or 4,000 tonnes per person alive today. It is thus an extension of our species that exceeds our own biomass by five orders of magnitude, which in turn is already exceptionally large. Humanity's total biomass is estimated to be double the total biomass of large vertebrates existing before our ancestors started hunting them to extinction (Curr. Biol. (2015) *25*, R965–R967).

The currently existing, and rapidly growing, technosphere is thus an outgrowth of life on Earth that is developing comparable stature to the biosphere. Much of it is in solid structures made of concrete of steel, but an increasing part consists of the all-pervasive and mobile plastics. What will become of those when the Anthropocene comes to an end and geology moves on?

The remains of the day

As plastics have been around for less than a century, there can be no direct evidence as to what will happen to them on geological timescales. However, geologists like Zalasiewicz have proposed speculative scenarios that are based on the fact that plastics are carbon-rich, like the biomass that we observe in fossilised form, and thus may eventually see a similar range of fates as those of organisms of the past.

When our waste becomes buried in sedimentary strata, for instance, Zalasiewicz predicts that some of the hydrocarbons contained in the plastics may be released to become fossil fuel reserves of the future (http://bit.ly/2voKHZh). Some items may mould the surrounding sediment before being broken down, leaving future researchers from species yet to evolve scratching their heads over the shapes of biro pens and CD cases.

One may find the geologist's view reassuring that in the long term, everything we have made from the Earth will merge back into it and our legacy will only testify to a weird phase that our planet went through, like the Ediacaran. In the short term, however, if we want to continue to enjoy the rich but dwindling biodiversity of life on Earth, we really have to do something drastic to curb our production of plastics.

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Q & A

Jonathan Losos

Jonathan Losos is an evolutionary ecologist at Harvard and Curator of Herpetology at the Museum of Comparative Zoology. His work has focused on pattern and process in evolutionary diversification, from within-population natural selection to macroevolutionary radiation. His work has combined evolution experiments, phylogenetics, behavior, ecology, functional morphology, developmental biology and genomics to understand the evolutionary diversification of Anolis *lizards, making these lizards one of the best-known examples of replicated adaptive radiation. His first book,* Lizards in an Evolutionary Tree: Ecology and Adaptive Radiation of Anoles*, won the Daniel Giraud Elliot Medal from the National Academy of Sciences. His second book, for a general audience,* Improbable Destinies: Fate, Chance and the Future of Evolution*, was just published by Penguin-Random House.*

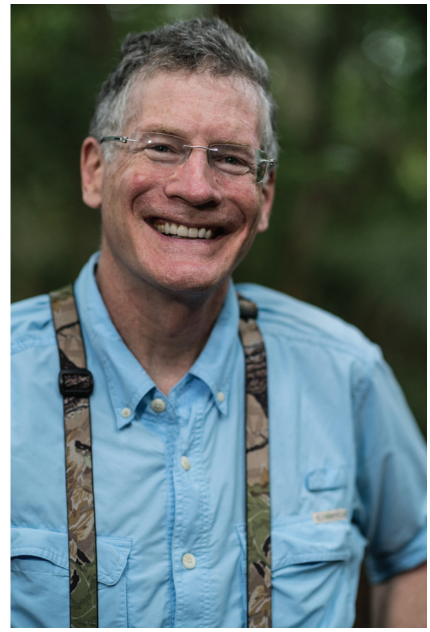

Photo: Days Edge Productions.

How did you get started in biology? Dinosaurs, of course. Like many five-year-olds, I was fascinated by the reptilian behemoths. Indeed, I was legendary at nursery school (and am still occasionally reminded of this a half-century later) for my basket full of plastic dinos with which I faithfully arrived every day. But a big turning point for me was a particular episode of Leave it to Beaver, the one in which the Beaver purchases a mail-order baby alligator. Needless to say, Ward and June Cleaver were not amused. But for me, it was an inspiration, because I knew that local pet stores sold baby caimans, the neotropical relative of alligators. The question was: how to convince my mother to allow a crocodilian in the house. Fortunately, my mom — not liking to say 'no' — passed the buck to the local zoo director, a family friend, expecting him to put the kibosh on the idea. To her dismay and my delight, however, he said that having an alligator was how he got his start in herpetology, and the next thing you know, I had a caiman in a kiddie's wading pool in the basement. My mom even went out and bought a second caiman because the first one looked lonely. Despite being nasty little animals, caimans turned out to be entrancing, and my fascination with reptiles was cemented.

How did you transition from caimans to* Anolis *lizards? In my first week as a freshman at Harvard, I looked up the university's herpetologist, Ernest Williams, the Grand Old Man of Anolis. Before I knew it, I was volunteering in the Museum of Comparative Zoology and then assisting Williams' last graduate student, Greg Mayer, on an anole field trip to Jamaica — which was great, but not what I expected: Mayer politely explained, when asked, that I shouldn't bring my racket and tennis shorts. From that point on, my studies have focused on anoles — with short digressions into other lizards and local opossums. Indeed, my research career has been more linear than that of almost anyone I know — my current work traces directly back to my doctoral studies, which in turn were inspired by my undergraduate experiences. I should point out, however, that when I graduated from college, having done my honor's thesis on anoles, I vowed never to study them again for two reasons: first, there was nothing left to learn, and, second, I didn't want to be a little fish in a big pool. The first point, of course, was naïve, but the second was more reasonable: Williams had trained an extraordinary cadre of students who had gone on to dominate the field: Schoener, Roughgarden, Trivers, Huey, Hertz and others. What I, and the rest of the field, didn't realize was that all of these workers had moved on to other things or were using anoles only as ecological actors in broad-ranging community ecology studies, for the most part leaving Anolis un-studied. It wasn't until two years and a dozen failed research projects later that I rediscovered anoles, and since then it's basically been all anoles, all the time.

