HEALTHCARE IN THE 21st CENTURY:

THE FUTURE OF MEDICINE

1. ENDING AGING & DISEASE
2. DIAGNOSTICS
3. INVINCIBLE MENTAL HEALTH

THE FUTURE OF MEDICINE

As Winston Churchill once observed, "The further backward you look, the further forward you can see." The history of disease is much older than humankind itself. For as long as there has been life on earth, aging and disease have been its inseparable companions. Examination of the history of Western "scientific" medical practice reveals a continuity of certain aspects of the medical paradigm. Study of medical history also reveals a long, hard struggle to improve human health, a struggle that will ultimately culminate in a grand victory; the elimination of ill health and suffering in the 21st Century. Assuming that the approximately ten billion people who have ever lived survived an average of 40 years and spent just 2% of their lives in misery and sickness from disease, then a not inconsiderable price of ~70 trillion man-hours of human suffering will have been paid to achieve this end.

"Biotechnology and genetic engineering are comparatively well-known because of their many important successes over the last several decades. But advocates of these approaches often ignore a future post-biotechnology discipline, just now appearing on the 2-3 decade R&D horizon, that can almost guarantee whole-body elimination of biological senescence and the indefinite maintenance of healthy mind and body, while producing few if any unwanted medical side effects. This new technology involves the application of molecular nanotechnology and nanorobotics to human health care. Over the next decade or two, it will become increasingly clear that all of biotechnology is but a small subset - albeit an important subset - of nanotechnology. Indeed, the 21st century will be dominated by nanotechnology - the engineering and manufacturing of objects with atomic-scale precision - not biotechnology.

Humanity is poised at the brink of completion of one of its greatest and most noble enterprises. Early in the 21st century, our growing abilities to swiftly repair most traumatic physical injuries, eliminate pathogens, and alleviate suffering using molecular tools will begin to coalesce in a new medical paradigm called nanomedicine. Nanomedicine may be broadly defined as the comprehensive monitoring, control, construction, repair, defense, and improvement of all human biological systems, working from the molecular level, using engineered nanodevices and nanostructures, molecular machine systems, and ultimately nanorobots too small for the eye to see.*


Though thoroughly grounded in scientific and engineering fact, at present (2010), the field of nanomedicine remains in its infancy. Medical philosopher, Edmond A. Murphy notes that, "to the physician, the more remote the area of speculation from the welfare of the patient, the more clearly [this speculation] must be shown to give promise of ultimate benefit." This stringent requirement for utility and relevance is clearly met, indeed vastly exceeded by nanomedicine, in our opinion. The first early applications of this budding field are only now...
coming out of the lab and into human clinical trials.

"Molecular nanotechnology has been defined as the three-dimensional positional control of molecular structure to create materials and devices to molecular precision. The human body is comprised of molecules; hence the availability of molecular nanotechnology will permit dramatic progress in human medical services. More than just an extension of "molecular medicine," nanomedicine will employ molecular machine systems to address medical problems, and will use molecular knowledge to maintain and improve human health at the molecular scale. Nanomedicine will have extraordinary and far-reaching implications for the medical profession, for the definition of disease, for the diagnosis and treatment of medical conditions including aging, and ultimately for the improvement and extension of natural human biological structure and function. Nanomedicine is the preservation and improvement of human health using molecular tools and molecular knowledge of the human body."

The body is constantly under assault from the environment, and the immune system is continually waging a silent war against these threats. Toxins, bacteria, fungi, parasites and viruses are all continuously attacking the body and trying to do it harm. Nanomedicine; the application of nanotechnology to medicine, generally means molecular control over biological structures. Many nanotechnological techniques imagined only a few years ago are today already making remarkable progress toward becoming reality. We are currently exploring how to put to use dendrimers, (branched spherical molecules) carbon buckyballs, and other specifically engineered nanoparticle drugs to combat everything from bacteria and viruses to cancer. Nanoshells could also be used to concentrate infrared (laser) light to heat, and thereby selectively destroy cancerous cells. It may become possible to orally administer drugs that can currently only be delivered by injection. Nanoparticle encapsulation of the drug will help it to easily pass through the stomach lining and into the bloodstream where its payload would be released. Inhaled nanoparticles can even stimulate the regeneration of cartilage in damaged joints.

