

COMMENTARY

Gender Diversity in a STEM Subfield – Analysis of a Large Scientific Society and Its Annual Conferences

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Abstract. Speaking engagements, serving as session chairs, and receiving awards at national meetings are essential stepping stones towards professional success for scientific researchers. Studies of gender parity in meetings of national scientific societies repeatedly uncover bias in speaker selection, engendering underrepresentation of women among featured presenters. To continue this dialogue, we analyzed membership data and annual conference programs of a large scientific society (>7000 members annually) in a male-rich (~70% males), technology-oriented STEM subfield. We detected a pronounced skew towards males among invited keynote lecturers, plenary speakers, and recipients of the society's Senior Investigator award (15%, 13%, and 8% females, respectively). However, the proportion of females

among Mid-Career and Young Investigator award recipients and oral session chairs resembled the current gender distribution of the general membership. Female members were more likely to present at the conferences and equally likely to apply and be accepted for oral presentations as their male counterparts. The gender of a session chair had no effect on the gender distribution of selected applicants. Interestingly, we identified several research subareas that were naturally enriched (i.e., not influenced by unequal selection of presenters) for either female or male participants, illustrating within a single subfield the gender divide along biology-technology line typical of all STEM disciplines. Two female-enriched topics experienced a rapid growth in popularity within the examined period, more than doubling the number of associated researchers. Collectively, these findings contribute to the contemporary discourse on gender in science and hopefully will propel positive changes within this and other societies.

Keywords: Gender diversity in STEM, Conference participation, Women in science, Gender equality, Scientific conference, Speaker selection

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Introduction

Speaking engagements, opportunities to serve as session chairs, and receiving awards at national meetings are foundational aspects of a successful scientific career. These activities provide a platform for researchers to share their work,

increase their professional visibility, initiate new collaborations, and signal external validation to hiring and promoting committees. It is thus critical that all members of a scientific society, regardless of gender, are equally able to access these essential stepping stones towards academic career advancement.

Studies focused on gender parity in professional meetings of national scientific societies systematically report bias in speaker selection that engenders underrepresentation of women among featured presenters [1–5]. Meetings of societies in both female-rich and relatively gender-balanced scientific disciplines witness these discrepancies, which are thought to be driven by the lack of female representation in conference organizing committees,

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higher refusal rates among invited female speakers, and implicit gender bias [1–3, 9]. The existence of several blogs and social media initiatives illuminating the issue also suggests that many fields of scientific inquiry are concerned with maintaining gender balance at domestic and international conferences [5–8].

The first critical steps on the path towards achieving balanced gender representation are (1) collecting data on female and male participation at large conferences, and (2) disseminating the information to raise awareness about the issue [10, 11]. Particularly in cases where implicit bias is at blame, making conference organizers and the general community aware of the existing gender gap may be sufficient to mitigate the issue, as exemplified by the highly positive experience of the American Society of Microbiology (ASM) [12]. Within 2 years of uncovering gender inequity among invited speakers, ASM managed to achieve a nearly complete balance of featured presenters at its general meeting in 2015.

To further the dialogue on the topic of gender diversity, we analyzed membership data and annual conference programs of a large scientific society (>7000 members annually) in a male-rich technology-oriented STEM subfield. Examining data from 2011 to 2015, we characterized the current and historical trends in gender distribution of members, speakers, session chairs, and award recipients. As the scientific society does not routinely collect demographic data, we developed a semi-automated pipeline for gender assignment based on an individual's first name. We identified that the proportion of females among Mid-Career and Young Investigator award recipients and oral session chairs (25%) closely resembled the proportion of females in the general membership (30%). Compared with males, a higher percentage of female members presented at annual conferences, and both groups were equally likely to apply for an oral presentation and be selected to deliver one. However, a large discrepancy was detected in the gender ratios of invited keynote lecturers and plenary speakers (15% and 13% females, respectively). We also identified several research subareas enriched for either female or male participants, though we note that this skewed distribution was not induced by unequal selection of presenters. Two subareas strongly enriched for female presenters were characterized as vastly popular with a rapidly growing number of associated researchers. We hope that the society initiates systematic collection of demographic information on its members to substantiate the trends described here and uses this information to design conference programs that reflect the interests of both its male and female members.

