Arrival of the Fittest: Solving Evolution's Greatest Puzzle

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“Natural selection can preserve innovations, but it cannot create them. Nature’s many innovations—some uncannily perfect—call for natural principles that accelerate life’s ability to innovate.”

Darwin’s theory of natural selection explains how useful adaptations are preserved over time. But the biggest mystery about evolution eluded him. As genetics pioneer Hugo de Vries put it, “natural selection may explain the survival of the fittest, but it cannot explain the arrival of the fittest.”

Can random mutations over a mere 3.8 billion years really be responsible for wings, eyeballs, knees, camouflage, lactose digestion, photosynthesis, and the rest of nature’s creative marvels? And if the answer is no, what is the mechanism that explains evolution’s speed and efficiency?

In *Arrival of the Fittest*, renowned evolutionary biologist Andreas Wagner draws on over fifteen years of research to present the missing piece in Darwin's theory. Using experimental and computational technologies that were heretofore unimagined, he has found that adaptations are not just driven by chance, but by a set of laws that allow nature to discover new molecules and mechanisms in a fraction of the time that random variation would take.

Consider the Arctic cod, a fish that lives and thrives within six degrees of the North Pole, in waters that regularly fall below 0 degrees. At that temperature, the internal fluids of most organisms turn into ice crystals. And yet, the arctic cod survives by producing proteins that lower the freezing temperature of its body fluids, much like antifreeze does for a car’s engine coolant. The invention of those proteins is an archetypal example of nature’s enormous powers of creativity.

Meticulously researched, carefully argued, evocatively written, and full of fascinating examples from the animal kingdom, *Arrival of the Fittest* offers up the final puzzle piece in the mystery of life’s rich diversity.

Arrival of the Fittest: Solving Evolution's Greatest Puzzle Details

Date	:	Published October 2nd 2014 by Current
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Wagner

From Reader Review Arrival of the Fittest: Solving Evolution's Greatest Puzzle for online ebook

Ernst Hafen says

I am a developmental geneticist and even had the privilege to have contributed a few scientific results discussed in the book. I also know how difficult it is to teach biological concepts and what the author coins the innovability of evolution to first year biology and chemistry students. For me this book has been very inspiring. It provides mathematical insights into how innovability works. Wagner reduces the complexity of this process to three interconnected processes of protein structure, metabolic networks and gene regulatory networks. The three are arranged in multidimentional libraries which the 10^30 organisms on earth have explored for 3.5 billion years by moving - one mutations at a time - from one book in these libraries to the next. Experimental evidence by the author's group and others shows that the adjacent books in the libraries are diverse and that there many different solutions to a given problem (eg ability to live in a specific environment or to specify a certain shape limb). Combined with redundancy conferring robustness and natural selection's power to preserve small innovations we have the ingredients for the diversity of live. In the final chapter Andreas Wagner describes how Boolean Logic can be used to model the behavior of these networks and he shows parallels with the architecture of modern computers.

Andreas Wagner's writing is crisp and his analogies and examples from nature are excellent and engaging. I have read many book by Richard Dawkins. Wagner does not have to shy comparison with Dawkins also in literary style. As a computational and molecular biologist he brings the knowledge of modern systems biology that Dawkins is lacking. In summary this is an excellent and up to date book on biology. I will recommend it to my students and anyone interested in biology. I listened to the audio version. Sean Pratt does an excellent job!

Alger says

Deeply disappointing both as a guide to current thinking and theory in evolutionary theory, and as a popular science book. Wagner is very bad at explaining things, even when those things are his professional opinions on evolution.

A key problem for the reader is that Wagner can't seem to pitch his discussion at a consistent level. He spends far too many pages describing unremarkable and widely understood principles so that he can set these scarecrows up to be knocked down by his sneeringly presented Big Insight; this is especially true when his objection is banal and under-described.

Take for example the whole mess of the Metaphor of The Library. Wagner devotes dozens of pages describing how the Library of Congress System is organized, then many pages more on how the analogous genetic library he proposes would look in that context, then tells us in a sentence that the library is a terrible metaphor because the genome works nothing like a library anyway. And then refers back to the genetic library metaphor constantly after that. This means that Wagner objects entirely to his own choice of metaphor. Yes, he does. It only gets worse from here. Granted, Wagner gives us this lengthy and confusing explanation to illustrate his research finding that there is more than one possible genotype to express the same phenotype. He appears to think that his proof is a sea change in genetic understanding rather than an unproven near certainty for many decades.