The true potential power of nanomedicine, however, lies in still theoretical, tiny medical nanobots. "Nanobots" will be devices as small as a microbe, but they will not possess the ability to self-replicate. These engineered nanodevices, or nanomachines, will repair the damage that accumulates as a result of metabolism (being alive) by performing nanorobotic therapeutic procedures on each of the ~75 trillion cells that comprise the human body. They will contain various substructures such as an onboard power supply, nanocomputer, sensors, manipulators, pumps, and pressure tanks. By the early 2020s, molecular manufacturing - the ability to manufacture objects chiefly out of carbon with atomic precision, in very large numbers (through massively parallel assembly) using nanofactories - will enable the first nanobots to be inexpensively produced for use in medicine. Researchers have already begun to tackle the problem of how to construct such devices. We are only just beginning to learn how to assemble structures atom-by-atom. These structures (nanoparts) have to then be brought together to construct components, which must next be assembled into micron-scale machine systems like a complete medical nanobot. Once this has been worked out, we must figure out how to produce massively parallel assembly lines that build entire nanobots in batches of millions or even billions of units at once. This is definitely no easy task, but it is possible, and with sustained effort over the remainder of the present decade, by 2020 medicine should receive a major shot in the arm thanks to this technology. Once in common clinical use, nanobots will have an enormous positive impact on the lives of billions of people.

As doctors begin to use medical nanobots in their daily practice, they will gain the ability to rapidly repair almost any physical injury, cure virtually every known disease that disables and kills people today, and vastly extend human life and healthspan. An array of nanobots, each specifically tailored to a particular function, has been envisioned by Robert A. Freitas Jr.: 

Respirocytes are a design for an artificial red blood cell. The human body contains approximately 30 trillion natural red blood cells which circulate in the bloodstream and occupy roughly half of the blood volume. A single disc-shaped red blood cell measures around 6-8 μm in diameter and 2-3 μm thick. Respirocytes will be much smaller - an entire respirocyte will be a 'perfect' sphere measuring only a single μm in diameter - about the same size as a bacterium. A respirocyte will be an atomically-precise arrangement of 18 billion structural atoms. An onboard nanocomputer controls the loading/unloading of oxygen and carbon dioxide molecules to and from microscopic pressure tanks made of diamondoid crystal via thousands of molecular-scale pumps arranged over its surface. Just 5 ml (or one thousandth of our total blood volume) worth of respirocytes added to a person's blood could double their natural oxygen-carrying and carbon dioxide removing capacity. A single respirocyte will be capable of transporting hundreds of times more bioavailable oxygen than a natural red blood cell, at only a fraction the size. Half a liter - the most respirocytes that could be safely added to a person's blood - would allow them to sprint at top speed for twelve minutes, or remain underwater for up to four hours without taking a single breath. Alternatively, respirocytes would buy valuable time in the event of a heart attack, or drowning, and due to their diminutive form factor they would be able to supply needed oxygen to cells that would otherwise be starved following a crushing or other accident that constricts blood flow.
Microbivores, or nanorobotic phagocytes (artificial white blood cells) introduced into the bloodstream would form a synthetic immune system, a search and destroy task-force constantly on patrol for pathogenic microbes, viruses and fungi. During each of its operation cycles, a target microbe sticks to the surface of the microbivores reversible binding sites "like a fly on flypaper." Silos in the surface of the 2-3 micron long device house telescoping grapples which securely anchor to the plasma membrane of the microbe, then transport it to an opening called the ingestion port. Once internalized into the two cubic micron cell-repair chamber, the microbivore blends the pathogen into a slurry. The remains are pistonned into a digestion chamber of similar dimensions where a series of engineered enzymes are sequentially injected/extracted several times. The process progressively reduces the remains into free amino acids, simple fatty acids, mononucleotides, and sugars. At the end of this process, an exhaust port on the back of the microvirobie discharges the resultant basic molecules/nutrients harmlessly back into the bloodstream, completing one 30 second cycle. Multiple-drug resistant strains of bacteria stand no chance against the microvirobie. Even the deadliest of infectious pathogens could be completely cleared from the system within just minutes or hours with no negative effect to the patient, and using only a few milliliters of microvirobies. Contrast this with the weeks or months required to achieve similar results (best case scenario) with current antibiotics. Microbivores are expected to be on the order of a thousand times faster acting than even antibiotic-aided natural phagocytes. With additional programming, similar nanobots could be used to detect and selectively destroy cancerous cells, or even clear obstructions from the bloodstream in just minutes, preventing ischemic damage in the event of a stroke.

