Futurist Scenarios Concerning Radical Life Extension

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Abstract

A fundamental component of Transhumanism, radical life extension is the process of utilizing ever increasing technologies to further extend the average life span of humans. This iterative process has continued to increase in speed since the digital age. As society develops a larger knowledge base, and scientific fields combine their knowledge bases, the capability of medical professionals continues to increase at an exponential rate. Through an understanding of these technological trends the social, legal, logistical and economic implications can be better understood. Scenarios can be used to better categorize these implications based on the evolution of these technologies. By considering biological, non-biological and linear life extension technologies a broad analysis of the varied implications can be constructed. Based on these scenarios one can conclude radical life extension technologies will have significant impacts on the current social definitions of what it means to be human and how society organizes itself. Continued research towards radical life extension technologies comes with high social implications which must be considered in tandem.

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Introduction

The 20th century has brought about a revolution like no other in recorded time. The digital age has connected the world, made information easily accessible, allowed humans to peer further into space than ever before and even develop experiments to further understand the early nanoseconds after the big bang. In under one hundred years, society went from its first manned flight of an aircraft to landing men on the moon. Automobiles, aircraft, rail systems and their supporting infrastructure have connected all points on the globe, making transportation of individuals and goods second nature. The space shuttle and private launch vehicles have made access to low earth orbit more accessible than ever before. In less than fifty years the computer has gone from the size of room to the size of a pack of gum while increasing getting faster, cheaper and having orders of magnitude increased memory storage capability. Recent advances in technology have brought about significant advances in the fields of medicine and biology. These technologies have ushered in a time period where modification of the body, brain and DNA have all become increasingly popular. Newfound capabilities have allowed scientists to begin advancing technology necessary to radically expand human lifespan. These most recent paradigm-shifting technologies are just some of the radical technological advancements society has made over the past few hundred years. Connoisseurs of history will quickly observe the ever increasing speed of innovation occurring around the world. We must go back just five centuries to observe Columbus's traversal of the Atlantic Ocean in search of spices from India; the journey concluded with Columbus "finding" the new world, now known as North America, and changing the way we see the world forever. Predating this journey, society took thousands of years to make fundamental discoveries such as written language, fire and the wheel.

One potential major technological change believed to be technologically viable is radical life extension. This collection of technologies would allow individuals to greatly extend their biological lifespan. Radical life enhancement technologies incorporate human developed technologies and utilize them to circumvent biological limitations of the human body. These technologies can broadly be categorized into biological and non-biological enhancements. The biological enhancements use technology to repair and replace biologic functionality with the objective of extending the functionality of the human body. Non-biological technologies use technological enhancements to separate the human consciousness from the human body. By allowing the human consciousness to continue to survive after the viable lifespan of the human body, individuals can continue to live on in virtual realities or robotic bodies. These solutions can provide significant extension to the human lifespan.

As advancing technology moves society ever closer to the ability to radically extend lifespan, the reception of society to these capabilities will play a significant role in their ultimate availability and prevalence. The magnitude of the paradigm shift that could occur would have the potential to shake the social infrastructure existing in modern society to near collapse. Radically extended life expectancy for portions of the population has the potential to produce large social division, economic instability and put further pressure on the global carrying capacity of the Earth. As technology progresses, the feedback of society becomes of great importance to how the technology will ultimately be received and implemented. This allows for a more efficient rollout of the technology and limits resistance to ideals which global society disagrees with implementing. Through the use of scenarios the pace of change, maturity and level of acceptance of the technology can be better understood. The pace of technological innovation continues to increase, potentially surpassing the pace of social, institutional and political change in the coming decades.

When considering the timescale of technological change, a clear exponential trend in global technological capability is evident. In 1970 Gordon Moore, co-founder of Intel, proposed that over the next few decades we would observe a doubling of the number of transistors which could be densely packed onto a one square inch integrated circuit every two years. Moore's Law, as his prediction is known, continues to hold. The price of computation and the number of transistors being produced yearly has also been following similar trends. These exponential trends are moving society rapidly towards limitations imposed by chemistry, physics and biology. As with all paradigms, as the technology reaches its limitations, a new technology breaks into the market and slowly replaces the antiquated technology. This framework of technological evolution can be observed throughout history in most industries and technological sectors.

Biological limitations require a significantly slower evolutionary timescale for adapting to change. Human bodies evolve in the framework of chaotic evolution over thousands of years. This disjunction between the pace of change in the human environment and the speed at which the body adapts continues to grow as technology rapidly outpaces biological evolution. This issue has prompted the scientific community to search for ways of circumventing biological limitations in an effort to keep pace with other aspects of rapid technological change. The human brain, like all systems, has strong strengths and weaknesses. The human brain possess pattern recognition capabilities far superior to any digital technologies to date. This pattern recognition is however hindered by the vastly limited computational capability of the human brain. The computational capability of modern computers far outstrips the human brain when concerning mathematical computation. The human brain is capability of, at best, dozens of calculations per second. When compared to the billions of calculations per second completed by a modern computer the need for biological circumvention becomes quickly apparent.

Blending biological and technological capabilities would allow humans to take better advantage of our technological advances while making significant improvements to our biological selves. Scientists identified this shortcoming of biological structure in 1923 when geneticist John Burdon Sanderson Haldane published *Daedalus: Science and the Future*. Dr. Haldane theorized technological advancement to come in the near future would vastly improve the capability of biological systems. This came to be known as transhumanism. Transhumanism in modern science is considered to be using technology to circumvent biological limitations imposed on society. On the surface transhumanistic technologies can be thought of as radical cutting edge procedures. Proposals currently exist for everything from replacing the human visual system with superior digital sensors to downloading the human consciousness onto a computer. While these theoretical capabilities are radical considering modern technological limitations, one must consider the exponential increase in technological capabilities occurring in modern society. Transhumanistic tendencies are nothing new for society. While we currently seek the technology to incorporate digital technologies into our biology, humans have been supplementing their biology with tools and technology for centuries. For example, we augment our eyesight through glasses, which records indicate have existed as early as 1286. Eyeglasses allow individuals to surpass their biological limitations and increase their eyesight. While considered commonplace in modern times[1], eyeglasses were one of the first transhumanistic

[1] This example considers both electronic and mechanical forms of transhumanistic technologies. More contemporary definitions of transhumanism might exclude the latter.

technologies to seed the idea that humans could surpass their biological limitations. As technology improves the capability of humans to extend their limitations improves.

Utilizing transhumanistic technologies, members of society seek to radically extend the lifespan of the human species. A central component of transhumanism is the capability to radically extend the life expectancy. As biological systems are improved, replaced and extended by human technologies their capabilities continue to increase. The ultimate goal of radical life extension is to utilize technology to quicken the pace of change. As the pace of technological progress rapidly advances, it is postulated that similar growth will occur in the field of transhumanism, especially focused on radical life extension. As technological progress allows for radical life extension and the significant circumventing of biological limitations, social, ethical and economic issues are to be expected. Societal change is occurring at a rate far outstripping modern political and social infrastructure. Futurists consider this point in time to be a precursor to a time known as the singularity. A major proponent of this concept is futurist and engineer Ray Kurzweil. Dr. Kurzweil has been involved with artificial intelligence research since the early 1970s making major contributions to the field through his company KurzweilAI and other ventures. Kurzweil defines the singularity as "... a future period during which the pace of technological change will be so rapid, its impact so deep, that human life will be irreversibly transformed. Although neither utopian nor dystopian, this epoch will transform the concepts that we rely on to give meaning to our lives, from our business models to the cycle of human life, including death itself" (Kurzweil 97). Dr. Kurzweil supports the idea that exponential growth in technologies, while slow at first, explodes in rapid growth after a number of iterations. Numerous organizations record and plot notable technological advancements throughout history as a function of time. Dr. Kurzweil has taken these lists, merged them, and concludes they suggest an exponential tract of technological progress.

