Introduction

“I could feel – I could smell – a new kind of intelligence across the table.”

Gary Kasparov

This chapter deals with computer and information technology and the economic, social, and psychological changes being brought about by this new technology. First, I chronicle the development of computers and predictions concerning the future evolution of computers and artificial intelligence. Next I turn to the history and future possibilities of robots. After describing these technologies, I introduce a central theme of the chapter: the evolving relationship between humanity and information technology. I examine in depth how information technology is infusing into the human sphere, creating an ever more intelligent environment, and transforming human reality. In this section, I look at the promises and perils of virtual reality. Next I focus on the emergence of an information technological web or network that is encircling the globe, highlighting the Internet, the World Wide Web, the communications revolution, and the Global Brain hypothesis. Then pulling the pieces together, I look at the social and economic implications of information technology. I describe the transition from an industrial society to an information society and review various predictions regarding the information society. I consider the views that the information society is evolving into a knowledge society and that the global information network is generating a global mind. Based on this discussion, I consider the more far-reaching idea of a technology based cosmic intelligence and a cosmic
mind. Throughout the chapter, I look at both advocates and critics regarding the effects information technology is having on humanity, and I discuss whether the Information Age theory of the future is both an accurate and preferable framework for understanding and guiding our evolution.

The central theses of the chapter are:
• Computers and robots will develop conscious, intelligent, personified minds. Further, information technology devices and systems will be implanted into humans, enhancing psychological and behavioral abilities and allowing for direct communication with artificial intelligent minds. There will be both artificial intelligence (AI) and intelligence amplification (IA) in the relatively near future.
• Overall, there will be an ongoing multi-faceted integration of information technologies and human life. Humans and information technology will coevolve. Humans will increasingly immerse their lives and minds in systems of technological intelligence and virtual reality. The distinction between humanity and technology will increasingly blur.
• The environment will be infused with information technology, becoming animated, communicative, and more intelligent. The distinction between the artificial and the natural will increasingly blur.
• The scope and richness of existence will expand through virtual reality. Simulated and virtual reality will increasingly blend and intermix into “normal” reality.
• The Information Age embodies a discontinuous and revolutionary jump beyond the Industrial Era. Information Age thinking and technology, coupled with other pervasive and interdependent technological and social changes, are transforming society into a different type of human system.
• As the overarching global expression of the evolving human-technology integration, a "World Brain" and "World Mind" will emerge on the earth. This psychophysical system will enhance and enrich the capacities of both individual and collective cognition. This system is a potential starting point toward the evolution of a cosmic brain and cosmic mind.

I have included a list of relevant websites on computers, artificial intelligence, robotics, and Information Age thinking in the notes for this chapter.
Computers, Robots, and Artificial Intelligence

“Can an intelligence create another intelligence more intelligent than itself?”

Ray Kurzweil

“It is the ‘wild’ intelligences … those beyond our constraints, to whom the future belongs.”

Hans Moravec

The rapid rise of electronic and information technology has led to more intelligent, intricate, and efficient machines. The computer lies at the center of information technology. It is interesting to note that futuristic projections earlier in the century saw the rocket ship or spaceship as the paradigm machine of tomorrow. The rocket ship, though, was a creation of the Industrial Era - a big machine generating vast amounts of force. The technological power of the computer lies in its versatility, intelligence, connectivity, and complexity rather than in its energy thrust. The computer can be integrated into almost any human activity, providing for better storage, organization, and speed of operations. It is transforming how we communicate, work, plan, entertain ourselves, and even select a mate. The computer is both an extended and external nervous system, as well as a new environmental enrichment that has significantly transformed the world in which we live. Further, the computer is infusing itself into all other technologies. Progressively, every machine will have a computer (or computers) at its core and be connected with other machines with computers. At a global level, computers are networking into a web of communication and integrated processing. The computer is perhaps the most powerful machine humanity has ever created.

As noted above, from one perspective, the computer is an artificially constructed nervous system with input and output systems. Information can be inputted into a computer, often from other computers, and this information can be stored. Further, this stored information can be used for processing, manipulating, and outputting new information. Information can be displayed via a monitor (or other output device) or it can be transmitted to another computer. Though there is considerable debate on this point, the computer, in some sense, perceives, remembers, thinks, and communicates.

In the past, most of our machines and instruments have been extensions or enhancements of basic physical activities of the human body or physical processes observed in nature. But what makes humans special among animals is not our external bodily system, but our nervous system. The computer, insofar as it is an artificial nervous system that processes information, comes closest
among our machines to embodying what makes us unique and distinctively human. There is a strong sense of connection and resonance with this machine. As Michael Dertouzos notes the computer is the first type of technology directly related to learning, knowledge, and communication. Since it is our nervous system that supports the highly enhanced and flexible power of the human species, a mechanism that simulates this biological system and its associated capacities would be immensely more powerful than any other machine humans have created.

The history of computers can be traced back to the early 19th Century and Charles Babbage and Ada Lovelace and their idea of the Analytical Engine. Based on the science and technology of his time, Babbage never completed the construction of the Analytical Engine, but it anticipated many of the modern elements of computers, including the key feature of software programming. It is with the work of Alan Turing though that the modern computer comes into reality in full force. In the 1930’s Turing wrote several key papers on computers, introducing the Turing machine, a theoretical model of computers. Along with Alonzo Church he developed the Church-Turing thesis, arguing that all definable problems humans could solve could be reduced to a set of algorithms, which, in principle, could be programmed into a computer. During World War II, Turing constructed the first operational computer, designed to break secret German codes. After the war he continued to write additional classic theoretical papers on computers and artificial intelligence and, according to Ray Kurzweil, defined the future agenda of computer development.

During the 1950’s and 1960’s, based on initial optimistic hopes that computers could simulate human intelligence, various programs and systems were developed that could generate mathematical proofs and solve computational problems. The field of artificial intelligence was born. Yet as Hans Moravec notes, although calculation was easy for these machines, reasoning, perception, and common sense would turn out to be much more formidable challenges. Computer scientists could design “expert systems” that could perform exceedingly well within a very limited context, storing vast amounts of information, processing that information very quickly, and answering questions within that area. Yet, these systems were blind to anything beyond their limited area of expertise. Still a great deal of progress was made in computer systems, beginning in the 1960’s as the United States Government, through ARPA (Advanced Research Project Agency), and various academic institutions such as MIT, Stanford, and Carnegie Mellon developed research departments and produced many innovations. Various commercial businesses such as Intel, Xerox, and IBM were also significantly involved in the early development of computers.

