CRYONICS: CURRENT STATUS AND FUTURE POSSIBILITIES

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“Cryonics-Life After Death” While some believe it’s impossible to know whether there is life after death, belief in immortality is timeless. People of all times and places in history have believed that the human soul survives death. If there is no consciousness beyond the grave, then life has fooled almost everyone from the Pharaohs of Egypt to the modern cryobiologists. The rationale for cryonics is that the process may be reversible in the future if performed soon enough, and that cryopreserved people may not really be dead by the information-theoretic definition of death. However, there is a high representation of scientists among cryonics supporters. Scientific support for cryonics is based on studies showing substantial preservation of brain cell structure by current methods, and projections of future technology, especially molecular nanotechnology and nanomedicine. Some scientists believe that future medicine will enable molecular-level repair and regeneration of damaged tissues and organs decades or centuries in the future. Disease and aging are also assumed to be reversible. Many ethical questions revolve around the issue of whether cryonics can work. If cryonics is simply an unproven medical procedure there is no more reason to believe that the soul goes away during cryopreservation than during a night’s sleep. Human embryos have been cryopreserved in liquid nitrogen for decades, yet many religious authorities believe these embryos have a soul. If cryonics does not work at any moment in time, it may be made to work in the future. Those who have been cryopreserved will simply wait.

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INTRODUCTION

Cryonics, the practice of deep-freezing the bodies of people who have died with the view to reviving them at some future time when new technologies offer a cure for their condition was a proposition, and later, a set of techniques first actively developed in California in the mid 1960s by Robert Ettinger. Cryonicists have hailed the procedure as one that affords both a ‘non-final resting place for some of the brightest people on the planet and an audacious symbol of what might be the most optimistic idea in human history’. The costs

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of whole body suspension are such, however, that attention inevitably came to be focused on the issue of how much, or rather how little, of the body need be preserved in order to successfully resuscitate the patient, indeed, of what, at a minimum, might constitute ‘a patient’.

Subscribing unreservedly to Bernal’s essentialist thesis that the brain may effectively stand in for the whole being, cryonic practitioners argue that ‘our memories, personalities and most other critical parts of our identities are in our brains’ and that the retention and preservation of self may therefore be secured through the long-term maintenance of that one organ—a procedure known as neuro-suspension or neuro-preservation. After the brain is perfused with glycerol or other cryoprotectants, a ‘cephalic isolation’ is performed with a sterilized panel saw and the severed head is placed in a small ‘dewar’ or cryogenic storage container, where it is preserved in liquid nitrogen, until the date of resuscitation. The brain is, at this point, unequivocally, in a vat (see Figure 1). The ultimate aim of this exercise is not simply to revive the brain in its existing condition. Cryonicists also share Bernal’s desire to enhance cerebral performance and longevity through the application of radical new technologies. As representatives of various cryonic organizations suggest, cryopreservation is primarily a tool for preventing bodily decay until new techniques for molecular level repair and enhancement, such as

Figure 1: The Brain In A Vat: A Cryopreserved Head Stored In A Small Dewar Or Cryonic Storage Tank (Courtesy Of The Alcor Foundation)
nanotechnology and cloning, mature. It is envisaged that these technologies may then be employed not only to renovate, but also to augment the existing faculties of the subject, completing the project of age-reversal and life extension. In the chimerical world of the cryonics community, it is imagined that revivification, when it occurs, will take place in stages. America's largest cryonic facilities address his clients' all too Putnamesque anxieties by posing the question 'so, are we planning to revive neurosuspension patients as 'heads on a plate', with tubing and wires sticking out?'

