



## Editorial

# Creativity: standing on the shoulders of Hobbes' *Leviathan*

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Novel ideas in organismal biology are generated by (1) borrowing from others, including borrowing from obscure sources and other disciplines, (2) natural history, (3) attention to oddities and outliers, and (4) acute forgetfulness, which antithetically and hypocritically can be framed as inattention to outliers.

When it comes to generating novel ideas in ecology and evolution, we stand on the shoulders of giants. But the giants are not necessarily famous people like Charles Darwin, Barbara McClintock, Francis Crick, Evelyn Hutchinson, Robert May, Rosemary Grant, and Peter Grant. Instead the giants are Hobbes' *Leviathan* (1651), a corpus of thought, distributed across thousands of individuals and labs over several centuries. Great ideas are often generated from the most idiosyncratic of sources, small anomalies that torment students, post-docs, faculty members, and other scientists. Even the most obscure person can generate data that are outliers that change the way we view the world. It is the institution of science itself and the funding of basic science by governments that form the giants upon whose shoulders we stand. The Natural Science and Engineering Council of Canada (NSERC) allows many of us to follow interesting threads, taking many unexpected changes of direction, including false starts. Attending random seminars at our home and neighbouring universities pushes us in new directions, even when—or especially when—the seminars are presented by graduate students. In the spirit of Thomas Hobbes, it should come as no surprise that my favourite ancient Greek philosopher is Mediocrities.

My core research program on evolution of sex was inspired by an hour-long one-on-one conversation with

Shirley Tilghman. When I was a graduate student, my colleagues, but certainly not me, invited her to speak. At the last minute, several fellow students bailed on meeting with her. As a courtesy to the student hosting her visit (who is now my next-door neighbour), I filled in to talk to this visiting medical molecular biologist, who I suspected would bore me to tears. Instead, I must profoundly thank Shirley Tilghman because, only after speaking with her, I have been seeing the world through epigenetically-coloured glasses. Tilghman and I have such disparate research interests that it is nigh impossible to recognize any resemblance between us. Yet, an unexpected conversation with her allowed me to develop new ideas that otherwise might have remained beyond my vision. For that reason, to this day, I hardly ever skip a biology colloquium, regardless of the speaker or topic. Out of pure self-interest, to expose myself to new tools and perspectives, I also coordinate a pair of semi-weekly events: a Science Café and an Inter-Disciplinary Lunch Event, with the not-so-ironic acronym IDLE. Idle time is essential for generating new ideas, letting the mind wander.

John Polanyi (2011) assiduously noted the importance of funding basic science, especially of low-cost science, for generating novelty:

But how good are we, scientists or non-scientists, at extrapolating from unmade scientific discoveries to desired technologies? Not good at all. The reason we fail is that it's in the nature of discovery to surprise, and in the nature of bureaucracy to oppose surprise. What's a 'plan' if it's not to diminish the element of surprise?[...]

There's an opportunity here for Canada. Demand that our university scientists make the biggest possible discoveries at the least possible cost, in the shortest possible time. Require that they surprise us, recognizing that there's nothing to beat the most innovative science for the highest degree of relevance.

Give us enough financial and intellectual freedom to let our minds wander, including the minds of our students. Freedom cultivates creativity.

There is another invaluable source for inspiration, other than universities and granting agencies, the source that originally persuaded many of us to pursue careers in ecology and evolution, namely natural history. Instead of waiting for our colleagues or experiments to reveal instructive outliers, it is invaluable to get outdoors and look around. We can often still be inspired by natural history trips, taken for no purpose other than to be gob-smacked by curiosities and oddities. "Darwin admonished us not to ignore the 'oddities and peculiarities' of life as we see it today. It is by the analysis of such oddities that evolutionary history can be reconstructed." (Margulis and Sagan 1988: 26). Sometimes peer-reviewed natural history papers have arisen from simply realizing that something is weird, e.g. noticing that eastern chipmunks regularly swim (Gorelick and Bertram 2009) or that flowering stems of a basal genus of columnar cacti regularly branch in unexpected ways (Gorelick and Machado 2011). But, most often, we simply add to our caches of factual wisdom, allowing for instant tests of novel hypotheses. When new hypotheses and ideas survive this scrutiny, there is usually something really interesting to pursue. In order to be more creative, I therefore schedule at least two natural history trips per year. And while this will not work for everybody, natural history is also a major reason that I canoe to work from May through December.

