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Rumors of Our Rarity are Greatly Exaggerated: Bad Statistics About Women in Science[1]

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Synopsis

During the past few years, three bad statistics have been persistently used in discussions of women in science, technology, engineering, and mathematics (STEM). The first was questionable when it was published in 1983 and has since been widely used. The second came to prominence in 2006 – and now leads an international and perhaps eternal life on the Web. The third may have made its debut in 2007. Its variants occur in popular and academic books and journals, including the 2011 *Proceedings of the National Academy of Sciences*.

This report presents case histories of the three bad statistics, suggests writing and editing practices which might reduce such occurrences, and provides primary sources of statistics on women in STEM.

> "Harder to kill than a vampire." That is what the sociologist Joel Best calls a bad statistic. But, as I have discovered over the years, among false statistics the hardest of all to slay are those promoted by feminist professors.

This claim begins "Persistent Myths in Feminist Scholarship," a 2009 essay [50] by Christina Hoff Sommers, a scholar at the American Enterprise Institute. I agree with Sommers that bad statistics can be hard to kill. But, I am not convinced that feminist professors have the monopoly on the vampire statistics market that her essay seems to suggest. "Bad statistics are used to promote all sorts of causes," as Joel Best notes in *Stat-spotting* [9].

[1]Partial references are given in the text or in footnotes. These are intended to give information that suffices to identify the appropriate full reference at the end of the article.

During the past few years, I have noticed three bad statistics used in discussions of women in science, technology, engineering, and mathematics (STEM). The first was questionable when it was published in 1983 and has since been widely used. The second came to prominence in 2006 – and now leads an international and perhaps eternal life on the Web. The third may have made its debut in 2007. Its variants occur in popular and academic books and journals, including the 2011 *Proceedings of the National Academy of Sciences*.

In this article, I give case histories of the three bad statistics, mention writing and editing practices which might reduce such occurrences, and give primary sources of statistics on women in STEM. The bad statistics can be viewed from different perspectives, including bias and quantitative illiteracy. Both are discussed in the conclusion.

1. The Solitary Statistic

In 1980, an article in *Science* reported large gender differences in scores on the quantitative section of the SAT (known as the SAT-M) taken by seventh and eighth graders [4]. There was no pretense that these occurred in a random sample.[2] About 10,000 students had taken the test as part of a talent search for a program at Johns Hopkins University. The *Science* article resulted in headlines such as "Do Males Have a Math Gene?" (*Newsweek*) or "The Gender Factor in Math" (*Time*), (see Figure 1 on the next page).

Three years later, talent search statistics were again featured in *Science* [5]. Between 1980 and 1983, about 64,000 students had participated. Two hundred and eighty of them scored 700 or above on the SAT-M – about 13 boys to every 1 girl.

During the next two decades, the talent searches continued at Johns Hopkins and were initiated at other universities, but – vampire-like – the 13 to 1 statistic never aged. Until 2005, it was reported without later statistics in journal articles (*Behavioral and Brain Science*, 1988 [2]; *Current Directions in Psychological Science*, 1992 [36, p. 62]; *Psychological Science*, 2000 [7,

[2]As Wai, Lubinski, & Benbow note of later studies using the talent search data, "As suggestive as these findings are, however, D. F. Lohman (personal communication, May 2007) noted one limitation: [they] were not based on random samples of the general population or even random samples of high-ability students," [56, p. 818].

Do Males Have a Math Gene?

Can girls do math as well as boys? All sorts of recent tests have shown that they cannot. Most educators and feminists tude Test normally given to high-school seniors. In the results on the math portion of the SAT—there was no appreciable dif-

Newsweek, Dec. 15, 1980

The Gender Factor in Math

A new study says males may be naturally abler than females

Until about the seventh grade, boys and girls do equally well at math. In early high school, when the emphasis Julian C. Stanley of Johns Hopkins University, males inherently have more mathematical ability than females.

Time, Dec. 15, 1980

Male superiority

Are boys born superior to girls in mathematical ability? The answer is probably Yes, say Camilla Persson Benbow and Julian C. Stanley, researchers in the department of psychology at the Johns

The Chronicle of Higher Education, December, 1980

Are Boys Better At Math?

New York Times, Dec. 7, 1980

BOYS HAVE SUPERIOR MATH ABILITY, STUDY SAYS

Boys are inherently better at math than girls, according to an eight-year study of 10,000 gifted students. Coun-

Education U.S.A., Dec. 15, 1980

SEX + MATH = ?

