LETTER

Interdisciplinarity, gender, and the hierarchy of the sciences

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The contribution of Henrique Pinheiro, Matt Durning, and David Campbell "Do women undertake interdisciplinary research more than men, and do self-citations bias observed differences?" concludes that "The key result of this study is that the presence of women in scientific publications is positively associated with interdisciplinarity even after controlling for a potential self-citation bias" (p. 388, 2022). Back in 2007, Rhoten and Pfirman first proposed a framework for why women could be more likely to want to engage in interdisciplinarity. The framework was based on consideration of survey responses from the Evaluation Associates (1999) analysis of researchers in higher education institutions in the United Kingdom (survey conducted in 1998), contextualized by later interviews conducted in the United States. Since then, as Pinheiro, Durning, and Campbell (2022) review, subsequent studies have found both additional evidence of gender differences with respect to interdisciplinary research (IDR), as well as no indications (e.g., Leahey, Beckman, & Stanko, 2017).

Our analysis of patterns of interdisciplinarity revealed two more phenomena that are relevant for our discussion here. First, innovation tends to happen at the periphery of scientific fields (Painter, Daniels, & Laubichler, 2021). The periphery, defined by looser connections to the core network of a scientific community, is also an area of overlap with other domains of knowledge and therefore favors interdisciplinary collaborations. Second, interdisciplinarity is costly in terms of citations and recognition, at least in the short term (Painter et al., 2021; Painter, Kempes et al., in preparation). These observations track with what Rhoten and Pfirman (2007) identified as gender-based preferences for interdisciplinary research.

In this letter, we raise the point that since the original 2007 Rhoten and Pfirman publication, some things have changed. Several more recent studies indicate that the field of Biology/Life Sciences has diverged from the other fields, with men engaging more in interdisciplinarity than women (Xiao, 2014; Zuber & Hüther, 2013). Specifically, Xiao (2014) observed that "female scientists in biology are less engaged in IDR [interdisciplinary research] than male but females in other science disciplines conduct more interdisciplinary work than males" (p. 100). Zuber and Hüther (2013) found that male predoc and postdoc biologists were more interdisciplinary, but the opposite was true for female predoc natural scientists, engineers, and social scientists/humanists, who were all more interdisciplinary. This emerging difference in the field of biology is possibly an explanation as to why Leahey et al. (2017) did not observe a gender difference, because it appears that most women in their study were life scientists.

This raises the question of what caused male biologists to become more engaged in interdisciplinarity since ca. 1998. Xiao (2014) proposed that it is due to the larger proportion of women in biology. Here, we explore another possibility—changes in the field itself.

1. CHANGES IN THE FIELD OF BIOLOGY

Bartham's (2021) first header in his "A Brief History of Biology: 2000–2020" review of major changes in the field over the past two decades was "Computationalism and the Concept of Information." Since the late 1990s, computational biology and bioinformatics have had rapid growth. A PubMed analysis of "computational biology" or "bioinformatics" counted fewer than 2,000 articles in 2000 but 16,000 by 2012 (Chitty, 2014). This increased to more than 22,000 by 2022.

Therefore, we propose that the interdisciplinarity reported by IDR life scientists can, at least partially, be attributed to connections between life sciences with more computational fields, and that more men than women are making these connections. Evidence for this can be seen in gender disparities in earned doctorates in 2021. The biological and biomedical sciences were 52% female overall but 36% for the subfields of bioinformatics, biostatistics, and computational biology (National Center for Science and Engineering Statistics, 2022).

2. THE LONG SHADOW OF THE HIERARCHY OF THE SCIENCES

The concept of a Hierarchy of the Sciences (HOS), ranging from mathematics to astronomy, followed by physics, chemistry, biology, and sociology, introduced by Auguste Comte (1835) has been widely influential and frequently misunderstood. A predominant interpretation holds that mathematics or formalization is an aspirational goal in all academic fields. Storer (1967) described "the drive in the softer sciences to become more rigorous through the use of mathematics" (p. 83), furthermore distinguishing biology, sociology, etc. (BSE) from mathematics, astronomy, physics, chemistry (MAPC) where "error, irrelevance, or sloppy thinking is relatively easy to detect" (p. 79). Fanelli and Glänzel (2013) in their exploration of the HOS, describe a continuum of the disciplines ranging MAPC to BSE with increasing complexity and diversity, less predictability, less perceived consensus (Cole, 1983), and less dependency on raw, innate talent/brilliance (Leslie, Cimpian et al., 2015). With these characteristics, it is readily apparent that contributions to the MAPC sciences are—by definition!—easier to assess, for example at the time of tenure and promotion. Supporting this, Gaughan (2023) recently found that "assistant professors in civil engineering and mathematics earn tenure more quickly than their colleagues in the life sciences" (p. 13).

