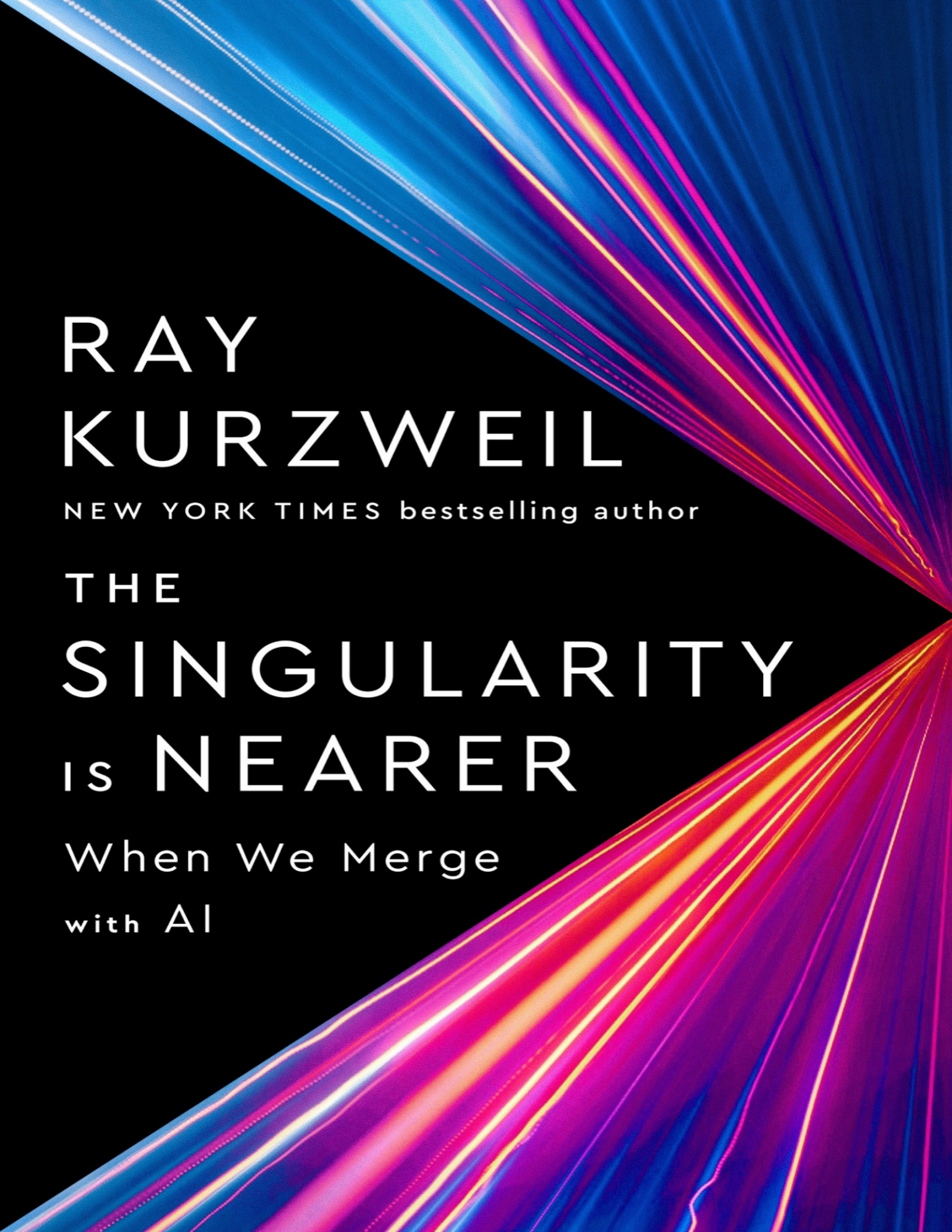
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KURZWEIL
NEW YORK TIMES bestselling author
THE
SINGULARITY
IS NEARER
When We Merge
with AI

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THE SINGULARITY IS NEARER

WHEN WE MERGE WITH AI

RAY KURZWEIL

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CONTENTS

To Sonya Rosenwald Kurzweil.
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(and love her) for fifty years!

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INTRODUCTION

In my 2005 book *The Singularity Is Near*, I set forth my theory that convergent, exponential technological trends are leading to a transition that will be utterly transformative for humanity. There are several key areas of change that are continuing to accelerate simultaneously: computing power is becoming cheaper, human biology is becoming better understood, and engineering is becoming possible at far smaller scales. As artificial intelligence grows in ability and information becomes more accessible, we are integrating these capabilities ever more closely with our natural biological intelligence. Eventually nanotechnology will enable these trends to culminate in directly expanding our brains with layers of virtual neurons in the cloud. In this way we will merge with AI and augment ourselves with millions of times the computational power that our biology gave us. This will expand our intelligence and consciousness so profoundly that it's difficult to comprehend. This event is what I mean by the Singularity.

