EMBO reports

viewpoint

A persistent problem

Traditional gender roles hold back female scientists

Anna Ledin, Lutz Bornmann, Frank Gannon & Gerlind Wallon

Women hold less than 15% of the full professorships in Europe, even though more than half of the European student population is female (EU, 2006). In the light of this, there are contrasting views about the future of women in academic research. Some analysts perceive an intractable gender gap at the higher levels of academia owing to the lower success rate of women at every step up the career ladder; others expect the gap to close over time, although it might take many years for equality to be achieved. A meta-analysis of 21 studies has shown that men have a statistically significant (7%) higher chance of receiving grants than women (Bornmann, 2007; Bornmann *et al*, 2007). We have noticed that female applicants have had a consistently lower success rate when applying for the European Molecular Biology Organization's (EMBO) Long-Term Fellowships (LTFs) and Young Investigator Programme (YIP)—in which success rate is measured as the proportion of awards given to applicants of each sex. In this study, we investigated various aspects of how a scientist's gender influences selection processes and careers.

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EMBO has been monitoring its selection processes for fellowships and awards with regard to gender for some time (Gannon *et al*, 2001; http://www.embo.org/gender/publications.html). Gender disaggregated statistics for the EMBO LTF programme are available from 1996 onwards and, on average, the success rate of women has been 20% lower than that of men. This difference has persisted despite the selection committees' awareness of and stated commitment to gender equality, and despite the fact that EMBO has received an almost equal number of applications from men and women in recent years. It is EMBO's policy that the only criterion for selection is scientific quality, and the scores from the committee are not adjusted to balance the results on any other terms.

To test whether unconscious gender bias influences the decisions made by the selection committee, we gender-blinded the committee for the two rounds of applications in 2006. We eliminated all references to gender from the applications, letters of recommendation and interview reports that were sent to the committee for scoring. Nevertheless, the difference in success rate persisted (Table 1). The finding that the committee reached the same conclusions when gender-blinded challenges some of the usual explanations given for the differences in success between male and female scientists when in direct competition.

We therefore looked for bias introduced from an external source. A recent publication suggested that letters of recommendation are written differently for men and women (Trix & Penska, 2003), and we wondered whether this was also the case for the interview reports submitted for the EMBO LTF selection process. We independently read the 283 reports from the Spring 2006 deadline and tried to deduce the gender of the applicants from the language used, as described by Trix & Penska (2003). We only guessed an applicant's gender when we felt sufficiently confident to do so—a total of 55 times (19%), of which 32 (11% overall) were correct. We concluded that it was not possible to accurately determine the gender of a significant number of the applicants from the interview reports, and that therefore the reports did not bias the committee members. Furthermore, there were no significant differences in age or experience between male and female applicants in 2006, so this could not be an alternative explanation for the lower average success rate of women.

Therefore, we set out to correlate the committee's decisions with an assumed unbiased measure: the bibliometric data for each applicant. We chose to study the cohort of LTF applicants from 1998, as this group also allowed us to investigate the career progression of the applicants since the time of application. We gathered the full bibliometric data of all 710 applicants up to the beginning of 2006 using the Web of Science database (Philadelphia, PA, USA; Thomson Scientific). We collected a total of 9,174 publications and calculated the sum and average of the impact factor (IF; journal impact factors from the 2000 and 2004 Journal Citation Reports, Thomson Scientific), cumulative citations and authorship rank for 1998 and 2006 for each applicant (Table 2).

Generalized linear models were calculated (StataCorp, 2005) to test for differences between female and male applicants. There were no statistically significant differences between awarded men and women for the number of publications, total citation counts or total IF (Table 2, column 'Until 1998'). However, awarded females had a statistically significant higher average IF than awarded males when all their publications

Table 1 | Applicants to EMBO's Long-Term Fellowship programme in 2006

	Applicants after pre-screening		Success rate percentage (%)
	Number (*n*)	Percentage (%)	
Women	416	47	28.0
Men	475	53	34.5
Difference	–	–	19.0

In total, 1,237 people applied (48% women) and out of these, 891 applications were sent out to the committee for scoring (47% women). All reference to gender was eliminated from the applications sent to the committee.

were considered, amounting to 2.34 higher impact points; but when the average IF for first and last author publications alone was considered, the difference was no longer significant. Furthermore, as the difference in average IF for total publications was small, it was probably impossible to detect by the committee. It should also be remembered that the publication record was only a part of the committee's considerations (Fig 1), and that a high total IF did not automatically ensure that an applicant was awarded a fellowship.