Why do boys traditionally do better than girls in math? Many say it's because boys are encouraged to pursue

Family Weekly, Jan. 25, 1981

Study suggests boys may be better at math

WASHINGTON (UPI) – Two psychologists said Friday boys are better than girls in math reasoning, and they urged educators to accept the fact that something more than social factors is re-

Ann Arbor News, Dec. 6, 1980

Figure 1: 1980–1981 headlines. Reproduced, with permission of University of Chicago Press, from: Eccles, Jacquelynne S., "Social Forces Shape Math Attitudes and Performance", *Signs*, **11**:2 (1986:Winter) p. 367.

p. 474]), scholarly books (*Male, Female: The Evolution of Human Sex Differences*, 1998 [23, p. 315]; *International Handbook of Giftedness and Talent*, 2000 [28, p. 640]; *The Blank Slate: The Modern Denial of Human Nature*, 2002 [46, pp. 344–345]; *Gender Differences in Mathematics*, 2004 [22][3]). In 1991, the statistic appeared in a popular book *Brain Sex: The Real Difference Between Men and Women* [40, p. 16] – still in print and referenced by a more recently published popular book (*Boys and Girls Learn Differently!*, 2001 [25, pp. 16–17]). In 2003, the statistic appeared – still unaccompanied by later statistics – in *The Essential Difference: Male and Female Brains and the Truth About Autism* [1, p. 74].[4]

So, what's the problem with reporting, years later, a solitary statistic from 1983? Nothing – if you are interested in discussing only what was known in 1983. However, to report this statistic without related later statistics is to suggest that nothing has since changed or more recent information does not exist. But, in Johns Hopkins talent search statistics collected between 1984 and 1991, the average 700-or-above boy to girl ratio was 5.7. The sample size was 243,428, considerably larger than the earlier samples. Talent searches conducted by Duke University between 1981 and 1992 produced an average 700-and-over ratio of 5.6. The sample size was 308,397. These findings were reported in conference proceedings rather than a high-circulation science magazine. They did not make headlines. In 2005, Hopkins researchers reported in *High Ability Studies*, a journal on giftedness, that the 700-and-over ratio had dropped to 3 [12]. New ratios were also reported in a letter to the editor of the *Johns Hopkins Magazine* in 1997 [53], and an interview in the *Chronicle of Higher Education* in 2005 [41].

In 2006, these statistics were brought to more general attention in background material for a petition from the Association for Women in Mathematics. (Disclosure: I was then the president elect and helped to compile this material. For details, see my article "Perceptions and Research: Mathematics, Gender, and the SAT" in the Mathematical Association of America's newsletter *FOCUS* [29].)

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[3] Chapters 1 and 2 in [22] discuss the attention given to the statistic, e.g., pages 14, 26. Other chapters cite it as evidence of the distribution of mathematical ability or performance, e.g., pages 66, 189.

[4] Although [5] is cited on p. 72, the 13 to 1 ratio makes its appearance on p. 74 with no mention of the talent search and no footnote: "if you look at those people scoring above 700, the sex ratio is 13:1 (men to women)."

Table 1: Talent Search sample sizes with 700-and-over ratios reported before 2006. Table is reproduced from [29]. Numbers are derived from data in (a). [3, p. 472]; (b). [11, p. 206]; (c). [53]; (d). [12]; (e). [6, p. 656] [reports a different ratio and an overall sample size of 23,736]; (f). [3] and [2, p. 172]; (g). [2, p. 172]; (h). [24].

Year	N			N scoring 700 or above		M/F Ratio Scores ≥ 700
	Total	M	F	M	F	
			Hopkins			
1972–1979[a]	9,927	5,674	4,253	–	–	–
1980-1982[b]	39,820	19,883	19,937	113	9	12.6
1984-1991[b]	243,428	122,185	121,063	622	106	5.7
1997[c]	–	–	–	–	–	4
2005[d]	–	–	–	–	–	3
			Nationwide			
1980-1982[a]	~24,000e	–	–	147	11	13
1983[f]				121	12	10
1980-1983[g]	–	–	–	268	23	12
			Duke			
1981-1983[h]	39,754	19,157	20,597	32	3	10.7
1984-1986	73,278	35,424	37,854	54	6	9.0
1987-1989	92,268	44,642	47,626	94	6	15.7
1990-1992	103,097	50,231	52,866	91	33	2.8
1981-1992	308,397	149,454	158,943	271	48	5.6

In 2007, old and new ratios were given in two publications addressed to a wide academic audience: a book called *Why Aren't More Women in Science?* [14] and an article in *Psychological Science in the Public Interest* [26]. However, a popular book published a year later (*The Sexual Paradox: Men, Women, and the Real Gender Gap*) cited only the 13 to 1 ratio [47, p. 25].[5]

This is the case for some, but not all, chapters of *The Science on Women and Science*, "a collection of articles by distinguished scholars," published in 2009 [51]. It was edited by Christina Hoff Sommers, whose claim begins this article. I tabulate the talent search ratios cited in [51] in Table 2.