The answer is no, although it is suggested that once thawed and repaired the 'newly healed brain' of a cryonics patient might remain, for a brief interregnum at least, 'suspended in the fluid of a 22nd century “artificial womb”, presumably a tank of archetypical Bernalian constitution and proportion. It is anticipated that the brain would remain there only for as long as it then takes to 'clone up' a new and youthful body to which it might be re-attached. Future medicine, cryonicists suggest, will have 'vast and general capabilities for tissue repair and regeneration'. They argue that the healing of spinal injuries and re-growth of lost limbs and organs will be 'relatively simple for a technology with detailed understanding and control of gene expression'. The challenge of repairing a brain with extensive microscopic freezing injury will, they acknowledge, prove to be 'a much more formidable task'. Undeterred by the sheer complexity, if not the potential impracticability of this exercise, they maintain that 'by the time medicine is able to repair this kind of injury, growing a healthy new body will be easy by comparison', 'genetic reprogramming of a single cell on the surface of brain will begin a process of growth and development that perhaps a year later append to the brain, a complete young adult body'. The eccentricity, not to mention the profound narcissism, of such conceptions has served to ensure that cryonics remains, along with the Raelians and Clonaid, high on the list of the world's most deliciously ridiculed quasi-scientific enterprises. This is unfortunate, if only in that it has by association also acted to denigrate or obscure the crucial role played in medical research by the technologies and techniques upon which it rests for its potential success: cryogenics. Unlike cryonics, in which a single individual's prospective immortality is secured through the preservation of their whole body or sizeable part thereof, cryogenic research in the medical sciences has been characterized by a collective, and arguably more democratic, approach to the acquisition of immortality.

Those who work in cryogenic researches chew the holism that has characterized the cryonicists' approach to the human body, preferring to engage with it not as a unique, indissoluble, private entity but rather as a reservoir of tissues and ultimately molecular resources that might be archived for research purposes. Where in cryonics custodial efforts are directed towards preserving a body or brain in order to facilitate the resurrection of an individual, cryogenic research is characterized by a somewhat more altruistic set of practices. Here, tissues are given to the care of custodian-technicians so that they might be used, not for the exclusive benefit of the donors who, unlike their cryonic counterparts, are irretrievably dead, but rather for the collective benefit of all those human beings whose quality of life and longevity is now, or may in the future, be seriously impaired by degenerative diseases. Some of these donors, it could be argued, acquire through their actions an altogether more...
fragmentary though no less meaningful form of eternity. Their cells and tissues are ‘immortalized’ through cryo-preservation for use in the development of radical new regenerative techniques. Donated whole brains, and tissues sourced from them, have proven to be particularly important in this enterprise, providing an essential resource for research into conditions that afflict the ageing, such as Alzheimer’s, neurological decline, and degenerative disease. It is surely ironic that the cryonicists’ only hope for resurrection will rest on the beneficence of those many donors who have contributed their bodies and organs to create collections of cryogenically stored tissues, cell lines, and extracted DNA without which research into life-threatening diseases could not proceed.

The first human to be cryopreserved under controlled conditions with the intent of future resuscitation was Dr. James Bedford, a 73 year-old retired psychology professor, land investor, and cryonics adherent. When Dr. Bedford died on January 12, 1967 from kidney cancer, his body was cooled, while preservatives were injected over a four-hour period with the aid of the cryopreservation team: Dr. Renault Able, attending physician; Dr. Dante Brunol, director of the perfusion; Robert Prehoda, author of three books supporting reduced metabolism research; and Bob Nelson, a cryonics pioneer.

Robert C W Ettinger, heralded as the father of cryonics, popularised the concept of cryonic preservation with his book, ‘The Prospect of Immortality’ (1964), in which he suggested that freezing was the easy part of the process and could in fact be accomplished with present technology. Ettinger believed that the complicated process of “thawing” could be worked out at a later time.

“Most of us now breathing have a good chance of physical life after death - a sober, scientific probability of revival and rejuvenation of our frozen bodies,” he wrote. “No matter what kills us, whether old age or disease, and even if freezing techniques are still crude when we die, sooner or later our friends of the future should be equal to the task of reviving and curing us.”

**ALCOR**

The field of cryonics, which made its debut in the 1960s, continues to push the envelope and search for a solution to death. The process consists of preserving legally dead humans or pets at very low temperature (below –130°C) in the hope that future science can restore them to life, youth, and health.

“The advancement of medicine and science is so much faster than it used to be. Science fiction is becoming science fact on a daily basis,” says Tanya Jones, Alcor Life Extension Foundation’s executive director. “All of a sudden, cryonics doesn’t look quite so far-fetched.”