Methods

Semi-Computation Approach to Gender Assignment

As gender information was not available, we implemented a computational strategy to deduce gender based on individuals' first names (Figure 1). We utilized a publicly available gender-matched dataset from the Open Gender Tracking Project, sponsored by the Knight Foundation (<https://github.com/>

[OpenGenderTracking/globalnamedata/tree/master/assets](https://github.com/OpenGenderTracking/globalnamedata/tree/master/assets)). This dataset contains 66,916 female and 37,240 male first names, each associated with a particular gender based on acquired census data. We used these data to assign a “most-likely” gender to individuals whose first name was included within this resource. All unisex names were assigned based on higher probability of the name belonging to a male or a female in the population census dataset. The remaining unassigned names required manual annotation, conducted on a case-by-case basis at the discretion of the analyst. Lists of award recipients, invited speakers, and session chairs are publicly available on the society's website and in online program archives.

Word Enrichment Analysis, Session Grouping, and Statistical Analyses

In cases where the specific placement of individuals with unassigned gender was not the primary focus of the analysis (i.e., overall historic trends), the distribution of males and females was assumed to be equivalent among unidentified and identified individuals. Unless indicated otherwise, reported p -values were calculated using unpaired two-tailed Student's t -test.

For subarea–gender association analyses we calculated the frequency at which each word (or its derivative) appeared in the presenter's title and tested for enrichments of female or male words using a Fisher's exact test. Calculated p -values were corrected for multiple hypothesis testing via a Benjamini-Hochberg false discovery rate (FDR) adjustment. A word was classified as enriched if the gender distribution among the associated participants deviated from the ratio expected based on the gender distribution of all conference participants (i.e., one female per two males) at $p < 0.1$.

To test for systemic bias in the selection of speakers within enriched subareas, we manually grouped topically related oral sessions held between 2012 and 2015 at the discretion of the analyst (note: no session application data was provided for 2011). To calculate the normalized percentage of male and female oral session applications relative to total conference participation, the following formula was used:

Normalized Percent of Applications

$$= \frac{\sum_{i=2012}^{n=2015} \left(\frac{App_{Gender,Session,i}}{App_{Gender,Conference,i}} \right)}{\left(\frac{App_{Female,Session,i}}{App_{Female,Conference,i}} + \frac{App_{Male,Session,i}}{App_{Male,Conference,i}} \right) n-i}$$

where $App_{Gender,Session,i}$ represents the number of oral applications to a session in year i from either males or females, and $App_{Gender,Conference,i}$ is the total number of applications to all sessions in year i from either males and females. Variables denoted with either *male* or *female* subscripts reflect subsets of data from only male or only female applicants.

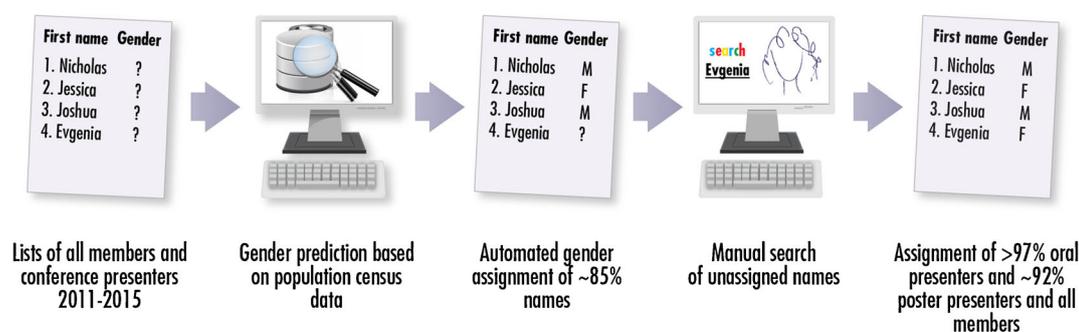


Figure 1. Semi-automated approach to gender assignment. We utilized a publicly available database of gender-matched first names (see Methods for detail) to designate genders of ~85% of the society members. The gender of the remaining members was assigned at the discretion of the researcher using a common web search and giving highest priority to oral presenters

For each grouped session we then calculated a percent deviation in expected gender acceptance using the following formula:

Percent Deviation

$$= \frac{\sum_{i=2012}^{n=2015} \left(\frac{Acc_{Gender,Session,i}}{Acc_{Total,Session,i}} - \frac{App_{Gender,Session,i}}{App_{Total,Session,i}} \right)}{n-i}$$

where $Acc_{Gender,Session,i}$ represents the number of male or female oral applicants accepted to a given session in year i , $Acc_{Total,Session,i}$ represents the total number of oral applicants accepted to the session in year i , and $App_{Total,Session,i}$ represents the total number of oral applicants to the session in year i . We tested for statistical significance in observed deviations and detected none, which are significant at $p < 0.05$.