In March 2010, Sommers wrote in *Forbes Magazine* [52] that efforts to encourage women in science "should take into account the true state of the research on gender and science – not just the assertions of impassioned activists."

It may be more difficult that Sommers thinks to agree on the "true state

[5] Interestingly, *Why Aren't More Women in Science?* which mentions later talent search ratios is cited in *The Sexual Paradox*, but the later talent search ratios are not. The author did not reply to my May 2008 query about this matter.

Table 2: Talent search ratios cited in *The Science on Women and Science*.

Chapter author	Ratio cited and description of population
Simon Baron-Cohen, p. 13	13 to 1 "among individuals who score above 700 (out of a possible 800) points, the sex ratio is thirteen to one (men to women)." Baron-Cohen cites Geary's 1996 article in *Behavioral and Brain Sciences* which gives the source, "The ratio of boys to girls at the lower end of SAT-M scores is a rather modest 1.5:1, but increases to 13:1 for those scoring $>$ 700 (Benbow & Stanley 1983)."
Jerre Levy & Doreen Kimura, p. 214	11 to 1 "among those [children aged 12 or 13] who scored 700 or above on the math SAT."
Amy Wax, p. 163, note 27	13 to 1 in "studies of profoundly gifted early adolescents." New ratios are not given. Wax writes "that pronounced male advantage has strongly moderated recently" and cites sources that give the ratios.
Richard Haier, p. 192	3 to 1 down from 13 to 1 in Johns Hopkins studies of mathematically precocious youth.

of the research on gender and science," but researchers can, at least, endeavor to cite current statistics accurately and to interpret them with care.

Citing current talent search statistics has now become easier. In June 2010, statistics from the Duke talent searches between 1981 and 2010 were published in an academic journal [57] and the drop in the 13 to 1 ratio was publicized in the *New York Times* [54]. Whether the statistics from the Duke samples have been interpreted with care is another matter [30].

After two decades, the 13 to 1 ratio has stopped being solitary, but this change coincided with the creation of two new vampire statistics.

2. The Fabricated Statistic

In August of 2006, a new book called *The Female Brain* appeared, written by a psychologist at the University of California [10]. It publicized the "finding" that "Women use 20,000 words per day, while men use 7,000." "Women talk almost three times as much as men, study finds," said headlines that spread from nation to nation across the World Wide Web. The book became a bestseller.

Word use was part of the evidence that "the female brain" is a "lean, mean communicating machine" which compels its owner(s) to connect and communicate. According to *The Female Brain*, opportunities to connect and communicate are not part of science and engineering, thus women tend to avoid these careers.

Comments on the Web said the "finding" that women talked more than men was so obvious that it didn't need a study. But at least one linguist thought it was very strange. Mark Liberman noted that studies of conversations had found that, on average, that men talk slightly more than women or there was no gender difference. And, where were the studies of daily word use? In his posts on Language Log, Liberman discussed the available evidence at length [35] and summarized it in a 2006 *Boston Globe* article [34]. His conclusion: Although *The Female Brain* lists numerous scientific articles in its bibliography, the ultimate source for this claim was apparently a self-help book – not scientific studies.

The next year, a scientific study of daily word use was published [39]. Its abstract says:

> Women are generally assumed to be more talkative than men. Data were analyzed from 396 participants who wore a voice recorder

> that sampled ambient sounds for several days. Participants' daily word use was extrapolated from the number of recorded words. Women and men both spoke about 16,000 words per day.

One such study is not conclusive evidence – but it certainly doesn't support "women talk three times more than men."

Later editions of *The Female Brain* do not say, "Women use 20,000 words per day, while men use 7,000." But, as Liberman notes, they do say, "[W]omen, on average, talk and listen a lot more than men. The numbers vary, but on average girls speak two to three times more words per day than boys" (p. 36). No reference is given.

And – harder to kill than a vampire – "Women talk almost three times as much as men" remains on the Web.

3. The Garbled Statistic

Like *The Female Brain*, "The Science of Sex Differences in Science and Mathematics," published in *Psychological Science in the Public Interest* in 2007, discusses the idea that women, more than men, avoid careers in academic science [26]. Although it reports old and new talent search ratios on pages 12 and 13, as I read page 14, I noticed other statistics that seemed outdated – or just plain wrong. These were in a table labeled "Representation of Women Among Tenure-Track Faculty in Elite Universities in Physical Science, Mathematics, and Engineering." In particular, women were supposedly 8.3% of tenure-track faculty at "elite" mathematics departments. The cited source was old (1997) and unlikely – an article on intelligence rather than a survey.

