its capacity for carbon storage and thereby further accelerating climate change.

The West African monsoon system is also listed as a tipping element that could be affected by a collapse of AMOC. Palaeoclimatic evidence suggests that a failure of the monsoons linked to weaker AMOC has happened before, but at present it is unclear what the impact on West Africa and the Sahel zone may be.

As each of these tipping elements is a complex system in itself and not all their interactions with each other are sufficiently understood, there remains a large element of uncertainty in predicting what changes will happen at what time. At the moment the latest and most comprehensive compendium of what we know about these systems is the report ‘Global Tipping Points’ prepared by Tim Lenton from the University of Exeter, UK together with a global team of more than 200 experts that was presented at the Dubai climate summit, COP28, in December 2023 (https://global-tipping-points.org/).

What is clear from the above studies, however, is that multiple Earth systems currently at an equilibrium state that we are used to will soon be at risk of departing from this state and cause catastrophic damage to the biosphere around the globe.

With luck, some of the changes will counteract each other (like the AMOC collapse making the Arctic cooler again), but others are bound to reinforce each other and topple further dominos in the chain.

As Armstrong McKay and other authors have emphasised in these studies, every 0.1°C of warming avoided can potentially protect the planet from some of the more dramatic consequences of some of these tipping elements. “Current policies leading to ~2 to 3°C warming are unsafe because they would likely trigger multiple climate tipping points,” Armstrong McKay and colleagues note. Thus, rather than giving in to the feeling of doom, one should read these as a further reason to engage in climate action.

Q & A

Nicholas Bellono

Nicholas Bellono is an Associate Professor in the Department of Molecular and Cellular Biology (MCB) at Harvard University. He studied cell physiology and ion channel biophysics at Brown University between 2011 and 2015 and pursued postdoctoral training in sensory biology at the University of California, San Francisco (UCSF) from 2015 to 2018. The Bellono Lab studies the molecular basis of unique adaptations and behaviors across numerous creatures.

How did you become interested in being a scientist? I spent a summer during college working with Heather Eisthen (Michigan State) at the Marine Biological Laboratory (MBL) in Woods Hole, Massachusetts. At that point, I had just got a job in her lab. I always liked animals (see illustrations from my first octopus ‘project’), but I didn’t know much about science and had really never heard of, thought about, or considered a career as a scientist. But Heather graciously offered me a position to visit the MBL with her group, and it seemed like a unique experience. Like many, my summer in Woods Hole made a huge impression on me. It’s a special place in which everyone is highly curious and excited about their work, does creative and fun experiments all day and night, and then hangs out at the beach. I thought: I could get paid to get a PhD and hang out on the beach between playing around with cool animals? This seemed too good to be true. I’m very grateful to Heather for the opportunity; otherwise I can’t imagine how I’d be doing this job.

What did you study during graduate school? I thought that I wanted to study neuroscience. I liked the day-to-day process of doing electrophysiology, which can be used to study all kinds of biological systems but is often applied to neurons and the brain. I especially enjoyed long, technically challenging experiments that required a lot of practice and failure — overcoming the challenge of making a tough measurement was one of my favorite parts of doing experiments. I also really liked that one could reduce a complex behavior or physiological process to a simple model in the context of a signaling pathway or protein function. With this in mind, I went to graduate school with a plan to analyze synapses to study learning and memory. Although I was focused on neuroscience, a wise advisor, Anita Zimmerman, convinced me to try rotating in a lab focused on pigmentation with Elena Oancea. Anita thought that I’d appreciate cell biology as well as pigmentation as a simple near-binary (pigment or not) readout for connecting molecular processes to organismal function: how do environmental signals such as sunlight control pigmentation? We ended up making patch-clamp measurements directly from the pigment-producing organelles called melanosomes to identify some of the major human pigmentation genes (determinants of eye color and so on) as components of ion channels. The combination of training in physiology with Anita and molecular biology with Elena made me appreciate the importance of reducing complex organismal phenotypes to the simplest components possible — the function of molecules — and what one can learn from applying simple, robust approaches in new places.

How did you choose a lab for postdoctoral training? I did my postdoctoral training with David Julius at UCSF. I knew that the art of asking biological questions was very important to me and I wanted to learn a new approach for doing so. My PhD experience taught me about studying
proteins and thinking about how their properties connect to cellular or organismal function. The Julius Lab’s method is often in reverse: start with a question about organismal function and identify the molecules. I thought that learning these complementary approaches would prove useful in asking new and distinct questions.

