SCIENTISTS'

Nightstand

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2022 Holiday Gift Guide
STEM books make excellent gifts. Early in December, we will begin posting brief reviews of recent books that we believe will please and enlighten the children and adults on your shopping list.

The Doors of Animal Perception

Lars Chittka

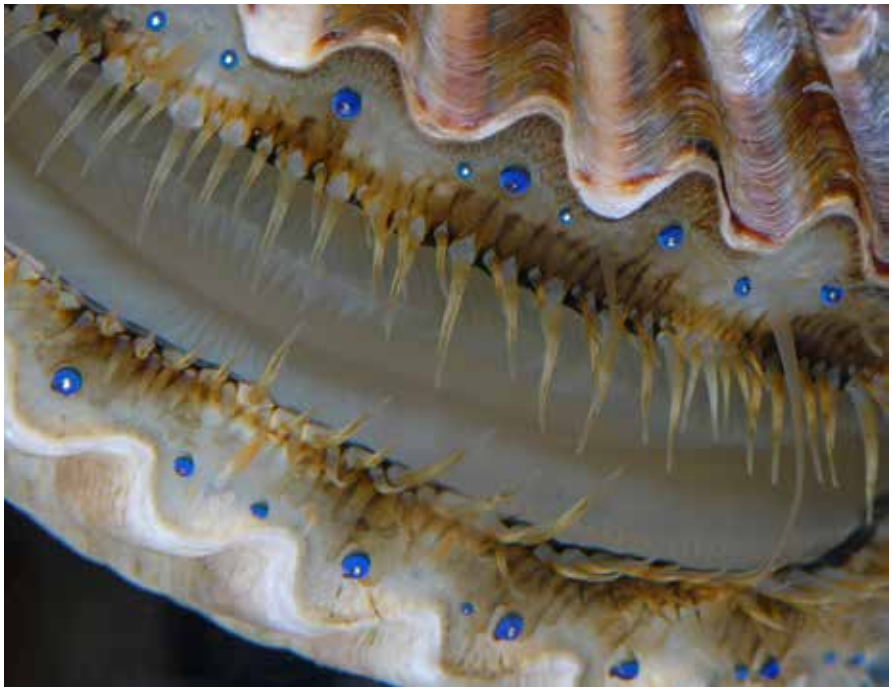
AN IMMENSE WORLD: How Animal Senses Reveal the Hidden Realms around Us. 449 pp. Random House, 2022. $30.

I would love to own a time machine, not (just) to travel back to the Cambrian Period, but also to meet the scientists of the future and the past and discuss with them what they might make of our present state of knowledge. High on my list of people to speak with would be John Lubbock, who discovered in the 1880s that ants can see ultraviolet light and that they communicate via a chemical "language." In his 1888 book *On the Senses, Instincts, and Intelligence of Animals*, Lubbock wrote that "we find in animals complex organs of sense, richly supplied with nerves, but the function of which we are as yet powerless to explain." To animals, he noted, the world "may be full of music which we cannot hear, of color which we cannot see, of sensations which we cannot conceive."

Lubbock's research provided the first scientific glimpses into nonhuman animal perception. A number of additional sensory capacities outside those accessible to humans are now common textbook knowledge—for instance, ultrasonic sonar in bats, sensitivity to magnetic fields in migrating birds, and infrared sensors in nocturnal snakes. If I were tasked with getting Lubbock up to speed regarding what is known about animal sensory abilities today, I'd hand him Ed Yong's recent book, *An Immense World: How Animal Senses Reveal the Hidden Realms around Us.* I have no doubt that the 19th-century pioneer would be thrilled beyond words by what has been discovered.

The book is a hugely entertaining and insightful tour de force, a sort of Alice-in-Wonderland journey into the world as perceived by animals. It is written by a science journalist in a manner that is fully accessible to nonexperts. As a scientist who studies (and teaches about) animal sensory systems, I was impressed by Yong's ability to explain inherently complex subjects accurately, without unduly simplifying matters. I tend to be weary of kibitzers offering their views on the "alternative realities" of animals, particularly if they speak of finding it remarkable that the world we perceive is not "reality," as if other types of sensation indicated the existence of some metaphysical parallel universe or meant that the world we see is actually an illusion. Yong deftly steers clear of any such cheesiness.

