CRYONICS

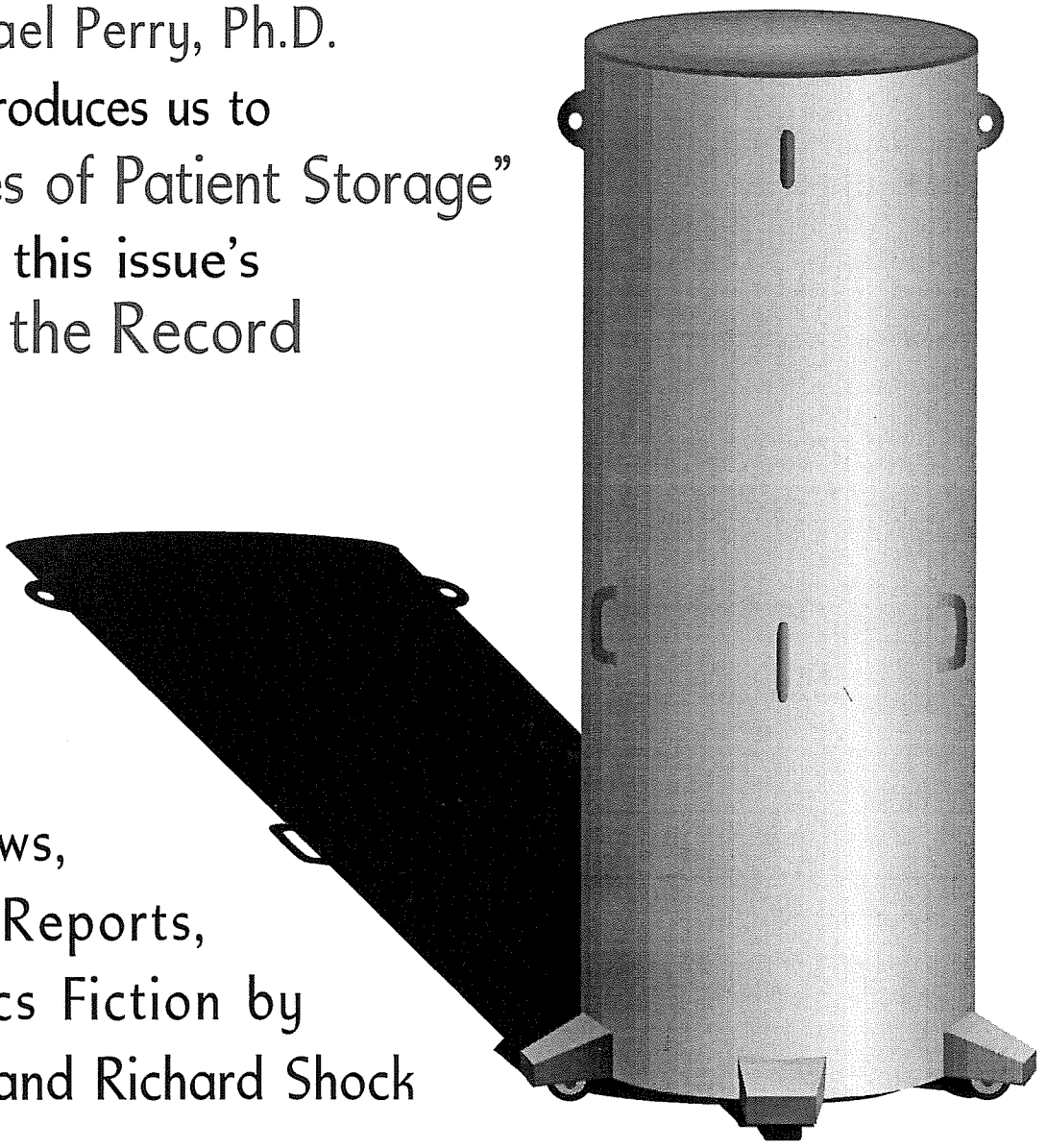
2nd Qtr, 1994 A PUBLICATION OF THE ALCOR LIFE EXTENSION FOUNDATION Volume 15:2

THIS ISSUE'S FEATURE:

The Molecular Repair *of the* Brain, Part II

By Ralph Merkle, Ph.D.

Michael Perry, Ph.D.
introduces us to
"The Realities of Patient Storage"
in this issue's
For the Record



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Linda Dunn and Richard Shock

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As human knowledge and medical technology continue to expand in scope, people considered beyond hope of restoration (by today's medical standards) will be restored to health. (This historical trend is very clear.) The coming control over living systems should allow fabrication of new organisms and sub-cell-sized devices for repair and revival of patients waiting in cryonic suspension. The challenge for cryonicists today is to devise techniques that will ensure the patients' survival.

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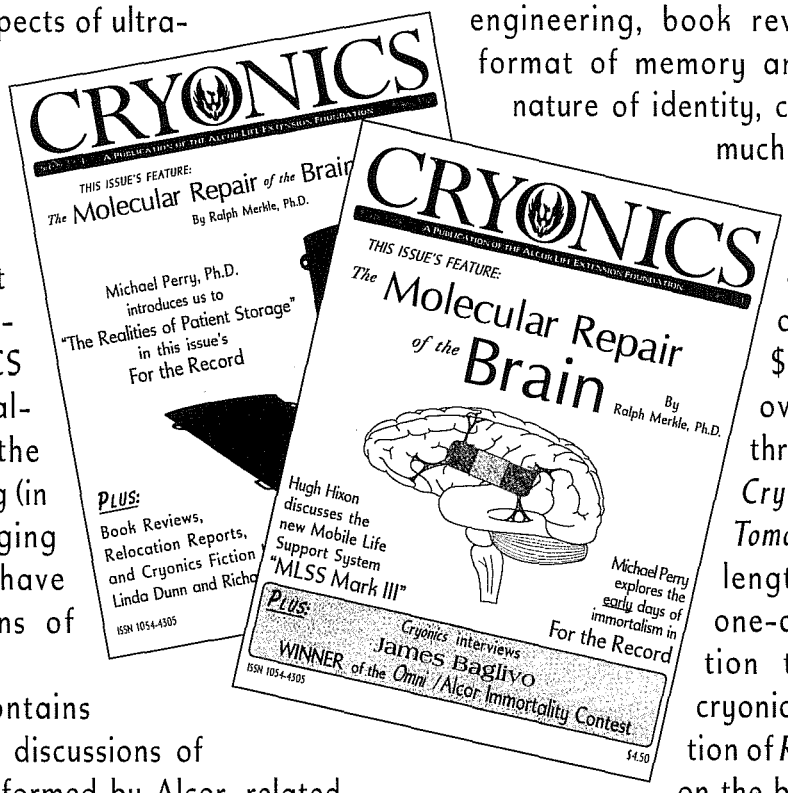

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CRYONICS

Editor: Ralph Whelan

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Letters intended for publication should be clearly marked as such.

UP FRONT

BY RALPH WHELAN, EDITOR

Two weeks ago, I tuned into Arizona's NBC-affiliate 10:00 news to catch a short piece on Alcor. This would be the third time we've been featured on this station in the past six months, but I hadn't seen the earlier bits, so I was feeling ... um ... "guardedly optimistic." (I.e., I expected we would be panned.) Boy, was I in for a surprise.

We've had a lot of really good press lately, so I was less guarded in my optimism than I might've been, but what I saw that night still made my jaw drop. It's not just that the piece was serious and positive throughout (which it was), and it's not just that they made frequent references to "this group of scientists" and "the promises of future medical technology." What blew my mind was what happened *after* the prepared segment, when they returned to the anchor persons for that wrap-up banter that's supposed to make you feel like these folks like nothing better than hanging out in front of a million people discussing last week's unusual amount of precipitation. Typically, after a cryonics segment, this is when they'll trot out their "cold shoulder" jokes and the obligatory Walt Disney reference.

Not this time. Today, Anchor Man turned to Anchor Woman and said, with the utmost sincerity, (roughly:) "So I guess when they only freeze the brain, they're counting on being able to use *cell regeneration* so they can create a whole new body to go with the brain." Anchor Woman: "Correct, they're really waiting on futuristic medicine at this point." Anchor Man: "Wow. Definitely futuristic." Ralph: "Wow. I just swallowed my gum."

I checked with other people. It was not a dream.

Steve Bridge talks more about the fantastic press we've been receiving since our relocation in his column. Steve also provides a perspective-piece on the rapid changes now occuring in the cryonics community in "Life in the Time of the Schism." For an overview of the past and present status of patient storage technology, *don't* rent any movies; see "The Realities of Patient Storage," this month's *For The Record* column by Alcor's Patient Caretaker Dr. Michael Perry. Thomas Donaldson shares with us the reasons why a cryonicist might have a waning interest in science fiction in "The Donaldson Perspective." Tom Mackey introduces himself with an insightful look at the evolution of humanity's relationship to God and Nature, in his short essay "The Historical Maturation of the Human Brain." We have two terrific pieces of cryonics fiction in this issue by Linda J. Dunn and Richard Shock. And of course, part two of Dr. Merkle's "The Molecular Repair of the Brain" is not to be missed.

Alcor's move to Scottsdale was not the only thing delaying this issue. Five Alcor Staffers and Suspension Team Members had to return early from Extropy Institute's *Extro 1* conference to participate in a cryonic suspension this past weekend. As I write this, Alcor's 28th patient cools to near the dry ice temperature of -79°C. This suspension began on Saturday, April 30, shortly after the 91-year-old Alcor Member experienced a heart attack in her New York home. There were several hours of ischemic time while her transfer to the Alcor Transport Team was coordinated. Still, her perfusion went surprisingly well, with a terminal glycerol concentration of about 5 molar achieved. More details will appear in the next issue.

On a related note, we take a moment in this issue to pay our respects to Jerry White, a member of the American Cryonics Society who was suspended on February 5, after many years of activism in the cryonics community. See "Long-Time Cryonicist Jerry White Enters Suspension" for a closer look at the life and activities of this pioneer.

Those who've been out to our new facility in Scottsdale now know what a bigger, better facility can do for an organization's morale and productivity. The new facility looks *great*, the staff is proud to be working there, and the future looks blindingly bright. Before heading back to Spain for the new tourist season at their hotels, the Comos Family stated that they are very satisfied with Alcor's new building, and that they are prepared to help make it even more attractive when they return to Scottsdale in the Fall. They are still planning a new cryonics facility just a few blocks from Alcor, though they now do not expect to complete it for three or four years. We're looking forward to assisting them in every way that we can.

In closing, I'd like to remind our Members that everything listed on page 36 of this issue can be purchased by Members at a 20% discount. Don't get caught without the intellectual ammo you might need to save some lives!

The Door Into Nowhere

We're grateful to Richard Shock, for sending in the following excerpt from a Spider Robinson piece in Yoji Kondo's *Requiem, and Tributes to the Grand Master*:

"In Ed Regis's recent wonderful book *Great Mambo Chicken and the Transhuman Condition*, there is an entire chapter on the repeated efforts of Keith Henson and the Alcor Foundation to get Robert [Heinlein] to agree to be cryogenically frozen after his death, in hopes of eventual resurrection. I was aware of the effort while it was going on: Henson wrote to me, entreating me to help him persuade Robert. I politely declined to argue with Robert on so personal a matter, but I certainly wished Henson luck: if any human I ever knew deserved even an outside chance at living forever, it was Robert Heinlein. And I could not help but wonder why he had turned Henson and the others down. They were willing to waive the usual fee for him. Sure, it was a long shot—but consider the prize! And what did he have to lose?

"The day Robert died I was on the phone with Jim Baen, sharing the grief. At some point I brought the subject of cryonics up, and said I wished now I'd had the guts to at least ask Robert why he'd said no.

"'I asked him once,' Jim admitted... So when I finally met Henson a few months ago, at a party at his home, I was able to tell him that I knew the answer to the mystery that had driven him crazy for so long. He was all ears ... and then when I told him, he stared off into the far distance with a baffled, frustrated look, and was silent for a long time.

"'How do I know it wouldn't interfere with rebirth?' is what Robert told Jim ..."

About the Cover

The cover of this issue was designed by Ralph Whelan, using Aldus Freehand (for the dewar) and Aldus Pagemaker.

LETTERS to the EDITOR

Dear Editor,

Recently I have heard several suggestions for research in cryonics, especially regarding the development of storage capability near -136°C, which would eliminate the cracking problem associated with ultra-low temperature freezing. Unfortunately, this does not address the problems in cryonics that, in my opinion, are much more important, such as: 1) damage caused by the delay between deanimation and the beginning of transport and stabilization; 2) lack of a back-up strategy for suspension patients in case low temperature storage becomes impossible; 3) freezing damage between -15°C and -60°C.

1) The delay after deanimation is a very serious problem. Warm autolysis beginning immediately after deanimation leads to the dissolution of important structures in less than two hours (E. Winkelmann: "Autolytische submikrosckopische Zellveranderungen in Cortex cerebelli der weissen Ratte," *Journal f. Hirnforschung*, 1964), while freezing damage only causes displacement and cracking of structures. This does not mean that all hope is lost after a delay, because brain structures are highly redundant. But autolytic damage will probably be much more difficult to repair than freezing damage. Many cryonics patients, even key persons of the movement like Jerry Leaf and John Erfurt, have experienced long delays after deanimation. Unexpected death happens often. Therefore, it is most important to develop pulse monitor and alarm devices and to set up organizational structures which can help the patient quickly in case of unexpected death.

2) If you look at human history, you will find that periods of freedom and peace are rare. At present it seems that most people have learned from history, but the risk of major catastrophes in the future remains high. This is no reason to give up, though. Despite many catastrophes in the past, human civilization has steadily and constantly progressed both technologically and economically. If we project this trend into the future, it seems likely that humanity will colonize space and conquer death. Unfortunately, this will only help you if your brain structure survives.

In case of a political or economic catastrophe, Alcor should be able to preserve you chemically, enclose you in a time capsule, and store you in a secure, possibly hidden place. The chemical preservation could be done using formaldehyde or even better using desiccation (see Douglas Skrecky's articles in *Canadian Cryonics News* and *Longevity Report*). The time capsule could be built of stainless steel or titanium. Alcor has an emergency option in its contracts, but it is not clear whether Alcor is actually prepared in this manner. If not, preparations should be made as soon as possible, because a catastrophe can come with little or no warning. (The First World War began suddenly in a relatively golden era with increasing wealth and increasing freedom for most people.)

I am signed up for cryonic suspension despite that such preparations have not been made because my life is very important to me and because it is possible that there will be no major catastrophe. Furthermore, there is no organization which offers chemical preservation, and preservation at ultra-low temperatures seems to be a better method in any case. Also, cryonic suspension would currently be a more secure option, anyway, because there are many people who would fight to save a cryonic suspension patient, and an unknown few who might fight for a chemically preserved patient. Nonetheless, the risk that there will be an economic or political catastrophe which makes maintaining patients in liquid nitrogen impossible is high enough that Alcor should be prepared.

3) Naturally it would be a fine thing if we could freeze patients without damage, but achieving this (if it is even possible without nanotechnology) will require many years of expensive research. Cryobiologists say that most damage occurs between -15°C and -60°C (Peter Mazur: "Freezing of Living Cells," *American Journal of Physiology*, Vol 247, 1984), and it seems that the damage which occurs below -130°C is fairly minor by comparison. For this reason, we should probably not invest too much time and money trying to develop storage at -136°C until there has been substantial progress in minimizing or eliminating damage between -15°C and -60°C.

In any case, solutions to problems 1) and 2), which to my mind are more significant problems, can be developed using already existing technology, and we should therefore attempt to address them first.

Klaus Reinhard, Alcor Member
Germany

Klaus,

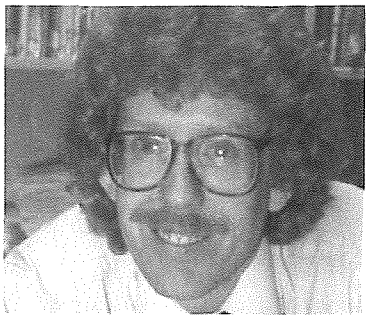
Thank you for your thought-provoking letter. Let me take a moment to address your three suggestions.

1) The delay after deanimation is indeed a very serious problem. However, I think you will find that in relatively few cases would the long delays after deanimation be reduced by pulse monitors or "alarm devices." To take the example (as you did) of Jerry Leaf: Jerry had a heart attack at home, while his wife (medically trained and the Administrator of the local hospital) was present. His wife immediately began CPR, continuing until the paramedics arrived. Alcor was notified promptly, and our Transport Team was present at the hospital several hours *before the hospital would release him to us. I think you'll find that in almost all cases of sudden death, it is the existing medico-legal infrastructure that causes the most autolytic damage, and it is our public education efforts that are most likely to have a positive impact on that infrastructure.*

2) If there was a civilization-ending catastrophe, and the Alcor patients and staff were not themselves destroyed, we would have at least two months to pursue the kind of chemical preservation that you describe, were we to decide that this was our optimal path. Still, it's probably true that there is more we could do to prepare for such an event. I'm sure this will see more attention when it moves closer to the top of our list of priorities.

