

## EVOLUTION

# Inevitable or improbable?

## A biologist sheds light on the evolutionary likelihood of human existence

By **Adrian Woolfson**

In their seminal book *Evolution and Healing*, Randolph Nesse and George C. Williams describe the design of human bodies as “simultaneously extraordinarily precise and unbelievably slipshod.” Indeed, they conclude that our inconsistencies are so incongruous that one could be forgiven for thinking that we had been “shaped by a prankster.”

By what agency did this unfortunate state of affairs come into being, and how might we amend it? Gene editing and synthetic biology offer the possibility of, respectively, “correcting” or “rewriting” human nature, allowing us to expunge unfavorable aspects of ourselves—such as our susceptibility to diseases and aging—while enabling the introduction of more appealing features. The legitimacy of such enterprises, however, to some extent depends on whether the evolution of humans on Earth was inevitable.

If our origin and nature were deterministically programmed into life’s history, it would be hard to argue that we should be any other way. If, on the other hand, we are the improbable products of a historically contingent evolutionary process, then human exceptionalism is compromised, and the artificial modification of our genomes may be perceived by some as being less of an affront to the natural order. In his compelling book *Improbable Destinies*, Jonathan Losos addresses this issue, recasting previous dialogues in the light of an experimental evolutionary agenda and, in so doing, arrives at a novel conclusion.

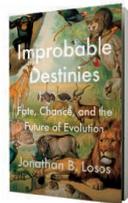
Until recently, the evolutionary determinism debate focused on two contrary interpretations of an outcrop of rock located in a small quarry in the Canadian Rocky Mountains known as the Burgess Shale. Contained within the Burgess Shale, and uniquely preserved by as-yet-unknown processes, are the fossilized remains of a bestiary of animals, both skeletal and soft-bodied. These fossils are remarkable in that they appear to have originated in a geological instant 570 to 530 million years ago during the Cambrian. They

comprise a bizarre zoo of outlandish body plans, some of which appeared to be unrepresented in living species.

In his 1989 book *Wonderful Life*, the Harvard biologist Stephen Jay Gould argued that the apparently arbitrary deletion of distinct body plans in the Cambrian suggests that life’s history was deeply contingent, underwritten by multiple chance events. As such, if the tape of life could be rewound back to the beginning and replayed again, it would be vanishingly unlikely that anything like humans would emerge again. The Cambridge paleontologist Simon Conway Morris, on the other hand, would have none of this.

Citing a long list of examples to illustrate the ubiquity of convergence—the phenomenon whereby unrelated species evolve a similar structure—Conway Morris claimed that the evolution of humanlike organisms would be a near inevitability of any replay. In his scheme, articulated in 2003 in *Life’s Solution*, nature’s deep self-organizing forces narrowly constrain potential evolutionary outcomes, resulting in a relatively sparse sampling of genetic space.

Losos closes the loop on this contentious debate, marshaling data from the burgeoning research area of experimental evolution. Unlike Darwin, who perceived the process of evolution to be imperceptibly slow and therefore inaccessible to direct experimenta-



**Improbable Destinies**  
Fate, Chance, and  
the Future of Evolution  
Jonathan B. Losos  
Riverhead Books, 2017.  
384 pp.

tion, contemporary evolutionary biologists have realized that evolution can occur in rapid bursts and may consequently be captured on the wing.

Given that microbes have an intergenerational time of 20 minutes or less, in 1988, the evolutionary biologist Richard Lenski reasoned that the bacterium *Escherichia coli* would comprise the perfect model experimental system to study condensed evolutionary time scales. Bacteria could additionally be frozen, allowing multiple parallel replays to be run again and again from any time point in their history. Twenty-eight years and 64,000 bacterial generations later, he concluded that the history of life owes its complexity both to repeatability and contingency.

Losos and other investigators have demonstrated a similar degree of repeatability in the natural evolution of the *Anolis* lizard, three-spined sticklebacks, guppies, and deer mice. Importantly, however, when experimental populations evolve in divergent environments, novel outcomes are more commonly observed than convergence.

These experiments were not a replay of the tape of life in time so much as a replay in space, but the findings were surprising in that they emerged within a relatively short time frame—a far cry from what one might have expected would be necessary to falsify the predictability hypothesis.

Losos concludes that “both sets of forces—the random and the predictable ... together give rise to what we call history.” With this, humans are humbled once again, cast firmly into the sea of ordered indeterminism. Although he does not attempt to use this as a justification for human genomic modification, Losos argues that the genetic principles underlying life’s multifarious convergent solutions might, among other things, be co-opted to rescue imperiled species. ■

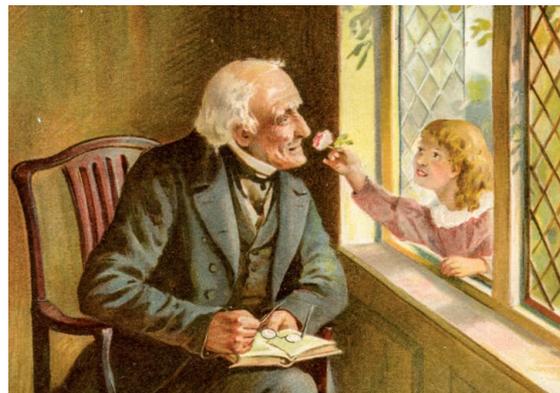
10.1126/science.aan8380

### PODCAST

**Smell Detectives**  
An Olfactory History of  
Nineteenth-Century Urban America  
Melanie A. Kiechle  
University of Washington Press,  
2017. 387 pp.

Before the germ theory of disease, urban dwellers placed great stock in odors—foul and fresh—as indicators of environmental health. This week on the *Science* podcast, historian Melanie Kiechle describes the rise and fall of the sense of smell in the 19th-century fight for fresh air.

10.1126/science.aao3022



In the 1800s, foul odors were believed to cause disease, leading many city residents to use their noses to make sense of sanitation.

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# Science

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*Science* **357** (6349), 362.

DOI: 10.1126/science.aan8380

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