Then there is the problem of needless information. Wagner includes a long chapter on the origins of life at

the smoky vents deep in the ocean, then introduces nothing about his topic of evolutionary fitness. Darwin and Mendel are propped up as strawmen for Wagner to tut over, as is the "new synthesis", as are dozens of other tangential theories and scientists, possibly to add some historical weight to this otherwise lightweight and needlessly obscure book.

For my critique of his actual science project to make sense, I will need to reveal Wagner's Big Idea. For anyone who either hasn't read this book, or was understandably confused by it, this is Wagner's book in one sentence:

> Define "evolutionary fitness" as Robustness and Openness to Improvement (or what Wagner calls "Evolvability") and the problem of how life innovates goes away.

Wagner used some 450 pages of wandering prose poems to gift us with just that.

Problem is this what is called a tautology (x=x), and worse it is a tautology that continues to beg the question of where these qualities come from since one innovation often needs be matched with other innovations to provide robustness. No one innovation is immediately "fit" on Wagner's terms, but it is graced with qualities that make it survive and superior over other discarded mutations. Wagner makes some attempts (via the library metaphor) to paper over the definitional circularity of his argument, but if you read closely there is no essential difference between his mechanism of evolutionary processes as described here and those of the gradualists he mocks except that Wagner energetically insists they are very, very different. Worse, his tautology seems to land him dangerously close to an argument that evolution has a direction, a goal, a map of how to get from squid to albatross.

In short: Don't bother.

Ryan Young says

now it's a trilogy. in order to understand how life arose on earth:
1. the origin of the species by charles darwin
2. the selfish gene by richard dawkins
3. arrival of the fittest by andreas wagner

Every iteration brings us closer to understanding how it actually works. we can now prove mathematically just how life could have found its myriad forms - and can model the progress of evolution from its origins to its current manifestations.

if you imagine a library filled with every possible configuration of dna letters (ATCG) or every possible metabolic reaction or every possible gene regulation circuit, it would fill a hyperastronomical number of volumes, too much for live to navigate since the beginning of the universe. based on this fact, it is highly unlikely that life would ever have originated, much less evolved to such variety as we see today. through computation and computer modeling, we can now show that life can find adaptations in the immediate neighborhood of whatever starting configuration life chose.

science man.

Angelo Giardini says

Sempre foi minha impressão como leigo que a barreira artificial entre o mundo biológico e não-biológico deveria eventualmente cair, o que implicaria a necessidade de uma teoria da evolução de "tudo" e não meramente dos seres vivos. Este livro traz o que parecem ser os primeiros resultados de um redirecionamento das pesquisas e experimentos mais recentes para tentar entender como a vida e a evolução funcionam enquanto fenômeno químico fruto de um tipo de ciclo de retroalimentação.

Leitura obrigatória para quem se interessa pelo tema.

Ryan Flett says

I went back and forth on whether I should give this book 3 stars or 4. The science is very interesting, but the writing is mostly mediocre. Wagner doesn't do the greatest job of breaking complex and abstract ideas down for readers who might not be well-versed in science and research, so if you're new to biology and evolution, this might not be the book for you.

That being said, if you are well versed in evolution and biology, I would highly recommend this book. It's research and theories paint a more complete, fuller picture of evolution and natural selection.

Mengsen Zhang says

Nice piece! I can see lots of care and courage put into the text. This is the beginning of evolution theory of the "whole" - the animate, the inanimate, and all, have to be seen as deeply connected in order to understand how evolution could possibly work at the observed pace. He has a really neat research paradigm to mathematically formalize and actually get one's hands dirty with the relationship between micro structure and macro function across different scales of the universe as time progress. Maybe, what's beautiful about evolution is indeed the math - what high dimensional function maps between the relative micro-macro worlds can create such intricate/entangled topology? Has he solved it? I think not. But at least we are learning how to ask the question.

Alexander says

The philosopher Henri Bergson once wrote that every philosopher only ever really pursues one single idea, continuously reformulated, in different ways. While Andreas Wagner isn't exactly a philosopher, *The Arrival of the Fittest* is, if nothing else, a condensation of just what it means to take an idea and run with it to the end, hammering it home from just about every other angle. As for the idea itself, it's actually pretty

straightforward: because evolution takes place among entire populations of individuals, and because there can be multiple genetic variations that give rise to same adaptive traits (there are many genetic routes to the same 'trait destination'), evolution can fast-track it's search for adaptive novelties by scouring through entire libraries of genetic change at the same time, with each library containing what amounts to multiple copies of the same book.