Finally, we wanted to identify research subareas that experienced increased or decreased participation between 2012 and 2015, considering all oral and poster presenters at the conference. We manually combined topically related poster sessions with the previously grouped oral sessions and filtered the resultant list to include only sessions that accounted for at least 1% of all conference participants. We rank ordered the list by the percent of involved conference participants (Figure 5a) and by magnitude of change in participation (Figure 5b, b), omitting any sessions where fluctuation between 2012 and 2015 was under 0.5%.

Results

Gender Assignment

With the permission of the Board of a large scientific society, we obtained membership and conference participation data over a 5-year span (2011–2015). Note the society granted us access to the information under the condition that its identity remains confidential. As the examined society does not routinely collect information about the gender of its members, we implemented a computational strategy to deduce gender based on individuals' first names (Figure 1). First, we utilized a publicly available gender matched dataset from the Open

Gender Tracking Project, sponsored by the Knight Foundation. The dataset consists of 104,156 unique first names, assigned with a gender based on population census data. This resource afforded automated, high-throughput gender assignment for ~85% of all society members. The remaining 15% of the members had names unaccounted for in this database and thus required manual annotation.

We were keenly interested in trends in selection of oral presenters and, therefore, focused our efforts on assigning gender there. For each unmatched oral presenter's name, we performed a common web search and looked for pervasive trends in gender identifying words associated with the name, images of males or females having the same name, and/or complementary census data. All manual assignments were made on a case-by-case basis at the discretion of the analyst. In total, we assigned gender to 92.5% of society members, 90.2% of poster presenters, and 97.3% of oral presenters. Information about award recipients, invited speakers, and session chairs is publicly available and could be found on the society's website and in online program archives. We conclude that this approach, while not perfect, provides a close approximation of the actual gender distribution and is the only such means by which we could perform these analyses. Moving forward we strongly urge this society, and others, to deliberately collect member demographic information.

Historic Trends in Society Membership, Conference Session Chairs, Invited Speakers, and Award Recipients

Having assigned gender to most of society members and conference participants, we examined gender distribution among all members of the society across 5 years, 2011–2015 (Figure 2a). We assumed the proportion of females and males among individuals with unassigned gender was the same as that of our assigned gender group. On average, ~30% of all members were female, possibly with a slight upward trend in female membership across the 5 years (+1.3% between 2011 and 2015). This gender distribution characterized the society as male-rich, a typical feature of technology-oriented scientific disciplines [13, 14].

The society annually sponsors three peer-nominated awards for Senior, Mid-Career, and Young Investigators. We

