Gender, Climate Change, and the Production of Scientific Knowledge[1]

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Abstract

This chapter builds on research in gender studies and the sociology and history of science to examine the role of men and masculinity in the production of scientific knowledge about climate change. We describe how male domination in science generates gendered assumptions, theories, and research agendas. We review scholarship comparing the representation of women and men in science, show how men's interests shape research questions, and outline the role of men and masculinity in defining what constitutes important scientific knowledge. The chapter concludes by describing how male perspectives, cultures, and interests shape climate science research priorities and prescriptions for the growing global climate change crisis.

Keywords
masculinity; climate change; climate science; gender; scientific knowledge; gender in science

Introduction

At a 1966 University of Chicago symposium, *Man the Hunter*, anthropologists congregated to discuss hunter-gatherer societies and the evolutionary significance of man the hunter. Attendees concluded that human evolution advanced, in part, due to the skills men developed through hunting; these included improved spatial cognition, communication, and cooperation. Modern humans and societies separating man from ape thus could be attributed to the work and progression of men (Washburn and Lancaster 1968; Francis 2004). Feminist anthropologists argued that the symposium's focus on, and conclusions about, men reflected a male bias deeply embedded in scientific research (Sterling 2014). In her essay, 'Woman the Gatherer', Slocum (1975:37) described the 'female perspective' as 'foreign' to anthropology and argued that the 'strong male bias in the questions asked and the interpretations given' impeded the 'full development' of the discipline. She and others argued that male anthropologists' affinity with the hunters blinded them to what the gatherers were doing; in their view, women's activities were incidental to, or simply in support of, the primary work of men.[1]

Anthropology was not unique among the sciences in its emphasis on men, nor its unreflexive embrace of men's interests and perspectives. The association between masculinity and science can be traced to the Enlightenment era. On the heels of the 17th century's Scientific Revolution, the Enlightenment marked an intellectual and cultural shift in the 18th century. Scientific inquiry, empiricism, and common sense came to be emphasised and privileged over traditional religion, dogmatic faith, and superstition (Love 2008). Men were conceived as rational beings, capable of objective reasoning achieved through the intellectual transcendence of the material world (Love 2008; Outram 2019). Women, on the other hand, were assumed to be emotional, inherently nurturing, and tied to the body, all of which made them unfit to pursue scientific inquiry (Sonnert 1995; Bordo 2004; Wagner and Wharton 2019). The result of an exclusively male *Homo Scientificus* was that women were systematically excluded, undermined, and dismissed from the production of scientific knowledge, and women and 'womanly' spheres were deemed of little interest as subjects of study in the centuries that followed (Cattell 1903). The overrepresentation of men in science, in part a legacy of the Enlightenment, contributes to masculinism, i.e., the 'boys' club' atmosphere that often characterises science (Pollack 2015).[2]

Women have, of course, demonstrated their scientific capabilities time and again, but their successes often have been defined as exceptions, and their contributions undervalued or overlooked. In many cases, their names have been buried by history and credited to men. For example, geneticist Nettie Stevens' 1905 discovery that chromosomes determine sex at conception is often credited to Thomas Hunt Morgan, one of her advisors (see Brush 1978); biologist Hilde Mangold's professor, Hans Spemann, named himself first author on her thesis on experimental embryology (after Mangold's death

[1] Published in F. Collyer (ed), Research Handbook on the Sociology of Knowledge (Edward Elgar, 2025).

in 1924, Spemann earned a 1935 Nobel Prize for the work which was known as the 'Spemann organiser'. Nobels are not awarded posthumously. Only recently has Mangold's work been recognised by being renamed the 'Spemann-Mangold organiser' (see Bouwmeester 2001) and recognition for the discovery of nuclear fission was not shared by physicist Lise Meitner: rather, her male collaborator, Otto Hahn, alone was awarded the 1944 Nobel Prize, see Sutton 2018). Perhaps most well-known for being overlooked were the contributions of Rosalind Franklin, the chemist, who furthered our understanding of the structure of DNA. (James Watson and Francis Crick shared the Nobel Prize in 1962 after her death, and until recently, the work was attributed only to Watson and Crick, see Markel 2021).

The women who are recognised for their contributions, physicist and chemist Marie Curie being the most famous example, are often mythologised as exceptions to the rule of male primacy in science. Today, even as many more women are trained as scientists, there is a lingering assumption that 'what makes women good scientists is the extent to which they deny their true selves to think like men' (Jardins 2010:4). Men's networks disadvantage women scientists, whether or not they 'think like men'. For instance, recent research finds that male scientists remain more likely to share their data with male colleagues over female colleagues (Marchant 2017; Massen et al., 2017). In order to more fully understand these gendered biases and assumptions about women and men in science, it is useful to explore the science of sex differences.

