

# Welcome to the 21st Century: The Uncharted Future Ahead

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## Introduction

The second half of the twentieth century was quite unlike any other 50-year period in human history. Radio and television brought instant news and entertainment from around the world to our homes. Computers emerged from the laboratory, were deployed in large corporations and universities, then came into the home, and most recently arrived in the palm of our hands (in the form of personal digital assistants and cell phones). The Internet and the worldwide web sprang upon us in the closing decade of the 20th century, and already a sizable fraction of the workforce (white-collar, blue-collar and even farmers) could not perform their jobs without them. Pharmaceuticals, vaccinations and advanced medical technologies have banished many diseases and causes of premature death from much (though sadly not all) of the world. And scientific research has continued its relentless advance, unveiling the secrets of subatomic particles, the extent of the universe and the digital code of life itself.

Needless to say, these developments have had profound impact on our social, governmental and religious institutions. Television and the automobile substantially changed our daily lifestyle. Now home computers, cell phones and telecommuting are changing our lifestyle again, except much more rapidly than before. Numerous institutions and customs, including racial segregation, male-only graduate programs and smoking in the workplace, have not been able to withstand the scrutiny of our modern age and have largely disappeared. National governments have been toppled in large part because modern information technology plainly exposed to the masses the indisputable fact that economic conditions and civil freedoms were significantly better elsewhere. Although regional conflicts continue, large-scale war has disappeared, certainly not because the technology to wage war is no longer available, but instead because the modern global economic system has made armed conflicts between major trading partners unthinkable [Friedman].

Obviously many problems have arisen along with the good. Environmental protection now has much more urgency than it did 100 years ago, as we have found that our expanding global economy produces trash, pollution and global warming as prolifically as it turns out goods and services. Madmen such as Osama bin Laden have proven to be as adept in using advanced technology as anyone else. The Internet has placed a huge wealth of information available on any desktop, enabling people to work and shop at home, but it has also launched epidemics of fraud, spam and pornography. Cell phones have facilitated an increasingly mobile and dispersed workforce, and have saved many a marriage, but they have also been used by terrorists to detonate bombs. Our global high-tech economy has greatly increased overall wealth (the U.S. gross domestic product, adjusted for inflation, has increased by a factor of 6.5 since 1950, with similar if smaller increases in many other countries), but millions have been left behind in poverty and ignorance, as starkly exposed to public view in the recent tragedies in New Orleans, Indonesia and Pakistan. Millions more, including many in the U.S., now fear being displaced in the rapidly changing world of global commerce. And numerous religious traditions have been challenged by the findings of modern science, requiring a re-thinking of belief systems, and spawning a backlash as exemplified by the recent campaign to replace conventional geology and biology with “scientific creationism” and

“intelligent design” in U.S. public schools. To many Christians, all of this is reminiscent of biblical prophecies of “wars and commotions” and “Men’s hearts failing them for fear” in the last days [Luke 21:9, 26].

What will the future hold? First of all, contrary to popular belief the current pace of scientific and technological advancement shows no sign of slowing down, and in fact is likely to accelerate in the coming years [Kurzweil, pg 7-30]. For example, even during the recent economic downturn, Moore’s Law (the doubling in aggregate power and capacity of computer chips every 18 months or so) continued unabated. It recently passed the 40-year milestone, and experts say that it is almost certain to continue for at least another ten years. Indeed, given some of the recent developments in the field of nanotechnology (the science of constructing materials and devices at or near the atomic scale), it is quite possible that Moore’s Law will continue for another 20 or 30 years, yielding computers and “smart” devices millions of times more powerful and capacious than the current state-of-the-art. And there is no shortage of suggestions of what to do with all that power – scientists and technologists are brimming with ideas for useful products and services, and venture capitalists are investing, not only in North America and Europe, but also in India and China.

Meanwhile, the field of biotechnology is taking off, promising an explosion of new advances in medical technology during the next few decades. These include effective treatments for a wide range of ailments and diseases, promising treatments for various forms of cancer, remarkable prostheses for numerous handicaps, and a trend to individually-targeted medication. What’s more, we are likely to see Moore’s Law-like phenomena in biotechnology, since much of this technology is now closely tied to computer technology. This is already true for genome sequencing – in recent years sequencing equipment has advanced even faster than Moore’s Law (this was the principal reason that the human genome project was completed ahead of schedule in 2003). The human genome required 15 years; at the present time, genomes of similar size and complexity are being sequenced in a month or so. The eventual goal is overnight service.

