

Designing Human 2.0 (Transhuman) – Regenerative Existence

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ABSTRACT

This paper explores regenerative existence for Human 2.0 – the transhuman. In building this focus, the author addresses the use of emerging technologies as propitious in designing the amended, extended, and suspended human body. Here, a first focus covers emerging biotechnologies for regenerative existence, which play a large role in extreme life extension. A second focus covers the digital technologies for enhancing realities, which will play a vital role in our adapting to immersive environments. In bringing these methods together, this paper concludes that the concept of designing a future human body is not only plausible, but will be in high demand around the year 2025.

Keywords: body, NBIC, regenerative existence, transhuman

INTRODUCTION

The biological design of the human being has been a mainstay for over two hundred thousand years. Recently, over the past one thousand years, a gradual augmentation of human physiology has taken place. History marks 600 BC as the beginning of prosthetics in nasal reconstruction of bone marrow, 1267 as the onset for magnifying lenses in enhancing vision,¹ and 1549 as an early attempt at inventing an artificial eardrum for aiding audition (Banzer, 1640).

Modern and future augmenting of human physiology calls for a strategy that incorporates a reasonable appropriation of science, technology and medicine. Within these spheres of influence, design concepts and theoretical narratives suggest how to safeguard what is decidedly crucial for humanity: health and well-being. The potential to overcome diseases that cripple physical and mental abilities, the potential to overcome ignorance and prejudice that cripple understanding and knowledge, and the potential to overcome dogmas that stand in the way of progress, are some of the narratives driving the sciences and technologies forward.

In providing a palatable design in augmentation of the near future Human 2.0, or transhuman, my focus is on what I call *regenerative existence*. Regenerative existence means the regenerating of cells that would otherwise succumb to disease and die off. Regenerative existence for humans means that the cells forming the body's systems – skeletal, muscular, organ, and central nervous system, which includes the brain – are regenerated. Thus, the entire human body becomes a system of regeneration through careful development and cautious use of biotechnological methods, such as stem cell therapy, and other applications of science and technology mentioned in this paper.

YEAR 2025 – HUMAN 1.0 TO HUMAN 2.0

Affecting the historical Human 1.0 is a symbiosis of events in the spheres of technology, science and medicine. Such events are accelerating change at varied speeds and in multiple directions. As a result, the human future may not be as biologists and paleontologists once thought, or as geneticists and experts in evolutionary theory have suggested. Our future may be the result of the very tools which brought computers, the Internet and artificial life to the forefront and which now are designing artificial intelligence, nanorobotics, synthetic environments and biosynthetic life.

This paper explores the amended body, extended body and suspended body within the time frame of 2008–2025. It covers some of the emerging biotechnologies for regenerative existence, which play a large role in extreme life extension, and covers some of the digital technologies for enhancing realities, which will play a vital role in our adapting to immersive environments. Further, no one field of expertise can solve the riddle of our future human. The future must be contemplated and explored through a transdisciplinary approach and toward a practice of open-ended evolution. In weaving these methods together, this paper notes that the concept of designing a future human is not only plausible, but will be in high demand around the year 2025. The appeal of Human 2.0's regenerative existence will increase exponentially as substantial

and reliable methods, tools and products become available, and as augmentations develop at ever-lower costs to society to benefit people worldwide.

THINKING ABOUT HUMAN 2.0 – AMENDED, EXTENDED, SUSPENDED

From the bevy of noted scientific accomplishments, front-page news articles, best-selling books, and televised programs on biotechnology and our human future,² it has become necessary to question what all the fuss is about. While many are intrigued and curious about the future human, others may find it peculiar and even frightening to engineer the human body and brain.

To preface this paper's position, it suggests one particular unambiguous concept: that the human as we know it today is not adequately equipped to sustain and survive in the future. While we are constantly seeking medical care to overcome disease and injury, it is a downhill battle as long as the body is ill equipped to overcome such obstacles. This paper supports the human right to augment as an ethical decision and to improve, to extend and augment our bodies and to protect life as fundamental rights. Dr Anders Sandberg at the Future of Humanity Institute, Oxford University, expresses the idea of "Morphological Freedom"³ as a right to modify one's body. He draws on the right to seek happiness and right to life as influencing the right to freedom, which influences the right to property and the right to one's body, which directly influences the right of morphological freedom.⁴ Further, Sandberg argues that:

A strong negative argument, possibly the most compelling argument for the acceptance of morphological freedom as a basic right that may not be infringed, is to protect from coercive biomedicine.

