A Sociotechnical Analysis of Gender Bias in Biomedicine

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Abstract

Every drug approved by the FDA prior to 1994 has only been tested in male cell lines, male animal models, and even male clinical trial participants. Because researchers believed that studying females would add variability to their data, women have been left out of the medical narrative from the very beginning of the research process, creating a major knowledge gap that leaves women's health conditions understudied and thus insufficiently treated. Furthermore, gender bias in the venture capital community creates additional barriers for market translation of women's health solutions despite the rise of femtech innovation. Therefore, this paper uses the STS framework of co-production to analyze the relationship between biomedicine and society through recent decades to highlight how gender bias has shaped biomedical research, scientific understanding, and the treatment of women in healthcare. The central research question, what are the sociotechnical implications of gender bias in biomedicine, is answered through the employment of historical case analysis, documentary research methods, and wicked problem framing to reveal the barriers preventing femtech from remedying such disparities. Therefore, in the context of co-production, a cultural shift in gendered power dynamics is critical to overturn the pervasive androcentrism in the biomedical research process and thus restructure the system to adequately address women's health needs.

A Sociotechnical Analysis of Gender Bias in Biomedicine

Understanding the Knowledge Gap

"We literally know less about every aspect of female biology compared to male biology" (Dusenbery, 2018). In this statement, Dr. Janine Austin Clayton, associate director for women's health research at the U.S. National Institutes of Health (NIH), references the major knowledge gap in scientific research created as a result of gender bias in the medical system. From the very beginning of the research process, women are left out of the medical narrative, as investigators overwhelmingly use male cells and animals in preclinical studies to avoid adding "variability" to their data (Lee, 2018). The problem continues as research progresses to the clinical trial stage, where women remain underrepresented, results are not analyzed by gender, and hormonal cycles are often entirely ignored (Dusenbery, 2018; Liu & Mager, 2016). Furthermore, conditions that disproportionately affect women are left understudied, and women are treated poorly in the healthcare system as a result (Jackson, 2019). Although historically, women have lived longer than men, these extra years of life expectancy are often filled with debilitating health conditions, an alarming phenomenon known as the "gender paradox." Recent changes in policy and scientific inquiry demonstrate awareness of this situation, and startups developing technologies for female health are beginning to emerge; however, these "femtech" ventures still only make up 3% of digital health care as investors in the male-dominated venture capital community often fail to recognize their value (Das, 2019).

An analysis of the relationship between women's health and society throughout the 20th century and recent decades will highlight how gender bias has shaped biomedical research, scientific understanding, and treatment of women in the healthcare system. As further grant money is allotted to employ the use of female animal models, female clinical trial inclusion

continues to improve, and the femtech industry begins to attract investor attention, there is increasing importance to unveil the underlying forces driving the gender-based knowledge gap in biomedical research. In order to explore the evolution of these scientific ideas, beliefs, and technological artifacts in a way that reveals their practical meaning in society, this issue is viewed through the theoretical lens of co-production. Therefore, the following research question is addressed: what are the sociotechnical implications of gender bias in biomedicine?

Research Question and Methods

The central question of this research paper is: what are the sociotechnical implications of gender bias in biomedicine? This research utilizes the STS framework of co-production by Sheila Jasanoff to identify how gender bias impacts the development of female health innovation to remedy disparities in the healthcare system. This thesis is organized in three main sections. First, historical case analysis is used to establish the role of gender bias in the creation of the knowledge gap in biomedical research. This section includes the gathering and organization of the past events that have shaped this narrative, drawing upon comprehensive texts regarding the history of women's health. Next, documentary research methods are used to demonstrate the impact that this knowledge gap has on women's healthcare outcomes. Evidence collected by this research includes research studies on the disparate health conditions affecting women due to biased research practices. The primary collection methods are primary literature and online articles found by searching keywords such as gender bias, biomedical research, women's health, research gap, femtech, and co-production.

The final section draws upon some of this documentary research to reveal the barriers faced by innovators in the femtech industry, but finishes with analysis based on wicked problem framing. This method is used to gather and assemble evidence in a way that reveals indirect and

hidden connections between symptoms and root causes of this complex and dynamic issue. In this thesis, wicked problem framing acts as a way to support the organization and reinterpretation of the issue of gender bias in biomedicine, a problem that appears amenable to technical solutions such as policy implementation and femtech innovation, yet remains unsolved despite recent efforts. Therefore, the employment of these methods is used to reveal key insights into the relationship between gender bias and biomedicine in the United States and ultimately draw the conclusion of this paper.