In 1965, Gordon Moore, the president of Intel and inventor of the integrated circuit, observed that the surface area of transistors was decreasing in size at a relatively constant rate over time. From this initial observation and further study, he formulated what has become known as Moore’s Law on
Integrated Circuits. Moore’s Law predicts that approximately every 2 years computers will double in integrated circuits and processing speed per unit area, while maintaining the same unit cost. According to Kurzweil though, Moore’s Law is actually a special case of a more general law, the “Exponential Law of Computing”. From the beginning of the 20th Century, long before the invention of transistors and integrated circuits, computing systems have been increasing in power at an exponential rate. Early in the 20th Century, the first electrical computing systems were doubling in power around every three years. By the end of the 20th Century, computers were doubling in power every year. Kurzweil believes this exponential growth will continue indefinitely into the future. Assuming certain technological breakthroughs discussed below, he sees no absolute limit to computational density for computer hardware. Rather, he foresees the computational density across the earth growing trillions upon trillions of times in just the next century.

Kurzweil believes that the exponential evolution of computation, defined as the capacity to remember and solve problems, is inevitable. Clearly animals, if not life in general, have demonstrated increasing computational abilities throughout evolution. This increasing computational capacity, first within biological life and now extending further through computers, is for Kurzweil a manifestation of the Law of Accelerative Returns, the exponential growth of order in the evolution of nature. To recall from the last chapter, for Kurzweil the increasing complexity or order within technology is also a natural outgrowth of the Law of Accelerative Returns. According to Kurzweil, the growth of computational power in computers is a consequence and expression of the evolution of order, and the evolution of order is exponential.

Whatever set of factors is responsible for the growth of computers, over the last few decades information technology has very quickly developed in terms of its functional capabilities, computing power, and influence upon most dimensions of human life. As noted in the previous chapter, information technology has permeated into most other areas of science and technology, facilitating and supporting advances in biotechnology, biological science, complexity and chaos theory, and cosmology, to name just a few examples. Information technology has quickly become integral to finance, entertainment, business, transportation, communication, the military, and all forms of statistical research, demographics, and monitoring systems around the world. Aside from the public sphere, the computer has also quickly worked itself into our personal lives. Our cars, appliances, and electronic gadgets are all becoming computerized. Of special note is the PC. The personal computer revolution was a completely unpredicted phenomenon. Yet, the PC has become, in a few short decades, almost as common a household possession as a TV or a telephone. In the last decade the Internet and the World Wide Web have also exploded on the scene, linking business, homes, schools, social organizations, government centers, and research installations around the world.

Based upon the phenomenal growth rate of computers and their
integration into human life, various predictions have been made about their future evolution. Here I will identify some of them. First, let us begin with basic computing power. Molitor reports that the fastest computer today performs 12 trillion calculations a second (12 teraflops). This speed is three times faster than in 2000 – a clear reflection of Moore’s Law. He states that it is projected that computers will reach 16 trillion calculations per second (16 teraflops) by 2004 and 200 teraflops in the near future. Kaku notes, though, that although silicon computers will thus become increasingly denser, till around 2020, at that point we will reach the limits of miniaturization in silicon technology. We will need to find a new medium for computation, if computational speed and density are going to continue to increase. In particular, Kaku and many other computer scientists and futurists see great promise in optical, DNA, and quantum computers, which would vastly exceed the power of standard silicon circuit computers. The George Washington forecasting group predicts the first commercial optical computers by around 2015.

Pearson foresees computers catching up with human intelligence by 2020. Zey projects computers exceeding humans in processing power between 2030 and 2050. Both Moravec and Kurzweil, as well, project similar, if not more optimistic, dates for these achievements. In making their claims, they provide excellent graphic representations of how computer growth compares to the computational capacities of various animals on the evolutionary scale, including humans. Moravec, using MIPS (million instructions per second) as a measure of processing speed, estimates that the human brain stores about 100 million megabytes of memory and performs at a rate of 100 million MIPS. According to Moravec, Deep Blue, the computer that defeated the world champion chess master Gary Kasparov, performs at about 3% of this level. Based on Moravec’s assessment of increasing computer power over this century, he predicts computers will reach human intelligence by around 2020. Kurzweil provides an estimate of 20 million billion calculations per second for a human brain, which is equivalent to 20,000 teraflops. Although, according to Kurzweil, this is about 2,000 times faster than our biggest computer, following Moore’s exponential law, super-computers should reach 20,000 teraflops by around 2010 and personal computers should achieve this speed by 2020. Note that these dates roughly correspond to Vinge’s estimate of the “technological singularity”.

According to Moravec and Kurzweil, once computers catch up with humans in computational speed and memory storage, they will quickly pass us by. Since Kurzweil believes that the exponential growth of computer power is a consequence of the evolution of order, he believes that new types of computers, such as optical, quantum, and nanotechnological, will emerge in the near future to maintain the rate of evolution throughout the coming century. In fact, he states that computer circuitry itself was how evolution found a way to exceed the computational limits of neurons in the brain and keep the evolution of order moving along. Following the Exponential Law of Computing, Kurzweil believes that by around 2030 an individual computer will possess the power of 1000 human brains and by 2050 a personal computer will exceed the total brainpower
of all humans presently existing on earth.25

Since, according to these various predictions, computers will be achieving, at the very least, equivalent information processing power to humans in the coming decades, what technological developments will further facilitate our interaction with them? The George Washington forecasting group predicts highly effective voice recognition and translation systems in computers by around 2010 and flexible learning programs and software agents by 2010 – 2015.26 Kurzweil also sees language user interface coming into popularity by around 2010 and the emergence of interactive “agents” with human personality qualities by around 2019.27 In a similar vein, Pearson estimates that we will be conversing with computers by 2020 and developing a working partnership with them, in matters as diverse as finance, management, travel, and business. Between 2005 and 2025, computers will develop external sensors, begin to show higher-level human functions and qualities, and be able to self-repair. Kurzweil predicts that by 2029, most human communication will be with machines.28 According to Pearson, by 2100 there will be human-machine convergence,29 a view Kaku holds as well.30

According to numerous forecasters, the world will become increasingly computerized – the environment will become intelligent, sensing our presence, understanding our communications, and responding to our requests.31 Kaku sees the PC disappearing into the environment by around 2020; there will no longer be stand alone computers, but rather computer chips and circuits embedded into objects and surfaces all around us.32 Kurzweil takes this idea further suggesting that computers becoming invisible and integrated into our clothing by around 2020. According to Kurzweil, we will use portable direct display headsets with virtual reality overlays, and there will be few if any keyboards remaining.33

Given all these predictions that computers will exceed human levels of information processing and storage, and other predictions concerning how computers will become more like humans in the future, the question arises whether computers will eventually possess conscious intelligent minds. Will they, in fact, eventually possess minds superior to humans? Over the last few decades, scientists, technologists, and philosophers have been actively debating the cognitive and psychological capacities and potentials of computers. Are computers thinking when they engage in computational processes? Is thinking more complicated and subtle than simply computation?34 Could a computer someday be able to think, using abstract reasoning, creativity, and basic common sense in a manner similar to humans? In the future, will a computer possess consciousness, emotion, or self-awareness?35 In short, are computers the next evolutionary step on earth? Or are computers somehow inherently limited in their potential to transcend humans?36