Many have expressed fears that technologies such as genetic modifications would be used in a coercive manner, enforcing cultural norms of normality or desirability. Preventing the development of technology cannot hinder this efficiently, since the technology is being developed for a large number of legitimate reasons on a broad front in many different cultures and jurisdictions. But misuse can be prevented by setting up strong ethical safeguards in our culture and institutions. (Sandberg, 2001, p. 24)

As such, morphological freedom as a human right to augment may be a crucial basic right to safeguard. As he states, "[i]f it is widely accepted that we have the right to control how our bodies are changed both in the positive sense (using available tools for self-transformation) and in the negative sense of being free to not change, then it becomes harder to argue for a compulsory change".

Humans have the intelligence and compassion to make this next stage of our existence a necessary and beneficial undertaking, not just for the opportune but decidedly for everyone who wants to augment and to extend life. Such decisions must be based on reasonable assessment of technologies and social protocol, as well as risk management and a balanced approach to the pros and cons of implementation.⁵

AN IMPULSE BEHIND DESIGNING HUMAN 2.0

"Humanity 3000", a yearly symposium endorsed by the Foundation for the Future, posed one question to a group of prominent thinkers at the beginning of the twenty-first century: "What are the factors that are most critical to the long term survival of humanity?" during the next few years, the next decade, and the rest of the first century of the millennium. Evolutionary biologist Dr Elisabet Sahtouris responded by quoting vaccine inventor Jonas Salk: "I now see the major shift in human evolution is from behaving like an animal struggling to survive to behaving like an animal choosing to evolve".

German philosopher Arthur Schopenhauer (1788) expressed this fundamental force in his cardinal principle that the "will to exist" is at the bottom of everything (Mencken, 1982, p. ii), that intelligence is a secondary manifestation of this primary will, and that every individual is the embodiment of a "will to live" which motivates every action with the sole purpose of survival (Mencken, 1982, p. 63), and "[T]hat the ever dominant and inherent impulse in all living beings, including man, is the will to remain alive – the will to attain power over those forces which make life difficult or impossible" (Mencken, 1982, p. 63).

Ten years ago, I designed a future Human 2.0 prototype,⁶ which was conceived by assessing the future potential of emerging technologies (NBIC + 7). Several of the applied design concepts originally influenced by NBIC+ experts and researchers are slowly coming to fruition and may eventually help to safeguard human existence. Regardless, humanity's current state of affairs concerning health and well-being are simply not good enough.

HUMAN 2.0 INTERNAL BODY – AMENDED

On a personal note, there is much I would like to change about the internal body. Nonetheless, given the time frame of 2025, I am adjusting my wish list to what is practicable, based on where technological advances are heading and where foreseeable trajectories lie. Looking at what I call the *Human 1.0* body, it is easy to see why we are in dire need of a body that can self-repair.

For humans to self-repair, we will become physically regenerative. We will perpetually regenerate worn-out cells, turning diseased cells to operative

cells. The field of biomedical engineering will do this by repairing damaged tissues and organs in vitro. Human 2.0 will have such options as reprogrammable blood, neurologically stimulated robotic prosthetics, regenerative organs, DNA-sequenced personalized genomics, synthetic chromosomes, and biocompatible nanorobots for repairing cell damage. We will expand our identities into simulated environments, such as immersive VR, with enhanced cognitive and sensory capabilities. We will explore enhanced communications through invisible wearable computers and neural extensions. We will experience highly sophisticated, immersive environments, resulting in expanded perceptual abilities. Finally, Human 2.0 also needs a safety net. The best safety net for the next few decades is cryonics, which will be, for Human 2.0, socially recognized as an acceptable alternative to death.