Chromallocytes, one variety of cell-repair nanobot, would enter the nucleus of a cell and extract all of the genetic material (chromosomes) and replace it with a synthetically produced copy of the original that has been manufactured in a laboratory to contain only non-defective base-pairs. The result of this cytysurgical "Chromosome Replacement Therapy" (CRT) process would be the removal of all inherited defective genes, reprogramming of cancerous cells back to a healthy state, and a permanent cure for all genetic diseases, or any combination thereof desired by the patient. CRT will enable us to exchange our old defective chromosomes with digitally precise new copies of our genes, manufactured in a laboratory by a benchtop size production device, using the patient's genome as the blueprint. By installing new DNA in every tissue cell in the body, this technology will make it possible to arrest and even reverse the effects that aging has on our biology, and most current causes of natural human death - forever severing the link between calendar age and physiological health. If you are biologically old, and do not wish to be, then for you, aging/being old is a disease, that you deserve to be cured of. Through a combination of nanobot therapies, say once a year or less frequently, accumulated metabolic toxins and other nondegradable material will be cleansed from your body, while chromallocytes delete any genetic mutations or damage. Any remaining structural damage to cells that they are unable to auto-repair such as disabled or enlarged mitochondria will be dealt with using dedicated cellular repair nanobots. These rejuvenation procedures will need to be repeated once a year (or less frequently) to revert all of the damage that occurs on a continual basis as a result of metabolism.

Clottocytes are a design for micron-scale, oxygen/glucose-powered, artificial mechanical platelets. Clottocytes would be 100 to 1,000 times faster in response than the body's natural platelets, stopping bleeding almost instantly (within about one second) even in the event of fairly large wounds. The clottocyte is conceived as a two micron diameter, sphenostral nanobot that contains a tightly-folded (biodegradable) fiber mesh payload which, when commanded by its internal nanocomputer, deploys in the general vicinity of a damaged blood vessel. Certain parts of the mesh are designed to dissolve exposing sticky sections upon contact with water in the blood plasma. The overlapping nettings of multiple activated clotcyttes trap blood cells and stop bleeding immediately. The clotting function performed by clottocytes is essentially equivalent to that of biological platelets, albeit at just 1/100,000th the concentration in the bloodstream, for approximately 20 nanobots/cubic centimeter of blood,) and much quicker acting.

Because nanobots and related technologies would, if successful, improve the user's abilities beyond normal human limits, their design is associated with the transhumanism movement which seeks such advances. Theoretical nanobot designs indicate 100 to 1,000 fold increases in effectiveness compared with biological systems. The potential for such astonishing improvements in performance over nature may come as a surprise; however consider that in addition to performing their specific functions, biological cells have the distinct disadvantage of also having to be alive. Supporting life's processes demands a lot of extra bulk and uses up resources which could otherwise be spent on the "secondary" function that is the primary reason for that cell's existence.

"DNA can be considered to be biological nanosworeware; ribosomes, large scale molecular constructors. Enzymes are what Nature chose as truly functional molecular sized assemblers. Genetic engineers are not creating new tools per se, but rather, adapting and improvising from what Nature has already provided. Future generations of engineers, armed with molecular engineering techniques, will have a real chance of imitating and perhaps improving upon Nature." - Imitating The Molecular Workings of Nature

Nanobots can also be designed and constructed with absolute atomic precision - a level
of perfection that is actually beyond that which say, an entire natural cell operates on. Practically every atom in a nanobot will have a particular function in the overall structure. Intelligent design of the human variety can now be much more direct and efficient than nature - but it took nature to get us this far.

Register Now and Save PCPCC Medical Home Conference April 23-24 - Washington DC www.pcpcc.net

Medical Manager Watch the EHR & Practice Management software demonstration online now Medical-Software.AdvancedMD.com

Engage with new patients Make your name/ your practice a household name in your area; www.Questions4Docs.com -----

THE END OF AGING AND DISEASE

The result of these somewhat radical interventions will be the effective end of aging as well as the reversal of one's current biological age to any new age that is desired. These procedures are anticipated to become commonplace as the technology evolves, a few decades hence. With routine annual checkups/repairs, and the occasional major tune-up, you could remain virtually constantly your ideal biological age. Most people would probably choose to remain perpetually in the prime of their lives - their early twenties - physiologically. People will still die at some point, however. Most deaths will likely become accidental, rather than "natural." Even if such procedures can keep you "clinically immortal," if you're hit by a flying car, you may still die, though cell repair nanobots and other advanced future medical techniques will be able to repair much more extensive injuries than are now possible. Based on projected rates of accidental death and suicide, a life expectancy of at least one thousand years is expected - if we don't annihilate ourselves in the interim. The field of biotechnology has similar objectives, so even if it fails to accomplish similar goals, nanotechnology (nanomedicine) is almost certain to do so.