Understanding the History of Gender Bias in Biomedicine

The History Behind the Knowledge Gap

Between 1997 and 2000, 10 drugs were withdrawn from the market due to adverse health effects. In four of the eight which posed higher risks for women than in men, the risk was likely due to physiological differences, an issue that experts attribute to the lack of adequate preclinical testing in female animal models (Wald & Wu, 2010). A study in the late eighties found that only 13.5% of the NIH's most recent budget had gone toward research on conditions "that are unique to or most prevalent or serious in women, have distinct causes of manifest themselves differently in women, or have different outcomes or interventions." This was an extensive list including reproductive health concerns in addition to breast and gynecological cancers, Alzheimer's disease, depression, osteoporosis, and autoimmune disease (Dusenbery, 2018). It was not until this time, now that women made up a critical mass of those within the medical community, that they were in a position to call attention to the way the medical knowledge that had been accumulating over the course of the twentieth century was disproportionately benefitting men. The explosion of biomedical research in the 1990s further highlighted this issue and the way that the medical community had failed to correct it. In 1990, the NIH formed the Office of Research

on Women's Health (ORWH), releasing a statement in 1991 that discusses the way that many of the health issues concerning women are of secondary importance in the research community, especially those that solely affect women and those that occur in both sexes but have already been studied in men. Shortly after, Women's Health Initiative was launched to "make up for lost time in one fell swoop", enrolling about 161,000 women for a long-term study on cardiovascular disease, cancer, and osteoporosis (Berg et al., 2013). Despite many of these steps taken, overwhelming biases continued to persist.

In 2014, the NIH announced that despite their efforts, there had been no progress to correct the male bias in preclinical research in the past twenty years, acknowledging that "the overreliance on male animals and cells in preclinical research obscures key sex differences that could guide clinical studies." As a result, they claimed that they would begin requiring all researchers seeking funding to report their plans to balance the use of male and female cells and animals, unless there was a sufficient reason not to. However, this promise only manifested in the requirement that researchers "consider sex as a biological variable", without outlining any specific metrics for analysis. Furthermore, this policy only applied to preclinical research on vertebrate animals and humans, excluding the study of cells and tissues. In 2015, women's health researchers further validated this observation, concluding that despite some important steps, "progress had been painfully slow – stalling for long periods of sometimes reversing direction"; clearly, not nearly enough change has been made (Dusenbery, 2018).

In recent years, female health start-ups have begun to fill the gaps and address unmet needs in diseases, conditions, and indications that solely, predominantly, or differently impact women. The term 'femtech' was coined in 2016 by Ida Tin, founder of Clue, a period tracking app, to fuel the culture shift towards de-stigmatization of women's issues and spark

conversations about the companies dedicated to women's health and research (Dodgson, 2020). Today, femtech is defined as technology, services, and products that improve women and girls' health and wellness. The industry includes areas that affect women solely, such as reproductive and menstrual health, areas that affect women differently, like sexual and pelvic/uterine health, as well as areas that affect women disproportionately, such as bone health, oncology, autoimmune, and brain health. While these products may aid research by collecting data on women's health, there are some privacy and data security concerns since many mobile femtech applications rely on users' personal health information (Lu, 2019). With access to such private information, there is the possibility that these technologies will become pervasive and lucrative marketing tools, thus commodifying women rather than solving the pertinent issues in the healthcare system. As Eileen Hoffman, a gynecologist at New York University, describes, "we have to be careful that we don't turn ourselves into profit centers" (Laurence & Weinhouse, 1997). Despite such objections, the femtech industry holds immense potential to provide technical solutions to many of the health disparities affecting women. In 2019 alone, the global femtech market generated $820.6 million and is predicted to reach at least $3 billion by 2030 (Ravid & Tobey, 2020). This thesis explores the factors limiting the scope of femtech's impact, including the research gaps that continues to persist despite policy attempts to encourage sex-specific analysis and the reallocation of funding towards women's health innovation. Additionally, the gender bias pervading other aspects of the startup experience such as the male-dominated venture capital scene and the stigmatization of female health conditions in the media also prevent widespread adoption of femtech solutions.