While I'm slightly skewing Wagner's own library metaphor (he writes instead of a single, multi-dimensional 'genotype library', in which multiple readers - individuals in a population - work their way through) the idea, I hope, is the same. The question then is why this solves 'evolution's greatest puzzle' - what, exactly, is the puzzle to solve? Well, it's in the first part of the title: the arrival of the fittest. While the mechanism of natural selection nicely explains why some genetic variants make the evolutionary cut while others don't (the *survival* of the fittest), it doesn't quite explain how all that variation got there in the first place. The usual solution given is that of random genetic drift: through copying errors and so fourth, nature will stumble across the right evolutionary solutions to make birds and mice and everything nice. But, in truth, this isn't quite enough.

The problem is the familiar one of monkeys banging away on a typewriter: after a long enough time, will any monkey produce a work of Shakespeare? Probably not. And so with random genetic change and the production of all the variety and complexity of life we see today. With the discovery of genotype networks however, things become alot easier - the trick is in realizing that unlike Shakespeare, nature didn't just produce 37 plays for monkeys to stumble across, but trillions upon trillions of them: that is, trillions upon trillions of ways to arrive at the same evolutionary solutions. Or, to use the lingo, nature is robust as all hell. Such is the idea that's detailed here, across multiple 'levels' of life, from DNA to metabolic networks, regulatory circuits, and even certain aspects of technology (as with computer chip designers, who, taking a leaf out of nature's page, employ simulated evolution to arrive at the best circuit designs for their silicon).

It's all very cool stuff, though one wonders if it really was worth the book-length treatment of it given here. While Wagner certainly has a flair for striking prose, many of the chapters here did feel rather padded out, as if an idea in search for applications - as many of them as they are. Part of the problem, in fact, is that in Wagner's attempt to make the science as digestible as possible, what might have taken a few paragraphs to get across ends up taking entire chapters. It's not even until about 170 pages in that Wagner actually even names the phenomenon he's discussing - phenotypic robustness, which, depending on my mood, is either an incredibly impressive or incredibly insulting feat. All in all, this is a great introduction to some of the cutting edge of evolutionary theory, even if, at the end of the day, it remains just that - an introduction. 3.5/5

Dennis Junk says

Highly conceptual, “Arrival of the Fittest” walks you through the steps, not just of understanding a difficult question, but of learning a new kind of thinking. The creationist argument that since natural selection only preserves innovative traits and never actually creates them—and so the likelihood of anything as complex as a human body coming about through natural selection is about the same as a 747 being built by a tornado tearing through a junkyard—exploits the limitations of our ready-made intuitions. It's hard for us to imagine how it might have happened, so we're ready to throw up our hands and say it must be supernatural, in the same way we leap from our ignorance about how ancient structures were built to the conclusion that they must be the work of extraterrestrials. But, stated another way, this argument boils down to the suggestion that, since it's difficult for our human intelligence to conceive of the evolutionary processes that led to complex life, there must be some sort of human-like intelligence behind it. (And saying that the notional creator’s intelligence is simply superior doesn’t save the argument from absurdity—it merely raises the more difficult question of how this being that’s even more impressive than humans came about.)

Wagner doesn't devote much space to dealing with creationism, but it's hard for anyone to read books about evolution in the US without carrying on a silent argument with the intelligent design folk in the back of our minds. The other old argument that “Arrival of the Fittest” reminds me of is that nature could only be comprehensible to us if it was created for us, by a being at least in some respects like us. Both of these arguments, it becomes clear, drastically overestimate the powers of human intellect and human imagination. Wagner at several points draws an analogy between evolution and technology, and one of his examples is the jet engine. Even the 747 had to come about through an evolutionary process—since no single human mind could have conceived of it ex nihilo. The process of invention took place by steps, and the availability of parts was necessary before design by recombination could take place. So it is with evolution.

Wagner's method relies heavily on a dual mix of abstraction and analogy. And the product is both clear and fascinating. He first asks us to imagine a library housing every possible book that could be written using a single alphabet. Most of the books are gibberish—they aren't viable for reading. But the idea is to help us think about the vast potential of randomly varying letter sequences when every change has a chance of altering a book’s meaning. The letter sequences are, naturally enough, analogs of genetic sequences. Wagner starts with the most basic requirement for a living being, a functioning metabolism. It turns out that metabolisms can consist of any number of possible chemical reactions, and every metabolism that works to give an organism sufficient energy is like a book in the universal library that has some kind of coherent meaning.

