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Perception Shifting in Neurosociety: Ethical and Societal Implications

Zack Lynch

This article was adapted from a lecture given by Zack Lynch at the 2nd Annual Workshop on Geoethical Nanotechnology, on July 20th, 2006 at the Green Mountain Retreat of Terasem Movement, Inc., Lincoln, VT.

Zack Lynch, Managing Director of NeuroInsights in San Francisco, CA, takes an edifying stroll through an evolutionary, technological timeline and discusses the profound advances of the last 250 years and how they have and will define our lives and society.

What I will share is not a prediction, but more a venture into social forecasting. Why not a prediction? Well, as history shows, people do a very poor job of predicting the future. For example, take Lord Kelvin [1] in 1895 who predicted that heavier than air, flying machines would not ever come into being, yet eight years later, humans were flying.

Or Thomas Edison's declaration in 1880 [2] that the phonograph he invented would have no commercial value or one of my most recent favorites, the CEO of a home appliance manufacturer who in 1955 [3] predicted that nuclear powered vacuum cleaners would soon become a reality within the next ten years.

Given the difficulty of prediction, how might we try to understand where society is headed in the future? As Ray Kurzweil [4] suggested earlier one of the best ways is to look at history. Of course, there are many ways we divide up history to support our arguments and what I will share with you is just one of those.

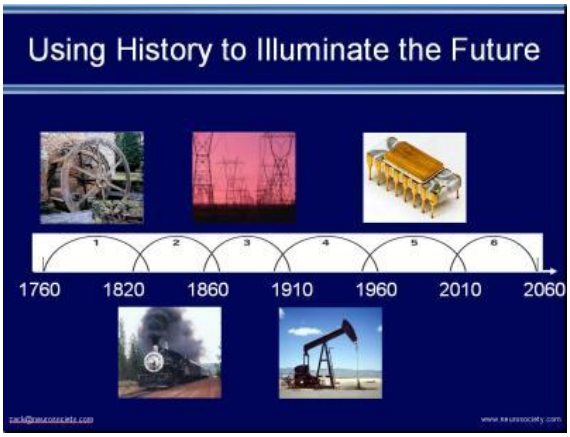

Image 1: Using History to Illuminate the Future

When we look back over the past 250 years, we see that since the industrial revolution, there has been a relatively consistent pattern of 50 to 60 year waves where new sets of

technologies have emerged to solve problems that were previously believed to be intractable.

In the 1760's, it was the initial water mechanization wave that sparked the Industrial Revolution [5] and brought inexpensive cotton to the masses. In the 1820's, the invention of steam power [6] accelerated our ability to trade goods and services with distant markets. The advent of electricity in the 1870's created the foundation of the modern city, supporting all aspects of what we consider today to be modern life.

Next, the introduction of inexpensive oil [7] motorized the world economy and made air travel possible and most recently, of course, the invention of the microchip [8] which has impacted information analysis and global knowledge exchange. Each of these innovations not only created new industries but completely transformed how individuals across the globe worked and lived.

Given this brief history, what new technologies will emerge in the coming years that are most likely to change our lives and how society operates? This conference is proof of and everyone in this audience would probably agree - this technology is neurotechnology. [9]

Today, the neuro technology industry includes companies researching developing pharmaceuticals, biological medical devices, as well as diagnostic and surgical equipment for the treatment of neurological diseases and psychiatric illnesses. There are over 450 public and private companies worldwide which can be categorized into three sectors.

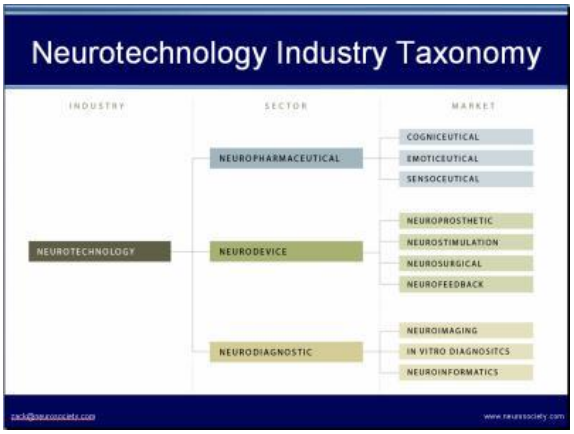

Image 2: Neurotechnology Industry Taxonomy

Neurotechnologies include neuropharmaceuticals [10], which include the widely used drugs for pain; psychosis, epilepsy, et cetera; neuro devices which included successfully established products that we've been discussing already today, such as cochlear implants or the deaf which have been implanted in over 80,000 people already; and neuro stimulation devises for the treatment of pain.

There are also emerging neuro-device approaches for the treatment of psychiatric illnesses including vegus nerve stimulation, deep brain stimulation, and, as we just heard, repetitive trans-cranial magnetic stimulation.

The neuro-diagnostic sector is broken into three markets, neuro imaging; in-vitro diagnostics; and neuro-informatics.

The market drivers here are of course; rising health care costs; consumer demand for diagnostic information; and the improved need for better information management.

In 2005, neuro technology products worldwide, across these three sectors, generated nearly $111 billion in revenue and grew in double digits. And several factors are driving the development of this industry, including demographic shifts, increasing economic

burden, accelerating intellectual property creation, and a push for personalized treatment.