In general, we can expect that computer-based devices will eventually extend their reach into virtually every consumer product (including many that we cannot even conceive of now), and will continue to improve in intelligence and usability. Wireless Internet communication will soon be pervasive, and even more services will rely on it. A large array of pharmaceuticals and exotic medical technologies will treat many medical conditions with greater efficacy and fewer side effects than anything now available. Genetic manipulations will be used not only to correct existing medical conditions, but also to produce children free from certain inherited defects, and possibly with enhanced intelligence. Human performance, including physical endurance, reasoning power and memory recall, will be enhanced. Many common physical handicaps, including deafness, blindness, motor impairment and others, will be mitigated or overcome. Finally, significant extensions of human life will be achieved, not just by postponing the inevitable for terminally ill patients, but by actually slowing the aging process and overcoming many of its ill effects. In the U.S., we are already adding roughly three years to life expectancy every ten years; medical innovations in the works are expected to accelerate this trend. Within a few decades, even conservative observers in this arena are saying that 120-year lifespans will become commonplace. Others are boldly predicting 200-year lifespans or more by the end of the 21st century.

Did you feel flat-footed with the advent of personal computers, the worldwide web, cellular telephones, genome sequencing or sheep cloning? Are you afraid to ask your friends what a blog, JPEG, MP3, podcast, nanotube, ozone hole, stem cell or telomere is, because this might betray your ignorance of changing times? Unfortunately, no relief is in sight – many more new and bewildering innovations are in store. Indeed, the acceleration of change is likely to be the defining characteristic of the 21st century, and managing this change for good rather than evil and social mayhem is likely to be the defining task of the 21st century.

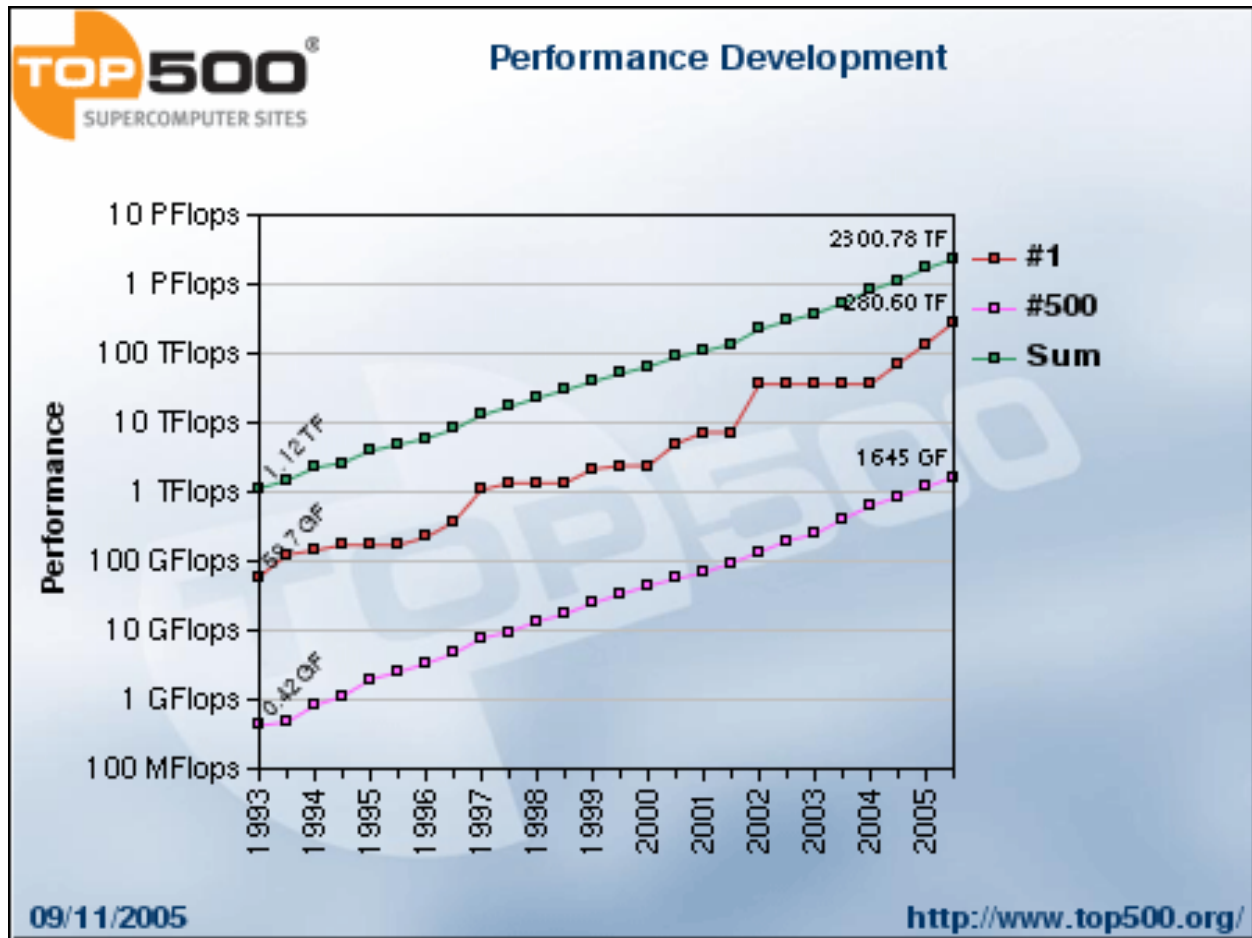
By the way, the terms above, along with many others, are all explained well at the “Wikipedia” (<http://www.wikipedia.com>), a volunteer-produced, Internet-based encyclopedia, another remarkable innovation of our times.

