approximates with the sun a simple two-body system. Imagine instead that the air was as viscous as water and full of currents, or that the planets were more numerous and subject to electromagnetic forces comparable to the force of gravity. In such worlds, Galileo's and Newton's approximately pure cases do not occur, and their work becomes more difficult by orders of magnitude. Geary's work is, by his own account, at least as hard as theirs would be, for there are at least *four different sorts* of forces bearing upon mathematical abilities according to the boxes in his Figure 1, and through their combined noise he manfully strains to discern the effect of one of them: "Proximate Biological Influences (e.g., sex hormones)."

Figure 1 makes the task look easier than it is, for all the arrows flow out of the box at the top left: "Sexual Selection," which is simply to diagram the unproven assumption that ultimately the source of "Sex Differences in Mathematical Problem Solving and Geometry" (box top right) must, like all *biological* phenomena, find their source in evolution. Unfortunately, there are other arrows that Figure 1 leaves out, such as, for example, the ones that must go into the box "Sex Differences in Social Preferences and Social Styles." Many things affect preferences and styles, and thus bear on this set of sex differences, and not only nice scientific things like whether the culture is agrarian or industrial, but also quirky things, like Marilyn Monroe and Albert Einstein. Marilyn was not much of a mathematician, though Einstein was, and no doubt this has had some effect on some people's "social preferences and social styles," and thus, according to Geary, on sex differences in mathematical abilities. In other words, the system in Figure 1 is *massively open!*

In such a system, where angels fear to tread, we can only admire Geary's speed in staking out the differential effect of XX relative to XY chromosomes. What merits our special attention is his *method.* What we really need here is something like lead balls falling through calm air. Luckily, we have them, in the form of newborn boys and girls. Unluckily, at that point the sexes manifest *equally* only the most basic of arithmetical skills, "numerosity." Worse yet, the skills in question appear only much later in life, after Marilyn, Einstein, and whatever other cultural influences.

Which brings us to the first methodological stratagem Geary proposes: to hear the sexual signal through the cultural noise, we need only attend to evidence that is "pancultural," so that varying cultural influences can cancel each other out. The methodological inference is of this form: pancultural, hence noncultural, therefore biological in origin. For instance, if men are taller than women panculturally, then the difference is noncultural, therefore biological in origin. But this form of inference is not generally reliable. Funerary practices are found everywhere (even where there is no mathematics) but surely there is no gene directing them. Likewise, news of Marilyn and Einstein pervades the mathematically educated world, but that hardly makes their effects noncultural or biological.

Mathematics itself is a cultural phenomenon. *Homo sapiens* might well have prospered indefinitely without it: unlike the heart, it is biologically unnecessary. Future paleoanthropologists will note that the fossil remains of mathematics texts and calculating machinery appear in the same strata with remains of sophisticated tools, buildings, musical instruments, automobiles, and Marilyn Monroe movies. The cultural changes accompanying the invention of mathematics occurred over most of the globe within a few millennia of each other: People turned to agriculture, built cities, and became more scientific, monotheistic, and monogamous. Given that mathematics is itself a rich cultural phenomenon lavishly embedded in yet other cultural phenomena, the purely biological effects of sex upon it cannot be isolated by Geary's simple panculturality stratagem.

A second dubious element of Geary's method is used whenever he identifies sex differences on social dimensions relevant to mathematical achievement. At these points he claims that "at least a portion of the sex differences on these social dimensions is biologically primary" (sect. 3.1, para. 8). This is a plausible assumption, but it haplessly renders Geary's conclusion *unfalsifiable:* devoid of empirical content. We begin with the idea that the sex differences in mathematics have either social or sexual causes, but if we then assume that the social causes are themselves, at least in part, the effects of sexual causes, then it is trivial that at least part of the differences in mathematics are the biological effects of sex itself. Given his method, Geary's thesis is guaranteed, whatever the evidence has shown, or may show—it is a mere tautology and says nothing about the empirical world.

What drives the debate Geary so masterfully epitomizes is *not science, but ethics.* Sure, we want to understand ourselves, and that is laudable. But when science informs ethics, it ought to proceed with extra caution. The ethical problem is this: Those who solve verbal mathematics problems are the leaders, while those who merely do the arithmetic are the followers. As Geary notes, "boys are not biologically primed to outperform girls in basic mathematics [i.e., arithmetic]" (sect. 4.1, para. 4). Many studies have shown that females are just as good as or better than males when it comes to arithmetical calculation. In the days before cheap computing machinery, the scientists of the Manhattan Project use ranks of females to tot up the figures for them, freeing them to apply mathematics to nature in making the bomb. The manager must know how much to invest at $x\%$ compound interest to yield $\$y$ in z years, while those who only do the arithmetic given them are the secretaries, tellers, and salespersons. And what holds for company leadership must surely hold for household leadership as well. He who does mathematics is born to lead, while she who merely does the arithmetic is born to crochet lace.