The presence of gender bias at every stage of the biomedical innovation process is evident as the negligence of many women's health issues continues to persist. Though there has

been extensive research on these issues at the preclinical and clinical levels, an evaluation of the intersections of these issues with the femtech industry has yet to be done.

Co-Production and Gender Bias in Biomedicine

Women comprise more than half of the U.S. population, yet for centuries their health needs have been relegated to second place (World Bank, 2019). From the advent of modern medicine, the paradigm of the 70-kilogram male as the basis of research has left women's issues neglected if not exacerbated. Thus, the androcentric construction of biomedicine is a topic that feminist STS scholars, women's health advocates, and women scientists have taken a variety of approaches to examine (Pape, 2021). The framework selected for this paper is co-production, an analytical lens developed by Sheila Jasanoff, a scholar in the field of Science and Technology Studies (STS). The central premise of co-production is the idea that the ordering of 'nature' through science and technology is inseparable from the ordering of society through political power and culture. In *States of Knowledge*, Jasanoff further describes the ever-changing nature of this relationship and the boundary between them due to the emergence of 'new facts, things, and systems of thought' (Jasanoff, 2004). Thus, this paper utilizes co-production to examine the relationship between gender bias and women's health as female empowerment changes the landscape of biomedicine in the United States. Co-production demonstrates how scientific ideas, beliefs, and associated technological artifacts evolve together with the representations, identities, discourses, and institutions that give practical effect and meaning to ideas and objects. Hence, this study uses co-production as a theory to understand the way that gender bias is woven into every level of the biomedical innovation process, thus co-evolving to perpetrate an androcentric healthcare system that continues to harm women.

To ensure an effective application of this STS framework, there are several important research considerations to address. A key principle of co-production is the acknowledgment of power differentials within the different variables of study, in this case, technology and society. The failure to account for such inequalities can result in an overly broad analysis that dissolves the justification for preserving the boundary between them. Therefore, this research paper applies co-production specifically to the intersection of the knowledge gap and the femtech industry to understand how gender bias impacts women's health innovation in order to provide a dynamic evaluation with overlapping sets of boundary-work.

The Impact of Gender Bias on Women's Health Innovation

According to the Institute of Medicine, sex refers is a biological construct dictated by the presence of biological traits, such as chromosomes, hormones, and reproductive organs; meanwhile, gender refers to the social expectations and experiences associated with identifying as a man or woman in a particular culture (Miller, 2012). Sex and gender do not always match, an idea that was popularized in 1972 by sexologists John Money and Anke Ehrhardt and further asserted by second-wave feminists in the 1970s (Fausto-Sterling, 2020). Furthermore, contemporary STS scholars second this notion, agreeing that labeling someone a man or a woman is a social decision, and further presenting that our beliefs about gender affect the kind of knowledge scientists produce about sex in the first place (Fausto-Sterling, 2020). Consequently, the majority of scientific research is derived largely from the study of cisgender (cis) men and women. As a result, this paper uses the terms 'sex' and 'gender' interchangeably, as well as the use of 'women' to generally refer to cisgender women, even though these issues are not exclusive to them. For example, sex bias in research affects anyone whose sex is assigned female, and gender bias in other capacities may affect anyone who identifies as a woman.

Therefore, the following sections provide a focused investigation of gender bias in regards to the biomedical study of cis-gender women due to limited resources and to avoid an overly complicated analysis.

To reiterate the claims of STS scholars, gender bias greatly impacts the research conducted in critical areas of human health; thus, if male models are the default for biomedical study, then physiological mechanisms proprietary to the female sex are left understudied and thus not fully understood. As a result, conditions presenting differently in women are missed or misdiagnosed, and there is an insufficient body of research for innovators in the femtech industry to develop solutions from. To further explore this topic, this section applies the framework of co-production to examine gender bias in biomedicine, the impact that it has on women's health outcomes, and the way in which it prevents femtech innovation from providing the ultimate solution.