Radical life extension encompasses a collection of technologies and potential implementations that may each ultimately lead to the capabilities of humans to live for hundreds of years. A number of technologies are currently theorized, or in development, which could contribute to the extension of the human lifespan. Radical life extension technologies must be differentiated from moderate self-preservation strategies practiced by a large percentage of the population. Healthy eating, exercise and regular health checkups will contribute to an individual's wellbeing but will not contribute to more than a moderate extension of the individual's lifespan. If realized, technologies like telomere extension therapies[2], mind uploading[3] and virtual reality[4] each have the potential to extend an individual's lifespan for hundreds of years, if not indefinitely. These technologies are a new class of social solutions and must be treated as such. They pose an entirely new set of social challenges which society will have to either accept or reject based on varying belief systems, legislations and economic incentives. Multiple scenarios exist for how society could handle this rapid and radical technological and ideological shift.

Economic incentives support the incremental march towards the continued development of transhumanistic technologies. Efficiency is a fundamental aspect of the economic model. Companies that can improve their efficiency are more likely to succeed in the open marketplace. They can produce more product for typically lower costs and with faster turnaround times.

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[2] Telomere extension therapies target the component of DNA that typically dies first in an effort to extend cell life.
[3] Mind uploading is the process of downloading an individual's consciousness onto a digital substrate in order to preserve consciousness after biological death of the body.
[4] Virtual reality is a broad category that includes all topics of being able to live, either completely or in part, inside another reality. These realities are created virtually by computer simulations.

Introducing transhumanistic technologies into their business model allows for higher efficiency and an overall edge over their competitors. In the summer of 2014 a South Korean ship manufacturing company began fitting their steel workers with robotic exoskeletons to improve their efficiency and reduce the load on their physical body. This allowed workers to maintain their energy levels longer throughout the day and increase the shipyards output without increasing their workforce (Hodson 2014). Economic incentives such as these continue to promote the development of these technologies. A significant percentage of transhumanistic technologies are also under development by the United States Military and the Defense Advanced Research Projects Agency (DARPA). These projects, typically classified, are shielded from public view and deployed when their development is complete. DARPA supports research in artificial intelligence, robotics, bioengineering and many other technologies that contribute to progressing transhumanistic technologies. These projects are developed at the discretion of these organizations under the veil of national security and are typically not made aware to the public until well into their development. At that point in time public debate on the potential ethical issues of any given technology is moot as it has been developed and brought into the world. Reminiscent of the scientists who worked on the Manhattan project developing the atomic bomb, no matter what the level of regret a technology once developed cannot be wiped from existence. This framework of economic incentive and governmental support for transhumanistic technologies suggests strong motivations for the continued development of these products towards uncertain social and ethical implications.

Radical life extension technologies, in certain implementations, contradict the values of some of the world's major religions. The concept of death and the afterlife is seen in almost all prominent religions. It signifies a transcendence to a better place and eternal happiness and is a required part of the lifecycle for observers. Devout religious believers signify death as the true beginning of their life as they can transcend to the afterlife. Known to be highly spiritual and a survey of many of the world's religions, Steve Jobs described death during his convocation ceremony at Stanford University in 2011. Jobs said, "No one wants to die. Even people who want to go to heaven don't want to die to get there. And yet death is the destination we all share. No one has ever escaped it. And that is as it should be, because Death is very likely the single best invention of Life. It is Life's change agent. It clears out the old to make way for the new". This philosophy is one shared by many around the world. To modify the body, given to humans by a supreme creator, is considered sinful and frowned upon by many religious institutions.

Outstripping the capabilities of planet earth to provide for society is a major concern as radical life extensions technologies allow individuals to live longer. With these theoretical limitations in place, society must begin to develop ways of circumventing these limitations from either the radical life extension technology perspective or by increasing the carrying capacity of earth. Let us first consider alleviating the ecological burden from the radical life extension perspective. Technologies such as mind uploading and virtual reality allow individuals to maintain consciousness, inside a virtual reality, without maintaining a physical presence. With individuals living well over a hundred years the planet would see exponential population growth like never before. The World Health Organization estimates that 55.8 million people died in the year 2012. With exponential increases to human life expectancy, only a fractional amount from this figure is a potential death estimate, considering the full implementation of radical life extension technologies, for the coming decades. Over the course of a century occurring post-radical life extension, the earth could expect to see upwards of 5 billion additional humans.

When this is added to the 7.2 billion current inhabitants of planet earth, the post-radical life extension figures far surpass even the most conservative global carrying capacity estimates.

Uncertainty of the future is a constant, especially in a rapidly changing world. Utilizing the increasingly vast collection of knowledge being massed by society, futurists can speculate scenarios for the evolution of the next century. While nothing can be definitively determined, developed scenarios can offer a look inside theoretical futures. They are consistent with evolving trends and are developed by a collection of collaborating aspects. These scenarios would suggest one future outcome over others if a hypothetical set of events play out. The use of scenarios to hypothesize future events can be seen frequently in Hollywood movies. Utopian and dystopian future scenarios are frequently the topic of Hollywood films. The future is gradually built up throughout a movie based on justification of events that lead from the modern day to a theoretical future. While these scenarios cannot be supported in hard evidence, and are by no means predictions, they suggest theoretical trends on a more granular level as to a future we might see given different scenarios of events playing out. There are three scenarios to consider with regards to radical life extension technologies. A first scenario to consider is a future with radical life extension supplemented by strong virtual reality and mind uploading technologies. This form of life varies vastly from the biological and accomplishes radical life extension through predominantly digital means. A second radical life extension scenario is that of biological radical life extension technologies. This scenario includes technologies such as telomere extension to circumvent the limitations of our current biological systems predominantly through bioengineering technologies. Finally a baseline scenario that includes no radical life extension technologies must be considered. This scenario includes linear paced life extension and acts as a comparison for theories that exist outside the realm of transhumanistic technologies.

Radical life extension provides many aspects, and limitless scenarios, which can be utilized to analyze the technology. A scope for the project was necessary to limit the paper to quality content in a number of specific areas of interest. I've chosen to broadly define three scenarios below which I believe encompass most of the foreseeable technological implications which will contribute to radical life extension. Biological radical life extension, non-biological radical life extension and linear life extension can broadly categorize all technologies which will impact human lifespan in the coming decades. For the purpose of simplicity these technologies are considered separately however the most likely outcome is a combination of all three of these scenarios. Practically nothing outlined below can exist in a technological vacuum. The specific blend of these technologies which become available will shape the future and drive the societal implications observed in the future.

Societal implications brought about by radical life extension are as diverse as the technologies which can produce them. I chose to focus my research around social, logistical, legal and economic impacts since these are some of the more relatable implications society could consider in the current day and age. Radical life extension technologies will also introduce significant implications for modern theology. The ability to radically extend life challenges modern theological traditions for many religions and will have an impact on both the relationship between practitioners and their religions as well as the institutional stability of the religions themselves. These implications are vast and complex and therefore have been concluded to be outside the scope of this paper. These implications have good leading edge indicators to observe as a guide map to the further implementation of these technologies. Understanding the impacts in these key fields can support a deeper understanding of large scale implications as they occur. Additional implications are inherently unknown and will challenge society as they occur.

Human nature is governed by an innate motivation to advance however many advancements come with unintended consequences. Society consists of a chaotic collection of individuals each pulling in their own direction to influence the collective society with their advancing contribution. With radical life extension technologies constantly change the shape of society, one can except to see future challenges in job availability, funding retirement and widening social divisions in society as financially well off citizens embrace emerging technologies. These potential challenges reflect our ability to anticipate the future but a multitude of potential challenges exist which have no obvious indicators in modern society. Future interactions between advancing technologies and society produces a complex new world, potentially unrecognizable to the society of today. The use of scenarios allows for the consideration of a future society as a way to anticipate and speculate about future implications of these technologies.