“And just as the universal library contains all meaningful books, the library of metabolisms contains all ‘meaningful’ metabolisms—those that allow an organism to survive—and many more, because not all metabolisms are meaningful, just as not all books are. Some metabolisms cannot procure energy, or they fail to manufacture important molecules. These are like the books where some chapters, paragraphs, or sentences are coherent but the book as a whole does not make sense. And many other metabolic texts are gibberish” (71-2).

The next steps are to try to imagine how big the library is and how easy it is to get from one section to another, keeping in mind that you can only take one step at a time in any direction. For simplicity’s sake, we imagine mutations as affecting a single gene at a time. The change has to be viable—resulting in a coherent text or a surviving organism. So you can’t leap from one part of the library to another. However, the library has to have more dimensions than the three we’re accustomed to inhabiting in real libraries. This is because the change can occur in any letter of the book or gene sequence. Each one represents a different direction we may travel through the library. Here’s where our vaunted human intellect reaches its limit; we can’t think in more than three (maybe 4, if you add time) dimensions, so it’s all but impossible for us to appreciate the vast potential of stepwise innovation. Wagner uses the term “hyperastronomical” to describe the number of potential gene combinations.

“Evolving organisms are like visitors to the metabolic library. Gene deletions and gene transfer allow them to walk through the library, to step from one metabolic text to another, often an immediate neighbor. All of a text’s neighbors form a neighborhood in this library, and such neighborhoods are as important for evolution as a city neighborhood is for people’s lives. City neighborhoods are useful because of proximity—everything is reachable within a few easy steps—and neighborhoods in the metabolic library are important for the same reason. Evolution can reach them in a few small steps, minor edits in a genotype. But residents of a city’s neighborhoods can walk in only four cardinal directions—north, south, east, or west—whereas evolution can head in five thousand directions. (Don’t even bother trying to visualize that.) And therefore the neighborhood of a metabolic text may be vastly more interesting, surprising, and diverse.” (92)

This is an abstract way of explaining how you get from photosensitive cells in a simple organism to the unimaginably complex eye of a bird-of-prey—though Wagner does trace this evolution more concretely through a series of actual creatures representing each level of complexity.

Each succeeding chapter in “Arrival of the Fittest” takes on a higher level of organization, from amino acids, to proteins, to regulatory circuits, and then moves onto to the connection between innovation in evolution and innovation in technology. One of the themes Wagner continually revisits is that for us humans to unravel the mysteries of evolution we’ve had to have the proper technology in place. We had to be able to understand the structure of DNA. We had to be able to sequence genes. We had to be able to do calculations with hyperastronomical numbers. All of this left me thinking that a thinking mind could only have come from nature—because no thinking mind, unaided by technology, can even begin to conceive of nature in all of its diversity and complexity. If there were such a thing as a creator, it would be more machine than human—and it would have come into existence through a process resembling evolution.

Eoin Flynn says

I really wanted to love this book. I am a scientist. And luckily I am one who happens to love science. And I particularly love the topics this book covers (evolutionary genetics and bioinformatics). It is written with great wit, poise and profound knowledge. Unfortunately for Andreas Wagner, who is clearly a talented author as well as scientist, the topics at hand are difficult to write about without being repetitive and at times, simply rather dull. I just could not love this book, though I tried.

It was a hard slog. Wagner has the sense to realise when the writing is becoming boring. He tries at such moments to inject little anecdotes about the persons conducting the science in order to break the monotony. It is not enough. The library of genetic data existing in multiple dimensions is undoubtedly an effective metaphor for communication, but it does not make reading about it any easier. Wagner makes the topic easy to understand for the lay person. But that does not make reading about it a pleasure.

Because it is not a pleasure to read you must put in extra effort to pay attention to the writing. To understand it fully. If you let your mind wander at all, you'll find yourself having to reread entire chapters, not just the last couple of paragraphs. This was tiresome for me and I'm a scientist! I could not realistically recommend this to a lay person with only an interest in pop-sci books and no good mathematical background.