Gender Bias in Biomedical Research

The systematic exclusion of women in the United States from the vast majority of research to develop new drugs, medical treatments, and surgical techniques has resulted in a shocking gap between what is known about men's health and what is known about women's health. A review of federally funded randomized controlled trials published in nine prominent medical journals in 2004 found that, on average, women made up 37% of trial subjects. When the analysis was replicated for studies conducted in 2009, the average had not changed (Liu & Mager, 2016). A 2013 review found that in 304 studies on cancer treatment and prevention conducted between 2001 and 2010, nearly 60% of subjects were men (Mazure & Jones, 2015). In more recent years, female representation has increased, but even when sufficiently included, study results are still not analyzed to determine whether they differ by gender. In a review of

federally funded trials, 75% of the studies did not report any outcomes by gender. Of over 700 ongoing studies, nearly 90% of the researchers said they planned to include women, but less than 1% said they planned to analyze their results by gender (Woitowich et al., 2020). Since researchers are not required to report the research by sex, women's side effects and responses to medications and diseases remain invisible. This failure to incorporate a concern for women's health into the research agenda is directly related to the oppression of women in this society; historically, the members of the medical establishment that have held the power to determine what will be studied and what will not have been predominantly male. Though such decisions were likely not meant to be intentionally exclusive, evidence shows that medical leaders have continually chosen to promote research on men, thus creating a "conceptual blindness" to the conditions affecting women (Studies et al., 1999).

By excluding women from research, scientists seem to agree that female bodies are different from male bodies, yet they contradict this notion by continuing to extrapolate those male-drawn conclusions to women, thus implying that these differences are irrelevant. Despite evidence that sex differences on the cellular level have been observed to have a significant impact on the biology of many tissues, most researchers continue to largely use male animals and cell lines in preclinical research. A 2014 review of over six hundred studies published in prominent surgery journals found that amount cell studies, three-quarters did not specify the sex of the cell lines used and of those that did, over 70% used only male cells (Shah et al., 2014). The assumption is often made that, due to the lack of difference in architecture or function between most cells from male and female organisms, the sex of the cells utilized in basic research is irrelevant. The study of cultured cells is an essential process for identifying biological mechanisms, pathways, and processes, which are often the basis for developing new diagnostic

and therapeutic solutions. Since all cell lines have a sex, the complement of sex chromosomes has the potential to influence biochemical pathways and cell physiology, and thus translational therapies to human disease. Therefore, the failure to include female cell lines in the majority of biomedical research ignores the potential for sex-specific mechanisms to have clinical implications in developed therapeutics.

This systematic discrimination persists in the selection of animal models as well. While there are certainly limitations to the insights that animal studies can reveal about human health, we often rely upon them to help us understand disease mechanisms and ultimately test the safety and efficacy of new treatments. Despite well-established sex differences in pharmacokinetics and pharmacodynamics, the vast majority of researchers continue to use male rodents exclusively in their drug studies. In biology journals, 22 to 42% had no mention of the animals' sex, and when both sexes were included, only a third had results analyzed by gender (Woitowich et al., 2020). Furthermore, a 2011 survey of journal articles reporting results of animal research found a male bias in eight of the ten fields. Neuroscience, pharmacology, and physiology revealed particularly extreme male skews, with single-sex studies of male animals outnumbering those of females 5.5:1, 5:1, and 3.7:1 respectively (Beery & Zucker, 2011). Since these are the disciplines in which animal research is most likely to translate into humans, there is no question that this has direct implications for healthcare outcomes.

Scientists acknowledge the disparities in scientific information, but assert that this knowledge gap was a result of unintended neglect. Researchers claim that studying women is much more difficult than studying men due to varying hormonal profiles that may affect drug dosage, metabolism, and side effects (Studies et al., 1999). This is yet another example of how socialized gender norms affect the research agenda, as "oppression makes women appear deviant

or problematic" (Studies et al., 1999). As a result, women's hormonal cycles appear not only to be different from men's physiology but also "problematic" to the male researchers in positions of power. This has led to the creation of the long-standing assumption that hormone cycles make female animals inherently more variable than males, which further dissuades researchers from including them in their studies. While this is already an inappropriate justification to solely conduct research that serves a narrow subset of the population, there is also recent scientific evidence that further disproves this notion. A meta-analysis of 293 articles compared various traits of male mice with those of female mice and found equivalent variability of each sex regardless of the female's stage in the estrus cycle. In fact, the males were actually the more variable subjects for some traits, particularly in the case of housing condition; when cased in groups, the males had greater variability in stress hormones and testosterone levels due to their tendency to fight amongst themselves (Lee, 2018).