Tracing the Science of Sex Differences

In the *Descent of Man* (1871), Charles Darwin posited his theory of sexual selection based on his assumptions about normative male and female behaviour.[3] He argued that sexual selection operated via two mechanisms: male-male competition and female choice. According to this theory, which remains a cornerstone of evolutionary biology today, eager males compete for access to or attention from 'coy' females, who choose the top-performing or most attractive male with which to mate (Gowaty 2003; Ah-King 2007; Roughgarden 2007). The implications for humans are profound: because of pressures to be the best, competition among men results in their evolution into stronger, smarter, superior humans. Because women only give birth, they are not pressured to evolve to the same extent, though their choices are reflected in their offspring. Hrdy (1999) reasons that an important conclusion many scientists drew from Darwin's theory of sexual selection was that women would never be men's equal, because they were less evolved. Milam (2010) and Saini (2017) expand on this line of reasoning, arguing that for Darwin and his male contemporaries – who were influenced by the Victorian gender order of separate spheres – the under-representation of women as doctors and scientists constituted biological proof of women's inferiority.

Although unchallenged by peers who shared his masculinist perspective, Darwin's ideas about gender did not go uncontested by Victorian women and early suffragists. Perhaps the most extensive rebuttal came from Eliza Burt Gamble (1894), a schoolteacher who delivered a scientific counter argument to Darwin's claims. She identified inconsistencies in his explanation of men's superiority, pointed to his contradictions, and made a case for women's significant role in evolution. Gamble's ideas were popular among other suffragists, but because women were marginal in the legitimate production of scientific knowledge, these ideas never entered the scientific mainstream and their challenges have since been described as 'the road not taken' (Saini 2017:22).

Darwin's justification for women's inferior social position set a precedent for the types of questions scientists would go on to ask and how they would seek to answer them. For example, geneticist Angus John Bateman (1948:365) reported an 'undiscriminating eagerness' to mate among male fruit flies and a 'discriminating passivity' among females, which he extrapolated to human behaviour. He concluded that women were more discerning in their selection of sexual partners, while men were naturally promiscuous. These conclusions conveniently aligned with his and many of his contemporaries' beliefs about the relationship between masculinity, femininity and sexuality (Brown et al., 2009). Decades later, sociobiologist Robert Trivers (1972) popularised Bateman's findings in an influential study of parental investment and sexual selection. Trivers offered an evolutionary explanation for gender differences in sexual behaviour, theorising that because women have more to lose if they invest in a 'bad' mate, they are more judicious, opting for quality over quantity. Men, on the other hand, he reasoned, are naturally inclined to increase their number of sexual partners because their level of investment in the reproduction process is slight—representing merely 'a day’s ejaculate' (Saini 2017:123).

The work of Darwin, Bateman, and Trivers gave scientific legitimacy to core cultural assumptions about masculinity and femininity built on notions of men’s sexual virility and women’s sexual reluctance (Browne 2002; Tang-Martinez 2016; Saini 2017). Research on primates, however, has challenged the dominant Darwinian view of females as inherently passive. Primatologist Sarah Blaffer Hrdy’s (1974) studies of Hanuman langur monkeys provide evidence of female collaboration and sexual aggression. She found female langurs to be sexually promiscuous, which she argues is a strategy to confuse paternity and prevent infanticide by adult males. Likewise, in her research on Bonobos, primatologist Amy Parish (1996) observed females soliciting sex outside the mating process, even engaging in sexual activities with each other (see also, Gowaty 2003). Research from women scientists like Hrdy and Parish did little to shift the dominant narrative endorsed by their male colleagues. On the contrary, after the publication of Hrdy’s 1974 research, Trivers 'told a reporter that Hrdy should concentrate on being a mother instead of on her work'; he later reported that he regretted the comment (Saini 2017:99).

The association between masculinity and science has made it difficult for female scientists to gain the respect of their male peers, regardless of the quality of their scientific research. This is due, in part, to the fact that scientific understandings about gender are socially embedded. It is easier for scientists to accept findings that affirm the status quo and ‘prove’ what everyone already believes to be true (Fisher 2011). These confirmation biases not only make it difficult for women to contribute to science, they have consequences for how women are treated by their male colleagues. It is well-documented that women in STEM disciplines experience higher rates of sexual harassment than women in non-STEM areas, especially while doing fieldwork (Gibbons 2014; National Academies of Sciences 2018). It is likely that beliefs about men’s natural sexual promiscuity and women’s presumed docile disposition normalise or even justify the sexual harassment of women. This idea is not far-fetched given these traits have been used to condone men’s infidelity (Symons 1979).

Gender bias and social assumptions about gender are also involved in the production and communication of scientific knowledge. For example, scientific descriptions of the reproductive process often cast sperm in an active, competitive role and depict eggs as passive, receptive vessels (Martin 2014). Richardson (2013) finds that explanations about chromosomes typically gender the X as female and assign X with female attributes, such as 'sociable' and 'motherly'. The Y, on the other hand, is cast as the 'macho' and 'dominant' male chromosome. In popular writing about sex chromosome biology, the X and the Y often are portrayed as a married couple or conceptualised as engaged in a battle of the sexes. In actuality, Richardson argues that 'there is nothing essential about the X and Y in relation to femaleness and maleness’ but framing them in this way draws a clear line between men and women in the otherwise ambiguous context of genetics (2013:6).