## **An Overview of Future Developments**

What I wish to do in this article is to briefly summarize some of these developments and then discuss the ethical, moral and social issues surrounding them. First, here is just a sampler of some of the amazing developments already in the works:

1. Advances in the field of nanotechnology (the design of devices and materials at or near the atomic scale) continue to confound skeptics who just a few years ago ridiculed the field as “cargo-cult” pseudoscience [Stix]. In just one of many recent developments, researchers at Hewlett-Packard have fabricated “nano-imprint crossbar” devices with half-pitch feature spacing of only 17 nanometers, which at the present time is five times smaller than the current semiconductor industry state-of-the-art. HP researchers are confident they can reduce this figure to four nanometers within two years [Kuekes][HP].
2. Carbon nanotubes, cylindrical-shaped structures of carbon atoms, are another striking nanotech achievement. A start-up company called Nantero soon hopes to have nanotube-based memory devices in commercial production, which they believe will ultimately replace many conventional memory devices [Nantero]. Equally amazing are recent demonstrations of nanotube-based circuitry, which has the potential of speeds and densities hundreds of times greater than silicon devices [Kurzweil, pg 114]. In a related development, ultra-thin sheets of nanotubes (each nanotube is only a few carbon atoms wide), have been produced by a process that is almost as simple as pulling scotch tape off a dispenser. Each sheet produced is 2,000 times thinner than paper and much stronger (per unit mass) than steel. Future applications range from strong, flexible, lightweight auto bodies to “sky hooks” for space travel [Peplow].
3. Large-scale scientific supercomputers, fueled by ever-more capable electronic devices, continue to advance in power. These systems are being used for many important scientific applications, including long-term simulations of the world’s climate, studies of nanoscale device physics, understanding the protein folding process, analyzing the exploding volume of experimental physics data, and designing future fusion energy systems. In the latest development, an IBM BlueGene/L system at the Lawrence Livermore Laboratory has achieved 280.6 Tflop/s (280.6 trillion floating-point arithmetic operations per second) on the industry-standard Linpack benchmark test. This system currently has 131,072 individual processors and over 32 Tbyte (i.e. 32 trillion bytes) of memory. Although many daunting technical challenges arise in these large

systems, including the need for a very fast interprocessor connection network and the need to reprogram large scientific programs to use parallel processors, researchers are confident in achieving 1 Pflop/s (i.e.,  $10^{15}$  floating-point operations per second) performance on actual scientific computations by 2008 or so, with improvements likely to continue at the same overall rate for years to come. See the chart below, which contains data from the Top 500 list, an updated ranking of the world's most powerful scientific computer systems [Top500].