An overall comparison of male and female applicants—those both awarded and rejected—showed that women had a statistically significant lower average number of publications, and a statistically significant lower IF and total citation counts for their first and last author publications specifically (Table 2). However, the difference in IF was no longer statistically significant when all publications were considered and, once again, this small difference in IF for first and last author publications is unlikely to have been noticed by a committee member reading each application individually.

Therefore, although we know from our gender-blinded study that the EMBO fellowship committee was not biased against female applicants, why were female applicants not scored as highly as male applicants? One part of the explanation might be that men are generally more productive than women, although the quality of the work presented—as judged by IF and citation numbers—is only different between the sexes when that variable is dependent on the total number of publications. It is possible that the higher average number of publications from male applicants (Table 2) could have biased the score given to men by a committee member.

We looked at the publications of the 1998 fellowship applicants from 1999 to 2006 to obtain an idea of how their science had progressed. Again, on average, women had published fewer papers than men, and even awarded women had published statistically significantly less than awarded men. Despite this, the differences in total and average IF were not statistically significant for awarded women—that is, their work has the same impact as awarded men. However, the total and average IF, and total citation counts for all women—including those rejected—was significantly lower when only first and last author publications were considered (Table 2). In other words, the overall gap between men and women was more pronounced in terms of the number and quality of publications than at the time of application.

This does not explain why women produce fewer publications, or whether there are other aspects of an application that can lead to a lower average success rate for women. Furthermore, although considering the factual data gives important insights to the applicants' careers, it does not allow one to understand the reasons for the differences in how their careers have developed. To gain a deeper insight into their personal situations and motivations, we conducted a survey of the LTF applicants from 1998. Responses were received from a representative group of 60% of the applicants (Table 3, column 'Fellowship

Table 2 | The median values of the bibliometric data for the applicants to EMBO's Long-Term Fellowship programme in 1998

	Until 1998				Between 1999 and 2006			
	Overall		Awarded		Overall		Awarded	
	Women (*n* = 275)	Men (*n* = 435)	Women (*n* = 41)	Men (*n* = 89)	Women (*n* = 275)	Men (*n* = 435)	Women (*n* = 41)	Men (*n* = 89)
Number of publications	*3.00	*4.00	4.00	6.00	*6.00	*8.00	*6.00	*8.00
Number of first and last author publications	*+2.00	*+2.00	3.00	3.00	*2.00	*3.00	*3.00	*4.00
Total impact factor of all publications	17.21	21.05	41.95	40.68	*33.50	*51.00	49.85	63.64
Total impact factor of first and last author publications	*7.37	*10.79	25.56	21.87	*12.97	*20.57	19.76	25.77
Average impact factor of all publications	4.89	5.10	*9.28	*6.94	5.83	6.32	7.38	7.56
Average impact factor of first and last author publications	4.16	4.56	9.35	7.25	*5.11	*5.79	6.20	6.76
Total citation counts of all publications	100.00	132.00	305.00	265.00	*88.00	*134.00	142.00	172.00
Total citation counts of first and last author publications	*44.00	*59.00	160.00	124.00	*31.00	*52.00	42.00	66.00

The number of publications includes citable publications of the type Article, Letter, Note and Reviews (9,174 in total). The bibliometric data presented as 'Until 1998' is from 1993 until the time of application in 1998, and 'Between 1999 and 2006' only includes the publications from the time of application until 2006. The total impact factor is the sum of the journal impact factors where the publications appeared. The average impact factor is the mean value of the total impact factor divided by the number of publications.
*The difference in mean values is statistically significant ($P < 0.05$); +the arithmetic mean values are 2.06 (women) and 2.61 (men).