Scenario One: Non-biological Radical Life Extension Technologies

Accomplishing radical life extension technologies through predominantly non-biological solutions is a viable scenario consistent with current trends in technological capabilities. This version relies heavily on non-biological technologies in order to circumvent death. At the point when the biological body is no longer capable of acting as a vessel for human consciousness the individual could theoretically upload their consciousness into a computer and continue to live inside a virtual reality. Nick Bostrom, a Swedish philosopher, and researcher on the anthropic principle, has done extensive research on the topic of whole brain emulation, otherwise known as mind uploading. In a 2008 technical report, Anders Sandberg and Nick Bostrom define whole brain emulation as, "The basic idea is to take a particular brain, scan its structure in detail, and construct a software model of it that is so faithful to the original that when run on appropriate hardware, it will behave in essentially the same way as the original brain" (Bostrom and Sandberg 2008). Whole brain emulation would allow the individual to 'upload' their neural behavior to a digital system and maintain consciousness through this system. Coupled with strong virtual reality technology the individual could become fully immersed in the reality and lose nothing but their original biological body. Their thoughts, memories, aspirations, likes, dislikes and all other components of their self which make an individual themselves would be ported over to the digital substrate and be capable of functioning in the virtual reality of their choosing.

Scenarios including whole brain emulation for the future are highly dependent on the development of multiple lines of technology as well as the philosophical conundrum of the anthropic principle. The anthropic principle is a philosophical question pertaining to multiverse theory, which questions the precision of values like the cosmological constant. It speculates the universe must support the capability of sapient life if we as humans will exist with an intellectual capacity great enough to question why the universe behaves the way it does (The Anthropic). Many researchers extrapolate on this principle to question whether the human brain is truly intelligent enough to understand its own inner workings. A paradox is often cited that as the brain increasing becomes more capable of understanding new thresholds of the inner workings of the brain, itself becomes increasing more complex. This paradox creates a recursive nature, which, barring transhumanistic technologies, could never be resolved. Transhumanistic technologies, such as artificial intelligence, introduce new tools that offer additional insight into the workings of the brain. Technologically enhanced entities have the potential to understand the inner workings of the brain at a level never before thought possible. This paradigm shift in understanding has the potential to lead to a level of understanding that allows for the porting of the conscious and continuation of life in a non-biological substrate.

The technologically enhanced radical life extension scenario takes a major diversion from the modern standard definition of what it means to be human. Not only does the scenario radically extend the human lifespan but also calls into question what it means to be human. On the surface this question appears straightforward, for centuries the answer has remained the same. Individuals point to the biological body, human consciousness and free will as cornerstone aspects of what it means to be human. This fundamental definition is slowly being called into question as radical changes are being made to the human body. At what point will we consider an individual no longer human? At what point does a transhumanistic technology no longer make someone human?

Advanced application in brain-machine interfacing has the potential to become significant in this non-biologically enhanced scenario. Brain-machine interfacing is a rapidly advancing technology capable of allowing the human brain, with minimal digital enhancements, to directly interact with robotic instrumentation. In the modern era this technology is predominantly advancing for assisting amputees, but has the potential to lead to a new paradigm in how the human consciousness interacts with the world. Current prosthetic technology for amputees requires non-intuitive movements by a part of the body other than the prosthetic in order to drive a movement on the prosthetic. This could come in the form of an amputee tightening their left shoulder blade as an action movement mean to initiate the action of closing their prosthetic hand. These behaviors are not intuitive for the user and complicate daily activity with the device. Neurorobotistics with the Defense Advanced Research Projects Agency (DARPA) recently developed a nearly passive robotic arm that utilizes brain-machine interfacing to allow an amputee to operate the arm using the same mental stimulus they would traditionally use to operate a biological arm. When the user thinks to pick up a nearby object the arm responds with no necessary unintuitive middle action commands from the user. In the fall of 2014 a double amputee was able to use two of the neurorobotic prosthesis at the same time and complete simple tasks (Moon). The device works by collecting neural and kinematic data from the user during a calibration period, which can then be paired with the real world intent of the user. During normal operation the device looks for similar neural and kinematic signatures that the system uses to instruct the arm on proper operating behavior (Johannes). This ability to increasingly quantify deep neural and kinematic behavior will increase as the technology develops and contribute to the ability to computationally emulate human consciousness. As both robotic and neural mapping technologies increase, it will become possible to completely emulate physical motor desire and transcribe them to a robotic presence allowing humans to live inside a robotic substrate. Coupled with whole brain emulation and virtual presence, technologies will allow individuals to move between virtual realities and physical presence on earth through robotic presence.

Radical life extension under this proposed scenario will significantly change societal construct as individuals transfer between biological, robotic and virtual presence. Having this variety of existing forms allows for humanity to greater expand into the realms of virtual reality as a way of managing rapid population growth as the ability to live for radically longer periods of time become realized. Not being limited to the physical world will allow for civilization to manage the issue of rapid population growth from the onset period of radical life extension.

These forms of non-biological presence will also greatly reduce physical resource use in the areas of food, water and oxygen. Virtual and robotic existence will vastly extend the carrying capacity of the earth by allowing rapid population growth without linear growth in resource use.

The technologically enhanced radical life extension scenario takes a major diversion from the modern standard definition of what it means to be human. The path chosen will greatly impact policy and the proliferation of this technology. Separation of the body and consciousness as individual parts of the self is one aspect of policy that has the potential to expedite the development of this technology. This allows for individuals to move from one body, in either virtual or physical presence, to another without being considered deceased. In modern society the physical body and consciousness are considered together, as one entity, to make up the individual. The degree to which less focus is placed on the physical body as a crucial aspect of the self will greatly influence the development speed of whole brain emulation technologies. Reduced emphasis on the body also has the potential to reduce regulation on research trials for new biotechnology drugs and procedures. This can expedite the pace of biological change as a supplementary technology. Conversely society may tend to hold onto feelings that the physical body and consciousness must remain paired to retain the whole individual. All major world religions are in support of organ transplantation when the end result is a life saved. This technology-enabled scenario has the potential to radically extend the human lifespan. It is worth reinforcing that radical life extension provides radically longer lifespans, potentially for as long as the individual would like to live. This is vastly different than living forever, an ideal which is likely not to be supported by many religions as it directly conflicts with both the concept of an afterlife and reincarnation. A technology supported radical life extension scenario emphasizes the current trend of utilizing developed technologies to further circumvent biological limitations.

Scenario Two: Biological Radical Life Extension Technologies

Biological radical life extension technologies utilize the modern biotechnology revolution to develop newly emerging drugs and therapies to extend human life expectancy. Successful implementation of radical life extension through biological processes requires a threefold approach. The vast majority of medical deaths can be factored into one of three categories. Death by non-communicable disease, communicable disease and natural causes. Implementing technology to battle these three leading causes of death through the biotechnology revolution has the potential to vastly improve the longevity potential of the physical human body. These technologies may include digital technologies and non-biological aspects but the focus of this radical life extension paradigm is primarily biological. Non-biological technologies are implemented in support of biological systems as opposed to a complete system alternative as discussed in scenario one. This scenario highlights a merger between biological and non-biological technologies to produce individuals who have transcended their biological limitations but remain in their biological bodies. The merger of humans and their technology allows individuals to retain their biological bodies with vastly improved capabilities. Improved strategies to fight disease and death by natural causes, as well as a system for biological repair are necessary technologies to refine in order to implement radical life extension technologies in the biotechnology scenario.

The first challenge to this path is the elimination, or near elimination, of modern non-communicable diseases. The World Health Organization (WHO) cites that 37 million of the 57 million deaths in the year 2008 were from non-communicable disease such as cancer, stroke, heart disease and diabetes (Data and Statistics). These are diseases that typically require a pharmaceutical or medical procedure solution. Improvements in these fields from exponential technological advancements can lead the way to vastly reducing these numbers. Computational science is leading the way in solutions for expediting novel drug discovery. With exponential growth in computation, storage and data transmission technologies, computers can now be used to simulate and model diseases and potential drug compounds. A shift has occurred in the way in which pharmaceutical companies conduct the search for new drugs. Previous to computational sciences, drug researchers would postulate a small number of compounds that suggest characteristics, based on their molecular composition, chemistry and composition, which may be potentially good drug compounds for fighting a disease. Experimental researchers then build the composition in the laboratory and conduct length and extensive studies on animals to determine the impact of the compound. This process is vastly prohibitive in cost, time and limited by the quality of theoretical compounds suggested by the researchers. A more modern approach is to develop a computational model of the disease and then test it against a database of every permutation of elemental compound that could possibly be synthesized in a laboratory. The compounds are then tested in the laboratory in order descending from their theoretical effectiveness. This 'brute force' approach eliminates the random spot searching previously done to research new pharmaceuticals. This process has in multiple instances returned serendipitous results not previously considered by traditional research think tanks. This process makes physical research trials more effective and reduces the discovery time for new drugs. As computational modeling technologies these simulations will become increasingly accurate and can be paired with evolutionary algorithms to test potential long-term side effects of the drugs in only a matter of days utilizing vast computational research networks. The computational implementation for drug discovery has already been implemented in search of cures for AIDS, malaria, cancer and a number of neurological disorders. Researchers at the Chiba Cancer Center in Japan have used this architecture to develop seven compounds that have been "able to screen three million compounds and identify seven that destroy neuroblastoma tumors in mice without causing any apparent side effects." ("Breakthrough in the Fight against Childhood Cancer"). Continued development and refinement of this technology has the potential to further increase its accuracy and impact on the pharmaceutical industry.

