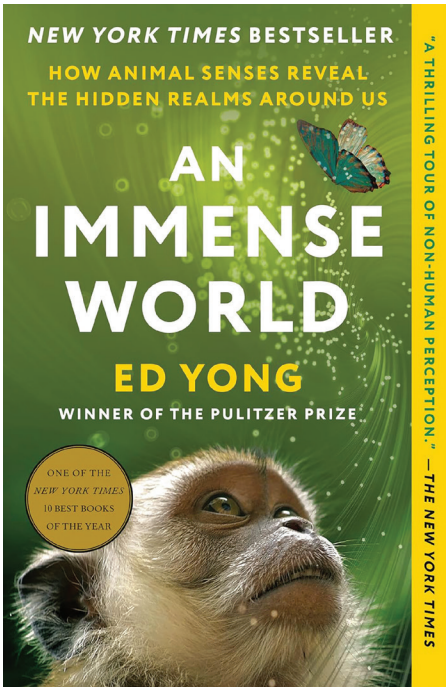
based on her insightful and generative book talk. Do you know a high school or college student who loved a recent biology-themed book and wants to review it in these pages collaboratively with you? Let us know at kmilks@mccsc.edu.

An Immense World: How Animal Senses Reveal the Hidden Realms Around Us. By Ed Yong. 2022. Penguin Random House. (ISBN 9780593133231). Hardcover. 464 pp. $23.49. Paperback, audiobook, and ebook also available.



An Immense World by Ed Yong delves readers into a world greater than their own: the world of animals big and small. Yong explores the many different types of senses found in the animal kingdom and focuses on one category per chapter. In each chapter, he discusses not only the facts that scientists know, but also how they came to know them as facts, including what observations and experiments led to conclusions. Furthermore, he explores what scientists *don't* know, and is transparent about the fact that the field of science exists to explore new ideas and the unknown, not discuss things already known.

Yong is careful not to compare human and animal senses; instead, he writes about animal senses in terms of a whole separate realm that does not deserve to be limited by our own senses. He argues that the term "sixth sense" as being arbitrary and only used in relation to our personal limitations of vision, hearing, olfaction, gustation, and tactician. For other animals, those five senses may be unnecessary, and fewer senses, or even entirely different senses, are what prove to be most important for them. Furthermore, he contradicts the idea that intelligence should inherently be based on human terms such as vision.

I'm a current high school senior who read this book last year as an independent reading assignment for AP Biology and really enjoyed it. I want to be a veterinarian, so I'm fascinated with animal behavior and the biology of animals and loved learning from Yong's deep dive into *why* and *how* animals use certain senses and not others. While I believe a lot of my personal interest in this book has to do with my career aspirations, I think anyone would benefit from reading it. Yong has written a wonderful book that is easy and fun to read, allowing students to stay engaged with the book so they can gain the most from the science in it. Plus, I feel *An Immense World* included enough scientific background, analysis, and history to be useful for educators.

This book left me thinking about how, as the title conveys, there is *An Immense World* outside of our own "bubble" of senses. Learning how other animals view the world created, for me, a feeling of connection to things I haven't experienced and gave me a new perspective on the world – both of which could very well make a great lesson in high school, college, and beyond.

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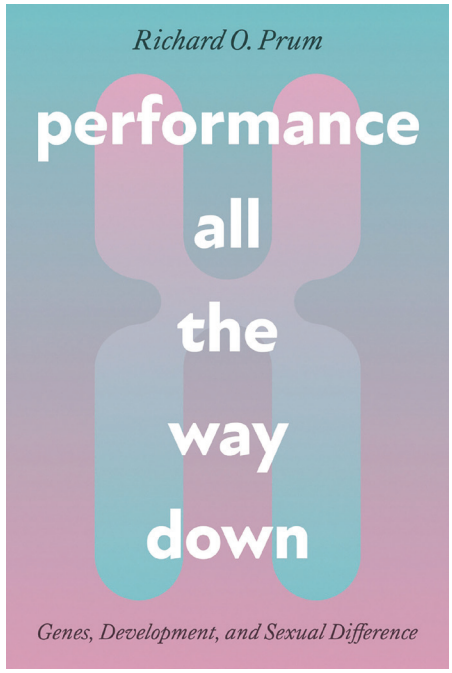
Performance All the Way Down. By Richard O. Prum. 2023. Chicago University Press. (ISBN 9780226829784). Paperback. 268 pp. $22.50. eBook also available.

We humans love to categorize the world around us. When my eldest was first learning to talk, she decided that every animal was either a cat or a dog. I found myself trapped in an argument with an unyielding baby: she kept jabbing her finger at a picture book and announcing "Da," while I kept saying, "No, that's a pig!"

And I felt a strong sense of *déjà vu* recently when a 10 month old paused on my living room carpet, pointed at the pet rabbit that we inherited from my father-in-law, and said "Ga" (cat). If "cat" and "dog"



were the only possible classifications for nonhuman animals, I suppose I'd agree with each of these babies' assessments – our rabbit *is* vaguely cat-like – but our world need not be divided into these babies' artificial cat/dog binary.

In *Performance All the Way Down*, Richard Prum offers a harder sell: that we've been hampering ourselves as people and as scientists by splitting the entire human world into a male/female sexual binary.