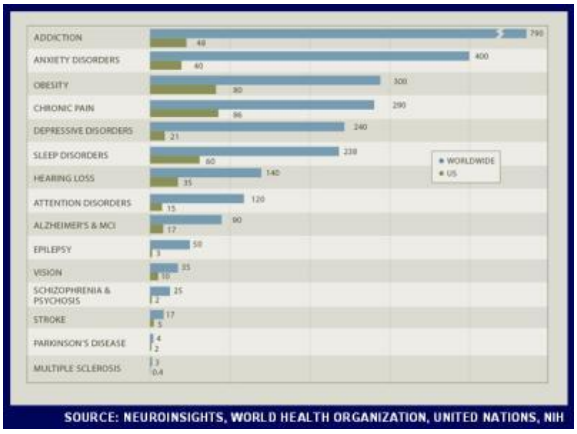

Image 3: Brain-related Illnesses; World / U.S.

Today, over 1.5 billion people worldwide suffer from some sort of brain related illness. That's one of every four people is directly impacted by some sort of brain related disease. You can see today incidence number is broken here, addiction, depression, chronic pain, sleep disorders, attention disorders, [11] all the way down to Parkinson's disease and Multiple Sclerosis [12]. These numbers are increasing as the global population expands and individuals live longer, creating unprecedented demand for treatments that delay, prevent, and cure chronic neurological diseases and psychiatric illnesses.

Of course, beyond the immeasurable human suffering caused by brain illness, there is also substantial, economic impact of brain disorders. A multitude of recent studies have attempted to quantify the economic costs of brain illness.

One recent report estimated the economic cost, including treatment and lost income, at over a trillion dollars, and I would estimate that this is far too low a number. Despite the scope and scale of the problem, there is help in the form of new tools and new technologies. As with previous waves of innovation, emerging technologies are enabling new solutions to what seemed to be insurmountable problems.

Nano-technology is making possible the delivery of complex compounds more easily to the brain. Advances in biotechnology in the areas like stem cells [13] are creating new possibilities for brain regeneration while brain image processing, driven by Moore's Law [14] like advances, are allowing us to understand the brain and the molecular events that are occurring in real time. While, of course, new techniques in neuroscience are making it possible to characterize the growing number of proteins involved in memory and emotions.

In addition to the development of individual technologies, there are multiple examples of converging technologies; for example, the convergence of biochips and brain imaging technology which will allow us to understand how the brain works from both the inside sub-cellular levels and from the system-wide level. Transforming how we diagnose disease and treat it.

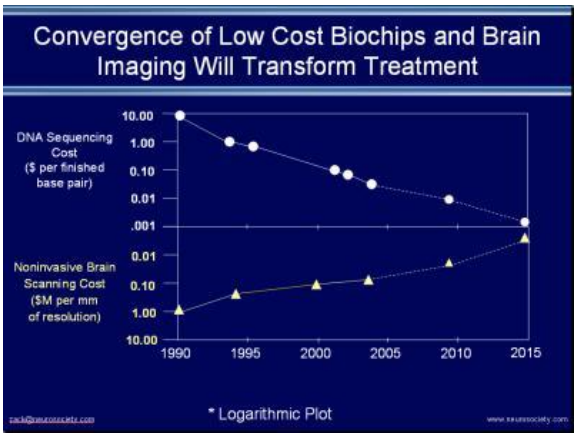

Image 4: Convergence of Low Cost Biochips and Brain Imaging Will Transform Treatment

As we saw this morning the exponential decrease in the cost of processing power is occurring across many sectors of the economy. As this chart plots, in recent years the

decreasing cost of biochips has made it possible to characterize a whole new number of your transmitters, receptors, ion channels and other proteins critical for normal brain function. While on the bottom here, we have at the same time higher resolution brain imaging technologies of course, continuously getting cheaper; leading us the time of 2015 when we should be able to start understanding many events in the brain.

Indeed more has been learned in the past five years than over the past fifty years about the brain. But the story doesn't end there. The same knowledge about how the brain functions will make it possible to enhance the performance of normal brains.

The implications of brain enhancement are profound. It's important to understand that at least in the next 50 years -- I'm not talking about a future where we can upload and download our brains. Instead, I believe that neurotechnology will provide us tools to temporarily influence parts of our brains to improve the natural processes that already exist. Now that we have solid grounding of where therapeutic neurotechnology stands, we'll move into the neuro-enhancement discussion. But of course, technological possibilities alone do not drive societies people do.

Will people choose to enhance their mental performance? I would say, yes, they will. In 1921, the philosopher Ludwig Wittgenstein [15] said, "The limits of our language are the limits of our world." I think that this is no where more true than in the ongoing therapy versus enhancement discussion.

Of course, distinguishing the line between therapy and enhancement remains a contentious and difficult project. What is normal? Clearly, every person enters the world with natural endowments that fall on some distribution of emotional, cognitive, and sensory capabilities.

Within the context of today's terminology and neuro-technologies, people consider healthy people individuals for non-medical purposes currently defined as enhancement when we're using these technologies for normal people.

However; this does not capture the actual intention or belief of many. This is why I've created the term, enablement or neuro-enablement for many of today's emerging technologies.

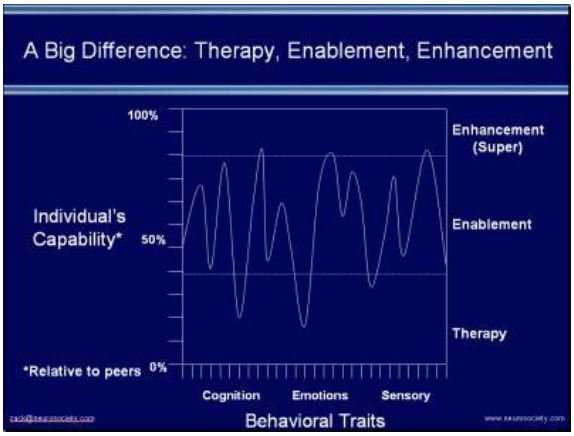

Image 5: Therapy, Enablement, Enhancement

Enablement implies many things different than enhancement. It implies lifting up from the bottom, and addresses issues of fairness, and socially equality. Neuro-enablement powers people. It provides a way for people to leverage better tools for mental health to achieve their desired objective.