3) While you may be correct that high-temperature (-15° C to -60° C) deterioration causes more information loss than low-temperature cracking, we must also consider which types of damage are more easily preventable with our level of funding and expertise. We are certainly going to pursue better methods of preventing the high-temperature damage, though that will probably turn out to be a long-term (and expensive) project. The construction of a -136° C storage facility seems certain to prevent a substantial amount of cracking, and may be achievable in the near term.

We'll keep you posted on our progress on these issues as our new research plan (now under construction) takes shape. Thank you, Klaus, for your perspective on these issues. I encourage other members/readers to share their thoughts on this matter.—Ed.



Notes from the President

New Home, New Life:

Alcor Moves to Arizona

by Stephen W. Bridge

When last we saw our intrepid band of cryonics explorers, they had formed a company to purchase a building in Scottsdale, Arizona. The building was bought, plans were made... and then everyone sat and watched while the brave scouts (Dave Pizer and I) worked on getting the Arizona Department of Health Services to approve the permits necessary to bring our suspended patients into Arizona.

Now it's April. The DHS approved our permits, and the pioneer wagons rolled east across the desert. The patients have been in Scottsdale since February 21st, and the staff have been here since March 3rd. All of the problems aren't yet solved (are they ever?), but our direction is positive and we're delighted to be here.

Let's recap some past history before getting into new details. (I will caution readers new to these discussions that legal issues dealing with cryonic suspension patients use terms like "human remains," "interment," and "anatomical gifts." While *we* refer to members in suspension as "patients"—and fully consider them as such—we cannot yet make a legal case for them being "alive." Therefore we are constricted to the use of laws dealing with anatomical gifts and dead human beings in order to acquire legal custody. We have no choice but to work within this framework and attempt to use it to the advantage of ourselves and our patients.)

Alcor's Board of Directors had been looking to move Alcor out of the Riverside facility for several years. We had outgrown the building not long after moving into it in 1987 with two full-time staff and with six patients. By early 1993, we had seven full-time staff and 27 patients. Additionally, in late 1992, as part of the Conditional Use Permit issued by the City of Riverside, we were forced to swallow a "poison pill" of a ban on animal research. In the beginning of 1993, we discovered that building code-mandated changes to the building and grounds might cost us as much as $50,000 to perform.

Combine this with the growing awareness of the earthquake damage risk in Riverside, which is in an especially vulnerable position near the San Andreas Fault, and the answer was clear: get out of town. Over the past couple of years, one of the places we had looked at most closely was Scottsdale, Arizona, near Phoenix. The central valley in Arizona has very low seismic risk, and animal research is permitted in the Scottsdale Airpark, a high-tech development in one of the most desirable areas of Maricopa County. Further discussion with Scottsdale's Planning and Development Department resulted in a statement from the city that cryonics was also compatible with the Airpark's I-1 zoning.

Alcor's section of the new Scottsdale facility.

In June of 1993, Alcor Director and Treasurer David Pizer (a resident of Phoenix) brought to the Board's attention a building for sale in the Airpark. The building was 19,800 sq. ft. and about 12 years old. It was divided into 11 units, some of which were leased; but some space was available which could be used by Alcor. The building was for sale for $770,000 (a price which later turned out to be almost $10.00 a square foot less than most other comparable buildings in the area). Alcor's Directors voted to make an offer on the building and to put down a $30,000 deposit.

At that point the amount of work suddenly quadrupled. We had 90 days to form a company to purchase the building, raise funds, and investigate the legalities and practicalities of moving a cryonics company into Arizona.

Dave Pizer and I formed *Cryonics Property, LLC*, a Limited Liability Company (LLC). An LLC is a new kind of Arizona company which combines the advantages of a corporation and a limited partnership. Several Alcor members and Alcor itself bought Interests (shares) in the LLC. Many other Alcor members sent in donations from $10.00 to $10,000 to cover Alcor's moving and remodeling expenses. This fund-raising was more difficult than we had anticipated, because it was begun during a period of intense disagreement among many active Alcor members over a wide variety of issues. The purchase of this building and the possible move to Arizona became yet two more footballs kicked onto the political field of the time.

To address the potential governmental/regulatory problems in Arizona, Dave and I (often with Dr. Mark Voelker, another Alcor Director living in Arizona at that time) engaged in a series of meetings with the Mayor of Scottsdale, Scottsdale Planning and Development, the Maricopa County Medical Examiner, and the Arizona Department of Health Services. The most complicated meetings were with the DHS, since it was likely that most of our work with patients (especially as Anatomical Donations) would fall under the jurisdiction of that Department.

There were several questions which needed to be answered by the DHS. How do we fill out the Death Certificate and Disposition Permits for anatomical donation and cryonic suspension? Do we have to register as a storage facility? Are neuropatients considered "bodies" or (as in California) "tissue samples"? The DHS staff, while a bit startled that a cryonics group was planning on moving to Arizona,

was friendly and helpful and tried very hard to deal with our questions open-mindedly. The first two questions were easily answered; but the third created some sincere head-scratching. Apparently the Arizona DHS staff (unlike the California version) doesn't ordinarily sit around debating frozen heads over coffee breaks.

These issues were finally solved, but one administrative regulation dealing with dead bodies was brought to our attention by Gregg Jacquin, Associate Director for the DHS: "A body kept in a private or public vault, including a receiving vault, longer than 15 days shall be placed in an airtight casket or other container." This was potentially a big problem, since liquid nitrogen is constantly evaporating and CANNOT be kept sealed up. Of course, we pointed out that we did not use a "vault" under the meaning of this regulation and that such a regulation did not appear to be applied to other anatomical donations in the state. For instance, the medical students at the University of Arizona College of Medicine were certainly not performing cadaver dissections while locked inside an "airtight container." We also explained to Mr. Jacquin that tissue kept in liquid nitrogen did not pose a public health threat.

We thought the problem had been taken care of, so we proceeded on with plans. In September, 1993, Cryonics Property, LLC closed on the building. Three days later we received a letter from Mr. Jacquin stating that this issue had NOT been resolved. Hastily, we hired Phoenix attorney Ron Carmichael (a fortuitous find for us, since he knew a lot of the "right" people, had the right attitude, and liked us, to boot) and arranged an early November meeting with Mr. Jacquin and his staff, plus Terri Skladany of the Attorney General's Office.

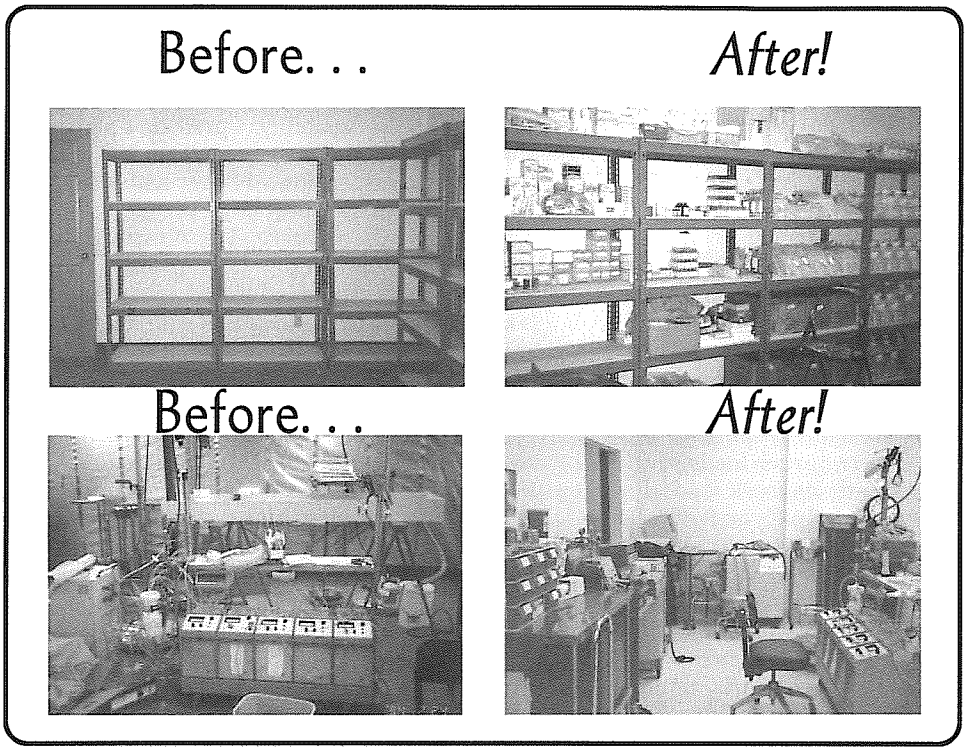
The meeting did not go particularly well. Mr. Jacquin insisted that this regulation applied to ALL bodies in Arizona, whether anatomical donations or not, and stated he was still concerned (in the face of all scientific evidence) that human tissue stored in liquid nitrogen posed a potential public health hazard. Ms. Skladany also expressed her concerns that the regulations be properly followed. We invited Mr. Jacquin and any other staff or experts he wished to bring to visit us in Riverside and see our operation first hand; but he declined.

This put us in a bit of a quandary. We didn't know what the next step was. Mr. Jacquin shortly let us know that he was asking the Arizona State Board of Funeral Directors and Embalmers to investigate the situation for possible regulation. We took a deep breath and gave out a long collective sigh—another agency to meet with and explain cryonics. Was there no end to this?

Fortunately, about this time it dawned on us (literally dawned on me while taking my morning shower) that if this regulation were applied to anatomical donations, it would make it impossible for anyone in Arizona to donate their entire bodies for medical or scientific research. Little research could be performed in 15 days, and *none* could be performed in a sealed container. However, Arizona law was quite explicit (in two separate laws) that residents of Arizona *do have* the right to donate their remains to science and otherwise have the right to dictate the disposition of their "human remains." Enforcing the "sealed container" regulation would mean that an administrative regulation was taking precedent over a legislative statute. Clearly that is not the way laws operate.

We made this case in letters to the Funeral Board and the DHS. The Funeral Board was concerned primarily with our relationships with morticians and did *not* have any interest in regulating us. However, we had some good fortune when Julie Tolleson, another Assistant Attorney General at the Funeral Board meeting, became interested in our case. In conversations with Ron Carmichael and me, she *agreed* with our position on regulation vs. statute and agreed to look into it further.

From then on, cooperation grew steadily better on this issue. We don't know the entire story of what discussions went on in private; but we do know our attorney spent a lot of hours on the phone explaining our position to as many government officials as would listen. As the pressure on me from Alcor's Directors began to mount ("Come on, Steve. Haven't you gotten them to answer you *yet*?"), it still appeared to me that our point was finally getting across.



At some point in January, the DHS conceded that the sealed container regulation was no longer an issue, and the last remaining problems lay in properly handling the transit permits from California to Arizona. One end of that had been solved in California with an immense amount of sudden cooperation from ... the California Department of Health Services? Yes, that's right. Now that we were *leaving*, they wanted those Disinterment and Transit forms to be processed as rapidly as possible. It took Alcor more than five years to get a registered death certificate and disposition permit on Richard Clair Jones, yet I got the disinterment/transit permit in about five minutes. Admittedly, part of this was due to a new attorney at the State DHS, who actually appeared to be a "public servant," and to new, friendly (even *interested*) staff at the Riverside County Health Department.

Once that end was solved, our attorney was able to point out the various legal reasons why the State of Arizona should then issue the transit permits from their end. Since the outcome was looking pretty sure now, we sent Tanya Jones and Scott Herman over to Scottsdale to begin painting and remodeling so the building would be ready for our arrival. After another couple of weeks of holding our breath (complicated by some sudden unrelated legislative problems in the DHS that side-tracked them), the transit forms were in our hand. A few days later, on February 21, 1994, the patients made their trip to Scottsdale. (See Ralph Whelan's article elsewhere in this issue for details on the physical aspects of the move.)

We then spent two frantic weeks packing

for the move of the operating room, offices, and personal items of Mike Perry, Joe Hovey and Hugh Hixon. It is amazing how much stuff (that is the only word to describe the variety) can be crowded into one building and two mini-warehouses. It is also amazing how much of it should have been thrown away years ago. (Anyone inclined to sneer should first examine *their own* possessions next time they move.) Of course, Ralph, Tanya, Derek Ryan, and myself also had to find a few dozen hours at our homes to pack up our household items. (Scott had already brought most of his personal items to Scottsdale while helping to prepare our new space for occupancy.)

The two truck loads of administrative items and one truck load of our personal possessions finally arrived in Scottsdale the first week in March, along with several pretty exhausted Alcor employees and volunteers. Even at that we hadn't quite gotten everything, and we had been one person short for driving vehicles. Hugh drove the ambulance to Arizona and left his own vehicle at the airport. So a few days later we sent Hugh and Scott back to Riverside one last time to get Hugh's vehicle, empty Hugh's mini-warehouse, and finish cleaning up the old building.

Setting up the operating room had been first priority, of course, and we were only down for less than 48 hours. Even then we had the capability to perform a patient stabilization, transport, and beginning stages of a suspension with our ambulance and remote transport kit.

We were extremely fortunate in finding a solution to one huge problem we had completely failed to see: what do you do with three truckloads of equipment, desks, boxes, refrigerators, etc. while you're deciding where to place everything. The truckers have to have the truck unpacked as rapidly as possible, and it would have been chaotic to simply fill all available space in the new units with boxes and equipment. Leaving everything out in the parking lot for two weeks didn't look like much of an option.

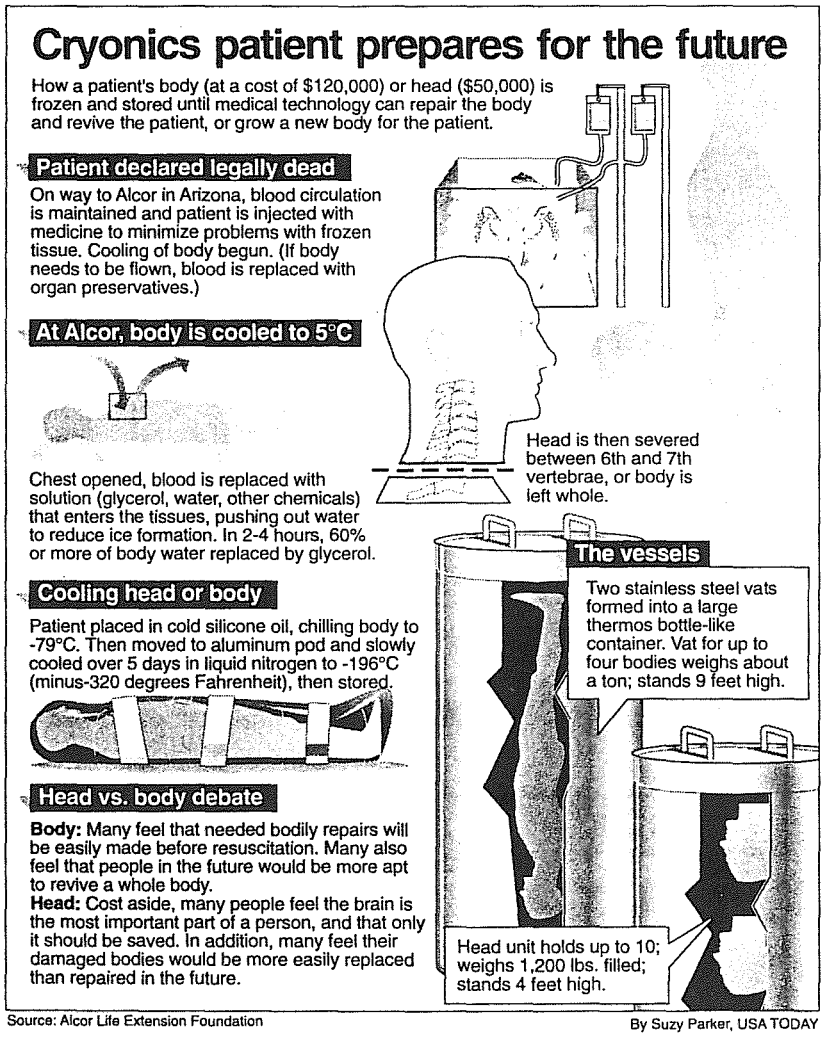
Happily for us, the imported beer distributor next door was at the low point of their cycle for stock (and probably had too much space leased to begin with), and they had the unit closest to us (#108) entirely empty. Alcor leased unit 108 for a staging area and the crisis was averted. It appears likely that for the time being Alcor will lease a small room in that unit for continued storage, and Hugh Hixon and Joe Hovey will lease another small area for personal storage instead of getting mini-warehouses.