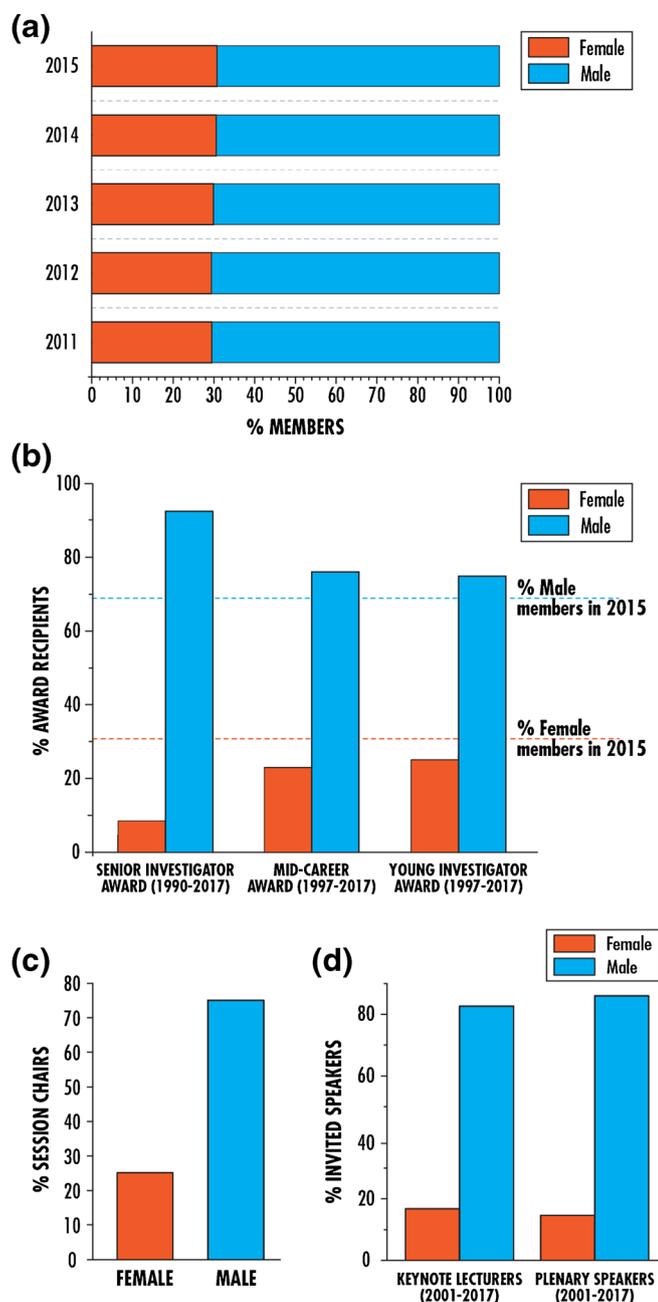


Figure 2. Historic trends of gender distribution in the society membership, award recipients, session chairs, and invited conference speakers. **(a)** Gender distribution among members of the large scientific society in 2011–2015. On average, females comprised ~30% of all society members. **(b)** Gender distribution among award recipients of the large scientific society in light of general membership in 2015. The distribution among the recipients of the Senior Investigator award was strongly skewed towards males (~92%), but the gender ratio of Mid-Career and Young Investigator award, recipients more proportionately reflected the current gender distribution of the society membership. **(c)** Gender distribution of session chairs (2011–2015). Every year exactly 25% of session chairs were female. **(d)** Gender distribution of keynote lecturers and plenary speakers invited to present at annual conferences (2001–2017). A distinct skew towards males was detected among the invited speakers

examined historic trends in gender distribution among all award recipients (Figure 2b). A pronounced skew towards males (~92%) was detected among the Senior Investigator award recipients. The ratio of females to males (25%:75%) among the Mid-Career and Young Investigator award recipients more closely resembled the current gender distribution of the society membership (30%:70%).

Every year the conference organizing committee composes a list of session chairs with a clear instruction to foster diversity of gender, age, national origin, and occupation in the selected group of scientists. Session chairs receive and evaluate submitted abstracts and generate the final roster of session presenters. Year after year, exactly 25% of session chairs were female (Figure 2c). Another primary duty of the conference organizing team is to select keynote lecturers and plenary speakers. Keynote lectures aim to illuminate state-of-the-art practices in areas of broad interest, and plenary speakers highlight remarkable scientific advances made in their respective fields of expertise. Our analysis revealed a distinct skew towards males in the distribution of both keynote lecturers and plenary speakers: 16% and 14% females, respectively (Figure 2d). This finding agrees with previous reports from other scientific societies in STEM disciplines on systematic underrepresentation of women among invited conference speakers [1–5]. We advocate that this imbalance should be addressed.

Member Participation in Annual Conferences

Next, we scrutinized trends in member participation in annual conferences of the scientific society (Figure 3a). Surprisingly, we observed that across all 5 years, female members were more likely to present at the conferences than male members (on average, 45.5% versus 38.1%; p -value < 0.01) [15]. Selection of oral presenters at the society's conference is application-based, and applicants who are not selected to deliver a talk are typically assigned to present a poster. Previous research has suggested that females may hesitate to nominate themselves for a talk and therefore directly opt for a poster because they are generally less self-promoting than males [16, 17]. Our findings do not support this proposition, as the female participants were as likely to apply for oral presentations as the males (on average, 46.2% versus 49.0%; p -value > 0.05). Similarly, females were equally likely to be selected to give oral presentations as males (24.0% versus 26.6%; p -value > 0.05).

Several studies report that the gender makeup of a selection committee correlates with the gender distribution of included speakers [1, 5]. Therefore, we examined a possibility that the gender of a session chair may influence the gender distribution of speakers in the corresponding session. We found that the gender of the chair did not detectably affect the gender composition of the sessions (Figure 3b; p -value > 0.05). This finding agrees with our observation that males and females were equally likely to be selected to deliver oral presentations (Figure 3a).