Regenerating the body Organs and limbs

As of 17 October 2007, there were 97,706 individuals waiting for an organ transplant in the United States,⁸ at least 2 million patients in China (Feng, 2006), more than 1700 in Australia, and 50,000 in Latin America (Saletan, 2007). "The organ shortage is getting worse, not better", claims the director of Organ Transplantation at Massachusetts General Hospital, Dr Jay Vacanti (Sternberg, 2002). In 2002, it was estimated that 70,000 people die each year due to a lack of organs for transplantation, and even those who do receive transplants die from complications, such as rejection of the new organ.

Human 2.0 will be able to repair, regenerate and replacing internal organs. In fact, the likely scenario in addressing the impoverished need for organs is to use xenoplantation, the therapeutic use of living animal tissues whose DNA is closest to our own. Nevertheless, why use pigs when we could clone our own non-differentiated cells to grow our own organs, and which would have the least amount of rejection? Such cells could be stored in liquid nitrogen until a time when a replacement organ is needed and then grown on demand. It seems plausible that growing our own organs would be far more ethical and respectful of animal life forms, and certainly would far surpass the potential rejection of interspecies cell exchange.

For example, a salamander has the natural capability to regrow its appendages. Unlike mammals who produce scar tissue at injury, the salamander forms a blastma which multiplies and re-evolves into specialized cells to construct a limb or other body part where it is relocated.⁹ Dr Anthony Atala, of the Institute for Regenerative Medicine, has grown a bladder from tissue cells of his patient's own bladder by scaffolding and molding the tissue into the shape of the bladder and then training the cells to take on the form and characteristics of the bladder.¹⁰

Rather than growing our organs, another approach is to use non-differentiated stem cells that do not bear the burden of ethical concerns. Such non-differentiated stem cells have been found in the body's adipose tissue. In February 2006, surgeons at Gregorio Marañón hospitala, Madrid, Spain, were successful in taking stem cells from adipose (fat) tissue and injecting the cells into a patient's heart to repair his damaged coronary arteries (Fuchs, 2007).

Alan Russell, Director of McGowan Institute for Regenerative Medicine, considers the future of organ degeneration is to regenerate organs, rather than replace them.¹¹ One future for Human 2.0 would be to regenerate internal organs continually through cellular therapy by importing stem cells into the body and training these stem cells to regenerate the differentiated cells of a particular organ. By 2025, we will be regenerating all organs, including our skin. The caveat, according to Russell is that we "[n]eed to get the cells to the right place at the right time" (Russell, 2007). The advanced stage of regenerative medicine is not a solo act. It becomes a multidisciplinary process incorporating genetic engineering, and advances in diagnostics and MRI scanning, and in vitro transport systems to get the cells to the right place. If the goal is to get the organs from an aging state to an asymptomatic state, one might have to have stem cells for breakfast, lunch and dinner. In that most of us take a daily vitamin, in the coming years we may be inclined to take a daily dose of stem cells, programmed to distribute themselves throughout the entire body. With investments in regenerative cells, this is a possible solution to aging organs.¹²

Spine

Evolutionary biologists claim that the human body was not designed to walk upright and walking, sitting and bending have caused our species to suffer from spine degeneration. It is estimated that 2.5 million people worldwide are paralyzed because of spinal cord injury, according to the International Campaign for Cures of Spinal Cord Injury Paralysis (Zelling & Ely, 2007). The yearly incidence of spinal cord injury (SCI) "is approximately 40 cases per million population in the U.S. or approximately 11,000 new cases each year",¹³ according to the Spinal Cord Injury Information Network.

If our Human 2.0 is a self-regenerating human, then diseases and injuries that affect the spine will be resolved through regenerative therapies. Scientist Hans Keirstead at the University of California, Irvine, leading research and clinical trials in gene chip and molecular analyses of hESC (human embryonic stem cells) (Philipkoski, 2007), has accomplished one large step toward this in his embryonic stem-cell treatment of rats. Keirstead injected embryonic stem cells into paralyzed rats' spinal cord, restoring inoperative SCI signals.