4. Quantum computing, a futuristic computing technology based on quantum superposition, one of the most eerie effects of quantum physics, is steadily becoming more of a solid possibility for a small but growing class of computational algorithms. Scientists have already demonstrated the factorization of (small) integers using a quantum computer, and are now trying to extend the capability of these systems beyond tiny laboratory demonstrations [Kurzweil, pg 119-121].

5. Micro-electro-mechanical systems (MEMS) devices are rapidly shrinking in size and cost. They are already being widely used for air-bag systems in autos. Future uses include unobtrusive monitors for a wide range of environmental, transportation and safety systems [Citris]. They are also likely to appear in consumer products – imagine yard sprinkler pipes, for instance, which automatically notify the owner when an underground leak occurs.

6. The field of artificial intelligence (AI) is experiencing a renaissance in the field of AI, epitomized by the defeat of world champion chess player Garry Kasparov by an IBM computer system in May 1997 and the recent successful completion of a 132-mile obstacle course by several computer-controlled robotic vehicles [Markoff]. Although many are still skeptical, some scientists, notably inventor Ray Kurzweil, are now predicting that computers will meet or exceed present-day human intelligence (say as defined by the “Turing test”) in the 2030s or 2040s. After that? Things may get very interesting then [Kurzweil, pg 259-297].

7. Scientists now understand the structure of several major sections of the brain, and are now pushing forward to model in detail the operation of some of these features. In one effort, Swiss researchers are employing an IBM BlueGene system, one-eighth the size of the system mentioned in item 3, to simulate a 10,000-neuron section of the brain. They estimate that to simulate the entire brain will require perhaps 1,000 times this much computing power, a level that should be available at reasonable cost in 10 to 15 years [Morgan; Kurzweil, pg 290].

8. Some are concerned about the energy requirements of future high-tech devices. But energy consumption levels of computer devices (per unit of computing power) have been steadily declining. In addition, numerous high-tech alternatives to fossil fuels are being developed, including nanotech-produced solar panels (which promise to reduce cost by a factor of ten or more), fuel cells for autos and portable devices, and further improvements in battery technology [Yarris; Kurzweil, pg 246-247]. With regards to passenger autos, high-tech NiMH batteries are already being used in hybrid cars, and experimental “plug-in” hybrids have achieved 80 mpg or more in normal driving [Molloy]. Substantial improvements in energy efficiency are in store for many other products as well.

9. In the environmental arena, nanoparticles are being investigated for use in treating, deactivating and removing a wide variety of environmental toxins. For example, zinc oxide nanoparticles provide a particularly powerful catalyst for detoxifying chlorinated phenols [Kurzweil, pg 252].

10. Researchers doing work on technology for the handicapped now see a future in which physically impaired persons can regain much of their lost facility through high-tech, mentally controlled prostheses. Scientists have already succeeded in training a monkey to manipulate a robotic arm by thought alone [Monkey; Garreau, pg 19-20; Kurzweil, pg 194-195]. What’s more, it has been shown that long-term amputees still use patterns of mental signals to control their missing “limbs” that are entirely similar to those with real limbs, giving hope that this type of technology will be effective for them [Kurzweil, pg 308].

11. Large-scale computer simulations are now being developed to test drugs “in silico,” or in other words to model the effectiveness of drug agents using a supercomputer, for a wide range of possible human subjects. Some researchers believe that within ten years we will be able to eliminate the need for many of the tests and clinical trials now required, yet produce drugs with fewer side effects and dangers [KG, pg 27].

12. Advanced computer-theater visualization facilities are being adopted in the medical field, for example by brain surgeons who view tumors in three dimensions prior to surgical procedures, thus permitting more effective and less invasive operations [Utah].