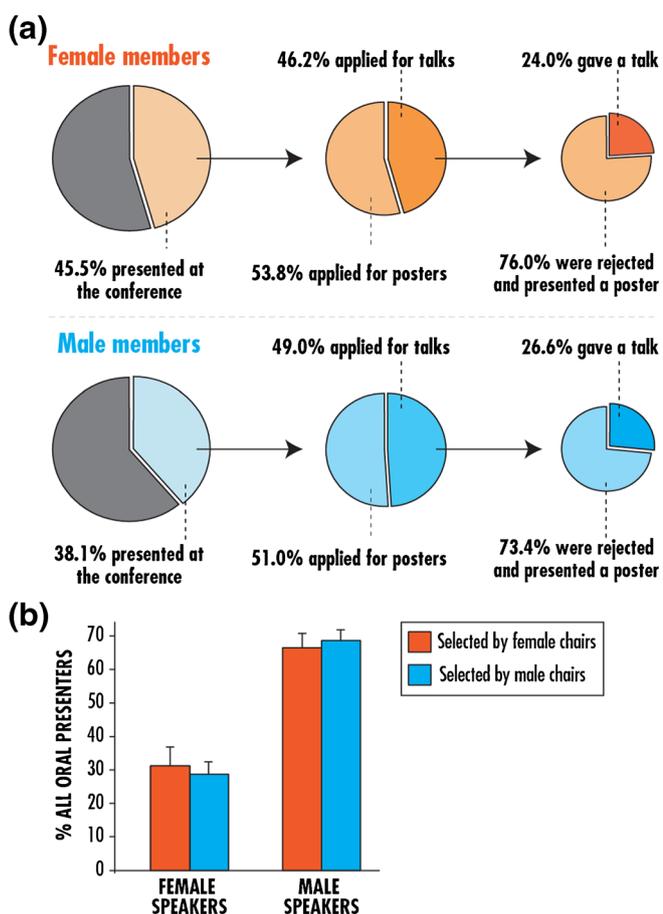


Figure 3. Participation of female and male members in annual conferences of the large scientific society. **(a)** Likelihood of the society female and male members to participate and present at its annual conferences (2011–2015). Female members of the society were more likely to present at the conference than male members (45.5% females versus 38.1% males; p -value < 0.01). Probability of the participants of either gender to apply for an oral presentation and to be selected to deliver one was equivalent (p -value > 0.05). **(b)** Gender distribution of oral presenters (2011–2015). The gender of the session chair did not have a detectable effect on the gender distribution of selected oral presenters (p -value > 0.05)

Associations between Gender and Research Subareas

Next we examined gender distribution across various research subareas of the scientific society represented at the conferences. To perform this analysis in the most unbiased manner and to avoid difficulties in distinguishing closely related topics, we extracted all unique words that appeared in the titles of poster and oral sessions, omitting conjunctions, transitions, prepositions, and words unrelated to research themes. Using this list, we calculated the frequency at which each word (or a derivative thereof) appeared in a session title each male and female member presented in. A word was categorized as enriched if the gender distribution among the associated presenters deviated from the ratio expected based on the gender distribution among all conference participants (i.e., one female per two males).

Figure 4a depicts all words enriched for either male or female participants (adjusted p -value < 0.1). Note, less than 15% of all unique words used in this analysis exhibited any gender associations (data not shown), which suggests that most research subareas were equally popular among presenters of both genders. The words “instrumentation,” “informatics,” and “analyzer,” as well as names of various analyzers (“TOF,” “FTMS,” “trap,” etc.), were strongly associated with male participants. Meanwhile, the words “carbohydrate,” “glycoprotein,” “PTM,” and “epigenetic” were classified as enriched for female presenters. Overall, the word–gender association analysis may have captured the well-known divide across scientific disciplines, where biologically oriented topics traditionally attract more females and technology- and computer sciences-related topics feature more males [13, 14].

We additionally tested a possibility that the observed segregation among the participants was induced by unbalanced selection of presenters in some subareas. We anticipate that in the absence of selection bias the gender distribution of selected speakers would reflect the gender distribution of applicants to a given session. To test for deviations in this expectation, we manually grouped topically related oral sessions based on similar titles and research themes at the discretion of the analyst. This grouping procedure provided a larger pool of oral applicants and acceptees to each session and thus increased statistical power.

No bias in speaker selection was observed in six sessions enriched for female presenters (Figure 4b in orange) and six sessions enriched for male participants (Figure 4b in blue). The gender distributions among presenters in the examined sessions (colored bar) closely mimicked the ratio of males and females expected based on the gender distribution in the applicant pool (white circle; all p -values > 0.05). This observation suggests that the aforementioned associations between gender and research subareas were self-induced and likely reflect varying preferences of female and male researchers. Our data, however, offer no insight about the roots of these varying preferences.

Relative Popularity of Research Subareas and Gender

Finally, we became interested in the relative popularity of “female” and “male” topics in the larger context of the conference and the scientific society between 2012 and 2015. Nearly all oral sessions had corresponding poster sessions, so we combined these thematically related poster and oral sessions into general research subareas. Figure 5a lists the top 16 most popular topics that together accounted for ~50% of all conference participants in 2015. The titles of 12 sessions did not contain any gender-enriched words; meanwhile, one session was likely to be slightly enriched for male presenters (“Systems biology”), and three sessions contained words strongly associated with female participants (“Glycoproteins,” “Antibody conjugates,” and “Targeted analysis of PTMs”).

