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The Tree of Gender Inequality in Science: Roots, Leaves, and Paths to Change

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Abstract:

Gender inequalities persist in the scientific community, including dentistry, affecting key aspects such as representation, success, and recognition. Despite progress in increasing women's participation in research, disparities remain, particularly in publication rates, citation impact, funding acquisition, and leadership positions. This opinion article examines the systemic and structural barriers that impede women's academic advancement, introduces the Tree of Gender Inequality in Science model, and discusses potential interventions to promote gender equity in science. Gender disparities in academia are deeply rooted in systemic biases and institutional structures. Women are consistently underrepresented among highly cited researchers, editorial boards, and grant recipients. Implicit biases, discriminatory hiring practices, and limited access to mentorship further hinder their career progression. However, interventions such as unconscious bias training, mentorship programs, and equity-based institutional reforms have the potential to address these inequalities. In conclusion, addressing gender disparities in academia requires a multifaceted approach that combines policy reforms, institutional commitment, and cultural shifts. Achieving gender equality is essential for scientific innovation and progress. Immediate action is needed to dismantle barriers and create inclusive environments that enable all researchers to thrive.

Keywords: Gender Inequality, Academia, Scientific Research, Systemic Bias, Gender Equity, Mentorship, Institutional Reforms

1. What is not new under the sun?

Gender inequalities remain prominent in the scientific community. A comprehensive study analyzing the publication history of over 1.5 million researchers found that women's representation had increased from 12% in 1955 to 35% in 2005.¹ By 2022, it was estimated that women comprised 41% of active researchers on Scopus.² However, this progress appears uneven across research fields and geographical regions,² as gender continues to influence key factors such as success, recognition, and representation in science.^{3,4} Women consistently face disadvantages, with lower citation rates and fewer published articles, leading to lower annual productivity and lower H-indices compared to their male counterparts.^{1,4} Notably, the gender inequality gap also reveals a paradoxical pattern: among the strata of the 20% most productive researchers, the gap still favors men by 37%.¹ Conversely, among middle and low-productive researchers, the gap appears to “favor” women.¹ Compounding this scenario, evidence indicates that women are less likely to be mentored by senior professors, have fewer collaborators, are significantly underrepresented among reviewers and editorial boards, have the fewest patent applications, and achieve less success in securing funding proposals.^{2,5} All these factors collectively contribute to a cumulative disadvantage that limits the academic capital of women throughout their careers.⁴ The findings in the current literature also confirm that men dominate a significant share of the most-cited studies, a trend that has remained unchanged over the decades.⁶

This article highlights persistent gender inequalities in academia, focusing on structural and systemic barriers that limit women's full participation and advancement in science. It introduces the Tree of Gender Inequality in Science model to illustrate interconnected challenges and emphasize the need for change

2. Why are women still consistently and (often) unconsciously left behind?

Systemic and structural problems do not have a single cause. Gender, for instance, has historically been one of the shaping pillars in many societies, including Western Europe and the Americas - in the former, mainly introduced by colonization and imperialism.⁷ Biological differences between men and women served as the basis for the construction and consolidation of gender-oriented roles and norms, strongly influenced by historical, religious, and socioeconomic aspects.⁷ Through the centuries, women have had an essential role in reproduction, and consequently in inheritance and the maintenance of power. As a result, they were confined to spaces oriented to this, subordinated to domestic life, and under the control of a patriarchal society.⁷ From this, so-called feminine gender roles were continuously reinforced, being associated with qualities of delicacy, fragility, modesty, and subservience. Traits such as objectivity, strength, and rationality are reserved for men.

As could not be otherwise, science presents itself as a place outside the home reserved for the “majority”: when asked to define a scientist, you would probably describe a white man wearing a white coat in a laboratory. Although it may seem like an innocent example, it is the tip of a whole system of oppression and systematic exclusion of women from science. This system acts at different levels of a career, or even

before it is chosen and begins, through practices of miss or underrepresentation in mentoring and academic advice, unfair financial compensation, scientific publication biased venues, and lower funding and awards to women.⁸ In turn, as a result of this, women are withdrawn (or withdraw early) from the scientific environment, along with reducing academic capital throughout their careers.^{1,4} Several studies have illustrated this phenomenon with different metaphors.^{1,8,9} The “Leaky Pipeline” model presents the progression of scientific careers as a pipe - from undergraduate to professorship, where women are “leaked” into the pipe and are minoritized in advanced career positions.^{9,10} However, there are two major criticisms of this model - its linearity (since career choices and trajectories may not be linear and people can leave and return at different points) and the absence of external influences on science that also affect the permanence and maintenance of women “in the pipeline”.^{10,11}