Hormones are similarly gendered, with testosterone widely known as the male hormone and source of masculinity, while oestrogen is known as the female hormone. Despite the fact that these hormones are found in both men and women, their discovery was proclaimed to be the 'chemical messengers of masculinity and femininity', and many scientists pursued lines of inquiry designed to show that testosterone-fuelled sex differences drove male superiority (Oudshoorn 1994:7). Research in the first half of the twentieth century operated under the assumption that male hormones produced men and female hormones produced women (Fausto-Sterling 2000; Fisher 2011). The discovery that both hormones were present in both sexes had the potential to '[destabilise] notions of a clear male/female divide' and create an opportunity to challenge dualistic thinking about sex differences, but the challenge was largely ignored (McLaren 2007:200). As far as many scientists are concerned, the male/female binary is real and its origins are biological, and so, despite admonitions to be circumspect in making conclusive claims, researchers have continued to search for a fundamental relationship between hormones and sex differences (e.g., Rippon et al., 2021; Gegenhuber et al., 2022).

Gender Representation and Bias in Science

Although gender biases in science extend into the twenty-first century, contemporary numbers of women in science, technology, engineering and mathematics (STEM) have grown closer to parity with men, though their representation varies by field. In 2020, women comprised 46 percent of biological scientists and 40 percent of chemists and material scientists. Only one-quarter of those working in computer science and mathematics are women, and fewer still (16.5 percent) engineers and architects are women (American Association of University Women 2020). In environmental science and geoscience only one-third are women; as we will discuss below: these are the fields most closely associated with climate change research (American Geosciences Institute 2020).

These percentages reflect a long-standing gender imbalance in the natural sciences and engineering, and raise several questions about the production of scientific knowledge that are the focus of the remainder of this chapter: Does it matter that many of these scientific fields are primarily the domain of men? Does the presence of these mainly male scientists and engineers lead to gendered biases in scientific research? What are the implications of the dominance of men in scientific fields related to climate change?

Investigations into gender bias in scientific research have documented the role of gendered perspectives and interests in determining what questions are asked, which scientific procedures are followed, how the data are analysed, and ultimately, what knowledge is produced. The gender bias being discussed here does not refer simply to discrimination against men or women scientists, although there is a large literature on the unfair treatment of women in science, technology, engineering and mathematics education and employment (Moss-Rascusin et al., 20122 Wadman 2020; UNESCO 2021). The bias under examination in this chapter refers to assumptions about gender that researchers bring to their investigations and professional roles. Such gender biases can be held by men or women, since neither gender is inoculated against the cultural forces that shape gender beliefs and expectations and produce bias in science.

Gender Bias in Technology

We have argued that masculinist gender biases in science have existed throughout history and across disciplines. Scientific inquiries into sex differences often have been informed by 'common sense' knowledge about men and women and tacit assumptions about masculine importance and superiority. The tendency is widespread in the products and thinking of those in many STEM fields to collapse men and women into one category that is represented by man as the standard point of reference for all humans. This standardisation of the male experience is reinforced through the commonplace usage of masculine generic language, where 'man' and 'mankind' are used instead of 'human' and 'humankind' (Stein 2015). For instance, many regulations, technologies, and standards have mainly or exclusively men in mind. Women in the military experience hip fractures more frequently than men because of marching regimens; women carpenters suffer hand and wrist fractures from using tools designed for men; dust, hazard, and eye masks designed for men’s faces don’t fit many women, and male crash-test dummies were used exclusively in the US for auto safety testing until 2011 (Perez 2019).

The twenty-first century’s male-dominated tech industry has continued to design 'universal' products with men in mind and women remain under-represented in the tech workforce (Daub 2021). Smartphones are designed to fit male hands and voice-recognition software responds more accurately to masculine voices. Apple’s health app was marketed as 'comprehensive', but it was missing a menstruation tracker, and when the company’s AI Siri, was introduced to the market, she could locate Viagra suppliers, but not abortion clinics. She could offer support if users stated they had a heart attack, but she did not recognise the phrase 'I was raped' (Perez 2019). These examples illustrate the issues that arise when products meant for universal use are designed by men with other men in mind.

There are gaps in the tech industry for women to fill, but it is harder for female-led start-ups to find investors, which may be attributed to the longstanding belief that men are better at innovation and technology. This difficulty is also related to the fact that most tech-start-ups are funded by venture capitalists, most of whom are men. Women’s innovations reflect a female perspective on consumer needs, which makes the value of their products less evident to male investors. For example, Janica Alvarez struggled to get funding for her tech-start-up for an innovative breast pump. The global breast-pump industry was estimated at USD1.84 billon in 2021 (Grand View Research 2022), but the breast pump dominating the market was uncomfortable and ill-fitted, making it difficult for most women to go hands-free while pumping (Perez 2019). Despite the need for redesign, male investors were not interested in Alvarez's product and her start-up shut down due to lack of funding in 2019 (Farr 2019). In contrast, Willow, a start-up run by men offering breast pumps, received significant investment (Shieber 2020).

