Ethical Paradigms in Biomechanical Innovations in Nanotechnology and Neurotechnology: Analyzing the impact of Computer Technology on Tissue Engineering and Human Enhancement

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Abstract: - This presentation begins with the following premise: In the last one hundred years, Medicine changed because of chemistry and large scale technologies. Molecular technology is destined to become the core technology underlying all of 21st century medicine and dentistry! Therefore, computer technology has become key in designing and developing biomechanical innovations in nanotechnology and neurotechnology, especially as they relate to tissue engineering and human enhancement. A wide taxonomy of innovations is considered including, but not limited to bioprinting, exoskeletons, scaffolding processes, in vivo injectible tissue engineering, and subvocal communications. Ethical and legal implications of these technologies create a new arena for computer scientists to play a role in the creation and dissemination of these devices.
Finally, the presentation considers future needs and developments on a continuum of human-machine interfaces.

Key-Words: - computer technology, bioprinting, nanotechnology, biomechanical engineering

1 The Problem

This presentation is an examination of key innovations in Nanomedicine that will enhance human capacities. During the last one hundred years the field of medicine developed with the aid in advances in chemistry and pharmaceuticals and the development of large scale technologies. For example, the artificial lung and kidney machines, bypass technology, and MRI and CT scanning gave doctors tools to diagnose and treat illnesses more accurately and precisely. Drugs such as pain killers and beta blockers helped patients live longer and more comfortably. The premise of this presentation is that the next one hundred years, during the 21st century, the greatest advancements in medicine and neurotechnology will be at the micro and nano levels. Molecular technology is destined to become the core technology underlying all of 21st century medicine, orthopedics, and dentistry!

With this shift in the Paradigm, it is also noted that there is an exponential decrease in the time to acceptance of the technology. For example, though the artificial kidney machine was invented in 1946, it took nearly 40 years for dialysis to be readily available to the general populace. Nanomaterials for neural regeneration and tissue engineering are being developed and utilized at an expansive ratio. Listed below are some of the changes that have occurred over the past ten years:

- 2000 Tissue Engineering was not relatively on the event horizon of medicine.
- 2006 Brain chip implantation becomes an accepted treatment, though they had been used in research since 1995.
- 2010 Tissue Engineering and Nanomedicine are now part of the culture of medicine and infiltrate the media.

2 The Problem

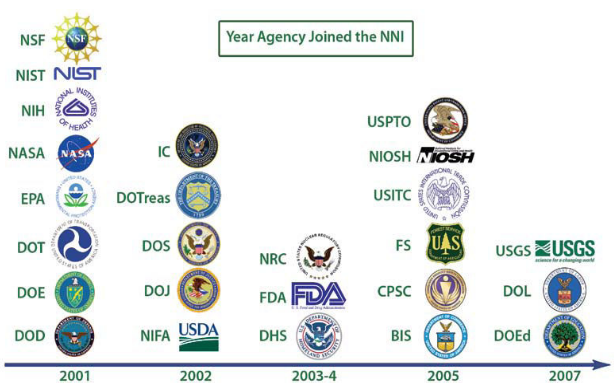
In defining the term Regenerative medicine, it is best to use the NIH standard definition: National Institute of Health (NIH) regenerative medicine and tissue engineering interchangeably: "to develop functional cell, tissue, and organ substitutes to repair, replace or enhance biological function that has been lost… (www.nih.gov)

These regenerate damaged tissues and organs can be developed in vitro or in vivo. As this field has expanded and grown in tandem with biomechanical engineering, advances in material design at the nanoscale, have creating new cross-disciplinary field: regenerative nanomedicine.

Nanomedicine refers to the fabrication, manipulation and utilization of submicron objects, particularly those between 1 nm and 100 nm for medical and scientific purposes, including nanobots, drug delivery devices, and composite biological cells and synthetic material.