Jones, who has been involved in cryonics for more than 17 years, helps to create and balance Alcor’s budget and monitors the organization’s ongoing research and clinical work. She also runs the team that collects patients and then performs cryopreservation. Alcor, a non-profit organization founded in 1972, uses vitrification (ice-free freezing) to cryopreserve human life. Considered the major player in the cryonics industry, Alcor’s membership currently sits at 850 people from around the globe, including the United States, United Kingdom, Canada, and Portugal. Today, the organization’s Arizona HQ is the host to 80 cryopreserved patients.
Alcor’s most famous patient, Major League baseball player Ted Williams, was cryopreserved after his death on July 5, 2002. Williams’ body was separated from his head in a procedure called neuroseparation. The head was stored in a steel can be filled with liquid nitrogen, while the body stands upright in a nine-foot tall cylindrical steel tank, also filled with liquid nitrogen. A long-standing urban legend maintains that Walt Disney was cryonically frozen as well. However, Disney was actually cremated shortly after his death on December 15, 1966. Most of Alcor’s members are not famous: doctors, engineers, computer programmers, TV repairmen, musicians, and librarians. Demographics have shifted over the years, moving from mostly technical individuals to those from all walks of life. Jones has also seen a rising trend in families becoming members as well.

THE PROCESS
Depending on the organization, typical cryopreservation process costs range from $20,000 to over $120,000. Because legal death is required for cryopreservation to take place, a death certificate is issued, which usually allows life insurance to cover all costs of cryopreservation and storage.

Cryonics is considered an anatomical donation, and members must sign written documentation and a legal contract giving Alcor the authority to act when they are pronounced dead. Alcor offers its members ‘standby’ services, whereby a trained team is available nearby a terminal person’s bedside or hospital room, ready to act if Alcor’s services are required.

Similar to organ transplants, time is of the essence to give the patient the best possible chance of receiving a good cryopreservation. Alcor transports remote patients to its facility using a customized emergency transport vehicle that looks similar to an ambulance on the inside, but is tailored to enable Alcor to provide care and monitoring consistent with the cryopreservation process.

Alcor’s mobile cryopreservation process begins when a patient is declared legally dead. The patient is then placed in an ice water bath, and blood circulation and breathing are artificially restored by a heart-lung resuscitator. The combination of simultaneous Cardiopulmonary Support (CPS) and rapid cooling are known to be effective for protecting the brain during cardiac arrest. Intravenous lines are established and protective medications are administered.

If the patient is in a hospital, he or she is moved to an alternate location while CPS and cooling are maintained without interruption. Femoral arteries and veins are surgically accessed, and the patient is placed on cardiopulmonary bypass. This means that blood is circulated through a portable heart-lung machine that takes over the function of the patient’s own heart and lungs. External CPS is no longer necessary and is discontinued.

Within minutes, a heat exchanger in the heart-lung machine reduces the patient’s temperature to a few degrees above the freezing point of water. The blood is replaced with an organ-preservation solution that is specially designed to support life at low temperature. If the patient is located outside of Arizona, he or she is covered in ice for air shipment to Alcor’s facility in Scottsdale. Once at Alcor, a surgeon connects major blood vessels to a perfusion circuit. A perfusate similar to the preservation solution used during transport is
circulated through the patient at a temperature near 0°C for several minutes. This washes out any remaining blood. The cryoprotectant concentration is then linearly increased over two hours.

This slow introduction minimizes osmotic stress and allows for the cryoprotectant concentration to equilibrate inside and outside cells. A rapid increase to the final concentration is then made. Temperature, pressure, and cryoprotectant concentration data are continuously monitored by computer. The status of the brain is monitored visually through two small holes in the skull made using a standard neurosurgical tool. This permits verification of brain perfusion and observation of the osmotic response of the brain. “A healthy brain slightly retracts from the skull in response to cryoprotectant perfusion,” Jones explains. “An injured brain swells, indicating that the blood-brain barrier has been compromised. This injury is often seen in patients who suffered a long period of untreated cardiac arrest.”

After cryoprotective perfusion, neuropatients are cooled under computer control by high velocity nitrogen gas at a temperature of −130°C. The goal is to cool all parts of the patient above −124°C (the glass transition temperature) as quickly as possible to avoid any ice formation. This requires approximately three hours, at the end of which the patient will have ‘vitrified’ (reached a stable, ice-free state). The patient is then further cooled to −196°C over approximately five days.