I think that this has applicability in particular for the neurotechnology discussion, because most of the tools in development for the brain today are not enhancements, in the sense that they do not create superhuman traits. Instead, they enable people to perform better. With that is the backdrop; what do we want from enablement, or enhancement? What are the goals of developing this technology?

Image 6: Goals of Brain Enhancement?

The first thing we need to realize is that that when speak a neuro-enhancement, they're talking about the complex interplay of our cognitive, emotional, and sensory systems. In terms of cognition what would we like, memory consolidation [16] enhancers, tools to improve language acquisition? What would be most useful? Well, much attention is focused on, of course, cognitive enhancements with less attention paid to cognition's sister, emotion. Here is where neurotechnology could play a whole new role in allowing individuals to live their lives unconstrained from their evolutionarily defined emotional structures.

Here, people might choose to live with less anger and more empathy. From a sensory perspective, neurotechnology could expand the sensory breadth and increase individual stamina - just to name a few.

It should be noted that even though the neuro-chemistry appears to be controlled by a reducible number of neurotransmitters and modulators, for example, the role of dopamine, and reward in plasticity, serotonin, aggression, and depression, and opioids in pain and pleasure.

These basic building blocks interact with cultural advances to give rise to an extraordinary amount of behavioral flexibility.

But of course, technological possibilities alone do not drive society (as I mentioned earlier), people do.

So, will people use this technology? Yes. People are meant to pay athletes enhancers to compete and win in races; individuals choose cosmetic surgery to improve their appearance. You can bet that if there's a way to safely improve human capital productiviity, workers will use these new tools to increase their efficiency and keep their jobs.

From a business perspective, it is clear that mental health is the ultimate competitive resource. It underpins the development of knowledge capital, and the capacity of employees to think, be creative, and be productive.

As more people live longer, and the global competition intensifies, people will need to learn new skills throughout their lives, and continuously just to keep their jobs. Performance enhancing neurotechnology represents the tools workers will use to succeed in continuous education.

But using neurotechnology for performance enhancement will not come without protest. Cultural concerns regarding what is natural will lead to ethical and moral tensions around the basic right to augment oneself.

Divisions will emerge across all levels of society as humanity grapples with this new way of living; impacting each nation and culture differently. However, the reality is that we live in a highly connected global society. Even if it is just a small group of individuals who choose to improve their mental performance, their choice will transform the basis of business competition for the rest of us.

One of the first industries that will be impacted by neurotechnology will be finance. Today's financial models are primarily based on the expectation that people are rational, economic actors however; as we all know, people are not always rational, economic actors.

Our emotional states influence our behavior. For example, we will make totally different decisions than when we are feeling safe than when we are feeling scared. In 2002, two economists won the Nobel Prize for their work that showed that individuals almost always overestimate the happiness, than an event like the purchase will bring, as well as the duration of that happiness.

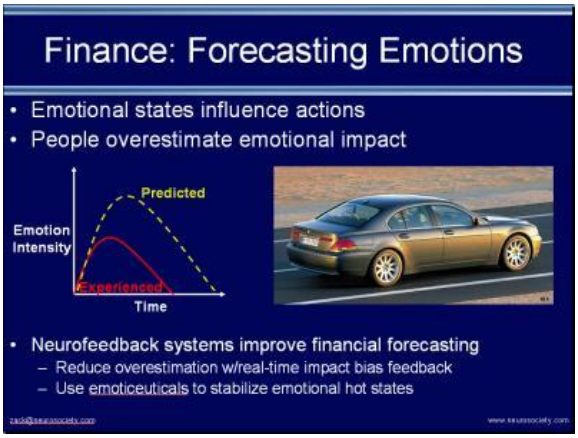

Image 7: Finance: Forecasting Emotions

For example, we might believe that a new BMW will make life much better. It will actually likely be less exciting than the anticipated and will not excite for as long as we thought. So how will financial institutions use neurotechnology?

Neurotechnology enabled traders will have at least two new tools at their disposal. First, they will have real time brain scanning and neuro-feedback software solutions that correlate previous brain states and trading success to the given trader. It's giving the trader a prediction capacity based on the continuously shifting neurobiology.

Think of your brain as a market of neurons matched up with the rest of the market economy. When the internal market matches up with the external market, you have a buy order.

Second, they might choose to use emotional stabilizers to maintain a calm state in intense financial transactions, representing the radical transformation of the prevailing view of managerial common sense for how to achieve the highest productivity in a financial organization and organize for the most profitable practices.

The authentic breakthroughs of the neurotechnology will unleash and alter cost structures throughout all industries in society, but like any new technology, neurotechnology is a double edged sword.

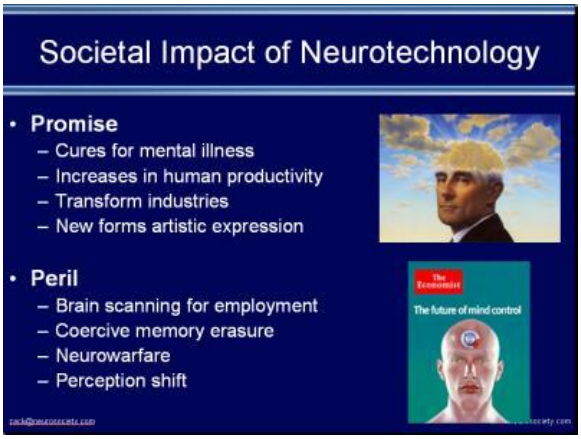

Image 8: Societal Impact of Neurotechnology

On the up side, it will represent new cures for mental illness, increasing human productivity, new opportunities for economic growth, and a potential flowering of artistic expression. These benefits, of course, are countered by the use of brain scanning as a requirement for employment, the testing of suspected criminals, even if they're innocent, Coercive memory erasure or its use as neuro-weapons that can selectively erase the memories or

shape the emotional state of individuals or even entire populations.