The other major problem that occurred early in the move was a "problem" that we have begged for in the past and could rarely get: immense media interest. In the weeks before we moved from Riverside, the *San Diego Union* and the *Los Angeles Times* had been preparing major articles on Alcor and cryonics. They added material about the move and sent reports out over the Associated Press wire. As a matter of fact, I read the *LA Times* article at breakfast on my way out of Riverside on March 3rd. And of course the Phoenix-Scottsdale media had been primed for the move for months.

Since we arrived, the phone hasn't stopped ringing. Television, radio, newspapers, magazines: everyone wanted the scoop on "Frozen Patients on Wheels." Fairly rapidly I arranged for print interviews with the *Scottsdale Progress-Tribune*, the *Arizona Republic*, and the *Phoenix Business Journal*. Since the building's interior didn't exactly look snappy and professional yet, I put off the television stations as long as I could. Finally, I allowed two local television stations in for stories, both of which were prominently featured on the evening news and which were completely positive. I made one station, whose crew just showed up at the door our first day here, go to the bottom of the list; but when they finally did our story, it was even more upbeat than that of the other stations. Other prominent print media included *Tempo* magazine of Germany, *Yes* magazine from England, the *New York Times*, the *Chicago Tribune*, the *Indianapolis Star* (my residence for 18 years), and ... (trumpets blare, please) *U.S.A. Today*.

Ralph, Derek, and I did about 28 interviews the first month we were here, and just as things started to ease off a bit, on April 6th the *U.S.A. Today* article came out. They call themselves the nation's newspaper, and they must be so, for radio stations at least. All of a sudden the phones went crazy again with requests for live radio interviews and talk shows. We did interviews in Chicago, Florida, San Antonio, Palm Springs, St. Louis, Indianapolis, Pittsburgh, Las Vegas, Atlanta, Connecticut, Seattle, Detroit, and a bunch of others I've forgotten. Most prominently, we were on "Canadian World Tonight" with Phillip Till and Mutual Network's "Jim Bohannon Show."

Amazingly, with the exception of some insensitive sarcasm on the part of the *LA Times* and one couple of idiot morning "comedians" in San Bernadino (who didn't even bother to talk to us), the press coverage was *completely positive and friendly.* This was exceptionally true here in Ari-



USA Today *ran a terrific article on April 6, with the above impressively accurate graphic.*

Waiting for the thaw of life: Frozen bodies get new home

By Bob Golfen
The Arizona Republic

Twenty-seven frozen time travelers arrived in the Valley last week, forsaking disaster-prone southern California for the relative stability of north Scottsdale.

The front offices of the Alcor Life Extension Foundation, in a small business

> *Cryonics is an ambulance to take a patient to a doctor 100 years in the future.*
> **STEVE BRIDGE**

The Arizona Republic *continues to supply Arizona citizens with upbeat, professional articles about Alcor and cryonics.*

zona, but was scarcely diminished elsewhere. I have been involved in cryonics since 1977, when most press coverage (if you could get a writer or editor to write some space filler) and most audience reaction at talks (if anyone came at all) was "Look at these weirdos!" Beginning in 1986 with the publication of *Engines of Creation* (K. Eric Drexler, Anchor-Doubleday), we noticed a significant change in the seriousness with which people took this idea. The initial bad press surrounding the Dora Kent case in early 1988 slowly changed to positive stories about the brave individualists battling the government, a change that became more marked in the reporting of Thomas Donaldson's court battle to preserve his brain in 1990.

But it seems that even more has changed today. The attitude of most of the reporters and interviewers this year seems to be: "There are lot of amazing developments in science and medicine today. Here are some people banking on those developments to change the way we look at death." Yes, a lot of the writers actually get the point of cryonics! Those of you who are newcomers to the field or who have not dealt with the press over the years may not fully appreciate what a massive change this represents. I'm not saying this means thousands of people will rush to sign up next month. But positive reporting from a large number of writers provides a start for *more* positive reporting from the next wave. An increasing number of people out of there will be getting the unconscious message that cryonics is "interesting" (instead of "weird"), "future-oriented" (instead of "sci-fi"), and "a positive choice" (instead of "desperate" or "a scam").

Our reactions from Arizona businesses and government have also been positive. When my new auto insurance agent came by to set up my policy, she was very friendly and excited to meet us. She said that she would "really have some status with my kids now." This attitude seems to prevail with most visitors, even the ones that don't know they are coming to a cryonics facility. Quite a number of students have already been in for tours, and we have spoken to two "Death and Dying" classes and a retired adults club at a local community center.

This week we also had a tour for representatives of the Department of Health Services, the Attorney General's Office, and the head of the Committee on Health Care of the Arizona House of Representatives. It is clear we will continue to deal with these agencies and individuals in the future, and I think we are off to a very positive start. It is likely that some kind of cryonics regulations may be put in place here in the next year or two; but we look on this as potentially positive. We are getting the opportunity to influence those regulations in an active manner, and regulation in itself can provide a type of acceptance or legitimization. These are perhaps scary words to our more libertarian members and readers; but states WILL eventually regulate cryonics. That's what states DO. It could be to our advantage to have the first regulations here where we are building comparatively friendly relations.

Most of you will want to know how the money worked out. We raised just about enough money for our initial moving and remodeling plans. Unfortunately part of that money is still in donated shares of Symbex Property Group (the company which owns the Riverside Building), which can't become liquid until the building is sold. Our cash flow for finishing some tasks has become tight, and we would still welcome donations toward making this building the best we can.

In future issues of the magazine we will begin listing plans we are developing and enacting for improvements in suspension patient security, laboratory and operating room equipment, and transport capability. This week we have also begun taking the first steps toward developing a new research plan and plans for suspension team training. Please let us know if any of these areas interest you. We will be needing advice, volunteers, and funding for each of them.

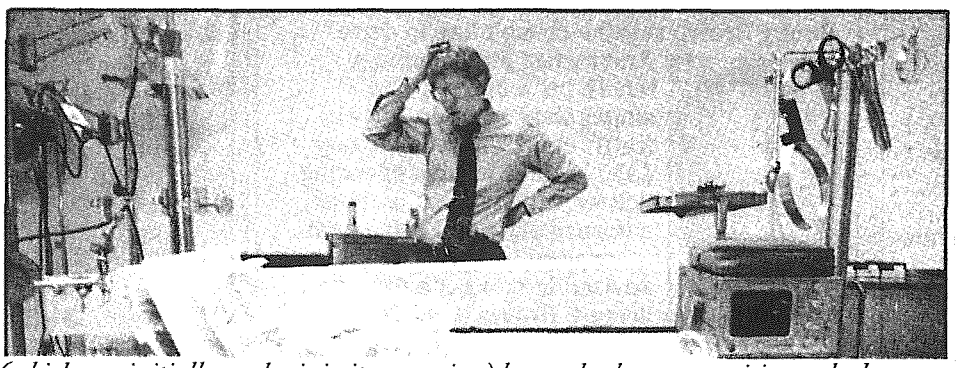
Finally, most of you have previously received an invitation to our first Scottsdale Open House on May 7th. This issue of *Cryonics* will reach you after that date; but we will plan other opportunities to visit in the months ahead. The next Open House will be Friday night, June 10th, from 5:00-9:00 p.m., in conjunction with the Venturist Weekend gathering.

Now we've parked our wagons, put up the new home, and settled in. We're proud of our new home and would love to show it off to you. Hope to see you soon.

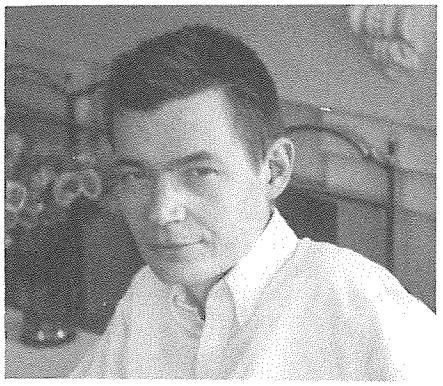
Cryonics firm gets settled in Scottsdale

By Mark J. Scarp
Scottsdale Progress Tribune

Ten human bodies hang upside down in large freezers, but to the peo-



Even the Scottsdale Progress Tribune *(which was initially sardonic in its reporting) has evolved a more positive outlook*



For the Record. . .

The Realities of Patient Storage

by Michael Perry, Ph.D.

Cryonics, in addressing through technolgy the ages-old problem of death, acquires some problems all its own. Prominent among them is the fact that frozen patients must be stored for a very long time, safely, and as economically as possible. An early, simplistic proposal would have made the task relatively easy, namely, burial in permafrost[1]. Essentially, there would be no maintenance, and a "cryonics storage facility" would be mostly a record-keeping center! Unfortunately, however, reality didn't cooperate: the polar regions of the earth just aren't cold enough. A few are frozen in permafrost today anyway, and there has been talk of combining this technique with some form of chemical fixation to guarantee adequate preservation. However, until more is known and developed, storage in liquid nitrogen must remain the method of choice for long-term preservation. This sensible position has been the prevailing viewpoint in the cryonics movement since before the first person was frozen. Storage vessels and associated technology thus have been under consideration and in use for some three decades. On the other hand, cryonics is a very small movement and resources have been limited. It will not be a surprise, then, that the innovations contributed by cryonicists to low-temperature storage have not been the flashier sort. In fact, roughly the same basic vacuum-insulated container has been used all along. Still, developments have occurred that I think will be of interest. Along with these, I'd like to report on the related topic of patient transfers (from older to newer units).

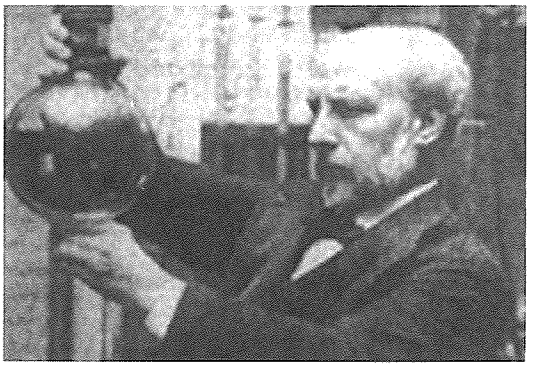
First, a little prehistory. Much of it has to do with the liquefaction of gases, an obvious prerequisite to a cryonics operation. Most of the basic work was done in the nineteenth century. Air (about 80% nitrogen) was first liquefied in 1877 by Louis Cailletet. Nitrogen was first liquefied in 1885 by the Polish chemists Wroblewski and Olszewski. Around 1892 the British chemist and physicist Sir James Dewar created the first of the double-walled, evacuated flasks which bear his name, and which have proved so handy in containing cold materials. Commercial development of air liquefaction products (including nitrogen) is traced to a plant in Germany started in 1895 by C. Linde.[2,3,4]

The exciting scientific quest that, one by one, reduced the "permanent gases" to unheard of liquids and solids, and the technical and commercial progress that, among other things, made cryonics possible, are stories well worth telling, but will have to wait for now. Instead we focus on matters of more direct concern to cryonics.

In one form or another, the dewar has been used to store cryonics patients since the first freezings in the '60s. Its use seems destined to continue, at least for several years and quite possibly much longer. Some highlights of this usage, and the philosophy behind it, can be briefly recounted.

A short primer on human cryogenic storage by Ev Cooper[5] (May 1967) reads, in part:

"The most general principles of liquid nitrogen storage are quite simple. The job is merely to keep enough liquid nitrogen (-195°C) in sufficiently close proximity to the object to be stored. Any heat picked up by the liquid ... excites some of [its] molecules ... . If the excitement ... is sufficient they excape from the liquid taking heat with them. A person could remain frozen in a sufficiently large open bowl if enough liquid nitrogen was kept in supply. Liquid nitrogen is chosen as a refrigerant as it is the least expensive, safe manner of obtaining extreme low temperatures. ..."

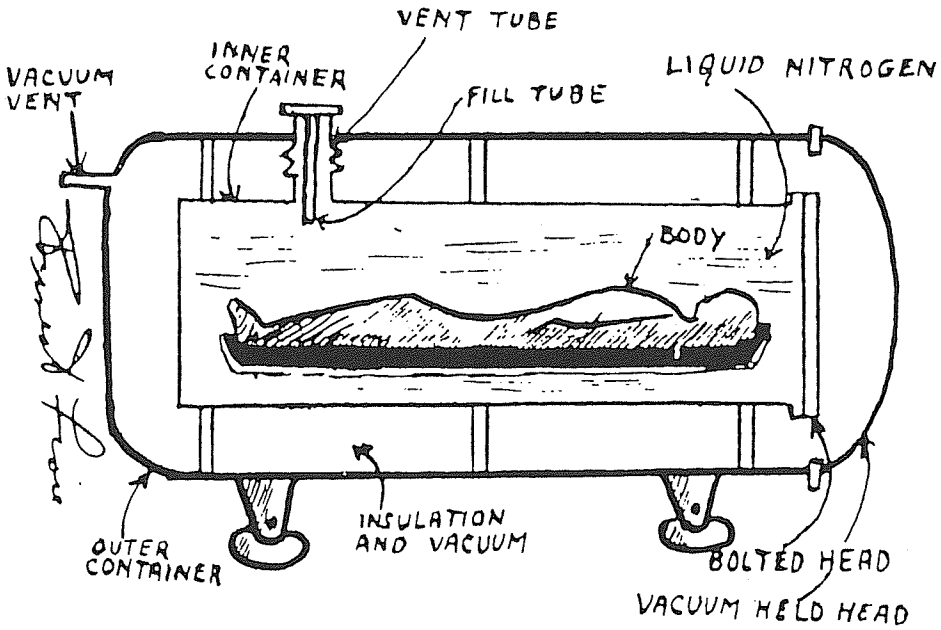


A little more should be said about Sir James' famous container, since it is so basic to patient storage. The need for such a vessel will be clear enough if you ever find yourself handling liquid nitrogen. Put some of the clear, cold fluid in an ordinary cup and it will very quickly boil away—and may crack your cup in two! Use of a metal cup or bucket will eliminate the cracking, but the intense cold may cause leaks to develop around seams, and you will still have the rapid boiloff regardless. Clearly something more sophisticated is needed. The dewar or "thermos" is basically two airtight containers, an inner vessel with a closely-fitting outer shell that nowhere touches it—except at the neck or opening at the top, where the two containers are bonded together. The empty space between the containers is evacuated, which greatly reduces the heat flow from outside to inside (or vice versa, in the case, say, of a thermos bottle with hot coffee inside). By and large, the heat must flow up the wall of the outer container, over the neck, and down inside—a roundabout pathway that offers a great obstacle even if the two shells are made of highly conductive materal such as metal. Smaller dewars such as the lunchbox thermos are made of aluminized glass for ease of fabrication; for similar reasons, larger containers used for biological samples or to store liquefied gases in bulk are generally of welded stainless steel, aluminum, or copper. (The evacuated space in these larger vessels also has layers of aluminized mylar or similar materials to further reduce heat flow.)

The report goes on to discuss construction of vessels for practical storage:

"If we wish to improve the efficiency of our simple system of the object in a bowl of liquid nitrogen, we then insulate the walls of the bowl and bring them upward and over the object to be kept cold. But we always leave an opening for the evaporating liquid nitrogen so the heat can escape. One of the best ways of insulating the walls of our container is to arrange a vacuum within the walls. ... To increase the efficiency further, many layers of reflective foil between very thin layers of plastic or glass mat are placed within the vacuum to stop any radiant heat from getting in. ..."

At the time only one person had been frozen under controlled conditions. This was James Bedford, who entered cryonic suspension Jan. 12, 1967. There had also been a freezing the previous April. (The patient had previously spent weeks in a mortuary however, so the biological viability was very doubtful.) In both cases cylindrical, horizontal, metal capsules were used, manufactured by Cryocare Equipment Corporation in Phoenix, Arizona. In the second (Bedford) capsule the patient was welded inside the inner container, which further reduced nitrogen boiloff. In fact the capsule performed very well, only requiring a refill every 7 months. (It was actually filled at intervals of about three months.) The drawback was that the evacuated space was inadequately sealed so the vacuum had to be periodically "hardened" by pumping (a valve being provided for the purpose).[6] Horizontal capsules would continue in use for several years. Meanwhile, in 1969 a new, upright design was put in service for the suspension of Ann Deblasio by the Cryonics Society of New York. This proved more practical than the earlier models, which in turn almost ceased to be used after 1981. (Unfortunately, most of the early suspensions had also terminated by then.) The lone exception was the Bedford capsule (a newer model, but still horizontal, manufactured in 1970 by Galiso of Fullerton, California). This durable vessel would remain in service for 21 years, a record.



FREEZE-WAIT-REANIMATE 5/67:
Early, horizontal cryonic storage container, sketched by Ernest Fiore.