“The use of biologic material in spine surgery has been one of the most exciting developments in spine care and continued research will bring many of these projects into the market place in the future”, said Dr An.¹⁴ The biologic technologies, materials made from living organisms for the purpose of curing and preventing disease in humans, are intended to repair degenerated vertebrae and discs. Instead of fusing bone or inserting prosthetics replacements, cell-based therapy of bone morphogenic proteins (BMP) will be used. Along with gene therapy, the BMPs will stimulate bone growth and new cell differentiation to repair spine degeneration and regenerate bone growth. Further, since the spine is the core of the central nervous system, new nerve cells will be grown and trained to reconnect to the spine and to the brain.

Nano-regenerative body

If Human 1.0 is considered a wet machine, Human 2.0 could be considered a moist computer and emergent technologies are hacking its code and tweaking its settings. One of the most exciting changes to the human body is the use of nanomedicine to repair cell damage. Nanomedicine, according to Robert Freitas, “is most simply and generally defined as the preservation and improvement of human health using molecular tools and molecular knowledge of the human body” (Freitas, 2007). The presence of hundreds and thousands of tiny nanorobots in our bodies does not sound inviting, but when we consider that a human cell is like a tiny computer, programmed to perform a specific or set of specific instructions, it becomes a bit more comforting.

Human 2.0 external body – amended

In fact, if we look at how accelerating change has had a huge impact on all spheres of life, it becomes less baffling to visualize how these changes are going to affect humanity. Computers have doubled, tripled and quadrupled in size and power in the last 15 years and this effect, and residual effects, on humans’ man–machine augmentations have really just begun to get interesting.

Already the external body amends with robotics, AI and engineered prosthetics with sensory capabilities, such as Proto 1 developed by the Defense Advanced Research Projects Agency (DARPA). Soon thought-controlled, bioactive materials will be bonded directly to bone as skeletal attachments and mimic personal behaviour. However, thought control is one thing and actual action is another. For an amputee to have to expend 30% more energy to propel a prosthetic limb is adding angst to injury. Human 2.0 will not only have a seamless fusion of biology and robotics; the trend is toward self-generating, energy-efficient prosthetics.¹⁵ The next-generation rocket-powered mechanical arm, also funded by DARPA and headed by Michael Goldfarb, a roboticist at Vanderbilt

University in Nashville, is more powerful, more dexterous, longer lasting by virtue of not being powered by batteries, and is even quieter than current prosthetic arms. In fact, it would display other biological attributes, says Goldfarb, “The prosthetic device will also give off steam as a byproduct of use, so it would be the first prosthetic device to actually ‘sweat’ like a person’s normal arm, with the right kind of plastic covering” (Christensen, 2007).

The external body has more in store in enhanced prosthetics. While neuroprosthetics is concerned with using artificial mechanisms to replace damage to the nervous system and sensory organs, the brain–computer interface (BCI) will extend brain functions beyond the body (Vita-More, 2006a). If we consider a prosthetic to be an artificial extension and human performance enhancement, then the Internet could be viewed metaphorically as an extension prosthetic.

HUMAN 2.0 – EXTENDED BODY

Cyberspace has been catalytic in extending our bodies across space and across time. Norbert Wiener’s writings on cybernetics have inspired generations of computer enthusiasts and theorists, especially Human 2.0 purveyors. It has been suggested that extending ourselves into digital media is a dualist version of our future personhood – that we are without a material body in an interactive cybernetic system. This would be like using the body as a service provider for the mind and its cognitive expressions processing information and reacting to information. The extended body is not just a matter of cybernetics. It is also involves physics and metaphysics as it relates to the idea that all information and essence exists within or on some type of substrate, even if that substrate is consciousness or mind (Vita-More, 2006b). This is one issue that propels debate on the idea of an extended body. Other issues concern a pragmatic approach to identity and self as they relate to what form to use for communication and transportation in synthetic and virtual environments.

This form is known as the human-controlled avatar, which is a graphical representation of the user. Avatars of all sorts of sizes and shapes can be found in Second Life, the Internet’s most frequented simulated environment, and are part of cyberspace’s social feedback loop. This behaviour is what I call *distributed embodied information*, with the caveat that the body is any structure, shape or form through which we exchange information and feelings, including sensorial exchanges. While the avatar and the simulated environments are in an embryonic stage, the potential is enormous for actually providing enhanced realities as alternatives to real-time environments. Herein biological materiality does not necessarily mean the known

human body, as it can be a hybrid avatar form comprising NBIC+ existing in synthetic realities and expanding perceptual experiences.