Gender and Medical and Pharmaceutical Sciences

Perhaps the most well-known cases of gender bias can be found in medical and pharmaceutical research where male bodies have been standardised as the 'human' model, and where research agendas are informed by masculine interests. There is a large body of research on the medical and pharmaceutical sciences showing that gender matters in the conduct of science. Treatment for depression is one example of how gender matters in medicine. Only half as many men as women are diagnosed with major depression, but men are four times more likely to commit suicide and twice as likely to abuse drugs and alcohol. Since suicide and substance abuse are often associated with depression, researchers reviewing these data conclude that stereotypes of 'typical' masculinity and 'normal' male behaviour tend to make both patients and clinicians (male or female) less likely to recognise depression among men (National Institute of Mental Health 2017; Swetlitz 2021). In medicine, gender bias surfaces in research that asks scientific questions about men's health to the exclusion of questions about women's health and includes mainly male subjects on the safety and efficacy of treatments. Drugs and protocols, then, are designed based on knowledge about their usefulness for men, but not women. Ultimately, recommendations for all patients are based on research conducted primarily on men.

The origins of the gender bias of medical science can be attributed to several factors: the scientific adoption of the male model as the universal human model; the tendency of mainly male researchers to identify the important questions and design the studies and treatments for diseases and conditions in which they are personally interested as men; male pharmaceutical corporation executives, scientists, and politicians who direct funding for research into conditions and diseases that they believe affects them as men; and unexamined attitudes held by both male and female medical professionals about which diseases are more likely to affect men or women.

One of the more notorious examples of gender bias in medical science and practice involves research and treatment of heart disease. Although cardiac disease is the leading killer of women, historically it has been viewed as primarily a man's disease. In the late 1980s researchers began documenting gender disparities in heart disease diagnosis and care, noting that women's risk of cardiovascular disease had long been ignored despite the fact that myocardial infarction is the primary cause of death for women who are more than 40 years of age, and women's risk of dying during the first two weeks after a heart attack is double that of men. Cardiovascular disease kills roughly the same proportions of men and women, however, clinical studies historically used men as subjects, and so much of what is known currently about diagnosing and treating coronary heart disease is known from studies about men (Beery 1995; *Lancet* 2019).

The major reasons for women's higher death rates from heart attack include late diagnosis (neither patients nor their doctors expect women to have heart problems); unsuitability of diagnostic instruments for women's bodies (smaller blood vessels made cannulation difficult); less aggressive treatment for women diagnosed with heart attacks (later angioplasties and fewer pacemakers and heart transplantations); and limited knowledge of the effects of various treatments on women since most cardiac research on treatment and drugs is conducted on men (Ruiz and Verbrugge 1997; Brazil 2020). Despite recognition of women's higher death rates resulting from inadequate treatment for heart disease, the gender disparities have persisted into the present. In the mid-2000s, leading medical journals noted the continuing gender gap in cardiac care by tracking differences in referral rates for cardiac catheterisation of men (40 percent) and women (4 percent), and although this gap narrowed in the 2010s, in 2021, the difference in catheterisation between men (10.4 percent) and women (4.9 percent) has persisted - as did the differences in stent placement (2.1 percent of men and 0.7 percent of women with similar rates of chest pain and cardiac stress test outcomes) (Vaccarino 2006; Steenblik et al., 2021).

These and other gender disparities in US healthcare have been recognised by members of Congress. In 1994 the National Institutes of Health issued guidelines for the inclusion of women and minorities as subjects in clinical research to address gender disparities in the federal funding of medical testing, research and clinical trials (National Institutes of Health 1994). Three years later, in response to reports of insurance companies refusing to pay for hospital stays following breast surgery, requiring instead so-called 'drive-through mastectomies', Connecticut Representative Rosa DeLauro sponsored H.R. 135, The Breast Cancer Patient Protection Act of 1997, to require medical managed-care programs to allow women to stay in hospital for up to two days after a mastectomy. The bill did not pass Congress, and has been reintroduced multiple times, most recently in 2017 when it was again referred to Committee (US Congress 2017).

Efforts to advance gender parity in the science associated with women's health have led to increased inclusion of women in clinical trials and treatment protocol research, expanded funding for investigations of diseases affecting primarily women, like breast cancer, and broadened awareness of gender inequality in medical science and practice. That researchers continue to find gender biases in pharmaceutical trials, medical research and medical treatments illustrates how difficult it is to change deep-seated gendered assumptions about women and men—what kinds of likely diseases each faces, the importance of early diagnoses, or types of appropriate treatment for each (Bird et al., 2014; Mirin 2020).

