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Future Technology Will Benignly Alter Human Existence

Ray Kurzweil

In the following viewpoint, Ray Kurzweil predicts that trends in technology will eventually change humanity. According to Kurzweil, genetic advancements will defeat disease and allow people to live longer; nanotechnology will restructure machinery and biology; and robotics will breed wondrous artificial intelligence that will merge with and improve human understanding. In time, a human-machine civilization will arise in which poverty, pollution, hunger, disease and other concerns will be overcome and the powers of thought and communication will be exponentially increased beyond what is currently imaginable. Ray Kurzweil is an inventor, scientist, author, and futurist.

As you read, consider the following questions:

1. As Kurzweil describes it, what is the "Singularity"?

Ray Kurzweil, "Reinventing Humanity: The Future of Human-Machine Intelligence,"


Will Future Technology Improve Humanity?

2. How does the author envision the use of nanotechnology in benefiting medical treatment?

3. In Kurzweil's view, why will artificial intelligence necessarily exceed human intelligence?

We stand on the threshold of the most profound and transformative event in the history of humanity, the "Singularity."

What is the Singularity? From my perspective, the Singularity is a future period during which the pace of technological change will be so fast and far-reaching that human existence on this planet will be irreversibly altered. We will combine our brain power—the knowledge, skills, and personality quirks that make us human—with our computer power in order to think, reason, communicate, and create in ways we can scarcely even contemplate today.

This merger of man and machine, coupled with the sudden explosion in machine intelligence and rapid innovation in the fields of gene research as well as nanotechnology, will result in a world where there is no distinction between the biological and the mechanical, or between physical and virtual reality. These technological revolutions will allow us to transcend our frail bodies with all their limitations. Illness, as we know it, will be eradicated. Through the use of nanotechnology, we will be able to manufacture almost any physical product upon demand, world hunger and poverty will be solved, and pollution will vanish. Human existence will undergo a quantum leap in evolution. We will be able to live as long as we choose. The coming into being of such a world is, in essence, the Singularity.

How is it possible we could be so close to this enormous change and not see it? The answer is the quickening nature of technological innovation. In thinking about the future, few people take into consideration the fact that human scientific progress is exponential: It expands by repeatedly multiplying
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by a constant (10 times 10 times 10 and so on) rather than linear; that is, expanding by repeatedly adding a constant (10 plus 10 plus 10, and so on). I emphasize the exponential-versus-linear perspective because it's the most important failure that prognosticators make in considering future trends.

Moving Faster Toward a New World

Our forebears expected what lay ahead of them to resemble what they had already experienced, with few exceptions. Because they lived during a time when the rate of technological innovation was so slow as to be unnoticeable, their expectations of an unchanged future were continually fulfilled. Today, we have witnessed the acceleration of the curve. Therefore, we anticipate continuous technological progress and the social repercussions that follow. We see the future as being different from the present. But the future will be far more surprising than most people realize, because few observers have truly internalized the implications of the fact that the rate of change is itself accelerating.

Exponential growth starts out slowly and virtually unnoticeably, but beyond the knee of the curve it turns explosive and profoundly transformative. My models show that we are doubling the paradigm-shift rate for technology innovation every decade. In other words, the twentieth century was gradually speeding up to today's rate of progress; its achievements, therefore, were equivalent to about 20 years of progress at the rate of 2000. We'll make another "20 years" of progress in just 14 years (by 2014), and then do the same again in only seven years. To express this another way, we won't experience 100 years of technological advance in the twenty-first century; we will witness on the order of 20,000 years of progress (again, when measured by today's progress rate), or progress on a level of about 1,000 times greater than what was achieved in the twentieth century.

How Will We Know the Singularity Is upon Us?

The first half of the twenty-first century will be characterized by three overlapping revolutions—in genetics, nanotechnology, and robotics. These will usher in the beginning of this period of tremendous change I refer to as the Singularity. We are in the early stages of the genetics revolution today. By understanding the information processes underlying life, we are learning to reprogram our biology to achieve the virtual elimination of disease, dramatic expansion of human potential, and radical life extension. However, Hans Moravec of Carnegie Mellon University's Robotics Institute points out that no matter how successfully we fine-tune our DNA-based biology, biology will never be able to match what we will be able to engineer once we fully understand life's principles of operation. In other words, we will always be "second-class robots."