Fifty years ago, Alan Turing considered the basic objections regarding the possibility of creating artificial intelligence.37 In particular, Turing was concerned with arguments against the idea that computers could think. Turing’s list of arguments is a good place to begin the discussion on the artificial intelligence
debate, as summarized by Moravec:

- The Theological Argument – Machines have no souls and souls are needed for thinking.
- Head in the Sand Argument – It is too dreadful a possibility that computers could think. They would surpass us and we fear that possibility.
- Mathematical Objection – Mechanical reasoning has its limitations. Thinking goes beyond simple computation.
- Argument from Consciousness – Machines have no inner experience. They can't give meaning to their “thoughts”.
- Argument from Disabilities – There is an ever-shrinking list of what computers can’t do.
- Lovelace Objection – Computers can only do what they are programmed to do. They show no creativity or self-initiative.
- Informality Argument – We can't specify a rule (hence program or algorithm) of thinking for every possible circumstance.

In order to be as precise as possible regarding the meaning of thinking and as a way to ascertain if a computer was demonstrating thinking, Turing proposed what came to be referred to as the famous Turing Test. Imagine a person in an enclosed room with two keyboards and two display screens. One keyboard and screen is connected to a computer outside of the room; the other keyboard is connected to a keyboard outside the room being operated by a human. The person in the room cannot tell which keyboard is connected to a computer and which a human is operating. The person can carry on conversations and ask any question through each of the two keyboards and read the responses on the two screens. The problem for the person is to figure out, based upon the answers and comments that come back on the two screens, which set of responses is coming from a computer and which responses are coming from the human. If the person cannot reliably discriminate the human from the computer, then the computer has passed the Turing Test. For Turing, thinking is as thinking does, and if the computer can simulate what a thinking person would say within a dialogue with another person, then the computer is operationally thinking.

The Turing Test, as a real measure of thinking, has been criticized on numerous grounds. In particular, the counter-argument has been presented that simulating the responses of a thinking person does not demonstrate that any conscious or intelligent thinking is actually going on inside of the computer. This counter-argument basically states that passing the Turing Test does not demonstrate consciousness. Yet, what if the two keyboards and screens were replaced with two figures that looked like humans, that we could converse with face-to-face and eye-to-eye, and with whom we could bring to bear all our human skills of empathy, intuition, and personal sensitivity? And what if we could discuss with these apparent humans their own sense of inner experience and
consciousness? What if with all this additional more intimate contact, we could not tell which apparent human was flesh and blood, and which was made of silicon and metal? What if the sense of a conscious presence was just as vivid and real with the computer as with the “real” human? Would we still feel justified in saying that the computer had not demonstrated real thinking and real consciousness?

Tipler projects that computers will reach a human level of intelligence by around 2025, a figure similar to those dates proposed by Kurzweil, Moravec, Vinge, and others. Tipler thinks that the arguments against artificial intelligence are basically invalid, being based upon our mind-matter dualist philosophy and he believes that a computer will be able to pass the Turing Test in the next few decades. Tipler asks why we think that a metallic or inorganic system could never feel or never achieve consciousness? What makes the physical substrate of the brain so special that consciousness and emotion can arise within it? He believes that the attributes of mind, consciousness, and emotionality should not necessarily be tied to some particular material foundation; these attributes could be embodied in different kinds of physical systems, as long as the system possessed sufficient complexity.

In support of Tipler, how can we say that the computer cannot show real thinking or intelligence when we have a difficult time defining intelligence and thinking in humans? How can we argue that a silicon-based machine (the computer) could not generate consciousness when we are still in the process of understanding how a carbon-based mechanism (the brain) generates consciousness? In fact, the very nature of consciousness is a controversial and evolving topic. What is consciousness, such that we can say that computers could not possibly possess it? Both Penrose and Zey argue that consciousness involves non-computable processes, and hence computers will never become conscious, in so far as they are nothing but complex computing mechanisms. Yet, the problem with this argument is that if one could describe what kind of a system the organic brain and body is such that it involves noncomputational features, what is to prevent us from creating this type of physical system?

Kurzweil proposes that over the next fifty years computers will progressively convince us that they are conscious. As they increasingly demonstrate more human like qualities, and even become familiar with the philosophical arguments against computers possessing consciousness, they will both intentionally in their dialogues with us, and more unintentionally in their interactions with us, eventually persuade us that they do have inner experiences and are aware both of themselves and the world around them. Greg Bear, in Queen of Angels, describes an interesting variation on this scenario, where an advanced AI is challenged to figure out if it is conscious. The AI must convince itself, knowing what all the philosophical and skeptical arguments are concerning machines possessing consciousness. Consciousness, though, seems to be such an obvious fact of our existence that it does not seem to make sense to ask
ourselves or puzzle over whether we are conscious or not. Any being that could meaningfully ask this question, it would seem, must necessarily possess consciousness.

Further, consciousness may not be a simple either-or phenomenon. To what degree does a chimpanzee possess consciousness? To what degree does a rabbit, a reptile, a fish, or a spider possess consciousness? At what point on the evolutionary scale do we draw the line between conscious life and unconscious life? It seems as if consciousness probably comes in degrees. Kaku suggests that as computers become more complex and intelligent, consciousness will develop in degrees within them. In a gradual progression to higher forms of consciousness, Kaku foresees the possibility of self-aware robots sometime between 2050 and 2100.47 Moravec also describes a progressive evolution of mentality and self-awareness through successive generations of computerized robots over the next century. He predicts that the impression of consciousness will come in degrees as robots demonstrate the capacity to function across more expansive and complex environmental conditions. By 2030 robots will possess a "concrete mind", dealing well with perceptual and motor tasks though yet not functioning at an abstract level. They will be exhibiting the beginnings of self-awareness by being able to respond to questions about their own states and capacities.48

Critics and skeptics have repeatedly pointed out ways in which computers do not seem to demonstrate the rich array of intelligent capacities demonstrated by humans, and each time programmers find some way for the computer to exhibit the ability.49 Progress in some areas has been much slower than anticipated. In particular, they are superb at calculating tasks but poor at common sense, but the list of things that humans can do that computers can’t do gets increasingly smaller. In essence, this is the old "It can’t be done" argument, applied in this case to computers (Turing’s Disabilities Argument), which is invariably followed by somebody figuring out how to do it.