Of course, the 8.3% could have been correct, depending on what "elite" meant. After all, I knew of one elite mathematics department that hadn't hired any tenure-track women during a ten-year period. With the right choice of departments, one could probably produce 8.3%. However, a 2002 survey listed in the bibliography and cited near the statistics seemed like a good candidate for the source – and, in fact, the numbers suggest that it was; see Table 3.

The *Psychological Science* numbers matched those from the survey, but the categories didn't. In the survey, these numbers indicated the percentages of women in all tenured or tenure-track positions at the top 50 departments – not the percentages of women in tenure-track positions as stated in the

Table 3: Percentages of female faculty members at the top 50 departments in 2002. Reproduced with permission from Nelson & Rogers, 2004, *A National Analysis of Diversity in Science and Engineering Faculties at Research Universities*, p. 6. Note that this report was updated in 2005.

Discipline	Assistant Professor	Assistant Professor	"Full" Professor	All Ranks
Chemistry (FY2003)	21.5%	20.5%	7.6%	12.1%
Math	19.6%	13.2%	4.6%	8.3%
Computer Science	10.8%	14.4%	8.3%	10.6%
Astronomy (FY2004)	22.0%	16.5%	9.5%	12.6%
Physics	11.2%	9.8%	4.6%	6.6%
Chemical Engineering	21.4%	19.2%	4.4%	10.5%
Civil Engineering	22.3%	11.5%	3.5%	9.8%
Electrical Engineering	10.9%	9.8%	3.8%	6.5%
Mechanical Engineering	15.7%	8.9%	3.2%	6.7%

Psychological Science article. As do many surveys of faculty demographics, this survey found a substantial difference between the percentages of women who were assistant professors and in all ranks. In mathematics, women were 8.3% of all ranks: 19.6% of assistant professors, 13.7% of associate professors, and 4.6% of full professors. No information about correlation between rank and tenure status was collected.[6]

In 2007, the survey of the top 50 STEM departments was repeated. Again, it did not collect information about correlation between tenure status and rank. As occurs often in recent surveys of STEM faculty demographics, the percentages of women in most categories had increased. In mathematics, women were 28% of assistant professors at the "top 50" departments rather than 19% that they were five years earlier; see Table 4.

In 2008, a magazine called *The American* published an article about women in science called "Why Can't a Woman be More like a Man?" [49]. It said:

> Women comprise just 19 percent of tenure-track professors in

[6]Nelson, personal communication, July 12, 2011.

Departments 1-50 FY2007				Departments 51-100 FY2007				Discipline
asst	assoc	prof	all	asst	assoc	prof	all	
21.7%	21.3%	9.7%	13.7%	20.6%	17.6%	9.9%	13.8%	Chemistry
28.0%	15.5%	7.2%	12.1%	25.2%	22.5%	6.9%	14.1%	Math
19.5%	11.3%	11.5%	13.5%	20.8%	12.0%	8.0%	12.8%	Computer Sci
25.3%	21.6%	12.3%	15.8%	not available				Astronomy**
17.5%	12.6%	6.8%	9.5%	15.6%	14.3%	4.9%	8.6%	Physics
23.7%	17.8%	8.3%	12.9%	25.3%	17.4%	4.9%	12.1%	Chemical Engr
25.3%	14.3%	7.1%	12.7%	23.8%	14.8%	7.0%	13.8%	Civil Engr
14.5%	14.1%	6.2%	9.7%	17.4%	10.2%	4.5%	9.1%	Electrical Engr
18.2%	12.0%	4.9%	9.0%	17.6%	11.8%	3.3%	8.4%	Mechanical Engr
30.7%	16.0%	8.5%	15.1%	31.0%	25.2%	9.0%	17.8%	Economics
35.9%	30.1%	17.4%	25.6%	38.6%	28.1%	17.9%	26.8%	Political Science
57.9%	45.6%	28.0%	39.7%	53.7%	45.9%	28.6%	39.8%	Sociology
44.8%	41.9%	29.9%	36.0%	52.9%	46.5%	28.9%	39.0%	Psychology
36.0%	30.9%	17.7%	24.8%	33.9%	28.7%	16.9%	23.9%	Biological Sci
28.6%	21.7%	10.6%	16.1%	27.7%	19.7%	12.4%	17.1%	Earth Sciences

Table 4: Percentages of female faculty members at the top 100 departments in 2007. Reproduced with permission from Nelson, Brammer, & Rhodes, 2007, *A National Analysis of Diversity in Science and Engineering Faculties at Research Universities*, p. 15. ** indicates that the top 40 (rather than 50) astronomy departments were surveyed. Note that this report was updated in 2010.