Masculinity, Femininity and Reproductive Medicine

There is an exception to the male standard rule in medical science. Since its institutionalisation, reproductive medicine has been focused on women who have always been associated with and held accountable for all aspects of reproduction, including contraception and fertility. Infertility refers to a couple's inability to conceive after a year of having unprotected sex, and it is no more common in women than in men. Still, it is often framed as a 'woman's issue' and treatments are female focused to the extent that 'male infertility gets repaired in female bodies' (Barnes 2014:29). For example, Clomiphene is a drug prescribed to a woman to increase ovulation when her male partner has a low sperm count. The assumption is that more eggs will increase the likelihood of a sperm hitting the target. Although this drug has also been found to increase men's sperm count, it has not been approved by the FDA to be used for this purpose (Margarelli 2021). One way to understand the logic of treating women for men's low sperm count is to acknowledge the intimate link between manhood and sexual competency – to question a man's ability to impregnate a woman can be seen as a threat to masculine identity – better to treat the woman than the man and avoid acknowledgement of his deficiencies.

During sexual activity, a man's ability to penetrate represents important symbolic proof of his ability to reproduce, which is illustrated best by early medical assessments of male fertility. In 1970, when urology was still in its infancy, assessments of male fertility were based on a two-question survey that asked men whether they could sustain an erection and if they could ejaculate. If a man answered yes to both questions, he was considered fertile, which meant any issues with conception were his wife's problem (Barnes 2014). If he answered no, then he could be considered impotent, a condition which was difficult to treat. While male infertility may have been relatively understudied compared to female infertility, impotence, with its immense symbolic baggage, has received an abundance of attention.

Prior to its medicalisation in the late-1990s, impotence was considered a psychological problem that was often attributed to women's failure to appropriately perform femininity. Aggressive suffragists; sexually liberated feminists; career women who challenge their husbands' breadwinner identities; women who fail to reach orgasm; women with low sexual desire; or women suffering from vaginismus (which could make penetration difficult for men), have all been offered as impediments to men's inability to perform masculinity successfully (Greenstein et al., 2006; McLaren 2007).

With the introduction of the pharmaceutical product Viagra (sildenafil), and subsequent reclassification of impotence as 'erectile dysfunction'; a man's inability to penetrate was no longer a masculinity problem – rather, it became a medical problem that could be treated with a little blue pill. Sildenafil was developed as a drug to increase blood flow to the heart, but when test subjects experienced erections as a side effect, they reportedly refused to return any remaining pills. Soon after, sildenafil was being researched as a treatment for impotence, and it wasn't long before it hit the market as Viagra and 'became the fastest selling pharmaceutical in history' (McLaren 2007:242). The fact that a new medical condition (erectile dysfunction) was classified to legitimise Viagra as a medical treatment illustrates how men's interests and anxieties inform medicine.

This gender bias is also evident in the differential official treatment of Viagra and contraceptives. It took forty years for the Japanese government to approve the birth control pill, but only six months to approve Viagra (McLaren 2007). In the US, Viagra has long been covered by health insurance plans because it is a medical treatment for a medical disorder. Contraceptives, on the other hand, have been argued to be 'lifestyle drugs' that are medically unnecessary, which means they are not covered by all insurance plans (Chen 2016). It is worth noting that Viagra is not a fertility treatment, and it does not increase sperm count or quality. It does, however, solve the problem of poor penetration. Although erectile dysfunction has been labelled a medical condition, Viagra could be considered a 'lifestyle drug' that helps men get erections on demand to improve men's sexual satisfaction and self-esteem. Sex researchers have long argued that with regard to orgasm, most women prefer clitoral stimulation to penetration (Masters and Johnson 1966; Kontula and Miettinen 2016). So, McLaren asks in his cultural history of impotence, 'Who were the erections for?' He argues that 'a man feared impotence, not so much because it might deprive him of pleasure, but because it would prevent him from providing proof that he could perform as a male should' (2007:xiii). Thus, as Loe (2001) notes, by restoring erections, Viagra was restoring masculinity.

Gender Representation and Bias in Environmental and Climate Science

If gender matters in *some* medical research, does it matter in *all* medical research, or in *all* scientific research? The feminist critique of science can be summarised as follows: male scientists put their own personal concerns (e.g., focus on diseases thought mainly to affect men) above the pursuit of general scientific knowledge; scientific values and priorities are shaped by masculine cultural perspectives and values; masculine cultural systems assert man's dominion over the natural world, define many features of nature as problems to be controlled, if not solved, and view understanding nature as the first step in conquering nature. Ecofeminist and men's studies researchers point to the historical power of institutionalised masculinity (in science, politics, commerce, and the military) to shape environmental science.[4] This research further defines masculinity-driven environmental science's 1) campaign to control nature, 2) tendency to define environmental problems as 'threats', 3) infatuation with large-scale, militarised solutions to environmental problems, and 4) pursuit of an aspect of science that ignores or minimises human dimensions (Longino 1987; Allison 2010; Pease 2019; Rivers 2019; Oreskes 2020). Each of these masculine features of environmental science is discussed in the sections below.