By 1991, however, Bedford's old housing, now stored at Alcor's recent location in Riverside, was overdue for replacement. The cumbersome, sprawling, container occupied too much floor space. Worse, its vacuum had repeatedly softened over the years and had to be hardened again. This in turn was getting more difficult, apparently because of the buildup of oxidation products inside, which continually released small amounts of gas and prevented the desired hardening. (To eliminate this problem would have required heating, which was ruled out because the patient inside could not be easily removed and had to stay at liquid nitrogen temperature.) I remember a pump running *continuously* on this container for a year, sometime before the dewar was finally retired. This in turn was a dicey operation, carried out May 25, 1991. Like Bedford's original capsule, this one was welded shut and had to be cut open—while it still had some liquid inside. On opening at one end we found Dr. Bedford inside on a stretcher, which however, could not be removed so he had to be cut loose. He was lifted out—wrapped in a sleeping bag it turned out—and quickly placed in a large, open foam box filled with liquid nitrogen. Sometime later we had an aluminum box or "pod" assembled, in this bath of cold liquid, around the good Doctor, now strapped inside, in an extra sleeping bag for good measure. (The pod was held together with rivets, which could be applied with a rivet gun at low temperature.) An overhead crane then quickly hoisted our patient up and then down into his new home, a nine-foot, upright, cylindrical "Bigfoot" dewar designed for four whole bodies.

"In 1969 a new, upright design was put in service for the suspension of Ann Deblasio by the Cryonics Society of New York. This proved more practical than the earlier models, which in turn almost ceased to be used after 1981. The lone exception was the Bedford capsule. This durable vessel would remain in service for 21 years, a record."

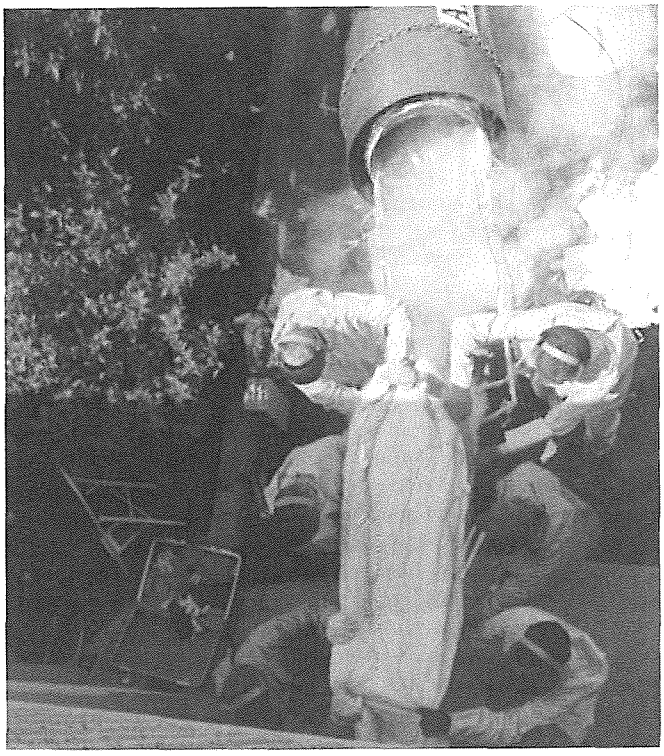
Patient transfers, a little less laborious than this but still a workout (we could do about one per hour), were also needed to retire some of our older, upright containers. In a typical case we would lift the patient out of one container, in a sleeping bag tied to a stretcher, place them in the liquid nitrogen vat, cut them free of the stretcher, assemble a pod with them strapped in and seal it up, then hoist the pod up, and down again, into a waiting Bigfoot. (The Bigfoot would have to be rapidly positioned under the pendant patient by several strong backs, for the lowering operation. Typically a patient spent only about 90 seconds out of liquid during this operation, with the head in a "neurocan" full of liquid.)

I realize this history is a little haphazard; some of the more recent events I witnessed directly, while for the earlier ones I've relied on old newsletters and the like. In between I think there were long stretches when not much was happening, at least in the areas of patient storage. However there are some further items that deserve mention. Patients

(whole-body that is) are generally now stored head-down, so their heads (the most important part, of course) will stay covered in liquid nitrogen in event of a long interruprion in supply, as might happen in civil unrest or natural disasters. (In the early days they were stored upright.) Some years ago, in 1989, I visited the Cryonics Institute's facility in Oak Park, Michigan. They had an interesting alternative to the upright, steel capsules I'd seen at other facilities. Their containers were not of metal, but *epoxy*, reinforced with fiberglass. Not horizontal, *not vertical either*, but canted at about a 45-degree angle, supported in massive wooden frames. Patients (one or two to a cylindrical container, I believe) are sealed inside, much as with the old horizontal steel capsules, but with epoxy, which takes about 24 hours to harden. (They are of course maintained in liquid nitrogen during this time, which however does not touch the glued-on lid.) The vessels are insulated with a softer vacuum than your typical metal container and the evacuated space is filled with perlite. I understand CI now has larger, rectangular upright units of the same basic construction in use, that can store four or more patients each.

I also visited Trans Time's facility in Berkeley, California, around 1989. They had a rather varied assortment of upright, cylindrical metal containers, including one behemoth ("King Kong") able to hold ten whole bodies. I should mention too that not all containers are for whole bodies. The ones for neuros or heads only are, as expected, scaled down versions of their whole-body cousins (say about 4 feet in height). Neuros are easier to store and consequently, I think, not as much effort has gone into trying to find just the right container for them. I should mention, however, the concrete vaults encasing the neuro containers at Alcor, which have yet to be matched in whole body storage. Alcor's Bigfoots are actually for neuros too, being designed to hold several in a central well along with the whole bodies. (More ambitious plans call for dedicating an entire Bigfoot to neuros when the patient population is large enough.) Alcor's Bigfoot design, which is being "cloned" elsewhere, is arguably the most advanced to date for the purpose it serves. The dewar can be opened without cutting, through a large foam-lined lid on top. An attached fill line makes it convenient to replenish liquid nitrogen, without opening the container. Boiloff of the approximately 1800-liter vessel is about 14 liters per day, or less than 1% (and this with the container nearly full, which increases the boiloff rate).

I understand CI's alternative technology also achieves a low boiloff rate, and has the advantage of being manufactured in-house, at a lower cost. (In the case of the Bigfoot, which requires a skilled, professional welding job, one manufacturer became squeamish about cryonics and another had to be found.) It is recognized, meanwhile, that the best storage technology available today is still not what one would like. A much larger unit or "cold room" would offer economies of scale and perhaps could help hold down cost if cryonics becomes widespread. This however, is mostly in the dreaming stage still, and we must make do with a multiplicity of units designed for a few patients each.



Removing Dr. Bedford from his horizontal capsule

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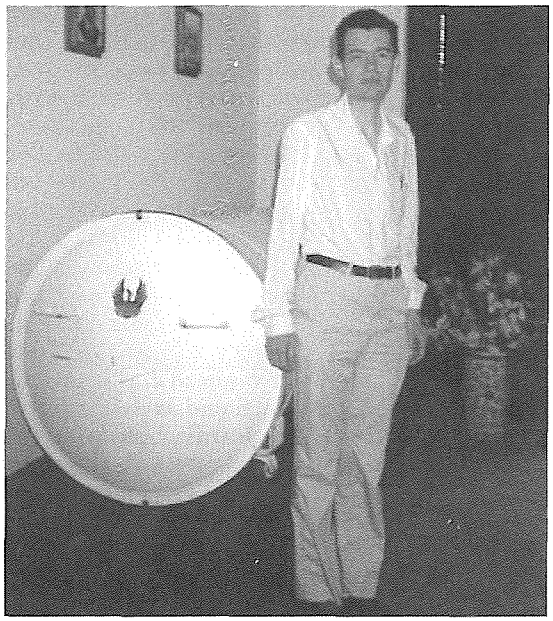


Mike Perry, with Bedford's first capsule

The current state-of-the-art

Long-Time Cryonicist Jerry White Enters Suspension

First Life Cycle: October 31, 1938 - February 5, 1994

by Jim Yount and Acor

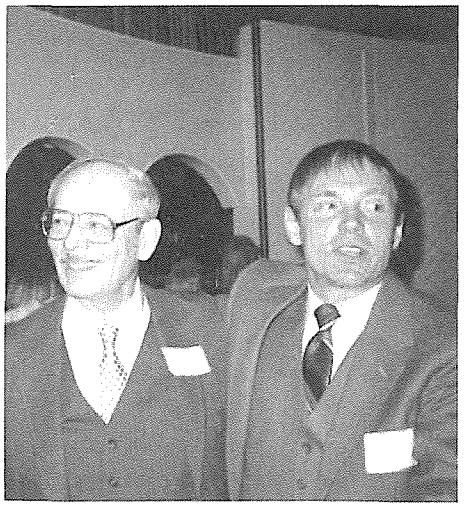
On February 5, long-time cryonicist Jerry White, age 55, was pronounced dead and was suspended. Jerry (Jerome B.) had been ill for many months with complications from the AIDS virus.

Jerry is one of the founders of the American Cryonics Society (ACS) and served in various capacities as an officer and Governor or committee member for most of ACS' history. Mr. White was also one of the founders of Trans Time, Inc., and served on the Trans Time Board for many years. He was frequently a guest on television and radio talk shows promoting cryonics as well as speaking to college and high school students and to clubs such as the Rotary Club and Mensa (Jerry was a Mensa member).

Jerry received a B.A. in Philosophy in 1966 from the University of New Mexico, Albequerque, NM. He continued his education at the University of California at Berkeley where he studied Computer Science and Education. Jerry was especially interested in the Psychology of Learning, programmed learning, and computer-aided learning.

From 1983 through 1992 Jerry was a lead designer for Sterling Federal Systems, Inc., of Palo Alto, California (Sterling Software), a contractor to NASA Ames. While at Sterling, Jerry worked on a variety of NASA projects including helping develop a computer program to analyze the atmosphere of Mars, and a variety of programs connected with the design of tilt-wing aircraft. He also worked for the University of California, College of Natural Resources; Honeywell Information Systems in San Francisco; the University of New Mexico, Albequerque; and the General Programmed Teaching Corporation.

From August 1957 through August 1959 Mr. White was in the Navy, where he served in the combat-information center as watch-



section supervisor (radar) and as master-at-arms. He was honorably discharged with a Captain's commendation.

Like many other cryonicists, Jerry had a wide range of interests. He was a Lincoln scholar and collected over 500 books on President Lincoln. (This collection has been given to ACS.) Jerry taught himself to read and speak Russian in elementary school. In addition to Russian, Jerry spoke and/or read German, Spanish, French, Greek, Latin, Hebrew, Yiddish, and Modern Mongolian. He was a student of comparative languages and language origins.

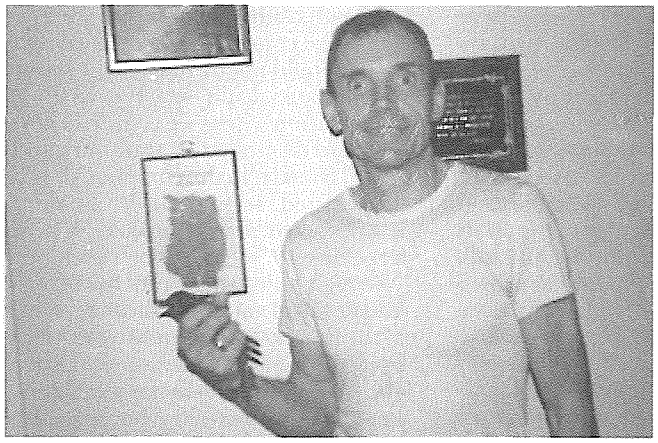
Jerry was an active member of the Libertarian party and a staunch advocate of personal freedom. He was also active in the Gay Rights movement and AIDS casuses. He did a number of newspaper interviews wherein he discussed his disease and his cryonic suspension arrangements.

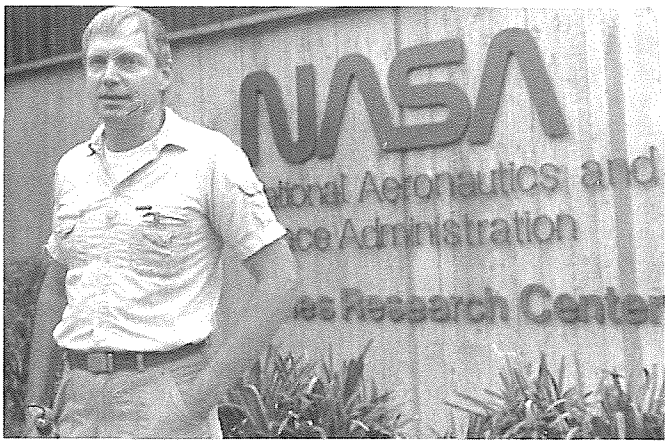
Jerry was the author of numerous papers/presentations, including "Heat Flow in the Human Patient," "Varieties of Deathism," "Syneidetics and the Symbolic Logic of Psychology and Cognition," "Whitehead's Philosophy of Process," "Cryonics and Syneidetics," "The Technology of Cryonics," and "Virus-Induced Repair of Damaged Neurons with Preservation of Long-Term Information Content."

Although Jerry was not an Alcor Member, he was known and very well-liked by many of us, and is a first-rate human being by every account. We share the grief of his friends and loved ones, as well as their fervent hope that his passing is a temporary one.

Jerry was suspended for ACS by Biopreservation. His suspension appears to have gone well, with cardiopulmonary support beginning right away, and total-body washout initiated within an hour-and-a-half of pronouncement.

Good luck and a safe journey to you, Jerry.





LIFE IN THE TIME OF THE SCHISM:

Some former Alcor members seek greener grass.

By Steve Bridge, President

As I've written in these pages several times before, cryonicists are rugged (or perhaps "dogged") individualists, believing their own point of view to be right and those who disagree with them to be liars, maniacs, or fools. From my advanced position of age and experience, I can see (because *I'm* really the one who is right) that it is truly amazing more cryonics groups have not been started. It appears that death is such an implacable enemy that even these individualists will give up some independence (*some*) to try and win.

Yet once in a while in cryonics—as in most movements where the participants feel strongly about the importance of the goals—the emotions, methods, and principles are so different that a split must occur. Such a split in the Cryonics Society of California in 1972 led to the formation of Alcor. A split in the American Cryonics Society several years ago led to the formation of the International Cryonics Foundation and to an end to cooperation between ACS and its former suspension services provider, Trans Time.

And in the past few months another such event has occurred, when several Alcor members and former Alcor members formed the nonprofit CryoCare Foundation. CryoCare's President is Brenda Peters, who was one of Alcor's Directors for several years. CryoCare has contracted with other organizations for services, including Biopreservation, Inc. (Michael Darwin's for-profit suspension company) and CryoSpan, Inc. (a for-profit company which provides long-term patient care). CryoSpan has been run by Paul Wakfer for the first few months of its existence; but Mr. Wakfer will be resigning from that position in the near future. Other activists in these groups include Saul Kent, Steven Harris, Charles Platt, and Billy Seidel. We don't know how many Alcor members eventually will switch to CryoCare; but as of this writing, we have received notice from about 40 members that they have switched or intend to switch.

During the past several months, Brenda Peters has organized an intense promotional campaign directed at current Alcor members, for the purpose of—and there is no way to say this any more politely—*raiding Alcor* to build the new organization. Ms. Peters and other CryoCare activists are fine writers and speakers, and are excellent at slanting arguments in their direction. Indeed, many of these people used that talent on behalf of Alcor for many years. Of course, many excellent debaters and writers remain in Alcor, and you may occasionally hear something that puts an Alcor spin on a story.

As you consider your options as an Alcor member, or for those of you who are considering which organization to join, you'll be reading and hearing many claims of greatness, competence, and scrupulous integrity pitted against hints of incompetence, falsehood, and naivete. Attempts to make one's own side look good and the other side look incompetent are normal as humans compete; but we ask that you take the time to talk to people on both sides before making up your mind.

In the past two years, I've heard some pretty horrible things said about leaders on both sides, most of which were shaded from the truth far enough that the truth could not be seen. You're sure to hear more. Most of the individuals who will state their opinions will give you the impression (or even boldly state) that their interpretation is completely factual, objective, and the only possible way of looking at the situation. (Important life lesson: when you meet someone who insists he or she is completely objective about *anything*, keep one hand on your wallet and the other on the salt shaker. You're dealing with someone who is trying to con you—or successfully conning himself.)

Alcor has tried hard to stay away from the arguments and accusations during the past few months; but there is one recent letter that requires some explanation. Brenda Peters recently sent a letter to somewhere in the neighborhood of 100 Alcor members, with various promotional information on CryoCare, but which also includes a paragraph critical of Alcor's Board of Directors. Since we do not know which individuals received this letter or which might receive it in the future, I think it is important to issue a correction in *Cryonics* magazine, as part of this article.