> math, 11 percent in physics, 10 percent in computer science, and 10 percent in electrical engineering.

This time I couldn't guess the source of the numbers – but readers of this article will. These numbers were not only rounded in an unusual way and relabeled ("assistant professor" was replaced by "tenure-track"), but out of date.

Most importantly, this information was not identified as pertaining to the "top 50 departments" or even "elite" departments. It appeared to refer to departments at all colleges and universities. There is no reason to assume that the situation for elite universities is the same as that for all academic institutions. In many surveys of faculty demographics, the percentage of female tenured or tenure-track faculty is inversely proportional to the prestige of the institution. For example, in mathematics, the 2005 Conference Board of the Mathematical Sciences Survey found women were 33% of tenure-track professors in MA-granting departments, but 28% of those in PhD-granting departments. (See American Association of University Professors surveys for other examples.) So, I was quite puzzled to see *The American*'s figures which seemed to say that women were, on average, 19% of tenure-track faculty in all mathematics departments – elite and otherwise.

I contacted the editor of *The American*. The author sent me the source, an article in *Science* [27] which gave – correctly – the findings of the 2002 survey. I replied, mentioning the 2007 survey and recent results for mathematics. *The American* did not post an update or correction. (However, the author, Christina Hoff Sommers, used the 2007 numbers for assistant professors in her chapter for *The Science on Women and Science* [51], but again neglected to mention that these referred to assistant professors at the "top 50" universities, not universities in general.)

Harder to kill than a vampire – the two sets of published "statistics" on the percentage of female tenure-track professors in science and engineering remain on the Web.

But, surely no one would use *those*. Not only were they obviously wrong (at least to the cognoscenti), but readers might easily guess that they came from secondary sources and look for the primary sources.

So, imagine my surprise, when I read in August of 2009:

> Nearly half of all physicians and biologists are females, as are the majority of new psychologists, veterinarians, and dentists, suggesting that women have achieved equality with men in the

> workforce. But the ranks of professionals in math-intensive careers remain lopsidedly male; up to 93% of tenure-track academic positions in some of the most mathematically-oriented fields are held by men.

Thus begins the advertising copy for a book called *The Mathematics of Sex* [16]. Where does the 93% come from? I have not found a reference for it in the book, but I think that I can guess its origins.

In 2008, one of the authors of *The Mathematics of Sex* gave a talk at the Templeton Foundation. His slides, posted on the Web,[7] reproduce the *Psychological Science* percentages. These are followed 55 slides later by percentages which appear to be derived from *The American*, although a source is not given.

The smallest percentage in the *Psychological Science* list is 7% when rounded. Subtract the 7% from 100%. Drop the "elite" and you get 93% of tenure-track professors in some subfields of engineering are men.

But, some readers will be screaming, even if the statistics were correct, you can't drop the "elite"! Doesn't everyone in academe know that statistics about elite universities do not necessarily describe all universities? (Does anyone think the average university has an endowment the size of Harvard's? Does anyone think the average university has salaries like Princeton's?) Doesn't everyone in academe know that without other modifiers "tenure-track positions" is likely to be interpreted as referring to academic institutions in general?

Apparently someone involved in the production of the book did not think of these things. Maybe it was a research assistant, or an author, or a copy editor – or some unhappy concatenation of the three.

I arrived at this conjecture, after much puzzlement, with the aid of Joel Best's books on statistics [8, 9]. In any event, two rather different groups of

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[7]Ceci, `http://www.templetonfellows.org/program/SteveCeci.pdf`, accessed July 19, 2011; see slides 12 and 67. Departing from the focus on "tenure track" or perhaps taking "tenure track" as a synonym for "assistant professor," Ceci, Williams, & Barnett stated in 2009 [15]: "The picture is the same across many science fields: Women are not being hired as assistant professors at the rate that they are earning PhD degrees." In the 2007 diversity survey, this was particularly noticeable for psychology. However, in most "math-intensive" fields, including mathematics, percentages of female assistant professors at the top 100 departments were close to or exceeded percentages of female recent PhDs. See Kessel & Nelson, 2011 [32].