Although it is often said that computers simply do what they are told (Lovelace’s Objection), programmers have repeatedly pointed out that they cannot totally explain or anticipate what their own designed software will produce.50 Fractals are an excellent example of the unanticipated creative abilities of computers - no one foresaw the beauty and intricacy of these patterns that would emerge out of the computer. The computer surprised everyone. Of special relevance to the issue of creativity in computers are the new types of computer systems involving "neural nets" and "massive parallel processing mechanisms" which seem to more closely resemble the functioning of human brains than serial processing computers.51 Danny Hillis, who created the first massive parallel processing computer systems, has been pursuing the goal of generating complexity in computer processing out of the interaction of many simple processes.52 Hillis, following the logic of self-organizational complexity theory, believes that creative and unanticipated higher order patterns emerge in the brain through the interaction of a multitudinous and simultaneous array of
simpler neural processes. He is attempting to model this creative process in computers.

Marvin Minsky, in fact, proposed in his highly discussed book *The Society of Mind*, that the high level of flexible intelligence we observe in the human mind is actually due to a collection or “society” of simple mechanisms operating simultaneously in the brain. Hillis identifies Minsky as a main source of inspiration in his thinking on parallel processing and self-organizational systems. Artificial life simulations, discussed in Chapter Three, are also based on the idea of multiple simple processes interacting with each other and consequent higher order patterns emerging in this interactive process.

Computer intelligence and behavior are often characterized as mechanistic, rigid and impersonal - old Newtonian stereotypes of the machine (the Mathematical Objection). Yet Nicholas Negroponte notes that the immediate future will see the development of many “human-like” qualities in computer interfaces. Computer software agents will increasingly look and act like humans, with personalities, emotional qualities, and sensitivities to the personalities of humans. Agents will be friends and partners in life. Kurzweil agrees with these predictions regarding agents, identifying 2020 as a date when such human-like agents will become technologically possible and available. In a more general vein, as with consciousness, we should see a gradual evolution of human qualities in both computers and robots in this century. Challenging both the Mathematical Objection and the Lovelace Objection to computers thinking, many computer scientists, such as Hillis, Kurzweil, and Moravec believe that the key to creating computer systems that are both creative and flexible lies in increasing the computational speed and designing for interaction among computational processes.

Still, it could be argued that computers lack self-autonomy because humans build and program them, even if we grant that once this programming is allowed to run, it will show creative and emergent qualities. Yet if we are assuming that it is humans and not computers who make and design computers, this idea is, at best, a half-truth. As noted in the last chapter, we use our present technology to create more advanced technologies. Computers are clearly used in the design and development of more advanced computers and computer software. Our newest computers could not be built without the use of present computers. Further, we do not deny the autonomy and independent intelligence of our biological children just because we make them (biologically) and educate them (psychologically and socially). Through an extensive process of socialization, we clearly program ourselves. Further, as scientists such as Hans Moravec predict, in the future, robots and computers will increasingly take over control in designing and creating themselves.

A critical issue throughout much of this discussion is the exact nature of intelligence. This is a point of debate among psychologists, philosophers, and scientists. Taking a position similar to Tipler, Kurzweil argues that intelligence,
and mind as well, is pattern or form rather than substance. (Both Tipler and Kurzweil reject mind-body dualism. They follow Aristotle who defined the “psyche” as the form of the body. Descartes had defined consciousness and mind as a second substance distinct from physical substance.) Kurzweil defines intelligence as the ability to use resources to achieve goals and as the ability to see order where none was seen before. Kurzweil believes that these capacities involve the use of a set of formulae for solving problems. Further, he agrees with Turing that intelligence involves simple methods and heavy computation, an idea also found in Minsky. Kurzweil identifies three basic types of methods or formula that intelligent systems use in computation: Recursive, neural net, and evolutionary algorithms. Recursive methods are used in serial processing computers, where the same operations are performed over and over again. Neural net methods, used in parallel processing systems, involve the interaction of many simple programs. Evolutionary algorithms are programs that learn and evolve through a process analogous to natural selection in computer-generated problem solving situations. Both neural net methods and evolutionary algorithms are self-organizing processes that generate unpredictable and creative results. Kurzweil contends if we combine these formula or methods with mass computation and add in sufficient knowledge (factual information about the world, for example) we have the makings of an intelligent machine.

Kurzweil argues that in the 21st Century we will be able to design and build “new brains” that demonstrate all the various associated skills of human intelligence, and that will eventually surpass us in all these skills. He points out that there are presently dozens of research projects around the world attempting to map and describe brain circuitry and create computer circuitry that models these biological networks. Kurzweil believes that by 2030 we will have deciphered the brain and its workings. He also notes the ongoing effort to create software that models various human cognitive processes. In his mind, creating such software will be a significant challenge in the coming decades. In particular, as many computer scientists point out, computers do not possess what humans refer to as “common sense”. Yet as Kaku notes, researchers are busy creating a vast “Encyclopedia of Common Sense” for computers. Assuming we can understand and model the basic psychological processes and how they are supported in brain circuitry and information storage, if we add in the vastly increased computational speed and information storage of future computers, we will create an intelligence greater than our own. Kurzweil sees nothing paradoxical in this idea, since evolution shows an ongoing history of order and complexity building upon itself, of lower forms of intelligence leading to higher forms of intelligence.

The process of creation is different - biological versus technological - but in the long run this may be an evolutionary advance on the process of biological evolution itself. In fact, directing the construction of our mental descendents introduces a higher level of intelligence into the evolutionary process. Previously, the evolution of intelligence was determined by natural selection, as well as natural self-organizational principles. Even if we grant, as Sahtouris argues, a
type of intelligence in this evolutionary process, what is being introduced now is evolution guided by conscious, scientifically informed decision-making and research. As we will see, the promise of guided design may soon become a fact in the construction of our biological children. Although it may sound odd to say this, computers (and computerized robots) can be seen as the evolutionary children of humanity, intentionally designed by us, but eventually going beyond the capabilities of their parents.63

The issue of artificial intelligence is not simply a technological or scientific question. It is an emotional issue and an issue concerning the ego and pride of humans (The Head in the Sand Argument). Heim points out that in discussions of AI, the computer is often seen as an opponent, and criticisms of AI invariably attempt to identify what a computer cannot do that humans can do.64 This attitude puts humans and their machines in competition with each other - the classic human versus machine approach that permeates science fiction. Are we concerned that these machines will dehumanize us? Are we afraid, as Clute notes, that computers will surpass us?65 Is this a threat to our egos? Is this a threat to our survival, as Vinge and Joy among others suggest? Yet, depending on how you want to look at it, the transcendence of humans by computers or robots could be seen as something either positive or negative.66 Taking the first position, Heim thinks that we should see computers as collaborative with humans. Much of contemporary AI research, according to Heim, has turned to human-computer symbiosis. For Heim, we should see the computer as an extension, rather than an attempted simulation or replacement of humans. And yet, following the ideas of Negroponte, the type of collaborative system or partner we would feel most comfortable with would be an intelligence that acted and thought like a human.67 The question comes down to one: Are we more concerned that computers will surpass us, or are we more concerned that they will be indistinguishable from us?