The nanotechnology revolution will enable us to redesign and rebuild—molecule by molecule—our bodies and brains and the world with which we interact, going far beyond the limitations of biology.

But the most powerful impending revolution is the robotic revolution. By robotic, I am not referring exclusively—or even primarily—to humanoid-looking droids that take up physical space, but rather to artificial intelligence in all its variations.

Following, I have laid out the principal components underlying each of these coming technological revolutions. While each new wave of progress will solve the problems from earlier transformations, each will also introduce new perils, but each, operating both separately and in concert, underpins the Singularity.

The Genetic Revolution

Genetic and molecular science will extend biology and correct its obvious flaws (such as our vulnerability to disease). By the year 2020, the full effects of the genetic revolution will be felt
across society. We are rapidly gaining the knowledge and the tools to drastically extend the usability of the “house” each of us calls his body and brain.

Nanomedicine researcher Robert Freitas estimates that eliminating 50% of medically preventable conditions would extend human life expectancy 150 years. If we were able to prevent 90% of naturally occurring medical problems, we’d live to be more than 1,000 years old.

We can see the beginnings of this awesome medical revolution today. The field of genetic biotechnology is fueled by the growing arsenal of tools. Drug discovery was once a matter of finding substrates (chemicals) that produced some beneficial result without excessive side effects, a research method similar to early humans’ seeking out rocks and other natural implements that could be used for helpful purposes. Today we are discovering the precise biochemical pathways that underlie both disease and aging processes. We are able to design drugs to carry out precise missions at the molecular level. With recently developed gene technologies, we’re on the verge of being able to control how genes express themselves. Gene expression is the process by which cellular components (specifically RNA and the ribosomes) produce proteins according to a precise genetic blueprint. While every human cell contains a complete DNA sample, and thus the full complement of the body’s genes, a specific cell, such as a skin cell or a pancreatic islet cell, gets its characteristics from only the fraction of genetic information relevant to that particular cell type.

Gene expression is controlled by peptides (molecules made up of sequences of up to 100 amino acids) and short RNA strands. We are now beginning to learn how these processes work. Many new therapies currently in development and testing are based on manipulating peptides either to turn off the expression of disease-causing genes or to turn on desirable genes that may otherwise not be expressed in a particular type of cell. A new technique called RNA interference is able to destroy the messenger RNA expressing a gene and thereby effectively turn that gene off.

Accelerating progress in biotechnology will enable us to reprogram our genes and metabolic processes to propel the fields of genomics (influencing genes), proteomics (understanding and influencing the role of proteins), gene therapy (suppressing gene expression as well as adding new genetic information), rational drug design (formulating drugs that target precise changes in disease and aging processes), as well as the therapeutic cloning of rejuvenated cells, tissues, and organs.

The Nanotechnology Revolution

Nanotechnology promises the tools to rebuild the physical world—our bodies and brains included—molecular fragment by molecular fragment and potentially atom by atom. We are shrinking the key features (working parts), in accordance with the law of accelerating returns, at an exponential rate (over four per linear dimension per decade or about 100 per 3-D volume). At this rate the key feature sizes for most electronic and many mechanical technologies will be in the nanotechnology range—generally considered to be less than 100 nanometers (one billionth of one meter)—by the 2020s. Electronics has already dipped below this threshold, although not yet in three-dimensional structures and not yet in structures that are capable of assembling other similar structures—an essential step before nanotechnology can reach its promised potential. Meanwhile, rapid progress has been made recently in preparing the conceptual framework and design ideas for the coming age of nanotechnology.

Nanotechnology has expanded to include any technology in which a machine’s key features are measured by fewer than 100 nanometers. Just as contemporary electronics has already quietly slipped into this nano realm, the area of biological and
medical applications has already entered the era of nanoparticles, in which nanoscale objects are being developed to create more-effective tests and treatments.