Masculine Campaign to Control Nature

The use of science to harness and control nature can be most easily observed in commerce, disease, and warfare. Controversies surrounding the chemical and pharmaceutical industries are quite illustrative. The publication of *Silent Spring* in 1962 by Rachel Carson, credited with launching the modern environmental movement, was a pointed indictment of the chemical industry's assault on 'pests' (Lear 1993). Carson intended *Silent Spring* to sound an alarm about the dangers associated with the widespread use of chemicals, in particular the pesticide DDT, used across the US after the Second World War. She did not advocate the elimination of insecticides and other chemicals, but called for a retreat from what she saw as chemical science's wholesale war on nature:

> All this is not to say there is no insect problem and no need of control. I am saying, rather, that control must be geared to realities, not to mythical situations, and that the methods employed must be such that they do not destroy us along with the insects (Carson 1962:9).

This analysis made Carson a target of the chemical industry, which demanded, 'Silence, Miss Carson', and editorialised in *Science* that her work made 'emotional appeals [that] tend to over-balance sound judgment based on facts' (Darby 1962; Baldwin 1962). This gendered indictment was illustrated by a depiction of Carson as a witch on the cover of *Farm Chemicals*, a trade publication in 1963 (Hazlett 2004).

The critique of industrial chemistry by environmental historians has extended decades beyond *Silent Spring*. Russell (2001) traced the rise of the modern US chemical industry to its role in World War I and beyond, when the US overtook Germany in the global chemistry trade. Numerous scholarly studies have documented the role of scientists in efforts to enlist or control nature, especially during wars, in a variety of scientific and technical fields. These studies describe the militarisation of virtually all areas of the natural and social sciences, and include research on the role of physics to invent, test, and produce nuclear weapons; oceanography and marine science to map the ocean floor and train marine mammals; meteorology to predict and control weather; microbiology to develop and test biological weapons; various fields of engineering (e.g., electrical, mechanical, aero-astro) to develop radar systems, aircraft, rockets, satellites, geography to produce maps and topographic models; psychology to assist in assessment, interrogation, and torture; and anthropology to provide cultural information for military campaigns (Hamblin 2005; Guillemin 2006; Baggott 2009; Palka 2011; Fleming 2012; Blue et al., 2013; Parker 2014; Kassel 2015; Stuewer 2018; Eldelson 2019).

There are two important points to be drawn from this catalogue of male-domination in science's involvement in warfare. First is the affinity between masculinity and war; and second is the implication of this affinity for climate science. Researchers have documented the cultural resonance between masculinity and nationalism (Enloe 1990; Nagel 1998; Anderson and Wendt 2015). The culture of nationalism resonates with the culture of masculinity. Terms like honour, patriotism, cowardice, bravery, and duty are hard to distinguish as either nationalistic or masculine since they seem so thoroughly tied both to the nation and to manhood. Women are less likely to be moved by such themes, but they have a role to play in militarised nationalism since they often are cast in supporting roles as symbolic or real assets to be honoured and defended. Given men's domination of science, it is not surprising that the cultural connections between masculinity and militarism can be discerned in many scientific priorities and projects, including climate science. The militarisation of climate science is especially evident in the view of climate change as a series of 'threats' and in large-scale geoengineering solutions to the climate problem.

Climate Change as a National Threat

In the two decades since the terrorist attacks on the US World Trade Centre and Pentagon, the rhetoric of security has come to dominate longstanding problems. 'Famine' has become 'food insecurity' and 'drought' has become 'water insecurity'; concerns about energy or diseases have become issues of 'energy security' and 'health security'. Environmental matters similarly have been 'securitised' as 'threats' to be defended against, not simply problems to be solved. The US military has an important place in this redefinition of environmental problems given its central mission is national security and in light of the vulnerability of military installations and missions to climate change.

In 2021, the US Department of Defence (2021a:2) issued its 'climate risk analysis':

> Climate change is reshaping the geostrategic, operational, and tactical environments with significant implications for US national security and defence. Increasing temperatures; changing precipitation patterns; and more frequent, intense, and unpredictable extreme weather conditions caused by climate change are exacerbating existing risks and creating new security challenges for US interests.

Although the US Department of Defence (2021b:3) acknowledged that the risks associated with climate change were not new, they were defined as a 'threat multiplier' on several fronts including threats to troop functions and readiness, military installations and supply chains, national borders, international agreements and geopolitical stability. More specific threats included those arising from instability caused by increased competition over resources; potential for intra- and international climate-related migration; disruption of food and water production and delivery systems; and the emergence and spread of pests and diseases (US Army 2019).

The threats of climate change are real and not limited to military institutions and operations, nor are they limited to national security – a proper province of the military. The emphasis on threat, however, tends to move the focus away from the main causes of climate change, i.e., increases in atmospheric greenhouse gases from fossil fuel production and consumption. Threats tend to cause reactive rather than proactive solutions. Ironically, military efforts to respond to the threats *from* (not *of*) climate change, contributes to the problem since military mobilisation to defend against threats generates more emissions and more environmental damage (McCarthy 2019). The US military's campaign to be 'greener' is widely criticised as either dangerous or an effort at 'greenwashing' a carbon intensive institution (Weinstein 2013; Clark and Williams 2021).

