in IFNαβR-deficient mice. Administration of IFN-λ to mice with persistent norovirus infection reduced virus shedding below detectable amounts (see the figure). Moreover, injection of exogenous IFN-λ cleared the virus from mice devoid of an adaptive immune system (thus, eliminating the possibility that the animals invoked norovirus antigen–specific targeting by T and B cells of the adaptive immune system). Similarly, the administration of exogenous IFN-λ also ablated acute rotavirus infection in vivo (*2*). Consequently, this finding may have far-reaching implications regarding "sterilizing" innate immunity against enteric viral infections.

Wild-type mice should be able to induce IFN-λ, so why did they fail to clear persistent norovirus infection? Baldridge *et al.* provide a possible link between the host's microbiota and the antiviral response governed by λ IFNs. The authors found that ablation of the gut microbiota by antibiotic treatment results in clearance of persistent murine norovirus infection; restoring gut microbiota with that from untreated mice (through fecal transplant) rescued virus replication. This result has been separately confirmed in both antibiotic-treated (*7*) and germ-free animals (*8*). By stark contrast, antibiotic-treated mice lacking IFN-λ signaling were unable to clear viral infection. Thus, IFN-λ is required to clear the virus, but its antiviral activity is diminished in the presence of the gut microbiota. This raises the possibility that the microbiota may directly or indirectly benefit the virus by inhibiting virally induced IFN-λ signaling. Indeed, another murine virus, mouse mammary tumor virus, exploits the host's gut microbiota by cloaking itself in bacterial lipopolysaccharide, a constituent of the outer membrane of Gram-negative bacteria (*9*). Virus-bound lipopolysaccharide triggers the pattern recognition receptor Toll-like receptor 4, which blocks the antivirus immune response by eliciting the production of IL-10, an immunosuppressive cytokine.

"Exploring the interaction between viruses and the surrounding microbial community should reveal how commensals contribute to the transmission of an array of viruses..."

Enteric viruses, including reoviruses (*10*, *11*), norovirus (*4*, *7*, *8*), and poliovirus (*10*, *12*), are known now to require the gut microbiota for successful replication and transmission. The mechanisms through which the microbiota facilitates propagation of these viruses are not yet clear. In the case of murine norovirus, it may be that viral infection of B cells requires the presence of glycans, resembling histo-blood group antigens synthesized by specific types of enteric bacteria (*7*). Another possibility, suggested by the study of Baldridge *et al.*, is that the gut microbiota may interfere with antiviral innate immunity, quenching IFN-λ signaling by an as-yet-undiscovered mechanism.

The findings of Nice *et al.* and Baldridge *et al.* prompt many questions. For example, it is unclear how MNV and other viruses elicit IFN-λ production, and what cell types sense this cytokine in the gut. Another question is why type I IFN production, which is triggered by MNV (*8*), does not contribute to the antivirus response in the gastrointestinal tract. One possibility is that the virus blocks the effects of both type I and type III IFNs with the help of the microbiota. It is also possible that a specific hierarchy exists through which IFNs control the virus, with IFN-λ providing superior protection in the gut whereas type I IFNs mainly protect systemic organs. That type III IFNs induce an antiviral response identical to that of type I IFNs and that their cognate receptor primarily lies within the intestinal epithelium can explain their essential role in the control of acute intestinal infections.

It appears that all orally transmitted viruses studied thus far exploit the gut microbiota for efficient transmission. However, many viruses enter the host through other surfaces, which also harbor commensal bacteria. Exploring the interaction between viruses and the surrounding microbial community should reveal how commensals contribute to the transmission of an array of viruses, not only enteric pathogens. ■

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SOCIAL SCIENCE

Gender inequality in science

How should a better gender balance be achieved?

By **Andrew M. Penner**

Why are women underrepresented in many areas of science, technology, engineering, and mathematics (STEM)? This is a question with no easy answers. In science, as in many areas of life, bias against women exists (*1*), but researchers disagree on how much bias matters: Some suggest that the effects of bias accumulate over time to shape careers (*2*), whereas others argue that gender differences in preferences are much more important (*3*). However, it is likely impossible to disentangle the effects of societal bias and individual preferences, because people's understanding of gender differences shape their preferences (*4*). Research suggests differences in innate ability are unlikely to play a major role (*3*), but one route to more equal representation across academic fields might be convincing both women and men that this is true. On page 262 of this issue, Leslie *et al.* (*5*) show that how ability is viewed within a field plays a key role in how well women are represented.