Evidently, hormonal variability is no longer a valid justification for the exclusion of female animals from basic and preclinical studies; however, the problem still remains that researchers avoid incorporating the female reproductive phases into their study design, which may require four times the number of female animals than males (Lee, 2018). As a result, the inclusion of female rodents is generally more expensive and labor-intensive, a discouraging factor for many researchers. Undoubtedly, the incorporation of these models into standard practice would increase cost and force researchers to make difficult decisions about how to allocate their already limited resources; however, it is morally unacceptable to determine this allocation on the basis of sex, especially when there is so much at stake for the excluded parties (Studies et al., 1999). Therefore, the considerations of cost cannot justify the exclusion of female models or the failure to perform gender-specific analysis in biomedical research studies at any

level. Accordingly, the relationship between historical power dynamics in the research community and policy-making structures have unjustly driven the research agenda to create a body of research that disproportionately serves men.

Implications for Women's Health

The systemic male bias that pervades the research environment is especially concerning considering the plethora of conditions disproportionately affecting women. Women are diagnosed with depression and anxiety at 2.25 times the rate of men, yet less than 45% of animal studies on these disorders used females (Beery & Zucker, 2011). While women have more stroke events than men over the course of their lives, along with poorer functional outcomes, an inspection of 40 animal stroke models found 65% studied only males, 10% included both sexes, and 25% failed to specify sex at all (Beery & Zucker, 2011). The pattern continues for autoimmune diseases such as Grave's disease and lupus, which are seven to ten times more prevalent among women, with roughly 80% of rodent drug studies using only male animals, despite their "attempt to highlight sex-dependent drug effects" (Dusenbery, 2018; Ngo et al., 2014). Even in the disciplines with the most well-analyzed data sets for animal models and human studies, the male bias is striking; 79% of organismal studies published in the journal *Pain* during 1996 to 2005 investigated only males, despite the fact that women are 1.5 times at a greater risk than men for many clinical pain conditions (Beery & Zucker, 2011). Therefore, even with overwhelming evidence demonstrating the skewed predisposition of women to many disease states, the gender-based power dynamics in the research community have prevented studies from properly representing the affected populations.

This bias becomes increasingly problematic as it compromises the safety and effectiveness of drugs in women. Between 1997 and 2000, 10 drugs were withdrawn from the

market due to adverse health effects. In four of the eight that posed higher risks for women than in men, the risk was likely due to physiological differences, an issue that experts attribute to the lack of adequate preclinical testing in female animal models (Wald & Wu, 2010). Unsurprisingly, the efficacy of drug treatment differs between women and men so much so, that female sex has been shown to be a risk factor for the development of adverse drug reactions (ADRs). A study reviewing 10 years of ADR found that more than 70% of the patients assessed were female (Gandhi et al., 2004). Women generally predominate among patients with drug-induced liver injury and appear to be more susceptible to neuropsychiatric ADR, gastrointestinal, and cutaneous allergic reactions. Furthermore, sex hormones, respiratory agents and treatments for genito-urinary and antineoplastic conditions, have been shown to give more ADRs in females than in men (Montastruc et al., 2002). As women differ from men in gene expression and regulation, in the susceptibility to, and risk for many medical conditions, and in the response to numerous drugs, gender differences in drug response may explain, at least in part, the inter-individual variations occurring in therapeutic response and toxicity. Therefore, as biased research methods create skewed healthcare outcomes, there is an increasingly obvious necessity to reform the system that perpetrates such disparities.

Industry Barriers for Femtech Innovation

Now is an especially urgent time to tackle this issue, as many women in the United States are sick, and despite advances in modern medicine, they are getting even sicker. Prevailing evidence indicates that men die at younger ages than women, due to a variety of behavioral, cultural, and social factors (Alberts et al., 2014). Contradictorily, even with these few additional years of life expectancy, women report poorer health outcomes and more hospitalizations than men throughout adulthood. This gender paradox is otherwise known as the “male-female health

survival paradox" since women have a lower mortality but higher morbidity. This phenomenon can be attributed to women having higher rates of debilitating but not life-threatening conditions (Rieker & Bird, 2005). Despite this crisis, female health solutions are not given enough attention in the biotechnology and pharmaceutical industries. With roughly $500 billion in annual medical expenses attributed to women, it is a blatant disconnect that only 4% of all healthcare research and development is spent specifically on women's health issues (Ravid & Tobey, 2020).