Managing communicable diseases becomes a challenge in this scenario as these diseases have increased mobility through a dense population. This scenario presumes large increases in population, and therefore significantly more dense population centers, as individuals can live much longer lives. As population density rapidly increases communicable disease rates will likely rise as well. Digitally enabled technologies will likely need to be employed to help irradiate communicable diseases such as HIV and tuberculosis. Many futurists predict heavy usage of nanotechnology to supplement natural biological function in futurist scenarios where individuals retain their biological bodies (Kurzweil 241). Nanorobots, under 100 microns in size, would be capable of entering the body to assist in biological functions such as nourishment, oxygen supply and repair. Nanoroboticists are working towards technology which could produce robots small enough to assist in biologic function and provide a real time digital interface with the human body. Foglets, small swarm nanorobots are at the leading edge of this trend. Foglets work as a networked swarm of bots that could enter the body for repair, real-time monitoring and enhancement of biological capabilities. These robots would work in unison with the human body to identify and repair problematic biologic material while enhancing the limited natural capabilities of the human body (Hall 2014). Utilizing technologies like swarms of foglets, humans can monitor their biologic function in real time and manage communicable diseases. Foglets, and other specialized nanorobots, could be dispersed into the body to administer targeted medications and conduct microsurgery to eliminate communicable diseases as soon as one is detected. Being able to target and eliminate communicable diseases before further transmission is key to their elimination ("Introduction to Communicable Diseases"). Current technologies only allow for identification of these diseases through the onset of symptoms, by this point most diseases have multiplied and begun to spread to new hosts, further perpetuation their existence. Nanomedicine has the potential to significantly reduce the visibility and prevalence of communicable diseases in an ever increasingly dense population.

Developing solutions to vastly delay death by natural causes is the most significant component to a possible biological scenario for radical life extension. Death by natural causes is an overarching terminology that refers to death towards the upper thresholds of the human life expectancy from complications that build over time. Common components of death by natural causes are telomere shortening, glycation, oxidative stresses and copy mutations in DNA (Edmunds 2014). These issues develop over a lifetime and cumulatively can lead to a biological body no longer functioning. Death by this category of causes is generally defined as 'death by natural causes' or 'dying of old age'. Nanomedicine technologies like foglets can combat many of these medical conditions that build over time. By constantly monitoring the individuals DNA, foglets can fix copy mutations and repair glycation. Nanomedicine will develop to include nanorobots capable of managing oxidation levels to manage oxidative stresses and improve immune system capabilities.

Telomere therapies suggest a solution to the replication problem in DNA which is an underpinning issue in aging. Telomeres are specific sequences of DNA found at the end of the chain of DNA in a cell. Each time a cell divides telomeres fall off, shortening the sequence chain for later use. The average cell can divide 50 to 70 times before its telomeres are depleted and the cell dies. Cells begin with this reserve of teleomeres that then depletes as individuals age ("Are Telomeres The Key To Aging And Cancer?"). Telomere rejuvenation therapy as the potential to restore these telomere sequences and effectively stop cell death. Early study of these concepts in cows and other animals shows promise for the future of these technologies (Lanza 2014). These telomere extension technologies could be administered through pharmaceutical compounds or with the assistance of nanorobots. Coupled with nanorobotic assets these technologies can dramatically slow the aging process leading to radically extended biological lifespans in humans.

Assistive technologies can improve biological function to further improve lifespans in predominantly biological humans. Respirocytes, or artificial red blood cells, are another developing technology capable of extending human lifespans while improving biological capabilities. Respirocytes are capable of holding reserves of oxygen up to 200 times greater than a human red blood cell (Freitas 2014). This vast technological difference suggests a transition away from the biologically limiting red blood cell towards enhanced respirocytes. Respirocytes would allow individuals to hold their breath underwater for hours instead of minutes or even allow for the human body to continue to receive oxygen for a substantial period of time in the event of heart failure. While not a completely biological technology, they are included in this scenario from their symbiotic relationship with biology. Respirocytes work symbiotically with the natural human body to enhance capabilities as opposed to modifying them.

Improvements to medical procedure technology, namely further implementation of robotics and 3D printing technology, has the potential to make a great impact to the way in which surgical procedures are conducted. While still both in their infancy, robotic surgery and

3D printing have the potential to be paradigm-shifting technologies for how society conducts surgery. Robotic surgery systems reduce incision size and give far greater control to the operator than traditional incisions made by a surgeon ("The Robotic Surgery Center" 2014). Robotic surgery systems are currently controlled by a surgeon but allow for 3D modeling of the environment in real time as well as the capability to make far more accurate and precise incisions. These improvements in capability can enhance surgery capability to defend against a wider range of diseases and ailments. 3D printing allows for one of a kind devices to be efficiently custom made for individuals suffering from a myriad of diseases. 3D printed medical components can replace spinal discs, bones and even complete organs. Researchers have begun developing 3D printed meshes to use for skin and muscles grafts to more aid in more efficient recovery from accidents (Koch 2014). 3D printing technology allows for one of a kind devices to be made which identically replicate the biological component being replaced. This drastically improves the rate of biologic acceptance of the new piece from the body as well as the fit of the device with existing local muscles and tissues. Utilization of these technologies can help greatly extend the lifespan of the overall human body.

The phenomena of using technoscientific advances in the field of medicine, known as biomedicalization, has already brought about significant advances in the field of biological longevity. Biomedicalization represents a growing shift in the medical pathos of the developed world in the recent decades. Modern medicine has moved past medicalization, the treatment of diseases, into a period where an increasing number of medical events are being classified as diseases in need of treatment. 'Curing death' can be incorporated into this shift in ideology. Nothing inherent has changed about the process of death, however the way in which the world is beginning to perceive death evolving. For centuries death was seen as a natural part of the human experience. Death was unavoidable and a consequence of being human. Recent decades have brought about a society which is beginning to challenge the eventuality of death in an effort to delay the inevitable as long as possible. This represents a shift in the way society perceives technological limitations. The biomedicalized period, considered to be 1985 through the present day, is the period when these advanced techniques became more commonplace in the healthcare field. The importance biomedicine places on advanced fields, such as DNA sequencing, is modification is essential to the further progression of biological medical advances which contribute to the scenario (Clarke, 161). Integration of digital technologies into the medical field is an essential component of the scenario. Without the impact of these technologies, and this shift in public thinking about death, the rapid development of radical life extension technologies is less likely.

This scenario challenges what it means to be biological. While retaining a predominantly biological form, this scenario includes a myriad of integrated technologies. From nanorobotic respirocytes and foglets floating through the human body, to 3D printed bones and muscles, the human form will drastically change in this futuristic scenario. This challenges what it means to be human. Civilization currently doesn't consider someone with a hip replacement or pin in their ankle any less human than anyone else. The integration of these technologies will be gradual and this scenario assumes this acceptance of these technologies into the human being without reclassification to continue. The merger of technology and biology is highlighted in this trend and shows the increasingly rate at which humans are merging with their technology. Retaining predominantly biological for longer has the potential to aid in acceptance of this technology and reduce the pace of technology that is felt by society as life expectancy is extended.

