1. Introduction: pipeline break

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We are now at the cusp of attaining the conditions needed for gender equality and equity in academic science. However, traditional academic science cultures are high walls, and those barriers have not yet fully been breached. Women now can enter many previously male-dominated academic fields but are still under-represented in higher positions. The so-called 'pipeline' thesis – encourage entry at the lower levels on the premise that with time, the increase will filter up to the higher levels – has led to the founding of numerous programmes and projects to encourage girls and young women to engage with science, technology and mathematics. An 'assisted pipeline' has worked up to and including PhD programmes and entry level positions in many academic science fields. However, it has been noted that the pipeline is 'leaky', with women being lost in ever greater proportions as they ascend the academic ladder (mixing metaphors). Indeed, their paucity at advanced levels is so great, with little – if any – improvement over the past 30 years, that it has been held that the pipeline is broken (see Etzkowitz et al., Chapter 19 in this volume).

As Paula England (2010) has argued more broadly, the gender revolution has 'stalled'. A simple funnel mechanism, an educational system attached to a pipeline with a 'capillary action' flow, propelling upward mobility of individuals expected to rise by virtue of increased input, has failed to produce equity, let alone equality. Instead, it has transmogrified into a mechanical model of an engine that has seized up and stopped running, at least temporarily, and is in stasis. In a ground vehicle, such as an automobile, a stall is inconvenient but not usually fatal unless a following vehicle runs into the stopped one. The academic system has proved resistant and resilient in the face of pressures to change. It bends, accepting gender research programmes, and is resilient, promoting relatively few female scientists, who generally accept the male model of science, thus keeping the existing system intact. Nevertheless, there are men and women scientists who attempt to innovate a female 'family friendly' model, balancing work and life with a private sphere, that an increasing number of

men also wish but do not dare to press for (Etzkowitz et al., 2000). Thus, systemic change is only likely to arrive as innovation from above, whether university, executive or legislative.

An airplane stall, if not quickly recovered, can result in a fatal crash. Is the gender revolution in science in a temporary recoverable stall, with renewal of progress in sight, or it is in a downward spiral, with few positive outcomes at hand or in prospect? This book demonstrates the state of the art of the condition of women in contemporary academic science in Europe and the United States (US). Increasing competition in European universities following the US model of 'up and out' tenure introduces a hyper-competitive model of academic science, with sharp distinctions even among elite universities, into a European academic structure heretofore based on principles of relative equality among academic institutions. Most European universities characteristically had probationary periods of a long-term nature before arriving at a professorship, with moderate workloads that allowed room for a private sphere. This provided an academic structure amenable to women's participation once admitted, even though exclusionary practices persist in highly conservative academic cultures.

Is the glass half full or half empty? What has clearly not worked to create systemic change are programmes such as US Advance that elevate relatively few individual women, while offering 'consciousness raising' workshops for males and mentoring for females in the hope of changing a system of asexual reproduction in which like reproduces like, with little tolerance for diversity (Etzkowitz et al., 2000; Rosser, Chapter 4 in this volume). Birkbeck, University of London (where two of the co-editors of this volume work, Lawton Smith and Poulovassilis, and a third, Etzkowitz, served as a visitor, linking the college to the European Union programme that supported the TRIGGER project on gender inequality in academia), is a microcosm of the contradictions of contemporary academic science. Birkbeck provided a welcoming environment in the 1950s for Rosalind Franklin, the empirical discoverer of DNA, who suffered discrimination at her previous academic home (Maddox, 2002). Starting with Desmond Bernal's leadership, Birkbeck's Crystallography Department, since renamed the Department of Biological Sciences, has long provided a welcoming environment, recruiting an academic staff with 50 per cent and above female representation (Brown, 2005). Birkbeck's Department of Computer Science and Information Systems is one of the earliest academic computing departments in the world, tracing its history back to the Computer Laboratory founded in 1946 where pioneering work in computer hardware and programming was undertaken by Andrew and Kathleen Booth in support of Bernal's Biomolecular Research Laboratory. However, in contrast to Biological Sciences, the proportion

of women in its academic staff has stayed persistently low, reflecting the national gender imbalance in the field (see below).