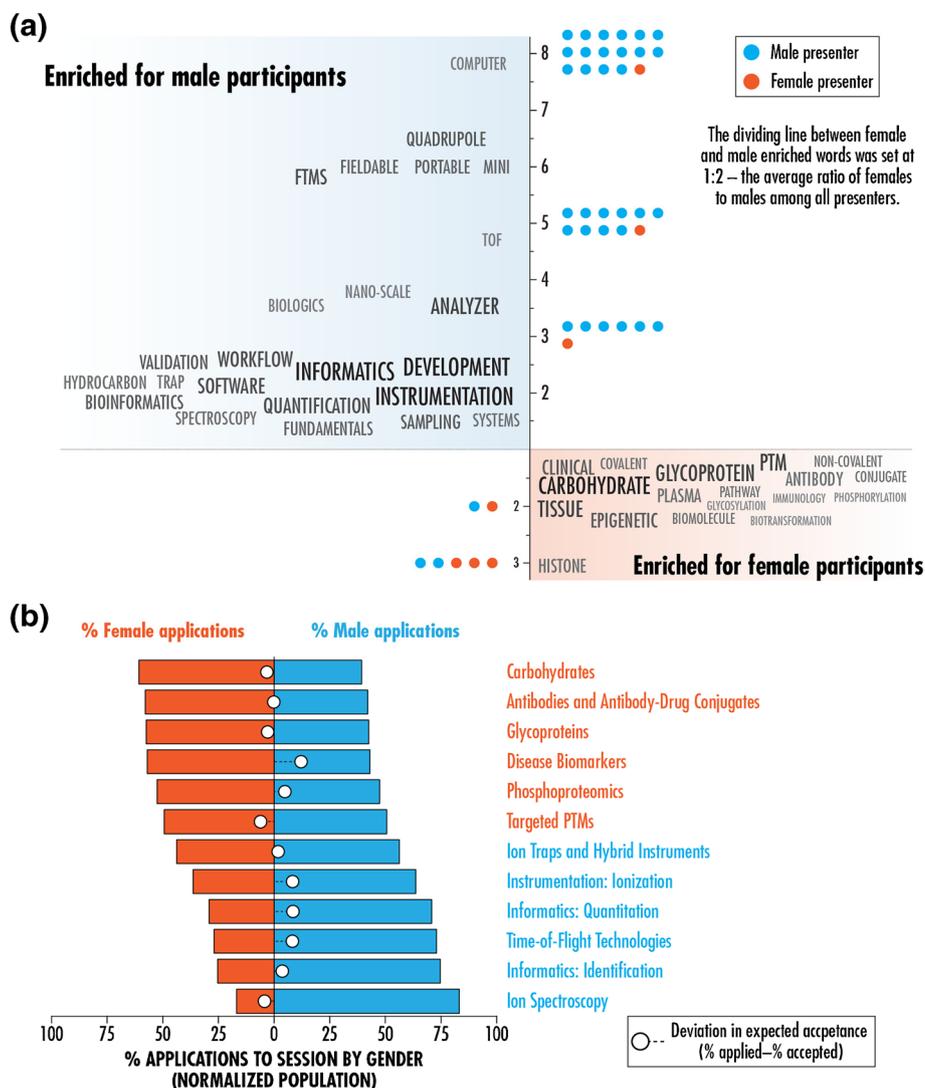


Figure 4. Enrichment of female and male participants in various research subareas represented at the annual conferences of the scientific society. **(a)** Enrichment of female and male participants in research subareas featuring indicated words in their titles. A word was designated as enriched if the gender distribution among the participants associated with it differed from the general gender distribution among all conference presenters (i.e., one female per two males). Size and boldness of words on the plot reflect significance of the detected enrichment (p -value, Fisher's exact test). **(b)** Gender distribution among applicants (colored bar) and presenters (white circle) in oral sessions featuring “female” (orange) and “male” (blue) words, as established by the analysis in Figure 4a. Gender distribution of the selected speakers did not significantly deviate from the ratio expected based on the applicant pool (p -value > 0.05)

We also searched for areas that steadily gained popularity between 2012 and 2015 and areas that experienced a decline in participation over the same period. Interestingly, two out of six topics we identified as strongly on the rise were enriched for female participants (Figure 5b). Both “Glycoproteins” and “Antibody conjugates” witnessed a strong increase in participation, more than doubling the number of researchers working in the areas in 2015 compared with 2012. Among the three areas that we categorized as declining in popularity (Figure 5c), “Instrumentation: analyzers,” a topic strongly associated with male participants, experienced a nearly 3-fold reduction in participation between 2012 and 2015. The rest of the topics, both rising and declining in popularity, exhibited no gender associations.