The emphasis of molecular discovery paired with my background in physiology made for a super fun time in exploring a bunch of biological systems and questions. David was a fantastic postdoc advisor who fostered a collaborative environment in which I was exposed to numerous new approaches. I ended up working closely with two awesome fellows among many others, Duncan Leitch and Jim Bayer, on electroreception and chemosensation in the gut, respectively. I was often asked: “why work on such different projects?” To me, they aren’t so different. Both systems are tasked with detecting very specific signals from a noisy background — sharks for very weak electric signals, and the gut with specific chemicals among a complicated convergence of neural signaling, immune signaling, the microbiome, and so on. Moving forward, I decided that I wanted to study how cells adapt to extract information from specific environments and how this facilitates the evolution of new animal traits.

How did you decide what to work on in your independent lab? I wasn’t totally sure what to study but thought about why the MBL got me interested in science and how that environment fostered creativity geared toward impactful discoveries and training. So, I aimed to establish an MBL-style group in which people could explore whatever they are curious about and do it without the constraint of a particular animal model or technique. In this vein, I had seen an octopus in an aquarium before going on job interviews and got really excited about their arms. It seemed like the arms were doing a lot: sensing and exploring, squeezing into tight places, and changing color, all in an almost uncoordinated but somehow coordinated manner. I thought that, if we could identify proteins underlying sensation and signal transduction, then maybe we could figure out ways in which the collective behavior of those molecules contributes to the function of this divergent but sophisticated nervous system. When I interviewed at Harvard MCB, Vlad Denic asked me what I was most excited about and suggested discussing that topic during my chalk talk versus ‘safer’ projects for which I had some data and direction. I had rehearsed nothing, had no data, and had minimal plans, but I explained how I thought an open-minded exploration of signal transduction in the octopus arm would be unique and informative for connecting the evolution of proteins to cellular and organismal function. Thankfully, my department thought that it was a good idea and invested in my group and an amazing animal facility. Fortunately, the octopus turned out to be an incredibly interesting system in which we characterized a family of chemotactic “taste by touch” sensory receptors that evolved from ancestral neurotransmitter receptors, thereby providing us with a model to broadly ask: where do sensory receptors come from? How do they diversify to mediate new functions? And how does this facilitate new behavior?

How has your environment influenced your research? Harvard MCB is a true basic biology department. Everyone studies what they are interested in, and the environment encourages people to do something new and different toward uncovering principles that span from molecules to organisms. The breadth and depth of the science have supported and influenced my group’s growth in the context of our goals first to study cool and inherently interesting questions that even a non-specialist can appreciate and second to try to learn something new that is broadly informative.

How do you decide which animals to study? I believe that comparative biology is incredibly powerful. And, simply put, looking somewhere new can teach us something new. Equally important, it can also reveal conserved principles across systems. Our goal in all projects is to pick questions in which there’s an interesting and unique behavior or trait that we can reduce to a rigorous and robust molecular analysis, ideally with as few molecules as possible. It’s typically a collaborative decision and very often serendipitous. Of course, the largest influence on what we study is the people who actually do the studies.

I’ve been incredibly fortunate to work with some amazingly creative, curious, and passionate people. This ranges from the incredible staff members who built and run our animal facility to house ~100 species so far to the students and postdocs who drive our science. Two recent stories (among many) demonstrate the randomness of this process. First, we got piranhas in the lab last year through a considerable effort to import them from the Amazon. Peter Kilian from the lab saw a show called something like ‘River Monsters’ on the Discovery Channel in which piranhas would only attack in a ‘feeding frenzy’ if there were injured prey in the water. What specific signal elicits the collective piranha feeding frenzy? Plus, they are piranhas, so we at least wanted to see them attack something in the lab. Second, postdoctoral fellow Corey
Allard started our studies on sea robins, which are weird fish that repurpose fin rays into leg-like appendages used for walking on the seafloor. This happened because we went to the MBL for squid and the Marine Resource Center staff showed us sea robins for fun. We thought that they were so weird that we just had to bring them back and see what they did with their legs. These ‘for fun’ experiments ended up starting a fantastic collaborative study to explore the genetic and physiological basis of novel traits (fish with legs). We’ve also had octopuses, jellyfish, photosynthetic sea slugs, amphibians, and many other animals and plants. I expect more to come!

**What is next for your research?**
For me, one of the best parts about being a scientist is that we get to study what we think is interesting, even if unanticipated. I believe that research is most fun when it starts with asking simple questions about curious natural phenomena, and that an open-minded exploration of our curiosities is important because we never know where the next discovery comes from and how it informs broader biology. I find that this general philosophy is useful for a training environment because it encourages creativity, thinking outside the box, and following the science by whatever means necessary: flexible techniques, systems, and fields, and perhaps most importantly collaboration and teamwork. I also think that this training approach instills a positive intensity for science versus distraction by following the ‘naturalness’ of that nature. The text covering her conversion to ornithology was intriguing to me as someone who has been obsessed with birds for as long as I can remember — I have a vague recollection of seeing my first common kestrel (*Falco tinnunculus*) at age seven. Seeing how someone in their 40s started on this same path was eye-opening.