He points out that such terms as *ultrasound* and *ultraviolet* can mislead us by making certain frequency ranges appear to be special just because they are outside the spectrum that is perceptible by humans. But humans may be unusually impoverished in some sensory areas. For instance, the vast majority of animal species can see ultraviolet (UV) light, and humans (along with a minority of other animals) are "special" only in their inability to do so. Yong calls out instances in which such terminology has led even scientists to fall victim to undue simplifications and misconceptions. A century after Lubbock discovered that ants can see shorter wavelengths than we can, such sensitivity was discovered, and subsequently fetishized, in vertebrates. For the sole reason that humans cannot see UV light, the ability of other animals to do so appeared to some scholars to enable a special "hidden" communication channel. The result was a wave of wholly unsurprising findings—such as that animals with UV color receptors use them (for instance, in choosing a mate)—and some bizarre ones: for example, the (now disproven) claim that birds of prey locate their ro-



Neon-blue eyes dot the rims of a bay scallop shell. Each eye contains two retinas and is on a tentacle that allows it to move around and explore the environment. The ways that scallops see the world differs drastically from human perception and is one of the many distinctions in sensory perception explored in Ed Yong's book. From *An Immense World*.

dent victims by looking for UV reflectance emanating from rodent urine.

Yong highlights the absurdity of this approach by imagining what a bee might say:

> If bees were scientists, they might marvel at the color we know as red, which they cannot see and which they might call "ultra-yellow." They might assert at first that other creatures can't see ultra-yellow, and then later wonder why many do so. . . . They might wonder whether the large bipedal animals that see this color exchange secret messages through their flushed cheeks. They might eventually realize that it is just another color, special mainly in its absence from their vision.

An Immense World contains a riot of entertaining scientific findings that have stood the test of time. It is also scientifically comprehensive and up to date. The book is clearly useful not just to members of the public interested in science but to experts in zoology. It even includes a good number of findings that I was unaware of. For example, we are introduced to the thirteen-lined ground squirrel (called that because it has 13 black stripes down its back), which, because of a few mutations in a cold sensor, can survive for months at temperatures close to freezing, and when placed on a heatable plate, it won't step off until the surface reaches 55 degrees Celsius. Of all the species that have been tested, the thirteen-lined ground squirrel and the Bactrian camel have the least-sensitive versions of a sensor that detects painful heat.

If you are a scientist stuck in the minutiae of studying a particular sensory system, it is easy to lose sight of the big picture, and to lose touch with the sense of wonder evoked by studying how the world looks from inside the cockpit of another creature. If your day-to-day grind includes (as mine does) turf wars with colleagues about such things as which particular nonlinear equation to use for converting sensory input into receptor neural signals, then Yong's book will give you occasion to stand back and say, "Yes! This is why I am in this field, and I love it!"

Yong has met many of the field's heroines and heroes, and he describes them as a beautiful tribe of scientists driven by the excitement and joy of discovering unexpected facets of the natural world. They stand in sharp contrast to the run-of-the-mill consortium grant science that funding agencies now often seem to favor—where huge money is converted into publications with more than 100 authors but only marginal gains in terms of pushing the boundaries of science. In the field portrayed in *An Immense World*, many of the most important discoveries are being made by individuals who are motivated solely by curiosity, using creative methods and technology they developed themselves rather than the off-the-shelf equipment used in mainstream labs. For example, one of the scientists Yong describes, Eric Warrant, hunts nocturnal bogong moths in Australia with a contraption he calls the Eye of Sauron. Warrant has performed experiments in which he put the captured moths into an insect flight simulator surrounded by large magnetic coils and then tried to subvert their navigation in various ways. By doing this, he was able to demonstrate that bogong moths achieve their migrations of more than 1,000 kilometers by sensing Earth's geomagnetic field, using an ability referred to as *magnetoreception*.

Some of the scientists Yong introduces us to are perceptually divergent, and he wonders whether experiencing the world differently from other humans is what has prompted these scholars to be curious about the diversity of animal senses. He mentions Michael Supa, a blind psychologist who demonstrated in the 1940s that he and other students who were either blind or blindfolded could detect obstacles using their hearing. The researchers exploring bat sonar at the time were aware of Supa's work and may have been influenced by it. When the term *echolocation* was coined in 1944, it was applied to the skills not just of bats but of blind people.

An Immense World is organized by sensory modalities: There are chapters on smells and tastes, light, color, pain, heat, contact and flow, surface vibrations, sound, echoes, electric fields, and magnetic fields. Yong points out that the Aristotelian segregation of the senses into vision, touch, hearing, smell, and taste is both incomplete and misleading. For example, hearing, like touch, uses mechanoreceptors; also, scientists still can't agree on what actually distinguishes the senses of smell and taste. The book has no in-text citations, but the endnotes and bibliography, which fill 68 pages, include the most important key sources.

