MAKING GENDER DIVERSITY WORK FOR SCIENTIFIC DISCOVERY AND INNOVATION

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Gendered Innovations in Science, Health & Medicine, Engineering, and Environment

UNIVERSITY OF COPENHAGEN

THE MUTUAL RELATIONSHIP BETWEEN REPRESENTATION AND RELEVANCE

nature human behaviour

PERSPECTIVE

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Making gender diversity work for scientific discovery and innovation

Mathias Wullum Nielsen[1]*, Carter Walter Bloch[1] and Londa Schiebinger[2]

Gender diversity has the potential to drive scientific discovery and innovation. Here, we distinguish three approaches to gender diversity: diversity in research teams, diversity in research methods and diversity in research questions. While gender diversity is commonly understood to refer only to the gender composition of research teams, fully realizing the potential of diversity for science and innovation also requires attention to the methods employed and questions raised in scientific knowledge-making. We provide a framework for understanding the best ways to support the three approaches to gender diversity across four interdependent domains — from research teams to the broader disciplines in which they are embedded to research organizations and ultimately to the different societies that shape them through specific gender norms and policies. Our analysis demonstrates that realizing the benefits of diversity for science requires careful management of these four interdependent domains.

Gender diversity is increasingly the norm in scientific work. Women and men already share laboratories, research facilities and work spaces in most disciplines, and universities and science policymakers see gender diversity as a key driver of excellence and innovation[1–6]. Yet, gender diversity comes with both challenges and opportunities. Careful management is required to maximize the benefits of diversity for scientific discovery.

This Perspective distinguishes three approaches to gender diversity: diversity in research teams, diversity in research methods and diversity in research questions (Fig. 1). Gender diversity is commonly understood to refer to the gender composition of research teams. However, fully realizing the potential of diversity for science and innovation also requires attention to diversity in research methods and in research questions.

Importantly, gender diversity functions within larger research contexts. In the second half of this paper, we provide a framework to understand how the three approaches to gender diversity function across four interdependent domains: research teams, disciplines, research organizations and societies at large (Fig. 2). In each of the four domains, we evaluate potential drivers and barriers to gender diversity. Understanding the interplay between our three approaches to diversity and how they function within institutional frameworks will assist universities, funding agencies, industries and governments to harness the power of diversity for discovery and innovation.

This Perspective integrates insights from multiple disciplines, including social psychology, management and social studies of science and innovation (search methods are specified in the Supplementary Notes and Supplementary Tables 1 and 2).

Many organizations understand the importance of increasing women's participation in science and technology, and, increasingly, funding agencies are emphasizing the value of bringing diverse methods, such as integrating sex and gender analysis, into research design. Crucially important also is being attuned to the novel research questions newcomers to traditional disciplines might bring. This attention to diversity goes well beyond the dynamics of the research team itself and needs to be fostered by disciplines, research organizations and societies at large.

Three approaches to gender diversity

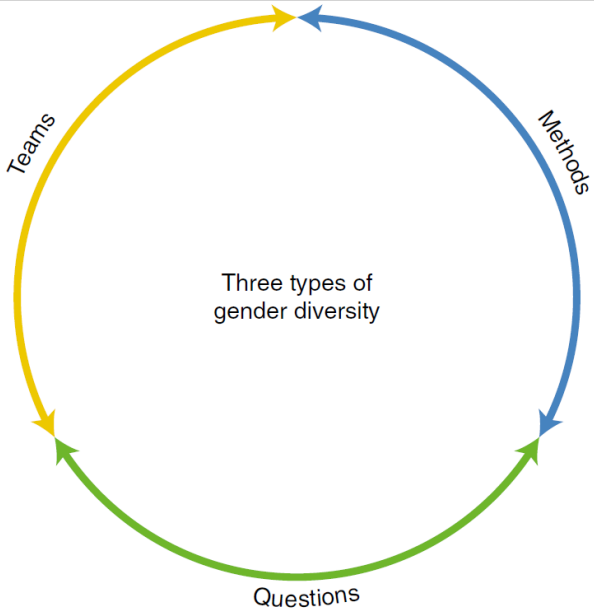
In this section, we distinguish three approaches to gender diversity: diversity in research teams, diversity in research methods and diversity in research questions.

Diversity in research teams. The best-understood approach to gender diversity concerns the composition of research teams. Diversity refers here to the different ideas, beliefs and perspectives that women, men and gender-diverse people bring to the team. The possible benefits of gender diversity are linked to cognitive diversity, conceptualized here as the different ways in which "people represent problems and go about solving them in team work"[7]. Research suggests that cognitive diversity can heighten creativity and encourage the search for novel solutions[8,9]. Experiments indicate that teams comprised of diverse problem-solvers can outperform teams that prioritize best-performing individuals[7].

Gender-diverse teams may, however, encounter higher levels of conflict than more homogeneous teams[10]. Careful team management is therefore imperative to reap the possible benefits of diversity (we return to this in the discussion of the four interdependent domains for scientific discovery and innovation).

The impact of gender diversity on team performance has been analysed extensively in laboratory studies and in corporate and public organizations, but not in science[11–13]. The few existing studies focusing on gender diversity in scientific teams typically evaluate research outcomes based on citation rates, publication productivity and patents. Surveying research from 2006 to 2015, we found eleven studies on team performance in research and innovation. Six studies examined research in for-profit research and development (R&D) firms[14–19] (Table 1), and, of these, five found possible benefits of team gender diversity for innovation and technological performance (measured by patents). Five of the original eleven studies focused on academic science[20–24], and two of these found possible benefits of gender diversity — one with respect to citation impact; another with respect to publication productivity. The remaining studies showed no notable effects of gender diversity.

Yet, gender diversity in teams may influence research outcomes in important ways not captured using traditional, bibliometric



	Teams	Methods	Questions
Focus	Gender composition of research teams	Integration of GSA into research design	Changes in research questions and priorities
Evaluation	Assess the numbers of citations, publications, patents, and so on	Analyse the proportion and quality of GSA in funding proposals and publications	Map large-scale patterns in the topics addressed and questions raised in research
Future research	How does team diversity contribute to the social impact of research?	What is the value of GSA to society in terms of human well-being and economic impact?	Will increasing the numbers of women change research questions, or will changing questions increase the numbers of women in research?

Fig. 1 | Three approaches to gender diversity. Each approach to diversity — diversity in research teams, diversity in research methods and diversity in research questions — has a distinct focus, modes of evaluation and opportunities for future research. The double-ended arrows indicate that these three approaches mutually influence one another; improvements in one likely lead to improvements in the others.

PNAS RESEARCH ARTICLE | SOCIAL SCIENCES OPEN ACCESS

Gender-diverse teams produce more novel and higher-impact scientific ideas

Yang Yang[a,b,c], Tanya Y. Tian[d], Teresa K. Woodruff[e], Benjamin F. Jones[f,g], and Brian Uzzi[b,f,h,1]

Edited by Susan Fiske, Princeton University, Princeton, NJ; received January 16, 2022; accepted July 24, 2022

Science's changing demographics raise new questions about research team diversity and research outcomes. We study mixed-gender research teams, examining 6.6 million papers published across the medical sciences since 2000 and establishing several core findings. First, the fraction of publications by mixed-gender teams has grown rapidly, yet mixed-gender teams continue to be underrepresented compared to the expectations of a null model. Second, despite their underrepresentation, the publications of mixed-gender teams are substantially more novel and impactful than the publications of same-gender teams of equivalent size. Third, the greater the gender balance on a team, the better the team scores on these performance measures. Fourth, these patterns generalize across medical subfields. Finally, the novelty and impact advantages seen with mixed-gender teams persist when considering numerous controls and potential related features, including fixed effects for the individual researchers, team structures, and network positioning, suggesting that a team's gender balance is an underrecognized yet powerful correlate of novel and impactful scientific discoveries.