Immersive environments

Human 2.0 will enjoy immersive environments distinct from VR. Like VR, an immersive environment is an artificial, interactive, electronic, computer-based world. Unlike VR, the immersive environment induces interactive and generative experience design, making our experiences more portable and interconnected with all our senses intact. The experience of being in an environment with a digital body, sans our physical body, is going to change how we view our own personhood as we become familiar within distributed, immersive experiences.

“The user, by virtue of being inside the computer, does not form the otherwise obvious preconception that he or she is interacting with a computer. The primary functional difference between body-mounted VR schemes and immersive environments is that VR tries to replace conventional perceptual input with alternate, computer supplied perceptual material, where immersive environments endeavor to complement the conventional environment, or at least to replace particular objects and actions within the present environment” (Lombardi, 1994).

In simulated environments, Human 2.0 will be living side by side with synthetic intelligent agents. Not only will this interplay redefine human lines of personhood, it will also increase human spatial awareness and perception due to the immersive integration of virtual and human-centered environments.

Agency

According to cognitive science, agency is the process of acquiring, interpreting, selecting and organizing sensory information. Human agency is our capacity to make choices and enforce our choices and, thereby, profound understanding, good judgment and deep insight are thought to be humanity’s noblest goals.

Over the eons, humanity has been struggling with the attainment of enlightenment. At the heart of this mission or calling, varied and sundry practices have been explored to bring human consciousness to a state of peace of mind and unconditional benevolence. In deference to each belief system, it is a noble quest. Nevertheless, our humanity is often swept aside when personal gain is within reach. Human 2.0 has a high probability of developing a more integrated and insightful relationship with him/herself and with others. Experiencing immersive environments as readily as experiencing daily life may tip off a paradigm shift in our perceptions and how we acquire, interpret, select and organize information.

HUMAN 2.0 SUSPENDED

Human 2.0 will not be so easily provoked and pushed into death. Baby boomers want to live longer, healthier lives. By 2025, baby boomers will be in their sixties to seventies and, with the aid of regenerative medicine, it is likely that Human 2.0 will be a youthful, active and sexy senior citizen. However, in order to prolong life for the long haul, cryonics may be the best alternative to deter disease and the eventuality of death. It is probable that cryonics will not have reanimated a patient by 2025. Reanimating a patient will require advances in nanotechnology, and especially nanomedicine, which may take several decades to master. Regardless, cryonics is making slow but steady progress in its research and development, in its technology and methods of suspending a patient. Cryoprotectants are becoming more effective in dealing with cell damage due to exposure to liquid nitrogen. Because cryonics has faced scientific and social scrutiny, the public’s acceptance of suspending life until a feasible and reliable technology is developed affords great concern. It is my projection that cryonics will become more mainstream as soon as social engineering brings society around to accepting the eventuality of extreme life extension as being more than a pipe dream or a trend but, rather, a viable decision to live longer. Even the concept of death is undergoing change. Years ago, a person was considered dead if he stopped breathing. Later, death was agreed on when a person’s heart stopped beating. More recently, death was based on cessation of neocortical functioning. Tomorrow, according to transhumanist philosopher Max More, death may be considered as “the irreversible loss of personality/identity” (More, 1999).

Modern science suggests we are in an invariant, unchanging state of being for long periods of time. To a proponent of assisted evolutionary choice – whether Darwinian or morphological – we are matter-in-motion. But human nature is complex. How much and what kinds of influences does genetic predisposition toward behavioural patterns make? How much and what kinds of influence does ethical anthropology affect how nature and humanity are bound together in shaping the foundations of culture – unique customs and traditions, how we live and survive?

Western civilization would weigh-in differently on human nature when compared with African cultures or West Asian cultures, or even the American Indian cultures. Aristotle thought that telos¹⁶ of human nature is the ability to reason. Kevin Kelly, founder of *Wired*, thinks that we are hackers, and it is our human nature persistently to hack away at our future.¹⁷ Yet, what appears to be a commonality within and between cultures is a desire to endure and an ability to adapt – no matter how fast or how slow.