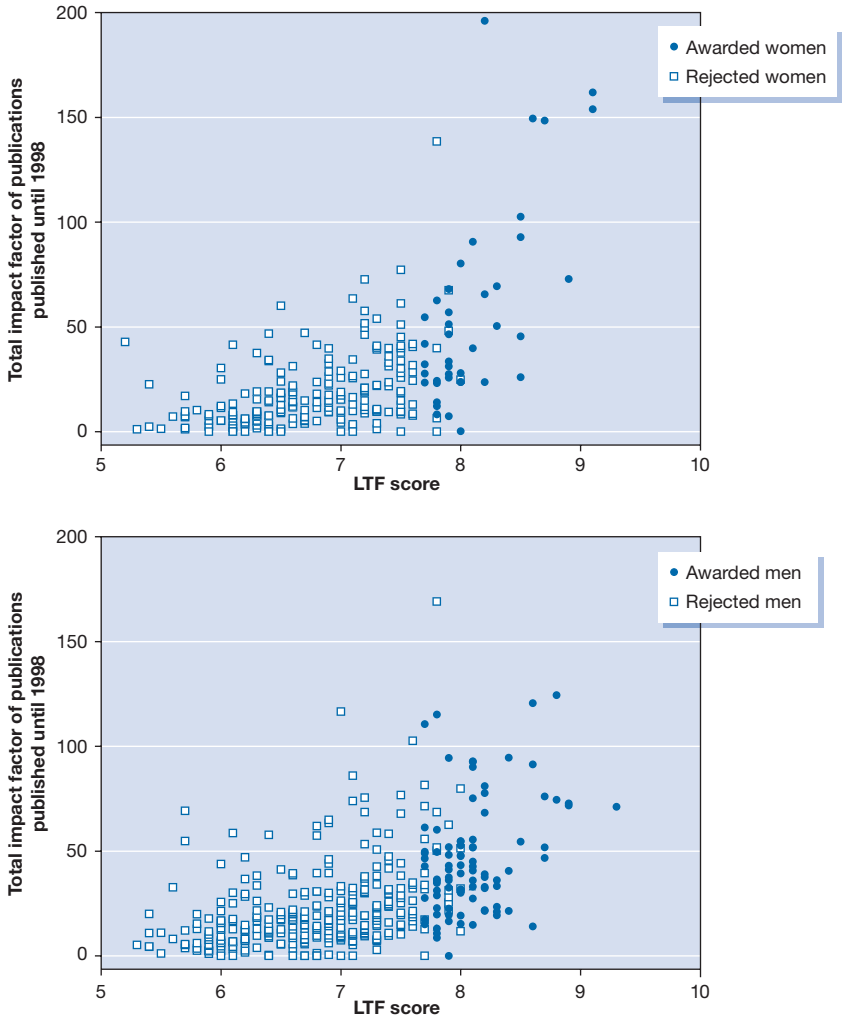

Fig 1 | The total impact factor of publications published between 1993 and 1998 for the applicants to EMBO's Long-Term Fellowship programme in 1998. The total impact factor for each applicant is plotted against their Long-Term Fellowship (LTF) score, which is the average score given to each applicant by the ten fellowship committee members.

applicants 1998′). Approximately 80% of both male and female respondents were still working in academia, with 59% of the respondents in a permanent position. More men (75%) than women (60%) were in higher-ranking positions as group leaders and professors. The majority of both genders were working full time—more than 36 hours per week.

Most of the former LTF applicants are balancing careers and families. Of the men and women, 90% had a partner, women more frequently had a partner who also held a PhD and worked in science, and 61% of female respondents and 69% of male respondents had children. Most respondents had two children and women took an average of 2–3 months parental leave per child; men did not take any substantial parental leave. The results of the survey also suggested that women more often adjust their own careers to suit their partners: women more frequently moved owing to their partner's work, full-time female scientists with children more often had a partner who worked more than 46 hours per week, and women more frequently earned less than 50% of the family income (Table 3).

Could the small gap between men and women with regard to their publications at the end of their PhD period be the consequence of a similar social/family arrangement as revealed above by the survey of the former LTF applicants? We investigated this possibility with a questionnaire sent to the applicants of the EMBO fellowships programme from autumn 2006. Perhaps unsurprisingly, we found similar trends in the working habits of these young scientists, although not as pronounced as with the older group. Again, we found that more female applicants had moved to suit their partners' careers, tended to work fewer hours than their partners, even at the PhD stage, and provided the smaller percentage of the family income (Table 3). In other words, even at the PhD level, women already balance career and family commitments, and this presumably affects their research.

Does this trend continue to the next step of the career ladder: the group-leader level? Applicants to EMBO's Young Investigator Programme are scientists who have committed themselves to an academic career path. The programme receives 25% of its applications from women—half the percentage of women who apply for the fellowship programme—with an average difference in success rate between men and women of 12% to the disadvantage of women.