Ms. Peters says, "Those of you with Alcor were happy to hear that Alcor and CryoCare had settled upon a "transfer agreement" insuring cryonics coverage until your insurance or other financial arrangements were officially in CryoCare's name. Many weeks have passed and great time and expense have been incurred to implement this plan, therefore we are sorry to report an unfortunate development. Even though Alcor's President, Steve Bridge has signed several Transfers, Alcor's board now refuses to honor the agreements. Because we wish to insure your protection, we encourage you to change your financial arrangements as soon as possible. This is the only way to insure CryoCare's team of professionals be on hand should you need them. This disturbing turn of events makes it all the more important that you waste no time in calling your insurance company to change your beneficiary!"

The implication here is that Alcor's Board of Directors approved the Transfer Agreements and then sneakily changed their minds. Further, I have had telephone calls from people who have heard rumors that Alcor's Board are holding members "hostage" by refusing to allow them to transfer to CryoCare.

The truth is that Alcor's Board of Directors had *not known* of the existence of the Transfer Agreement form before I signed the first seven. Charles Platt, Brenda Peters, and I discussed the arrangement via phone and e-mail and wrote what we thought was a fair way to handle member switches. I concluded this was within my area of responsibility and that there was no reason to drag in Alcor's Board for protracted nit-picking on the document. This turned out to be a poor assumption on my part. The other Directors, when they read the Transfer Agreement, pointed out several major problems.

First, we do not "own" the Member and cannot "transfer" responsibility. An individual quits one organization and joins another. Second, the agreement, in the case that CryoCare would suspend a member but Alcor was incorrectly sent the insurance payment—or vice versa—would require one organization to write a check to the other. Alcor's Directors did not believe it was proper for Alcor to be in a position of accepting funds that did not belong to us, and that Alcor should simply send the check back to the insurance company. Actually, a more likely scenario than accidental payment is that the suspending organization isn't yet listed as beneficiary, and so requests the beneficiary organization to file the death claim and pass the money along. It was the concern of some Directors that Alcor should not be placed in a position of some financial and legal responsibility for a suspension where we could not know the details of deanimation, transport, and care.

And frankly, in the competitive situation that existed, several Directors wondered why I appeared to be making it easier for CryoCare to "steal" Alcor's members.

Straightening this all out has taken much longer than I anticipated, not least because of the immense amount of work generated by Alcor's move to Arizona. (There are only so many hours in the week and in my ability to stay awake.) I have now issued a letter of clarification to individuals who

signed the Transfer Agreements. I have also designed a more appropriate "letter of resignation" for Alcor suspension members. We want to point out that we are NOT holding Alcor members hostage. We all believe in your freedom to choose your cryonics organization, although we plan to work hard to persuade you that Alcor is the best choice. If you have questions about what you have seen or heard, please talk with one of Alcor's staff or Board before making up your mind.

As the future unfolds, and as cryonics continues to expand, we can expect more organizations to come into being. Arguably, better service and more consistent standards will follow from a competitive market not monopolized by one group alone. More groups should also lead to more and different research initiatives. On the other hand, inevitable frictions will arise as the differing groups compete for members, or as new groups may be formed from those who formerly worked under one roof.

Meanwhile, at Alcor we remain committed to the highest standards of member services, patient care, and research. Our move to Arizona has opened up many new possibilities for security and progress (see my column on the move elsewhere in this issue). If you are thinking of joining a cryonics organization or of changing your organization, we urge you to investigate carefully, to make the best informed choice. Hopefully, that is one principle on which we can all agree.

The Historical Maturation of the Human Brain:

The Progressive Mastery of Mother Nature

by Tom Mackey

The strongest offspring of human nature is still, ultimately, just another one of her casualties. Mother Nature unknowingly weakens herself by continually annihilating it. Yes, Descartes, the mind is all we are; but no, Descartes, it's not transcendent. Still, the modern late adolescent brain could grow into an adult form that would master mother nature on her own turf: the material world. A fully matured human brain could be physically immortal and omnipotent and, hence, divine.

The human brain has been maturing—becoming more Godlike—for millenia. As a baby, with little technology, it looked up to Mother Nature as a goddess, for it could rarely control her. She was deified in all her multifarious forms. One can see this in the pagan polytheism of the Ancient Greeks and Romans.

Then, as it learned more about nature, the human brain entered childhood. The more it learned, the more it was inclined to consider natural objects, in themselves, unworthy of worship. This came with repeated observations that Mother Nature conducted herself in a rather routine manner that suggested she didn't give a damn about any of her offspring, which included the human brain. The brain, thus alienated from its mother who, in every instance, callously aged and annihilated it, withdrew within itself to find a way to avoid such child-beating. Being just a child, it couldn't discover anything among its own resources, so it contrived anthropomorphic deities (e.g., the Judeo-Christian one) which were supposed to avenge for mother's brutality, by providing both continual solace throughout the beating and an afterlife away from her.

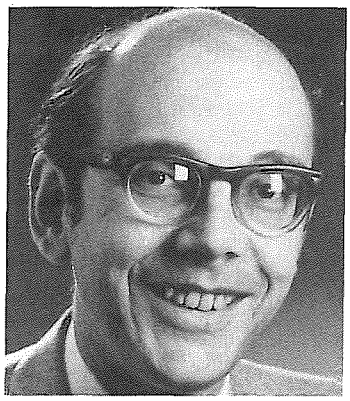
The human brain hit adolescence when, try as it repeatedly did, it couldn't prove the existence of an external deity. In fact, evidence showed that Mother Nature was all that could be verified and also suggested that quantitative formulae could fully describe and predict her actions, so the adolescent brain could cogently argue the contrary. But it didn't want to. Like many adolescents, the human brain developed an identity crisis. It didn't like considering itself just a subset of its mother. It wanted independence. For centuries, it had considered itself an autonomous entity created by a transcendent God. This entity could, therefore, be held accountable for its actions, with God, not mother nature, being the final arbiter.

The apparent fairness of this contrived moral scenario was insulted by the adolescent brain's progressive discovery of nature, a composite of scientific endeavors it often mistook as amoral. The adolescent brain often became reactionary, while pretending to be progressive, in thinking that not only was God dead, but so was much of the abstract reasoning it had employed in discovering nature. Knowing it couldn't use either reason or God to save metaphysics, the resistant adolescent brain quipped that both science in its abstractions and religion in its "otherworldliness" were escapes from real, concrete experience. So the brain, forced by its own reasoning to give up on an "afterlife," avoided this reasoning to hold on to the illusion that it was autonomous in an "existential" sense.

Ironically, though, in its convoluted denial of the fact that it was not yet free, this recalcitrant adolescent brain rid itself of some of the religious restrictions that still stagnate the scientific young adult brain's attempts to make itself free. Thank God—the fully matured brain—that an adolescent brain like Nietzsche played God. What's left of the childish brain still thinks no brain has the right to play God, remaining ignorant enough to condemn for grasping for "forbidden fruit."

Come on, human brain, understand yourself! You created religious myth to circumvent the pains of nature you were too weak to conquer. But then you created technology to conquer these same "natural" pains. You have been continually dissatisfied with Mother Nature, because she has failed to satisfy your constant will to live, and to live without pain.

Suffering and death may not be immutable consequences of human existence. The part of the human brain that realizes this is moving rapidly into adulthood. This part of the brain includes scientists who are investigating the causes of cellular damage that contribute to aging. A precise map of the genes of a human's DNA should be available in just a few years. As the human brain discovers many more secrets of DNA, it could obtain some rather divine powers of self-alteration. When the human brain has truly mastered mother nature, it may feel no need to believe in any God but itself. As God, the human brain would have the technological power to increase greatly both the quantity and the quality of life. It would have created and thus become the mother of a new nature. This re-creation could be heaven.



The Donaldson Perspective

About Science Fiction

by Thomas Donaldson, Ph.D.

When I was a teenager, and even in my early twenties, I read a lot of science fiction. Yes, I even read Heinlein's *The Door Into Summer*. I saved and worked and bought my very own telescope. (It was a 4.25" from Edmund's, which incidentally remains in business. When I went away to college, I gave the telescope to another younger boy, who shared my interest in astronomy.)

But as time passed, science fiction has seemed less and less interesting. Was this from changes in science fiction itself? Was it simply because I was growing up? Or because I went through other changes? I can't really say, and this column tells only my own experience. As a cryonicist, however, it may say something to other cryonicists, who may find they had similar experiences.

As for changes in science fiction, I feel there have been major ones, though someone more knowledgeable about science fiction in 1994 may find grounds to argue with me. Some books I read then remain with me even now. From time to time I look through the bookstores, but have never found anything like those books. So here they are: Frederic Brown's *The Lights in the Sky are Stars*; Clifford Simak's *City*; Jack Vance's *To Live Forever*; and Olaf Stapledon's *From the Last to the First Men*.

What caught my mind about these books? *The Lights in the Sky are Stars* by now has almost become contemporary (it's set in the late '90s). It is the story of the attempt of a former astronaut to become the pilot on the first exploration flight to Jupiter, about the year 2000. We read about his adventures in a sometimes sordid everyday world, almost like the present, but we also read of his hopes and ideas and his belief in space travel. He fails, really because of a classic tragic flaw. That failure, though, is far from the failure of his dreams.

City is a story about the end of the human race—not the standard end by disasters of one kind or another, caused or not caused by human beings themselves, but another end caused by time and change. Its narrators come from a race of intelligent dogs who no longer even remember human beings except as myth, and who don't even live on the place we call the Earth. And they think long and carefully about the meaning of these myths. What was a city? They never find out.

To Live Forever is the story of a man and a city-state, Clarges, in which immortality has been discovered, but (for fear of upheaval) made available only to a chosen few. And even at the start we see many signs of this arrangement breaking down, not by corruption but by the strain it causes on everyone involved. The word "death" has become an obscenity. Many people go insane from the strain of trying to reach that special immortal state available to so few. The main character, an immortal sentenced to death as an example for "murdering" an immortal who did not really die, tries to attain immortality for himself again. In doing so, he breaks apart the society itself. In the end, immortality becomes available to everyone.

From the Last to the First Men is written as a future history, with characters consisting of whole races and civilizations (and indeed is now way out of date!).

What caught me, and still does, about these books isn't their exploration of *technology* (though technology certainly played a major role). Nor were they adventure stories in any classic way. The strongest theme I can see in all of them comes from the questions we *really* ask about the future: Who are we? What will happen to us? Where are we going? They were each fictional explorations of these questions, sometimes with a bit of adventure added, somtimes not. Did any of them give real answers? No, but the questions were insistent.

When science fiction fell out of favor with me, I very much did not lose my interest in science and technology. Yet rather than go to science fiction for that I go to the original sources. Sure, we can have lots of stories which depend on some new or speculative invention, on technology in general. The characters in them may or may not be strong individuals.

"Hard" science fiction, if by that you mean science fiction which speculates but does not depend on obvious fantasy, continues to appear in bookstores. Still, something seems missing. Nor is it, to me, simply a matter of the sometimes ugly side of technology which some books present. Certainly, technology can produce ugly results... after all, those who create it themselves aren't all models of philosophical and moral rectitude.

Some science fiction pushes particular political, social, or environmental philosophies, even some with which (in a very broad way) I agree. That, however, is all trivia. If I know anything about the future, I know that *all* our contemporary politics and ideas, even our personalities, will become outmoded and forgotten after 500 years. (If we look carefully, we can even see such changes happening very slowly before us!)

And of course as a cryonicist, those questions press on me more than ever. We are making our own try for immortality. What will happen to us if we succeed remains a matter for wonder and fascination. I most fervently hope that it will succeed. (Even though sometimes it looks as if even *cryonicists* aren't acting as if they really want its success. Are all the old ideas about the evil of immortality still inside us?)

To Live Forever may even tell of our own contemporary problems, though in 20th-Century America those problems appear in a muted, far less dramatic way: we see right now an attempt to change the American health system. We also know that it is the *cost of dying*, more than any other medical cost, that raises the cost of medical care. And all the while, all those eminent politicians and scientists keep one answer virtuously from their minds.

THAWED ZOMBIE STALKS OWN SOUL!

Editors Note:

In a recent interview with Alcor President Steve Bridge on WIBC radio in Indianapolis, the very last caller said, "I guarantee that cryonics will work."

Dick Wolfsie, the host, responded, "Oh, how do you know that?"

Caller: "Because I was frozen 500 years ago."

Host: " ."

Steve: " ."

Finally the host said (with just the hint of a malicious grin), "Why don't you stay on the line and we'll have our producer talk with you. He loves these stories."

Steve: "Yeah, Dick, I think that's a whole other show."

Alcor Member Richard Shock was listening to the interview and sent in the following shocking account.

Fiction by Richard Shock

While I was naturally incredulous of a story in which someone claimed to have been frozen 500 years ago, the incident intrigued me. After threatening WIBC with various lawsuits (none of which contained the least merit), I managed to extract the telephone number of the supposed ex-corpsicle. Deriving his address from this number was elementary, as was cornering him at home and obtaining the biography that follows:

* * *

First of all, I'm not exactly 500. Actually it's closer to 450, give or take a decade. Back in 1504 I was born in Basel, Switzerland, a nice little town at that time, but about as dull as Muncie, Indiana on a Sunday afternoon.

For several years I had a fairly happy life in the mountains, eating cheese and yodeling and such, but when I got to be an old man of 38 I contracted the dread disease Pneumonia. While friends and relatives were gathering around me for the last time, a guy calling himself Theophrastus Bombastus von Hohenheim showed up at my bedside. Although he was supposed to be a big-shot alchemist and physician, von Hohenheim admitted that he couldn't cure me. However, during his research with weird chemicals and herbs recently brought from Cathay, he cooked up a process where animals could be made to sleep so deeply that not even freezing killed them. Since I was as good as dead anyway, von Hohenheim wanted to try this on me.

Back then I didn't know that Theophrastus von Hohenheim was actually famous all over Europe as Paracelsus, the first doctor in the West to use opium and other drugs like that. At the time, all I knew was that I was drowning on my own juices and just wanted to get the whole disturbing ordeal finished. I agreed to the experiment.

Things get blurry around this part of the story. From what I've been able to figure out, Paracelsus froze me and stuck my body in a glacier high in the mountains. Then he went to Alsance, intending to recover me in a year or two. Instead, he got so involved in his other ideas that he forgot all about me.

The tricky part was that even though the freezing kept my body preserved, it released my soul. I woke up over four hundred years later as a high school drop-out living in Greenwood, Indiana. Getting used to this other life was a challenge, especially since welfare didn't pay enough to live; I had to collect a lot of aluminum cans from along the highway just for weekly beer money. The food was better in Switzerland, but pretty soon I just couldn't get along without Penthouse Magazine and Cable TV.

I guess everything would be okay if this was the end of the story. The thing is, my original body had stayed frozen back in that Swiss glacier. Remember a few years ago when some hikers in the Alps reported an old body they found in a glacier melt? That was me. Sure, the authorities jumped in fast and announced the body was thousands of years old, but that was because the first corpse they pulled off the mountainside disappeared; after that, they had to fake up a mummified caveman body so no one would think the Swiss were nuts.

Paracelsus knew his business a lot better than anyone thought. My soul might've reincarnated in someone else, but my original body didn't die. When the glacier melted, my body revived and started looking for me. One day I was sitting out on the stoop of my girlfriend's mobile home when this creature who looked like the star of *Friday the 13th, Part VIII* comes stumbling into my yard and yodels at me in German. Apparently it escaped the morgue in Basel and walked to the airport, where it stowed away in a cold storage crate full of chocolate truffles. A woman at the Holiday Inn Psychic Fair told me that souls always leave an ectoplasmic thread attached to their bodies, so the Swiss "me" must've followed the line to Indiana.

I'm not sure what my former body would've done if it had been healthy. Maybe it would've killed me trying to get back my soul. Freezing didn't cure its pneumonia though, and by the time it reached Indiana the disease had slowed it down considerably. I thought about letting it die, but then how would I get rid of a rotten corpse? Borrowing some money from my girlfriend, I took the body to a doctor and introduced it as my feeble-minded brother, a common enough situation in Greenwood. Antibiotics cleared the pneumonia right up, just the way they did that case of the clap I got a couple years ago.

My girlfriend didn't mind too much when I told her my "brother" was going to be living with us from now on. Once I introduced my old body to Penthouse and Cable TV, it loosened up a lot and stopped acting so much like a crazed zombie. Sure, it's not very bright, but that still makes it smarter than half the guys I know around here. The only problem is that I think it's been having an affair with my girlfriend when I'm out cruising the bars in my Chevette.

Sometimes I just can't stand to live with myself.

* * *

As far as I have been able to determine, all the particulars in this case are true. Unfortunately, I could not determine whether the "body" I met lacked a soul. It did have an inordinate fondness for air conditioning and ice cubes, however.