What's so great about* Anolis *lizards? Convergence, convergence, convergence! And they have pretty dewlaps. But, really, convergence. Anoles have experienced independent evolutionary radiations on each of the islands of the Greater Antilles (Cuba, Hispaniola, Jamaica and Puerto Rico), but on each island, the outcome has been strikingly similar, with the same set of habitat specialists evolving on each island (with a few exceptions). Convergent evolution, of course, has long been known — Darwin wrote about it. But convergence of entire evolutionary radiations is a more recent idea, and anoles are one of the best examples — arguably the best, in terms of breadth and depth of research. We now know that the convergence extends beyond morphological adaptations for moving on different surfaces and includes features as disparate as foraging mode, social structure, sexual dimorphism, head shape and embryo development. Research is currently underway to determine the extent to which this phenotypic convergence is underlain by convergent evolution at the genomic level.

So, anoles must be your favorite animal. Well, I do love them, but my all-time favorite animal is the greatest species ever-evolved, that incredible amalgamation of duck, beaver, electric fish, otter and many more, the duck-billed platypus. I've been enamored with platypuses ever since my parents visited Australia when I was seven and brought me back a stuffed animal duckbill.

What do anoles and platypuses have in common? Nothing. In fact, in evolutionary terms, they are diametric opposites. The platypus is an evolutionary singleton, a species well-adapted to its particular way-of-life, but with no evolutionary parallel. Why hasn't something like the platypus evolved in streams elsewhere in the world? Could it have something to do with Gould's vaunted "historical contingencies", that is, chance events that send evolution down one road and not another? By contrast, anoles are the poster child of convergent evolution. In a sense, they are the embodiment of replaying the tape of life (spatially, across different islands, instead of temporally), and getting more-or-less the same outcome each time.

Speaking of Stephen Jay Gould and "replaying the tape of life", what did Gould think about anoles? Not much. Although Gould's office was less than 50 feet from Ernest Williams' in the Museum of Comparative Zoology, Gould never mentioned anole evolution in his work. He was, however, aware of their existence from his fieldwork in the Bahamas, once referring to them as "just a fleeting shadow running across a snail-studded ground." On at least two occasions, Gould was asked about anoles being the antithesis to his idea that contingencies would prevent evolution from following the same course multiple times. Both times he responded in the same way, saying that the scale was incommensurate, anoles being recently-evolved variations on a theme, whereas his ideas pertained to grand-scale evolution in the deep past. Anoles exhibit, he said, "predictability ... within a constrained design and clade of close relatives ... My contingency is at the much higher level of designs themselves." (http://www. anoleannals.org/2013/12/16/stephen- jay-gould-on-replicated-adaptive- radiation-in-anoles/).

What led you to write a book about evolutionary contingency and determinism? I was strongly influenced by Gould's ideas on evolution through his *Natural History* columns that I read as a boy and subsequently by his classic book *Wonderful Life*. My own research on anoles seemed to contradict his ideas, yet I came to view the anoles more as the exception that proves the rule, the odd counterpoint to the more Gouldian examples of evolutionary indeterminance, evidenced by non-convergent platypuses, elephants, and kiwis. I've always liked writing and was pondering writing a book when I heard a brilliant lecture by Rich Lenski on his microbial evolution work. The long-term evolution experiment is, of course, one of the most important evolution studies in the last quarter century, and it was explicitly set up to test Gould's ideas. I realized that in recent years, there has been a two-pronged approach to examining Gould's hypothesis, one using phylogenetics and genomics to assess the extent of convergent evolution as the counterpoint to Gould's predicted non-repeatability, the other using experiments to directly replay the evolutionary tape. These experiments mostly have been conducted in the lab, but increasingly researchers are conducting long-term evolution experiments in nature. My own work on anoles, in collaboration with Tom Schoener and others, was among the first such studies, but they have become increasingly common. I decided that it would be fun to write a book examining these two quite different approaches to examining evolutionary contingency and determinism. Given the characters (Stephen Jay Gould, Simon Conway Morris, Rich Lenski, John Endler and David Reznick), the places (Australia, Bahamas, Madagascar, East Lansing and Oxford) and species (aye-ayes, sticklebacks and dinosauroids), I felt the material couldn't help but be interesting. My job was to do justice to it with my writing. And as for whether I still think that anoles are the exception that proves the Gouldian rule, well, you'll have to read the book to find out.

Is there anything else you'd like to tell us? My second favorite animals are cats. The most enjoyable thing I've done recently is teach a new class entitled 'the science of cats'. The course is for freshmen: I sucker them in with cats and then when they're not looking, I slip in all kinds of ecology, behavior, evolution, genetics and so on using cutting-edge research currently being conducted on housecats. Plus, we went to a cat show and were bedazzled by bengals and savannahs.

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