Radical life extension will cause a monumental disturbance in society. Some fear that "ageless bodies" will lead to "a life of lesser engagements and weakened commitments." Perhaps the most significant danger in curing aging is in the cultural and intellectual stagnation of humankind that may result if the current generation were stopped in time. Nobel prize winning physicist Max Plank wrote, "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with the idea from the beginning." Most of the current opposition to ending aging, however, stems from a deeply rooted belief in its continued inevitability. Humanity has sought immortality by various means from time immemorial, but it has been nothing more than a pipe dream until very recently. Nanomedicine now promises to fulfill this age old dream within the next 20 years.

Another common concern raised immediately by nearly everyone is the issue of overpopulation. With the world's population already nearing 7 billion people (by late 2011) and projected to hit 8 billion in 2025, overpopulation is already becoming a problem in some countries. Overpopulation will not result solely from vastly extended lifespans. People could live forever, and the population will only grow if they continue having children. When people stop dying so frequently, the population will begin to grow almost as quickly as the birth rate. As a result, in the future we may be forced to choose between either forcing people to die of aging - an ethically unacceptable, undesirable and impractical option; limiting reproduction as much as possible; or allowing unbounded advancement toward the stars - perhaps the most attractive and effective solution. Radical life extension, and its anticipated resultant population spike may turn out to be the impetus for the beginning of a new chapter in the human story - our skyward expansion into space. Nanotechnology will give us many other tools for dealing with our increased numbers, even here on earth. It should become possible to feed and house many times more people on this planet than it can currently handle. Other nanotech enabled technologies will make it less expensive and more practical to leave behind our earthly cradle and even terrabions new worlds.

Biogerontologist, Aubrey De Grey states, "aging is a barbaric phenomenon that shouldn't be tolerated in polite society." De Grey believes that a cure for aging will be beneficial despite the many inherent potential problems. People will gain interest in and commitment to the far future - a future they would now expect to be a part of. As lifespans are extended to multiple centuries - and beyond - people will undoubtedly gain a new level of respect for the body, one another (including complete strangers), and for the environment/earth as a whole. With time to do so much and meet so many more people during an enhanced healthspan, we will all have more time to contemplate the consequences of our actions. If wisdom comes with age, then our collective wisdom should increase with the average age of the populace. Prison sentences will need to be reviewed, and in many cases, revised. Rates of violence and war are expected to drop.
off significantly as people have more to risk from early death. This alone will mark an historic social shift for humanity.

Aging and Disease result from the molecules in our tissues sliding into disorder, first destroying health, and eventually taking life itself. Nanotechnology will give us numerous novel approaches to repair our aging bodies and undo the disastrous results of the ravages of time. The advancements anticipated in the Nano age offer the first promising hope of a science-based fountain of youth. Radical life (and health) extension will become commonplace. The myriad maladies that have plagued humankind throughout history are about to be decommissioned over the coming decades.

**Nanoscience** in its current form is already beginning to find some application in medicine; however molecular manufacturing (MM) capabilities will have a much greater impact. MM will evolve the practice of medicine much faster than it ever has before.

### DIAGNOSTICS

The tools we employ in medicine will continue to shrink in size, and increase in power, while becoming less expensive. Diagnosis and research will become far more efficient than they are currently, enabling faster response to new diseases. As medicine becomes less uncertain and cheaper to practice, more people will gain access to it.

The high-tech, cutting edge tools required by medicine (especially medical research) are presently very expensive to produce. With MM it becomes a matter of designing and testing new surgical and diagnostic tools, but the production costs are entirely unrelated to the tool’s complexity. Producing larger quantities of these tools to treat more people become a matter of simply selecting a larger production run. Building with individual atoms makes it possible to produce entire tools that are incredibly small. Sensors, and indeed entire nanobots, will be made that are tiny enough to fit within living cells.