Even in disciplines with better gender balance, hard won parity may soon be lost in recruiting each new generation. As academia becomes ever more competitive, mandating early high achievement and a virtually total concentration on work, the male model of science is strongly reinforced even as policy initiatives relatively weakly attempt to induce change (see Meschitti, Chapter 2 in this volume). Perhaps ironically, as life and work spans lengthen, allowing for a more even distribution of work and life tasks over the life course, an outmoded academic structure creates a 'gender paradox' reducing the likelihood of women's rise unless emerging trends are forestalled and turned around.

1.1 GENDER IN SCIENTIFIC PUBLICATION AND ENTREPRENEURSHIP

In published scholarship, perceptions of gender have changed dramatically over the years. One of our editorial team – Colette Henry – is the Editor of a gender-focused journal, *International Journal of Gender and Entrepreneurship* (IJGE). Since its inception in 2009, IJGE has sought to publish contemporary research that offers the broadest possible conceptualization of gender in the context of entrepreneurship. In Colette Henry's experience, within the discipline of entrepreneurship, research studies have been gradually shifting from the early and extremely popular 'gender as variable' approach, whereby gender was only ever conceptualized as a binary construct, essentially acting as a proxy for biological sex (Cromie, 1987; Zolin et al., 2013). As such, gender was simply added into studies to 'count' women's low levels of participation and highlight their 'under'-performance in new venture creation activities, usually in comparison to men (De Bruin et al., 2007). Such approaches tended to be descriptive, privileging particular business models and sectors where men predominated, as if there was only one way to 'do' entrepreneurship (Ahl, 2006; Marlow, 2002). Little or no attempt was made to explore the reasons behind women's under-representation in entrepreneurship, to highlight the particular challenges that they faced, or to shed light on the stereotypical views and role models that collectively created embedded gender biases and an uneven playing field.

As more female scholars began to conduct research on women's entrepreneurship – and, by extension, on the influence of women's education on their subsequent career choices – more feminist approaches were adopted to critique the status quo and shape a more informed

understanding of the economic landscape women have to negotiate. Previously accepted notions of gender began to be criticized, and the traditional accepted male models no longer remained unchallenged. Feminist standpoint theory and post-structural feminist approaches have emerged as more appropriate theoretical lenses for gender scholars to employ. Such approaches also tend to use a broader and more appropriate definition of gender, defining it as 'social practices and representations associated with femininity or masculinity' (Ahl, 2007, p. 544). Accordingly, research adopting such approaches can be said to study the 'gender order', whereby they analyse both the social and the material implications of gender.

These observed shifts in how gender has been conceptualized over the years within entrepreneurship (Henry et al., 2016) have obvious spillover effects into other areas. If one wishes to study gender effectively, then wider lenses are needed so that its true relational, processual and performative aspects can be seen (Ahl, 2007; Henry et al., 2016). Adopting such a wide lens with regard to academia and, more specifically, science disciplines, not only allows for a fuller understanding of the barriers to women's career progression and the promotional opportunities (or lack of) that exist, but also accommodates a better understanding of the particular context in which they operate. Only with such understanding can we expect to uncover and operationalize opportunities for real change. In this regard, gender-focused publication outlets such as IJGE have a particularly valuable role to play in uncovering and platforming embedded gender biases, sharing experiences, promoting good practice and encouraging those responsible for ensuring gender equality within their universities to take action.

1.2 WOMEN'S EXPERIENCE AS TECHNICAL ENTREPRENEURS AND VENTURE CAPITALISTS

With the notable exception of biotechnology, female entrepreneurs are typically restricted to fields that are presumed appropriate, based on traditional gender prescriptions, with women funnelled into socialization and caring (Whittington and Smith-Doerr, 2005). Thus, in software, one of us – Henry Etzkowitz – has studied and invested in female entrepreneured software start-ups, a field in which, until quite recently, women were tacitly restricted to an education and training ghetto. In this fraught environment, against all odds, often inspired by the needs and interests of their young children, a few achieved breakthrough innovations, with scaling potential. Others created incremental niche firms, sometimes acquired by large firms to fill out their portfolios. For example, Salesforce acquired a female entrepreneur's firm

applying gaming techniques to job training. In this respect, in scope but not scale, women's entrepreneurial experience is not dissimilar to men's: a few truly disruptive firms with take-off potential, and a much larger proportion of incrementally innovative firms, constitute the universe.