3 Methodology of Categorization and Classification of Nanomaterials

As of August 2010, the ISO (International Organization for Standards) approved Iran's "Methodology of Categorization and Classification of Nanomaterials," which presents a methodology and a systematic method to categorize and classify nanomaterials according to their size, chemical nature, properties, and characteristics. (e.g. - 'muramic acid measurement for identification of nanosilver antibacterial activity') . The following agencies have adopted the ISO standards:



The term nanotechnology has been hard to define, partly because the field is multidisciplinary and different disciplines use the term in myriad ways. Some researchers claim that use of natural occurring nanoparticles should be treated different than their synthetically-prepared analogs, but exposure to naturally occurring particles can create significant health problems, problems areas which are often regulated by laws and government agencies (e.g., coal dust, talc, second-hand smoke). It will take a couple of years for this to be incorporated into US agencies, as well as the world.

Nanobots provide flexible maneuverable devices that can be placed and programmed to navigate inside the human body. Neural implants are beginning to expand beyond the therapeutic into the realm of enhancement. In the future these will be noninvasive, surgery-free, and distributed to millions or billions of points in the brain. They will allow for full-immersion virtual reality incorporating all of the senses with the expansion of human intelligence as we form a new intimate connection to diverse forms of nonbiological intelligence.

This paper begins with an examination of a key innovation in Nanomedicine that will enhance human capacities, Bioprinting.

A fairly recent development in neuro-manufacturing is bioprinting, a technique for regeneration of tissue using the adult stem cells of the recipient. Computer programming successfully is critical to a satisfactory outcome as the process deals with placing individual cells onto a matrix.

4 Bioprinting

Bioprinting allows for the regeneration of organ tissue using cells on a scaffold, with a 3D Printer that places one cell layer at a time to sculpt an organ. Synthetic polymers or naturally derived extracellular matrix proteins have been used to create the scaffolds. After the organ is constructed, the scaffold dissolves and the object can be surgically attached. There is a small chance of rejection as the cells come from the recipient. Success has been found with generating skin tissue, patches of heart tissue, and corneas. Experimentation is being conducted with several biomaterials in the form of self-assembled nanofibers/nanoparticles, electrospun nanofibers, nanocomposites, and hydroxyapatite which will become integral parts of biomedical devices to improve their in vivo performance.

Potential outcomes will include the regeneration of larger organs, such as pancreas and kidney, which could have a tremendous benefit to large numbers of patients. It would also decrease the need for organ transplants where time is not critical. New composites are being created to extend bioprinting into the realms or dental replacement and orthopedics.

Bioprinting is evolving rapidly from an external process to a composite one. In November 2011 in Sweden the second successful trachea regeneration was performed. "What we did is surgically remove his malignant tumor," Dr. Macchiarini said. "Then we replaced the trachea with this tissue-engineered scaffold." The Y-shaped scaffold, fashioned from nano-size fibers of a type of plastic called PET that is commonly used in soda bottles, was seeded with stem cells from Mr. Lyles's bone marrow. It was then placed in a bioreactor — a shoebox-size container holding the stem cells in solution — and

ISBN: 978-1-61804-109-8

rotated like a rotisserie chicken to allow the cells to soak in." (http://www.nytimes.com/2012/01/13/health/research/surgeons-transplant)

Heart flaps have been created in vivo using the human body as the "bioreactor" to regenerate and differentiate cells. However, nanobots will be needed to monitor the process and report back to the medical team any anomalies that may develop.

5 Exoskeletons

The term, "exoskeleton", refers to enhancement devices that can be worn on the outside of the body. But unlike the armor of knights or the carapaces of the Romans, these devices include a native intelligent which can sense pressure, direction, and provide a human-computer interface. The early adopters of exoskeletons were the military leaderships, with the use of HULCs, or Human Universal Load Carrier (a trademark of Lockheed Martin and Berkeley Bionics) which allows an individual to carry nearly 200 pounds of equipment loaded directly onto the device, thus bypassing the user. The HULC supports the user's leg and knee joints, greatly improved endurance. Computers located within the devices allow for sensory feedback directly to the user.

Beyond the military applications, nurses in Japan are experimenting with similar devices weighing less than 10 kg. to enhance their ability to lift 200 pound patients from their beds. It takes about 2-3 hours to become acclimated to the device.