Discussion

National and international scientific conferences and symposia are major professional events for scientists in the field. They provide an opportunity to share discoveries, celebrate achievements, and establish professional relationships. The composition of conference presenters sends implicit messages about who belongs in the field and whose contributions are most valued [10, 11, 17, 18]. Thus, to create an atmosphere of inclusivity and parity, it is essential that both male and female scientists are represented proportionately to the general membership. Our analysis revealed that the gender distribution among keynote lecturers and plenary speakers—the field experts specifically

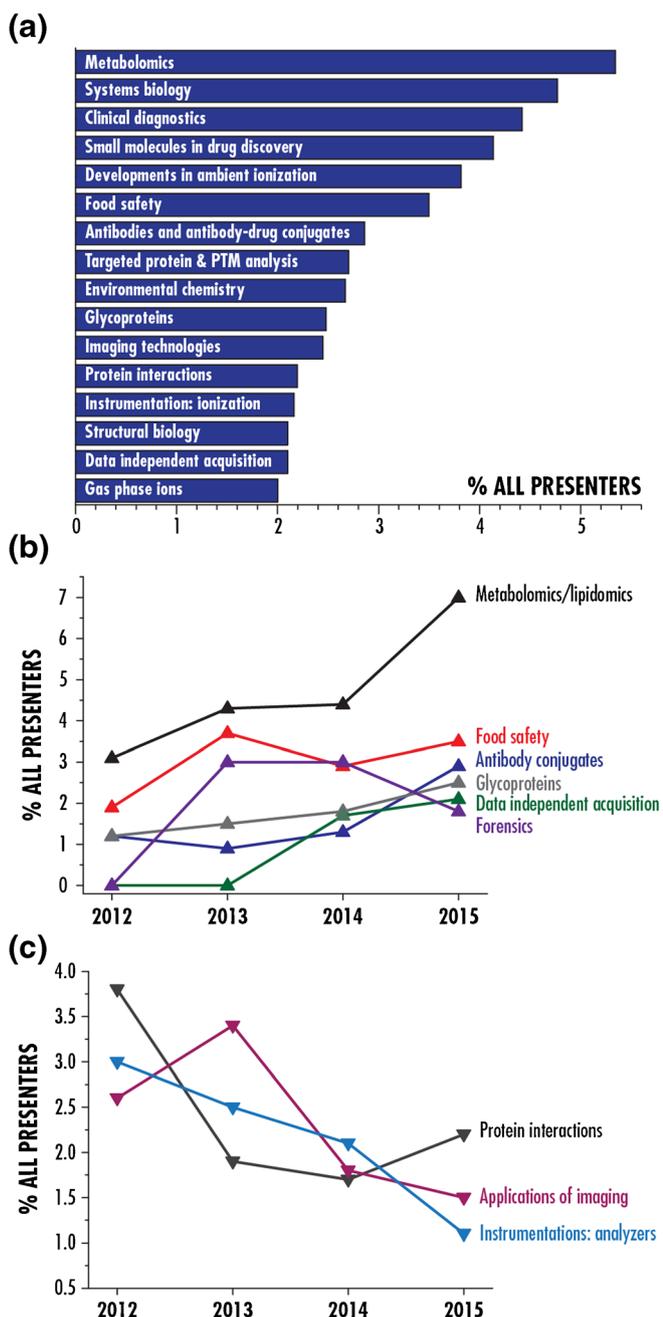


Figure 5. Popularity of research topics in the annual conferences of the large scientific society. **(a)** Sixteen research subareas that attracted the most presenters at the annual conference in 2015. ~50% of all conference participants presented their work in one of these topics. Titles of the topics contain both “female” and “male” words, as established by the analysis in Figure 4a. **(b)** Research subareas that experienced an influx of participants between 2012 and 2015. Two “female” topics, Glycoproteins and Antibody conjugates, more than doubled the total number of associated participants. **(c)** Research areas that experienced a decline in participation between 2012 and 2015. Instrumentation: analyzers, a topic strongly enriched for male participants, drew three times more participants in 2012 as it did in 2015

invited to present at conferences—is disproportionately skewed towards male presenters (Figure 2d). The percentage of females among these speakers is unduly low, even after considering general male prevalence in society membership (Figure 2a). This finding echoes the reports from other national societies in STEM disciplines [1–5], and we hope our work draws deserving attention to this disparity and provides a departure point for a lasting solution.

On a positive note, we detected no evidence of gender discrimination in the selection of oral presenters. Both male and female applicants were equally likely to be selected to deliver an oral presentation (Figure 3a and Figure 4b), and the gender of the session chair did not influence the gender makeup of the selected session speakers (Figure 3b). We also observed a greater proportion of females among conference presenters than in the general membership, suggesting that females are active contributors to research activity in this scientific society (Figure 3a).