Personally, I think it's obvious that this supposed binary doesn't fit everyone. Even in the Talmud – an ancient compendium of Jewish philosophy – several additional categories were offered for members of the community whose physiological development resulted in a person whose body didn't match the expected phenotype for either male or female.

But a categorization scheme doesn't have to be perfect to be useful. In the book *Invisible Women*, Caroline Criado Perez documents numerous real-world examples, from fields such as medicine, automobile design, and city planning, where researchers noticed that women were being systematically harmed … just as soon as the researchers introduced a man/woman category to disaggregate their datasets. Until researchers checked to see whether there was some commonality between the people being harmed, we'd known only that the world we've built was failing some people. We would undertake very different future action than if we knew we'd built a world that systematically fails women.

And I should note that the categories of "man" and "woman" fail to accommodate even more people than "male" and "female" – after all, I'm somebody who wears nail polish and makeup, does caretaking work, and was bullied during graduate school by advisors who considered my demeanor to be insufficiently masculine, despite my body having undergone pretty stereotypically male development. Eugenia Cheng offers a better approach in *X + Y: A Mathematician's Manifesto for Rethinking Gender* – that we categorize people by the ways they interact with the world around them – but, still, people are being sorted.

A field of study called "queer theory" instead conveys the idea that all categories fail because all boundaries are fundamentally fuzzy. This concept should feel unsurprising to any biologist: after all, when two species are diverging, there's no crisp temporal, spatial, or genetic boundary that would allow us to categorize every individual. Symbiotic clusters like lichens are quite different from both plants and fungi. Even my own body harbors a mix of cells, some with matching genetic information (subject to inevitable microchimerism), some from a range of bacterial species, all of which can influence my moods and behaviors.

At times, it's important to recognize this fuzziness – my mental and physical well-being depends upon the behaviors of both the bacterial and the mammalian cells inside my body – and at other times, it's more helpful to hew to categorization – if I'm prescribed a course of antibiotics, certain cells inside my body are far more likely to die. Similarly, it's worth questioning how often we're helped by categorizing individual human bodies based on the history of their physiological development – in drug testing, researchers are beginning to realize that we need to pay more attention to the interplay between medication and the monthly hormone cycling of a large percentage of our population – and how often these categorizations cause harm – either by stifling our thinking or by stigmatizing people who feel excluded from the limited set of categories we offer.

In *Performance All the Way Down*, Prum offers a meticulous tour of the molecular pathways that underlie stereotypical sexual development in humans, as well as the myriad ways that any individual person's development might differ. Again, the idea that such differences arise should seem unsurprising to any biologist: if a pathway requires a cascade of transcription factors binding to promoters, then there are many opportunities for a constitutively active transcription factor or an altered promoter sequence to result in a phenotype that differs from what we'd otherwise expect. At the molecular level, the thermodynamic drivers of cellular activity are *statistical*: Gibbs free energy depends upon the entropy of a process, which is a rough measure of the probability distribution of states. There's always a chance that something other than our most likely prediction will occur: in some cases, this sort of statistically unlikely but possible event underlies the protein misfolding of Alzheimer's disease. And everything in biology is the result of evolution, a haphazard process that, over time, has resulted in the organisms best able to propagate themselves becoming more common. If there weren't variation between individuals, evolution would have nothing to select among (indeed, low variation among a population is often a harbinger of impending extinction).

So I found myself constantly agreeing with Prum. This was my one complaint with Prum's charming prior book, *The Evolution of Beauty:* I personally think it's so likely that some nonhuman animals have an emotional response to beauty that I felt baffled by the rigor with which Prum presented the book's arguments. Instead, I mostly enjoyed *The Evolution of Beauty* for the plethora of anecdotes about other animals, particularly all the information about birds: Prum is quite the bird expert!

I felt less baffled by the stridency of Prum's argumentation in *Performance All the Way Down.* After all, we live in a world where people who exhibit any difference from stereotypical developmental pathways *have* been stigmatized. And, as I discussed recently in a review of Jordan-Young and Karkazis's *Testosterone: An Unauthorized Biography*, our reflexive impulse to categorize based on a male/female binary *has* impeded scientific research: we've only recently begun to discover the essential functions of testosterone in stereotypically "female" bodies because testosterone was deemed a "male" hormone. In both cultural and scientific contexts, I think we *have* caused harm by invoking male/female categorization too often. Like a hammer, this sort of categorization is an occasionally useful tool; like a hammer, this tool can be harmful when misused.

Because I agree so wholeheartedly with Prum's central message, I found myself wishing that the book was more clearly aimed at a particular audience. I think that general readers might find a lot of the scientific jargon and gene names overwhelming. I think that a scientific audience might dislike stylistic conventions from academic queer theory, such as the tendency to quote original sources instead of explaining their ideas in an author's own words, or the use of that field's own set of insular jargon. The prose here is much less accessible than in Prum's earlier *Evolution of Beauty*.

If you read *Performance All the Way Down*, you'll be presented with an abundance of interesting stories drawn from developmental biology, ecology, cultural anthropology, and more. My own copy is replete with dog-eared pages that had information I'm excited to think more about. I strongly believe that this is a good book, in several senses of the word "good": I think that the ideas are generally correct, and I think that our world would be a better place if these ideas were more broadly disseminated. I just wish that it were easier to read!

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