Significance

Science teams made up of men and women produce papers that are more novel and highly cited than those of all-men or all-women teams. These performance advantages increase the greater the team's gender balance and appear nearly universal. On average, they hold for small and large teams, the 45 subfields of medicine, and

R&D MANAGEMENT

How diversity contributes to academic research teams performance

Petra De Saá-Pérez[1], Nieves L. Díaz-Díaz[2], Inmaculada Aguiar-Díaz[3] and José Luis Ballesteros-Rodríguez[4]

The objective of this paper is to analyse how the job-related diversity in academic research teams influences their scientific performance. To achieve that objective, an empirical study of a university's research teams was carried out during the years 2006–2009. The results reflect a non-significant effect of functional diversity on research teams' performance, whereas status diversity affects in a positive and significant way. However, educational diversity has a significant negative impact when a certain threshold is exceeded. The effect of institutional diversity presents an inverted U-shaped relation with the number of published articles by the research teams. The results reveal that the relationship between diversity and research performance may not be a simple and direct one because its effect could depend on the organisational context and the type of diversity attributes.

JOHNSON Cornell University

By Whom and When Is Women's Expertise Recognized? The Interactive Effects of Gender and Education in Science and Engineering Teams

Aparna Joshi[1]

Administrative Science Quarterly
59 (2)202–239

DOI: 10.1177/0001839214528331
asq.sagepub.com
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DIVERSITY IN RESEARCH METHODS

Gendered Innovations

in Science, Health & Medicine, Engineering, and Environment

What is **Gendered Innovations**?

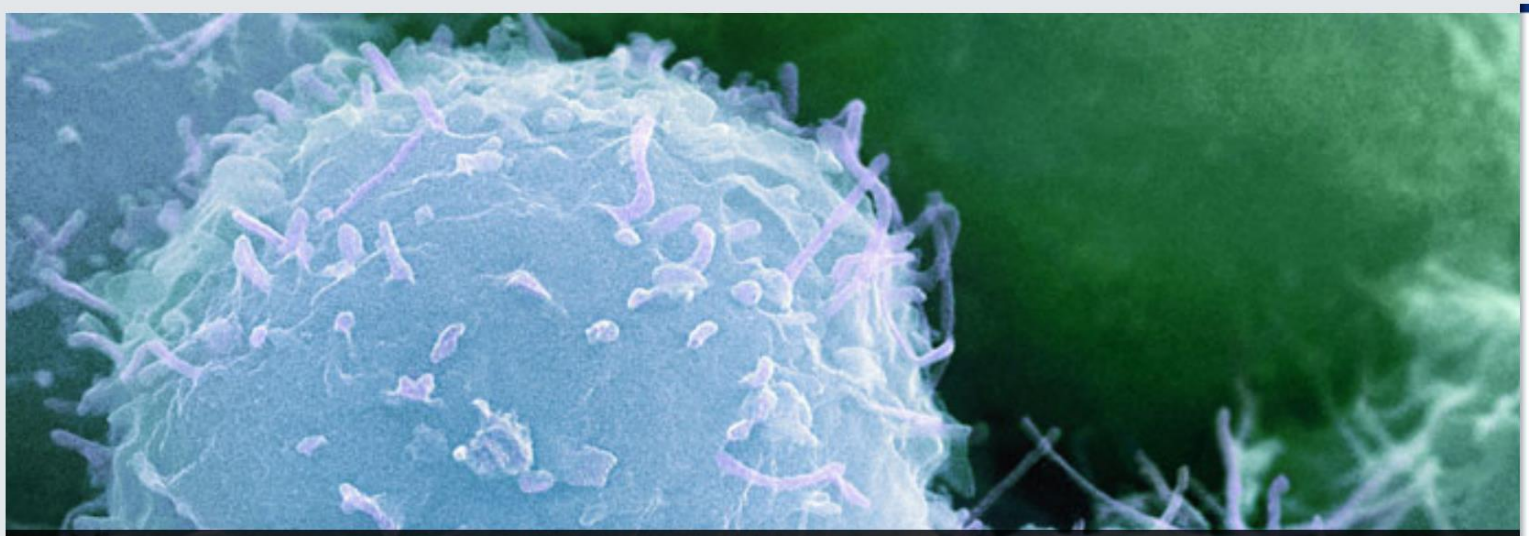
SEX & GENDER ANALYSIS
- Methods
- Terms
- Checklists