Connected with the Leaky Pipeline, particularly noteworthy is the “Glass Ceiling Effect”. This metaphor refers to the invisible barriers women and marginalized groups face when attempting to advance to higher-level positions.⁹ Barriers such as less authority and networking, lower wages, lower international mobility, and giving women poor and exhausting leadership roles, restrict women to lower- and mid-level organizational roles, mainly when accounting for male-dominated professions.^{9,12} It contributes to a vertical or hierarchical segregational pattern known as the “Scissors Effect” and perpetuates stereotypes such as the belief that “women lack ambition”.¹³ For instance, this pattern has been observed in multiple studies across different fields of research, showing proportions of women below the parity zone (40% to 60% representation) in advanced-career positions, last authorship positions, and among top-cited researchers.^{2,4,6}

However, there are also horizontal gender-based segregational patterns - related to the differential occupation pattern of men and women in different areas of economic activity or study.¹³ In this context, models such as the “Revolving Doors” come into play.^{12,14} The “Revolving Doors” of Jacobs,¹⁴ synthesizes those individuals (mainly women) who pass in and out in occupations in a fluid labor market, but have a higher likelihood to remain in gendered-concordant occupational positions and have less chance of leaving them due to the life-long social control who operates by influencing sex-role socialization, then influencing choices of education, and maintenance in work. This could explain the concentration of women in research areas closely related to “female social desired roles”, such as Nursing, Psychology, Social Sciences, and Health Professions, along with the low advancement of women’s representation in Computer Science, Physics, Mathematics, and Engineering.²

Such effects create a vicious cycle that reinforces implicit biases and exacerbates gender inequalities in complementing ways that are difficult to represent in a unique concept or metaphor.^{9,15} Women are the target of multiple ingrained biases—serious and trivial, subtle, and obvious, intentional, and unintentional—the sum of which is discouraging to their ambitions and detrimental to their career advancement.¹⁵ For instance, a randomized controlled trial demonstrated that an identical curriculum vitae was evaluated more favorably when attributed to a fictitious male candidate than to a fictitious female candidate in the selection process for a postdoctoral fellowship.¹⁶ Additionally, gender inequality in academia cannot be separated from

broader systems of exploitation and is one manifestation of this dynamic, where mechanisms of systemic domination work to maintain hierarchical structures that concentrate power and privilege.¹⁷ These mechanisms not only devalue women's contributions, but society as a whole fails to gain from innovative, more inclusive research that takes a more pluralistic view of the different subjects involved in scientific practices, from the idea to the main findings.²

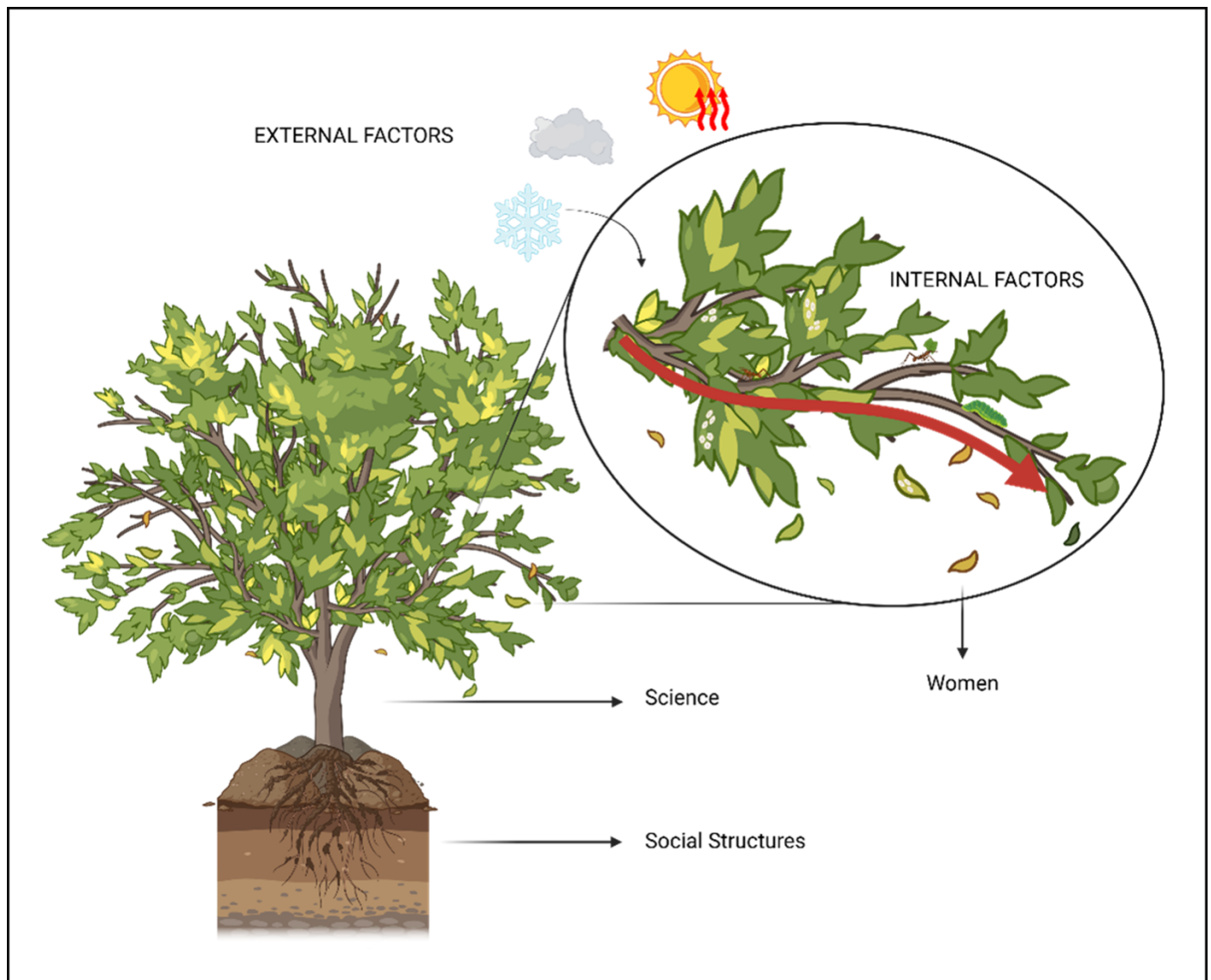
3. The tree of gender inequality in science