While remaining predominantly biological has benefits for social acceptance of the technology, it creates a number of long-term challenges for sustainable growth of the technology. While many will be more willing to accept biological technologies over radical new digital technologies, remaining in a biological form for decades longer can stress the carrying capacity of the earth. Quickly approaching 6 billion people, experts have begun to question the number of inhabitants the earth can sustainably support at any given time. Unlike in the first scenario, this scenario will have physical population growth only bounded by the average life expectancy. As the life expectancy continues to grow rapidly, fewer individuals will die than are being born producing population growth. Until there is a leveling out in the average life expectancy this growth will continue to occur. Once average life expectancy stabilizes, equilibrium can be met with the number of births and deaths annually. Until this time population will continue to rise further stressing the global ecosystem.

Radical life extension through predominantly biological means has the potential for greater social acceptance however possesses challenges for stability of the global ecosystem. Technologies to enhance biologic capabilities will extend the lifespan of the human body, allowing individuals to live decades longer in their predominantly biological bodies. Enhancement technologies such as nanomedicine, 3D printing and robotic surgery are poised to extend the capabilities of the human body and better manage aliments and diseases. As the global population explodes, technology and social policy will dictate the outcome of the scenario as the global carrying capacity of the earth is challenged.

Scenario Three: Linear Life Extension Technologies

Humanity has directed a consistent rise in the average human lifespan over the past century as technology has enabled them to have greater influence over their environment. While few doubt this trend will stop, the pace of growth is contested by scientists and futurists around the world. A baseline scenario one must consider is a future in which no radical life extension occurs. This would be predominantly characterized by continued linear life extension technologies. Technologies would continue to develop in a stepwise fashion. Life expectancy would continue to rise a few years each decade, as has been observed over the last century. This scenario assumes humanity is not on the cusp of an exponential growth of technological advancement in the medical field and will progress as it has for the last century.

As one cannot accurately anticipate when this trend will take place, if at all, continued linear progression scenarios must be considered. The preceding two scenarios highlight a coming era of rapid technological and medical technologies. These trends would promote an exponential growth trend in both technology and the average human life expectancy. Many leading edge indicators suggest exponential growth trends in technology will continue however the doubling time and lifespan of the trend cannot accurately be anticipated. As with all exponential trends, early periods in the trend appear linear when considered on short time scales. As the trend progresses the doublings become more apparent and the exponential nature of the trend can easily be observed. Many believe society is nearing the bottom of the exponential curve with medical and robotics technologies having the potential to usher in a new paradigm of human advancement.

Outside influences have the potential to delay technological advancement, regardless of the stability of the technology. During his keynote talk at SIMPosium 2014 in Denver, CO, Ray Kurzweil discussed leading edge trends in technological advancement. He highlighted how the achievable density of transistors on a chip, Moore's Law, and neuroimaging resolution continue to rapidly double. Kurzweil pointed out how these are only two of the dozens of technological trends currently experience rapidly cycle exponential growth. While Kurzweil has an optimistic, almost utopian, view of the future, not all share his views. While these technological trends can rapidly progress, social, political and economic pressures can halt progress on a technology in its tracks. As technological development occurs at more rapid paces, legal and medical approval systems must keep pace if the trend is to impact humanity.

Drug approval institutions such as the US Food and Drug Administration (FDA) must keep pace with exponential medical advances for them to have an impact on the general public. Current practices can force companies to wait decades before a new drug or medical technology is available to the public. With exponential growth in medical technology, these timelines will become insufficient for rapid deployment of new technologies. New technologies will not be economically viable to develop in countries like the United States if legal approvals are vastly outpaced by the iterative advancement of pharmaceuticals. This phenomena would have new, more advanced pharmaceuticals entering the market abroad before trials and approvals were completed by the FDA. Countries that can utilize emerging technologies to verify drug reliability quickly and efficiently will see significant growth in these industries.

Limited social acceptance of emerging technologies has the potential to suspend exponential growth in fields necessary for radical life extension. Social fear of the technologies, or radical life extension itself, in the right sectors of the population has the potential to limit the growth of the field. For hundreds of years groups in society have disapproved of emerging technologies. The luddites of the early 19th-century were a group of textile artists who became displaced after the advent of the textile mill. This group acted out against the technological advancement as it displaced them from their jobs and limited the artistry in textile manufacturing. The group sought to destroy the new machines and warn the public about an impending era of automation that would displace skilled workers (Gregorie 2014). Almost three hundred years later these concerns are still valid for many in the populous as enabled technologies replace humans in predominantly unskilled labor.

Futurists defend both sides of the debate as to whether advancements in technology truly do displace workers or if advancements in technology create opportunities for humans in other fields with an overall increase in global capability, which leads to a higher standard of living for everyone. Futurist Ray Kurzweil takes an alternative standpoint claiming high rates of unemployment is a temporary issue which he believes will end in the early 2040s. At this point in time Kurzweil believes the rapid pace of advancement will be predominantly completed by artificial intelligence and computational systems leaving most humans to enjoy the world around us without the burden of work (Kurzweil 2005). This trend of increasingly fewer jobs is sometimes known as the automated economy and continues to challenge the current economic model of the world. The ability to efficiently modify the global economic structure to adapt to the automated economy will significantly impact the economic viability of emerging technologies.

Similar to social environments, the political landscape is slow to change and has traditionally been slow to adopt new and radical ideas. This lackluster pace would become problematic under a paradigm where technologies are advancing increasingly rapidly. Without legal precedent and laws in place many of these technologies may face legal challenges to their adoption. Many criticize governments around the world for being slow to adapt to change. Legal precedent is typically slow to change and the government is, in many instances, considered to be one step behind the curve. This precedent may become problematic as technologies necessary for radical life extension come to market requiring legal protection or approvals. Lack of precedent may also prove beneficial for these new technologies as there are no legal precedents to stop their implementation. Litigation over new technologies can greatly increase their time to market essentially cutting off the capability for agile, exponential growth. The mixture of existing, and lacking, precedent will be a significant variable in the future success of radical life extension technologies. These precedence will also to evolve to serve a greater range of existing life states such as virtual reality humans and robots with human consciousness. At the forefront of this legal revolution are the mock trials of the BINA48 robot. Beginning at the 2003 convention of the International Bar Association, the mock trials proposed a scenario in which a computer was suing its owner for planning to shut it off. The computer, BINA48, was part of a hypothetical situation where the employer was planning to dismantle BINA48 and use parts to build a new machine. BINA48 was capable of determining this from internal company communications and reached out to the law firm for help. These yearly theoretical trials help legal professionals develop a more complete understanding of the challenging biocyberethical issues coming in the near future (Soskis 2014). These precedents set for artificial intelligence will have close correlation to individuals with transhumanistic upgrades. As the line blurs between biological human and computational machine, finer legal definitions will be necessary to determine who is granted what rights under the legal system. Mock trials and other theoretical scenarios such as the BINA48 trial are currently limited and without their continued development, adding foresight to legal precedent and legislation, the legal process may significantly slow technological advancement.

While investments in science and technology can be proven to be fiscally responsible for society, these investments are predominantly seen during times of financial stability. Some question whether financial instability caused by rapid technological change will outpace the ability for society to continue to fund necessary research. In the event rapid technological growth does in fact significantly contribute to high levels of unemployment, society will be forced to put resources towards managing social issues. During the 2014 recession, federal nanotechnology research and development budgets, across agencies, fell sharply by over $220 million ("R&D budget and Policy Program"). Maintaining financially stable economies throughout the growth of technologies leading to radical life extension will be critical for funding to be maintained in the appropriate industries. In recent decades' financial instability, war and significant price fluctuations on energy resources like oil have destabilized world governments taking away their ability to continue research while putting all available efforts towards maintaining their society and economic viability.