> **…that the committee reached the same conclusions when gender-blinded […] challenges some of the usual explanations given for the differences in success between male and female scientists…**

In a manner analogous to the study of the EMBO postdoctoral fellows, we investigated the cohort of YIP applicants from 2001 and 2002, a total of 297 scientists. Bibliometric parameters from 9,719 publications were collected and calculated as described previously. On average, the bibliometric data showed similar trends as for the fellows: women had published fewer papers, but the differences in the IF and citations per paper were not statistically significantly different between men and women (Table 4). We therefore questioned these applicants in a survey similar to the one described previously and obtained similar results (Table 3). In addition, men often held higher-ranking positions, had larger grants and consequently larger laboratories, and women often had a higher teaching load than men (see the Supplementary information online for complete questionnaires).

Table 3 | Data accumulated in 2006 and 2007 for EMBO applicants at different stages of their careers

	Fellowship applicants 2006		Fellowship applicants 1998		YIP applicants 2001/2002	
	Women	Men	Women	Men	Women	Men
Number (%) of applicants	299 (46)	352 (54)	275 (39)	435 (61)	85 (29)	212 (71)
Number (%) of respondents	122 (49)	129 (51)	151 (38)	247 (62)	67 (29)	164 (71)
Working in academia (%)	94	97	80	81	99	96
In a permanent position (%)	6	3	57	60	72	81
Work full-time (36 h per week or more) (%)	98	100	*93	*100	99	100
Work more than 46 h per week (%)	65	74	*51	*64	*58	*83
Have a partner (%)	73	71	89	90	86	93
Have children (%)	13	24	61	69	69	82
Partner has a PhD (%)	43	37	*62	*44	*67	*45
Moved for partner (%)	32	19	*51	*18	*37	*16
Partner is working (%)	*93	*79	*98	*87	100	93
Partner is working part-time (%)	*1	*18	*6	*28	*4	*33
Partner works more than 46 h per week (%)	*60	*29	*54	*29	*62	*30
Provides more than 50% of the family income (%)	*42	*71	*32	*76	*34	*86
Have a mentor (%)	42	47	38	32	*32	*49
Would like to have a mentor (of those who do not have a mentor) (%)	76	68	*69	*48	*71	*46
Consider men to get more career support from supervisors (%)	*27	*10	*43	*15	*44	*14
Have witnessed negative discrimination against women (%)	*17	*2	*22	*8	*34	*8
Have been discriminated against because of their gender (%)	*7	*0	*13	*3	*15	*4

The applicants were asked to complete a questionnaire about their personal life, and the main findings are presented. The fellowship applicants from Autumn 2006 just finished their PhDs, the fellowship applicants from 1998 were approximately 8 years on from their PhDs and the Young Investigator Programme applicants already held an independent group leader position when they applied in 2001/2002. The complete results can be found in the Supplementary information online.
*The difference in the frequencies is statistically significant ($P < 0.05$).

Our data confirm that women have a tendency to select a partner who has at least the same level of qualification as they have themselves. When a decision has to be made on the career of the partner—where to move next for a postdoc—women more frequently put their own careers in second place. Among those women who do make it to the independent group leader level, fewer have moved for their partner's career than among the former fellowship applicants—37% and 51%, respectively. We assume that women who follow their partners are less likely to find a laboratory that suits their expertise and expectations; a factor that might influence the quality of their fellowship applications and the outcome of their fellowship in general: they publish fewer papers owing to working in a sub-optimal environment.

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The fact that women bear children and take on the majority of child care responsibilities leads to career breaks and fewer weekly working hours for women, resulting in decreased productivity and consequently decreased competitiveness and an increased rate of drop-out. In fact, 22% of the female fellowship applicants from 1998 had not published since 2003—as opposed to 14% of the male applicants—suggesting that a higher percentage of women were likely to have discontinued their academic careers. Recent studies (EC, 2003; DTI, 2002) have shown that a significant percentage of women trained in science, engineering or technology are not in professional positions that require these qualifications. In any case, removing these applicants from the calculations did not change the general outcome with regard to publication number and impact.