Looking forward, we see a whole new set of ethical and legal challenges centered around brain privacy. Will governments have the right to mandate brain scans of suspected criminals; aren't individuals innocent until proven guilty?

Image 9: Brain Privacy: New Ethical and Legal Challenges

Is it right to use neurotechnology to control the actions and thoughts of convicted individuals as alternatives to prison? Should parents have rights to vaccinate their children against addictive qualities of nicotine, cocaine, alcohol, and other substances? What are the long term social implications for choices here?

These and other issues related to cognitive liberty are emerging quickly and will grow in importance in the coming years. The issue that concerns me the greatest is the behavioral differences that may emerge as individuals begin to consciously shape their emotions and thus, their perceptions. How will they perceive each other, family relationships, and political rhetoric; the economic outlook and cultural norms? What happens when substantial shifts if specific basic emotions become possible?

How will this impact how we feel about the events that define our lives? What could be more important than feelings; our perceptions, our underlying feelings regarding an event that drive our decisions and actions. From the mundane to the most profound, nothing less than war and peace are driven by feelings of one's perspective of their events.

Arts, marriage, birth, death, disease, religion are all powerful sources of feelings. Because they make us feel uplifted, and thankful or destitute and homeless or hopeless; they drive our actions. In short, feelings just don't matter; they are what mattering means.

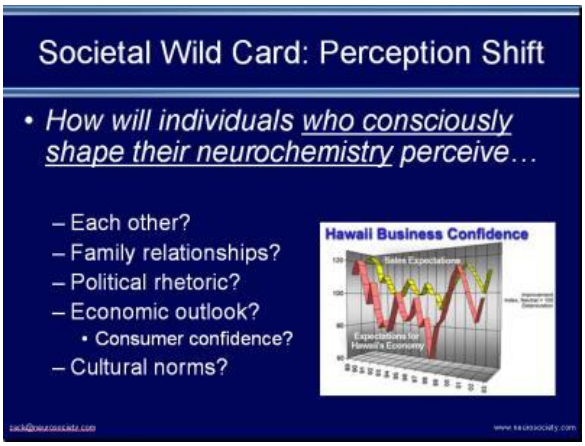

Image 10: Societal Wild Card: Perception Shift

As tools emerge to allow individuals to quickly and radically reshape their feelings in whole new combinations, human culture will forever be changed. Today we sit on the cusp of a societal transformation and the forces driving it are clear.

In the last 200 years, global population has soared from nearly 300 million to over 6.5 billion. At the same time, life spans have more than doubled from 30 to 70 years. Our aging and large population coupled with global extensive connectedness has created new problems for modern humans.

Constantly blasted with images of unattainable lifestyle, people face daily identity crisis as they search for meaning in a world with

continuously shifting truths. In every culture, feelings of uncertainty, depression, anger, and resentment have surfaced on a vast scale.

Having spent thousands of years improving our control over the physical environment, humans will soon have new tools to address the mental stress however, that arises from living longer lives in a highly connected urbanized world. With this diffusion of neurotechnology, a new form of human society will emerge; a post industrial, post informational, neuro-society. Thank you.

Endnotes

1. William Thomson, 1st Baron Kelvin - (June 26, 1824–December 17, 1907) was mathematical physicist, engineer, and outstanding leader in the physical sciences of the 19th century. He did important work in the mathematical analysis of electricity and thermodynamics, and did much to unify the emerging discipline of physics in its modern form.
http://en.wikipedia.org/wiki/William_Thomson,_1st_Baron_Kelvin April 25, 2007 12:06PM EST

2. Thomas Edison's declaration in 1880 - On January 27, 1880, Thomas Edison received the historic patent embodying the principles of his incandescent lamp that paved the way for the universal domestic use of electric light. Three of his most famous inventions, the phonograph, a practical incandescent light bulb, and the moving picture camera, dazzled the public and revolutionized the way people live throughout the world. His thundering dynamos transformed the United States into the world's greatest industrial superpower.
http://www.ourdocuments.gov/doc.php?flash=true&doc=46 April 25, 2007 12:17PM EST

3. 1955 - A vacuum cleaner manufacturer predicted in 1955: "Nuclear powered vacuum cleaners will probably become a reality within 10 years." A writer for the Brooklyn Eagle predicted in 1900 that "mail will be delivered to homes in pneumatic tubes." Futuristic scenarios conceived in the 1950s saw masses of people commuting to work in helicopters. On the other hand, there were many important inventions that no one foresaw: microwave ovens, Velcro, TV dinners, laser surgery, air bags, the Internet.
http://www.worldhistorysite.com/prediction.html
April 25, 2007 12:22PM EST

4. Ray Kurzweil - (born February 12,1948) is a pioneer in the fields of optical character recognition (OCR), text-to-speech synthesis, speech recognition technology, and electronic keyboard instruments. He is the author of several books on health, artificial intelligence, transhumanism, technological singularity, and futurism.
http://en.wikipedia.org/wiki/Raymond_Kurzweil
April 25, 2007 12:24PM EST

5._Industrial Revolution - was a major shift of technological, socioeconomic, and cultural conditions in the late 18th century and early19th century.
http://en.wikipedia.org/wiki/Industrial_Revolution April 25, 2007 12:30PM EST

6. Invention of steam power - During the Industrial Revolution, **steam power** replaced water power and muscle power (which often came from horses) as the primary source of power in use in industry. Its first use was to pump water from mines.