Shifting global power, and the introduction of cyber warfare, has the potential to stall scientific advancement as warring groups continually involve tangential parties. While the present day and age is widely considered to be safer than any in history, warring groups are increasingly involving third parties in their attacks. From terrorism to cyber bugs and viruses, third parties are increasingly involved on the cyber warfront. Stuxnet, a cyber-weapon released into nuclear facilities in Iran, circumvented security protocols in an attempt to over spin and destroy uranium enriching centrifuges (Zetter 2014). Many believe Stuxnet was an attempt by foreign nations to slow Iran's nuclear weapons research although Iran will only officially admit to peaceful nuclear research. Whichever the case, the introduction of the virus caused damage to both military and energy producing facilities. This attack is an example of cyber warfare having dire consequences for research and the progression of technology. Political and military influences have the capability to restrict research on specific topics for entire regions or classifications of individuals. These influences slow the pace of technological advancement and can ultimately stall the pace of change seen throughout the world.

As access to information and the internet spread around the world, the platform of cybercrime levels the playing field for groups to influence the capabilities of others. For every group motivated to a specific end, there exists another group seeking to stop such a plot. Stem cell research, cloning, genetically modified organisms and nuclear research are all common examples of these types of research. These fields of research have garnered strong support, and opposition, for their continued development. While one group finds the endeavor necessary, another group sees reason to suspend research on the topic. In years past prevailing public opinion influences the pace and acceptable parameters allowed in these research fields. In the modern world, activist groups have taken to cyber warfare to delay progress in these fields by attacking institutions conducting next generation research. Now, no matter how small the group opposed to the research, their influence can be significant and delay research in specified fields. In recent years, companies such as Monsanto, a producer of genetically modified farming seeds, came under cyberattack. The hacking activist group Anonymous took credit for the attack. Anonymous is an activist group that seeks to use cyber warfare to advance their ethical beliefs (Mills 2014). While Anonymous does not represent a majority opinion, their influence was able to impede on Monsanto and temporarily delay their activities. Cyber activism gives small groups with radical opinions an outlet to inflict potentially substantial damages on mainstream research institutions to further progress their causes. If technology leads to large scale disenfranchisement of sections of the population, cyber activism against these organizations will likely result in attempts to delay further change.

Although trends in technological advancement suggest exponential growth in radical life extension technologies, social, economic and political motivations have the potential to delay these technologies. Current trends in technological advancement continue since these technologies improve our lives, benefit our economies and are generally accepted as beneficial by the population. While these trends benefit the vast majority of the population, a disenfranchised group is beginning to form, as a digital divide creates tension between digitally capable groups and those who can no longer stay competitive in an increasingly academic digital world. If these trends continue to grow, and this disenfranchised group reaches a critical mass, anti-technology sentiment may grow with it. This scenario would vastly limit access to radical life extension technologies and level out the advancement to more traditional linear advancement. As technology progresses the social, economic and political implications will come to have a significant impact on the viability of these technologies.

Legal Implications

Radical life extension technologies are poised to challenge social and legal definitions for many centuries thought to be straightforward. In a scenario where humans adopt increasingly non-biological technologies to enhance themselves how, will that impact the definition of what it means to be human? Do individuals whose brains have been emulated and now reside in virtual space have the same rights as those still retaining biological bodies? Do artificially constructed beings based on human sentient qualities operating on digital substrate have the same rights as humans? The legal precedence for these questions will in large part be shaped by public opinion and interpretation of current laws. In his movie *The Singularity is Near*, Ray Kurzweil intersperses clips from the theoretical life of an artificial intelligence, as she progresses through life and society evolution around her. This artificial intelligence has a run in with the law and must face trial to determine if her existence can be considered human (Kurzweil 2004). These types of legal quandaries will become increasingly frequent in both scenario one and two as humans begin to merge with computational machinery. The definitions of who is human, alive or dead will no longer be sufficient to describe the state of an individual.

Shifting precedent in the legal system is predominantly an issue under the first scenario dealing with non-biological radical life extension. The technologies outlined in scenario one most strongly correlate to turbulent legal battles as individuals in the first scenario would be melding their biological bodies with advanced technologies. This blended status would provide individuals who started off biological and then heavily utilized digital technologies to enhance their capability and extend their lives. Consideration will have to be made as to what constitutes being human as some individuals might be living in a brain emulation in virtual reality with no physical biological presence remaining. What, if anything, differences these individuals from artificial intelligence based on human sentience in the eyes of the law? This type of legal precedent will be difficult to enact and one which must be considered before it is necessary. The mock trials of BINA48 are an excellent step in the right direction to determine this new legal horizon.

Intellectual property behind DNA modification and other advanced radical life extension technologies has the potential to raise legal questions for the ownership of the human body. As technology advances, individuals are increasingly filling their body with non-native biological and non-biological materials. Pacemakers, contact lenses and organ transplants are all examples of current body modification for medical purposes. These technologies can help set a precedent for the future legality of body modification technologies. Current precedent gives full ownership of the incoming object to the individual in which it is behind places. Companies or previous owners hold no lingering ownership or rights to these technologies or intellectual property. This precedent has been further supported by the US Supreme Court decision in 2013 to disallow patenting of DNA sequences (Timmer 2015). By disallowing these patents the United States has set a precedent that the human body cannot be owned. This will become significant for pre-birth transhumanistic technologies, which would merge biological components of birth with manufactured technologies such as gene alteration. These technologies are commonly referred to as 'designer babies', allowing parents to alter hair color, eye color and other basic traits before a baby is born. During a future period of more mature transhumanic technologies it can be anticipated that these pre-birth modifications will be capable of altering significantly more characteristics. A component of radical life extension in these technologies would be the ability to eliminate disease in individuals before their birth. Targeting DNA that could make them susceptible to Alzheimer's, cancer and other degenerative diseases could be massive business for companies capable of developing this life extension technology. Understanding the intellectual property issues and ethics behind fair use of such a significant technology must be debated and fully understood as the technology rapidly becomes feasible.

Logistical Implications

Logistic considerations relating to carrying capacity, energy availability, global climate change and food availability must be considered when analyzing potential futurist scenarios.

The pace of development and adoption of radical life extension technologies has the potential to greatly impact the considerations listed above however there is no doubt a civilization of individuals which continue to reproduce but do not perish would have significant implications for the global ecosystem. The impacts of these considerations are the least well known and will vary greatly based on the speed of technological deployment for radical life extension technologies. In scenario one with technologies such as whole brain emulation it could be hypothesized that once the technology became available people would immediately begin adoption. This adoption would likely follow the technological diffusion model of early, mainstream and late adopters but would ultimately lead to individuals facing biological death and transitioning their lives to a digital substrate. This would presumably have little impact on global carrying capacity and food availability but would require massive computational and energy resources to sustain the digital substrate keeping these individuals alive. Digital virtual realities would provide additional space for the exponentially growing population and could potentially become preferred over the physical earth for individuals to live their lives. Based on the best available scenario architectures for this type of non-biological transhumanistic radical life extension it would appear this scenario would have the least impact on the global ecosystem logistics.

Scenario two and three prove to be significantly more detrimental to the global ecosystem as these scenarios provide biological life extension without the non-biological virtual reality to house the exponential growth of civilization. Scenario two in particular provides open-ended radical life extension without the consideration of alternative space for people to live. Biological radical life extension technologies further expedite the current trends in rapid population growth and prove unsustainable when scaled. This fact alone makes radical life extension under the second scenario problematic. The same can be said for scenario three which has limited radical life extension but has humanity continuing on the same path of growth in life expectancy. Logistically these scenarios are unsustainable without outside influence from other emerging technologies. These could come in the form of humanity becoming a multi-planetary species, solving the energy crisis or any collection of technologies that greatly, and radically, improve the efficiency of utilization of earths' resources. These shortcomings of the third scenario are already becoming evident in global medicine. The trend exponential advances in life expectancy seen in the late 90s and early 2000s has begun to stall. Cameron Scott points to this in his article for SingularityHUB, in which he writes, "Between 1990 and 2011, U.S. life expectancy at birth grew 5 percent from 75 years to 79. Between 1970 and 1990, infants also gained five years of expected life after starting at 70" (2014). These shortcomings predict the leveling off of traditional medical technologies for combating aging. This suggests a more radical, paradigm shifting, technological revolution is in order to begin the next phase of rapid advancement. These challenges are consistent with the general lack of long term viability for the second and third scenarios.