I am torn in my assessment of this book. It is excellently written, highly informative and can be understood, even by non-scientists, quite readily (if they pay close attention). This makes it a resounding success as a teaching exercise. It would receive 5/5 on that front. If however you wish to read it for pleasure (as it is marketed) the topic is not one that lends itself to narrative structure nor eloquence and it is perhaps not the book for you...

Emily says

I finished this Thursday night, and I thought about it for a while, and then I listened to the epilogue again Friday morning, and then Friday evening I read a stack of reviews of both the physical book and the audiobook, and I came to a rather disconcerting conclusion. I had no idea what the author was saying. One of the reviews on Audible described this book as "impenetrable for the non-scientist" and another says:

> It can be slow going on audio. The author necessarily builds large, complex analogies for explaining molecular interactions. If you become distracted, let your mind wander, or stop and start the audio throughout the day or week, it's relatively easy to lose the author's argument.

I hate to have to admit that I'm a lay person, but I am. I have a liberal arts degree with an enduring interest for the sciences, specifically biology. I read an okay number of science-y books on an annual basis, and my understanding of them is usually fine. Additionally, I don't usually have any trouble listening to audiobooks. In fact, finding most of them too plodding, I usually listen at somewhere between 1.25x and 1.5x depending on the narrator. So what went wrong here?

I think that Wagner's writing is pretty obtuse, perhaps not deliberately so, but I was mortified when I finished the book and realized that I had no clear idea of what the difference between genotype and phenotype was (college science is nearly two decades back at this point). One minute and two sentences on the internet was all it took to clear that up, and once I read the definitions I realized that Wagner had covered this, and that a good portion of the book was about how genotype does not necessarily equal phenotype, which is one of the mechanism of those problem-solving leaps that organisms can make, but goodness gracious, it went right over my head in the text. The same person I quoted above suggests some prerequisites to reading this, and I might try that and give this a second go. Perhaps a chapter at a time, or maybe the paper book from my local library.

Alex Apffel says

In my opinion, Evolution and, more specifically Natural Selection, is the most powerful force in Nature and our understanding of it, starting with Darwin, is probably humanities greatest insight into the world around us. But one thing that Darwin recognized his theory could not explain was where new things, innovations, come from. It would simply take too many random mutations to explore the space of possibilities. Andreas Wagner's book, does an excellent job of presenting the challenge. The solution, as he presents it, is more difficult to understand, but he does a fair job.

Clif Hostetler says

It's true that evolutionary development of life depends on random mutations, but it's more complicated than that. Nature's building blocks of life (metabolic systems, protein interactions, and gene regulation networks) are unimaginably complex, yet they are endowed with inherent properties that are both innovatable and robust (i.e. progressive and conservative at the same time).

The author makes the point that there is insufficient time in the universe for random mutations acting alone to create life. The author makes this point with the following quotation:

> The first vertebrates to use crystallins in lenses did so more than five hundred million years ago, and the opsins that enable the falcon’s vision are some seven hundred million years old. They originated some three billion years after life first appeared on earth. That sounds like a helpfully long amount of time to come up with these molecular innovations. But each one of those opsin and crystallin proteins is a chain of hundreds of amino acids, highly specific sequences of molecules written in an alphabet of twenty amino acid letters. If only one such sequence could sense light or help form a transparent cameralike lens, how many different hundred-amino-acid-long protein strings would we have to sift through? The first amino acid of such a string could be any one of the twenty kinds of amino acids, and the same holds for the second amino acid. Because 20 x 20 = 400, there are 400 possible strings of two amino acids. Consider also the third amino acid, and you have arrived at 20 x 20 x 20, or 8,000, possibilities. At four amino acids we already have 160,000 possibilities. For a protein with a hundred amino acids (crystallins and opsins are much longer), the numbers multiply to a 1 with more than 130

> trailing zeroes, or more than 10^130 possible amino acid strings. To get a sense of this number's magnitude, consider that most atoms in the universe are hydrogen atoms, and physicists have estimated the number of these atoms as 10^90, or 1,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000. This is "only" a 1 with 90 zeroes. The number of potential proteins is not merely astronomical, it is hyperastronomical, much greater than the number of hydrogen atoms in the universe. To find a specific sequence like that is not just less likely than winning the jackpot in the lottery, it is less likely than winning a jackpot every year since the Big Bang." In fact, it's countless billions of times less likely. If a trillion different organisms had tried an amino acid string every second since life began, they might have tried a tiny fraction of the 10^130 potential ones. They would never have found the one opsin string. There are a lot of different ways to arrange molecules. And not nearly enough time.

