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YOU CAN LIVE LONG ENOUGH TO LIVE FOREVER

*Do not go gentle into that good night,
Old Age should burn and rave at close of day;
Rage, rage against the dying of the light.*

—Dylan Thomas

“I don’t want to achieve immortality through my work. I want to achieve immortality through not dying.”

—Woody Allen

Written at the height of the Cold War, Isaac Asimov’s 1966 science-fiction thriller *Fantastic Voyage* shifted the public’s fascination from space travel to an even more fascinating journey—inside the human body. In the novel, scientists on “our side” as well as the unnamed “other side” have developed a miniaturization technology that promises victory for whoever can perfect it first. However, the technology has a fatal flaw: the miniaturization wears off quickly.

Professor Benes has figured out a breakthrough that overcomes this limitation, but before he has a chance to communicate his crucial insight, he falls into a coma, with a potentially fatal blood clot in his brain. Against a backdrop of international intrigue, our side sends in a submarine with a team of five people using the still time-limited miniaturization technology to travel inside Benes’s body and destroy the blood clot.

The team includes pilot Owens, who helms the submarine *Proteus* (now blood cell-size); Duvall, a brilliant neurosurgeon in charge of the medical mission; Peterson, the beautiful surgical assistant (played by Raquel Welch in the highly successful movie version); Michaels, a human-circulatory expert; and Grant, the mission leader from central intelligence. In the course of the drama, readers and moviegoers are treated to a genuinely fantastic voyage

through the human body as the intrepid crew battles enormous white blood cells, insidious antibodies, annoying platelets, and a myriad of other threats as they struggle to achieve their goal before the miniaturization catastrophically wears off.

The metaphor of *Fantastic Voyage* fits our book on several levels. First, we hope to treat you, our readers, to a fantastic voyage through the human body. Our understanding of the complex processes underlying life, disease, and aging has progressed enormously since 1966. We now have an unprecedented ability to comprehend our biology at the level of the tiniest molecular structures. We also have the opportunity to vastly extend our longevity, improve our well-being, and expand our ability to experience the world around us.

Asimov's fascination with miniaturization was prophetic. We are now in the early stages of a profound revolution in which we are indeed shrinking

Proteus as Prototype

A team at UCLA headed by biomedical engineer Carlo Montemagno is building a blood cell-size "submarine" intended for critical medical maneuvers inside the human body.¹ "In living systems, molecules perform repetitive functions the way machines do," Montemagno explains. "Some molecules take matter or information and move it from one location to another, while others filter and pump. I look at how to take pieces of these molecular machines and engineer them into hybrid devices. That means devices that are living and nonliving; they incorporate all the functionality you find in living systems but are artificial and engineered." The team has already created what it calls a nanocopter, with a propeller made of nickel and a motor the size of a virus that uses the body's own ATP (adenosine triphosphate, a complex molecule that stores energy) for power.

Virologist Peixuan Guo at Purdue University has created a remotely guided motorized nanomotor made from viral RNA and DNA and powered by the body's own chemical fuels. Guo has already guided his device inside cells to destroy the hepatitis virus.²

Another team at the University of California at Irvine is using a \$2.9 million National Institutes of Health grant to develop a microscopic vessel that would be remotely piloted by surgeons through the esophagus, stomach, small intestine, and colon to find tiny tumors and perform immediate biopsies.³ Ultimately, it will be able to destroy the tumors it finds.

The results of this technology revolution will go far beyond mere health maintenance to include a vast expansion of our human potential.

our technology down to the molecular level. We actually are developing blood cell-size submarines called nanobots (robots whose key features are measured in nanometers, or billionths of a meter) to be sent into the human body on vital health missions. Although we won't literally be shrinking ourselves to ride inside these nanobots, as in Asimov's imagined tale (at least not in the next several decades), we will be able to place ourselves in virtual-reality environments and see out of the eyes of these tiny robots. We will be able to control their movements as if we were inside, just as soldiers today remotely control intelligent weapons systems.

IMMORTALITY IS WITHIN OUR GRASP

Do we have the knowledge and the tools today to live forever? If all science and technology development suddenly stopped, the answer would have to be no. We do have the means to dramatically slow disease and the aging process far more than most people realize, but we do not yet have all the techniques we need to indefinitely extend human life. However, it is clear that far from halting, the pace of scientific and technological discovery is accelerating.

According to models that Ray has created, our paradigm-shift rate—the rate of technical progress—is doubling every decade, and the capability (price performance, capacity, and speed) of specific information technologies is doubling every year.⁴ So the answer to our question is actually a definitive yes—the knowledge exists, if aggressively applied, for you to slow aging and disease processes to such a degree that you can be in good health and good spirits when the more radical life-extending and life-enhancing technologies become available over the next couple of decades.