Diversity is essential not just in the organisms we study, but in ourselves. Look at how much organismal biology changed when women were welcomed into ecology and evolution. Ecology became more than just the study of competition, but started embracing cooperation (e.g. symbiosis and mutualism) and null models. Evolution started embracing the effects of plasticity, non-Mendelian inheritance, and maternal effects. And we can do even better by training and hiring many more biologists with diverse cultural, linguistic, and economic backgrounds (Gorelick and Bertram 2010). We could also use greater diversity of approaches. With research on evolution of sex, I rely heavily on experts in theories of sexuality, gender, feminism, queer, and trans (e.g. Edwards 1990; Hird 2006), whose work induces me to ask questions and borrow tools that I never would have

otherwise arrived at from my white male sexually-repressed natural science background.

Why are outliers so important in discovery and for egging us on to generate new ideas and perspectives? Outliers are vexing, like an earworm (*ohrwurm*), tormenting us until we think in radically different ways. Information theorists have long understood the value of outliers as carriers of information. Consider a sequence of binary numbers, i.e. zeroes and ones. If the first  $n-1$  elements of the sequence are random digits, then another element in the sequence provides little new information. Consider another sequence in which the first  $n-1$  elements are all zero. Another ( $n^{\text{th}}$ ) zero provides little new information because we already surmised the pattern. However, if the  $n^{\text{th}}$  element in the sequence is a one, that is valuable new information, a numerical oddity, that genuinely piques our interest. It can radically change our view of the underlying sequence. Corroboration of hypotheses and confirmation of theories may be useful, but provides no new insights. Falsification of hypotheses is far more likely to instigate a paradigm shift.

Information theory also shows the importance of forgetting, or at least the importance of disregarding some details. A Turing machine is the quintessential theoretical device in computer science and computability theory (Turing 1937). A Turing machine is a digital tape that can contain a zero, one, or blank at each location, along with a read/write head that can move along the tape one digit at a time and can—based on a finite set of instructions—change the focal digit to a different value. If the head can only read and move, but not write, then this theoretical computer can be constructed so that it uses no energy. The thermodynamics of computing are far different if we allow the head to also write. Writing is the equivalent of erasing whatever digit was originally read. Erasing, possibly including writing, is the one Turing machine operation that requires energy (Landauer 1961; Bennett 1982). Extrapolating this computational construct to cognition, the most energy-intensive operation is the ability to forget, possibly replacing a pre-existing construct with a novel one. Learning is easy; unlearning is difficult. Sometimes data cloud the issue. Often preconceived notions point us away from productive directions. Thus, novel ideas are generated both by focusing on informative outliers (i.e. oddities) and also by ignoring uninformative outliers. The art is figuring out which outliers/oddities are informative.

Organismal biologists, however, do not need to become experts in the thermodynamics of theoretical computing to see that creativity is driven by forgetting and disregarding. All we have to do is go back to Hobbes' *Leviathan* (1651: 5), who stated that "Imagination," therefore, is nothing but 'decaying

sense,'...an obscuring.' We can truly be creative and see farther by standing on the tall shoulders of the giant comprised of myriad scientists, but realize that sometimes it is also helpful to forget or ignore some of what we see from those heights.

### Acknowledgments

Thanks to the Natural Sciences and Engineering Research Council of Canada (NSERC) for funding, Sue Bertram for feedback, and Martin Gerrits for introducing me to Shirley Tilghman.

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