CASE STUDIES
- Science
- Health & Medicine
- Engineering
- Environment

DESIGN THINKING

POLICY RECOMMENDATIONS

INSTITUTIONAL TRANSFORMATION

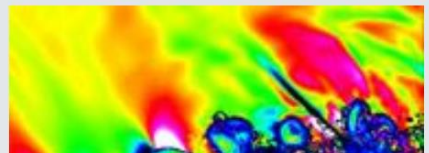


SCIENCE

Sex and Gender Methods for Research | Gendered Innovations

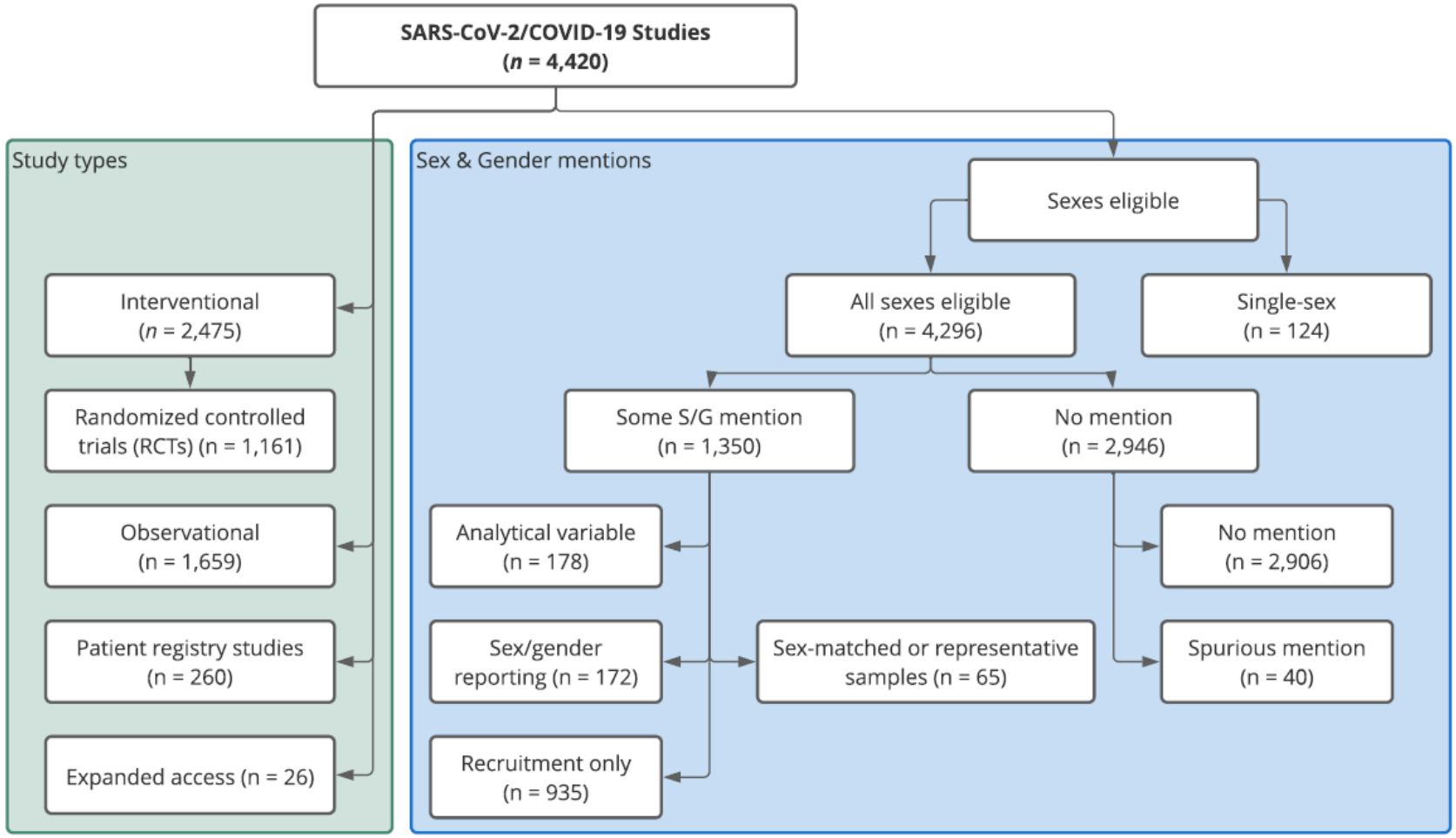
SCIENCE
HEALTH & MEDICINE
ENGINEERING
ENVIRONMENT

FEATURED CASE STUDIES



Why Gendered Innovations?

"Gendered Innovations" employs methods of

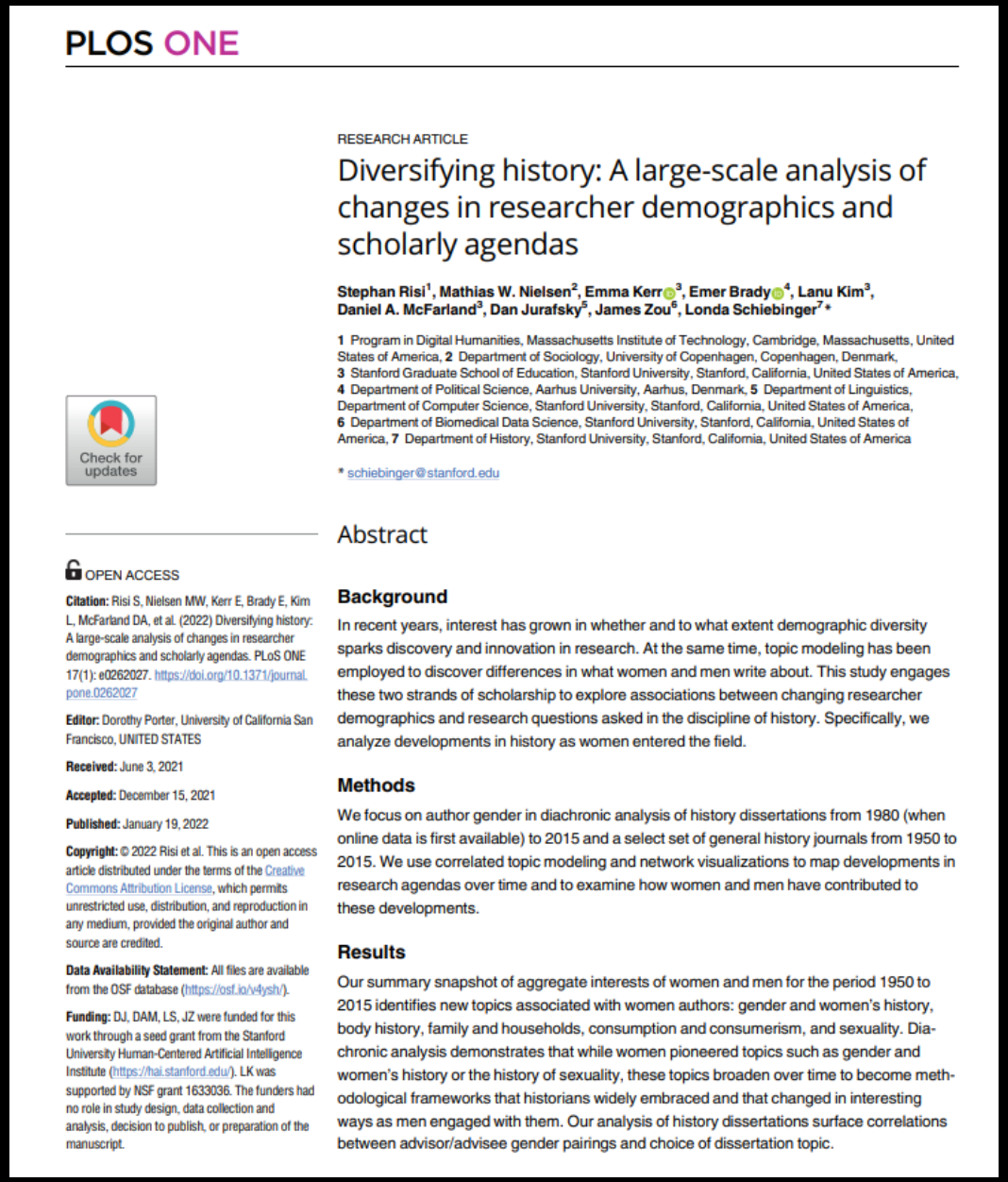


Published trials:

8 of 45 pharmacological trials on COVID report sex disaggregated results.

Brady, EM, Nielsen, MW, Andersen, JP, Oertelt-Prigione, S. (forthcoming) 'Lack of consideration of sex and gender in COVID-19 clinical studies'. *Nature Communications.*

DIVERSITY IN RESEARCH QUESTIONS



PLOS ONE

RESEARCH ARTICLE

Diversifying history: A large-scale analysis of changes in researcher demographics and scholarly agendas

Stephan Risi[1], Mathias W. Nielsen[2], Emma Kerr[3], Emer Brady[4], Lanu Kim[3], Daniel A. McFarland[3], Dan Jurafsky[5], James Zou[6], Londa Schiebinger[7]*

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Abstract

Background

In recent years, interest has grown in whether and to what extent demographic diversity sparks discovery and innovation in research. At the same time, topic modeling has been employed to discover differences in what women and men write about. This study engages these two strands of scholarship to explore associations between changing researcher demographics and research questions asked in the discipline of history. Specifically, we analyze developments in history as women entered the field.