Apart from restricted entry into technical entrepreneurship, with the modest exception of training programmes that prepare women to pitch to potential investors, the key point at which the genders diverge is access to venture capital and significant support to scale their firms. For example, consider the experience of a female academic inventor, holding significant patents on the now commonplace graphical user interface, invented to allow her young son – and by extension all preschoolers and non-literate persons without reading skills, and for that matter adults who find it easier to click on visual symbols than type in text strings – to easily interact with computers. Men offered to join the firm as chief executive officer (CEO), but the intrepid female inventor refused to stand down. Intellinet achieved a series of National Science Foundation (NSF) and National Institute of Standards and Technology (NIST) grants but was unable to break into the venture capital arena, despite her acceptance into one of the venture capital (VC) pitch training programmes. Whereas Windows, superseding DOS, was capitalized through Microsoft, 'Pictures' diffused into general use, with Intellinet closing and its founder departing the field of artificial intelligence, having 'burnt out'.

The resistance to women's entry into the venture capital industry, and the concomitant virtual exclusion of female entrepreneurs from funding, came to a head in Silicon Valley a few years ago. Ellen Chao, a former member of a venture capital firm, bravely brought a suit charging discrimination. Although the legal system rejected her specific claim against an individual, the legal process brought to light not only egregious discrimination but also women's virtual absence (with token exceptions, such as Marissa Mayer, CEO of Yelp) from senior positions in the Silicon Valley ecosystem. As it happened, a noted venture capital firm had made it a condition of employment to have been a start-up entrepreneur. This seemingly appropriate requirement virtually ensured women's absence from their macho firm environment due to first order exclusion from the start-up scene. Again, there have been token exceptions, such as Heidi Roizen whose firm, having been acquired by Apple, was eventually allowed into the venture capital industry.

On the other hand, when the organizational environment is encouraging, or at least gender neutral, women appear on the start-up scene in significant numbers. The founder of Stanford University's student government StartX Accelerator noted the high rate of female participation as an unexpected, positive effect of the iconic entrepreneurship training initiative in support of proto-firms (Etzkowitz, 2013).

Silicon Valley is currently grappling with gender, diversity and other social issues that an algorithmically focused recent generation of firm founders had blindsided themselves from recognizing, let alone addressing. Hiding behind a 'hands off' ideology of technological determinism, only positive network effects were expected, with monetization the oft unstated but assumed objective. They ignored the deleterious side-effects of their algorithmic creations and the blithe biases of their actions, until attention was forced upon them. Nevertheless, diversity and gender equity, if not yet equality, is now on the Valley's agenda, thanks to employee protest, litigation and external criticism.

1.3 GENDER IMBALANCE IN COMPUTER SCIENCE: GLOBAL, NATIONAL AND LOCAL PERSPECTIVES

Computer science is a predominantly male discipline (for example, just two of the 26 academic staff and one of the five systems support staff in Birkbeck's Department of Computer Science and Information Systems, in which one of us – Alex Poulovassilis – works, are women). The proportion of women choosing to study computer science at university in the United Kingdom (UK) and US has declined from the 1980s, when it was more than 35 per cent, to less than 20 per cent now. Several studies attribute this to the male orientation of the home computing and games industries starting in the mid-1980s, which were marketed towards boys and encouraged the perception of computing as a 'geek' pursuit and hence a turn-off for girls (Devlin and Hern, 2017). Those women who do enter the profession are often confronted with gender imbalanced work spaces and cultures, giving rise to further reductions in their numbers away from technical career pathways and the so-called 'leaky pipeline' (Simard and Gilmartin, 2010).

There are a number of implications of this gender imbalance: from an employer and innovation perspective, not utilizing the full range of talent, potential and creativity available in the workforce; from a societal perspective, skewing socio-technical debates, products and services towards particular audiences rather than globally for all, having a knock-on effect of further increasing embedded imbalances; and from an individual's perspective, a detrimental effect on personal career choices, development and fulfilment.