If we agree that continued existence is one fundamental, shared characteristic of human nature, based on genetics and also acculturated, then we can find more evidence that the methods of staying power change over time and are unique to cultures throughout the world.

There are various views on a future human condition, such as its lack of dignity and human nature¹⁸, unfeeling cyborgs or disembodied data. These opinions are incomplete and represent, in large part, ideological views and personal preferences rather than a whole interpretation of a current condition, technological changes, the needs of society, and human ingenuity and a fundamental characteristic of human which is known in the Western world to strive to do “good” and make things “better”. While there are many highly qualified and sophisticated minds who reverently discuss human potential and the consequences, there are others (Fukuyama, 2002) who contend that tampering with biology would irrevocably endanger our human nature. Some (Hayles, 1999) are concerned that we will become bits of information without a body hanging around in space. And yet others¹⁹ (Smith & Morra, 2005) see us as chimeras – beings without a species identity – confused outcasts. And, further, there are alarmist pessimists (McKibben, 2004) and those who think humans are instinctively malicious who are driving by fear of a “monster inside”.²⁰

Regardless, a key question ought to be: What is the most consequential and universal characteristic of a human? An underlying element found in human nature over time has been a deliberate attempt to survive and defeat death, nevertheless forever succumbing to death, thereby accepting death and even honoring it as a given fact. Here is the specific and crucial difference between the current human and future human – the element of biological death not being an outcome or result of being alive. All the other elements – the technologies for designing and engineering future humans – what we might look like, whether we have posthuman bodies or are uploaded into computers – are secondary. Not only this; the human and the environment are an interconnected hybrid space, and I believe it is this shared relationship that affects human understanding, consciousness and learning.

Ockham’s razor would slice through the NBIC+ technologies I have briefly discussed to get at the simplest point of view. Putting aside genetics and prosthetics, and cybernetics, the most straightforward and uncomplicated understanding of Human 2.0 is that of regenerative human design. If the human is defined by its characteristics and one of the key characteristics is its predetermined mortality, then Human 2.0 is not only a next-

generation body, but also a next-generation psychology – that Human 2.0 nature will not be characterized by a pre-determined life span.

Here rests the elegant line between man and machine, information and the senses, genetics and human nature, as expressed by Russell Blackford (2007):

Wonderful though the body’s design may be, and however precisely our organs may perform their work, they are not necessarily ideal for any purpose, and certainly not for our conscious goals and desires in the current environments where we actually find ourselves ...

And nature and man as expressed by Max More (1999):

Mother Nature, truly we are grateful for what you have made us. No doubt you did the best you could. However, with all due respect, we must say that you have in many ways done a poor job with the human constitution. You have made us vulnerable to disease and damage. You compel us to age and die – just as we’re beginning to attain wisdom ... You held out on us by giving the sharpest senses to other animals ... [a]nd, you forgot to give us the operating manual for ourselves!

CONCLUSION

This paper addresses an understanding that the Human 1.0 is prone to disease and injury and that augmenting human physiology toward the Human 2.0 is necessary in pursuing health and well-being. Further, in considering the history of human augmentation, it is essential to be both optimistic and critical about our human merging with technology, rather than postulating theories driven to digress and depress human potential and dignity. Humanity ought to be designing ways in which we can finally deal with the suffering of humans and for once be intelligent to help people not just exist, survive and sustain, but to overcome the ailments of evolution’s early blueprint, which not only can but ought to be modified.

“[A]s John Stuart Mill once asked, ‘If the artificial is not better than that natural to what end are all the arts of life?’ It’s precisely because we have lost faith in the arts of life – in human creation, in human agency – that we feel compelled to accept the givens of nature” (Malik, 2002). “It’s unnatural” has continuously been the cry of those who seek to obstruct progress. The “duty of [hu]man”, as Mill put it, “is the same in respect to his own nature as in respect to the nature of other things, namely not to follow but to amend it”.²¹

In this paper, I have attempted to explain, however briefly, a few ideas concerning regenerative existence for Human 2.0 – the transhuman. We

stand on the edge as extensions of our humanness, as individuals who need to protect our life force. Protecting and regenerating our life force – the continuation of existence – is a very serious next stage for humanity.