Methods

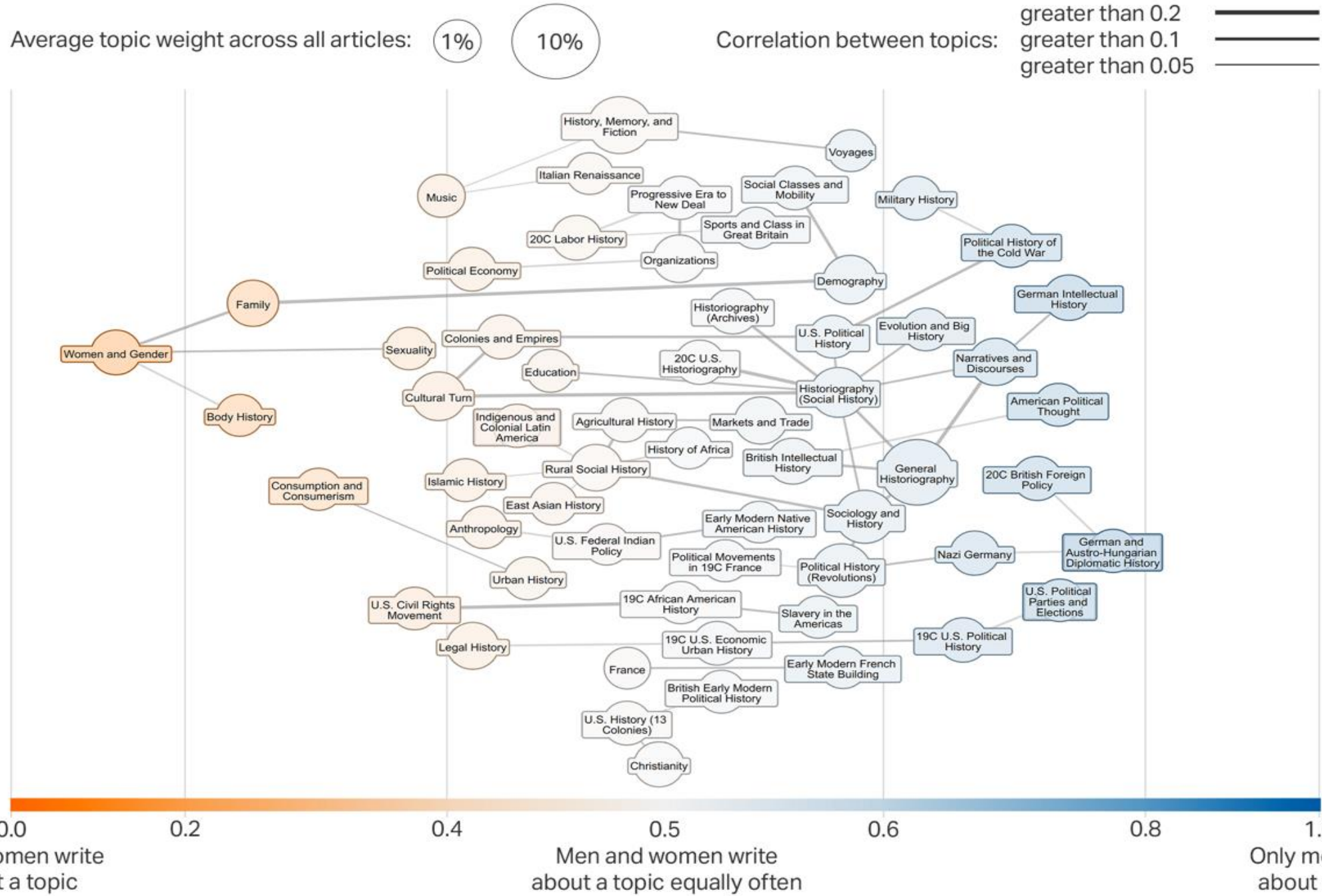
We focus on author gender in diachronic analysis of history dissertations from 1980 (when online data is first available) to 2015 and a select set of general history journals from 1950 to 2015. We use correlated topic modeling and network visualizations to map developments in research agendas over time and to examine how women and men have contributed to these developments.

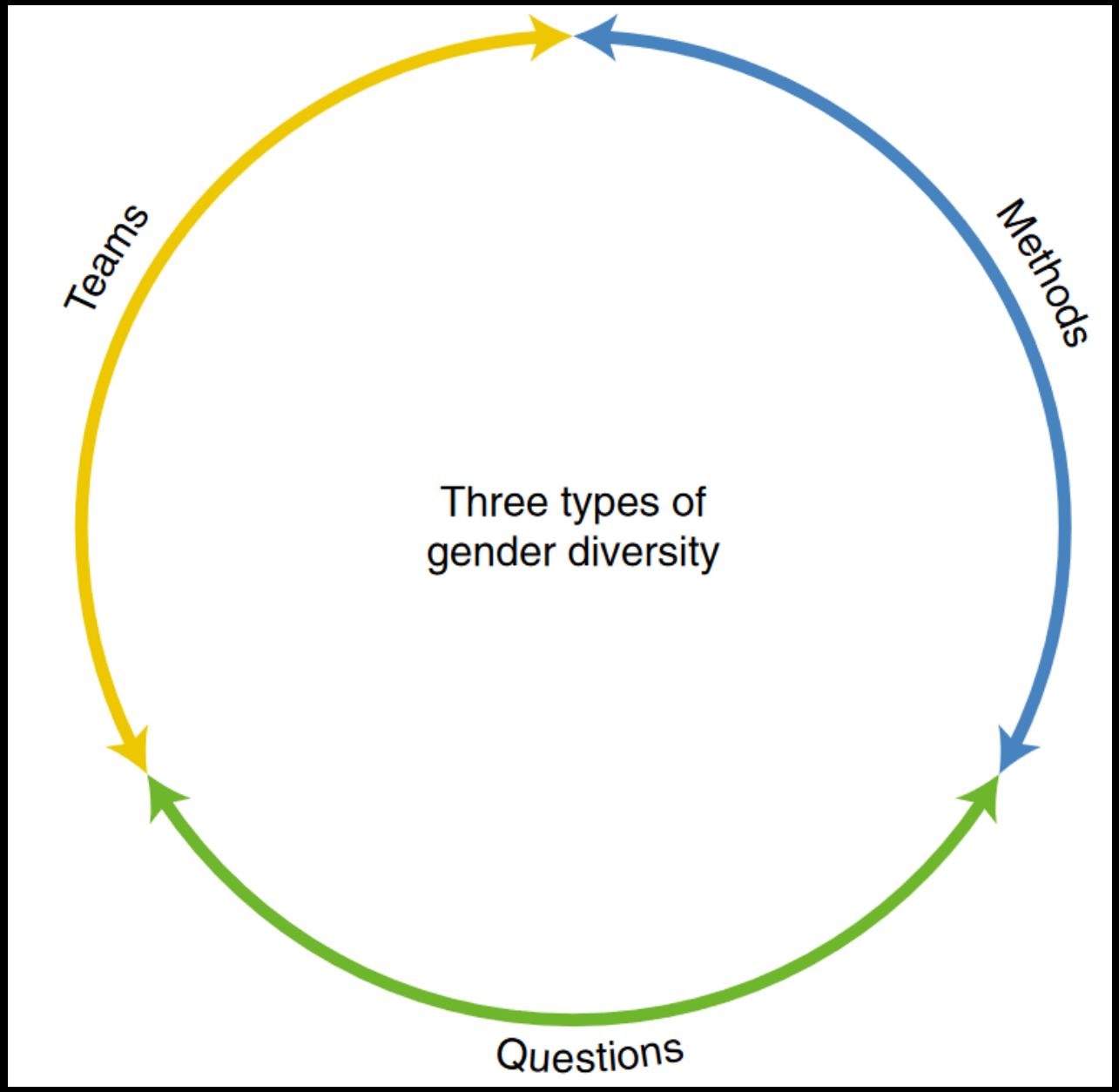
Results

Our summary snapshot of aggregate interests of women and men for the period 1950 to 2015 identifies new topics associated with women authors: gender and women's history, body history, family and households, consumption and consumerism, and sexuality. Diachronic analysis demonstrates that while women pioneered topics such as gender and women's history or the history of sexuality, these topics broaden over time to become methodological frameworks that historians widely embraced and that changed in interesting ways as men engaged with them. Our analysis of history dissertations surface correlations between advisor/advisee gender pairings and choice of dissertation topic.

- JSTOR : 10,367 full-text articles (1951 to 2014) from a set of core History journals published in the US: American Historical Review, Journal of American History, Journal of Modern History, Journal of Social History, etc.

- ProQuest: 21,548 history dissertation abstracts written in the US between 1980 (when dissertations are first digitized) and 2015.


