societal benefits of vaccination, it is essential to respond to the new public mood. "Today, we are in the paradoxical situation of having highly effective vaccines, but doubting publics," she says. It's not enough to tell people how well vaccines work against diseases that, in some lucky parts of the world, can seem theoretical – something that happened long ago, or far away. Instead, researchers and public-health professionals must look at the vaccine experience: the whole process of having children, discussing vaccines with family and social circles and choosing whether or not to immunize your child or, later in life, receive vaccinations yourself.

Rumours and misinformation

Larson studies rumours about vaccines, drawing on historical examples in various regions. These range from demonstrations against smallpox immunization in the nineteenth century to polio-vaccination boycotts in Nigeria in the twenty-first, showcasing a social world of fear, doubt and risk assessment that can influence behaviour. Larson writes: "Digital media has certainly contributed to the social amplification of risk, but there is no single culprit in this wave of dissent."

My research supports her position, showing how fast health misinformation can change people's behaviour. In the context of COVID-19, a huge demand for the malaria drug hydroxychloroquine followed US President Donald Trump's unfounded claims that it could treat infection with the coronavirus. The demand for a COVID-19 vaccine will be vast, yet some will still refuse it, risking those who cannot be vaccinated because of other health issues.

Larson explains that our bodies respond to information about vaccines in ways that often have nothing to do with the properties of the medicine itself. Psychogenic reactions can include fainting, spasms and laboured breathing. They vary from case to case, but once such a reaction is publicized, it can materialize in new places. For example, after videos showing girls convulsing – allegedly after receiving a vaccine against the human papillomavirus (HPV) – were shared on social media, a small town in Colombia saw a wave of hospitalizations supposedly linked to the immunization. An investigation concluded that the physical symptoms were attributable not to the vaccine, but to fear and anxiety. When the Colombian president announced as much, enraged townspeople became more suspicious of the HPV vaccine, not less.

Emotional contagion, too, can sway attitudes. People share rumours of purported 'vaccine damage' out of worry or anger at charges of profiteering or political control of populations. This last concern has, for example, bedevilled the global campaign to eliminate polio; it is part of the US discourse, too.

Digital wildfire

No book on the modern history of vaccines can ignore the appalling public-health impact of the fraudulent claim that the MMR (measles, mumps and rubella) vaccine causes autism. Larson shows how the rise of Andrew Wakefield, the physician struck off for his now debunked 1998 study on this link, was tied to the development of new tools for information-seeking. She points to an under-studied facet of contemporary health movements: how growing Internet use made it possible for people to share experiences across vast distances. The Wakefield claim lent itself to viral replication. It was, Larson writes, "a simple, repeatable, confirmation of a brewing anxiety". It became a meme that spread like "digital wildfire", leading to resurgences of three dangerous diseases.

To defeat the misinformation hydra, Larson calls on scientists to make engagement authentic – public input should begin with the setting of the research agenda and continue through open dialogue as new concerns emerge. All too often, she points out, scientific communication is reduced to marketing and sloganeering, rather than listening and integrating public debate. Vaccine hesitancy is a problem of dignity as much as of the abundance of falsehoods: individuals want to have their choices respected, amid growing distrust in authority.

Larson concludes that for vaccine uptake to increase, the public must be inspired to protect one another. She calls immunization "one of the biggest worldwide experiments in collectivism and cooperation in modern times". Especially in the time of COVID-19, her research helps us to understand that facts are only one piece of this puzzle. No longer can social-media companies avoid the part their technology plays in manufacturing a level of dissent inimical to the public good.

It is apparent from Larson's book and my own research that to counter vaccine hesitancy, a broad coalition of medical professionals, journalists, civil-society organizations and technologists must develop a plan for challenging misinformation. If there is no research into to how bad information rises to the top of search engines and circulates online, and no strategy to halt that contagion, vaccines will continue to divide society rather than unify it against a common threat – just when we need them most.

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Equity: a mathematician shares her solution

If research thrives on collaboration, a book asks, why do we reward individualism? **By Jory C. Lerback**

Much has been written about the female premiers of Germany, Finland, New Zealand and Taiwan, and their remarkable success at dealing with COVID-19. But, as many pundits have noted, to focus on their gender is to miss much more important issues: the personal characteristics that define how these leaders operate, and the social climate that rewards communitarian behaviour.