Longevity expert and gerontologist Aubrey de Grey uses the metaphor of maintaining a house to explain this key concept. How long does a house last? The answer obviously depends on how well you take care of it. If you do nothing, the roof will spring a leak before long, water and the elements will invade, and eventually the house will disintegrate. But if you proactively take care of the structure, repair all damage, confront all dangers, and rebuild or renovate parts from time to time using new materials and technologies, the life of the house can essentially be extended without limit.

The same holds true for our bodies and brains. The only difference is that while we fully understand the methods underlying the maintenance of a house, we do not yet fully understand all of the biological principles of life.

But with our rapidly increasing comprehension of the human genome, the proteins expressed by the genome (proteome), and the biochemical processes and pathways of our metabolism, we are quickly gaining that knowledge. We are beginning to understand aging, not as a single inexorable progression but as a group of related biological processes. Strategies for reversing each of these aging progressions using different combinations of biotechnology techniques are emerging. Many scientists, including the authors of this book, believe that we will have the means to stop and even reverse aging within the next two decades. In the meantime, we can slow each aging process to a crawl using the methods outlined in this book.

In this way, the goal of extending longevity can be taken in three steps, or Bridges. This book is intended to serve as a guide to living long enough in good health and spirits—Bridge One—to take advantage of the full development of the biotechnology revolution—Bridge Two. This, in turn, will lead to the nanotechnology-AI (artificial intelligence) revolution—Bridge Three—which has the potential to allow us to live indefinitely.

This, then, is the premise of our book and the case we will make throughout: the knowledge of how to maintain our biological “house” and extend its longevity and vitality without limit is close at hand. We will tell you how to use the extensive knowledge that we do have today to remain healthy as the reverse engineering (decoding and understanding the principal methods) of our biology proceeds.

THE 21ST CENTURY IS WORTH LIVING TO EXPERIENCE

Most of our conceptions of human life in the 21st century will be turned on their head. Not the least of these is the expectation expressed in the adage about the inevitability of death and taxes. We’ll leave the issue of the future of taxes to another book,⁵ but belief in the inevitability of death and how this perspective will soon change is very much the primary theme of this book. As we succeed in understanding the genome and the proteome, many dramatic advances in treating disease and even reversing aging will emerge. The first two decades of the 21st century will be a golden era of biotechnology.

Many experts believe that within a decade we will be adding more than a year to human life expectancy every year. At that point, with each passing year, your remaining life expectancy will move further into the future. (Aubrey de Grey believes that we will successfully stop aging in mice—who

share 99 percent of our genetic code—within 10 years, and that human therapies to halt and reverse aging will follow 5 to 10 years after that.) A small minority of older boomers will make it past this impending critical threshold. You can be among them. The authors of this book are of this generation and are intent on living through this threshold era in good health and spirits. Unfortunately, most of our fellow baby boomers remain oblivious to the hidden degenerative processes inside their bodies and will die unnecessarily young.

As interesting as the first two decades of this century are likely to be, subsequent decades should lead to even more dramatic changes. Ray has spent several decades studying and modeling technology trends and their impact on society. Perhaps his most profound observation is that the rate of change is itself accelerating. This means that the past is not a reliable guide to the future. The 20th century was not 100 years of progress at *today's* rate but, rather, was equivalent to about 20 years, because we've been speeding up to current rates of change. And we'll make another 20 years of progress at today's rate, equivalent to that of the entire 20th century, in the next 14 years. And then we'll do it again in just 7 years. Because of this exponential growth, the 21st century will equal 20,000 years of progress at today's rate of progress—1,000 times greater than what we witnessed in the 20th century, which itself was no slouch for change.

The result will be profound changes in every facet of our lives, from our health and longevity to our economy and society, even our concepts of who we are and what it means to be human. Within a couple of decades we will have the knowledge to revitalize our health, expand our experiences—such as full-immersion virtual reality incorporating all of the senses, augmented reality, and enhanced human intelligence and capability—and expand our horizons.

As we peer even further into the 21st century, nanotechnology will enable us to rebuild and extend our bodies and brains and create virtually any product from mere information, resulting in remarkable gains in prosperity. We will develop means to vastly expand our physical and mental capabilities by directly interfacing our biological systems with human-created technology.

Although human ability to take command of the course of life and death is controversial, we believe that the ability to broaden our horizons is a unique and desirable attribute of our species. And we certainly believe that it is worth the effort to remain healthy and vital today to experience this remarkable century ahead.