Average topic weight across all articles:
1%
10%
Correlation between topics:
greater than 0.2
greater than 0.1
greater than 0.05
History, Memory, and Fiction
Voyages
Italian Renaissance
Music
Social Classes and Mobility
Progressive Era to New Deal
Military History
Sports and Class in Great Britain
20C Labor History
Political History of the Cold War
Organizations
Political Economy
Demography
Family
German Intellectual History
Historiography (Archives)
Evolution and Big History
U.S. Political History
Colonies and Empires
Sexuality
Women and Gender
Narratives and Discourses
20C U.S. Historiography
Education
Historiography (Social History)
Cultural Turn
American Political Thought
Body History
Indigenous and Colonial Latin America
Agricultural History
Markets and Trade
History of Africa
British Intellectual History
General Historiography
Rural Social History
20C British Foreign Policy
Islamic History
Consumption and Consumerism
East Asian History
Sociology and History
Early Modern Native American History
Anthropology
U.S. Federal Indian Policy
Political Movements in 19C France
Political History (Revolutions)
Nazi Germany
German and Austro-Hungarian Diplomatic History
Urban History
U.S. Political Parties and Elections
19C African American History
U.S. Civil Rights Movement
Slavery in the Americas
19C U.S. Economic Urban History
19C U.S. Political History
Legal History
France
Early Modern French State Building
British Early Modern Political History
U.S. History (13 Colonies)
Christianity
0.0
0.2
0.4
0.5
0.6
0.8
1.0
Only women write about a topic
Men and women write about a topic equally often
Only men write about a topic


Teams
Methods
Three types of
gender diversity
Questions

nature human behaviour

One and a half million medical papers reveal a link between author gender and attention to gender and sex analysis

Mathias Wullum Nielsen ✉, Jens Peter Andersen, Londa Schiebinger & Jesper W. Schneider

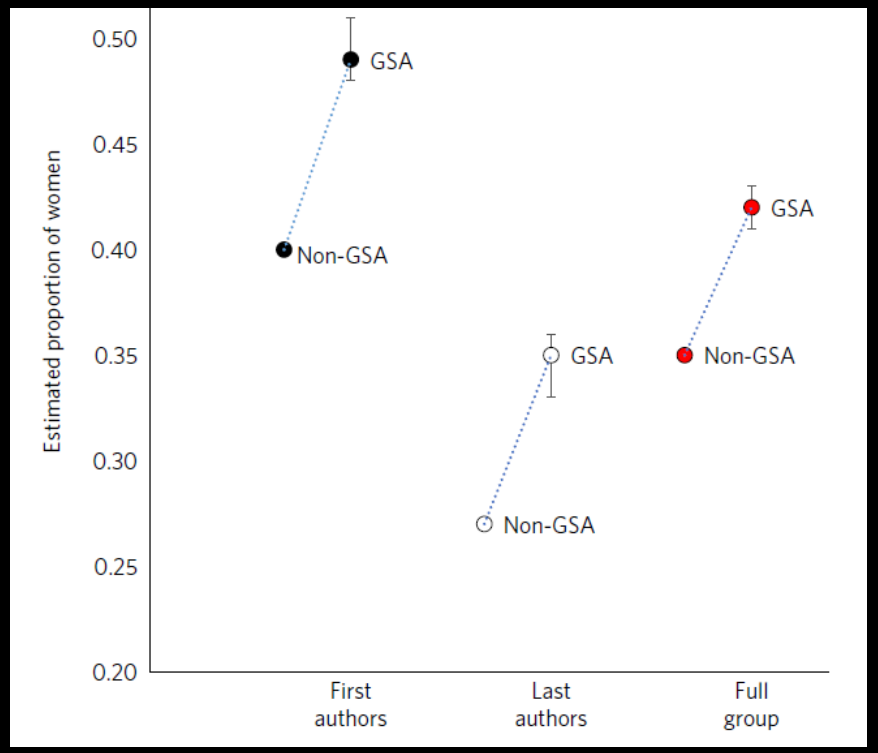


Fig. 2 | Plot of estimated marginal means. The estimated marginal means for f_first, f_last and fw in models 1, 2 and 3 are shown. Error bars represent 95% CI (for estimate specifications, see Supplementary Table 5). The plots visualize the participation of women (relative to men) as first authors, last authors and overall representation in the byline for studies that do and do not involve GSA. The figure shows that women's estimated share of authorships is higher in GSA studies than in non-GSA studies for all three author variables.

Factors affecting sex-related reporting in medical research: a cross-disciplinary bibliometric analysis

Cassidy R Sugimoto, Yong-Yeol Ahn, Elise Smith, Benoit Macaluso, Vincent Larivière

Lancet 2019; 393: 550–59

See Comment page 497

School of Informatics, Computing, and Engineering, Indiana University Bloomington, USA (C R Sugimoto PhD, Y-Y Ahn PhD); École de Bibliothéconomie et des Sciences de l'Information, Université de Montréal, Canada (E Smith PhD, V Larivière PhD); and Observatoire des Sciences et des Technologies, Centre Interuniversitaire de Recherche

Summary

Background Clinical and preclinical studies have shown that there are sex-based differences at the genetic, cellular, biochemical, and physiological levels. Despite this, numerous studies have shown poor levels of inclusion of female populations into medical research. These disparities in sex inclusion in research are further complicated by the absence of sufficient reporting and analysis by sex of study populations. Disparities in the inclusion of the sexes in medical research substantially reduce the utility of the results of such research for the entire population. The absence of sex-related reporting are problematical for the translation of research from the preclinical to clinical and applied health settings. Large-scale studies are needed to identify the extent of sex-related reporting and where disparities are more prevalent. In addition, while several studies have shown the dearth of female researchers in science, few have evaluated whether a scarcity of women in science might be related to disparities in sex inclusion and reporting. We aimed to do a cross-disciplinary analysis of the degree of sex-related reporting across the health sciences—from biomedical, to clinical, and public health research—and the role of author gender in sex-related reporting.