http://en.wikipedia.org/wiki/Steam_power_during_the_Industrial_Revolution April 25, 2007 12:32PM EST

7. Introduction of inexpensive oil - During the late 1940s the situation changed when the introduction of inexpensive oil and natural gas for space heating reduced the rapid growth of district heating. Energy Citation Database http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=6801150 April 25, 2007 12:46PM EST

8. Invention of the microchip - Two separate inventors, unaware of each other's activities, invented almost identical integrated circuits or ICs at nearly the same time. Jack Kilby, an engineer with a background in ceramic-based silk screen circuit boards and transistor-based hearing aids, started working for Texas Instruments in 1958. A year earlier, research engineer Robert Noyce had co-founded the Fairchild Semiconductor Corporation. From 1958 to 1959, both electrical engineers were working on an answer to the same dilemma: how to make more of less. http://inventors.about.com/library/weekly/aa080498.htm April 25, 2007 12:50PM EST

9. Neurotechnology - the set of tools that analyze and influence the human nervous system, especially the brain. These technologies include neural modeling simulations, biological computers, human-brain interfaces, any of various neuron and brain mapping technologies, and psychopharmaceuticals. http://en.wikipedia.org/wiki/Neurotechnology April 25, 2007 12:54PM EST

10. Neuropharmaceuticals - are pharmacological agents whose primary mode of action is through altering the metabolism of neurotransmitters. Clinical analysis usually applies directly to mechanisms of the diseases of the nervous system which will likely then be translated into disease perception, prevention, and curing, such as studies of brain display techniques, trials to test innovative pharmaceuticals, and formation of novel therapies such as stem cell implants and gene transfer. http://www.neuropharmaceuticals.com/ April 25, 2007 12:58PM EST

11. Parkinson's disease is a movement disorder that is chronic and progressive, meaning that symptoms continue and worsen over time. As many as one million Americans suffer from Parkinson's disease. http://www.pdf.org/AboutPD/ April 25, 2007 1:02PM EST

12. Multiple Sclerosis - MS is thought to be an autoimmune disease that affects the central nervous system (CNS). The CNS consists of the brain, spinal cord, and the optic nerves. Surrounding and protecting the nerve fibers of the CNS is a fatty tissue called myelin, which helps nerve fibers conduct electrical impulses.http://www.nationalmssociety.org/site/PageServer?pagename=HOM_ABOUT_what_is_ms April 25, 2007 1:06PM EST

13. Stem cells - Research on stem cells is advancing knowledge about how an organism develops from a single cell and how healthy cells replace damaged cells in adult organisms. This promising area of science is also leading scientists to investigate the possibility of cell-based therapies to treat disease, which is often referred to as regenerative or reparative medicine.

http://stemcells.nih.gov/info/basics/basics1.asp April 25, 2007 1:10PM EST

14. Moore's Law - is the empirical observation made in 1965 that the number of transistors on an circuit for minimum component cost doubles every 24 months. It is attributed to Gordon E. Moore (born 1929), a co-founder of Intel. Although it is sometimes quoted as every 18 months, Intel's official Moore's Law page, as well as an interview with Gordon Moore himself, state that it is every two years.
http://en.wikipedia.org/wiki/Moore's_law
April 25, 2007 1:35PM EST

15. Ludwig Josef Johann Wittgenstein (April 26, 1889–April 29,1951) was an Austrian philosopher who contributed several ground-breaking ideas to philosophy, primarily in the foundations of logic, the philosophy of mathematics, the philosophy of language, and the philosophy of mind. His influence has been wide-ranging, placing him among the most significant philosophers of the 20th century. http://en.wikipedia.org/wiki/Ludwig_Wittgenstein April 25, 2007 1:28PM EST

16. Memory Consolidation Theory - The hypothesis that new memories consolidate slowly over time was proposed 100 years ago, and continues to guide memory research. In modern consolidation theory, it is assumed that new memories are initially 'labile' and sensitive to disruption before undergoing a series of processes (e.g., glutamate release, protein synthesis, neural growth and rearrangement) that render the memory representations progressively more stable. It is these processes that are generally referred to as "consolidation". www.memory-key.com/NatureofMemory/consolidation.htm
April 25, 2007 1:37PM EST

Bio

Zack Lynch is Managing Director of NeuroInsights, the world's leading neurotechnology research and advisory firm and the publisher of the investment newsletter, *Neurotech Insights*, an industry weblog providing commentary on the intersection of neuroscience and society. Zack is also co-author of NeuroInsights' annual report on The Neurotechnology Industry. Previously, he was an executive and founder of several enterprise software companies in profit optimization and collaborative forecasting. Zack received an MA in Economic Geography and double BS in Evolutionary Biology and Environmental Science, all from UCLA.

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The Geoethics of Self-Replicating Biomedical Nanotechnology for Cryonic Revival

Martine Rothblatt, Ph.D.

This article was submitted for publication in Terasem Movement, Inc.'s Journal of Geoethical Nanotechnology by Martine Rothblatt, Ph.D.

Dr. Rothblatt stresses the important principles and use of nanotechnology in the successful revival of people who are and will be cryogenically suspended.

Self-replicating biomedical nanotechnology [1] will probably be necessary to achieve revival from cryonic [2] or [3] vitrified (both hereinafter referred to as cryonic) biostasis. [4] This article analyzes whether such use of nanotechnology is consistent with generally recognized principles of geoethics. It concludes that provided the self-replicating biomedical nanotechnology is assuredly-contained and intended for cryonic revival it is geoethical. Assured containment of self-replicating biomedical nanotechnology requires a physical barrier to prevent the movement of self-replicating nanobots beyond a containment zone, as well as a competent monitoring and enforcement organization separate from the entity carrying out the cryonic revival.