In the area of testing and diagnosis, nanoparticles are already being employed in experimental biological tests as tags and labels to greatly enhance sensitivity in detecting substances such as proteins. Magnetic nanotags can be used to bind with antibodies that can then be read using magnetic probes while still inside the body. Successful experiments have been conducted with gold nanoparticles that are bound to DNA segments and can rapidly test for specific DNA sequences in a sample. Small nanoscale beads called quantum dots can be programmed with specific codes combining multiple colors, similar to a color bar code, that can facilitate tracking of substances through the body.

In the future, nanoscale devices will run hundreds of tests simultaneously on tiny samples of a given substance. These devices will allow extensive tests to be conducted on nearly invisible samples of blood.

In the area of treatment, a particularly exciting application of this technology is the harnessing of nanoparticles to deliver medication to specific sites in the body. Nanoparticles can guide drugs into cell walls and through the blood-brain barrier. Nanoscale packages can be designed to hold drugs, protect them through the gastrointestinal tract, ferry them to specific locations, and then release them in sophisticated ways that can be influenced and controlled, wirelessly, from outside the body.

Nanotherapeutics in Alachua, Florida, has developed a biodegradable polymer only several nanometers thick that uses this approach. Meanwhile, scientists at McGill University in Montreal have demonstrated a nanopill with structures in the 25 to 45 nanometer range. The nanopill is small enough to pass through the cell wall and deliver medications directly to targeted structures inside the cell.

MicroCHIPS of Bedford, Massachusetts, has developed a computerized device that is implanted under the skin and delivers precise mixtures of medicines from hundreds of nanoscale wells inside the device. Future versions of the device are expected to be able to measure blood levels of substances such as glucose. The system could be used as an artificial pancreas, releasing precise amounts of insulin based on the blood glucose response. The system would also be capable of simulating any other hormone-producing organ, and if trials go smoothly, the system could be on the market by 2008. Another innovative proposal is to guide nanoparticles (probably composed of gold) to a tumor site and then heat them with infrared beams to destroy the cancer cells.

The revolution in nanotechnology will allow us to do a great deal more than simply treat disease. Ultimately, nanotech will enable us to redesign and rebuild not only our bodies and brains, but also the world with which we interact. The full realization of nanotechnology, however, will lag behind the biotechnology revolution by about one decade. But by the mid to late 2020s, the effects of the nanotech revolution will be widespread and obvious.

Nanotechnology and the Human Brain
The most important and radical application particularly of circa-2030 nanobots will be to expand our minds through the merger of biological and nonbiological, or "machine," intelligence. In the next 25 years, we will learn how to augment our 100 trillion very slow interneuronal connections with high-speed virtual connections via nanorobotics. This will allow us to greatly boost our pattern-recognition abilities, memories, and overall thinking capacity, as well as to directly interface with powerful forms of computer intelligence. The technology will also provide wireless communication from one brain to another.
Humans, the Lower Life Form

In the future, I believe, we will be able to send signals to and from human and machine brains. We will be able to directly harness the memory and mathematical capabilities of machines. We will be able to communicate across the internet by means of thought signals alone. Human speech and language, as we know it, will become obsolete. Ultimately, humans will become a lower form of life, unable to compete with either intelligent machines or cyborgs.


In other words, the age of telepathic communication is almost upon us.

Our brains today are relatively fixed in design. Although we do add patterns of interneuronal connections and neurotransmitter concentrations as a normal part of the learning process, the current overall capacity of the human brain is highly constrained. As humanity’s artificial-intelligence (AI) capabilities begin to upstage our human intelligence at the end of the 2030s, we will be able to move beyond the basic architecture of the brain’s neural regions.

Brain implants based on massively distributed intelligent nanobots will greatly expand our memories and otherwise vastly improve all of our sensory, pattern-recognition, and cognitive abilities. Since the nanobots will be communicating with one another, they will be able to create any set of new neural connections, break existing connections (by suppressing neural firing), create new hybrid biological and computer networks, and add completely mechanical networks, as well as interface intimately with new computer programs and artificial intelligences.

The implementation of artificial intelligence in our biological systems will mark an evolutionary leap forward for humanity, but it also implies we will indeed become more “machine” than “human.” Billions of nanobots will travel through the bloodstream in our bodies and brains. In our bodies, they will destroy pathogens, correct DNA errors, eliminate toxins, and perform many other tasks to enhance our physical well-being. As a result, we will be able to live indefinitely without aging.