Two puzzles complicate typical explanations of women's underrepresentation in science. First, race and gender interact in ways that are problematic for one-size-fits-all approaches. In the United States, for example, although Asian women choose physical science majors at lower rates than Asian men, they do so at similar rates to white men, and at nearly twice the rate of white women. Of U.S. Asians who earned Bachelor's degrees in 2011, 1.9% of women and 2.4% of men majored in the physical sciences, compared to 2.1% of white men and 1.0% of white women (*6*). Second, gender representation varies considerably both within STEM and within non-STEM fields. As noted by Leslie *et al.*, in 2011 women received 54% of U.S. Ph.D.'s in molecular biology, compared with 18% in physics, 72% in psychology, and 31% in philosophy.

Leslie *et al.* offer a novel framework for understanding this second puzzle by showing that how ability is viewed in different fields correlates with the degree to which

Is leaving science bad? German Chancellor Angela Merkel trained as a physical chemist but left research to enter politics. Many women leave STEM fields to work in other areas and make important contributions to society. Leslie *et al*. show that women are better represented in fields of study that view ability as related to effort than in those that view ability as innate.

PHOTO: HERBERT KNOSOWSKI/REUTERS/POOL

women are represented. In philosophy and physics, which are dominated by men, ability is considered to be innate. In molecular biology and psychology, in which women are well-represented, effort is viewed as important. This intriguing finding accounts for gender sorting into STEM versus non-STEM fields. It also explains why women are more represented in some STEM fields than others. Further, it avoids a problem plaguing many popular accounts for the underrepresentation of women in STEM, which fail to explain why women now pursue law degrees at similar rates to men, even though law school has a competitive culture, lawyers work long hours, and law firms are not yet as family friendly as one might hope.

Past studies of the underrepresentation of women in science have paid considerable attention to tracing the development of gender-related attitudes and stereotypes about science over students' careers. Building on this work, understanding how and when students become aware of the ability beliefs of specific fields will be instructive. Given how vital people think mathematical ability is for success in STEM fields, it will also be important to examine whether mathematical ability is viewed in particularly innate terms. If so, then we might expect fields in which mathematics is viewed as more central to have particularly low participation of women.

A number of broader questions and challenges remain. Given that women have been graduating from college at higher rates than men for over three decades, the idea that men's curricular choices should be used as the baseline for women to emulate seems problematic. It is commonly suggested that more women are needed in science to meet U.S. workforce needs, but many students with STEM degrees do not end up employed in STEM fields (*7*). Some fields, like computer science, have experienced job growth and have a dearth of women, but it is unclear that women should be encouraged to enter fields solely because they are underrepresented. Rather, we might consider achieving gender parity in some fields by encouraging men to major in them at rates more similar to those of women.

It is also important to consider differences in the opportunities available to men and women outside of STEM, because women who excel in mathematics and science typically have stronger skills in other domains than do men (*8*). Angela Merkel (see the photo) and Margaret Thatcher were obviously exceptional in their achievements after leaving science, but we risk trivializing the contributions of women and men who choose to pursue other endeavors when we define success as becoming a STEM professor at a research university. This is especially true given that many women leave STEM to go into fields such as education and health care. To be sure, there are substantial issues with how society devalues women's work, as pay declines in fields that come to be seen as women's work (*9*), but it is unclear that this constitutes failure on the part of the individuals who enter these fields, or that society does not benefit from their choices.

Like most researchers who study gender inequality in STEM fields, my inclination is to argue that we need these talented women in STEM fields. Yet, given the importance of having talented men and women in education, health care, and throughout the economy, it seems important to take a broader perspective on issues of gender equality. Perhaps it is time to ask a new question about gender representation in STEM: Would society be better off if men were more like women? ■

Department of Sociology, University of California, Irvine, Irvine, CA, USA. E-mail: andrew.penner@uci.edu

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