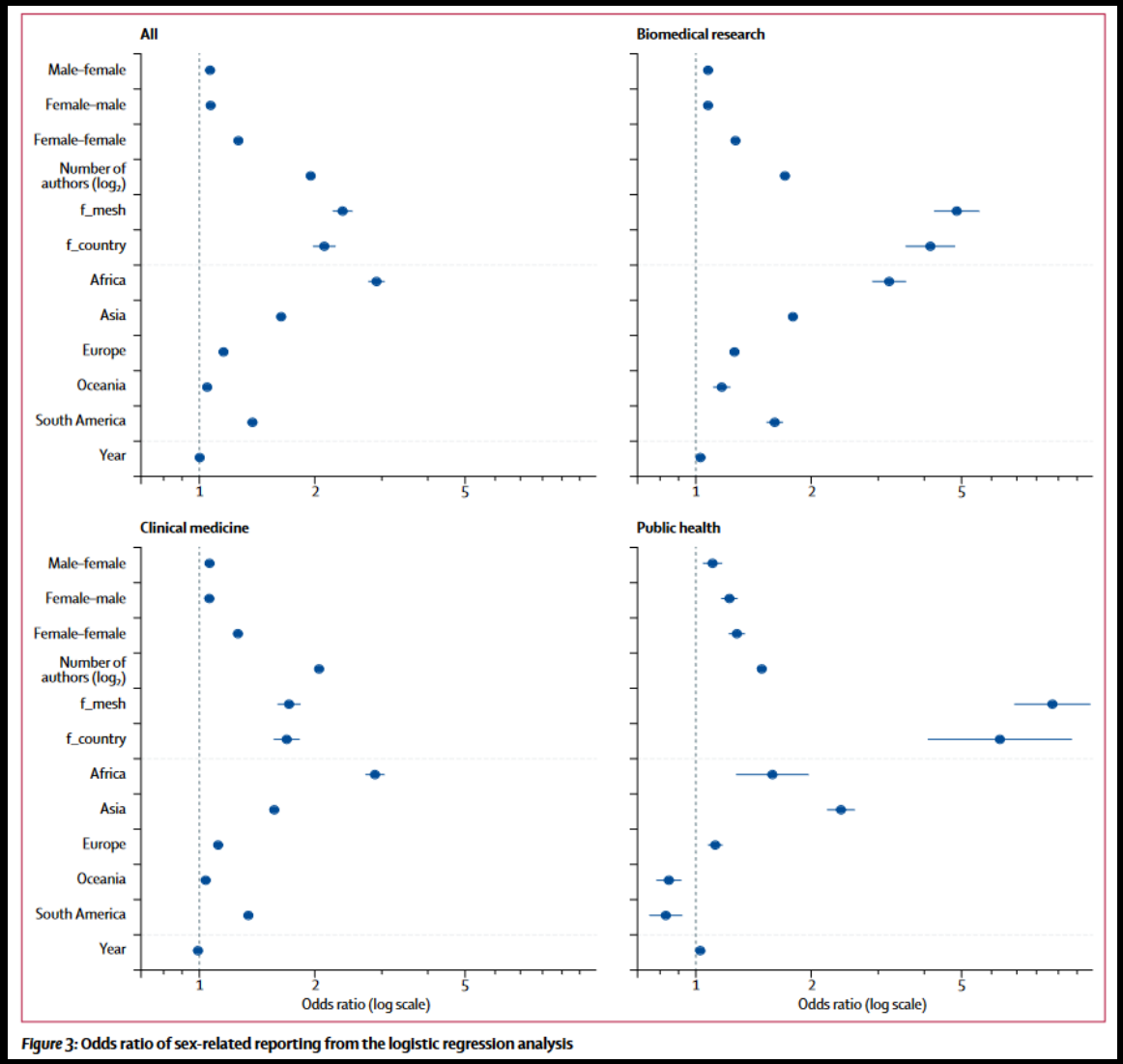


Figure 3: Odds ratio of sex-related reporting from the logistic regression analysis

HISTORY OF INNOVATION

Who do we invent for? Patents by women focus more on women's health, but few women get to invent

Rembrand Koning[1]*, Sampsa Samila[2], John-Paul Ferguson[3]

Women engage in less commercial patenting and invention than do men, which may affect what is invented. Using text analysis of all U.S. biomedical patents filed from 1976 through 2010, we found that patents with all-female inventor teams are 35% more likely than all-male teams to focus on women's health. This effect holds over decades and across research areas. We also found that female researchers are more likely to discover female-focused ideas. These findings suggest that the inventor gender gap is partially responsible for thousands of missing female-focused inventions since 1976. More generally, our findings suggest that who benefits from innovation depends on who gets to invent.

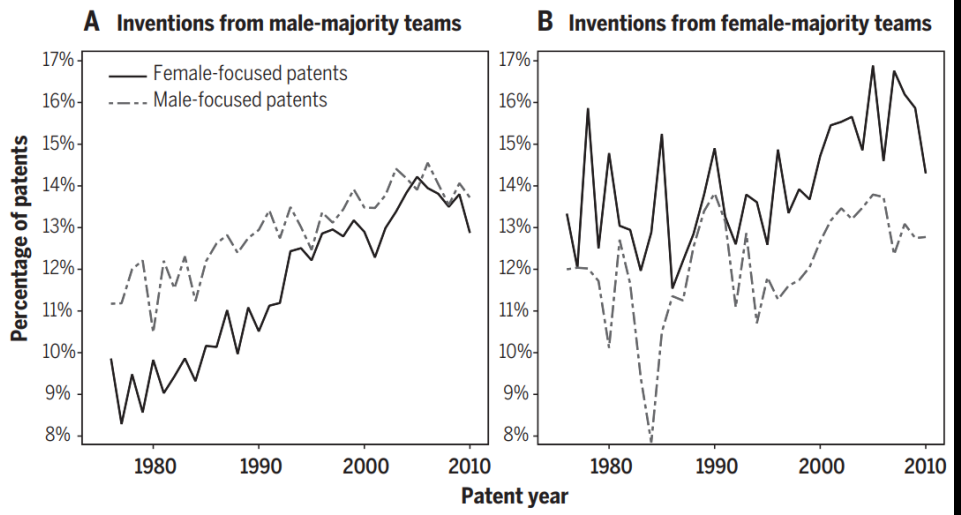
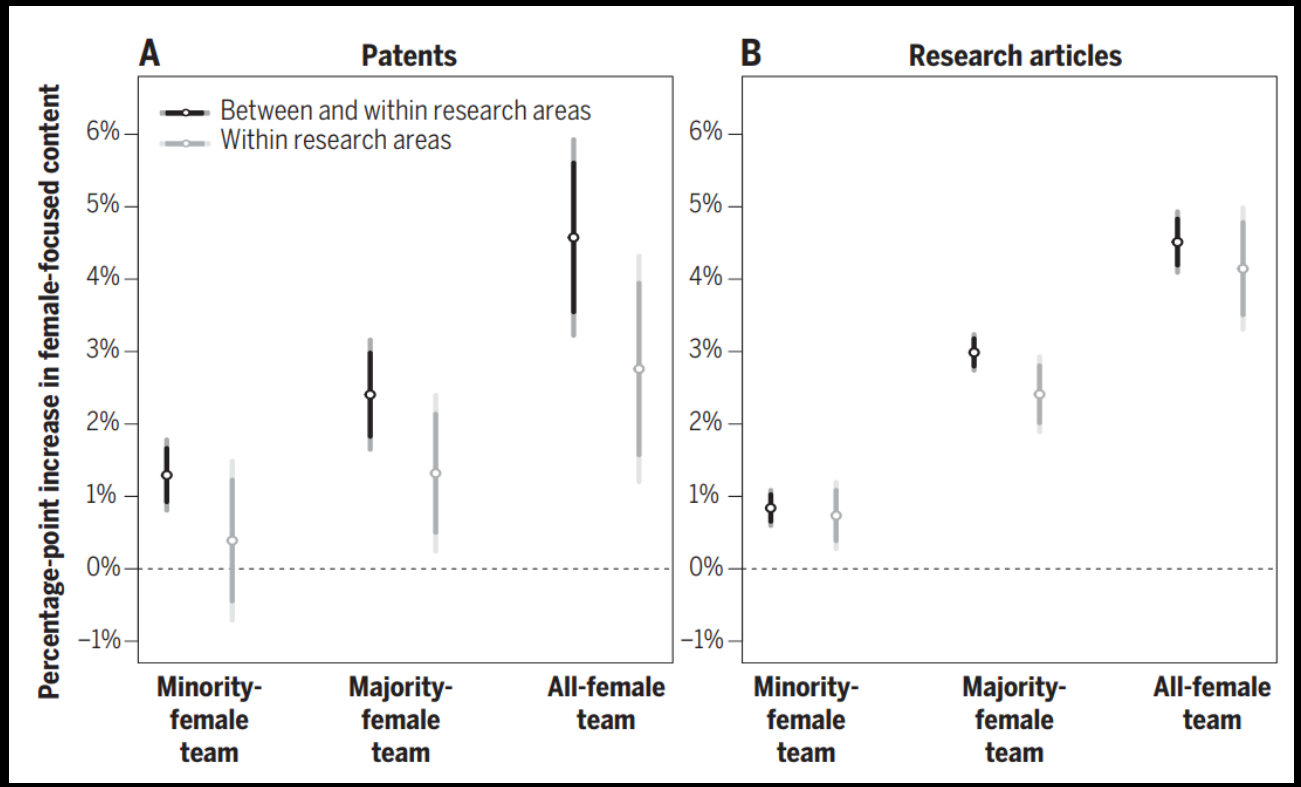


Fig. 2. Percentage of U.S. biomedical patents that are male-focused and female-focused broken out by the gender composition of the inventor team. (**A**) The percentages for patents with majority-male teams (>50% men). (**B**) The percentages for patents with majority-female teams (≥50% women).