This means that interdisciplinarity connecting mathematics with another field—in this case biology—is likely to increase perceptions of rigor and combat questions about quality that often come up during tenure review of interdisciplinary cases (Boix-Mansilla, 2006; Stokols, Fuqua et al., 2003) when less quantitative fields are being integrated.

This case of biology and mathematics brings up a larger point: Depending on the fields being connected, interdisciplinarity can sometimes have positive impacts on career trajectories, but in other cases it causes confusion and poses challenges in the assessment of excellence. This means that future studies of the interdisciplinary workforce, and consequences for facilitating interdisciplinarity, need to consider not only types of interdisciplinarity (Klein, 2010; Stokols et al., 2003), distances between fields (Porter, Cohen et al., 2007; Leahey et al., 2017), shifts in interdisciplinary engagement throughout career stages (Evaluation Associates, 1999; Pfirman, Martin et al., 2007; Pfirman & Martin, 2010; Zuber & Hüther,

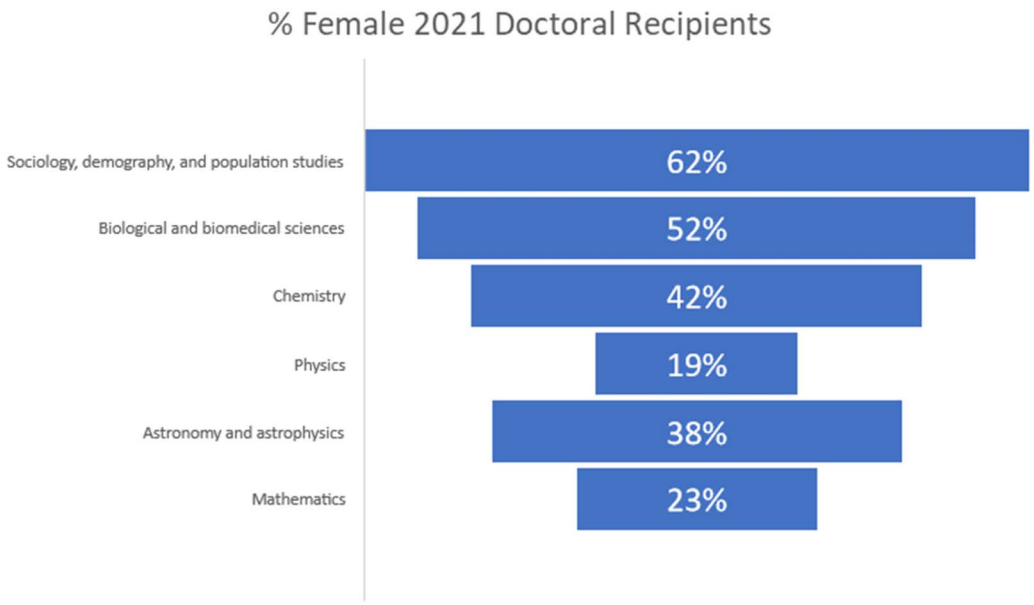

Figure 1. Percentage of female earned US research doctorate recipients in 2021 (National Center for Science and Engineering Statistics, 2022) ordered according to Comte's Hierarchy of the Sciences. Note the systematic increase—with the exception of physics—in the percentage of women.

2013), specialization along the career trajectory (Leahey, 2006), and field context (Leahey et al., 2017), but also which fields are being connected. Connecting a MAPC to a BSE field, as in the case of bioinformatics, can add to perceptions of excellence, yet connecting a BSE to a MAPC field, can result in questions about rigor. Gardner (2013) observed that "it is perhaps not surprising that those in the soft disciplines were more likely to feel at once tentative but also more open to the idea of paradigm-crossing interdisciplinarity, whereas those in the hard disciplines seemed the most reticent to do so" (pp. 27–28). And, as shown in Figure 1, it is more likely that men will choose to connect MAPC fields to BSE ones, thus positioning themselves to benefit from positive HOS biases.

Although these perceptions of the HOS are undoubtedly influencing the individual and collective behavior of today's scientists, a closer reading of Comte's ideas might help shed some light on changing patterns of interdisciplinarity. Comte's hierarchy had (at least) two dimensions as well as an important temporal aspect. Formalization favored the MAPC sciences, and complexity favored biology and sociology. The ultimate goal was to arrive at a "positive" understanding of the most complex of subjects, life and human society. If we focus on Comte's historical model of scientific development, we are currently seeing the acceleration of the "positive" stage in the life and social sciences.

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COMPETING INTERESTS

The authors have no competing interests to declare.

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