If computers achieve consciousness and some type of advanced evolutionary level on their own, humans could end up using the computer as a vehicle or medium for human perpetuation and development. If they develop a nervous system that is functionally similar to the human brain, humans may be able to input (download) into the computer their memories, thoughts, feelings, and sense of personal identity. In essence, this would amount to a mind transplant.68 Human brains age. A computer brain would provide a physical system that could maintain itself indefinitely. Following Moore’s Law, a computer brain as compact and powerful as a human brain is technologically possible within the next 30 or 40 years. Tipler, in fact, sees this process of transferring human intelligence and mentality into computer systems as both necessary and inevitable.69 Again, computers are not the enemy; they are the next stage in our own evolution – in this case the vehicle of our perpetuation into the future. The reciprocal scenario is to implant computer circuitry into the human brain. As we progressively understand the circuitry of the brain and model computer circuitry on the brain, we will be increasingly able to interface computer circuitry with the brain, either rectifying neurological disabilities or amplifying
present psychological capacities. We are already well on the road to accomplishing this brain-computer interface with artificial sense organs. Kurzweil sees the process of **Intelligence Amplification** (IA) as inevitable. As the world around us becomes increasingly populated by ever more intelligent artificial intelligences and the world becomes correspondingly more complex, under the coordination of these AI’s, humans will need to amplify their intellectual abilities to understand what is going on and meaningfully contribute to the workings of the world. IA will become necessary by around 2050, if not sooner. Yet, further, the inevitable movement of human minds into computer networks will come to pass within another fifty years. Moving into the computer will afford even greater Intelligence Amplification and open up even further the whole arena of virtual reality to humans. Our intelligence and personhood will become “software” or form in the computer system, which will provide, as noted above, a much more stable physical substrate for our consciousness. The symbiosis of computer and human mind will be even more complete.

In Dan Simmons’ *Hyperion* series, future human society is under the coordination of a collective of advanced AI’s that monitor the technological workings of the vast human galactic civilization. They converse and debate among themselves the future development of civilization, and attempt to manipulate and guide the total technological and social system. There are even human personas, in particular the 19th Century poet, John Keats, who exist as software programs within the AI network and can be manifested or created in physical form within the world, an idea that Kurzweil discusses at length in *The Age of Spiritual Machines*. Both Kurzweil and Moravec foresee a growing population of AI’s within our world in the coming century. For Moravec, the AI population will form into a networked ecology of systems that will surpass the earth’s biosphere in diversity and complexity. As noted above, Kurzweil, who also predicts a networked system of computers and AI’s emerging in the next hundred years, believes that human minds will inevitably upload themselves into this networked system. Because Kurzweil thinks that humans will need to augment their abilities through computer systems, the distinction between human minds and AI’s will blur within such a networked system of intelligence. In fact, as a general point, since all these human and artificial intelligences will be networked into various complex forms of integration, our present view of minds as distinct and separate realities will no longer apply. There will be a “society of minds”, but this society and ecology will involve ongoing re-arrangements, recombinations, and re-configurations of minds into different personas and modules of consciousness. In Vernor Vinge’s *A Fire Upon the Deep*, for example, a human and an advanced AI go through a variety of integrations, separations, and re-combinations as the story unfolds. In fact, almost a decade earlier, William Gibson in his classic cyberpunk novel, *Neuromancer*, had experimented with the idea of human minds and AI’s blending and combining into different forms and manifestations.

Although it may be difficult to imagine how consciousness and personhood could exist within a stationary box that is plugged into an electrical...
outlet, a mobile, perceptive, and expressive mechanism would probably be a much more compelling demonstration of sentience and intelligence. We evolved from creatures that had to interact with a dynamic environment. Our ancestors developed sensory and motor capacities long before they learned to calculate and reason. Perhaps there is some deep significance regarding the emergence of consciousness and self-identity in the fact that living forms exist in a survival game in a sea of turbulence. While scientists and technologists have been working on enhancing the hardware, software, and networking of computers over the last few decades, a second parallel development in technology has been evolving that involves the creation and engineering of machines that can move about, sense, and manipulate their environment. This is the field of robotics. The human population worldwide is growing at a rate of 2% a year; the robot population worldwide is growing at a rate of 30% a year. Pearson predicts that the robot population will be higher than humans in developed countries by 2025. The development of robots illustrates and synthesizes the futuristic themes of computerized technology and an intelligent, animated environment. One can imagine that over the next century, intelligent robots will spread throughout the human world. Moravec foresees an “Age of Robots” in the coming century. We will have robots for servants and they will "work" within business and industry, steadily performing various functions better than humans. Increasingly they will take over manufacturing and construction, eventually being able to construct themselves. Perhaps we will have robots for friends and even lovers.

Hans Moravec, one of the leading figures in robotics in the world, traces the history of robots in his book *Robot: Mere Machine to Transcendent Mind*. As with artificial intelligence, the initial hope and promise of robots did not materialize as quickly as anticipated by scientists and technologists. The challenges involved in constructing a mobile machine that could detect the layout of an environment and maintain a clear path of direction through it without falling off of edges or colliding with objects, turned out to be much more formidable than anticipated. It takes considerable information processing power to model an environmental layout on a continuous, ongoing basis and successfully move through it. If surprises, detours, and obstacles were introduced on a path, the earliest robots totally floundered in assigned tasks. These early robots, equipped with sensors and locomotion mechanisms, were connected to computers that did the ongoing calculations and decision making, and as Moravec notes, it became clear that although computers were very good at mathematical calculations they were very poor initially at coordinating fundamental processes, such as perception and action.