Flexibility in substrate for the human consciousness also has the potential to make deep space exploration and habitation of other worlds increasingly possible. Ray Kurzweil describes the six epochs of technology evolution as a roadmap of milestones for the integration of technology into the human condition. In this model epoch six, the final epoch, is when humans, aided with their technology, have the capability to expand their influence throughout the universe (Honan 2014). Deep space human exploration is currently limited not only by technological limitations but by the lifespan of a human. In order to travel to even earths nearest star, Proxima Centauri, would take thousands of years with current propulsion technology (Tziolas 2012). In order to extend human influence to the rest of the universe, humans would need a ship capable of carrying generations of civilization as individuals died and were born throughout the journey. Even with propulsion technology capable of traveling near the speed of light, the journey to star systems outside the local group would require journeys on the order of millions of years (Dunbar 2014).

The rate of continued expansion of the human condition varies depending on the future scenario in question. The varied substrate capabilities outlined in the first scenario make this scenario an ideal one for rapid exploration and dissemination of human influence throughout the universe. The digital nature of consciousness in scenario one suggests a potential future capability to digitally transmit consciousness between celestial bodies as opposed to physical travel in a starship. This would move humanity into the sixth epoch of technological advancement significantly faster than in either of the other two scenarios as both would still require physical travel between locations.

Monitoring Social Acceptance

Social acceptance of radical life extension ideals is evident in modern society and media. The pace of progression for these technologies is dependent in part on the paradigm of social adoption for them. The relationship between a technology or movement and the media can be a significant indicator for the pace of adoption. Media attention brings a technology out of the laboratory and begins the interaction with the general public. How technologies are received by the public can greatly influence future funding and adoption. Monitoring social acceptance and portrayal of a technology can act as a leading edge indicator to predict future funding trends, rate of adoption or ethical acceptance of the emerging technology. Radical life extension, and other transhumanistic technologies, have increasingly been highlighted in society as the public becomes increasingly aware of the accelerating pace of technological change. A multitude of movies, books, documentaries and events have begun to evolve around the discussion of radical life extension. These pieces initiate public discussion and can act as benchmarks for acceptance and perception of emerging technologies.

Societal interaction with the concept of radical life extension has increased steadily over the past two decades predominantly showing optimistic application of the technology. Early theatrical depictions of transhumanistic technologies such as *The Matrix* in 1999 depicted a dystopian world where transhumanistic technologies had run amuck through society causing social mayhem. This depiction highlights the problematic adoption scenario of an 'us' versus 'them' reality where non-enhanced humans wage war with intelligent machines. This early theatric scenario clearly depicts limited social comfort with the technology as the dystopian scenarios requires non-enhanced humans to save the day. As time, and the societal discussion shifted, movies began to challenge individual ideals of a transhumanistic movement as opposed to the movement itself. This can best be observed in the movie *Transcendence*, which follows a husband and wife leading a technological revolution in an attempt to preserve his consciousness after biological death. The movie sheds a utopian light on the transhumanistic technologies but highly criticizes the control a few individuals have over the advancement and usage of the technology. This can be considered as a cautionary tale to allowing private institutions too much control of the technologies and their implications. Movie scenarios have increasingly begun to take place in these utopian futures where one aspect of the technology had gone amiss. This symbolizes greater social acceptance with the technology suite as a whole as the community begins to delve deeper into the ethical and social issues of individual components of the movement. This was evident in the 2010 movie *Inception*, which explored the idea of consciousness and the concept of manipulation. The plot of Inception challenges the status quo in the realm of manipulation of the self and altering reality. Inception delves into the concept of multiple realities, something that would become increasingly present in the first scenario outlined above. Separating the consciousness from the physical body allows one individual to take many virtual forms. *Inception* challenges the public perception of the consciousness and physical self being inseparable.

Cinematic media continues to challenge society by introducing new scenarios, presumed by researchers to be just over the horizon, which society may have to face in the coming decades. *Her*, released in 2013, develops a scenario in which a non-enhanced human falls in love with a computer operating systems. This presents challenges as the artificial intelligence continues to rapidly evolve and lose the connection it once had with its human companion. It begins to increasingly find comfort from other enhanced beings and altogether lose the ability to meaningfully connect with non-enhanced humans. *Her* challenges the concept of love between a human and a computational being as well as highlights the potential divide between future humans who become enhanced and those who do not. Society continues to move towards a time when individuals will adopt increasingly digital enhancement technologies that vastly improve their capabilities. These human enhancements, coupled with increase in sentient machines capable of humanlike emotion, will challenge the ideals surrounding love, marriage and human rights. *Her* addresses these coming challenges in a love story accessible by the general public. The divide which forms between Samantha, the operating system, and her owner Theodore subtly addresses the challenges society will face in the future as some individuals become enhanced and others do not. This concept parallels with the digital divide existing in the world today. The diffusion of innovation throughout society forces less advanced communities to adopt new technologies in order to remain competitive. This creates a stepwise adoption of incoming technologies referred to as the diffusion of innovation by Dr. Everett Rodgers (Rodgers 2003). This societal pressure to remain competitive creates a stepwise adoption of increasingly advanced radical life extension technologies in a constantly attempt to eliminate individual scenarios like that posed in *Her*. This 'social arms race' of continuously attempting to remain up to date with existing technological trends further ensures progression of the technology from a social backing.

Monitoring how radical life extension technologies are portrayed in the media provide leading edge indicators which can help suggest the level of acceptance throughout society. In monitoring these indicators researchers, and investors, can better gauge social acceptance for the technologies. This drives further investment and allocation of resources for public relations and advertising. Hollywood portrayals of transhumanistic technologies in movies can provide a general feeling for how individuals perceive these technologies will impact the world. Movies which include apocalypse scenarios driven by transhumanistic technologies lead researchers to believe people are less confident in the future of the technology. Media portrayals like that of *Transcendence* show a clear discomfort with the technology from the perspective of the writers. This is in juxtaposition to the movie *Her* which depicts a more utopian future where humans have increasingly intimate relationships with their technology. This wide spectrum of depictions helps reflect social acceptance of the technologies but cannot be considered in a vacuum. Media depictions reflect the opinions of their creators which seek resonance with their target audience. These depictions can however be considered as one leading edge indicator.

Economic Implications

Whole brain emulation, and its supporting technologies, provide a pathway to a non-biological form of radical life extension which is consistent with economic incentives to further progress the technologies. In the web video "Welcome to Life: the singularity, ruined by lawyers" Tom Scott, a writer for the Guardian's technology blog, illustrates an economic perspective of how whole brain emulation is realized in the future. Scott's scenario depicts a 'welcome to life' boot sequence for an individual who has just become deceased and whose consciousness is being uploaded to a computer. This welcome sequence appears to the user after their consciousness was uploaded to a company's server by the primary care physician of the individual. This service provides continued consciousness after biological death has occurred. While a fictitious scenario, it highlights consequences and real world causality which might impact whole brain emulation technologies. During the scenario the user is asked to choose a 'tier' of life they wish to exist in. These range from advertisement free plans which provide enhanced cognitive function and total recall to limited plans which replace backgrounds with advertisements and change subconscious thought from the individual to be more in line with companies supporting the afterlife network. If the user then wishes to continue they must accept that potential dangerous or radical ideals be deleted from their memory through this fictitious US government regulation. These components of the scenario highlight social aspects that have the potential to encroach on whole brain emulation technologies ("Welcome to Life: The Singularity, Ruined by Lawyers"). In a predominantly capitalist world, it could be reasonably suspected whole brain emulation and non-biological life extension capabilities would be privatized and susceptible to manipulation by these controlling companies. With data from individuals' lives easily accessible and modifiable it is likely government regulation with play a significant role in how these technologies are appropriated.

Economic incentives suggest the continued rapid development of radical life extension technologies. Developing these technologies, as with all new processes, will be a stepwise transition. In a predominantly capitalist global economy, all companies are incentivized to design technologies better those we have today. This is strong support for the first and second scenario outlined about. Whether the technological progress is biological or otherwise, these technologies are likely lead to the continued exponential growth of the life expectancy in the developed world.