As can be seen, so far, no model carries with it and seeks to unify all the phenomena considered here about gender inequality in science. Metaphorically, as can be seen in Figure 1, we present the Tree of Gender Inequality model.

At the base, we have the soil, which is the social structure on which various trees, such as science, grow. Science, therefore, is directly influenced by different contextual determinants “present in the soil”, such as countries' levels of economic development, sex-role socialization and social norms, institutions' concerns and implementation of equity indicators and protective programs, and policies to combat discriminatory values, attitudes, and beliefs about women.^{4,18,19} Suffering from all these influences are women, represented here as leaves of the tree. The distribution of leaves can reinforce aspects of vertical and horizontal gender-based segregation.¹³ In terms of vertical segregation, we seek to represent the different possibilities for career progression in branches, which reinforces the idea of non-linearity discussed above.¹⁰ As the career stages progress, leaves fall and make the branches more evident; however, the possibility of them sprouting up again is not extinguished. In turn, horizontal segregation can be seen in the tree through the different parts with missing leaves, which illustrates the difference in the proportion of women between areas, which can make the tree “less full” not only in its crown but also at its base.

In addition, two fundamental aspects emerge from this model. What makes the leaves fall and not sprout again, in addition to the influences from the soil, are represented here by factors internal and external to the tree. Internal factors, illustrated here as ants, fungi, and caterpillars, are all those gender-biased practices internal to science; they can be cited, but not limited to, biased reference letters, less mentorship, unfair evaluation in peer-review and selection processes for positions, underrepresentation as authors and part of the editorial committee in prestigious journals, and reduced invitations to women to speak in events.^{2,14} External effects, illustrated here as unstable weather and extreme temperature variations, represent those events that contribute to the non-maintenance of women in science, but are external to it and shared with other occupational places. Examples include the motherhood penalty and the burden of caring and unpaid domestic activities,^{20,21} and exposure to gender-based harassment and violence.²² Both external and internal factors can be modified to a lesser or greater extent, and interventions at individual, institutional, and contextual levels can be applied to “keep and nurture the leaves on the branches”.

Figure 1. Tree of Gender Inequality in Science model. Women are represented as leaves distributed across non-linear career pathways. Gender inequalities arise from societal and institutional determinants, as well as internal and external factors that affect retention and advancement in science.



Why a new model? Existing models capture specific dimensions of gender inequality, but no single framework simultaneously incorporates contextual determinants, internal academic mechanisms, external societal pressures, and non-linear career trajectories. The Tree of Gender Inequality model is proposed as an integrative framework.

4. So, what are the ways to keep science leafy?

The first step is to see the problem, not ignore it. The second is to act – by planning and testing interventions that address internal and external factors rather than just symptoms, along with practices to stimulate “leaf growth”. As presented in the UNESCO Call for Action: Closing the Gender Gap in Science, 19 effective policies and interventions aimed at reducing gender inequality in academia should focus on: [1]

reducing gender stereotypes and gender biases in science by promoting positive female role models; [2] improving and expanding educational pathways for women in science; and [3] creating safe, inclusive, and supportive work environments to retain women in the scientific workforce.¹³ These recommendations are echoed in reports from Elsevier² and the European Institute for Gender Equality.²³ Efforts should target both the individual and organizational levels. At the individual level, training on identifying unconscious and conscious biases can help address gender biases and draw up strategic routes to avoid this in the academic environment.⁸ At the organizational level,²⁴ implementing equity-based models of governance, promoting changes in interpretive and symbolic representations, and making institutional structural and operational changes - such as mentorship and sponsorship programs for women's career progression, and policies of workplace flexibility and support for motherhood - including paid maternity leave, are critical steps.²³⁻²⁵

Gender equality is not just a moral imperative but a prerequisite for scientific innovation and progress. We must collectively commit to breaking down barriers, challenging stereotypes, and building systems that provide equal opportunities for all. Science cannot afford to leave half of its potential behind.

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