In our brains, nanobots will interact with our biological neurons. This will provide full-immersion virtual reality incorporating all of the senses, as well as neurological correlates of our emotions, from within the nervous system. More importantly, this intimate connection between our biological thinking and the machine intelligence we are creating will profoundly expand human intelligence.

Warfare will move toward nanobot-based weapons, as well as cyber-weapons. Learning will first move online, but once our brains are fully online we will be able to download new knowledge and skills. The role of work will be to create knowledge of all kinds, from music and art to math and science. The role of play will also be to create knowledge. In the future, there won’t be a clear distinction between work and play.

The Robotic Revolution

Of the three technological revolutions underlying the Singularity (genetic, nano-mechanical, and robotic), the most profound is robotic or, as it is commonly called, the strong artificial intelligence revolution. This refers to the creation of computer thinking ability that exceeds the thinking ability of humans. We are very close to the day when fully biological humans (as we now know them today) cease to be the dominant intelligence on the planet. By the end of this century, computational or mechanical intelligence will be trillions of trillions of times more powerful than unaided human brain
power. I argue that computer, or as I call it nonbiological intelligence, should still be considered human since it is fully derived from human-machine civilization and will be based, at least in part, on a human-made version of a fully functional human brain. The merger of these two worlds of intelligence is not merely a merger of biological and mechanical thinking mediums, but also and more importantly, a merger of method and organizational thinking that will expand our minds in virtually every imaginable way.

Biological human thinking is limited to $10^{16}$ to the $16^{th}$ power calculations per second (cps) per human brain (based on neuromorphic modeling of brain regions) and about $10^{26}$ to the $26^{th}$ power cps for all human brains. These figures will not appreciably change, even with bioengineering adjustments to our genome. The processing capacity of nonbiological intelligence or strong AI, in contrast, is growing at an exponential rate (with the rate itself increasing) and will vastly exceed biological intelligence by the mid-2040s.

Artificial intelligence will necessarily exceed human intelligence for several reasons.

First, machines can share knowledge and communicate with one another far more efficiently than can humans. As humans, we do not have the means to exchange the vast patterns of interneuronal connections and neurotransmitter-concentration levels that comprise our learning, knowledge, and skills, other than through slow, language-based communication.

Second, humanity's intellectual skills have developed in ways that have been evolutionarily encouraged in natural environments. Those skills, which are primarily based on our abilities to recognize and extract meaning from patterns, enable us to be highly proficient in certain tasks such as distinguishing faces, identifying objects, and recognizing language sounds. Unfortunately, our brains are less well-suited for dealing with more-complex patterns, such as those that exist in financial, scientific, or product data. The application of computer-based techniques will allow us to fully master pattern-recognition paradigms. Finally, as human knowledge migrates to the Web, machines will demonstrate increased proficiency in reading, understanding, and synthesizing all human-machine information.

The Chicken or the Egg?

A key question regarding the Singularity is whether the "chicken" (strong AI) or the "egg" (nanotechnology) will come first. In other words, will strong AI lead to full nanotechnology (molecular-manufacturing assemblers that can turn information into physical products), or will full nanotechnology lead to strong AI?

The logic of the first premise is that strong AI would be in a position to solve any remaining design problems required to implement full nanotechnology. The second premise is based on the assumption that hardware requirements for strong AI will be met by nanotechnology-based computation. Likewise, the software requirements for engineering strong AI would be facilitated by nanobots. These microscopic machines will allow us to create highly detailed scans of human brains along with diagrams of how the human brain is able to do all the wonderful things that have long mystified us, such as create meaning, contextualize information, and experience emotion. Once we fully understand how the brain functions, we will be able to re-create the phenomena of human thinking in machines. We will endow computers, already superior to us in the performance of mechanical tasks, with lifelike intelligence.

Progress in both areas (nano and robotic) will necessarily use our most-advanced tools, so advances in each field will simultaneously facilitate the other. However, I do expect that the most important nanotechnological breakthroughs will emerge prior to strong AI, but only by a few years (around 2025 for nanotechnology and 2029 for strong AI).
As revolutionary as nanotechnology will be, strong AI will have far more profound consequences. Nanotechnology is powerful but not necessarily intelligent. We can devise ways of at least trying to manage the enormous powers of nanotechnology, but superintelligence by its nature cannot be controlled.