Militarised responses to climate change are not limited to the military as an institution. Various US governmental agencies with defence missions (e.g., Department of Defence, Department of Energy, Department of Homeland Security, National Aeronautics and Space Administration) have large budgets for funding basic scientific research (in addition to their weapons and war-related research budgets). These funds far exceed less security-oriented agencies such as the National Science Foundation (American Association for the Advancement of Science 2021). Defence-related research funding is an important mechanism for understanding the militarisation of science, including climate science (see Oreskes 2020).

Large-Scale, Militarised Solutions to Environmental Problems

Greenhouse gas emissions are widely identified as the primary causal agents of climate change, however, reducing emissions is rarely found at the top of the military agenda. Efforts to green military operations are generally pursued as cost-saving measures, and less critical to military operations than hardening installations and troops against the impacts of climate change (Eversden 2021). In addition to the search for environmental and climate-change generated enemies and ways to defend against them, there are two areas which reflect the masculine infatuation of many climate scientists with large-scale militarised solutions to environmental problems including climate change: geoengineering and global climate modelling. Although these two approaches represent a small fraction of all climate science, they are most illustrative of approaches requiring massive resources, advanced technologies and elite knowledge.

Geoengineering is 'the deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change' (Philosophical Transactions of the Royal Society 2009:ix). Analysts typically divide geoengineering approaches into two categories: Carbon Dioxide Removal (CDR) techniques which eliminate CO_2 from the atmosphere, and Solar Radiation Management (SRM) techniques that reflect a small percentage of the sun's light and heat back into space. In 2015, the US National Academies of Science issued two major reports on geoengineering as a means to slow climate change (National Academies of Sciences 2015a, 2015b). These reports were followed in 2021 by a second report on 'solar geoengineering' which explored and more strongly recommended that 'given the urgency of climate change concerns… the US federal government should establish… a transdisciplinary, solar geoengineering research program' (National Academies of Sciences 2021:8).

Carbon Dioxide Removal (CDR) projects tend not to be large-scale, planetary-wide efforts at geoengineering, and thus have a less militarised face. CDR projects are not always high-tech (e.g., planting more forests to absorb carbon dioxide), although many approaches require advanced engineering solutions. For instance, the US Department of Energy funds a variety of research and demonstration projects on underground carbon sequestration (pumping carbon dioxide into underground reservoirs or geological formations) involving collaboration between national labs and university researchers (US Department of Energy 2021). The safety and efficacy of sequestering large amounts of carbon on the scale needed to reduce CO_2 emissions remain both unclear and controversial, though the projects continue to be funded (Asayama 2021).

Unlike CDR, projects designed to manage solar radiation typically demand larger-scale military-style approaches. Among the more extravagant SRM proposals are those from physicist Lowell Wood, who advocates shooting sulphate or nanoparticles into the Arctic atmosphere with aircraft continuously circumnavigating the Arctic; a 25-kilometer sky hose hooked up to a military super blimp, or large artillery pieces – a technique that Fleming (2007:48) described as 'basically declaring war on the stratosphere'. Another grand military-scale solar radiation management project, this one suggested by astronomer Roger Angel, involves positioning space mirrors 'cooling the earth with a cloud of [trillions of] small spacecraft' that would be launched to 'form a long, cylindrical cloud with a diameter about half that of Earth, and about 10 times longer… to uniformly reduce sunlight by about two percent over the entire planet' (*Science Daily* 2006; Angel 2006).

The arrogance and recklessness of these schemes is not characteristic of all geoengineering proposals, nor were these projects typical of those considered worthy of exploration in the National Academies of

Sciences 2021 report. The National Academies of Sciences (2021:7) recommended that solar geoengineers include research governance and 'exit ramps' on all research projects. One example of ongoing geoengineering efforts is Harvard University's Solar Geoengineering Research Program which includes several theoretical and experimental projects to study the effects of atmospheric and stratospheric aerosols on climate; another example is the work of US National Oceanic and Atmospheric Administration scientists to simulate the effects of 'climate interventions' such as solar aerosol injection (Harvard University 2022; US National Oceanic and Atmospheric Administration 2022).

Disinterest in the Human Dimensions of Climate Change

Although the National Academies of Sciences (2021:151) references the 'human dimensions' in its solar geoengineering report, in light of the technical challenges associated with this field, the social aspects of solar geoengineering are not a central concern of researchers. Climate science disinterest in the human dimensions of climate change can be attributed to the attractiveness and high status of projects that emphasise highly technical methodologies, pursue major environmental control objectives, and appeal to military-related funding agencies. The very methodologies most valued and employed by climate scientists tend to render humans invisible. This is especially the case with large-scale research approaches like global climate models.