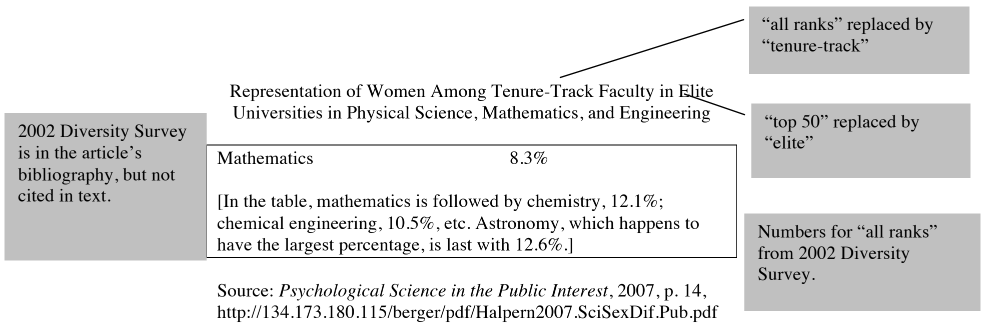

Figure 2: Analysis of the *Psychological Science* table. Due to copyright restrictions, I have not reproduced the table. However, the entire article may be downloaded at the URL given in the figure (`http://134.173.180.115/berger/pdf/Halpern2007.SciSexDif.Pub.pdf`, accessed July 19, 2011).

"statistics" about tenure-track women in STEM were published in 2009:

> Anywhere from 64% to 93% of the professors on tenure track in these [mathematically intensive] fields are men. (*The Mathematics of Sex* [16], p. *ix*)
>
> Women comprise just 28 percent of tenure-track professors in math, 18 percent in physics, 20 percent in computer science, and 14 percent in electrical engineering. (*The Science on Women and Science* [51], p. 80).

I wrote to authors of *The Mathematics of Sex* in August 2009,[8] expressing my concern that their statistics had serious flaws and contrasting these statistics with others from primary sources (including the diversity survey). Among the tables of statistics that I attached, I included a figure pointing out the errors in the *Psychological Science* table (see Figure 2).

The authors replied, but did not indicate to me any interest in correcting their statistics or telling me their source. However, they did contact the principal investigator for the diversity surveys.[9]

They published a somewhat more accurate version of the diversity survey statistics in October 2010 [17]:

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[8] Although the book's publication date is 2010, copies were available in 2009. As discussed in [31], the 2007 diversity survey report had been forwarded to the book's authors in February 2009.

[9] Nelson, personal communication, September 19, 2009.

> In the top 100 U.S. universities, only 9% to 16% of tenure-track positions in math-intensive fields are occupied by women (Nelson & Brammer, 2010). (*Current Directions in Psychological Science*, vol. 19, no. 5, p. 275)

This acknowledges the source of the percentages (an updated report from the diversity survey, which – again – did not collect information on correlation between tenure status and rank) and notes that they concern the top 100 universities. But, it replaces "all ranks" by "tenure-track."[10] A similar statement is given in February 2011 [18]:

> Among the top 100 US universities, only 8.8–15.8% of tenure-track positions in many math-intensive fields (combined across ranks) are held by women. (*Proceedings of the National Academy of Sciences*, vol. 108, no. 8, p. 3157)

"All ranks" has again been replaced by "tenure track." This statement is followed by a reference to supplemental material which says:

> Percentages of women hired on tenure track were as follows: chemistry, 21.2%; mathematics, 26.8%; computer science, 20.0%; physics, 16.8%; chemical engineering, 24.2%; civil engineering, 24.7%; electrical engineering, 15.5%; and mechanical engineering, 18.0%.

Readers may, perhaps, be able to correctly conclude from the context that these percentages refer to the top 100 universities. However, they are unlikely to know that "assistant professor" has been replaced by "tenure track." And, they may wonder at the apparent inconsistency between the percentages of women holding tenure-track positions and hired on tenure track.

Another oddity in the *Current Directions* [17] and *PNAS* [18] articles is their descriptions of the increase in proportions of female PhDs in scientific fields. For example, the *PNAS* article states "Forty years ago, women's presence in most [scientific] fields was *several orders of magnitude less*; e.g., in 1970 only 13% of PhDs in life sciences went to women" (emphasis added)

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[10]This article was covered by *TIME Magazine* which dropped the "top 100," reporting that "only about 9% to 16% of tenure-track positions in math-heavy fields are occupied by women."

and mentions that in 2006 women earned 52% of PhDs in life sciences. It says: "In the most math-intensive fields, however, women's growth has been less pronounced." But, it does not mention that, during the same period, women's share of PhDs increased 5-fold in mathematics to 30%, 6-fold in physical sciences to 29%, and 40-fold in engineering to 20%, but only 3-fold in psychology and almost 4-fold in the life sciences [32]. In terms of orders of magnitude, whether computed in base 10 (as is customary) or in base 2 (which gives non-zero increase in order of magnitude for each case), women's share of PhDs in "math-intensive" fields grew more, not less, than in other scientific fields.

The diversity survey statistics are quoted more accurately in March 2011 [55]:[11]

> In the top 100 US universities, only 8.8% (in mechanical engineering) to 15.8% (in astronomy) of all professorial ranks combined in many quantitative fields are occupied by women (Nelson & Brammer, 2010, Table 11). (*Perspectives on Psychological Science*, vol. 6, no. 2, p. 134)

This article cites the *PNAS* article and is co-authored by one of its authors. It is accompanied by a commentary written by Donna Nelson (principal investigator for the diversity survey) and myself [32].