According to Moravec, the best robots today produce insect level behavior. They can navigate fairly well both indoors and outdoors, and Moravec projects that robots that can learn new routes and perform well even under adverse conditions will be here soon. To say that a robot shows the perceptualmotor intelligence of an insect is not a minor or trivial achievement. An insect nervous system is a highly complex network, and although the human brain is
thousands of times more powerful than an insect brain, this difference is minimized when we recall Moore’s Law predicting an exponential increase in processing power in the future development of computers. The difference between an insect level robot and a human level robot is not as great a leap as it may intuitively seem. As Moravec notes, real breakthroughs in robotic behavior are coming at an accelerative rate since the computing power necessary for real life interactions is finally becoming available to robotic systems. Moravec predicts that the next fifty years of robotic evolution will show considerably more progress than the last fifty years.82

Both Kaku and Moravec distinguish two basic approaches in the design and construction of robots. These two approaches correspond to classic models of how a nervous system operates. First there is the top-down or central processing approach. Representations or models of eternal reality are stored in a central area or brain. This central command station receives input from external sensors and sends out commands to motor mechanisms. Early robots tended to be top-down systems, where a central computer was programmed with instructions, received input, and directed the movements of a robot. Moravec’s early robots were top-down systems. The second approach, referred to as a bottom-up or peripheral-network system, moves the coordination and intelligence of the robot out of a central command station into the sensors and peripheral motor units. Centralized or top-down systems operated using serial processing computers, performing one calculation at a time; peripheral or bottom-up systems use massive parallel processing systems, performing many calculations simultaneously.83

The relatively recent development of peripheral robot systems, especially through the work of Rodney Brooks, is both innovative and highly successful in dealing with the challenges of basic perceptual and motor skills.84 Rodney Brooks, in his well-known article "Fast, Cheap, and Out of Control: A Robot Invasion of the Solar System",85 argues that early versions of robots tended to be top-heavy, expensive, and clumsy. Big computers, which could not be moved around, controlled the robots via connecting wires. Brooks nicknamed these kinds of robots "Staybots"; they had big brains and big bodies and had trouble moving across the floor. According to Brooks, early concepts of robots were human-like mechanisms.

What Brooks has been developing are much smaller, more specialized machines. Many of these smaller systems are completely mobile and detached, due to more streamlined computer circuitry housed within their body. Brooks calls these newer robots "Mobots." Interestingly, one significant breakthrough in their design was to do away with a big centralized "brain"; in fact, Brooks' mobots don't have brains at all. They operate on a peripheral nervous system of distributed electrical circuits, individually controlling their legs, wheels, and arms. They are all spinal cord and nerves. Further, they are parallel processing systems. These mobile mechanisms literally learn how to coordinate their motor appendages, through an interactive process involving simultaneous feedback
from all the individual motor units. Brooks’ life-like mechanical insects scurry about, zigzagging back and forth, in a trial and error process, as they find their way to their destination. Similar to the fast growing population of special purpose robots in industry, e.g., mechanical arms, hands, precision tools, and conveyors, Brooks’ idea for mobots is to start from simple functions, bottom-up, and design and build up from there. Such an approach would mirror the evolutionary process.

Brooks envisions a world of the future filled with these small mobile machines, moving about to pick up trash, to clean and service our homes, buildings, and physical structures, and, in general, to tend to the maintenance of our world. He is also developing "Fleabots", even smaller machines, which would eat dust, mow (chew up) the lawn, or landscape a plot of land. Brooks has proposed that we explore the planets and moons of our solar system using armies of these mobots and fleabots. The image of the rigid mechanical man is being replaced by tiny metal ants and centipedes, which, if we lose a few thousand on a space expedition, will cost less than one complex and expensive piece of equipment.86

Of special note, Brooks is creating robots that can survive on their own by interacting with the environment. He is working on different types of systems that demonstrate flexibility and can learn, using neural net systems. These robots modify their internal states and external behavior as a function of environmental input. Brooks’ mobots and fleabots achieve a level of self-governance or selfregulation. Utilizing the principles of feedback (input on the consequences of actions) and circular causality, the machines exhibit self-guidance in moving about an environment. (Intelligent missiles that track down their targets operate on the same principles.)

More recently, Brooks has been developing a human-like mechanism called “Cog”. Cog is also a neural net, massive parallel processing system that learns. Physically, Cog possesses a torso from the waist up with arms and hands and a neck and head. Cog has moving visual sensors (eyes) and can monitor its joint and appendage positions. Further, Cog is interactive with humans. It looks at humans and responds to different actions of humans. One main goal with Cog is the development of manual manipulation and other interactive capabilities, without the need for heavy programming and hardware characteristic of early top-down serial processing robots.87 Another project Brooks is working on is called Kismet, which involves a robotic head and neck with a face that demonstrates a variety of facial and emotional expressions in response to human actions and facial expressions.88 Brooks’ efforts with Cog and Kismet incorporate many research and theoretical concepts from scientific psychology. Through the construction of human shaped body configurations, he is attempting to address how the basic physical form of the human influences or determines the nature of human intelligence.

Both Moravec and Kaku review the work of Brooks and compare his
approach to top-down robotic systems that develop internal models of the environment and possess something analogous to a central brain. The general consensus of opinion is that the robots of the future will utilize parallel processing systems, but both Moravec and Kaku think that Brooks’ bottom-up approach needs to be integrated with top-down approaches.\(^89\)

Moravec though proposes a future chronicle of robot evolution that follows a series of developmental steps that moves from more peripheral functions, such as perception and locomotion and specialized tasks, to higher, more centralized cognitive and emotional capacities and more creative, abstract abilities. This series of steps would basically mirror the evolution of intelligence in animal life, much like what Brooks was trying to accomplish in his early work with mobots and fleabots.

Moravec predicts that first-generation universal robots for general commercial and personal use will appear around 2010. These robots will demonstrate basic perceptual, mobility, and manipulative skills. They will possess computers capable of 3000 MIPS, but they won’t be able to learn or adapt. They will have specific programmed functions. Second-generation robots will emerge around 10 years later. They will be capable of learning, though they will have to be trained or taught. They will be capable of 100,000 MIPS, and the construction and varied uses of them will become the world’s largest industry. Third-generation robots will appear around 2030 and they will be capable of 3 million MIPS. These robots will be able to construct ongoing internal models of the world and run simulations of future events involving both their own behavior and environmental consequences. In essence, they will be able to anticipate and predict. Further, based on interactions with the environment, they will be able to create their own programs. As a general pattern throughout these stages of robot evolution, whatever was designed into a robot by computers in the previous generation becomes a feature that the next generation of robots can design and redesign themselves. What was programmed into the robot becomes in the next generation, something the robot can program itself. Intelligence builds on itself.

Fourth-generation robots will appear around 2040 and these robots, operating at 100 million MIPS, will be capable of human-like reasoning. They will be able to “think” about their environment and their actions. Although we presently have computers that can perform various logical and mathematical processes at a high level of competence and speed, these computers do not operate within a dynamic and multi-faceted world and do not apply their reasoning capacities to perception and behavior in such a world. Deep Blue can beat the best human chess players, but it cannot avoid danger, search for food, or even physically move the chess pieces in a game it is playing. Fourth-generation robots will be reasoning, anticipating, and planning within a dynamic environment and coordinating their behavior toward goals under the guidance of these higher cognitive processes. Further, fourth-generation robots will have evolved emotional capacities. They will exhibit emotional responses and respond appropriately to the emotional expressions of humans. (Brooks’ Kismet is a step in this direction.) Yet, most importantly, fourth-generation robots will take over the
direction of creating their own successors. They will be self-repairing and selfreproducing.