1. Why the Need for Self-Replicating Biomedical Nanotechnology

In cryonic biostasis an individual is neither quite living nor dead. The individual's body is brought down to a sufficiently low temperature that only negligible degradation of its cell and tissue structures occur. To avoid legal problems, this freezing process occurs only after there has been a legal pronouncement of death, such as is due to a lack of detectable cardiac or brain activity. In general, though, such freezing could precede and hence be itself the cause of a legal pronouncement of death.

"In cryonic biostasis an individual is neither quite living nor dead."

Despite the legal pronouncement of death, the individual is not really dead because nothing irreversible has occurred. With adequate technology the individual could be warmed, cured and revitalized. Warming and revival is easy to demonstrate with vertebrates other than mammals such as fish and reptiles. The company, 21st Century Medicine, [5] has also demonstrated this feat in 2007 with a dog's kidney.

Although the individual's biostasis is reversible, they are also not really alive. They fail to demonstrate the hallmarks of biological life such as growth and taking nutrients from the environment. They are incapable of any kind of action or communication. There is an important exception to the lifelessness of cryonauts, and that pertains to any cryonauts

who previously transplanted their minds into cybernetic form. Those individuals remain alive, although their bodies are as useless as a dead limb. Until the medical field recognizes mind-uploaded cyberconsciousness as the continuation of brain function, (and hence inconsistent with brain death), such individuals will nevertheless be considered legally dead. Once the medical field does recognize mind transplants, then the freezing of a diseased body will not be a killing of the body, but merely the first stage of a therapeutic procedure, namely transport into a more medically advanced future.

In a medically advanced future it will be possible for cell-sized machines ("medical nanobots") to burrow into a frozen body, repair damage caused by freezing, cure illness, controllably de-freeze the body and assist a medical team in returning the body to full life. A vast number of medical nanobots may be needed for this procedure. A typical body contains over 23 billion red blood cells alone. Too many nanobots could initially generate an immense inflammatory reaction. Yet, as a body starts to come to life, billions of new cells will be created and many of these may need to be modified or treated by the medical nanobots. To be effective, the medical nanobots may well need to replicate and interact with cells as rapidly as cells replicate and interact. In essence, if medical nanobots are to assess and ensure the health of billions of cells, then they may very well need to self-replicate as autonomously as do those billions of cells.

A plausible scenario for self-replicating medical nanobots in the service of cryonic biostasis revival was provided by James Halperin in his novel *The First Immortal:*

"[W]e'd built a series of replicators and disassembler/assemblers that seemed suited for biostasis reversal; the first units capable of both dis- and reassembly that were also small enough to penetrate frozen bloodstreams. D/A's each contained a tiny computer capable of holding slightly more information than human DNA does. These in turn were connected by radiolike devices to a network of much larger central computers.

By law, we'd been required to design replicators devoid of survival skills, and with redundant systems that automatically repaired mutations. The machines could reproduce themselves, build the D/A's to specification, and nothing more. It was an irritating law, I'd often mused, but a sensible one.

Also required, and equally rational, was that all nanotech experiments be performed in palm-sized sealed laboratories using Molecular Reconstruction Software. We could hook these mini-workshops into any two-way screens and actually build every nanomachine we design, using an array of sample atoms and molecules right there in the lab. We could even insert genetic materials to test the machines. But if anyone tried to unseal the lab to remove the physical machines, electrical charges would vaporize the contents. Thus we could design and test nanomachines, but the machines themselves couldn't be unleashed until their capabilities had been analyzed and cleared.

Last week, the World Government Nanotech Agency had issued a permit and instruction code enabling us to build the replicators outside our sealed labs.

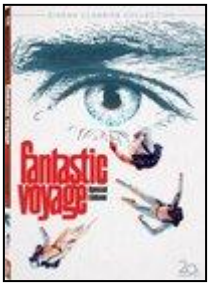
Now we were ready to rock and roll." [6]

Medical nanobots are a straightforward extrapolation of current trends. Kurzweil [7] has shown that electronic devices have been shrinking in dimension by a factor of five every two years. At this rate, nanobots will be achieved no later than the year 2020. Indeed, the first primitive man-made molecular

machines have already been demonstrated. The writing has been on the wall ever since IBM demonstrated an ability to spell out its name with atoms, before the turn of the century.

The intelligence needed to make a nanobot useful is also becoming available in ever-smaller packages, consistent with the rate of device shrinkage in general. Kurzweil has also shown that trends going back decades lead inexorably to a near-term future in which nanobot-size devices can incorporate the intelligence of a supercomputer. It takes but a minute portion of such intelligence to remain in wireless network communications at all times, both with other medical nanobots and with ex vivo controllers.

The 1960s movie *Fantastic Voyage* involved a nanobot-size submarine floating around in the



human body searching for disease. The intrepid bionauts [8] wasted almost all of their time floating from place to place. Much more realistic is a scenario in which medical nanobots rapidly self-replicate and take up positions throughout the body, wirelessly informing each other of medical problems to be fixed, or simply fixing them and passing the information on.

2. Why the Principles of Geoethics Apply

Geoethics is the expansion of bioethics to potentially, global-impact situations. While bioethics concerns itself with the rights and wrongs of medical attention to particular patients, geoethics is focused on the rights and wrongs of medical attention to the planet.

There are three fundamental principles of geoethics, each of which is a macroscopic expansion of its bioethical cognate. These are shown in the following table.

