability to advice and counsel early stage female scholars starting or advancing in their careers. The widely studied practice Green and Bauer (1995; Ibarra et al. 2010) of mentoring obtained special results in gender empowerment, career counseling, and excellent research achievement when female mentors meet female mentee. The sharing of a common research path is often the occasion for mentor and mentee to meet and to start a social and professional relationship that is fruitful for both sides as well as the general affirmation of gender equality. Our social responsibility as women starts here, passing of the baton to a new generation of young women scientists that will live and work in a world more open to equal opportunities for women in science, where the quality of research will be the only evaluation parameter. We hope and we work for it.

References

European Union. 2003. *She Figures 2003*: *Women and Science Statistics and Indicators*, http://ec.europa.eu/research/science-society/pdf/she_figures_2003.pdf (accessed 1 March 2014).

_____. 2005. *The European Charter for Researchers: The Code of Conduct for the Recruitment of Researchers,* http://ec.europa.eu/euraxess/index.cfm/rights/europeanCharter (accessed 1 March 2014).

_____. 2011. *The Quote-Instrument: Different Approaches Across Europe* (Working Paper), http://ec.europa.eu/justice/gender-equality/files/quota-working_paper_en.pdf (accessed 1 March 2014).

_____. 2013. *She Figures 2012*: *Gender in Research and Innovation*, *Statistics and Indicators,* http://ec.europa.eu/research/science-society/document_library/pdf_06/she-figures-2012_en.pdf (accessed 1 March 2014).

Green, S.G. and Bauer, T.N. 1995. Supervisory Mentoring by Advisers: Relationships with Doctoral Student Potential, Productivity, and Commitment. *Personnel Psychology* 48: 537–562. doi:10.1111/j.1744-6570.1995.tb01769.x

Ibarra, H., Carter, N.M. and Silva, C. 2010. *Why Men Still Get More Promotions than Women. Harvard Business Review* (September 2010), http://hbr.org/2010/09/why-men-still-get-more-promotions-than-women/ (accessed 1 March 2014).

Organisation for Economic Cooperation and Development (OECD). 2013. *Employment Rate of Women*. Employment and Labour Markets: Key Tables from OECD, No. 5. doi:10.1787/emp-fe-table-2013-1-en

Vignette 3.3

A Reflection on Advancing in the Mathematical Sciences in South Africa

Diane Wilcox

Uncertainty about one's ability to execute one's research plan can be one of the most challenging aspects of graduate student life. As a result, institutional and circumstantial hurdles can seem menacing, particularly when it takes significant discipline and perseverance to redefine one's own and society's boundaries of knowledge through some process of scientific discovery which one is still discovering.

When I graduated with a B.Sc. in 1994, women were a small minority among the candidates majoring in mathematics and in computer science. Fortunately demographics were improving. By the time I submitted my Ph.D. for examination in 2001, gender seemed less of an impediment to my progress as a mathematician than to general social interaction: it can be difficult to interact confidently with family or friends when a proof you're working on becomes more and more convoluted or when you're grappling with concepts and cannot see how pieces fit together.

I was fortunate to have been spared much overt chauvinism and did not encounter sexual harassment as a university student. Therefore, my own social challenges often seemed more idiosyncratic than symptomatic of fundamental prejudices in society (cf. Hanisch 1970). Having attained success at something less ordinary, the challenge of reintegrating to the mainstream, while continuing research, would turn out to be as difficult. Over the years, it has become easier to appreciate that barriers are an aspect of social cohesion and it takes significant emotional intelligence and mentoring to nonconform acceptably. Mathematical scientists are not best known for their EQ's and the system is not always sympathetic.

Thus, I am most thankful for friends and mentors who have offered encouragement, feedback and critical review and for generous funding to conduct and disseminate research.

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Big career highlights have included extending the theory of semi-Fredholm relations, developing the theory of Atkinson operators in a generality that had not been detailed before my first publications, the ICM2002 and graduation in December that year, and a decade more of continued discovery and new insights in financial markets, mathematical modeling and multivalued operators. The honor of being enabled to prove theorems, dissecting the applicability of theories, developing new perspectives, and meeting leading thinkers has been its own amazing reward.

As a mid-career researcher I have found pressures due to gender inequity became more acute: referral networks for women's promotion on merit are still limited and childbearing makes us less mobile to pursue promising opportunities. Coping with incongruities and hypocrisy can be perplexing and implied skepticism of one's credentials, which can be as stringent from the female camp, can cause negative feedbacks. Even the best policies do not always benefit pioneers who create precedents, while academics with comparable capacity, but more celebrated or focused contributions, may move through the ranks more quickly.