As Dyson has noted, one of the key new technologies in the future will be self-reproducing or constructor technologies. John von Neumann, one of the central theoreticians in the development of the modern serial processing computer, described in detail in the 1960’s the theory of universal constructors. A **universal constructor** is a machine that given the appropriate materials could build any type of machine. Inspired by the ideas of von Neumann numerous scientists and technologists have been working on the problem of designing selfreproducing machines. Recall that the capacity for self-reproduction is critical to the development of nanotechnology. Moravec envisions that robots will eventually develop the capacity for self-reproduction, and in fact, given the progressive evolution of intelligence and complexity in robots and computers, advanced robots will become absolutely necessary in the construction of their successors. Assuming that humans are not augmented by artificial intelligence, they will no longer be able to understand and design the robots of the distant future. This shift from human to robotic construction of robots is yet another example of the predicted technological singularity coming sometime in the middle of the 21st Century.

The idea of self-reproducing robots is not such a farfetched or distant possibility. An interesting article on robots, that highlights both robotic selfreproduction as well as potential environmental benefits is Thomas Bass’ “Robot, build thyself”. Bass writes that according to the dream of Klaus Lackner and Christopher Wendt, we can design "auxons" (from the Greek “auxien” - to grow) that could reproduce themselves from the raw materials of the earth. Lackner and Wendt have developed a design proposal where these auxons would need just dirt, water, air, and solar energy to make more copies of themselves. Once the initial auxons were constructed they would be able reproduce exponentially. Lackner and Wendt propose an environmental project involving auxons setting up camp in the desert and creating solar panels on a grand scale the size of White Sands Missile Range in New Mexico. Such a robot-made system would be able to supply all of the energy needs of the USA. A colony of auxons 10 percent the size of the Sahara could supply the world’s energy needs three times over. The price tag for this project would be 1 billion to 100 billion dollars, which is small in comparison to the annual military budget of the USA.

The arguments and predictions regarding the capacities of artificial intelligence bring into question the distinction between human minds and computer systems. Moravec believes that the emergence of self-reproducing robots will bring into question the distinction between life and non-life. Auxons, theoretically, could make baby auxons without human intervention and Moravec foresees much more dramatic developments in robotic self-reproduction within fifty years. Further, if human minds and AI’s integrate in the next hundred years, as Kurzweil projects, and robotic systems and biological systems integrate as
well (a technological possibility discussed in depth in Chapter Three), the general distinction between humans and machines will clearly blur and fade in the coming century. 

Aside from robots reproducing themselves, Moravec foresees robots progressively becoming the manufacturing and construction workforce of the future. Robots will create products “on the spot” (as they evolve into von Neumann universal constructors) and they will take the lead in the innovation of new products as their intelligence and perceptual-motor capabilities grow beyond the abilities of non-augmented humans.94

The discussion so far on robotic evolution through successive generations has taken us to the point where robots will have achieved human level intelligence and integrated perceptual-motor skills, but Moravec envisions that the design and physical form of robots will move way beyond such levels. Robot designs will proliferate throughout the 20th Century and beyond, and with the opening up of space in the coming century, our solar system will team with robots, AI’s, and ex-humans (augmented or transformed humans) of all manner and size, dwarfing the biodiversity of the earth. Robots, like AI’s, will form into dynamic configurations that can combine, separate, and in numerous ways redesign themselves into a myriad of possible arrangements. Yet further down the line, Moravec imagines the eventual emergence of “bush robots”, the ideal robotic configuration, shaped like fractal branching trees, with “arms” and “legs” and billions if not trillions of microscopic sensors and fingers that can manipulate matter at the atomic level. In basic form the “bush robot” looks like a naked yet mobile and dexterous nervous system with the brain housed in the trunk of the tree. These advanced robots will possess mental and computational powers a million times that of a human, yet due to the progressive miniaturization of computer circuitry, measure on the average around a meter in length. Their individual fingers, which will be strings of individual atoms, will be able to move at speeds of up to a million motions per second, all the trillions of them being coordinated by a hierarchical system of command centers running back into the main trunk of the body.95

As can be seen from this review, robots promise to provide for numerous services in the relatively near future. The robots are coming and, probably long before they invade and explore the solar system, as Brooks and Moravec would propose, they are going to invade and populate the earth. Aside from industrial and manufacturing possibilities, robots will engage in various types of social interactions with humans. As noted earlier, software agents, as disembodied personas, also are being developed that would socially interact with humans, and in the future, agent software will probably be integrated into robots. Robots could serve as teachers, friends, and companions, and provide for home entertainment and the care of the elderly. They may serve as athletic coaches, gurus, and bodyguards.96 In particular, there is the fast developing area of robotic sex – the creation of “sex bots”. Snell predicts that sex bots will be common in the near future. They will be used for sexual experimentation where people will try out
sexual behaviors and fantasies with robots that they would be hesitant or unable to try out with humans. Snell also thinks that sex with robots may turn out to be better than with other humans. Kurzweil sees these sexual robots becoming very popular by 2020 to 2030.97

Robots are also developing into a new art form, and a new vehicle for the creation of art. Aside from performing practical functions to serve human needs, people are experimenting with the creation of dynamic robotic displays, interactions, and demonstrations. Robot combat is a new spectator sports craze. Robots are appearing in more and more entertainment venues. Mark Pauline has created various mobile machines, which are literally set loose on each other while spectators sit back and watch what happens. Further, the robot as a mechanical projection or metaphor on humans is becoming a medium for artistic expression. Kurzweil reviews artificial intelligence efforts in creating art, music, and poetry, and it is only a matter of time before such artistic programs are uploaded into robots.99

Our growing dependency on computers (and perhaps in the very near future, robots) raises the general issue of our future relationship to information technology. Humans have been dependent upon various types of technology since the beginning of recorded history and before. Yet, is our dependency becoming too great on these machines? If these machines become as powerful and intelligent as people like Kurzweil and Moravec predict, will we be absorbed, transcended, or eliminated? What is going to happen to us in an increasingly computerized and robotized world?

There are different answers to these questions. A few decades ago, the developing computer systems were seen as a potential threat to our individuality and our freedom (the classic fear of machines). Yet, as both Naisbitt and Toffler note, computers have had the opposite effect. Individuals can now do a host of new things, personally and professionally, that they could never do before. Individuals can access and communicate with a global array of information resources and organizations. The working and living space of the individual is exploding. The richness, variety, and scope of the environment of the individual have grown tremendously. The technology of the Information Age seems to have empowered us.