13. Several remarkable discoveries have been recently made in the use of stem cells. Recently researchers announced that the injection of stem cells appears to have the potential of directly repairing some of the damage caused by spinal cord injury – partially paralyzed mice were able to walk again [Neergaard]. In another recent test, conducted jointly in the U.S. and Brazil, patients who were candidates for a heart transplant had stem cells from their bone marrow injected into the left ventricle of their hearts. In many cases, the damaged tissue regenerated itself, eliminating the need for the transplant [KG, pg 222].

14. Virus-induced expression of a human growth factor has reversed age-related changes in the skeletal muscle of mice. Increases of almost 30% in strength were witnessed in aged animals, compared with control subjects [de Magalhaes; Barton-Davis]. Along this line, mice at the Wistar Institute in Pennsylvania have the seemingly miraculous ability to regenerate limbs and regrow vital organs [Philipkoski]. Even more intriguing is the recent discovery that by genetically engineering mice to “overexpress” a certain gene, scientists were able to extend the lifespan of these mice by 20% to 30% [Kurosu]. Needless to say, there is considerable interest in the potential applications of these discoveries for humans.

15. Some remarkable cancer therapies are in development. The drug manufacturer Merck has developed and now tested a vaccine against human papilloma virus, thought to be the cause of 75% of all cervical cancer. Vaccines are in the works for other forms of cancer as well [Johnson]. Another approach that may be broadly effective against many types of cancer is through the use of “angiogenesis inhibitors,” namely agents that inhibit the creation of new blood vessels critical to tumor growth. There are now roughly 60 antiangiogenic drugs in various stages of development. These drugs promise to be much safer than standard cancer therapies, and may one day be taken to prevent cancers before they form [KG, pg 240]. Great strides are also being made in the early detection of cancer. A Harvard team has developed a chip to detect prostate cancer, using silicon wires just 10 nanometers wide. When as few as three or four prostate-specific antigen (PSA) molecules are detected, the device generates a signal. These devices are slated to become commercially available in 2007 [KG, pg 154].

16. Some exciting research is being conducted on a synthetic form of HDL (“good”) cholesterol produced by recombinant methods. In a phase one trial involving 47 human subjects, this drug resulted in dramatic regression of arterial plaque after just five weekly treatments. The small company that developed this drug has just been acquired for \$1.3 billion [KG, pg 207]. Another promising drug for reversing atherosclerosis is now being tested by Pfizer. It boosts levels of HDL by blocking an enzyme that normally breaks it down [Kurzweil, pg 217].

17. In the diabetes arena, researchers at the Children’s Hospital in Boston have discovered that two particular genes are changed when diabetes develops, thus suggesting effective treatment for child-onset diabetes [KG, pg 130]. In a related development, researchers have successfully attached insulin-producing cells to a microchip that can be implanted in the body to provide an adequate supply of insulin and regulated by a device that automatically monitors blood glucose levels. This

device, called by some the “holy grail” of diabetes management, is already undergoing clinical trials [KG, pg 130].

18. University of Michigan researchers are developing a bio-artificial kidney for cleaning blood. In a clinical trial, six out of ten critically ill patients, all but one of which had been judged to have no more than a 10 to 20 percent chance of survival, were successfully treated [KG, pg 193]. Researchers have also outlined a design for a replacement to human red blood cells that are hundreds of times more capable than biological blood in the critical oxygen-transport function, thus permitting many heart-lung patients to regain an active lifestyle. Replacements for white blood cells have already been developed, which devour pathogens much more rapidly than natural process [KG, pg 227].

19. A team at UCLA is building a “submarine” the size of a blood cell for performing critical medical maneuvers inside the body. The team has already produced a virus-sized vehicle that uses the body’s own ATP, a complex molecule that stores power, for energy. In a related development, virologists at Purdue have created a remotely guided “nanomotor,” and have guided the device to destroy a hepatitis virus [KG, pg 2]. Along this line, Johns Hopkins researchers have developed plastic polymer spheres that surround tiny doses of medications that can be inhaled, thus avoiding what is otherwise a difficult problem in today’s medicine – how to get advanced medication into the body without going through the gastrointestinal tract, which often dramatically decreases the drug’s effectiveness [KG, pg 27].