If the patient has selected whole-body preservation, they are cooled in a two-stage process (first rapid, then gradual) temperature descent using nitrogen vapor. The patient will then be transferred to a cryogenic Dewar for further cooling in nitrogen vapour to a temperature of −196°C over two weeks. Broadly speaking, whole-body preservation is the same as the neuropatient procedure, but takes around twice as long. “Patients are monitored by sensitive instruments during this long cooling period to detect tissue fracturing events that tend to occur when large objects are cooled below the glass transition temperature,” Jones says. “And, contrary to media reports, fracturing is not a result of mishandling. It is a universal problem for large organs cooled to liquid nitrogen temperature.” Following cooling, patients are transferred into liquid nitrogen at a temperature of −196°C. They are thereafter kept in Alcor’s Patient Care Bay. Since Alcor uses liquid nitrogen to keep cryonics patients cold, electricity is not required for current patient care systems.

REVIVAL

This brings us to the heart of Ettinger’s thesis, at which lies a crucial assumption: that no matter how great the physical damage induced by the freezing process it will still be possible to reverse it through the application of new biomedical technologies. In fact, for re-animation to occur, it would be necessary to remedy both the damage inflicted to cells by the disease or injuries that caused death, as well as that inflicted by the freezing process. If this were ever to happen it would only be as a consequence of work currently being undertaken in molecular biology into methods of arresting or reversing degenerative disease and, in the new field of nanotechnology: molecular level cellular repair systems. It is, again, paradoxical that the advances that have been made in both these domains in recent years have depended, in large part, on the ability to access and utilize archives of cryogenically preserved collections of donated human tissues, cell lines...
and DNA, which have proven to be invaluable biomolecular research tools. Two examples may serve to illustrate the point.

If, as cryonicists are wont to argue, identity rests wholly within the brain, then it remains a prerequisite for success that this organ, at the very least, be subject to full renovation. The best chances of revival would occur if healthy living patients/brains were frozen, however, it is of course illegal to freeze the living. Most ‘patients’, including neuro-suspension patients, are over 60 years of age at death, and many are reported to already be showing signs of dementia or other neurodegenerative diseases, such as Parkinson’s and Alzheimer’s. The ability to cryogenically store or bank fresh brain tissue has revolutionized approaches to the study of brain function, disease, and repair. Prior to the development of cryopreservation, donated brain tissues could only be fixed in formalin—this allowed for examination of the gross morphology of the tissue, but not for the analysis of genetic or biochemical function. The significance of cryopreservation is that it allows tissues to be stored in a living, if suspended, state. Molecular level interactions between proteins, such as immuno-reactivity, are not destroyed, as they had been when fixed in alcohol, but remain available for study over time. From the early 1960s onwards, brain banking centres in the US and the UK began to develop techniques for cryopreserving the brain, not as a single potentially revivable entity, but rather as a cache of exploitable resources that might be widely employed in studies of the causation and treatment of neuro-degenerative disease. Simple and effective protocols for cryopreserving brain tissues are now employed routinely in brain banking centres worldwide, enabling brain tissues to be archived at \(-85^\circ\text{C}\) for future microscopic, radiographic, or neuro-chemical investigation. More recent cutting edge research depends on the use of other collections of cryogenically preserved tissues. These include, for example, collections of human embryonic stem cells and cell lines. Several recent studies have demonstrated that human neural tissue extracted from donated foetuses and cultured in vitro may be successfully transplanted into the brains of Parkinson’s sufferers, where it begins to establish new synaptic connections, becoming partially integrated into the circuitry of adjacent neural tissue. The self-renewing and pluripotent properties of embryonic stem cells are such that they may be used to generate a potentially unlimited supply of donor cells for transplantation therapy of this kind. They may also be used as vectors to deliver molecules for gene therapies devised to address degenerative diseases of the central nervous system. However, in order to undertake this research it has been necessary to develop new methodologies for storing and handling stem cells. A great variety of cell lines, including those derived from donated human embryos, may now be induced in culture, but it is technically and economically infeasible for researchers to maintain all the cell lines they need for their research in culture over an indefinite period of time. Key lines may be lost to infection or corrupted by genetic drift or contamination. Were it not for the capacity to freeze down and indefinitely archive the vast number of primary and genetically modified cell lines that are now being produced and employed as tools in biomolecular research, current projects on transplant therapies for diabetes, spinal cord injuries, neurological disorders, arteriosclerosis, and very many other degenerative diseases
simply could not proceed. Very recently, an Israeli research team announced that they had successfully developed a method of vitrifying human embryonic stem cells, noting that this breakthrough would facilitate the establishment of large-scale human embryonic stem cell banks that could benefit millions of patients worldwide.