The book ends with a melancholy lesson about sensory pollution of the environment caused by humans. When we hear the term *pollution*, we usually think

of the kind of chemical contamination that poisons plants and animals. But humans mess with the environment in all sensory modalities. That we are losing the night through excessive use of too-bright electric light sources in our cities and beyond has been much discussed; this light pollution disrupts the diurnal rhythms of animals, their communication, their navigation, their search for mates, and their life expectancy. Sound pollution is also common. The noises from our cities and from transportation interfere with sound signaling between animals. The level of low-frequency noise from ocean shipping has increased by a factor of 32 since World War II, and Yong lists some of the results:

> As ships pass in the night, humpback whales stop singing, orcas stop foraging, and right whales become stressed. Crabs stop feeding, cuttlefish change colors, damselfish are more easily caught.

The list of pollutions continues for all sensory modalities. But because these changes have taken place gradually over the past century, humans are behaving like frogs in a pot of water that is coming slowly to a boil. As sensory pollution has increased and species have gradually disappeared, we have come to accept each stage as a new normal.

Yong points out that there is still time to reverse these trends. There are many reasons to do so, including some that are in our own best interest. Noise affects human stress levels and ability to sleep. Illuminating our settlements so brightly that they can be seen from space wastes both energy and money, and, contrary to what is sometimes alleged, there is no evidence for a link between crime and "poor" city lighting.

Many of us spend enormous sums of money to travel to distant but "serene" nature spaces. Yong builds a convincing case that we can have such environments at our fingertips, if only we take appropriate steps. Doing so will preserve the diversity of sensory worlds in the animal queendom, of which we are a part, and will enrich us in multiple ways.

Lars Chittka is a professor in the Department of Sensory and Behavioural Ecology at Queen Mary University of London and is the author of The Mind of a Bee (Princeton University Press, 2022). His research interests include the color vision and cognitive abilities of bees, and their interactions with flowers.

Writing History

Brian Hayes

INVENTING THE ALPHABET: The Origins of Letters from Antiquity to the Present. Johanna Drucker. 380 pp. The University of Chicago Press, 2022. $40.

Johanna Drucker has given her book a title in which the smallest word carries the heaviest weight. To speak of inventing *the* alphabet is to imply there is only one alphabet in all the world—despite the bafflement of English-speaking tourists confronting street signs in Athens or Moscow or Cairo. Drucker makes the point explicitly in her introduction:

> Ask the average literate person about the alphabet and often the response is, "Which alphabet? Our alphabet? You mean the Greek alphabet?" In fact the alphabet was invented only once, by Semitic speakers in the ancient Near East. Alphabetic scripts all derive from the same root; as they spread, their letterforms were modified. Even scripts as visually distinct as Arabic, Cyrillic, Latin, Greek, Hebrew, Devanagari, Tamil, and Gheeze have a common source.

Drucker's view shines a spotlight on the alphabet as a cultural artifact of extraordinary antiquity and importance. The graphic forms of the letters have varied and evolved. So have the mappings from written symbol to spoken sound. A few letters have been added and others have been dropped in some linguistic communities. But through it all, the alphabet has somehow maintained its integrity, even as civilizations and their languages come and go.

Today, variants of the alphabet form the writing systems commonly used to represent almost all the world's living languages. The major exceptions are the languages of China, Korea, and Japan.

The genre of *Inventing the Alphabet* is not history but historiography. The book's primary aim is not to investigate the origin of the alphabet but to record the progression of ideas about that origin, as they evolved over a span of millennia. Looking back from the present moment, much of the story reads as a catalog of fallacy and error. Before the 19th century, writers on alphabetic history had little material evidence to guide them, and in many cases, they had ideological or theological commitments to *mis*guide them. Drucker treats these flawed theories with care and respect, placing them in their historical context, rather than judging them by present-day criteria. She is less forgiving of a few 20th-century commentators whose falsehoods seem to reflect a willful disregard of evidence.

Curiously, the earliest surviving account of alphabetic origins got the story mostly right. The Greek historian Herodotus, writing around 440 BCE, states that the alphabet was brought to Greece by Phoenician settlers. Herodotus is vague about the time of this cultural exchange, and also about who the Phoenicians were, and from where they came. Nevertheless, later research has confirmed the key fact that the Greek alphabet derives, with some alterations, from a much older Phoenician one.