Again, these inconsistencies can be attributed to the co-production of societal and technological components of the biomedical system. With the majority of industry leaders being male, they have historically held the power to drive the direction of biomedical innovation. With monetary profit as the primary motivation, companies that manufacture and sell drugs hesitate to spend the money necessary to test a drug candidate in both male and female animals. As a result, pharmaceutical giants, such as Genentech, have agreed upon three stringent conditions that must be met in order to include female animals in their studies: it must be known to affect men and women differently, its basic physiological mechanism must be well understood, and it must have a reasonable animal model. Outside of these criteria, leaders are generally "not compelled" to study the sex differences (Wald & Wu, 2010). While some researchers advocate for political intervention, it is unlikely that the NIH will introduce a blanket policy requiring the use of male and female animals. According to Vivian Pinn, director of the NIH Office of Research on Women's Health (ORWH), "the research and how it's designed has to be based on the science of what is being studied and the availability of models" (Laurence & Weinhouse, 1997). Thus, the current industry ideologies act as additional hurdles that further perpetuate the use of male models and prevent the integration of female health into biomedicine. Evidently, a shift in the

power dynamic is the only way to remedy such injustices with women-centered technological innovation.

In recent decades, it appears that this shift may have begun. According to U.S. Census data, the representation of women in the workforce has increased from 38% in 1970 to 48% in 2019, with Science, Technology, Engineering, and Mathematics (STEM) workers increasing from 8% to 27% (Martinez & Christnacht, 2021). Despite large gains made in several areas in science and technology, women still do not participate equally in all areas of STEM, especially in leadership positions. A significant amount of research has focused on this gender gap and possible remedies, with outright discrimination and harassment as the leading problems up to the 20th century and more recent factors being covert sexism, discrimination, and lack of female mentors (McCullough, 2011). Although these hurdles slow the shift towards a more equal balance of power, recently empowered women with STEM degrees and access to capital have begun calling attention to women's health issues and creating technical solutions through femtech innovation.

In recent years, there has been an unprecedented growth in the number of tech startups designing products for women and transforming the healthcare landscape. The term femtech is applied specifically to the services, products, and diagnostics which use technology to improve women's health and wellness (Roscher, 2017). Currently, the femtech industry comprises over 500 start-ups, with the occurrence of 46 exits, 12 IPOs, and three deals greater than $1B (Barreto, 2021). Despite such incredible growth, gendered power dynamics in business create many barriers to industry expansion. Firstly, gender bias and "conceptual blindness" cause femtech to be extremely undervalued. In 2019, Forbes estimated femtech to become a $50B industry by 2025, yet the healthcare burden from the fertility market alone is projected to reach

$31.4B in that same timeframe (Barreto, 2021; Das, 2019). Recent estimates by femtech industry leaders value the menstruation, contraceptives, and menopause segments $29.5B, $26.8B, and $13.6B respectively, and predict the entirety of femtech to reach $1T (Barreto, 2021). Again, due to societal gender dynamics, this information quantifying the femtech landscape is not well circulated in the venture capital (VC) space. Across notable market research sources, the term 'femtech' is not even defined, and thus women's healthcare companies cannot be tagged as such. This is unsurprising since the demographics of the VC community reflecting the historical patterns created as a result of women's oppression, with 94% of decision-makers being men and nearly three-quarters of firms without a single female partner (Chilazi, 2019).

Yet another consequence of this skewed gender dynamic is the failure of individual investors to understand the true value of femtech products since women's health issues are not held as a priority. As a result, women's health solutions fail to receive the attention they deserve, illustrated by the less than 1% of VC funding attributed to femtech reported in 2019 (Sandhu et al., 2020). Many femtech founders report experiencing uncomfortable pitch environments, with male investors harboring dismissive or otherwise disrespectful comments towards the discussion of female anatomy or health conditions (Scherl, 2018). These issues can be attributed to societal factors such as the absence of comprehensive women's healthcare education in addition to the ever-pervasive taboos associated with women's bodies. Furthermore, these factors reveal themselves as more concrete barriers when presented through media censorship. Many platforms, such as Facebook and Twitter, block the use of words such as "vagina" and "sexual dysfunction," key terms for the advertisement of many femtech products. Meanwhile, these same sites allow the use of the equivalent male terminology, "penis" and "erectile dysfunction" (O'Connor, 2020). This is a direct example of the pervasive gender bias that influences the

development of female healthcare solutions. The inability to advertise on popular media platforms would be detrimental to any company, especially one that is already at a historical disadvantage due to a gendered power imbalance. Thus, these societal components present additional struggles for female founders to fund their own projects in women's health innovation.