A number of actions are being undertaken in the UK, US and Western Europe (the gender imbalance in computer science is by no means a global phenomenon: elsewhere in the world there is much better participation of

women in computer science education and careers). Encouraging more girls to study computing at school – particularly at secondary school, where there may be negative pressures from peers – is of paramount importance. Careful design of early years computing curricula to attract all pupils to the discipline is necessary. Also important is exposure to female role models as early as possible and throughout school; these may be science teachers, alumni or guest lecturers from the tech industry (Cole, 2017).

Looking specifically at academia, a recent analysis of researchers' publication patterns (Elsevier, 2017) identifies 22 per cent of computer science researchers in the European Union (EU), US and UK as being women. This study points to the facts that: (1) women are less likely than men to collaborate internationally on research articles; and (2) women are generally less internationally mobile than men. It notes that if international collaboration occurs less frequently for women, then their international research networks may remain small, and this may negatively affect their career advancement. The same study finds that women publish fewer research papers on average than men, but that there is no evidence that this affects how their papers are cited or downloaded (the same numbers of citations and downloads per paper, on average, as for men). It finds a possible detrimental effect of career breaks on long-term productivity.

There are many ongoing national and global initiatives that aim to encourage more women to study computer science and to enter the profession: BCS Women;[1] ACM-W;[2] yearly celebrations of significant women computer scientists – Ada Lovelace Day,[3] Grace Hopper Celebration,[4] Karen Sparck Jones lecture;[5] initiatives such as CodeFirst:Girls,[6] Women Who Code,[7] and Computing At School,[8] and extensive outreach activities from universities towards schools.

Universities that are succeeding in closing the gender gap on their computing courses, such as Carnegie Mellon University in the US, are doing so through a number of means: changing their culture and environment so that women do not feel so out of place and outnumbered; changing their entry criteria so as not to demand prior advanced study of subjects such as computing, maths or physics in which girls are under-represented at school,

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1 https://bcswomen.bcs.org/.
2 https://women.acm.org/.
3 https://findingada.com/.
4 https://ghc.anitab.org/.
5 https://www.bcs.org/events-home/karen-spaerck-jones-lecture/.
6 https://www.codefirstgirls.org.uk/.
7 https://www.womenwhocode.com/.
8 https://www.computingatschool.org.uk/.

and to incorporate instead the prerequisite material within the early years of their degree programmes; mitigating against implicit bias; promoting the visibility of women and their achievements; and providing extensive mentoring and networking opportunities (Frieze and Quesenberry, 2019).

At Stanford University (where one of us – Henry Etzkowitz – is based), a gender equity initiative reached deeply into undergraduate course content and teaching style, including practical examples of computer usage in teaching, a practice that gender researchers had demonstrated drew women's interest into the field. Instructors also called on members of both genders equally in discussion periods. Observation of teaching showed an apparently scripted active performance style, delivered with well-enunciated phrasing, designed to hold listener interest. Virtual parity in undergraduate enrollment was reached, but there has recently been some backsliding and female enrollment decline in the wake of the programme champion's departure, leaving behind the question of whether Stanford's achievement in gender equality at the undergraduate level has truly been institutionalized. However, Silicon Valley's newly acquired direction towards gender equality is a strong pull factor, drawing both women and men into Stanford's computer science programme, making it by far the university's largest major subject in response to the Valley's ever-growing talent needs.

At Birkbeck's Department of Computer Science and Information Systems, female student intake is at around the UK average for undergraduate studies and a little higher than the UK average for postgraduate studies. There are no significant differences between women's and men's performance on our courses. To close the gender gap, the department has put in place similar initiatives to those reported in Frieze and Quesenberry (2019), including:

- Athena SWAN mentoring activities – the department is a Bronze award holder since May 2018;[9]
- ComputingWomen@BBK initiative, which organizes networking events, peer mentoring and invited talks by distinguished female computer scientists;
- participation in the new Institute of Coding – comprising more than 100 universities and employers – one aim of which is to widen the participation of under-represented groups in digital skills training in the UK;

[9] The Athena SWAN Bronze award is the first positive level of a United Kingdom gender inclusion model developed for academia. Failure to qualify could preclude universities from access to research funds. Higher award levels are Silver and Gold.