The term "singularity" is borrowed from mathematics (where it refers to an undefined point in a function, like when dividing by zero) and physics (where it refers to the infinitely dense point at the center of a black hole, where the normal laws of physics break down). But it is important to remember that I use the term as a metaphor. My prediction of the technological Singularity does not suggest that rates of change will actually become infinite, as exponential growth does not imply infinity, nor does a physical singularity. A black hole has gravity strong enough to trap even light

itself, but there is no means in quantum mechanics to account for a truly infinite amount of mass. Rather, I use the singularity metaphor because it captures our inability to comprehend such a radical shift with our current level of intelligence. But as the transition happens, we will enhance our cognition quickly enough to adapt.

As I detailed in *The Singularity Is Near*, long-term trends suggest that the Singularity will happen around 2045. At the time that book was published, that date lay forty years—two full generations—in the future. At that distance I could make predictions about the broad forces that would bring about this transformation, but for most readers the subject was still relatively far removed from daily reality in 2005. And many critics argued then that my timeline was overoptimistic, or even that the Singularity was impossible.

Since then, though, something remarkable has happened. Progress has continued to accelerate in defiance of the doubters. Social media and smartphones have gone from virtually nonexistent to all-day companions that now connect a majority of the world's population. Algorithmic innovations and the emergence of big data have allowed AI to achieve startling breakthroughs sooner than even experts expected—from mastering games like *Jeopardy!* and Go to driving automobiles, writing essays, passing bar exams, and diagnosing cancer. Now, powerful and flexible large language models like GPT-4 and Gemini can translate natural-language instructions into computer code—dramatically reducing the barrier between humans and machines. By the time you read this, tens of millions of people likely will have experienced these capabilities firsthand. Meanwhile, the cost to sequence a human's genome has fallen by about 99.997 percent, and neural networks have begun unlocking major medical discoveries by simulating biology digitally. We're even gaining the ability to finally connect computers to brains directly.

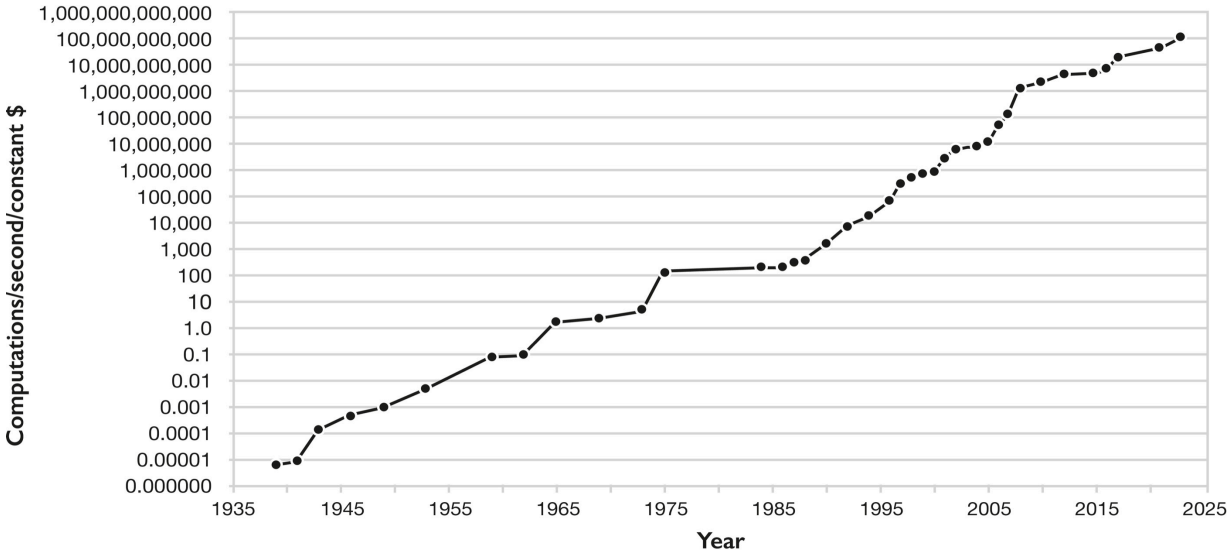
Underlying all these developments is what I call the law of accelerating returns: information technologies like computing get exponentially cheaper because each advance makes it easier to

design the next stage of their own evolution. As a result, as I write this, one dollar buys about 11,200 times as much computing power, adjusting for inflation, as it did when *The Singularity Is Near* hit shelves.