Between Herodotus and the era of modern scholarship lie two millennia of unconstrained speculation, some of it astute, some asinine. One recurrent theme concerns the story of Moses on Mount Sinai. When he received the stone tablets inscribed with the Ten Commandments, in what alphabet were those laws written? Some medieval and Renaissance authors postulated that the script of the tablets was humanity's first written language, and so our alphabet must be viewed as a direct gift from God. As late as the 18th century, the novelist Daniel Defoe defended this assertion with a highly imaginative argument: If writing had existed earlier, we would have received more detailed descriptions of prior events such as the drunkenness of Noah. Drucker comments that "Defoe could not resolve the basic contradictions that lingered: if writing did not exist before Moses received the Tablets, then how could he and the children of Israel read the Laws?"

The search for biblical validation of alphabetic origin stories was at least focused on the right part of the world. Others looked farther afield. In 1569 the Belgian writer Johannes Goropius Becanus insisted that a dialect of Flemish was the language of Adam, and in 1764 Gaelic nationalist Rowland Jones believed the first writing was in a Celtic script. Attempts to claim the alphabet as a trophy accomplishment of certain ethnic and linguistic groups continued

into the 20th century, and turned sinister with the contention that the credit should go to a (fabricated) Aryan race rather than the Semitic peoples of the eastern Mediterranean.

What transformed the study of the alphabet into a scientific enterprise, Drucker writes, was the flowering of systematic archaeology, starting in the 19th century and continuing today. Simply put, more digging produced more data. The number of alphabet specimens from the crucial period—the second millennium BCE—is still only in the hundreds, but it's enough for Drucker to express confidence about the identity of the originators. They were people of the land of Canaan, occupying the coastal cities of Tyre, Sidon, and Byblos, in territory that roughly corresponds to the modern nation of Lebanon. Their language was in the Semitic family but distinct from ancient Hebrew. These people were indeed the ones we know as the Phoenicians, although that's not a name they applied to themselves.

Curiously, the oldest known alphabetic inscriptions, discovered only in recent decades, are found not in the homeland of the Phoenicians but in Egypt and in the Sinai peninsula (which was then, as now, controlled by Egypt). These writings, carved or scratched in soft stone, are written in a Semitic language but show the influence of Egyptian hieroglyphics. Given this evidence of bilingualism, the graffitists were probably more than casual travelers passing through Egyptian territory; Drucker suggests mercenaries, workers, or slaves. She offers a thumbnail summary of the current state of knowledge: "The alphabet was formed in the context of cultural exchanges between Semitic-speaking people from the Levant and communities in Egypt after or around 1800 BCE."

Drucker is a diligent and accomplished scholar, and is currently the Breslauer Professor of Bibliographical Studies at the University of California, Los Angeles. She is also an artist, a typographer, and book designer. *Inventing the Alphabet* is an eye-opening synthesis, distilling an immense body of work by hundreds of authors and researchers. In fact, she reports that the project began more than 40 years ago, in her first year of graduate study. Given this broad scope, it seems churlish to ask for more, but I could not help noticing that almost all the sources are European. It would be interesting to hear more from the Arabic and South Asian communities who share our alphabetic heritage.

Drucker's central claim that the alphabet was invented only once is surely true; all of the alphabetic scripts known today can be traced back to the Phoenician characters. But it's another matter to suggest that the differences between modern scripts are minor enough that we can still speak of *the* alphabet. One might as well say that because life on Earth emerged only once, there is only one life-form on the planet today. In this respect Drucker sometimes overreaches. For example, she dismisses arguments that the Greek alphabet stands apart from its predecessors because it was the first to include distinct letters for vowels. She may be right to do so, but she does not supply detailed arguments in support of that position.

The fact that all alphabets come from the same source is in itself intriguing, and even disturbing. Why would such a useful device arise only once in all of human history? Perhaps the reason is that once the alphabet existed, there was no need to reinvent it. After all, the letters were never patented. But this is only half an answer. People who had no contact with Mediterranean cultures, such as those in the Americas, invented their own writing systems, but none of them chose to develop an alphabet. I can't help wondering what would have happened if the Phoenicians had not come up with their ingenious scheme for converting spoken language into a stream of written symbols. I can barely imagine the modern world without it.

Brian Hayes is a former editor and columnist for American Scientist. *His most recent book is* Foolproof, and Other Mathematical Meditations *(MIT Press, 2017).*

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