Francesca Truffa[†] Ashley Wong[‡]

This Version: February 6, 2022

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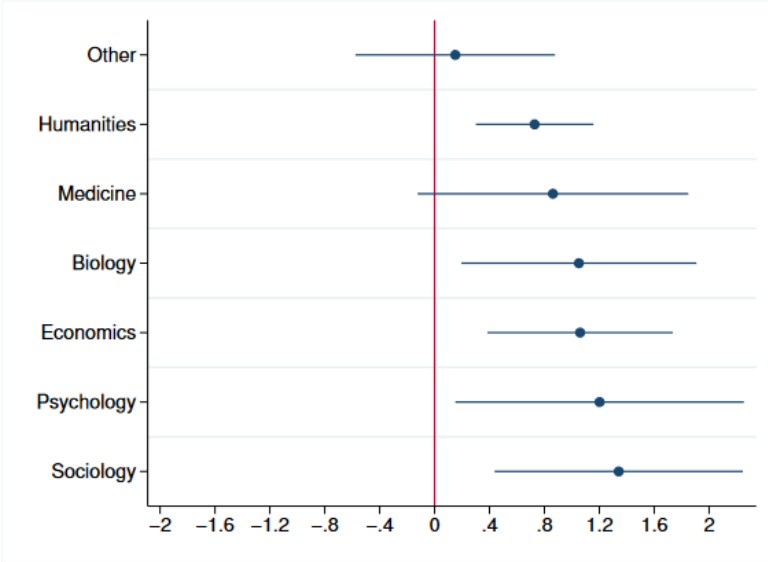
Abstract

Can diversity lead to greater research focus on populations underrepresented in science? Diverse researchers can bring new questions and perspectives, but exposure to diversity may also inspire scientists, regardless of demographic identity, to pursue new topics. This paper studies a new determinant of research ideas: the diversity of the academic environment. Between 1960 and 1990, 76 all-male US universities, including many elite and prominent research institutions, transitioned to coeducation. Using a generalized difference-in-differences design, we document a 42% increase in the number of gender-related research publications authored by scholars at newly coed universities. This increase is explained by a combination of a more diverse researcher pool in terms of gender and prior research interests, as well as a shift in the research focus of individual scientists towards more gender-related topics. A bounding exercise

Figure A12: Effect of Turning Coed on Gender-Related Papers by Field



Notes: This figure plots the average effects for years 3 to 6 and their 95% confidence intervals from estimating a modified version of equation (1) in which we interact the event time dummies with a categorical variable for each field of study. The outcome variable is the number of gender-related papers. The specification is estimated using a conditional fixed effects Poisson model. In the specification, we include the school-subfield fixed effects, year fixed effects, and discipline-by-year fixed effects. We cluster at the school level.

Promoting Gender and Sex analysis in Science

POLICY FORUM

DIVERSITY

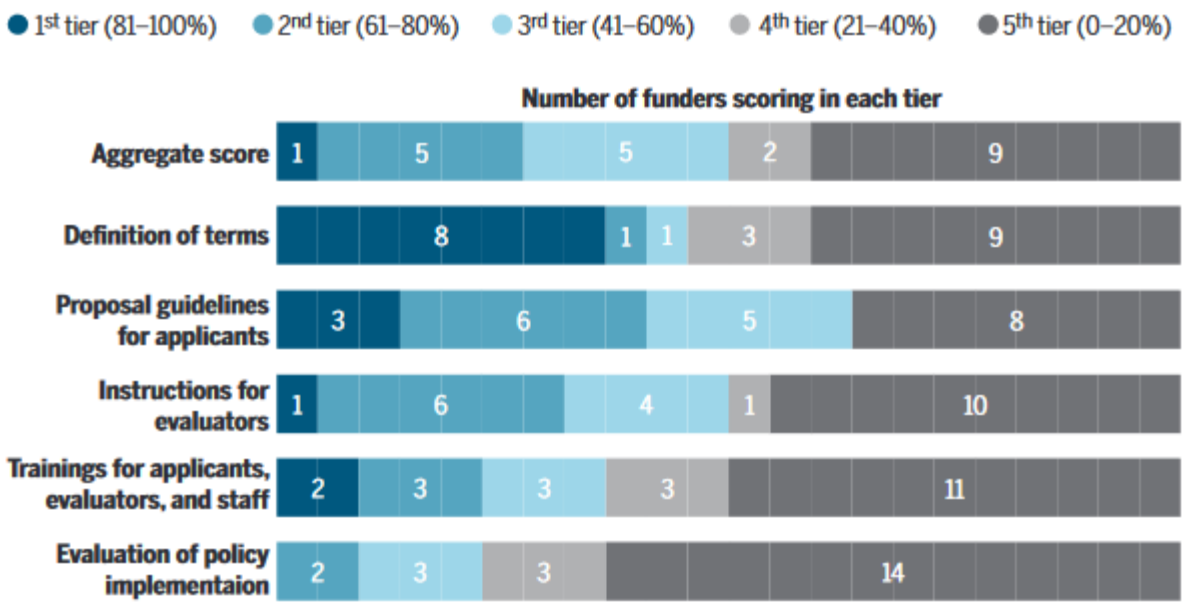
A framework for sex, gender, and diversity analysis in research

Funding agencies have ample room to improve their policies

By **Lilian Hunt[1], Mathias Wullum Nielsen[2], Londa Schiebinger[3,4]**

Agencies' performance on the policy framework

Using a scoring matrix (see supplementary materials), funding agencies were awarded points reflective of their performance on each of five parts of the sex, gender, and diversity analysis (SG&DA) policy framework (bottom five bars). Those five component-level scores were aggregated into an overall score (top bar). For each component and the aggregate, agencies were assigned to five tiers based on the percentage of the total possible points that they received for that component or aggregate. Bars reflect the number of agencies (out of 22 in total) whose scores fall within a given tier for that component or aggregate.



A framework to implement and evaluate policies

The framework covers five aspects of public funding agencies' efforts to promote sex, gender, and diversity analysis (SG&DA).