The book links to research — recent and otherwise — throughout to evidence her narratives about individual bird species, and these are sufficiently sparse as not to cause non-academics to baulk at reading, whilst hopefully still being inspiring for many. In a few spots I thought that there was scope for more — especially concerning the geolocator work that O’Kane undertook with grey catbirds (*Dumetella carolinensis*). The book’s memoir but doesn’t dwell at length on the author’s life history ‘pre-birds’, although what is revealed about her work as a human and civil rights investigative journalist is both intriguing and a lens through which to view her subsequent outreach.

The narrative starts in earnest with the author’s move to New Orleans only a month before Hurricane Katrina, which would destroy her new home. I started reading the book over Christmas 2023 whilst visiting my parents and, having finished the harrowing section on how the author and her partner became climate change refugees, woke up to hear on the news that a T5 tornado had caused extensive damage to properties in North West England near our home — the lead item on the national news, given that such storms are (or at least were) very unusual here. A few phone calls to neighbours later, we found out that we were unaffected: the tornado had passed a few kilometres from our house. The supercell thunderstorm that spawned it had come in the wake of unseasonal land and sea temperatures at the end of the hottest year on record. The sentiments of a now deleted viral tweet by @shocks continued to haunt me: “you will experience climate change through a series of increasingly wild videos, until you are the one taking the video”. Unlike O’Kane, we had escaped climate refugee status but for how long?

O’Kane ‘discovered’ birds in the wake of Katrina. Intriguingly, many are introduced species, such as house sparrows (*Passer domesticus*) and monk parakeets (*Myiopsitta monachus*), and this speaks to the challenge that a connection with nature is not always bounded by the ‘naturalness’ of that nature. The text covering her conversion to ornithology was intriguing to me as someone who has been obsessed with birds for as long as I can remember — I have a vague recollection of seeing my first common kestrel (*Falco tinnunculus*) at age seven. Seeing how someone in their 40s started on this same path was eye-opening.

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The bulk of the book concerns O’Kane’s exploits in and around Warner Park following her move to Madison, after she started a PhD programme at the University of Wisconsin. A class in ornithology led her to eventually record 141 bird species in the park and soon set her on a crash course with those who managed this space and their plans to dramatically change it. O’Kane marshalled community support from a diverse set of park devotees, and this evolved into ‘Wild Warner’, a park-centred environmental defence group that would set the stage for the development of O’Kane’s ‘Birding to Change the World’ community-based course, which aims to “meet a public

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**Book review**

**Social and avian justice**

**Alexander C. Lees**

*Birding to Change the World: A Memoir*  
Trish O’Kane  
(Harper Collins, New York, NY; 2024)  
ISBN: 978-0-063223-141

Birds command a disproportionate amount of interest from academics and layfolk alike. They are far more visible than most life on Earth and can be observed in virtually any habitat at any time of year, with field identification of most of the 11,000 or so species achievable by non-experts with the right tools. Consequently, more time is spent watching and studying birds than it is dedicated towards any other taxonomic group. The number of bird book titles alone likely significantly outnumbers the number of bird species globally, and where once natural history sections were dominated by field guides to birds, or books about bird ecology, there are now more and more titles about people’s relationships with birds and how birds have shaped their lives. *Birding to Change the World* is one such book from this burgeoning genre and explores Trish O’Kane’s journey into bird obsession, and her success in leveraging that love to make one corner of North America a better place for people and nature. As billed, the book is a memoir but doesn’t dwell at length on the author’s life history ‘pre-birds’, although what is revealed about her work as a human and civil rights investigative journalist is both intriguing and a lens through which to view her subsequent outreach.

The narrative begins with the author’s move to New Orleans only a month before Hurricane Katrina, which would destroy her new home. I started reading the book over Christmas 2023 whilst visiting my parents and, having finished the harrowing section on how the author and her partner became climate change refugees, woke up to hear on the news that a T5 tornado had caused extensive damage to properties in North West England near our home — the lead item on the national news, given that such storms are (or at least were) very unusual here. A few phone calls to neighbours later, we found out that we were unaffected: the tornado had passed a few kilometres from our house. The supercell thunderstorm that spawned it had come in the wake of unseasonal land and sea temperatures at the end of the hottest year on record. The sentiments of a now deleted viral tweet by @shocks continued to haunt me: “you will experience climate change through a series of increasingly wild videos, until you are the one taking the video”. Unlike O’Kane, we had escaped climate refugee status but for how long?

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