This quasi-longitudinal study has allowed us to look at the development of the careers of men and women from the late PhD stage to the early group leader stage. Our data offer an explanation as to why the careers of women do not take off at the same rate as those of men. It confirms the so-called 'productivity puzzle' as described by Cole & Zuckermann (1984) and more recently confirmed by Symonds *et al* (2006), which highlights the fact that women produce fewer papers than men, particularly during the first decade of scientific activity. The data are supported by the results of Long (1992) who postulated the 'impact enigma',

Table 4 | Median values of the bibliometric data for all applicants to EMBO's Young Investigator programme in 2001 and 2002

	Until 2001/02		Between 2001/02 and 2007	
	Women ($n = 85$)	Men ($n = 212$)	Women ($n = 85$)	Men ($n = 212$)
Number of publications	*15.00	*18.00	*8.00	*11.00
Number of first and last author publications	*8.00	*10.00	*4.00	*6.00
Total impact factor of all publications	100.69	120.19	*45.65	*66.51
Total impact factor of first and last author publications	*46.59	*64.80	*24.00	*36.81
Average impact factor of all publications	6.73	6.71	5.96	6.38
Average impact factor of first and last author publications	6.56	6.86	6.00	5.76
Total citation counts of all publications	665.00	825.00	66.00	91.00
Total citation counts of first and last author publications	*277.00	*407.00	29.00	48.50

The number of publications includes citable publications of the type Article, Letter, Note and Reviews (9,719 in total). The bibliometric data presented as 'Until 2001/02' is from 1984 until the time of application in 2001 or 2002; 'Between 2001/02 and 2007' includes only the publications from time of application until 2007. The total impact factor is the sum of the journal impact factors where the publications appeared. The average impact factor is the mean value of the total impact factor divided by the number of publications.
*The difference in mean values is statistically significant ($P < 0.05$).

based on his findings that women publish fewer but higher-impact papers than men. The question is, why is this so? We believe that our data offer some explanation for why women publish less and why they might be slower to advance—quite simply, because women on average have less time available at work and have a greater burden to carry outside the laboratory.

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Although we have shown that traditional gender roles are a likely explanation for women's loss of competitiveness, we have further evidence that these are not exclusive factors. From the results of our survey, we found that women tended to receive less professional support than men: 32% of the female YIP applicants reported that they had a mentor, whereas 71% of those who did not have a mentor would have liked to have had one. For men, the situation was more balanced: 49% had a mentor and 46% wanted one. Therefore, more women at the group-leader level miss out on the valuable support and networking that a mentor has to offer. In general women feel that they are in need of better mentoring. Furthermore, women more frequently reported that their supervisors became less supportive and more critical when they had children, and 27–44% of the women questioned—2006 and 1998 LTF applicants and YIP applicants—felt that, in hindsight, men had received more support from their supervisors at the PhD and postdoctoral level.

In addition, 17% and 34% of the women at the early postdoctoral level or the group leader level, respectively, had witnessed what they felt to be negative discrimination of women, and 7% and 13%, respectively, felt that they had been discriminated against. We fully accept that this is subjective, but if we also consider the responses of the male applicants to the programmes—2–8% of who reported having witnessed the negative discrimination of women—we feel justified in concluding that there is an element of discrimination against women, even in modern professional environments.

We asked the YIP applicants about the recruitment procedures and gender policies at their respective institutes. Of the respondents, 67% felt that the recruitment procedures at their institutes were transparent, and 8% of the women and 1% of the men felt that they had been discriminated against because of their gender. Only 34% reported that their institute had an explicit gender policy and only 50% of those felt that their institutes adhered to that policy. Of the respondents, 83% said that their institute offered parental leave of some kind. Measures that either help parents—such as tenure clock-stop or temporary relief from teaching duties—or that recognize that women face extra challenges in the current system—such as appointing a women's representative, keeping statistics or actively trying to recruit women—were only present at the institutions of 12–29% of the respondents (see Supplementary information online). These data indicate that there is a pervasive ignorance of the effects that the current system has on the careers of women at the institutional level (NSF, 2006).

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The data that we present suggest subtle differences in the average applications of men and women, which collectively combine to real effects that are reflected by lower success rates for women. In addition, there remains a pervasive culture of negative bias—whether conscious or unconscious—against women in academia, resulting in a lack of professional support and networking. This same culture also ascribes women traditional roles in the home. Together these factors constitute a harmful mix that leads to women being

less successful than men over the course of their careers.

Employers, policy-makers, scientists and society all need to consider whether we can afford to lose such a large number of trained specialists from the workforce. The consequence of the current system is that a large percentage of higher education graduates are not reinvesting their skills in the economy, owing to traditional gender roles that are no longer in accordance with the demands of modern women and men. We need to ensure that men and women who want to have families are not prevented from also having careers and contributing to society in every way that they can. This can only be achieved by a significant change in the way that society and individuals think about the roles of men and women, and by taking positive action to improve the working conditions and available support for both women and men at all stages of their careers.

Supplementary information is available at *EMBO reports* online (http://emboreports.org)

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