- provision of both undergraduate and postgraduate degrees that do not require prior advanced level study of computing, maths or the physical sciences;
- none of our undergraduate degrees require the demonstration of prior aptitude for computer programming;
- at postgraduate level three postgraduate conversion programmes for graduates of other disciplines are offered, two of which do require demonstration of prior aptitude for programming (the MSc in computer science and the MSc in data science) and one of which does not (the MSc in information technology, which also includes some management modules). The proportion of women studying on these programmes is 24 per cent on the MSc CS, 24 per cent on the MSc DS, and 32 per cent on the MSc IT.

From personal experience (Poulovassilis), equitable sharing of parenting, caring, family and household responsibilities is important. For example, a senior UK female computer scientist states, through personal communication, that: 'We are doing well for senior women computer scientists in my department. However, senior women computer scientists do not have children – there are six in my department and none of them have children.' Also important is vocalizing concerns about perceived unfair treatment; this can be with peers and managers not only within one's own department or faculty, but also more broadly. Cross-departmental mentoring programmes help to identify inconsistent institutional practices and to empower people to speak out. It is important for women not to get caught up in an endless spiral of idealized diligence and perfectionism across all areas of one's activity. It is more realistic to choose which activities to expend one's main energies on at a given time, protect one's time to focus on these activities, and be content to be less perfect elsewhere. Having supportive senior colleagues, of either gender, can make a big difference to one's career development. Finally, it is important to network and meet other women within one's own organization and beyond, as there are plenty of inspirational women computer scientists locally, nationally and internationally.

1.4 TRANSFORMING INSTITUTIONS BY GENDERING CONTENTS AND GAINING EQUALITY IN RESEARCH

This book has arisen from the Transforming Institutions by Gendering Contents and Gaining Equality in Research (TRIGGER) project at Birkbeck. Birkbeck was part of a five-country European consortium

championing the role of female academics in scientific subjects (2014–2017).[10] TRIGGER's nine actions were designed to meet three objectives. These were: to identify the nature of and causes underlying gender inequality within Birkbeck, to make recommendations for internal college changes, and to organize a series of interventionist activities.

Actions focused on four broad areas. These were: identifying Birkbeck gender cultures, leadership development, networking for career advancement, and commercialization of academic research. They were designed to bring about transformation in college practices, include leading the college Athena SWAN mentoring programme, organizing workshops on leadership and networking events to promote interactive learning experiences. Video interviews (online), conducted with both college leaders including the President and Master and senior academics, have set the tone of the college's commitment to gender equality. Those with a range of academic and professional staff have provided role models for colleagues at different career stages.

The programme was outward looking, learning from experiences so as to foster gender equality elsewhere. These included TRIGGER partner teams in France, Italy, the Czech Republic and Spain; US, Swedish and Irish higher education institutions; and from the corporate sector, professional bodies and public authorities. Networking events always included academics and practitioners, so that knowledge exchange meant more than the co-presence of people from different organizations at these events.

The research process included data collection through focus groups, surveys and analysis of statistics. It revealed a clear need and demand for improving gender relations. When TRIGGER started, the Athena SWAN process was in its early stages, the college having been awarded bronze status in 2013. Few resources were available to meet commitments made in the Athena SWAN application, including mentoring. Different departments had different habits and values (valuing collaboration or competition, for example, or promoting junior researchers). Gender stereotyping and gendered expectations are still a reality that greatly impacts upon women's experiences. On the practical side, very few opportunities for networking existed, with little support for commercializing research. Of strategic significance to the state of gender relations and prospects for culture change was the dominance of men in key senior positions within the college.

The TRIGGER project provided both resources and strategic thinking. For example, the TRIGGER team became an integral part of the

[10] http://www.bbk.ac.uk/trigger/.

college Athena SWAN Self Assessment Team and the Actions Sub Group which helped to identify and drive practical actions and interventions to support gender equality. TRIGGER's contributions through Athena SWAN helped to shape aspects of the 2017–2023 Birkbeck People Strategy, 'Building Success Together'. This recognizes 'Building Workforce Diversity' as a core strategic aim and includes specific gender equality goals.