Mary has more: Sex differences, autism, coherence, and theory of mind

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Abstract: We challenge the notion that differences in spatial ability are the best or only explanation for observed sex differences in mathematical word problems. We suggest two ideas from the study of autism: sex differences in theory of mind and in central coherence.

"Amy has two candies. She has one candy less than Mary. How many candies does Mary have?"

Geary suggests that the male superiority with such word puzzles is due to greater spatial skill. Teaching a spatial strategy improves performance, but male superiority remains. Thus, spatial skill is unlikely to be the source of the sex difference. We would like to illustrate some alternative explanations through the example of autism.

Autism is a particularly pertinent case, since in this disorder the pattern of peaks and troughs is better explained by hypotheses concerning theory of mind and central coherence than by general notions of spatial skill and verbal impairment (Frith 1989). The consistently found performance peak in Block Design was traditionally thought to indicate intact or superior general visuospatial ability. An alternative explanation is that a cognitive style of weak "central coherence" allows individuals with autism to see the presented design in terms of its parts, which map onto the individual blocks used to reconstruct the design (Frith & Happé 1994). Shah & Frith (1993) showed that when the designs were presegmented, performance in normal and learning disabled but not autistic individuals improved significantly. In contrast, manipulation of spatial factors (rotation and obliques) did not differentially affect the groups.

Thus a modification that eradicates group differences can identify the source of that difference at the cognitive level. By this

logic, spatial ability cannot account for the sex difference in word problems.

As Geary points out, these problems are oddly phrased. In many respects the questions, as communications, violate Gricean maxims. In terms of relevance theory (Sperber & Wilson 1986), the listener is justified in assuming that the speaker intends the most accessible interpretation. Anything else is trickery. The prediction would be that you can improve performance by making the correct interpretation relevant (e.g., by highlighting Mary).

Why should females be more sensitive to this pragmatic violation? Listeners will only be misled by these puzzles if they are trying to "read the speaker's mind." It is the normal concern with underlying meaning, versus surface form, that misleads. The same problem is seen in young children's failure to judge an inadequate message as ambiguous – especially when the speaker's intention is clear (Beal & Flavell 1984). Recognising the speaker's intention depends upon theory of mind – the ability to attribute independent mental states to self and others (Premack & Woodruff 1978). Greater sensitivity to mental states would therefore be a disadvantage in these word puzzles. Perhaps females have better developed theory-of-mind skills.

Some tentative evidence emerged in data from 70 normal 3- to 5-year-olds; even after age and verbal ability were partialled out, gender was a significant predictor of theory-of-mind performance (Happé 1995). To suggest that theory-of-mind skills may be better in females is not the same as Geary's argument concerning cooperative versus competitive social style. Theory of mind is necessary for both types of social interaction; reading minds allows deception and empathy, Machiavellian plotting, and insightful pedagogy. Male competition through resource gathering may take second place to this special human adaptation; if you can lie, cheat, and bluff, you don't need to have resources to get a mate. Females, as the higher-investing, more discriminating sex may have evolved better theory-of-mind skills.

Since children with autism typically fail test of theory of mind (Frith 1989), we would predict that they would be less misled (than verbal-ability-matched controls) by mathematical word problems. There is another reason, too, why children with autism might be relatively good at these puzzles. As mentioned above, children with autism show weak central coherence, attending to parts over wholes and paying preferential attention to surface form versus gist. This cognitive style may be characterised in terms of greater bottom-up processing and less top-down influence. One way to fail the word puzzles is to leap to conclusions. In this case, incorrect answers will be given faster than correct ones, even though the arithmetical operations themselves are of equal difficulty. If top-down strategies cause failure, then inducing a bottom-up strategy should aid performance. This suggestion predicts that—in contrast to the other hypotheses—making the content of the word puzzles more artificial and unfamiliar would help. It is interesting to note that sex differences on Block Design and Embedded Figures (Voyer et al., 1995) suggest that females may have stronger central coherence than males.

These modifications would only be informative if they removed the sex difference: just improving performance in boys and girls is not enough. Work on autism reminds us of this lesson, and may also suggest some interesting avenues for future research on sex differences. After all, autism, a disorder with a high male:female ratio, has been described as "an extreme form of maleness" (Asperger 1944).

Differences in male and female cognitive abilities: Sexual selection or division of labor?

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Abstract: In Darwinian terminology, "sexual selection" refers to purely reproductive competition and is conceptually distinct from natural selection as it affects reproduction generally. As natural selection may favor the evolution of sexual dimorphism by virtue of the division of labor between males and females, this possibility needs to be taken very seriously.