PRINCIPLES	BIOETHICS	GEOETHICS
Intend to help the patient	Non-malfeasance; Beneficence; Respect Autonomy	Consent
Treat similar patients similarly	Justice	Equipoise
Accountability	Peer Review	Assurance

The first principle, called Consent, is that no procedure should occur unless its purpose is to benefit the affected party. Since there may very well be differences of opinion as to whether or not a procedure is of benefit, the geoethical **Consent Principle** requires affirmative consent from whoever is to be affected by a medical procedure. If someone consents to something, by definition they believe that thing is of benefit to them. It should be noted in this regard that even consent to suicide may be evidence of benefit since such an individual no longer holds any value for their life, or values death even higher.

Bioethics often confuses or blurs this concept with the different terms "non-malfeasance" and "beneficence." In fact, there is no real difference as to whether one "first, does no harm," or "intends to do good." What really underlies both terms is respect for the autonomy of the patient. If patient autonomy is disrespected, then they may be used as research subjects regardless of benefit. This situation is what may be described as "Nazi medicine." On the other hand, if patient autonomy is respected, then the physician cannot help but "intend to do good." Consequently, non-malfeasance and beneficence are simply two faces of respecting autonomy. The modern way to evidence

autonomy is via the process of informed consent.

The Consent Principle applies to self-replicating nanobots because they constitute a form of artificial life that impacts upon the earth and its biological subsystems. Consequently, the deployment of self-replicating nanobots must be geoethically consented to by the earth's representatives, which are governments or government-designated competency organizations, such as the World Health Organization.

The second principle of geoethics is the **Equipoise Principle.** This principle is an outgrowth of the bioethical principle of justice, an obligation to treat everyone fairly. In the case of geoethics, "everyone" is not a set of patients in the hospital waiting room, but millions of people throughout the earth. These millions are at risk of technological harm, for as Ulrich Beck [9] has shown such risk is the inevitable "pollution" of technology. The only way to treat such populations fairly is to give them a stake in the benefits of a technology to counter-balance the risks to which they have consented. Both John Rawls [10] and Jurgen Habermas [11] have derived differential improvement in the well-being of those least well off (e.g., most susceptible to the technological pollution) as a universal benchmark of justice. Consequently, a geoethical concomitant of self-replicating medical nanobots for cryonic revival is the provision of related benefits to those who are most at risk from nanobot harm.

The third principle of geoethics is the **Assurance Principle**. This principle is related to the bioethical concept of peer review. Every ethical medical procedure must either follow medical consensus, or be subject to a peer review process such as an Institutional Review Board or at least an informal consultation among experts. For a geoethical green light there must similarly be an independent body to ensure that possibly world-impacting medical procedures are carried out consistently with the principles of Consent and Equipoise.

Absent the Assurance Principle it is entirely possible that well-meaning medical nanotechnologists could "cut corners" on the terms of Consent or Equipoise that they agreed to in order to have the right to carry out their cryonic revival procedures. There is nothing evil here – just human nature wanting to help the people in biostasis return to life, or to achieve scientific fame. Nevertheless, 'the road to hell is paved with good intentions.' When the risks are as great as the "grey goo" [12] scenarios of self-replicating nanotechnology run amok, it is imperative that there be at all times a wholly independent watchdog entity to keep the medical nanotechnologists true to the terms of their authorization.

3. Practical Application of Geoethics to Self-Replicating Medical Nanotechnology for Cryonic Revival

Medical nanotechnologists should proceed with self-replicating medical nanobots for therapeutic purposes only after they demonstrate to regulatory authorities (Geoethical Consent Principle) that their procedures are fail-safe, provide medical surveillance and healthcare technology to populations lacking the same (Geoethical Equipoise Principle), and empower under a long-term, non-cancelable contract a qualified third party to audit, monitor and enforce compliance with its undertakings to regulators and to at-risk populations (Geoethical Assurance Principle). In practice this will require developing self-replicating medical nanobots that can only survive within a therapeutic operating suite, as well as bio-surveillance techniques that can monitor medical nanobot presence outside of such an

operating suite. In addition, a long-term auditing contract will need to be funded under an annuity structure to ensure its financial independence.

There are at least two ways that self-replicating medical nanobots can be confined to a therapeutic operating suite. First, they can all be equipped with RF capability that triggers a shut-down upon receiving a signal at the boundaries of the operating theatre. Alternatively, they can all be equipped with RF capability the constancy of which is essential to their continued operation. Such a "heartbeat" signal could be transmitted only within the operating theatre. Double boundaries could further enhance the fail-safe nature of these techniques, as well as more intense scans for the bodies of revived and released cryonauts. All medical nanobots could also be programmed with a limited lifetime to yet further ensure they would not survive long outside of the operating suite.

Global nanobot surveillance is important so that society does not repeat the unprecedented horror of the AIDS pandemic. [13] This pandemic spread because world society lacks a bio-surveillance system for novel viruses, especially ones characterized by high latency such as HIV. [14] Matters were gravely aggravated by ignoring even gross clinical manifestations of the disease due to irrational societal prejudices against imagined disease vectors such as gay men, intravenous drug users and, in the very early days, people from Haiti. The pandemic is today accelerating because the world lacks a fundamental health care system empowered to treat the illness and provide prophylaxis [15] against its further spread. These errors should all be made impossible to repeat via the Equipoise Principle of Geoethics.

To achieve Equipoise for self-replicating medical nanobots the sponsoring organization must be obligated to establish bio-surveillance stations capable of monitoring rogue medical nanobots throughout the world. This need not be an unduly expensive undertaking, for the surveillance equipment will probably cost not more than $100 per station. At an average density of 10,000 persons per hospital, and six billion persons in the world, this amounts to a financial obligation on the order of $60 million.