Determined Not to Lose Our Patients

—by Ralph Whelan—

This article summarizes and augments my two previous patient-move articles, which appeared in the February and March issues of The Alcor Phoenix. *If you have not seen those articles and are interested in more detail on the move of our patients, you can purchase back issues of* The Phoenix *for $2.50 apiece.*

I imagine it will be fascinating to hear, upon revival from cryonic suspension, the tale of the journey you've been on.

Probably your wide-eyed curiosity will first be directed at the *then-present*, at the wonders and (I suspect) the wild variation of "the future" from all of your best-measured guesses.

But you'll get your fill of that. Eventually, your thoughts will wander back to those poor saps who tried to make a living out of carting your cool heels across the decades. I have to imagine that it will seem increasingly important to you to find out what it was like for them. After all, you were *right there* for all those years, counting on them to do the right things, to beat the odds and the naysayers, *to pull you back from the brink*. You'll want to know what it took to pull it off.

Probably it will have involved—among other things—a few relocations. Here's what one of those was like for us.

Figure 1

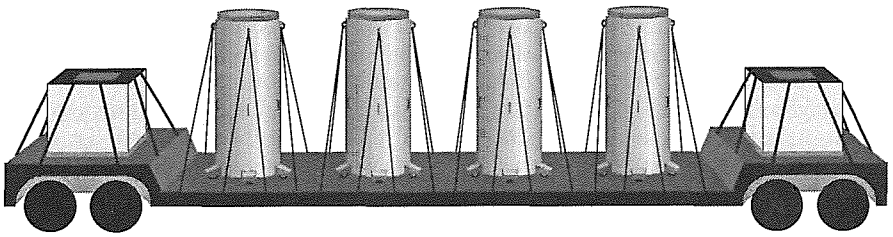
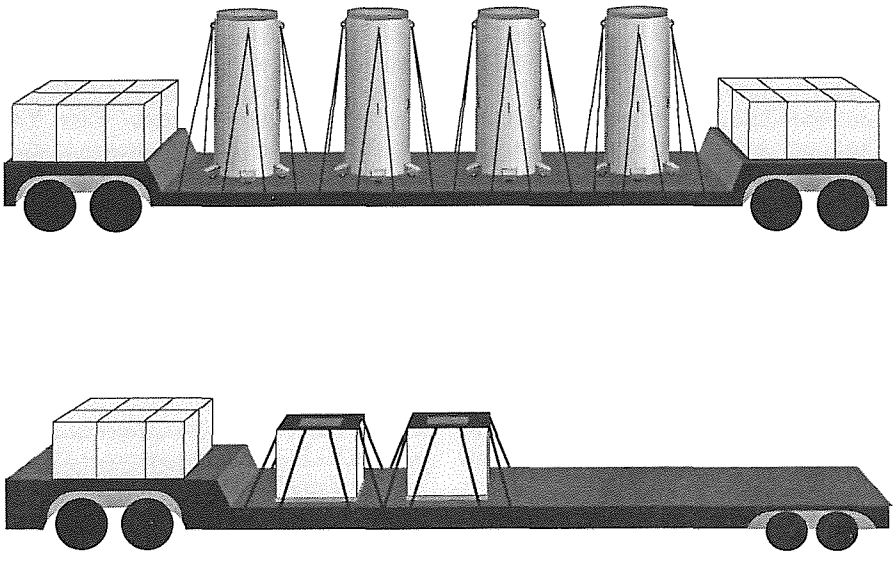


Figure 2

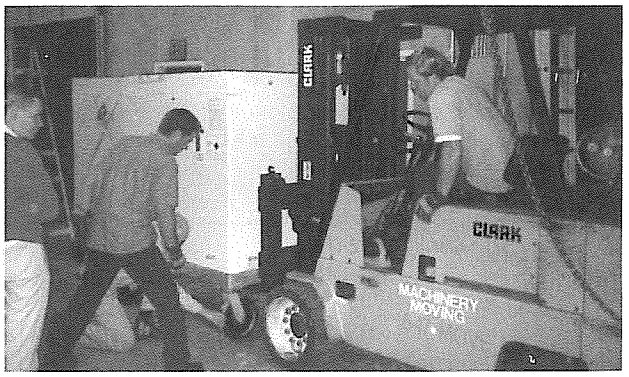


From start to finish, political pressures were the most abiding complication in the process of relocating our 27 patients from Riverside, California to Scottsdale, Arizona. The need for a new, larger facility for Alcor mounted steadily and all-too-visibly throughout the late '80s and early '90s. And while growth brings change, it's not always the change you'd predict. Alcor management (the Board of Directors and the staff) had begun splitting into two hazily defined political camps during the "Dora Kent Saga" of 1988; the dichotomization—slow but continuous for several years—accelerated tremendously when Alcor Vice President and Suspension Team Leader Jerry Leaf was cryonically suspended in the Summer of 1991. Jerry was universally respected in cryonics circles (something few will ever achieve), and his presence unified a frenetic group. His loss was too big a bolus of entropy for Alcor's existing management structure to grin and bear. The politics got ugly, and a split began to seem inevitable.

Amidst all of this turmoil, the ground began to shake. Literally. As if Alcor's obvious need for newer, nicer, larger quarters wasn't enough of a political football, the "The Big One" jogged out onto the playing field and started warming up. Newspaper articles and evening news bits began quoting seismologists to the effect that—likely as not—a devastating earthquake woud hit Southern California within five years.

To those of us who'd already been pushing for a move out of Southern California, this was more evidence of an obvious need to *hurry*. To those who viewed the now increasing emphasis on a years-old threat as disingenuous, this was more evidence of ... you name it. People were accused of putting their political agendas above the safety of the patients. People were accused of using "the safety of the patients" as a false battle cry in pushing their political agendas.

Meanwhile, the Alcor Directors had to decide whether or not to support the purchase of a building that seemed to meet all of our needs at a startlingly low price, but that would require—at least to a small degree—*a Patient Care Fund investment*. The roof over the patients' heads may or may not represent a reasonable Patient Care Fund investment, depending on whom you



Dr. Perry (far left) and Hugh Hixon (kneeling) assist the movers with the massive cephelarium ("neuro") vaults

ask; but there's no question that it can transform organizational management into a passable spectator sport.

Bargains don't come cheap. It seemed this one might even cost us a chunk of our membership. But was that even avoidable any more? And didn't the Alcor Mission Statement say patient safety above all else?

While the Board and many concerned members wrestled with these issues, the Alcor Staff confronted more mundane problems. Like engineering the move of 27 patients 350 miles at -320°F. This project fell into my lap, so I did what anybody else would've done. I called the Movers, and asked them what *they* would do.

We met with representatives from three different companies, two of whom returned bids for the job. Of the two, Chipman Relocation Services, a division of United Van Lines, was clearly the more professional. Further, Chipman subcontracted all of its heavy/huge/tricky jobs to Dunkel Bros. Professional Equipment Movers. The Dunkel Bros. representatives were confident that they could handle the move of the patients, and we were impressed by their experience and expertise.

The Dunkel Bros. were quick in convincing us that lifting the 10-feet-tall 4-patient "Bigfoot" dewars from the top using chains and a forklift was the safest way to load them onto trucks.

Actually, we weren't all *that* easily convinced. In fact, we staged a "dry run" and made them demonstrate their asserted proficiency by moving a Bigfoot dewar—full of liquid nitrogen but without any patients. We had them load it in the prescribed manner, drive it to Scottsdale, and unload it at the new facility, with cameras clicking, recorders recording, and cryonicists scrutinizing them every inch of the way.

So, it could be done. The next question was, *How many dewars should go on each of how many trucks of what kind, and why?*

I couldn't answer that at first either, so I started by defining some limits. We had a total of six liquid-nitrogen-bearing dewars in need of transport, so we would certainly need no more than six trucks. How *few* might we need? Could we have as few as one?

It seemed that one of their "double drop" trailers was rated to carry about as much as all six of our remaining dewars weighed, so I began conservatively with a one-truck plan (figure 1). Many of us were uncomfortable, though, with the "one basket" approach to moving all of our patients, and I later discovered that 1) coming in under the weight limit does not assure proper weight *distribution*, and 2) *un*loading the dewars at the other end would require a forklift, and the Dunkel Bros. insisted (reasonably enough) that it be *their* forklift, and their forklift weighs *18,000 lbs.*

Nine of Alcor's neuropatients are carried over the threshold of their new home

Enter Plan B. With a two-truck approach, we would be well under weight capacity, and we would be able to bring the forklift. Further, we would have some flexibility in the event of technical difficulties en route: if one truck broke down, we *could* (since the trucks had the capacity) transfer the dewars to the functional truck using the forklift.

So we went with two trucks. We put the four Bigfoot dewars on the double-drop trailer (figure 2), with unrelated cargo in front and behind, and we put the two neuropatient vaults onto a "single-step" trailer, with space enough left over behind them for the forklift. The whole array was strapped and chained in place, and then covered with tarps.

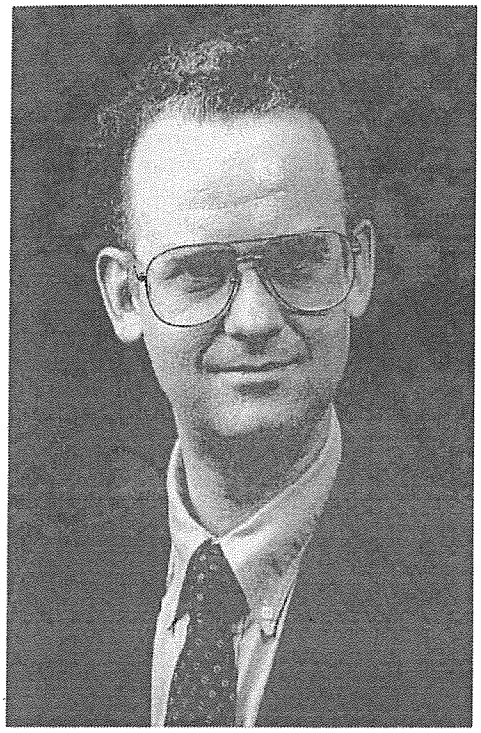
The voyage itself was blissfully unremarkable.

The political pressures, which also had been moving fast, began to let up a bit right about this time. This was partly because of a certain sense of inevitability achieved by the relocation of Alcor and our patients, and partly because of a relocation of another sort. A few dozen Alcor Members hit the road as well, but not the road to Scottsdale. (See "Life in the Time of the Schism" by Steve Bridge, page 12.)

Which is the right road? Hopefully there are *many* roads to a healthy, happy, unbounded future. I'm on the one that looks brightest to me, and while I'm happy that so many friends and associates remain my traveling companions, I'm respectful of those who've chosen a different route. The more trails we blaze, the more fellow travelers we'll attract, and the more cryonics will move into the mainstream. That just can't hurt any of us, least of all the 27 people whom we plan to carry far enough down this road that they can pick themselves up, thank us, and ponder what *new* road to follow.

In doing so, they may indeed begin by looking back to see where they've been. So it's to you 27 special people that I dedicate this article. My congratulations to you for your foresight and good fortune. I hope that this glimpse at your past helps you with your future.

How to keep a cool head on the road

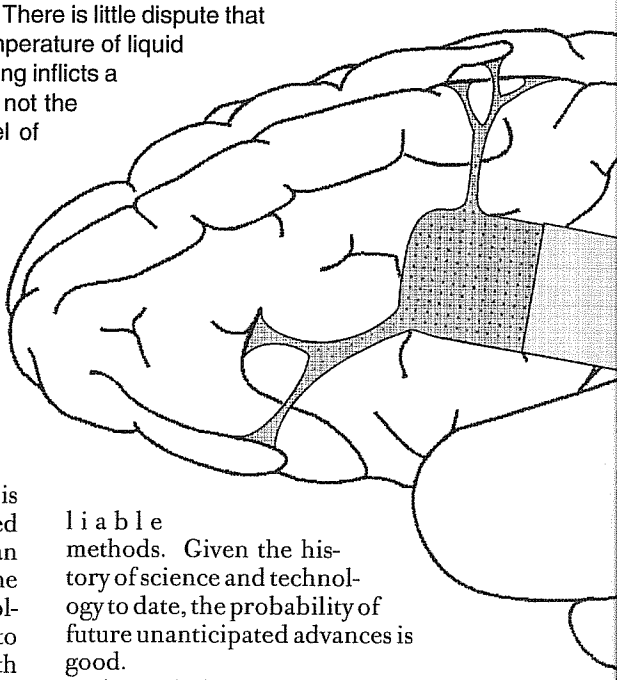


The Molecular Repair of th

A short version of this paper entitled "The Technical Feasibility of Cryonics" appeared in *Medical Hypotheses* Vol. 39, 1992; 6-16. Part I of this paper appeared in the January, 1994 issue of *CRYONICS* (Volume 15:1). Reprints of the first half of this paper are available from Alcor free of charge. Volume 15:1 of *CRYONICS* can be purchased for $4.50, and reprints of both parts of this paper can be purchased for $3.00

Abstract

Cryonic suspension is a method of stabilizing the condition of someone who is terminally ill so that they can be transported to the medical care facilities that will be available in the late 21st or 22nd century. There is little dispute that the condition of a person stored at the temperature of liquid nitrogen is stable, but the process of freezing inflicts a level of damage which cannot be reversed by current medical technology. Whether or not the damage inflicted by current methods can ever be reversed depends both on the level of damage and the ultimate limits of future medical technology. The failure to reverse freezing injury with current methods does not imply that it can never be reversed in the future, just as the inability to build a personal computer in 1890 did not imply that such machines would never be economically built. This paper considers the limits of what medical technology should eventually be able to achieve (based on the currently understood laws of chemistry and physics) and the kinds of damage caused by current methods of freezing. It then considers whether methods of repairing the kinds of damage caused by current suspension techniques are likely to be achieved in the future.



Technical Overview

Even if information theoretic death has not occurred, a frozen brain is *not* a healthy structure. While repair might be feasible in principle, it would be comforting to have at least some idea about how such repairs might be done in practice. As long as we assume that the laws of physics, chemistry, and biochemistry with which we are familiar today will still form the basic framework within which repair will take place in the future, we can draw well founded conclusions about the capabilities and limits of any such repair technology.

The Nature of This Proposal

To decide whether or not to pursue cryonic suspension we must answer one question: will restoration of frozen tissue to a healthy and functional state ever prove feasible? If the answer is "yes," then cryonics will save lives. If the answer is "no," then it can be ignored. As discussed earlier, effectively the most that we can usefully learn about frozen tissue is the type, location and orientation of each molecule. If this information is sufficient to permit inference of the healthy state with memory and personality intact, then repair is in principle feasible. The most that future technology could offer, therefore, is the ability to restore the structure whenever such restoration was feasible in principle. We propose that just this limit will be closely approached by future advances in technology.

Ralph Merkle is a nanotechnologist at Xerox PARC. He can be reached for comments via email at **merkle@parc.xerox.com**

It is unreasonable to think that the current proposal will in fact form the basis for future repair methods for two reasons:

First, better technologies and approaches are likely to be developed. Necessarily, we must restrict ourselves to methods and techniques that can be analyzed and understood using the currently understood laws of physics and chemistry. Future scientific advances, not anticipated at this time, are likely to result in cheaper, simpler or more reliable methods. Given the history of science and technology to date, the probability of future unanticipated advances is good.

Second, this proposal was selected because of its conceptual simplicity and its obvious power to restore virtually any structure where restoration is in principle feasible. These are unlikely to be design objectives of future systems. Conceptual simplicity is advantageous when the resources available for the design process are limited. Future design capabilities can reasonably be expected to outstrip current capabilities, and the efforts of a large group can reasonably be expected to allow analysis of much more complex proposals than considered here.

Further, future systems will be designed to restore specific individuals suffering from specific types of damage, and can therefore use specific methods that are less general but which are more efficient or less costly for the particular type of dam-

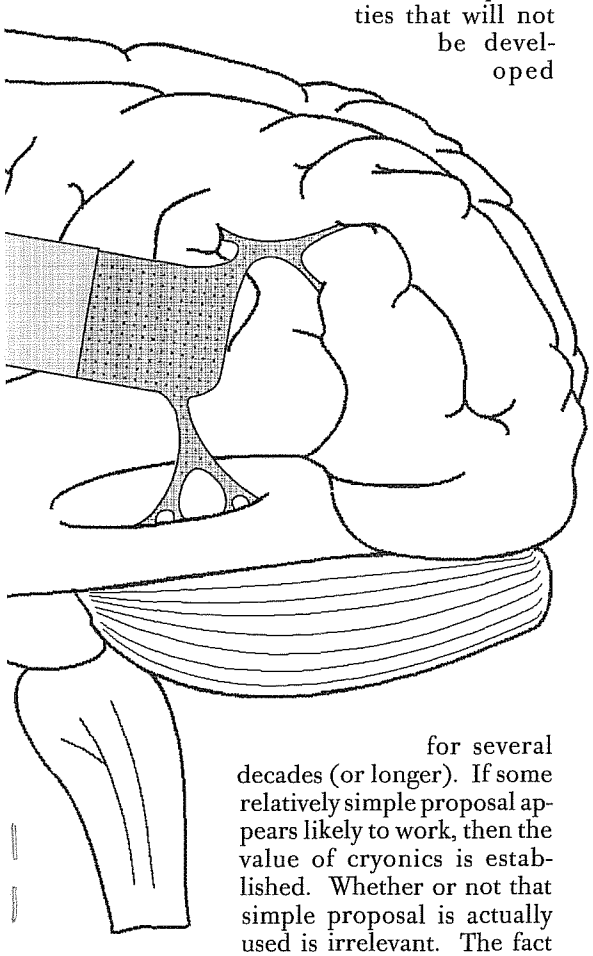
he Brain, Part II

by Ralph C. Merkle, Ph.D.

age involved. It is easier for a general-purpose proposal to rely on relatively simple and powerful methods, even if those methods are less efficient.