Therefore, despite the overwhelming body of evidence demonstrating the urgency to turn attention to women's health issues, male bias continues to dominate biomedicine at virtually every level. Evidently, androcentrism is built into the prominent scientific and political structures, creating a medical system and investment landscape that unduly serve men. While femtech innovation may seem to provide the means to solve this issue, alternative biases are present that inhibit industry expansion and societal acceptance. The gendered power dynamics in both the biomedical and venture capital communities have created a system built against such advancements. Therefore, despite innovative efforts by female researchers, women's health advocates, and femtech leaders, the issue of gender bias in biomedicine remains unsolved. Consequently, the means for such a solution will require the shift of power into the hands of those with intentions to reform the system currently based on centuries of male bias.

Limitations

Though conclusive results were drawn from this study, there are some limitations to the current analysis. Firstly, this study relies heavily on biomedical research conducted in the past decade; however, these studies have different target populations and evaluation criteria that result in individual outcomes. Although the presentation of such evidence heavily supports the conclusion of this paper, there is room for alternative interpretations and the inclusion of additional data. Furthermore, this study is limited by the amount of literature available; the femtech industry has only started to gain traction in recent years, and thus cannot be fully

analyzed in a broader scope. As more research in this field progresses, there will be opportunities for further analysis and the ability to reveal more robust insights into the relationship between gender bias in biomedicine and the emerging femtech industry. Finally, this research would have more validity if it were completed by feminist STS scholars, women's health advocates, or medical professionals whose experience may provide a better framework for analyzing the issue. Despite these limitations, this work is still able to encapsulate the sociotechnical impact of gender bias in biomedicine and provide key insights into the nature of this complex issue.

Conclusion

Although the presence of gender bias in biomedicine will require significant reformation of the current research and political structures to remedy the knowledge gap, there is a need for all persons and agencies involved in biomedical research to work together to further our knowledge about women's health. On an individual level, researchers can play a critical role by designing their studies to incorporate the assessment of female cell lines, animal models, and human trial participants and analyze their outcomes by gender. On the agency level, the NIH can work with researchers to identify barriers to including women and develop initiatives to promote the study of female physiology. Meanwhile, femtech innovators can continue developing female health solutions based on the available research and pushing through the barriers in the market landscape. Finally, the synergy of female physicians, academics, and venture capitalists has the potential to advance the femtech industry towards widespread recognition.

The sections above establish that gender in biomedical research has led to the creation of a major knowledge gap in biomedical research that ultimately produces negative outcomes for women in the healthcare system. Furthermore, the knowledge gap negatively impacts the ability to ameliorate this gap through female health innovation, since there is an insufficient body of

research to create solutions from. Additionally, femtech innovators experience gender bias in the startup process that create barriers to translation and widespread adoption of their technologies. It is also established that even as the NIH takes steps towards promoting gender-inclusivity, the male preference is far too intertwined with the drug development process that fully integrating sex differences into biomedical research would require a complete cultural shift within science.

Evidently, the relationship between socialized gender roles and the development of technologies had led bias to persist, not only throughout the biomedical research process but in many of the cultural and ideological structures that our society in built upon. Not only does bias impact the development of healthcare technologies, but also the distribution and access to medical care that patients receive. Therefore, the issue of bias is multifaceted and deeply rooted in nearly every aspect of the way we live. While its direct effects may not be as obvious in other contexts, the research presented in this thesis provides strong evidence for its negative impact on the ability of female health innovators to acquire funding, conduct research, develop technical solutions, and eventually translate their products to market. Despite these challenges, the shifting power dynamics in STEM fields help the femtech industry continue to grow. Therefore, although the androcentric biomedical system cannot be remodeled overnight, there are steps that can still be taken towards ameliorating the knowledge gap and creating solutions to improve women's health.