In poorer countries, where people do not routinely visit hospitals for elective or required operations, it will be necessary to establish sentinel health stations, and to staff them with personnel trained to provide medical assistance, in order to provide rural residents with an incentive to visit such stations and to participate in bio-surveillance for rogue medical nanobots. Roughly one billion persons are currently believed to be without any meaningful health care. To establish 100,000 sentinel bio-surveillance and basic health care stations as an outreach to such persons might cost in the neighborhood of one billion dollars annually, allocating $10,000 per station to cover the costs of a local allied health professional (an actual MD would not be necessary), basic medications, and a pre-fab solar-powered and telemed-equipped structure.

An auditing firm with competency in the area of medical nanotechnology would today charge on the order of $200,000 per year, per professional working full-time. Assuming ten full-time people would be needed to monitor a medical nanotechnology facility, the annual costs would be $2 million. This implies a need to establish a prepaid contract in the amount of $40 million so that at 5% interest the consultancy's fees could be assuredly paid even if there were disagreements between the two organizations.

In summary, the costs of Equipoise dominate the geoethics of self-replicating medical

nanotechnology. Nevertheless, the total geoethical costs of approximately $1.1 billion are a reasonably attainable start-up cost for a firm with the intellectual property to commercialize self-replicating medical nanobots. Amounts several times higher than this are routinely paid by cellular telephone companies simply for the right to use a portion of the airwaves for their communications service.

Endnotes

1. Nanotechnology - refers broadly to a field of applied science and technology whose unifying theme is the control of matter on a scale smaller than 1 micrometre, normally 1 to 100 nanometers, and the fabrication of devices within that size range. http://en.wikipedia.org/wiki/Nanotechnology August 17, 2007 12:27PM EST

2. Cryonic - the low temperature preservation of humans and other animals that can no longer be sustained by contemporary medicine until resuscitation may be possible in the future. Human cryopreservation is not currently reversible. In the United States, cryonics can only be legally performed on humans after clinical death. http://en.wikipedia.org/wiki/Cryonics August 17, 2007 12:29PM EST

3. Vitrification - a process of converting a material into a glass-like amorphous solid which is free from any crystalline structure, either by the quick removal or addition of heat, or by mixing with an additive. Solidification of a vitreous solid occurs at the glass transition temperature (which is lower than melting temperature, *T*m, due to supercooling). http://en.wikipedia.org/wiki/Vitrification August 17, 2007 12:30PM EST

4. Biostasis - the ability of an organism to tolerate environmental changes without having to actively adapt to them. The word is also used as a synonym for cryostasis or cryonics. http://en.wikipedia.org/wiki/Biostasis August 17, 2007 12:31PM EST

5. 21st Century Medicine - 21st Century Medicine has developed an entire platform technology focused on the creation and commercialization of hypothermic preservation and cryopreservation techniques, especially by vitrification.
These developments have taken science far beyond today's preservation limits. 21CM scientists have proven that long-term preservation of complex living systems is possible.
http://www.21cm.com/index.stm August 17, 2007 12:36PM EST

6. The First Immortal - Halperin, James L. *The First Immortal*. New York: The Ballantine Publishing Group, 1998: 218 – 219. Copyright ©1998 by James L. Halperin

7. Ray Kurzweil - (born February 12, 1948) is a pioneer in the fields of optical character recognition (OCR), text-to-speech synthesis, speech recognition technology, and electronic keyboard instruments. He is the author of several books on health, artificial intelligence, transhumanism, technological singularity, and futurism.
http://en.wikipedia.org/wiki/Ray_Kurzweil August 17, 2007 12:40PM EST

8. Bionaut – a human inhabitant of the Biosphere - a sealed, small scale replica of the Earth environment.
http://www.doney.net/aroundaz/biosphere2.htm August 17, 2007 2:35PM EST

9. Dr. Ulrich Beck - (born May 15, 1944) is a German sociologist who holds a professorship at Munich University and at the London School of Economics. Beck currently studies modernization, ecological problems,

individualization, and globalization. http://en.wikipedia.org/wiki/Ulrich_Beck August 17, 2007 2:38PM EST

10. John Rawls - (February 21, 1921 – November 24, 2002) was an American philosopher, a professor of political philosophy at Harvard University and author of *A Theory of Justice* (1971), *Political Liberalism*, *Justice as Fairness: A Restatement*, and *The Law of Peoples*. http://en.wikipedia.org/wiki/John_Rawls August 17, 2007 2:43PM EST

11. Jurgen Habermas - (born June 18, 1929) is a German philosopher and sociologist in the tradition of critical theory and American pragmatism. http://en.wikipedia.org/wiki/J%C3%BCrgen_Habermas

12. Grey goo - refers to a hypothetical end-of-the-world scenario involving molecular nanotechnology in which out-of-control self-replicating robots consume all living matter on Earth while building more of themselves (a scenario known as ecophagy). http://en.wikipedia.org/wiki/Grey_goo August 17, 2007 3:11PM EST

13. AIDS pandemic - **Acquired Immune Deficiency Syndrome** (**AIDS**) has led to the deaths of more than 25 million people since it was first recognized in 1981, making it one of the most destructive epidemics in recorded history. http://en.wikipedia.org/wiki/AIDS_pandemic August 17, 2007 3:15PM EST

14. HIV - **Human immunodeficiency virus** (**HIV**) is a retrovirus that can lead to *acquired immunodeficiency syndrome* (AIDS, a condition in humans in which the immune system begins to fail, leading to life-threatening opportunistic infections). http://en.wikipedia.org/wiki/HIV August 17, 2007 3:17PM EST

15. Prophylaxis-(Greek *to guard or prevent beforehand*) is any medical or public health procedure whose purpose is to prevent, rather than treat or cure, disease. http://en.wikipedia.org/wiki/Prophylaxis August 17, 2007 3:21PM EST

Bio

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