Why, then, discuss a powerful, general purpose method that is inefficient, fails to take advantage of the specific types of damage involved, and which will almost certainly be superseded by future technology?

The purpose of this paper is not to lay the groundwork for future systems, but to answer a question: will cryonics work? The value of cryonics is clearly and decisively based on technical capabilities that will not be developed for several decades (or longer). If some relatively simple proposal appears likely to work, then the value of cryonics is established. Whether or not that simple proposal is actually used is irrelevant. The fact that it *could* be used in the improbable case that all other technical progress and all other approaches fail is sufficient to let us decide *today* whether or not cryonic suspension is of value.



The philosophical issues involved in this type of long range technical forecasting and the methodologies appropriate to this area are addressed by work in "exploratory engineering."[1, 13] The purpose of exploratory engineering is to provide lower bounds on future technical capabilities based on currently understood scientific principles. A successful example is Konstantin Tsiolkovsky's forecast around the turn of the century that multi-staged rockets could go to the moon. His forecast was based on well understood principles of Newtonian mechanics. While it did not predict when such flights would take place, nor who would develop the technology, nor the details of the Saturn V booster, it did predict that the technical capability was feasible and would eventually be developed. In a similar spirit, we will discuss the technical capabilities that should be feasible and what those capabilities should make possible.

Conceptually, the approach that we will follow is simple:

1.) Determine the coordinates and orientations of all major molecules, and store this information in a data base.

2.) Analyze the information stored in the data base with a computer program which determines what changes in the existing structure should be made to restore it to a healthy and functional state.

3.) Take the original molecules and move them, one at a time, back to their correct locations.

The reader will no doubt agree that this proposal is conceptually simple, but might be concerned about a number of technical issues. The major issues are addressed in the following analysis.

An obvious inefficiency of this approach is that it will take apart and then put back together again structures and whole regions that are in fact functional or only slightly damaged. Simply leaving a functional region intact, or using relatively simple special case repair methods for minor damage would be faster and less costly. Despite these obvious drawbacks, the general purpose approach demonstrates the principles involved. As long as the inefficiencies are not so extreme that they make the approach infeasible or uneconomical in the long run, then this simpler approach is easier to evaluate.

Overview of the Brain

The brain has a volume of 1350 cubic centimeters (about one and a half quarts) and a weight of slightly more than 1400 grams (about three pounds). The smallest normal human brain weighed 1100 grams, while the largest weighed 2050 grams [15, page 24]. It is almost 80% water by weight. The remaining 20% is slightly less than 40% protein, slightly over 50% lipids, and a few percent of other material[6, page 419]. Thus, an average brain has slightly over 100 grams of protein, about 175 grams of lipids, and some 30 to 40 grams of "other stuff."

How Many Molecules

If we are considering restoration down to the molecular level, an obvious question is: how many molecules are there? We can easily approximate the answer, starting with the proteins. An "average" protein molecule has a molecular weight of about 50,000 amu. One mole of "average" protein is 50,000 grams (by definition), so the 100 grams of protein in the brain is 100/50,000 or .002 moles. One mole is 6.02×10^{23} molecules, so .002 moles is 1.2×10^{21} molecules.

We proceed in the same way for the lipids (lipids are most often used to make cell membranes)—a "typical" lipid might have a molecular weight of 500 amu, which is 100 times less than the molecular weight of a protein. This implies the brain has about $175/500 \times 6.02 \times 10^{23}$ or about 2×10^{23} lipid molecules.

Finally, water has a molecular weight of 18, so there will be about $1400 \times 0.8/18 \times 6.02 \times 10^{23}$ or about 4×10^{25} water molecules in the brain. In many cases a substantial percentage of water will have been replaced with cryoprotectant during the process of suspension; glycerol at a concentration of 4 molar or more, for example. Both water and glycerol will be treated in bulk, and so the change from water molecules to glycerol (or other cryoprotectants) should not have a significant impact on the calculations that follow.

These numbers are fundamental. Repair of the brain down to the molecular level will require that we cope with them in some fashion.

How Much Time

Another parameter whose value we must decide is the amount of repair time per molecule. We assume that such repair time includes the time required to determine the location of the molecule in the frozen tissue and the time required to restore the molecule to its correct location, as well as the time to diagnose and repair any structural defects in the molecule. The computational power required to analyze larger-scale structural damage—e.g., this

mitochondria has suffered damage to its internal membrane structure (so called "flocculent densities")—should be less than the power required to analyze each individual molecule. An analysis at the level of sub-cellular organelles involves several orders of magnitude fewer components and will therefore require correspondingly less computational power. Analysis at the cellular level involves even fewer components. We therefore neglect the time required for these additional computational burdens. The total time required for repair is just the sum over all molecules of the time required by one repair device to repair that molecule divided by the number of repair devices. The more repair devices there are, the faster the repair will be. The more molecules there are, and the more time it takes to repair each molecule, the slower repair will be.

"The speed of assembler-directed reactions is likely to prove faster than current biological systems. The arm of an assembler should be capable of making a complete motion and causing a single chemical transformation in about a microsecond."

The time required for a ribosome to manufacture a protein molecule of 400 amino acids is about 10 seconds[5, page 393], or about 25 milliseconds to add each amino acid. DNA polymerase III can add an additional base to a replicating DNA strand in about 7 milliseconds[5, page 289]. In both cases, synthesis takes place in solution and involves significant delays while the needed components diffuse to the reactive sites. The speed of assembler-directed reactions is likely to prove faster than current biological systems. The arm of an assembler should be capable of making a complete motion and causing a single chemical transformation in about a microsecond[28]. However, we will conservatively base our computations on the speed of synthesis already demonstrated by biological systems, and in particular on the slower speed of protein synthesis.

We must do more than synthesize the required molecules—we must analyze the existing molecules, possibly repair them, and also move them from their original location to the desired final location. Existing antibodies can identify specific molecular species by selectively binding to them, so identifying individual molecules is feasible in principle. Even assuming that the actual technology employed is different it seems unlikely that such analysis will require substantially longer than the synthesis time involved, so it seems reasonable to multiply the synthesis time by a factor of a few to provide an estimate of time spent per molecule. This should, in principle, allow time for the complete disassembly and reassembly of the selected molecule using methods no faster than those employed in biological systems. While the precise size of this multiplicative factor can reasonably be debated, a factor of 10 should be sufficient. The total time required to simply move a molecule from its original location to its correct final location in the repaired structure should be smaller than the time required to disassemble and reassemble it, so we will assume that the total time required for analysis, repair and movement is 100 seconds per protein molecule.

Temperature of Analysis

Warming the tissue before determining its molecular structure creates definite problems: everything will move around. A simple solution to this problem is to keep the tissue frozen until after all the desired structural information is recovered. In this case the analysis will take place at a low temperature. Whether or not subsequent operations should be performed at the same low temperature is left open. A later section considers the various approaches that can be taken to restore the structure after it has been analyzed.

Repair or Replace?

In practice, most molecules will probably be intact—they would not have to be either disassembled or reassembled. This should greatly reduce repair time. On a more philosophical note, existing biological systems generally do not bother to repair macromolecules (a notable exception is DNA—a host of molecular mechanisms for the repair of this molecule are used in most organisms). Most molecules are generally used for a period of time and then broken down and replaced. There is a slow and steady turnover of molecular structure—the atoms in the roast beef sandwich eaten yesterday are used today to repair and replace muscles, skin, nerve cells, etc. If we adopted nature's philosophy we would simply discard and replace any damaged molecules, greatly simplifying molecular "repair".

Carried to its logical conclusion, we would discard and replace *all* the molecules in the structure. Having once determined the type, location and orientation of a molecule in the original (frozen) structure, we would simply throw that molecule out without further examination and replace it. This requires only that we be able to identify the location and type of individual molecules. It would not be necessary to determine if the molecule was damaged, nor would it be necessary to correct any damage found. By definition, the replacement molecule would be taken from a stock-pile of structurally correct molecules that had been previously synthesized, in bulk, by the simplest and most economical method available.

Discarding and replacing even a few atoms might disturb some people. This can be avoided by analyzing and repairing any damaged molecules. However, for those who view the simpler removal and replacement of damaged molecules as acceptable, the repair process can be significantly simplified. For purposes of this paper, however, we will continue to use the longer time estimate based on the premise that full repair of every molecule is required. This appears to be conservative. (Those who feel that replacing their atoms will change their identity should think carefully before eating their next meal!)

Total Repair Machine Seconds

We shall assume that the repair time for other molecules is similar per unit mass. That is, we shall assume that the repair time for the lipids (which each weigh about 500 amu, 100 times less than a protein) is about 100 times less than the repair time for a protein. The repair time for one lipid molecule is assumed to be 1 second. We will neglect water molecules in this analysis, assuming that they can be handled in bulk.

We have assumed that the time required to analyze and synthesize an individual molecule will dominate the time required to determine its present location, the time required to determine the appropriate location it should occupy in the repaired structure, and the time required to put it in this position. These assumptions are plausible but will be considered further when the methods of gaining access to and of moving molecules during the repair process are considered.

This analysis accounts for the bulk of the molecules—it seems unlikely that other molecular species will add significant additional repair time.

Based on these assumptions, we find

that we require 100 seconds x 1.2 x 10^{21} protein molecules + 1 second times 2 x 10^{23} lipids, or 3.2 x 10^{23} repair-machine-seconds. This number is not as fundamental as the number of molecules in the brain. It is based on the (probably conservative) assumption that repair of 50,000 amu requires 100 seconds. Faster repair would imply repair could be done with fewer repair machines, or in less time.

How Many Repair Machines

If we now fix the total time required for repair, we can determine the number of repair devices that must function in parallel. We shall rather arbitrarily adopt 10^8 seconds, which is very close to three years, as the total time in which we wish to complete repairs.

If the total repair time is 10^8 seconds, and we require 3.2 x 10^{23} repair-machine-seconds, then we require 3.2 x 10^{15} repair machines for complete repair of the brain. This corresponds to 3.2 x 10^{15} / (6.02 x 10^{23}) or 5.3 x 10^{-9} moles, or 5.3 nanomoles of repair machines. If each repair device weighs 10^9 to 10^{10} amu, then the total weight of all the repair devices is 53 to 530 grams: a few ounces to just over a pound.

Thus, the weight of the devices required to repair each and every molecule in the brain, assuming the repair devices operate no faster than current biological methods, is about 4% to 40% of the total mass of the brain.

By way of comparison, there are about 10^{14} cells[21, page 3] in the human body and each cell has about 10^7 ribosomes[5, page 652] giving 10^{21} ribosomes. Thus, there are about six orders of magnitude more ribosomes in the human body than the number of repair machines we estimate are required to repair the human brain.

It seems unlikely that either more or larger repair devices are inherently required. However, it is comforting to know that errors in these estimates of even several orders of magnitude can be easily tolerated. A requirement for 530 kilograms of repair devices (1,000 to 10,000 times more than we calculate is needed) would have little practical impact on feasibility. Although repair scenarios that involve deployment of the repair devices within the volume of the brain could not be used if we required 530 kilograms of repair devices, a number of other repair scenarios would still work—one such approach is discussed in this paper. Given that nanotechnology is feasible, manufacturing costs for repair devices will be small. The cost of even 530 kilograms of repair devices should eventually be significantly less than a few hundred dollars. The feasibility of repair down to the molecular level is insensitive to even large errors in the projections given here.

The Repair Process

We now turn to the physical deployment of these repair devices. That is, although the raw number of repair devices is sufficient, we must devise an orderly method of deploying these repair devices so they can carry out the needed repairs.

Other Proposals: On-board Repair

We shall broadly divide repair scenarios into two classes: on-board and off-board. In the on-board scenarios, the repair devices are deployed within the volume of the brain. Existing structures are disassembled in place, their component molecules examined and repaired, and rebuilt on the spot. (We here class as "on-board" those scenarios in which the repair devices operate within the physical volume of the brain, even though there might be substantial off-board support. That is, there might be a very large computer outside the tissue directing the repair process, but we would still refer to the overall repair approach as "on-board"). The on-board repair scenario has been considered in some detail by Drexler[8]. We will give a brief outline of the on-board repair scenario here, but will not consider it in any depth. For various reasons, it is quite plausible that on-board repair scenarios will be developed before off-board repair scenarios.

The first advantage of on-board repair is an easier evolutionary path from partial repair systems deployed in living human beings to the total repair systems required for repair of the more extensive damage found in the person who has been cryonically suspended. That is, a simple repair device for finding and removing fatty deposits blocking the circulatory system could be developed and deployed in living humans[2], and need not deal with all the problems involved in total repair. A more complex device, developed as an incremental improvement, might then repair more complex damage (perhaps identifying and killing cancer cells) again within a living human. Once developed, there will be continued pressure for evolutionary improvements in on-board repair capabilities which should ultimately lead to repair of virtually arbitrary damage. This evolutionary path should eventually produce a device capable of repairing frozen tissue.

It is interesting to note that "At the end of this month [August 1990], MITI's Agency of Industrial Science and Technology (AIST) will submit a budget request for ¥30 million ($200,000) to launch a 'microrobot' project next year, with the aim of developing tiny robots for the internal medical treatment and repair of human beings. ... MITI is planning to pour ¥25,000 million ($170 million) into the microrobot project over the next ten years..."[29]. Iwao Fujimasa said their objective is a robot less than .04 inches in size that will be able to travel through veins and inside organs[7, 9]. While substantially larger than the proposals considered here, the direction of future evolutionary improvements should be clear.

A second advantage of on-board repair is emotional. In on-board repair, the original structure (you) is left intact at the macroscopic and even light microscopic level. The disassembly and reassembly of the component molecules is done at a level smaller than can be seen, and might therefore prove less troubling than other forms of repair in which the disassembly and reassembly processes are more visible. Ultimately, though, correct restoration of the structure is the overriding concern.

A third advantage of on-board repair is the ability to leave functional structures intact. That is, in on-board repair we can focus on those structures that are damaged, while leaving working structures alone. If minor damage has occurred, then an on-board repair system need make only minor repairs.

The major drawback of on-board repair is the increased complexity of the system. As discussed earlier, this is only a drawback when the design tools and the resources available for the design are limited. We can reasonably presume that future design tools and future resources will greatly exceed present efforts. Developments in computer aided design of complex systems will put the design of remarkably complex systems within easy grasp.

In on-board repair, we might first logically partition the volume of the brain into a matrix of cubes, and then deploy each repair device in its own cube. Repair devices would first get as close as possible

"There are about six orders of magnitude more ribosomes in the human body than the number of repair machines we estimate are required to repair the human brain."

to their assigned cube by moving through the circulatory system (we presume it would be cleared out as a first step) and would then disassemble the tissue between them and their destination. Once in position, each repair device would analyze the tissue in its assigned volume and perform any repairs required.

The Current Proposal: Off-Board Repair

The second class of repair scenarios, the off-board scenarios, allow the total volume of repair devices to greatly exceed the volume of the human brain.

The primary advantage of off-board repair is conceptual simplicity. It employs simple brute force to insure that a solution is feasible and to avoid complex design issues. As discussed earlier, these are virtues in thinking about the problem today but are unlikely to carry much weight in the future when an actual system is being designed.

The other advantages of this approach are fairly obvious. Lingering concerns about volume and heat dissipation can be eliminated. If a ton of repair devices should prove necessary, then a ton can be provided. Concerns about design complexity can be greatly reduced. Off-board repair scenarios do not require that the repair devices be mobile—simplifying communications and power distribution, and eliminating the need for locomotor capabilities and navigational abilities. The only previous paper on off-board repair scenarios was by Merkle[31].

Off-board repair scenarios can be naturally divided into three phases. In the first phase, we must analyze the structure to determine its state. The primary purpose of this phase is simply to gather information about the structure, although in the process the disassembly of the structure into its component molecules will also take place. Various methods of gaining access to and analyzing the overall structure are feasible—in this paper we shall primarily consider one approach.