These issues – relational abilities and enabling contexts – are central to mathematician Eugenia Cheng's constructive argument in *x*+*y*. Whether one plus one is two, she shows, depends on how you define your variables and their relationship. One violinist and one pianist (Cheng plays the piano) might make two musicians, cacophony or sweet music, depending on how they interact. Considering such scenarios is the beauty of category theory, Cheng's branch of pure mathematics.

She applies category theory to the

under-representation of women and people from gender minorities in science, technology, engineering, mathematics and medicine (STEMM). Programmes to recruit, train and support women in these fields rely on the equation [women] + [STEMM training] = [more women in STEMM]. But given that many qualified women leave, clearly there are other variables at play.

Some of the reasons relate directly to gender, such as explicit bias (including sexual harassment) and historical legal and social barriers. Cheng does not dispute the value of policy interventions to address these, but warns that they merely patch up symptoms of a deeper problem with how STEMM values people. Her experience in mathematics — for example, of being bullied and belittled because of sexism, racism and ageism — led her to seek out a more creative environment. She is currently at the School of the Art Institute of Chicago in Illinois, where she can teach maths as a community-oriented and curiosity-driven subject, rather than a series of tests.

In *x+y*, she focuses on manifestations of inequality that relate only superficially to gender. Take the 2019 finding that grant applications that include 'broader' language, more often used by men, tend to score higher than those with more specific language, more commonly used by women (see *Nature* http://doi.org/gfz7jk; 2019). Men, for instance, might write 'control' and 'detection' where women tend to reach for topic-specific words such as 'community' or 'health'. Such studies demonstrate differences in average measured outcomes that correlate with gender.

Cheng argues that expecting individuals to conform with gendered averages has a high chance of being incorrect, and paves the way for undue criticism of outliers. "If a female mathematician is considered an anomaly," she quips, "does that tell us something about women, about mathematicians, or about our preconceived expectations?"

Cheng suggests that we focus on styles of behaviour instead. Drawing on category theory, she classifies people as 'congressive' — collaborative, emphasizing community and interdependence — or 'ingressive': more competitive, prioritizing individualism and independence. Avoiding another binary, she sees these traits as a complex spectrum, and modifiable through experience and training.

I find this terminology compelling. It sidesteps debates on the origins (nature versus nurture) of notional gender differences. Importantly, it offers a way to address other intersecting aspects of diversity — ethnicity, sexuality, disability, education and more — as Cheng does throughout the book.

When she teaches mathematics, Eugenia Cheng rewards curiosity and open-mindedness.

SCHOOL OF THE ART INSTITUTE OF CHICAGO

She argues that STEMM benefits from congressive behaviour, with team projects increasingly the norm. Researchers must think about existing knowledge from various perspectives and share fresh insight in clear and compelling ways. Yet STEMM institutions foster ingressive behaviours. Awards go to individuals; reviewers describe grant applications as 'competitive' rather than 'interesting' or 'well thought out'. Offering insights for my own research into inequity in publishing, Cheng shows how ingressive — sometimes even aggressive — structures of peer review slide easily from constructive criticism to gatekeeping.

"The upheaval of the COVID-19 pandemic is an opportunity for more just, equitable change."

Clearly, we should stop trying solely to recruit women into hostile STEMM environments; instead, we should train researchers to be inclusive. Cheng leads by example in her teaching of "often maths-phobic" art students. She writes: "I nurture, encourage and reward congressive behaviour such as curiosity, open-mindedness and collaboration, not ingressive behaviour such as showing off, posturing or belittling others."

The upheaval of the COVID-19 pandemic is an opportunity for more just, equitable and congressive change. STEMM disciplines are rethinking how to share knowledge and support open collaboration. Let's hope leaders can ensure that this shift in values is represented in new organizational structures.

Cheng enjoins us to consider our place on the congressive–ingressive spectrum, to take time to ensure that our language, actions and priorities reflect non-gendered values. I would add that this reflection should also extend to anti-racist values.

Cheng explores the broader implications of her categories for society — in politics and voting systems, for example. She highlights the congressive Finnish education system and identifies possible alternatives to ingressive practices in the classroom. For instance, of a study of teenagers' willingness to claim mathematical expertise, she points out: "in Europe only the boys have learnt to bullshit as much as the Americans".

x+y provides useful new tools for change, for those — like me — involved in diversity, equity and inclusion initiatives. For those who are not yet involved, she sets out reasons to become so. And I'm a new fan of pure mathematics. Dr Cheng, can we be friends?

x+y: A Mathematician's Manifesto for Rethinking Gender
Eugenia Cheng
Profile (2020)

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