In other words, there's more than simple random mutation needed for life to develop. So what would that be?

The author goes on to explain that adaptations are not just driven by chance, but by a set of laws that allow nature to discover new molecules and mechanisms in a fraction of the time that random variation would take. Metabolic systems, protein interactions, and gene regulation networks share a particular kind of robustness such that even drastic changes to the underlying structure leaves their operations unchanged. For example, the complex of chemical reactions that metabolize glucose in E. coli can overlap by as little as 20 percent and still function perfectly well.

At the same time, very small genetic changes can radically alter the phenotype. Some such alterations portend certain death, but a few lead to powerful new innovations: the ability to fly, for example, or the first light-sensitive cells eventually leading to photosynthesis. Searching all the genetic possibilities at random would take forever, but a species — with all the same functions, but widely varying genes — can search millions of genetic options all at once, dramatically increasing evolution's efficiency.

Robustness itself is a response to environmental complexity. To withstand heat, cold, moisture, and dryness, living things developed a modular toolset of molecules such as amino acids, which combined in complex ways to produce a range of innovations in response to any given problem.

The author clearly suggests that the environment is a key factor in species adaptation. In an elegantly written final paragraph in one of the later book chapters he notes:

> "...Environmental change requires complexity, which begets robustness, which begets genotype networks, which enable innovations, the very kind that allow life to cope with environmental change, increase its complexity, and so on, in an ascending spiral of ever-increasing innovability...is the hidden architecture of life"

Two words were used so often in this book that I had to check on their meanings. I've decided to provide their definitions here:

Genotype networks are a concept used in systems biology to study sets of genotypes having the same phenotype, and the ability of these to bring forth novel phenotypes. Genotype networks are a key to innovability.

Innovability means ability/capability to innovate.

This book knocked my sock off, that's why I gave it five stars. When I listen or read books about the cutting edge of science I am usually exposing myself to concepts that I've previously been exposed to. I continue to go through books on the subject in order the help the information to soak into my understanding. This book

on the other hand has some explanations of the complexity of evolution and life that were new to me.

Atila Iamarino says

Um livro muito bom (para mim) que fica em um meio do caminho estranho. O Andreas Wagner é um dos pesquisadores mais inovadores na área de como evoluem sistemas biológicos (a biologia de sistemas). Já li e citei vários artigos dele, é sem dúvida uma das pessoas mais indicadas para falar sobre o assunto. Mas esse livro ficou em uma encruzilhada que considero ruim. Por um lado, fala de uma parte de biologia evolutiva que não é muito acessível ao grande público, com as interações entre genes, proteínas, reguladores, redes metabólicas e afins. Por outro, esse assunto é super importante e interessante para biólogos (a quem recomendo o livro, mas para esse público grande parte do livro é desnecessária, já que recapitula evolução, genética e outras áreas que não acrescentam muito para quem já conhece.

A ideia principal, como sistemas biológicos são organizados de maneira que exploram muito rapidamente a evolução de novas características e ao mesmo tempo são robustos, é na minha opinião uma das descobertas recentes mais importantes. Por isso o livro é interessante. Mas para quem essa informação é acessível uma boa parte do livro é desnecessária (um review seria mais prático) e para quem isso não é acessível, o livro é denso demais. Pode servir a leigos interessados em evolução, mas outros livros como o Quando Éramos Peixes: Uma viagem pelos 3,5 mil milhões de anos de história do corpo humano fazem isso muito melhor. É um conteúdo que contribui mais em um livro sobre ideias mais amplas, como o The Evolution of Everything: How New Ideas Emerge que citou ele, do que como uma obra em si.

Edwin Herbert says

The theory of evolution answers many questions about the growing and winnowing of the tree of life, but it does not answer questions about "innovability" - how advantageous phenotypic changes are initiated in the first place. This book goes a long way in answering that question. Complex at times, but well worth the read.

M says

I am having some difficulty in identifying exactly what underwhelmed me about this book. The premise and subject matter are interesting. The research presented is important. Perhaps the metaphor of the library was either overused or not sufficiently elucidating?

This is still worth reading if you are interested in evolutionary theory. It is not a definitive treatment of the questions it tries to address (it would benefit from a less lofty subtitle). There is a lot more to say about the mechanisms of variation and the odds of useful adaptations arising.