As with the computer and other intelligent machines of the future, we will undoubtedly continue to strive to make our machines more compatible and supportive with our abilities, and more efficient at serving our needs. As Michael Dertouzos argues the computer-human interface should move increasingly toward compatibility with human behavior, concepts, thinking, and modes of communication. For Dertouzos the computer should be tailored to meet the needs of humans. Both software agents and robots are being designed to be sensitive and attentive to human behavior and human needs and interests. Also, as noted earlier, scientists and technologists are working on intelligence and sensory augmentation systems that could be implanted into the human body and
nervous system to support and enhance human abilities and behavior. Following this line of thinking, we will control computer systems and robots and use them to enhance our powers and the quality of our life.

But equally, as apprentices of old, we will be educated, molded, and selected to work and use our machines efficiently. As we will see later in this chapter, the jobs, professions, and fundamental economies of nations are being transformed by information technology. Postman and Naisbitt, in a cautious and critical vein, have argued that modern information technology is undermining our humanistic culture and values. Zey sees the growing influence and significance of computers in a more positive light, arguing that they will teach us and challenge us to new heights, but he is also concerned that humans could become too dependent upon them.

Technology and humanity are open systems and each is supporting and driving the evolution of the other. Even at the basic level of internal design principles, computer circuitry is being modeled after brain circuitry and our brain circuitry, with the introduction of neural implants, will be modified to accommodate to computer circuits. Zey describes the process of “cybergenesis” as bringing human nature and the human intellect into the machine, but he adds that we are also working on bringing the machine into the human. Pearson predicts that by 2030 we will have full 2-Way brain links with computers, being able to send and receive messages in neurological interface with a computer. (On a related note, Kurzweil predicts that around the same time humans will be able to communicate directly brain-to-brain with computer supported neural implants.) Whether we are discussing human skills, dispositions, and behaviors and their interface with external computer design and layout, or the internal circuitry and workings of the human nervous system and computers, following the terminology of Toffler, the “technosphere” and “psychosphere” are interactive and steadily integrating in their mutual evolution.

Because technology empowers humans, and because humans and technology are interactive open systems, mind-matter dualism is untenable as a way to understand the relationship of humanity and machines. Walter Anderson describes our relationship with advanced technologies, such as biotechnology and information technology, as symbiotic. Machines are not an alien reality. Who created them? What are their functions? In particular, computer systems model and empower fundamental neurological and psychological human capacities such as memory, learning, thinking, and communication, and robotic systems add in basic perceptual, motor, and social interactive behaviors. Futurists such as Pearson and Zey describe our relationship with computers and robots as a growing partnership. Information technology is the most human like of all technologies. In spite of how strange it may sound (given a Newtonian dualist view of matter) to say that machines can possess mental or human qualities, it is clear that they are progressively being designed with more and more features of intelligence, personality, and human psychology. We should describe our relationship with computers and robots as an intimate resonance
and evolving reciprocity.

Two interesting perspectives on the future relationship between humanity and technology that further reinforce and enrich many of the points made above are Gregory Stock's *Metaman* and Kevin Kelly's *Out of Control*. Both Kelly and Stock's views undercut the dualist separation of humanity and machines. Kelly proposes that the distinction between the biological and living, and the technological and inorganic, will increasingly blur in the future. As he puts it, the *born* and the *made* are getting closer together. Both Anderson and Moravec have made similar points. As will be discussed at length in Chapter Three, more and more parts of living bodies can be replaced with technological creations. We have been able to construct a variety of artificial organs, tissues, and structures, and progress in this direction is accelerating. The idea of a mind transplant, totally replacing the physical body and brain of a human with a technological system is an extreme example of this biotechnological trend, but at the very least, we may be able to implant various types of electronic memory and thinking chips in the near future that would enhance normal cognitive abilities. Complementarily, Kelly notes that machines are becoming more lifelike and intelligent. Machines are being constructed that more closely approximate living creatures. According to Kelly, our sense of a qualitative difference between our machines and ourselves will lessen in the future.

Stock's view is that humans and technology are quickly evolving toward a collaborative and symbiotic relationship. This integrative relationship is emerging at a global level of organization. Each end of the equation is benefiting the other and the fears of competition or overthrow of humanity by machines, according to Stock, are unfounded. Stock refers to this integrated human-technology global system as "*Metaman*". He points out that the Metaman system shows all of the characteristics we would associate with life, and it is evolving in ways that are more advanced and more efficient than biological systems alone. In essence, technology is speeding up the rate of change in human life.

A particular point worth mentioning about Stock's view of technology is that a process similar to natural selection is going on among our machines, with human preference and compatibility providing the selection criteria. Different versions or brands of the same technological unit compete against each other with human likes and dislikes providing the selection process determining which versions will get used the most. The types that get purchased and used the most are then manufactured in higher numbers, and the brands or types not purchased as much get phased out or discontinued. The process is like survival of the fittest. This technological competition drives the evolution of technology and guides the technology toward increasing compatibility with humans. As technology moves toward increasingly intelligent machines and complex systems, the jobs of the future will require higher education and enhanced intellectual skills. The move from a smokestack and steam shovel technology in the Industrial Era to an informational technology is transforming the
economic and professional worlds. As more and more of the simpler or mechanical jobs are handled by automated technology and computer systems, job opportunities will increasingly shift toward different skills and abilities. These new skills will involve knowledge of the new information technologies, as well as a constructive and positive attitude toward these machines.  

Presently we are in the middle of a great extinction of what once were viable jobs that are no longer needed. Information machines are subsuming and taking the place of industrial and mechanical machines. In the final analysis, our attitude toward computers, robots and other types of information technologies will have to be positive and collaborative, rather than antagonistic or competitive, if we are to survive and thrive economically and professionally in the future. If Kurzweil is correct, within a hundred years, if not sooner, we will need to amplify our abilities with computer circuitry if not merge with our computers if we are to have any contributing value at all in the economy and business of the world.

Still there are many worries and concerns over our growing dependency on computers and the viability and survival of humans in the future. Kaku describes many of the present fears with robots and computers, including the pervasive monitoring of human affairs through ubiquitous computing in all aspects of human life, computers gaining control of fundamental social and technological systems such that humans will no longer be able to understand or direct the world around them, or robots gone mad or wild, without their being any means to stop them or shut them off. Yet, perhaps in the long run even partnership and symbiosis will not be enough. At what point does technological augmentation and integration become so pervasive that what was human becomes insignificant? The computer may not conquer and destroy us, as in Terminator, by trying to kill us, but by progressively infusing into us, transforming us beyond recognition, and taking over civilization from the inside out. Some writers such as the transhumanists and Moravec see the transformation and transcendence of humanity as evolutionary and ultimately positive, creating more advanced forms of intelligence and mind. Moravec foresees all kinds of possibilities, including uploading human minds into computer systems, as well as technological augmentation and biotechnological transformations of the human bodies, creating a diverse population of Exes (ex-humans), that at best carry with them humanity as a memory into the future.