The TRIGGER team provided valuable insights as a regular standing item at the College Equalities Committee, and for the College Strategic Equalities Review Group (SERG) as part of the Staff Working Group. SERG findings highlighted the institutional benefits of improving coordination of staff and student equality actions; defined new Equality Objectives; and recommended new structures for the governance and management of equalities. Its recommendation that an appointment be made to support the commercialization of research in the School of Business, Economics and Informatics was accepted.

TRIGGER events have including a facilitated engagement between Birkbeck staff and business leaders on 'Embedding Equality'. They are publicized widely within the college to encourage future job applicants, mentors and mentees, and to disseminate best practice inside and outside of Birkbeck. TRIGGER events complement other college events such as 'Women in Science' in Science Week, and the annual Rosalind Franklin lecture.

Five chapters in this book (2, 5, 6, 7 and 12) and the Foreword directly relate to TRIGGER. The other chapters were invited by the TRIGGER team from colleagues during the course of the project.

1.5 CONCLUSION: A CALL FOR REFLECTION AND ACTION

Our volume is a progress report on the slowdown in the gender revolution in science and its prospect for pick-up. Initiatives from internal academic leadership to change academic cultures to make them inclusive can be effective, for example initiatives in the Molecular Biology Department at the University of Colorado, Boulder; 'family friendly' in the Stanford Chemistry Department; and in Public Health at Johns Hopkins University in Baltimore. On the positive side, Johns Hopkins University has instituted formal recognition of gender imbalances in career progression. A Dean for Diversity sits on every committee in the college, there are an Associate Dean, Office of Women in Science and Medicine, and a Women's Task force. However, in spite of representation at senior levels, these officers

and their actions have been unable to address the gender imbalance in senior positions in academic medicine. The problem is US-wide.

The causes of the problems are not the institutions and policies; rather, it is the long-established practices whereby there has been a resistance to promoting women. This is compounded because there are no women co-chairs of committees who sit on these committees apart from women representing nurses and administrative staff. Missing at Johns Hopkins Hospital is an executive leadership programme for women; helping women to get to the top and function effectively. Hence, as was the focus of the TRIGGER programme, gender equality requires both organizational and cultural change.

The authors of chapters within this volume report that the situation is getting both better and worse. The chapters that follow include a methodological diversity of qualitative and quantitative research styles at different levels of analysis: macro, micro and meso, following the classical biological sciences research design of going one level above and one level below the phenomena to be elucidated. Macro analyses at the societal level – for example, national and multinational gender policies – provide a 'top-down' view both of resistance to gender equity as well as powerful tools to achieve it. Micro analyses at the individual level – for example, individual scientists' gender related discrimination experiences – provide a 'bottom-up' perspective of the struggle to overcome inequalities; while meso analyses at the organizational level reveal the oft disguised fraught gender relations of academic departments, research institutes and firms. The organizational level is thus the 'battleground' research focus of the struggle for equity and equality in science, technology and innovation.

Finally, this diversity of levels and utilization of a range of research tools reflects the selection of relevant theoretical perspectives and identification of good practice in tackling gender inequality within academic science. An international comparative strategy provides research and practical insights into the agenda and practice of tackling gender inequities in academic structures with salient similarities and differences. The chapters in this volume include measures taken within higher education and professional bodies to address institutionalized inequality through the lens of cultures and institutions (Chapters 2–7), how opportunities are created by higher education institutions to support gender equality through, for example, networking and mentoring (Chapters 8–11), and theory, practice and evidence of how gender inequality in universities' 'third stream activities', that of entrepreneurship and innovation, has been addressed by higher education and professional bodies (Chapters 12–18).

As editors, it is our responsibility to take the next step and make infer-

ences on revising academic structures to accommodate women and men who wish to balance family and work, high achievement in research, mentoring the next generation and putting research results to use, whether commercially or philanthropically. This book provides insight into how feminist and gender theories as well as human capital, neo-institutional and entrepreneurship perspectives can be used to understand both the complexity and simplicity of the nature, causes and cures of gender inequality. We trust that the work will provide the reader both with 'Aha' moments of common personal experience recognition, inspiring solidarity, sisterhood and comradeship, as well as clues to strategies and tactics useful to restructure one's scientific, academic or other workplaces.

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