4. Avoiding Bad Statistics

After reading Joel Best's *Damned Lies and Statistics* [8] and *Stat-spotting* [9], I suspect that factors contributing to bad statistics include ignorance of how statistics are produced, innumeracy, and selection of the most dramatic statistics.

These factors may explain why *The American* didn't post a correction or a source – apparently no one thought there was a mistake and no one thought a source should be cited. (This is rather sad. *The American* is published by the American Enterprise Institute which claims to pursue its ideals "through independent thinking, open debate, reasoned argument, and the highest standards of research and exposition."[12]) The garbling and the

[11] The corresponding percentage for economics, which is sometimes considered by these authors to be a quantitative field, is 16.3%. Thus, the range might have extended to 16.3%.

[12] `http://www.aei.org/about` accessed July 19, 2011.

absence of a source for the statistics in *The Mathematics of Sex* may have occurred for similar reasons, exacerbated by hurried production. (That garbled statistics and various typographical errors went unnoticed is also rather sad. *The Mathematics of Sex* was published by the venerable Oxford University Press which has as its mission "to publish works that further Oxford University's objectives, including its objectives of excellence in research, scholarship, and education."[13]) Academic readers will have their own explanations for the lack of corrections published by academic journals such as the *Proceedings of the National Academy of Sciences*.

Although noticing mistakes may require numerical sophistication or knowledge of particular fields, accurate reporting of names, dates, and sources of statistics does not take much skill. At the very least, authors and research assistants can copy categories and sources as well as numbers. Editors can (and should) ask for sources.

Sources can be indicated in a variety of ways. As the *Chicago Manual of Style* puts it, "Whichever system is chosen, the primary criterion is sufficient information to lead readers to the sources used" [19, p. 594]. In scholarly work, citations in the text indicate the sources that provide evidence for claims and the sources themselves are listed in the bibliography. Journals in psychology often require that authors follow very specific guidelines from the American Psychological Association [48]. In popular books, sources are often given in endnotes. Newspaper articles frequently give the source for information that is presented graphically, but tend not to give citations in articles. However, they often include enough information to allow readers to find sources from a Web search.

Absence of any documentation for statistics suggests authors and editors do not consider it very important. That may be the case in some instances. However, publications such as *The Mathematics of Sex* and *The Science on Women and Science* begin with the premise that there are few women in some fields of science. It seems very strange to make the effort to write about a phenomenon without accurately documenting its existence.

For readers who notice, the absence of documentation or the presence of statistical and mathematical peculiarities suggest that more subtle errors are

[13] `http://www.oup.com/us/corporate/aboutoupusa/?view=usa` accessed July 19, 2011.

lurking.[14] For those who do not – beware! Bad statistics may not suck your blood, but they can keep you in the dark.

5. How Many Women in Science? Perhaps More Than You Think

The Conference Board of the Mathematical Sciences (CBMS), Computing Research Association, American Institute of Physics, and the National Science Foundation (NSF) collect statistics on degrees granted and faculty demographics. All of their figures indicate that women are considerably less rare among tenure-track STEM faculty than suggested by the figures given in *The Mathematics of Sex*.

According to the NSF statistics from the Survey of Doctorate Recipients[15] (see Table 5), at four-year institutions, the percentages of women in tenure-track positions range from 19.1% (engineering) and 22.6% (computer science), to 29.4% (mathematics and statistics) and 33.7% (biological and related sciences), to 70.4% (health). According to the CBMS 2005 Survey, women are 50% of the full-time permanent mathematics faculty at two-year colleges.[16]

6. Concluding Remarks

This is a complicated story which can be viewed from different perspectives. Over the years, several themes have surfaced periodically in my mind with respect to the events that I've described. Writing, editing, and citation practices have already been mentioned, along with ignorance of statistics. Another is misunderstanding of mathematics, which in this context is included with misunderstanding of statistics under the label of "quantitative illiteracy."

In 1983, the talent search ratios – findings from a small non-random sample – may have gained currency due to interest in gender differences, but lack of knowledge or concern about sampling methods or sample size may also have been a contributing factor. Similarly, in 2006 few seemed to

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[14] For a detailed discussion of errors and weaknesses in the PNAS article, see [33].

[15] National Science Foundation, Division of Science Resources Statistics, 2009, Characteristics of Doctoral Scientists and Engineers in the United States: 2006. Detailed Statistical Tables NSF 09-317. Arlington, VA.

[16] CBMS Survey, Fall 2005, p. 169.