The following graph, which I'll discuss in depth later in the book, summarizes the most important trend powering our technological civilization: the long-term exponential growth (shown as a roughly straight line on this logarithmic scale) in the amount of computing power a constant dollar can purchase. Moore's law famously observes that transistors have been steadily shrinking, allowing computers to get ever more powerful—but that is just one manifestation of the law of accelerating returns, which already held true long before transistors were invented and can be expected to continue even after transistors reach their physical limits and are succeeded by new technologies. This trend has defined the modern world, and almost all the coming breakthroughs discussed in this book will be enabled by it directly or indirectly.

Price-Performance of Computation, 1939–2023[1]

Best achieved price-performance in computations per second per constant 2023 dollar



To maximize comparability of machines, this graph focuses on price-performance during the era of programmable computers, but approximations for earlier electromechanical computing devices show that this trend stretches back at least to the 1880s.[2]

So we have kept on schedule for the Singularity. The urgency of this book comes from the nature of exponential change itself. Trends that were barely noticeable at the start of this century are now actively impacting billions of lives. In the early 2020s we entered the sharply steepening part of the exponential curve, and the pace of innovation is affecting society like never before. For perspective, the moment you're reading this is probably closer to the creation of the first superhuman AI than to the release of my last book, 2012's *How to Create a Mind*. And you're probably closer to the Singularity than to the release of my 1999 book *The Age of Spiritual Machines*. Or, measured in terms of human life, babies born today will be just graduating college when the Singularity happens. This is, on a very personal level, a different kind of "near" than it was in 2005.

That is why I've written this book now. Humanity's millennia-long march toward the Singularity has become a sprint. In the introduction to *The Singularity Is Near*, I wrote that we were then "in the early stages of this transition." Now we are entering its culmination. That book was about glimpsing a distant horizon—this one is about the last miles along the path to reach it.

Luckily, we can now see this path much more clearly. Although many technological challenges remain before we can achieve the Singularity, its key precursors are rapidly moving from the realm of theoretical science to active research and development. During the coming decade, people will interact with AI that can seem convincingly human, and simple brain–computer interfaces will impact daily life much like smartphones do today. A digital revolution in biotech will cure diseases and meaningfully extend people's healthy lives. At the same time, though, many workers will feel the sting of economic disruption, and all of us will face risks from accidental or deliberate misuse of these new capabilities. During the 2030s, self-improving AI and maturing nanotechnology will unite humans and our machine creations as never before—heightening both the promise and the peril even further. If we can meet the scientific, ethical, social, and political challenges posed by these advances, by 2045 we will transform life on earth profoundly for the better. Yet if we fail, our very survival is in question. And so this book is about our final approach to the Singularity—the opportunities and dangers we must confront together over the last generation of the world as we knew it.

To begin, we'll explore how the Singularity will actually happen, and put this in the context of our species' long quest to reinvent our own intelligence. Creating sentience with technology raises important philosophical questions, so we'll address how this transition affects our own identity and sense of purpose. Then we will turn to the practical trends that will characterize the coming decades. As I will show, the law of accelerating returns is driving

exponential improvements across a very wide range of metrics that reflect human well-being. One of the most obvious downsides of innovation, though, is unemployment caused by automation in its various forms. While these harms are real, we'll see why there is good reason for long-term optimism—and why we are ultimately not in competition with AI.

As these technologies unlock enormous material abundance for our civilization, our focus will shift to overcoming the next barrier to our full flourishing: the frailties of our biology. So next, we'll look ahead to the tools we'll use over the coming decades to gain increasing mastery over biology itself—first by defeating the aging of our bodies and then by augmenting our limited brains and ushering in the Singularity. Yet these breakthroughs may also put us in jeopardy. Revolutionary new systems in biotechnology, nanotechnology, or artificial intelligence could possibly lead to an existential catastrophe like a devastating pandemic or a chain reaction of self-replicating machines. We'll conclude with an assessment of these threats, which warrant careful planning, but as I'll explain, there are very promising approaches for how to mitigate them.

These are the most exciting and momentous years in all of history. We cannot say with confidence what life will be like after the Singularity. But by understanding and anticipating the transitions leading up to it, we can help ensure that humanity's final approach will be safe and successful.

CHAPTER 1

WHERE ARE WE IN THE SIX STAGES?