Choices for Society

As radical life extension technologies progress in technological readiness, society as a whole potentially has the ability to decide as to what extent these technologies should be made available for use. It has been seen that economic, technological, biomedical and military incentives continue to push these technologies forward without significant societal contribution or legislative action. Further development of these technologies is economically advantageous for both public and private companies as well as organizations like world militaries who can enhance their capabilities by introducing transhumanistic technologies. These incentives establish a natural growth in technologies but not one which cannot be stopped with significant societal intervention. Technological progress based on economic and military incentives certainly does not exclusively translate into technologies that are good for society as a whole. This is a decision to be made by society, policy makers and large corporations as the technologies continue to mature and have greater impact on the world.

Precedent exists for development of futuristic technologies to be halted based on social outrage. The best example of this scenario is the global effort to stop the proliferation of nuclear weapons. The Non-Proliferation Treaty (NPT), which went into effect in 1970, was a treaty signed by 190 countries, which aimed to slow the development of nuclear weapons, their proliferation and generally promote disarmament of nuclear arsenals around the world ("UNODA - Non-Proliferation of Nuclear Weapons"). NPT was a reactionary treaty brought about by the Cold War in which countries feared the further proliferation, and usage, of nuclear weapons. The continued militarization of this technology was widely considered to have future negative implications for society motivating countries to develop the NPT to stall this development. Moving these technologies to non-military applications was a major objective of the NPT. Today nuclear technologies have made significant positive contributions to society, nuclear power currently supplies 11% of energy worldwide ("World Nuclear Association"). Global intervention on the future of nuclear technologies allowed for the future development to be redirected from military to energy sector development in an effort to both neutralize future threats from the technology while putting its applications to good use for humanity.

Radical life extension technologies could soon reach a crossroads similar to that of nuclear technologies in the 1970s. Society will soon have to decide the roadmap it wishes to see with respect to life extension and body modification beyond biological limitations. Where global citizens stand on issues such as economic stability, military conflict, technological beliefs and the ability to sustainably manage more humans on Earth will all play an important role in how society views radical life extension technologies.

Personal Perspective

The sections outlined above provide my best attempt at an objective view of potential future radical life extension technologies available in the not so distant future. Opinions vary from person to person and are greatly impacted by their life experiences, scope of available information and how they may personally be impacted by the topic in question. My personal passion for science and engineering creates an unavoidable bias towards a future where scientific advances support increases to the global standard of living. Throughout history many have predicted that humanity had learned all there is to know. I believe the information density of the universe to be significantly vaster than anyone living today could believe. With the aid computational resources and artificial intelligence I believe humanity is capable of solving each stepwise problem before us. Vast computational resources available in the 21st century provide civilization a powerful tool never before imagined. As observed by Ray Kurzweil, and other futurists, the pace of technological progress is advancing exponentially to an end we cannot know. This rapid change continues to further outpace social dragging society into increasingly complex realms of existence. This rapid divergence between the pace of society and the technology that allows it to function leaves uncertainty for the sustainability of this trend.

Looking at past paradigm shifts can help anticipate the impact future technologies. To date humanity has encountered a multitude of time periods which could be classified as paradigm shifting. These times, when life changed radically for citizens, in many ways mirror the challenges facing society today. The most recent, and arguably most well-known, paradigm shift for society was the industrial revolution. This time period of rapid industrialization can be characterized by factory jobs, common interchangeable parts and most importantly the significantly increased prevalence of using powered tools to increase the efficiency of society. This invention changed society rapidly. No longer did it taken a dozen men to clear a field when a steam tractor could do it in a quarter of the time. This change accurately mirrors the digital revolution we live in today as computers continually replace humans in the workforce. This paradigm shifting rapid change shocks society, the economy and the pace of change around the world. Historically these periods come to a close with what is known as the 'leveling off period' when the pace of change slows as society adapts to the most recent rapid growth in a period before new rapid change begins. The history of technological advancement can ultimately be characterized by this sinusoidal pace of development. The newfound digital technologies we now possess hold striking similarity to the machine powered tools of the early 1900s. These preceding periods of rapid technological advancement faced similar issues to those facing radical life extension technologies. Over time these technologies were accepted by society and become integral components of society. I cannot identify any leading edge indicators as part of this period of rapid technological advancement which to me differentiate it in any significant way from those experiences previously be society. This suggests radical life extension technologies will ultimately be accepted by society and move towards becoming commonplace enhancements as the costs lower and availability increases.

Assuming a socially stable society with emerging digital technology one must next consider the implications this technology will have on the society of the future. These impacts can be anticipated based from considering fields in which the new technologies have the potential to play a significant role. In recent decades biotechnology and medicine have been significantly impacted by the proliferation of digital technologies. From computational modeling of new pharmaceuticals to robotic microsurgery systems, digital infrastructure has had a significant impact on society's ability to administer medical treatments and progress the field of study. As the capabilities of these technologies mature it can be reasonably anticipated that the impact to the medical field will continue to mature as well. These advances are supported by incentives to continue radical life extension technology research across a wide spectrum of motivations. Longer lifespans act as an incentive for individuals to endorse the technology while corporations seek the massive financial windfalls which would come with breakthroughs in the field. Militaries around the world constantly seek technologies to protect and better enhance their soldiers. These motivations continue to incentivize continued momentum in the research field to further the viability of emerging products and technologies.

Considering the motivations behind further development of the technology along with the proven robustness of society to withstand periods of radical paradigm shifting technological advancement, full implementation of radical life extension technologies seems both likely and ethical. The burden of proof challenges one to disprove the likelihood that current technological trends will not continue. This leaves sinusoidal paradigms of rapid technological advancement to continually, and exponentially, increase leading towards rapid advancement in all sectors of society. I believe the advancements on the horizon are poised to revolutionize medicine and bring about a significantly deeper understanding of the human body and how to manipulate it. This understanding will allow engineers to develop tools for achieving these modifications, radically extending the lifespan of humans.

Conclusion

The potential development of radical life extension technologies has the potential to significantly impact all aspects of modern society. Using technology to circumvent limitations is a cornerstone of humanity and one which has been observed throughout history. The deep knowledge being collected in modern society on how the human brain, body, DNA and lifecycle operate leaves opportunity in coming decades to begin more significant manipulation on these systems. The future development of these technologies can take multiple paths which will be greatly influenced by society factors such as financial incentives, theological beliefs and real world applications for the intermittent technologies.

Three main scenarios exist for how these technologies may develop. An initial scenario is the technologies developing predominantly through non-biological technologies. This scenario can be best characterized by technologies such as extending human life through uploading of the mind to a computational substrate to preserve consciousness after biological death of the body. This consciousness could then be downloaded to other biological, or non-biological, vessels to continue life for the individual. This scenario requires rapid, exponential, development of the technology to reach these technological levels in a realistic period of time. A second scenario, biological radical life extension, also requires these rapid technological developments. Biological radical life extension can be characterized by technologies which allow the individual to greatly extend the life of their biological body. This scenario requires development of technologies which target causes of biological death. Finding curses for diseases, the ability to modify teleomere length and fix genetic mutations which build up over a lifetime are all essential to these radical life extensions scenario. A third and final scenario postulates a future where none of the above technologies come into rapid fruition. This linear process model outlines a future where the digital revolution has limited impact of the future of medicine and advances continue at their linear pace. Without insight into the future, the scenario which will play out cannot be determined. However, using assumptions developed through an analysis of social interaction, in-depth knowledge of the technology, and historical outcomes one can begin to postulate a future based on one of these scenarios or a combination of multiple.

With projections for radical life extension technologies anticipating eventual control over death, by most ethical structures it could be considered unethical to halt the development of these technologies. When considering the technologies from different ethical points of view allowing the continuation of these technologies is overwhelmingly ethical. Utilitarian ethics theory suggests the most ethical decision is that which does more benefit than harm for the greatest number of people. This ethical construct is particularly applicable for radical life extension technologies. For any shortcomings advanced medical technologies may have, the overall impact is significant, far reaching and of great benefit to society.

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