References

Alberts, S. C., Archie, E. A., Gesquiere, L. R., Altmann, J., Vaupel, J. W., & Christensen, K. (2014). The Male-Female Health-Survival Paradox: A Comparative Perspective on Sex Differences in Aging and Mortality. In *Sociality, Hierarchy, Health: Comparative Biodemography: A Collection of Papers*. National Academies Press (US). https://www.ncbi.nlm.nih.gov/books/NBK242444/

Barreto, B. (2021). *What's Femtech? – FemTech Focus*. https://femtechfocus.org/whats-femtech/

Chilazi, S. (2019). *Venture Capital and Entrepreneurship*. https://wappp.hks.harvard.edu/venture-capital-and-entrepreneurship

Das, R. (2019, September 24). *Is Technology Pink? Investments in Femtech to Cross the $1.3 Billion Mark in 2020*. Forbes. https://www.forbes.com/sites/reenitadas/2019/09/24/is-technology-pink-investments-in-femtech-to-cross-the-13-billion-mark-in-2020/

Dodgson, L. (2020, June 5). *Why Founder of Clue Ida Tin Coined the Term "FemTech."* https://www.insider.com/founder-of-clue-ida-tin-coined-the-term-femtech-2020-6

Dusenbery, M. (2018). *Doing Harm: The Truth About How Bad Medicine and Lazy Science Leave Women Dismissed, Misdiagnosed, and Sick*. HarperCollins.

Fausto-Sterling, A. (2020). *Sexing the Body: Gender Politics and the Construction of Sexuality*. Basic Books.

Laurence, L., & Weinhouse, B. (1997). *Outrageous Practices: How Gender Bias Threatens Women's Health*. Rutgers University Press.

Lee, S. K. (2018). Sex as an important biological variable in biomedical research. *BMB Reports*, *51*(4), 167–173. https://doi.org/10.5483/BMBRep.2018.51.4.034

Lu, D. (2019). The femtech gold rush. *New Scientist*, *242*(3232), 20–21. https://doi.org/10.1016/S0262-4079(19)30973-X

Martinez, A., & Christnacht, C. (2021, January 26). *Women Making Gains in STEM Occupations but Still Underrepresented*. The United States Census Bureau. https://www.census.gov/library/stories/2021/01/women-making-gains-in-stem-occupations-but-still-underrepresented.html

McCullough, L. (2011). *Women's Leadership in Science, Technology, Engineering & Mathematics: Barriers to Participation*. Forum on Public Policy.

Ngo, S. T., Steyn, F. J., & McCombe, P. A. (2014). Gender differences in autoimmune disease. *Frontiers in Neuroendocrinology*, *35*(3), 347–369. https://doi.org/10.1016/j.yfrne.2014.04.004

O'Connor, S. (2020, January 17). *Feminine Wellness Ads & Censorship: Fair or Unfair?* StringCan Interactive. https://www.stringcaninteractive.com/feminine-wellness-ads-censorship-fair-or-unfair/

Ravid, O., & Tobey, D. (2020, December 11). *Contributed: The Rise of Femtech*. MobiHealthNews. https://www.mobihealthnews.com/news/contributed-rise-femtech

Roscher, F. (2017, March 4). *Tech-Savvy Women: The Femtech Revolution*. https://www.handelsblatt.com/english/companies/tech-savvy-women-the-femtech-revolution/23567352.html?ticket=ST-1064713-a1IJOe211jvOoQGKuCHr-ap1

Sandhu, N., Gambon, E., & Stotz, C. (2020, August 3). *Femtech is expansive—It's time to start treating it as such*. Rock Health. https://rockhealth.com/femtech-is-expansive-its-time-to-start-treating-it-as-such/

Scherl, R. B. (2018). *Orgasmic Leadership: Profiting from the Coming Surge in Women's Sexual Health and Wellness*. Indie Books International.

Shah, K., McCormack, C. E., & Bradbury, N. A. (2014). Do you know the sex of your cells? *American Journal of Physiology. Cell Physiology*, *306*(1), C3-18. https://doi.org/10.1152/ajpcell.00281.2013

Studies, I. of M. (US) C. on the E. and L. I. R. to the I. of W. in C., Mastroianni, A. C., Faden, R., & Federman, D. (1999). Justice and the Inclusion of Women in Clinical Studies: A Conceptual Framework. In *Women and Health Research: Ethical and Legal Issues of Including Women in Clinical Studies: Volume 2: Workshop and Commissioned Papers*. National Academies Press (US). https://www.ncbi.nlm.nih.gov/books/NBK236575/

Woitowich, N. C., Beery, A., & Woodruff, T. (2020). A 10-year follow-up study of sex inclusion in the biological sciences. *ELife*, *9*, e56344. https://doi.org/10.7554/eLife.56344

World Bank. (2019). *Population, female (% of total population)—United States*. The World Bank | Data. https://data.worldbank.org/indicator/SP.POP.TOTL.FE.ZS?locations=US