Further, we identified that most research subareas represented at the annual conferences were equally popular among male and female participants, although statistical testing revealed a few topics that were enriched for presenters of one gender than the other (Figure 4a). Males showed a defined interest in technology-oriented subfields, such as informatics and instrument development. Conversely, females exhibited a stronger preference for research rooted in biological applications, such as histone and carbohydrate analyses. We detected no evidence of systematic gender selection bias that may serve to propagate these distortions; the detected enrichment for presenters of either gender in these topics was likely self-induced. This finding mirrors the well described disparities in female participation across various scientific disciplines [13, 14], where biology-related fields attract more women and technology- and computation-related fields attract more men. The reasons for these differences have been extensively discussed in literature with early education experiences and gender role conformity cited as the major contributors [9, 19–22]. Interestingly, two research subareas strongly enriched for female presenters were identified among the fastest growing and the most popular topics represented at the conferences. The implications of this observation are difficult to interpret, but one may foresee a rise of female leaders in these subareas.

The proportion of females in STEM fields consistently dwindles as one moves higher through educational, academic, and managerial ranks [23–25]. These trends are concerning and persist despite years of diverse efforts to attract and retain women. The explanation behind this observation is a subject of heated debates [9, 13, 18, 26–29], and we hope that our case study contributes to this discourse by proving an insight into functioning of this large male-rich scientific society and its annual conferences.

Conclusion

In this study, a large scientific society granted us access to its membership and conference participation data between 2011 and 2015. By leveraging publicly available census data and

other online resources, we assigned a likely gender to the vast majority of the listed individuals. Using these data, in addition to information made publicly available by the society, we explored trends in conference participation of male and female members of the society. Specifically, we focused on the allocation of awards and society honors, selection of session chairs and invited speakers, application and acceptance to oral sessions at the annual conference, preferences in research subareas, and recent shifts in popularity of research topics. Our analyses provide considerable insight into the current state of affairs of member activities within this society, inform changes of which society leadership might make to promote inclusivity, and serve as a guide for analyzing member activities within other scientific consortia.

Broadly, we find that males constitute a larger proportion of society membership, outnumbering females by approximately 2-fold over the years investigated. Historically, more males have received honors from this society, particularly Senior Investigator awards. The allocation of Mid-Career and Young Investigator awards shows a marked uptick in female recipients, which may reflect the gradual increase in female participation in the society. We also observe that the distribution of session chairs closely resembles the overall gender distribution in the general membership. However, a disparity exists among plenary lecturers and keynote speakers, where the proportion of invited male speakers thus far has exceeded that of the society's general membership. Female members of the society are ~7.4% more likely to present at the annual conference than males, and male and female applicants apply and are accepted to oral sessions approximately at the same frequency. The gender of the session chair does not significantly influence the gender distribution of speakers selected to present in the session.

Most research subareas represented at the annual conferences are equally popular among male and female participants, although statistical testing reveals a few topics that are more popular among presenters of one gender than the other. We find that males exhibit a defined interest in technology-oriented subfields, such as informatics and instrument development. Conversely, females show a stronger preference for research rooted in biological applications, such as histone and carbohydrate analyses. We find no evidence of systematic gender selection bias that may serve to propagate these distortions; the detected enrichment for presenters of either gender in these topics is likely self-induced.

Through the assessment of the relative popularity of research subareas at this society's annual conference, we report that sessions associated with biological applications—namely, metabolomics, systems biology, and clinical diagnostics—are among the most popular. Recent years have witnessed a growth in interest in metabolomic and lipidomic analyses, food safety, antibody conjugates, glycoproteins, data-independent analysis, and forensics. Alternatively, protein interactions, imaging applications, and analyzer development sessions have declined in participation. Two of the increasingly popular topics, glycoproteins and antibody conjugates, are strongly associated with female members of the society, whereas males heavily

dominate analyzer development, one of the area declining in popularity.

Overall, we believe that this large scientific society and its annual conference organizers have made strong efforts to be inclusive and supportive of all its members. While we can identify some distinct trends in research topic preferences between males and females, we uncovered no direct evidence of gender bias in selection of speakers. Importantly, we emphasize the need for more female plenary and keynote speakers to be featured at the annual conferences in the future. Likewise, to ensure that the gender distribution continues to move towards parity, we recommend that the society systematically collects gender, age, and other essential demographic information on its members. Such data will enable better assessment of the trends reported here and could be utilized to design conference programs that proportionately reflect its entire membership and cater to its diverse interests.

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