In *The Singularity Is Near*, I described the basis of consciousness as information. I cited six epochs, or stages, from the beginning of our universe, with each stage creating the next stage from the information processing of the last. Thus, the evolution of intelligence works via an indirect sequence of other processes.

The First Epoch was the birth of the laws of physics and the chemistry they make possible. A few hundred thousand years after the big bang, atoms formed from electrons circling around a core of protons and neutrons. Protons in a nucleus seemingly should not be so close together, because the electromagnetic force tries to drive them violently apart. However, there happens to be a separate force called the strong nuclear force, which keeps the protons together. "Whoever" designed the rules of the universe provided this additional force, otherwise evolution through atoms would have been impossible.

Billions of years later, atoms formed molecules that could represent elaborate information. Carbon was the most useful building block, in that it could form four bonds, as opposed to one, two, or three for many other nuclei. That we live in a world that permits complex chemistry is extremely unlikely. For example, if the strength of gravity were ever so slightly weaker, there would be no supernovas to create the chemical elements that life is made from. If it were just slightly stronger, stars would burn out and die before

intelligent life could form. Just this one physical constant had to be in an extremely narrow range or we would not be here. We live in a universe that is very precisely balanced to allow a level of order that has enabled evolution to unfold.

Several billion years ago, the Second Epoch began: life. Molecules became complex enough to define an entire organism in one molecule. Thus, living creatures, each with their own DNA, were able to evolve and spread.

In the Third Epoch, animals described by DNA then formed brains, which themselves stored and processed information. These brains gave evolutionary advantages, which helped brains develop more complexity over millions of years.

In the Fourth Epoch, animals used their higher-level cognitive ability, along with their thumbs, to translate thoughts into complex actions. This was humans. Our species used these abilities to create technology that was able to store and manipulate information—from papyrus to hard drives. These technologies augmented our brains' abilities to perceive, recall, and evaluate information patterns. This is another source of evolution that itself is far greater than the level of progress before it. With brains, we added roughly one cubic inch of brain matter every 100,000 years, whereas with digital computation we are doubling price-performance about every sixteen months.

In the Fifth Epoch, we will directly merge biological human cognition with the speed and power of our digital technology. This is brain–computer interfaces. Human neural processing happens at a speed of several hundred cycles per second, as compared with several billion per second for digital technology. In addition to speed and memory size, augmenting our brains with nonbiological computers will allow us to add many more layers to our neocortices —unlocking vastly more complex and abstract cognition than we can currently imagine.

The Sixth Epoch is where our intelligence spreads throughout the universe, turning ordinary matter into computronium, which is

matter organized at the ultimate density of computation.

In my 1999 book *The Age of Spiritual Machines*, I predicted that a Turing test—wherein an AI can communicate by text indistinguishably from a human—would be passed by 2029. I repeated that in 2005's *The Singularity Is Near.* Passing a valid Turing test means that an AI has mastered language and commonsense reasoning as possessed by humans. Turing described his concept in 1950,[1] but he did not specify how the test should be administered. In a bet that I have with Mitch Kapor, we defined our own rules that are much more difficult than other interpretations.

My expectation was that in order to pass a valid Turing test by 2029, we would need to be able to attain a great variety of intellectual achievements with AI by 2020. And indeed, since that prediction, AI has mastered many of humanity's toughest intellectual challenges—from games like *Jeopardy!* and Go to serious applications like radiology and drug discovery. As I write this, top AI systems like Gemini and GPT-4 are broadening their abilities to many different domains of performance—encouraging steps on the road to general intelligence.

Ultimately, when a program passes the Turing test, it will actually need to make itself appear far less intelligent in many areas because otherwise it would be clear that it is an AI. For example, if it could correctly solve any math problem instantly, it would fail the test. Thus, at the Turing test level, AIs will have capabilities that in fact go far beyond the best humans in most fields.

Humans are now in the Fourth Epoch, with our technology already producing results that exceed what we can understand for some tasks. For the aspects of the Turing test that AI has not yet mastered, we are making rapid and accelerating progress. Passing the Turing test, which I have been anticipating for 2029, will bring us to the Fifth Epoch.

A key capability in the 2030s will be to connect the upper ranges of our neocortices to the cloud, which will directly extend our

thinking. In this way, rather than AI being a competitor, it will become an extension of ourselves. By the time this happens, the nonbiological portions of our minds will provide thousands of times more cognitive capacity than the biological parts.

As this progresses exponentially, we will extend our minds many millions-fold by 2045. It is this incomprehensible speed and magnitude of transformation that will enable us to borrow the singularity metaphor from physics to describe our future.