Critics have faulted the research findings of the Intergovernmental Panel on Climate Change (IPCC) because of its reliance on global-scale general circulation models (GCMs). For instance, feminist scholars argue that much science reflects a classically masculine approach which minimises knowledge gained from human lived experience in favour of abstract representations of reality (Haraway 1988; Harding 1991; Litfin1997). Climate justice critics fault GCMs for their tendency to overlook differences among populations in favour of generalised projections (O'Lear 2016).[5]

Although GCMs are acknowledged by their designers to be complex, inaccurate and incomplete representations of the actual global climate system, they are the backbone of the IPCC's Assessment Reports (ARs) issued every several years, most recently AR6 in 2021-2023. These reports are relied on by researchers and governments around the world to gauge the impact of climate change on the planet and negotiate agreements to limit carbon emissions. The climate models used by the IPCC and other climate researchers rest on the prestige of their mainly male designers (prominent scientists and engineers); the widely inaccessible advanced technology used to create them (supercomputers); recondite technical language (Navier-Stokes equations and computationally intensive numerical models); and the elevated status of the institutions where they are refined and tested (national laboratories, scientific agencies, leading universities) (e.g., Palmer 2020). Critics have maintained that the agenda and priorities of climate science reflect the personal and career interests of predominantly male climate scientists and their elitist institutional affiliations (Beck and Forsyth 2015; Barkemeyer et al., 2016). They note that climate researchers' highly technical findings are inaccessible to non-specialists, especially those whose interests and perspectives are seldom represented in scientific labs. Critics argue that the importance of this work makes it all the more essential to point out omissions in IPCC reports, particularly in the area of climate justice, and especially with regard to gender, racial and national inequalities related to climate change.

The fascination of climate scientists and engineers with large-scale models of, and complex solutions to, global climate change, is not surprising given the technical challenges of both. The challenges of these approaches, however, leave little room for grappling with the social aspects of either their approaches or the general problem of climate change. The dominance of these approaches has contributed to a failure to include the human dimensions of climate change within the United Nations Framework Convention on Climate Change (UNFCCC) and its affiliated IPCC because of the over-representation of mainly male climate scientists among their ranks. This omission has become a source of commentary and protest around the world (Brault 2017; Corry and Reiner 2020).

The UNFCCC's annual Conference of the Parties (COP) meetings of the world's climate change leaders and researchers have become sites not only for sharing scientific results and negotiating policy agreements, but for protests by many organisations concerned with the exclusion of social justice matters from climate change considerations. In 2008, the feminist interest group GenderCC – Women for Climate Justice was organised to publicise the connection between climate change and women's inequality. Their slogan was 'No Climate Justice without Gender Justice!' GenderCC and various research groups documented the low representation of women on IPCC scientific committees and at COP meetings. Their protests are justified: researchers have found that women's authorship on IPCC reports has ranged from less than five percent in 1990 to only around 20 percent in 2018. Similarly, women's presence at annual COP meetings has ranged from a low of around 15 percent in 1997 to 28 percent in 2003; women's representation at COP26 in Glasgow in 2021 had only advanced slightly and remained considerably lower than men's at 30 percent (Chiu 2021; UNFCCC 2021).

Conclusion

The presence of women in climate science and policy meetings does not guarantee a focus on the human dimensions of climate change. Women researchers and activists do, however, reflect women's ongoing concerns about inequality, justice, and social welfare. Researchers find consistent differences between men and women on climate change issues and the kinds of questions they ask. Gender differences include women's greater interest in health risks associated with environmental problems, likelihood of believing that global warming is occurring and is human caused, support for regulating carbon dioxide as a pollutant, concern about the impact of global warming on both the US and other countries, particularly developing countries, and recognition of the potential impact of climate change on future generations (Ballew et al., 2018). The longstanding male dominance of the natural science fields and the institutionalisation of masculine perspectives in climate science and policy will be difficult to disrupt. An important step toward exposing and contesting masculinist assumptions and militarised responses to climate change is to include both women and men in research on climate change, and to include considerations of gender in all environmental research.

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Endnotes

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[1] Most of our examples are drawn from US and European cases and reflect our US research backgrounds. Although we do not discuss other studies in detail, researchers have identified similar patterns regarding the under-representation of women in STEM research in Russia (Antoshchuk 2021), Japan (Yoshikawa et al., 2018), China (Yang and Gao 2021; Chan 2022), Australia (Broadley 2015), Taiwan, and South Africa (Ro et al., 2021).

[2] 'Masculinism' is defined as the advocacy of male superiority and should be distinguished from 'masculinity' which refers to the characteristics, cultures, interests, and organisations associatedexclusively with men.

[3] 'Sexual selection' is distinguished from 'natural selection' in part due to the 'female choice' component of the former, see Gayon 2010; Hoskin and House 2011).

[4] Climate science 'aims to explain and predict the workings of a global climate system' (Parker 2018:n.p.) and is part of the larger field of environmental science. Anthropogenic climate change and advances in computing technology contributed to the emergence of climate science, which draws 'from a variety of domains, including meteorology, oceanography, physics, chemistry and more' (Parker 2018:n.p.). As such, our discussions of areas such as geo-engineering and climate change research and policy fall under the domain of climate science.

[5] In contrast to feminist scholars, climate change skeptics criticise GCMs claiming their predictions are 'alarmist' social constructions that generate 'phantom threats' designed to satisfy environmental pressure groups and to promote scientists' self-interest in fame and funding (Singer 1992; Henderson and Hooper 2017).