Discouraging experiences are less likely to occur once there is sufficient critical mass and South Africa's National Research Foundation has launched several initiatives to increase research output, including focus programs for women (Mouton et al. 2009). The strategy has shown success and mathematical scientists are writing more papers. There are always counter-examples. I, myself, experienced diminished output of published papers, despite a promising start. Several factors contributed to this decline including: student project supervision; evolution in research focus and associated further skills development; parenting; relocation; and time-allocation to promoting women-in-science. Thus, over-exuberant encouragement to publish has sometimes been more frustrating than motivating.

I acknowledge that I have taken on more than I could cope with at times. This sort of career error has the downside of eroding one's professional integrity by making one seem unnecessarily weak or even incompetent. Professional education now commonly includes learning how to say "no" and administrators should be vigilant of unreasonable workloads that lead to burn-out.

In a competitive environment, we all want to be distinguished. As I morphed from being a young researcher to a more established academic, I, too, have found myself "sizing up" competition from younger researchers. This highlighted how building the women-in-science network has some natural enemies within and corroborated that biases paradoxically push up the bar by which women get measured as capable or outstanding scientists (Raymond 2013).

Gender issues in STEM are complex, not least because they are subsumed by their context in greater society (Hill et al. 2010; Hyde and Mertz 2009). At a women-in-science meeting an established academic once offered some advice to younger women. Highlighting the professionalism required to be an academic, she concluded with: "you don't want to be one of those women." I was intrigued. While I'm aware people judge one another and have heard scathing gossip, I have not met a scientist who I could bin as "one of those women." Since we all have different life stories, there's little logic in expecting all women in STEM to conform to a standardized mold. Nevertheless, females are sometimes forced to curtail their personalities in professional environments, while males are less censured (Pronin et al. 2004; Rudman 1998; Bowles et al. 2007).

Unsurprisingly, I have found that developing a comprehensive and competitive research program as a leading investigator comes with fresh challenges. Good science is not a clear-cut process (Dyson 2014; Levy2010) and it takes skill and confidence to cope with the complexity of project management and work on multifaceted problems (Gladwell 2013). Discovery entails experimentation and risk. Fortunately, women have also emerged as great risk managers (Widmer 2013), giving further evidence for fairer sex demographics for the future.

Prejudice will continue to be a reality for members of marginalized minorities, particularly when obstacles are scaled or expectations are exceeded in historically elite areas, as long as we are blinkered by our biases. We've certainly made progress, but our journey is not over for a global community in which women are not just regarded as clever, but as being able and necessary to advance in science and play leading roles without being stereotyped.

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References

Bowles, H.R., L. Babcock, and L. Lai. 2007. Social Incentives for Gender Differences in the Propensity to Initiate Negotiations: Sometimes it Does Hurt to Ask. *Organizational Behavior and Human Decision Processes* 103: 84–103.

Dyson, F. 2014. The Case for Blunders. *The New York Review of Books* (March 6 Issue).

Gladwell, M. 2013. Complexity and the Ten-Thousand-Hour Rule. *The New Yorker* (August 21 Issue).

Hanisch, C. 1970. The Personal Is Political. In *Notes from the Second Year*: *Women*'*s Liberation*: *Major Writings of the Radical Feminists,* ed. Firestone, Shulamith and Anne Koedt. New York: Radical Feminism.

Hill, C., C. Corbett and A. St. Rose. 2010. *Why so Few*? Washington, DC: AAUW.

Hyde, J. and J. Mertz. 2009. Gender, Culture, and Mathematics Performance. *Proceedings of the National Academy of Sciences* 106 (*22*): 8801–8807.

Levy, J. 2010. *Scientific Feuds* London: New Holland.

Mouton, J., M. Ritter, and N. Boshoff. 2009. *Facing the Facts: Women's Participation in Science, Engineering and Technology*, Collaborative report published by the DST, NACI and SET4W of South Africa.

Pronin, E., Steele, C.M. and Ross, L. 2004. Identity Bifurcation in Response to Stereotype Threat: Women and Mathematics. *Journal of Experimental Social Psychology*, 40, 152–168.

Raymond, J. 2013. Most of Us Are Biased. *Nature* 495: 33–43.

Rudman, L.A. 1998. Self-Promotion as a Risk Factor for Women: The Costs and Benefits of Counterstereotypical Impression Management. *Journal of Personality and Social Psychology*, 74 (3): 629–645.

Widmer, L. 2013. Woman at Work: Why Women Should Lead Risk Management. *Risk Management* (May 1 Issue).