Definition of terms
- Clear and quality definitions
- Definitions readily available

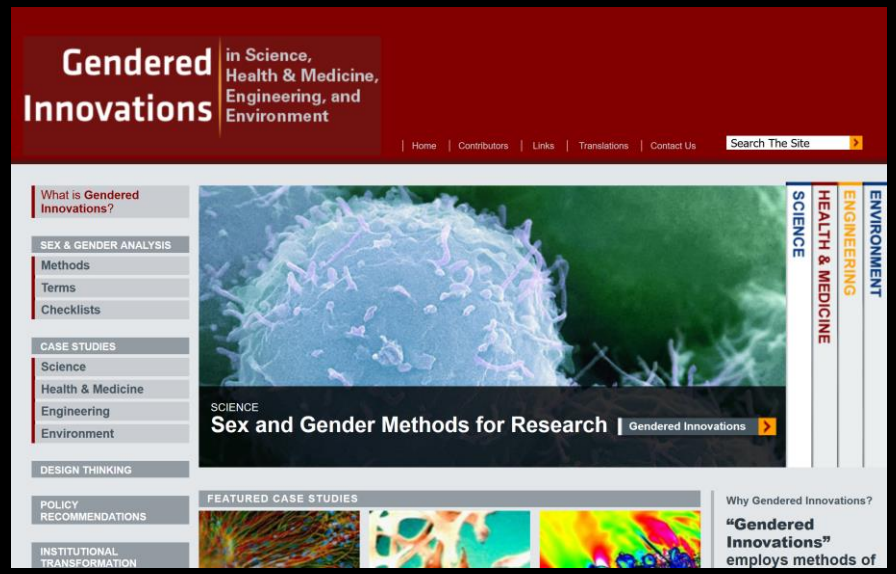
Proposal guidelines for applicants
- Instructions to applicants to include SG&DA
- Encourage or require?
- Examples given
- Specify how SG&DA is included at each stage of the research cycle—detail for yes and justify for no

Instructions for evaluators
- Instructions for reviewers to include SG&DA in their evaluations
- Assessment at each stage of the research process
- Monitoring

Trainings for applicants, evaluators, and staff
- Training, resources, and support available for applicants
- Training, resources, and support available for proposal evaluators
- Training, resources, and support available for relevant agency staff
- Training mandatory through certification
- Development of open access resources: courses and high-quality materials

Evaluation of policy implementation
- Number and proportion of proposals that include SG&DA
- Number and proportion of proposals that include quality SG&DA
- Quality of evaluators' scoring & comments
- Number of applicants, evaluators, & staff who engaged in training
- Number and proportion of publications from funded proposals that include SG&DA

Resources


Gendered Innovations
in Science, Health & Medicine, Engineering, and Environment
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What is Gendered Innovations?
SEX & GENDER ANALYSIS
Methods
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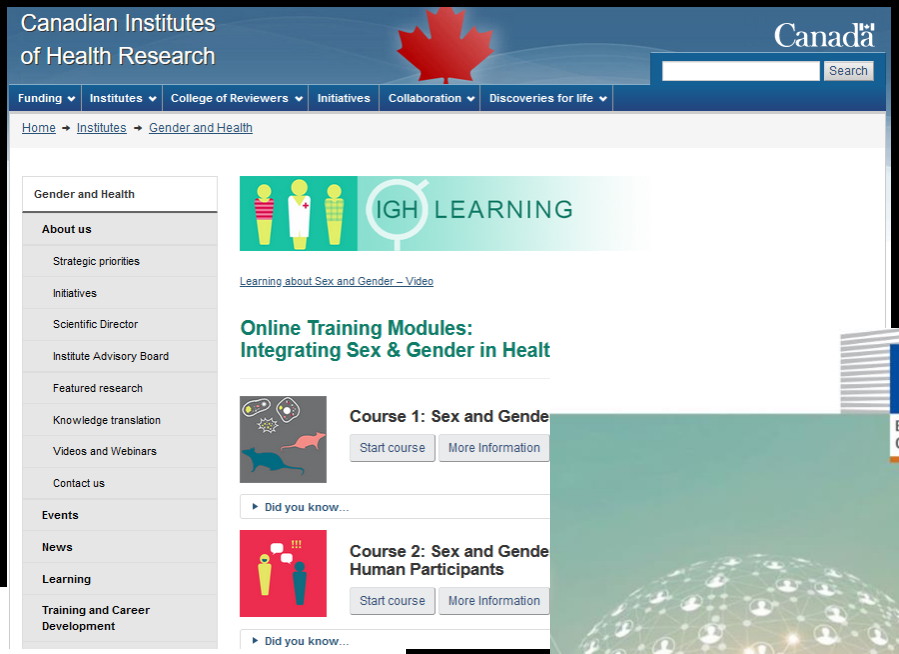
SCIENCE
Sex and Gender Methods for Research | Gendered Innovations
FEATURED CASE STUDIES
Why Gendered Innovations?
"Gendered Innovations" employs methods of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Canada
Search
Funding
Institutes
College of Reviewers
Initiatives
Collaboration
Discoveries for life
Home → Institutes → Gender and Health
Gender and Health
About us
Strategic priorities
Initiatives
Scientific Director
Institute Advisory Board
Featured research
Knowledge translation
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Learning about Sex and Gender – Video
Online Training Modules:
Integrating Sex & Gender in Healt
Course 1: Sex and Gende
Start course
More Information
Did you know...
Course 2: Sex and Gende
Human Participants
Start course
More Information
Did you know...


NIH National Institutes of Health
Office of Research on Women's Health
HOME > SEX & GENDER > ONLINE COURSES ON SEX / GENDER DIFFERENCES
Online Courses on Sex / Gender Differences
This online series of courses provides a foundation for sex and gender accountability in medical research and treatment. After completing the courses, researchers, clinicians, and students in the health professions will be able to integrate knowledge of sex and gender differences and similarities into their research and practice.
The Basic Science and the Biological Basis for Sex- and Gender-Related Differences
Sex & Gender
NIH Policy on Sex as a Biological Variable (SABV)
Sex/Gender Influences in Health and Disease


European Commission
GENDERED INNOVATIONS 2:
How Inclusive Analysis Contributes to Research and Innovation
Policy Review


THE LANCET


Science


nature


BMJ Global Health


PLOS MEDICINE


nature medicine


Cell


nature cancer


Nordic Studies on Alcohol and Drugs


PLOS BIOLOGY


JNR
JOURNAL OF
Neuroscience
Research


nature communications

Looking forward

INTERSECTIONAL APPROACHES

An intersectional approach (see Section 2.3) is important to consider when setting research priorities, developing hypotheses and formulating study designs. Taking an intersectional approach can better predict variations in health outcomes and determine user needs, and ultimately lead to more inclusive research and engineering solutions (Faulkner, 2004; Weber and Fore, 2007). For example, sex, socioeconomics, gendered divisions of labour and language interact to determine how agricultural workers are exposed to endocrine disruptors (see Gendered Innovations 1 case study 'Environmental chemicals'). Recent research also demonstrates how an intersectional approach can improve the accuracy of AI-based facial recognition (see case study 'Facial recognition') and energy-efficiency measures (see case study 'Smart energy solutions').

Identify problem

Intersectional approaches may be relevant in studies involving human subjects. While sex and gender are important concepts to consider (see 'Analysing sex' and 'Analysing gender' above), they are shaped by other social and biological factors. The way the research problem is formulated will determine which intersecting variables are required for analysis. The most important categories, factors and relationships cannot be determined a priori, but emerge in the process of investigation (Hankivsky, 2014).

Before beginning a study, researchers should conduct systematic literature searches to identify factors and categories of potential relevance. These categories and factors can be biological, sociocultural or psychological aspects of users, customers, participants, experimental subjects or cells (see box right). Even intersecting factors, such as diet or genetic variability, may be important to consider. Such factors may reveal subgroup differences among males and females that would have been obscured by using only sex as a variable (see Gendered Innovations 1 case study 'Nutrigenomics').

Factors to consider in an intersectional analysis may include:

- gender
- disabilities
- ethnicity
- race
- age
- geographic location
- socioeconomic status
- nationality
- sexual orientation
- LGBTI+ identity
- religion
- educational background
- lifestyle
- language
- family configuration
- environment
- genetics
- sex hormones
- reproductive status
- body composition
- comorbidities
- body size.

In this phase, it is also important to consider the social contexts, including societal, institutional and community-level circumstances (e.g. laws, policies, healthcare providers, school systems, law enforcement, religious institutions,