20. Scientists have identified seven broad categories of molecular and cellular difference between older and younger people (now termed the “seven deadly things”), which researchers are now actively attempting to understand and ultimately defeat: (1) a decline in the number of cells in certain tissues; (2) an accumulation of unwanted cells of certain types; (3) mutations in chromosomes; (4) mutations in mitochondria; (5) random cross-links between long-lived extracellular proteins; (6) an accumulation of chemically inert but bulky “junk” in our lysosomes; and (7) similar “junk” in extracellular spaces. Some progress has been made in most of these seven items [de Grey].

### **Ethical, Moral and Social Issues**

Recent discussion of future technological wonders frightens many people, and not just social conservatives, religious fundamentalists and anti-technology “Luddites.” Many scientists see vast potential for trouble, such as genetic experiments that go awry, nanotech “grey goo” that multiplies without bounds, robots running amok, computers smarter than their human masters, biotech experiments creating and destroying human life, etc. (insert your favorite science fiction scenario here). Computer Technologist Bill Joy has written perhaps the gravest warning of the dangers ahead in his widely publicized essay “Why the Future Doesn’t Need Us” [Joy]. He emphasizes not only the many dangers of technology running amok, but also the possibility that future intelligent systems may increasingly deal with humans as mere “pets” – amusing companions, but no longer a vital, decision-making part of the operating world. Even inventor Ray Kurzweil, one of the more optimistic observers in this arena, has soberly discussed some of these dangers in his latest book [Kurzweil, pg 391-424].

Even if major disasters can be avoided, there will be many difficult issues to confront, notably the potential for social, economic and international strife, and the continual challenge to make these advances available to society in a reasonably democratic way. But some argue that only by aggressively exploiting these and other advanced technologies can we hope to overcome the daunting challenges we now face worldwide, where hundreds of millions lack sufficient food, decent housing, health care, energy, education and a livable environment. Indeed, these issues are dividing the political landscape in a new dimension, as observers of widely disparate backgrounds and political stripes can be found on both sides of the debate [Hughes, pg 107-184].

If there is one thing that these scientists agree on, it is that many of these developments are unstoppable. For example, how will anyone be able to convince some handicapped person that he/she cannot take advantage of some promising new thought-controlled prosthesis, just because a few nonhandicapped bluesnoses are concerned about “ethical issues” of such technology? Also, how can anyone convince poor farmers in rural China that they should not use a new strain of nutrient-enhanced rice that will enhance the health of millions, just because some amply-fed Americans and Europeans are nervous (without much scientific basis) about genetically modified crops? You can’t. So the best we can do is to manage these changes: thoughtfully consider the dangers, insist on thorough testing, and then carefully monitor the results. At the very least, we need to judiciously pick our battles – a knee-jerk opposition by some group to everything new and different will only identify that group, in the public view, as an opponent of progress.

We have already seen ethical concerns expressed in the area of stem cell research – critics assert that destroying a collection of stem cells is tantamount to destroying a human life. As a result, the U.S. Congress has blocked most federal funding for stem cell research. The Catholic Church, among others, has opposed stem cell research for the same reason. In response, some states, such as California, have initiated and funded their own stem cell research programs. However, scientists have now demonstrated a way to derive stems in mice without destroying the mouse embryos [Wade]. This development, if doable for humans as well as mice (which seems likely), will answer most if not all of the current ethical objections for this very promising research arena. In any event, it is clear that this sort of issue will be thrust on society over and over again in the coming years.

Writers such as Garreau and Hughes have examined a number of these issues, including the following [Garreau; Hughes]: (1) How can we prevent advanced technologies from falling into the hands of those who might use them for evil purposes? (2) How can we encourage constructive uses of new technology, and yet discourage unethical uses (such as “designing” a deaf child), without severe restrictions on individual freedom? (3) How are we going to handle the economic divide between those who can afford exotic technology and those who cannot? (4) How are we going to finance the medical and pension costs of an increasingly aged population (even if many of these people will be able to continue doing productive work)? (5) How can we avoid society becoming so conservative and risk-averse (due in part to the many older citizens) that any substantive changes or new initiatives are not democratically possible? (6) How will “enhanced humans” and “conventional humans” peacefully and respectfully co-exist? (7) What type of governmental system will be best in this environment? (8) How will religious movements adapt to these changes?