Currently, it is impossible to revive cryonics patients due to damage done at the cellular level during cryopreservation. Advanced nanotechnology and stem cell therapy are needed to repair this damage. To make that happen these technologies must progress far beyond their current capabilities. Cures for conditions such as cancer, AIDS, diabetes, heart problems alongside simple old age will also need to be developed to treat diseased organs.

“Stem cell research has provided insight into the fact that growing a new body around the brain is possible,” Jones says. For years, researchers have injected stem cells into hearts to repair damaged muscles. And now, entire organs can be grown in the lab and transplanted. However, putting it all together to grow an entire body is much farther down the road.

“While we are seeing that stem cells can actually revive every organ in the body, we still have many years of research until cryonics is a reversible procedure,” Jones says. “However, recent testing has proven that it is already reversible for an individual organ down to—130°C, based on the testing of rabbit kidneys.”

According to Ben Best, a future nanotechnology of molecular-sized machines might be able to repair freezing or other damage associated with cryopreservation - as well as damage due to disease and ageing.

“Bull sperm have been successfully cryopreserved in liquid nitrogen and used for fertilization since the early 1950s,” he said. “And, since 1982, human embryos stored in liquid nitrogen have been used by fertility clinics with much success. Additionally, nematode worms have been successfully cryopreserved in liquid nitrogen and then revived.”

Medical and technical advances continue to give cryonicists hope for future successful revivals. In fact, last year, scientists at the J Craig Venter Institute successfully transferred an entire genome from one bacterium to another. In Maryland, scientists recently built an entire microbial chromosome. The genome project provides scientists and researchers with many statistical variables, and offers a view of the divergence of the human genome across an extremely broad population, according to Jones. Researchers have recently discovered that there are three or four other markers for the onset of Type 2 diabetes that they hadn’t recognized before,” she explains. “This might eventually lead to a comprehensive cure for diabetes.”

Alcor itself is heavily involved in its own research, and recently created a cardiopulmonary bypass lab to test its entire cryopreservation process from start to finish, and actively work toward making the process reversible.

“We take great pains to do research and technical development that will support the viability of the brain in an emergency medical situation,” Jones said.

The chance that cryonics will work depends greatly upon the conditions under which a person is cryopreserved, as well as on how much money and effort is put into the technologies and organizational enhancements that can make cryonics work, according to Best. “It is possible that true reversible cryopreservation may be
perfected within 30 years," he says. "If so, the reanimation of those preserved under this superior cryopreservation technology would occur on a ‘last in, first out’ basis." Most cryonicists believe reanimations will occur within 50 to 100 years for those currently being cryopreserved. "Within that time frame, virtually all current diseases should be curable and elderly people can probably be rejuvenated to a youthful condition,” reckons Best.

**CRYONICS FOR SKEPTICS**

There is a fair share of criticism about cryonics that comes from a myriad of sources, including scientific skeptics, incredulous doctors, and outraged religious figures. Some even view cryonics as occultish. A major objection many Christians have concerning cryonics hinges on a perception of death. Because cryonic suspension cannot yet take place until after legal death, cryonics is often viewed as “going against God”. And, because Christianity teaches that the soul departs the body at the time of death, this issue plays a major role in shaping the Christian view of cryonics. In an article in *Scientific American*, Dr. Michael Shermer, founding publisher of *Skeptic* magazine, compared freezing people immediately after death and reanimating them later to thawing out a can of frozen strawberries. “During freezing, the water within each cell expands, crystallizes, and ruptures the cell membranes. When defrosted, all the intracellular goo oozes out, turning your strawberries into runny mush. This is your brain on cryonics.” In fact, Shermer calls the theory behind cryonics “borderlands science, because it dwells in that fuzzy region of claims that have yet to pass any tests but have some basis, however remote, in reality.” While he admits that it is not impossible for cryonics to succeed, he thinks it is extremely unlikely.