NOTES

1. BioArt concepts and Human 2.0 attributes of applied design are described in detail on the website and accompanying writings, located at <http://www.natasha.cc>
2. Some examples are: *BusinessWeek*, Cover Story, 13 June 2005: "Biotech, finally"; *New York Times magazine*, Cover Story by Alex Heard, "They want to live", 28 September 1997; "Bloodless: Technology hits home", 2003 PBS documentary with partial funding from the Ethical, Legal, and Social Issues of the US Department of Energy Human Genome Program; "Flight from death: The quest for immortality", 2003, US televised documentary.
3. Morphological freedom" defined by Dr Max More as "[t]he ability to alter bodily form at will through technologies such as surgery, genetic engineering, nanotechnology, uploading" (More, 1992).
4. Dr Anders Sandberg's graphical description located at: <http://www.nada.kth.se/~asa/Texts/MorphologicalFreedom.htm>
5. The Proactionary Principle is the method for measuring the pros and cons of technological change.
6. The Human 2.0 prototype is known as "Primo Posthuman". <http://www.natasha.cc/primo.htm>
7. NBIC+ refers to nanotechnology/nanoscience, biotechnology/bioscience, information technology/information science, and cognitive science, plus other emergent technologies. Additional technologies include cybernetics, robotics, nanomedicine, artificial intelligence, genetic engineering, cloning, prosthetics, telemedicine, microscopic surgery, neuroscience, for example.
8. OPTN is The Organ Procurement and Transplantation Network, located at <http://www.optn.org>
9. Research biologist Dr. David Gardiner claims that "[a]ll vertebrates seem to have that ability as embryos. But the salamander's cells are somehow able to go back to that embryonic state and access that process", says Dr David Gardiner, a research biologist at the University of California, Irvine who is on one of the DARPA-funded teams. "The difference isn't in the genes, but in how we use them – which ones are activated and when."
10. Bladder tissue grown at Wake Forest University Baptist Medical Center in Winston-Salem, NC.
11. Alan Russell's talk at the TED 2006 conference.
12. DARPA is said to have donated \$15,000,000,000 to Stephen Badylak, DVM MD PhD, professor of surgery at the University of Pittsburgh School of Medicine and director of the Center of Pre-clinical Tissue Engineering, to work on regeneration of limbs.
13. "Spinal cord injury, facts and figures at a glance", June 2006, the "Fact Sheet" published by National Spinal Cord Injury Statistical Center (NSCISC) and supported by the National Institute on Disability and Rehabilitation Research, US department of Education, Washington, DC.
14. *The Spine Journal*TM (TSJTM), North American Spine Society Presents Breakthrough Research in Spine Biologics: The Future of Spine Care. The Spine JournalTM releases "Biologics and Bioactive Materials" supplement.
15. The Polytechnic campus at Arizona State University is working on SPARKy (Spring Ankle with Regenerative Kinetics), a groundbreaking energy-storing transtibial (below the knee) prosthesis. Team includes Assistant Professor Thomas Sugar.
16. Teleology is the study of ends, purposes, and goals.
17. Kevin Kelly's talk at TED Conference and personal telephone conversation in June 2006.
18. Human nature is known as the fundamental nature and substance of humans. This includes a collection of human behaviors which are constant (or fairly constant) over time and across very different cultural contexts. The existence of an invariable human nature is a subject of historical debate, particularly in modern times.
19. Wesley J. Smith, "The Catman Cometh", 2006, at his blog Secondhand Smoke: <http://www.wesleyjsmith.com/blog/2006/06/catman-cometh.html>
20. Hurd, Denis. (1997). The monster inside: 19th century racial constructs in the 24th century – mythos Star Trek. *Journal of Popular Culture*, 31, Summer, 23–35.

21. Quote of John Stuart Mill quote found at http://www.brainyquote.com/quotes/authors/j/john_stuart_mill.html

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