One thing that is clear is that education must become a top priority, and not just for youth but for adults as well. Sadly, education in the U.S., while somewhat improved over past years, is still mired in mediocrity. In an international study, 44% of eighth-graders in Singapore scored at the most advanced level in mathematics, as did 38% percent in Taiwan, but only 7% in the U.S. American 15-year-olds are also below the international average when it comes to applying math to real-life tasks [Friedman, pg 272]. The U.S. cannot continue to rely on a steady stream of bright students from Asia to make up this education deficit – many of these talented young people now see comparable opportunities in their own booming economies. What’s more, we now face the reality that in the dynamic global economy, workers will have to re-educate themselves several times in their careers, and careers will last longer due to longer lifespans. At present, we are completely unprepared for this type of large-scale adult education.

Along this line, many are concerned with the ethical and environment problems of a worldwide population that will be living significantly longer, due to progressively improved medical care. However, writers such as Max More point out that attempting to limit population by opposing available medical technology is not only unethical, it is also largely ineffective, since, in mathematical terms, longer life has no effect on the exponential growth rate (it matters little how long we live after we have reproduced). What’s more, one consequence of our increasing wealth and educational opportunities is that the world fertility rate has dropped dramatically since 1950, from five children per woman down to about three, with even steeper declines in developed nations. As a result, the latest United Nations estimates are for the world population to level out at approximately 9.5 billion, a significantly lower figure than earlier feared [More].

Joel Garreau argues that the single most significant issue we will have to face in the coming century is the fundamental question of what it means to be human [Garreau, pg 229-265]. Will we define “humanity” based on our current (early 21st century) biology and psychology? If not, what aspects of our bodies, minds, emotions, art, religion and aspirations constitute being human? If we gain power to change human personality, are there some aspects of human personality that would be better cast aside (such as predilections for violence, domination and mental illness)? At what point will computers and robots merit civil rights and legal protection? Will we baptize our computers and robots (provided they are waterproof)? Such questions may seem amusingly futuristic at the present time, but in the not-too-distant future they may be major items of public discourse.

## **Conclusion**

In spite of the many dangers and challenges, there are numerous reasons to be optimistic about the future. Certainly one of these is the possibility of significant life extension, living in an environment when worldwide knowledge (both of our own world and the universe as a whole) is growing without bounds. This is reminiscent of the biblical passage “and now nothing will be restrained from them, which they have imagined to do” [Gen 11:6].

Along this line, Marc Geddes has observed that the desire for immortality “is one of the deepest, most enduring dreams of humanity.” He argues that not only is the quest for immortality morally good, it is in fact the very foundation of morality: “Rational people understand that actions have consequences. A life of crime may help a person in the short term, but in the long run it may get

you killed or imprisoned. ... People are more likely to be moral when they understand they will have to face the consequences of their actions in the future. It follows that the further into the future one plans for, the more moral one's behavior should become." [Geddes].

Albert Schweitzer once wrote:

Affirmation of life is the spiritual act by which man ceases to live unreflectively and begins to devote himself to his life with reverence in order to raise it to its true value. To affirm life is to deepen, to make more inward, and to exalt the will to live. At the same time the man who has become a thinking being feels a compulsion to give to every will-to-live the same reverence for life that he gives to his own. He experiences that other life in his own. He accepts as being good: to preserve life, to promote life, to raise to its highest value life which is capable of development; and as being evil: to destroy life, to injure life, to repress life which is capable of development. This is the absolute, fundamental principle of the moral, and it is a necessity of thought. [Schweitzer, pg 157].

The hope for a better future has been a driving force for mankind from its inception. French theologian Pierre Teilhard de Chardin argued that human progress was inexorable, virtually mandated by the laws of the universe. He further saw the idea of progress as the one theme that could re-unify science and religion: "To incorporate the progress of the world in our picture of the kingdom of God ... would immediately and radically put an end to the internal conflict from which we are suffering." [Teilhard, pg 96].

One way or another, the future is coming. Whether it will be hellish or heavenly will largely be up to us. Welcome to the 21st century.

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