The complexity of the human body dictates that determination of its state requires the collection of large volumes of data. An analysis of these data will even be available in real-time, (crunched by integrated nanocomputers millions of times faster than current-day computers.) Monitoring the patient's condition continuously, they will construct a detailed model of the patient's body, and apply a predictive approach to both the course of the disease or other ailment and any possible course of action in treating the condition. The sensors/nanocomputers could even provide recommendations based on computation of the probabilities of various potential treatments. The small size and low cost of nanosensors will, for the first time, make gathering this information possible, even in routine diagnosis. Traditional medical diagnosis has been more of a trial and error process, requiring an extremely conservative, one step at a time, approach. With real-time monitoring of a patient's systems, it becomes possible to identify problems much earlier, allowing for a more aggressive and experimental treatment approach. Thousands of medical tests will be combined into a single, inexpensive, hand-held device. This will make diagnosis much more reliable, hence increasing accuracy while reducing malpractice/insurance liability.

Implantable medical devices today are of limited capability due to their bulk. Nano devices will be compact and efficient, making them easier to implant. Future devices will continually take readings (producing a continuous record of a patient's health, and detecting problems as they occur) and make adjustments to the body's chemical balance when necessary. These
implantable devices make it possible to monitor the health of the population and identify the exact time and location of infectious disease outbreaks, toxins in the environment, etc. so that they can be contained immediately.

Medicine, as it is practiced today, is fraught with uncertainty. Doctors have to guess the condition their patient has, and then guess the best way to treat it, while (ideally) having a minimal effect on the rest of the body. Nanomedicine will reduce or completely eliminate side-effects and uncertainty while providing a much higher level of care at a fraction the cost. Regulatory agencies, doctors and even patients themselves are expected to resist these changes at first, because people generally favor the familiar. But, once people see the largely beneficial direction these changes are headed in, most will probably join the revolution.

INVINCIBLE MENTAL HEALTH

Mental health, invincible superhappiness/paradise engineering & the hedonistic imperative:

Arguably the single most exciting prospect of molecular nanotechnology is the potential to rewrite the very subjective quality of every moment of our experience itself into something infinitely more fulfilling. Natural selection evolved a motivational system based more on gradients of pain than gradients of bliss, for the simple reason that pain was more effective at ensuring our survival in the very different world of our ancestors. That world has wholly changed, yet for the most part, we have not. We will not travel to the stars as territorial apes.

"Homo sapiens, the first truly free species, is about to decommission natural selection, the force that made us.... Soon we must look deep within ourselves and decide what we wish to become." - Edward O. Wilson

David Pearce of HedWeb has outlined what he has termed "The Hedonistic Imperative" - an outline for "a strategy to eradicate suffering in all sentient life." Contrary to popular culture's naive view that superhappiness must necessarily come with dystopian trade-offs, states of sustained hyper-dopaminergic overdrive could actually incite a wholly new motivational system animated by gradients of well-being. Contemporary views shaped by pleasure seeking drug users give an inaccurate portrayal of this concept because they are still firmly strapped to the "hedonic treadmill." Simply put, this is the concept that what goes up must come down, and applied to our mental state, it becomes clear that mood enhancement is not much use without sustainability - hence the intrinsic problem with practically every existing supposed "antidepressant" or recreational drug. Current pharmacological empathogen-entactogens offer only a tantalizingly cruel glimpse of a state of mind more beautiful than the drug-naive mind can begin to imagine.

This is the factor that molecular nanotechnology/nanomedicine will allow us to once and for all obviate. For the first time in history we will have the technological power to unplug the hedonic treadmill, at once outsmarting our evolutionary heritage, and gaining the ability to transcend the limitations of our biology.

Aldous Huxley once said, "If we could sniff or swallow something that would, for five or six hours each day, abolish our solitude as individuals, unite us with our fellows in a glowing exaltation of affection and make life in all its aspects seem not only worth living, but divinely beautiful and significant, and if this heavenly, world-transfiguring drug were of such a kind that we could wake up next morning with a clear head and an undamaged constitution-then, it seems to me, all our problems (and not merely the one small problem of discovering a novel pleasure) would be wholly solved and earth would become paradise."

Biological evolution has served us well in the sense that we owe our very existences to its methodical persistence. But, it has brought us to a point where we have the sophistication to take over ourselves. Humans can apply logic, intelligence and problem solving rather than broad-spectrum trial and error to the evolutionary endeavor, applying choice in the pursuit of our destiny. We already control the direction of our own evolution to a greater extent than nature.

It is possible that our superintelligent posthuman descendants (or perhaps even our future selves) will be animated by gradients of bliss that are literally billions of times richer than anything biologically accessible today.