Farmers can enhance their endurance with leg exoskeletons which would allow them to work longer hours in the field. The implications and usages of this technology are only limited by the imagination, from construction to transportation, to roboticized home aids. If they become neutrally attached to the user, then is this "iron" human still human?

Finally, this paper considers some ethical concerns in the future needs and developments of human-machine interfaces and invites the audience to participate in a lively discussion on bioethical considerations.

6 Subvocal communications

Of particular interest is the emerging field of subvocal communications, pioneered by Chuck Jorgensen from NASA. What is subvocal speech? "Recorded surface signals from the larynx and sublingual areas below the jaw are filtered and transformed into features using a complex dual quad tree wavelet transform. Feature sets for six subvocally pronounced control words, 10 digits, 17 vowel phonemes and 23 consonant phonemes are trained using a scaled conjugate gradient neural network." (Jorgensen, 2005) The process allows for the capturing and transmission of nerve signals between the brain and the throat and tongue, so it is not telepathy, as a receiver is required on the other end to capture the transmission. The technology used is electromyography, which is the study of muscle function through its electrical properties. Electrical activity associated with speech can be detected by the use of non-invasive surface sensors mounted in the region of the face and neck. Signals are transmitted to a receiver which can reproduce the sound and pitch of the original vibrations.

The potential for this technology is astounding, from communications between astronauts in space, to enhancing speech for individuals with vocal cord damage, to industrial applications. Recently, a new company has been formed in Illinois, Ambient, to develop a product called Audeo. "The audeo is being developed by Ambient as an innovative new way of silently communicating with the world around you. The audeo allows an individual to directly utilize the minute neurological signals from the brain which control the vocal cords to communicate silently." (retrieved from http://www.theaudeo.com/?action=technology May 28, 2012)

What advantages would a subvocal speech system have over other forms of non-verbal communication? What are its limitations? Some of the applications are obvious. Others are more subtle, such as allowing for sub rosa communications in a court room between client and attorney or in a classroom between students. Legal limitations may need to be placed on the usage of this technology to maintain the integrity of use and determine culpability of misuse.

Another recent development in neuro-manufacturing is bioprinting, a technique for regeneration of tissue using the adult stem cells of the recipient.

7 Ethical and Legal Implications

We are the species that goes beyond our limitations, and these technologies raise the questions of how do we define human. To date, we have defined ourselves by our limitations. Are enhanced individuals still persons? How many parts can be regenerated and replaced and still have the same individual? What is the culpability of the medical profession as well as the biomechanical engineers that design these products? Are augmented people equal to non-augmented humans? One of the questions facing our courts will be: How do you tease out the rights of persons vs. persons who are augmented? (proportional autonomy)

How will agencies such as the FDA, EPA, and TOSCA deal with this human enhancement?
Whether using a property-personhood dichotomy or property-person continuum, the rights of the individual may change when the human performance of the individual is enhanced by nano or other technology. Three ethical issues will have to be determined and established: privacy, autonomy, and culpability (of the manufacturer).

8 What About The Future?

In conclusion, it is recommended that a proactive approach including continuing dialogue and collaboration among all those involved in the cross disciplinary field of regenerative medicine, scientists, ethicists, lawmakers, economists, futurists, as well members of the public must be established. Secondly, there is a need to establish a comprehensive definition or classification schemata of nanomaterials in a way that is suitable for scientific, regulatory, and policy purposes, such as the ISO Standards.

We will continually incorporate more and more computer technology into ourselves and our lives, until we become one with it. (e.g., Ray Kurzweil's view of the Singularity.) Our lawmakers and policy makers need to consider the impact of the person – properties boundaries changing.

How many of us carry our iPhones or smartphones or small wireless computer to our meetings [and everywhere else]? When someone has a question no one can answer, in just a few seconds, we conjure up the answer with Google. It is a short step to neural enhancement.

Boyce Law of Temporal Displacement

In dealing with technology over the past 30 years, the author has made an observation. There appears to be an inverse correlation between changing technology and dealing with the change. In simpler terms, As technology becomes faster, our patience decreases. We expect and anticipate computer technology changes to have direct and immediate impact on our, and all of humanities lives for improved human performance and enhancement.

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