Table 5: Employed doctoral scientists and engineers in 4-year educational institutions, by broad field of doctorate, sex, and tenure status: 2006.

Field and sex	All employed	Tenured	Not tenured: On tenure track	Not tenured: Not on tenure track	Tenure not applicable
All fields	271,540	127,640	47,330	29,340	67,230
Male	(67.4)	(76.2)	(61.5)	(57.3)	(59.1)
Female	(32.6)	(23.8)	(38.5)	(42.7)	(40.9)
Science	226,400	106,070	37,710	25,080	57,540
Male	(66.7)	(75.6)	(62.0)	(57.3)	(57.7)
Female	(33.3)	(24.4)	(38.0)	(42.7)	(42.3)
Biological, agricultural, and environmental life sciences	79,810	31,050	12,050	10,540	26,170
Male	(65.9)	(77.8)	(66.3)	(55.6)	(55.6)
Female	(34.1)	(22.2)	(33.7)	(44.4)	(44.4)
Computer and information sciences	5,790	2,860	1,760	430	740
Male	(78.3)	(79.4)	(77.4)	(74.2)	(78.6)
Female	(21.7)	(20.6)	(22.6)	(25.8)	(21.4)
Mathematics and statistics	17,290	10,800	3,270	1,130	2,090
Male	(81.0)	(86.4)	(70.6)	(68.1)	(76.6)
Female	(19.0)	(13.6)	(29.4)	(31.9)	(23.4)
Physical sciences	38,760	18,210	5,890	3,790	10,870
Male	(82.0)	(86.3)	(74.3)	(81.5)	(79.1)
Female	(18.0)	(13.7)	(25.7)	(18.5)	(20.9)
Psychology	34,640	14,130	5,530	4,660	10,320
Male	(46.1)	(57.4)	(42.8)	(37.5)	(36.4)
Female	(53.9)	(42.6)	(57.2)	(62.5)	(63.6)
Social sciences	50,110	29,030	9,220	4,520	7,340
Male	(64.3)	(70.8)	(53.9)	(56.8)	(56.4)
Female	(35.7)	(29.2)	(46.1)	(43.2)	(43.6)
Engineering	30,230	15,640	5,650	2,240	6,700
Male	(87.9)	(92.8)	(80.9)	(88.9)	(82.1)
Female	(12.1)	(7.2)	(19.1)	(11.1)	(17.9)
Health	14,920	5,930	3,970	2,020	2,990
Male	(35.2)	(43.4)	(29.6)	(23.1)	(34.5)
Female	(64.8)	(56.6)	(70.4)	(76.9)	(65.5)

NOTES: Percentage distribution is shown in parentheses. Numbers are rounded to nearest 10. Detail may not add to total because of rounding. 4-year educational institutions include 4-year colleges or universities, medical schools (including university-affiliated hospitals or medical centers), and university-affiliated research institutions.

SOURCE: National Science Foundation/Division of Science Resources Statistics, Survey of Doctorate Recipients: 2006.

have wondered about how the fabricated statistic ("Women talk almost three times as much as men") could have been generated in a scientific study. Do you count words (and does that include "uh"s and "um"s) or do you count length of time? Does that include every social context? How do you record every word that's been uttered?

Along with issues of sampling, the garbling of the diversity survey statistics seems to have mathematical aspects. These statistics are percentages, which can be viewed as averages or part-whole relationships. Misunderstanding of either concept may have contributed to the mislabeled percentages. One misunderstanding of averages (think of global warming!) is to construe the average of a set of measurements as equal to the value of each measurement. For part-whole relationships, there can be slips in understanding which set is meant to be the whole or whether it matters. In misuse of terms such as "exponential" or "order of magnitude," mathematical misunderstanding seems to be the primary factor.

And, then there is bias . . .

As some researchers see it, there is a "perseverative search for gender differences," which "are far too sexy a topic." "It is clear that many people do not want to believe that girls and women can be good at mathematics" says Susan Chipman. Researchers execute "backflips in experimental design and interpretation of data in order to produce sex differences in math performance" say Jeremy and Paula Caplan. Consistent with this perspective, as the 13 to 1 talent search ratio lost currency, the garbled statistics about STEM faculty came to prominence. As the garbled statistics became more accurate, a new inaccuracy was introduced: the change in percentages of women earning PhDs in scientific fields became "exponential growth," increase in "orders of magnitude," or "meteoric" with – supposedly – the exception of "math-intensive" fields.

Whatever their origins, statistics which are mislabeled, misinterpreted, fictitious, or otherwise defective remain in circulation because they are accepted by editors, readers, and referees. Ultimately, quantitative illiteracy may be the life-blood of these vampires.

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