The nano/robotic revolution will also force us to reconsider the very definition of human. Not only will we be surrounded by machines that will display distinctly human characteristics, but we will be less human from a literal standpoint. Despite the wonderful future potential of medicine, real human longevity will only be attained when we move away from our biological bodies entirely. As we move toward a software-based existence, we will gain the means of "backing ourselves up" (storing the key patterns underlying our knowledge, skills, and personality in a digital setting) thereby enabling a virtual immortality. Thanks to nanotechnology, we will have bodies that we can not just modify but change into new forms at will. We will be able to quickly change our bodies in full-immersion virtual-reality environments incorporating all of the senses during the 2020s and in real reality in the 2040s.

Implications of the Singularity
What will be the nature of human experience once computer intelligence predominates? What are the implications for the human-machine civilization when strong AI and nanotechnology can create any product, any situation, any environment that we can imagine at will? I stress the role of imagination here because we will still be constrained in our creations to what we can imagine. But our tools for bringing imagination to life are growing exponentially more powerful.

People often go through three stages in considering the impact of future technology: awe and wonderment at its potential to overcome age-old problems, then a sense of dread at the new grave dangers that accompany these novel technologies, followed finally by the realization that the only viable and responsible path is to set a careful course that can realize the benefits while managing the dangers.

My own expectation is that the creative and constructive applications of these technologies will dominate, as I believe they do today. However, we need to vastly increase our investment in developing specific defensive technologies. We are at the critical stage where we need to directly implement defensive technologies for nanotechnology during the late teen years of this century.

I believe that a narrow relinquishment of the development of certain capabilities needs to be part of our ethical response to the dangers of twenty-first-century technological challenges. For example, [cofounder of Sun Microsystems and future tech centre] Bill Joy and I wrote a joint op-ed piece in the New York Times criticizing the publication of the 1918 flu genome on the web as it constitutes a dangerous blueprint. Another constructive example of this is the ethical guidelines proposed by the Foresight Institute: namely, that nanotechnologists agree to relinquish the development of physical entities that can self-replicate in a natural environment free of any human control or override mechanism. However, deciding in favor of too many limitations and restrictions would undermine economic progress and is ethically unjustified given the opportunity to alleviate disease, overcome poverty, and clean up the environment.

We don’t have to look past today to see the intertwined promise and peril of technological advancement. Imagine describing the dangers (atomic and hydrogen bombs for one thing) that exist today to people who lived a couple of hundred years ago. They would think it mad to take such risks. But how many people in 2006 would really want to go back to
the short, brutish, disease-filled, poverty-stricken, disaster-prone lives that 99% of the human race struggled through two centuries ago?

We may romanticize the past, but up until fairly recently most of humanity lived extremely fragile lives in which one all-too-common misfortune could spell disaster. Two hundred years ago, life expectancy for females in the record-holding country (Sweden) was roughly 35 years, very brief compared with the longest life expectancy today—almost 85 years for Japanese women. Life expectancy for males was roughly 33 years, compared with the current 79 years. Half a day was often required to prepare an evening meal, and hard labor characterized most human activity. There were no social safety nets. Substantial portions of our species still live in this precarious way, which is at least one reason to continue technological progress and the economic improvement that accompanies it.

Only technology, with its ability to provide orders of magnitude of advances in capability and affordability has the scale to confront problems such as poverty, disease, pollution, and the other overriding concerns of society today. The benefits of applying ourselves to these challenges cannot be overstated.

A New Evolution

As the Singularity approaches, we will have to reconsider our ideas about the nature of human life and redesign our human institutions. Intelligence on and around Earth will continue to expand exponentially until we reach the limits of matter and energy to support intelligent computation. As we approach this limit in our corner of the galaxy, the intelligence of our civilization will expand outward into the rest of the universe, quickly reaching the fastest speed possible. We understand that speed to be the speed of light, but there are suggestions that we may be able to circumvent this apparent limit (conceivably by taking shortcuts through "wormholes," or hypothetical shortcuts through space and time).