**THE ETHICS OF CRYONICS**

While questions pertaining to the ethics and religious implications of cryonics continue to abound, Jones and Best stand behind the high standards of their organizations and the protocols they follow. “With full disclosures and signed consent, it is highly ethical,” Jones says. “When you think about the grand scheme of things, cryonics is a lot more conservative than burial or conventional cremation.” And with programs to help revived patients integrate back into society, Jones believes strongly that there is a place for current cryonics patients 50 to 100 years down the road.

According to Best, there is absolutely no conflict between religion and medicine - even for medical procedures that can extend life for hundreds or thousands of years.

“Cryonics is a medical procedure, a radical form of first-aid, and is no more an affront to religion than a heart transplant,” he says. The bottom line for Jones is, if cryonics doesn’t work, it doesn’t work, and patients have lost nothing. “But if it does work, they’ve gained so much. We’re here to find that out.” Ralph Merkle, Alcor Life Extension Foundation director, told *E&T*: “Cryonics is there to save lives and restore health. Today’s medical technology can’t always keep us alive, let alone healthy. A future medicine based on a mature nanotechnology should be able to preserve life and restore health in all but the most extreme circumstances. “Tissue preserved at the temperature of liquid nitrogen does not deteriorate, even after centuries of storage. Therefore, if current medical technology can’t
keep us alive, we can instead choose to be preserved in liquid nitrogen, with the expectation that future medical technology should be able to reverse any cryopreservation injury and restore good health." "If skeptics don’t want to pursue this area, that’s fine, but I ask them not to interfere with my own efforts to save the lives of myself and the people I love," he concluded.

CONCLUSION

The fusing of one science fiction fantasy with another is producing an extraordinarily potent and resonant imaginary—one that takes us full circle, back from the icy depths of the cryonic storage chamber to the relative warmth of room temperature, a new vision for securing immortality. The ‘transhumanists’ that populate the most peripheral zone of the futurist community are currently galvanized by the idea of ‘uploading’—the ‘process of copying one’s mind from the natural substrate of the brain into an artificial one, manufactured by humans’ or of transferring human individual identity into an artificial system via ‘whole brain emulation’. The brain of the cryonics patient undergoes one final act of translation. Having been frozen into a solid mass, it is sliced on a microtome. Each slice is then scanned by a computer using very high-resolution instruments. The computer then (apparently) employs this data to reconstruct the patient’s brain circuitry in ‘an artificial substrate (probably dedicated brain-simulating hardware). The simulation is activated, and the patient finds herself or himself in a shiny new body’. Or at least they think they do...

Whether the neurosuspension subject might one day wake up in a cloned body or be recovered as an uploaded icon on a desktop computer, either outcome will only be realized if, and when, we acquire a mastery of molecular understanding and manipulation equal to that of Putnam’s demonic scientist. If any of us needs to worry about whether or not he or she is a brain in a vat, surely it is the cryonics patient?

Although the project of cryonics has attracted much ridicule, it would be unfortunate indeed if the central role that cryogenics has played in the biomedical sciences and in new nanotechnologies were to be overlooked as a consequence. As the curator of one US cryogenics research institute informed me ruefully, ‘the most common question people ask when they come to the lab is “have you got Walt Disney’s head here somewhere?”’. It would be equally disappointing if the narcissism of the project of cryonics were to obscure the very major contribution that is made to contemporary biomedical research by those tissue donors and Research scientists who together create the archives of cryogenically stored tissues and cells lines that have been employed for the collective benefit of all human beings. ‘Immortalized’ in a quite different, but arguably much more meaningful way than their cryonic counterparts these donors may, at least, take their ease in death. Neurosuspension patients, conversely, may have every reason to consider what instantiation they might wake up to, and indeed, several lifetimes in which to contemplate their fate.

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