We shall presume that the analysis phase takes place while the tissue is still frozen. While the exact temperature is left open, it seems preferable to perform analysis prior to warming. The thawing process itself causes damage and, once thawed, continued deterioration will proceed unchecked by the mechanisms present in healthy tissue. This cannot be tolerated during a repair time of several years. Either faster analysis or some means of blocking deterioration would have to be used if analysis were to take place after warming. We will not explore these possibilities here (although this appears worthwhile). The temperature at which other phases takes place is left open.

The second phase of off-board repair is determination of the healthy state. In this phase, the structural information derived from the analysis phase is used to determine what the healthy state of the tissue had been prior to suspension and any preceding illness. This phase involves only computation based on the information provided by the analysis phase.

"Knowing the type, location and orientation of every molecule in the frozen structure under repair and retaining the actual physical molecules (thus avoiding any philosophical objections that replacing the original molecules might somehow diminish or negate the individuality of the person undergoing repair) is the best that we can hope to achieve."

The third phase is repair. In this phase, we must restore the structure in accordance with the blue-print provided by the second phase, the determination of the healthy state.

Intermediate States During Off-Board Repair

Repair methods in general start with frozen tissue, and end with healthy tissue. The nature of the intermediate states characterizes the different repair approaches. In off-board repair the tissue undergoing repair must pass through three highly characteristic states, described in the following three paragraphs.

The first state is the starting state, prior to any repair efforts. The tissue is frozen (unrepaired).

In the second state, immediately following the analysis phase, the tissue has been disassembled into its individual molecules. A detailed structural data base has been built which provides a description of the location, orientation, and type of each molecule, as discussed earlier. For those who are concerned that their identity or "self" is dependent in some fundamental way on the specific atoms which compose their molecules, the original molecules can be retained in a molecular "filing cabinet." While keeping physical track of the original molecules is more difficult technically, it is feasible and does not alter off-board repair in any fundamental fashion.

In the third state, the tissue is restored and fully functional.

By characterizing the intermediate state which must be achieved during the repair process, we reduce the problem from "Start with frozen tissue and generate healthy tissue" to "Start with frozen tissue and generate a structural data base and a molecular filing cabinet. Take the structural data base and the molecular filing cabinet and generate healthy tissue." It is characteristic of off-board repair that we disassemble the molecular structure into its component pieces prior to attempting repair.

As an example, suppose we wish to repair a car. Rather than try and diagnose exactly what's wrong, we decide to take the car apart into its component pieces. Once the pieces are spread out in front of us, we can easily clean each piece, and then reassemble the car. Of course, we'll have to keep track of where all the pieces go so we can reassemble the structure, but in exchange for this bookkeeping task we gain a conceptually simple method of insuring that we actually can get access to everything and repair it. While this is a rather extreme method of repairing a broken carburetor, it certainly is a good argument that we should be able to repair even rather badly damaged cars. So, too, with off-board repair. While it might be an extreme method of fixing any particular form of damage, it provides a good argument that damage can be repaired under a wide range of circumstances.

Off-Board Repair is the Best that can be Achieved

Regardless of the initial level of damage, regardless of the functional integrity or lack thereof of any or all of the frozen structure, regardless of whether easier and less exhaustive techniques might or might not work, we can take any frozen structure and convert it into the canonical state described above. Further, this is the best that we can do. Knowing the type, location and orientation of every molecule in the frozen structure under repair and retaining the actual physical molecules (thus avoiding any philosophical objections that replacing the original molecules might somehow diminish or negate the individuality of the person undergoing repair) is the best that

we can hope to achieve. We have reached some sort of limit with this approach, a limit that will make repair feasible under circumstances which would astonish most people today.

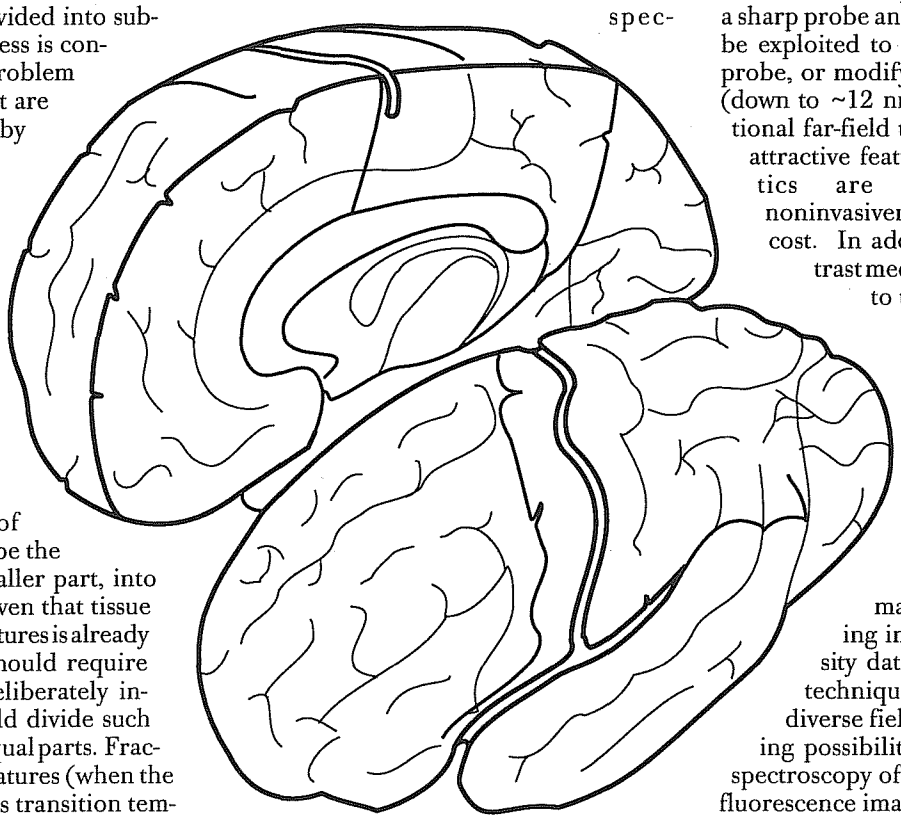
One particular approach to off-board repair is divide-and-conquer. This method is one of the technically simplest approaches. We discuss this method in the following section.

Divide-and-Conquer

Divide-and-conquer is a general purpose problem-solving method frequently used in computer science and elsewhere. In this method, if a problem proves too difficult to solve it is first divided into sub-problems, each of which is solved in turn. Should the sub-problems prove too difficult to solve, they are in turn divided into sub-sub-problems. This process is continued until the original problem is divided into pieces that are small enough to be solved by direct methods.

If we apply divide-and-conquer to the analysis of a physical object—such as the brain—then we must be able to physically divide the object of analysis into two pieces and recursively apply the same method to the two pieces. This means that we must be able to divide a piece of frozen tissue, whether it be the entire brain or some smaller part, into roughly equal halves. Given that tissue at liquid nitrogen temperatures is already prone to fracturing, it should require only modest effort to deliberately induce a fracture that would divide such a piece into two roughly equal parts. Fractures made at low temperatures (when the material is below the glass transition temperature) are extremely clean, and result in little or no loss of structural information. Indeed, freeze fracture techniques are used for the study of synaptic structures. Hayat [19, page 398] says "Membranes split during freeze-fracturing along their central hydrophobic plane, exposing intra-membranous surfaces. ... The fracture plane often follows the contours of membranes and leaves bumps or depressions where it passes around vesicles and other cell organelles. ... The fracturing process provides more accurate insight into the molecular architecture of membranes than any other ultrastructural method." It seems unlikely that the fracture itself will result in any significant loss of structural information.

The freshly exposed faces can now be analyzed by various surface analysis techniques. Work with STMs supports the idea that very high resolution is feasible[22]. For example, optical absorption microscopy "...generates an absorption spectrum of the surface with a resolution of 1 nanometer [a few atomic diameters]." Kumar Wickramasinghe of IBM's T. J. Watson Research Center said: "We should be able to record the spectrum of a single molecule" on a surface. Williams and Wickramasinghe said [24] "The ability to measure variations in chemical potential also allows the possibility of selectively identifying subunits of biological macromolecules either through a direct measurement of their chemical-potential gradients or by decorating them with different metals. This suggest a potentially simple method for sequencing DNA." While current devices are large, the fundamental physical principles on which they rely do not require large size. Many of the devices depend primarily on the interaction between a single atom at the tip of the STM probe and the atoms on the surface of the specimen under analysis. Clearly, substantial reductions in size in such devices are feasible[1].



High resolution optical techniques can also be employed. Near field microscopy, employing light with a wavelength of hundreds of nanometers, has achieved a resolution of 12 nanometers (much smaller than a wavelength of light). To quote the abstract of a recent review article on the subject: "The near-field optical interaction between a sharp probe and a sample of interest can be exploited to image, spectroscopically probe, or modify surfaces at a resolution (down to ~12 nm) inaccessible by traditional far-field techniques. Many of the attractive features of conventional optics are retained, including noninvasiveness, reliability, and low cost. In addition, most optical contrast mechanisms can be extended to the near-field regime, resulting in a technique of considerable versatility. This versatility is demonstrated by several examples, such as the imaging of nanometric-scale features in mammalian tissue sections and the creation of ultrasmall, magneto-optic domains having implications for high-density data storage. Although the technique may find uses in many diverse fields, two of the most exciting possibilities are localized optical spectroscopy of semiconductors and the fluorescence imaging of living cells."[36]. Another article said: "Our signals are currently of such magnitude that almost any application originally conceived for far-field optics can now be extended to the near-field regime, including: dynamical studies at video rates and beyond; low noise, high resolution spectroscopy (also aided by the negligible auto-fluorescence of the

[1]It is interesting to note that current research into the three-dimensional structure of neurons often embeds neural tissue in plastic, and then produces a series of thin sections (typically 50 to 100 nanometers thick in electron microscopic reconstruction work) by using an ultramicrotome. The serial sections are then examined by a person (typically a graduate student) and the structures of interest in each section are outlined on a digitizing tablet and entered into a computer. The resulting data-base is used to build a three-dimensional image of the neuron[27]. This work has been quite successful at determining the three-dimensional structure of small volumes (small enough for a graduate student to examine in a few weeks or months) despite the adverse effects of tissue preparation and sectioning. Sections vary in thickness. They also buckle, fold, and tear. Despite these difficulties, the human visual system can reconstruct the original shape of the object in three dimensions. Current electron microscopic reconstructions are quite capable of analyzing even the finest dendrites and thinnest axons, as well as determining the location and size of synapses[12,13], and even finer detail[14]. It seems reasonable that the less damaging method of inducing a fracture at low temperature, and the more informative and less damaging analysis possible with nanotechnology (as opposed to destructive analysis of thin sections by a high energy electron beam) will produce more information about the structure being analyzed.

probe); minute differential absorption measurements; magnetooptics; and superresolution lithography."[30].

How Small are the Pieces

The division into halves continues until the pieces are small enough to allow direct analysis by repair devices. If we presume that division continues until each repair device is assigned its own piece to repair, then there will be both 3.2×10^{15} repair devices and pieces. If the 1350 cubic centimeter volume of the brain is divided into this many cubes, each such cube would be about .4 microns (422 nanometers) on a side. Each cube could then be directly analyzed (disassembled into its component molecules) by a repair device during our three-year repair period.

One might view these cubes as the pieces of a three-dimensional jig-saw puzzle, the only difference being that we have cheated and carefully recorded the position of each piece. Just as the picture on a jig-saw puzzle is clearly visible despite the fractures between the pieces, so too the three-dimensional "picture" of the brain is clearly visible despite its division into pieces[2].

Moving Pieces

There are a great many possible methods of handling the mechanical problems involved in dividing and moving the pieces. It seems unlikely that mechanical movement of the pieces will prove an insurmountable impediment, and therefore we do not consider it in detail. However, for the sake of concreteness, we outline one possibility. Human arms are about 1 meter in length, and can easily handle objects from 1 to 10 centimeters in size (.01 to .1 times the length of the arm). It should be feasible, therefore, to construct a series of progressively shorter arms which handle pieces of progressively smaller size. If each set of arms were ten times shorter than the preceding set, then we would have devices with arms of: 1 meter, 1 decimeter, 1 centimeter, 1 millimeter, 100 microns, 10 microns, 1 micron, and finally .1 microns or 100 nanometers. (Note that an assembler has arms roughly 100 nanometers long.) Thus, we would need to design 8 different sizes of manipulators. At each succeeding size the manipulators would be more numerous, and so would be able to deal with the many more pieces into which the original object was divided. Transport and mechanical manipulation of an object would be done by arms of the appropriate size. As objects were divided into smaller pieces that could no longer be handled by arms of a particular size, they would be handed to arms of a smaller size.

If it requires about three years to analyze each piece, then the time required both to divide the brain into pieces and to move each piece to an immobile repair device can reasonably be neglected. It seems unlikely that moving the pieces will take a significant fraction of three years.

Memory Requirements

The information storage requirements for a structural data-base that holds the detailed description and location of each major molecule in the brain can be met by projected storage methods. DNA has an information storage density of about 10^{21} bits/cubic centimeter. Conceptually similar but somewhat higher density molecular "tape" systems that store 10^{22} bits/cubic centimeter [1] should be quite feasible. If we assume that every lipid molecule is "significant" but that water molecules, simple ions and the like are not, then the number of significant molecules is roughly the same as the number of lipid molecules[3] (the number of protein molecules is more than two orders of magnitude smaller, so we will neglect it in this estimate). The digital description of these 2×10^{23} significant molecules requires 10^{25} bits (assuming that 50 bits are required to encode the location and description of each molecule). This is about 1,000 cubic centimeters (1 liter, roughly a quart) of "tape" storage. If a storage system of such capacity strikes the reader as infeasible, consider that a human being has about 10^{14} cells[21, page 3] and that each cell stores 10^{10} bits in its DNA[5]. Thus, every human that you see is a device which (among other things) has a raw storage capacity of 10^{24} bits—and human beings are unlikely to be optimal information storage devices.

A simple method of reducing storage requirements by several orders of magnitude would be to analyze and repair only a small amount of tissue at a time. This would eliminate the need to store the entire 10^{25} bit description at one time. A smaller memory could hold the description of the tissue actually under repair, and this smaller memory could then be cleared and re-used during repair of the next section of tissue.

Computational Requirements

The computational power required to analyze a data base with 10^{25} bits is well within known theoretical limits[3,10,17]. It has been seriously proposed that it might be possible to increase the total computational power achievable within the universe beyond any fixed bound in the distant future[25, page 658]. More conservative lower bounds to nearer-term future computational capabilities can be derived from the reversible rod-logic molecular model of computation, which dissipates about 10^{-23} joules per gate operation when operating at 100 picoseconds at room temperature[28]. A wide range of other possibilities exist. Likharev proposed a computational element based on Josephson junctions which operates at 4 K and in which energy dissipation per switching operation is 10^{-24} joules with a switching time of 10^{-9} seconds[18, 20]. Continued evolutionary reductions in the size and energy dissipation of properly designed NMOS[38] and CMOS[37, 41] circuits should eventually produce logic elements that are both very small (though significantly larger than Drexler's mechanical proposals) and which dissipate extraordinarily small amounts of energy per logic operation. Extrapolation of current trends suggest that energy dissipations in the 10^{-23} joule range will be achieved before 2030[16, fig. 1]. There is no presently known reason to expect the trend to stop or even slow down at that time[3,17].

Energy costs appear to be the limiting factor in rod logic (rather than the number of gates, or the speed of operation of the gates). Today, electric power costs about 10 cents per kilowatt hour. Future costs of power will almost certainly be much lower. Molecular manufacturing should eventually sharply reduce the cost of solar cells and increase their efficiency to close to the theoretical limits. With a manufacturing cost of under 10 cents per kilogram[28] the cost of a one square meter solar cell will be less than a penny. As a consequence the cost of solar power will be dominated by other costs, such as the cost of the land on which the solar cell is placed. While solar cells can be placed on the roofs of existing structures or in otherwise unused areas, we will simply use existing real estate prices to estimate costs. Low cost land in the desert southwestern United States can be purchased for less than $1,000 per acre. (This price corresponds to about 25 cents per square meter, significantly larger than the pro-

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[3] For those concerned about the omission of water molecules and the like, we could just as easily store the coordinates of every molecule. This would increase the storage requirement, but would still be entirely feasible.

[2] Under favorable circumstances, we might be able to terminate the division process sooner. That is, it might be that a relatively large piece of tissue (several tens of microns or larger) was relatively intact, and required little if any repair. Devising methods to take advantage of the minimal damage that might occur under favorable circumstances is beyond the scope of this paper.

jected future manufacturing cost of a one square meter solar cell.) Land elsewhere in the world (arid regions of the Australian outback, for example) is much cheaper. For simplicity and conservatism, though, we'll simply adopt the $1,000 per acre price for the following calculations. Renting an acre of land for a year at an annual price of 10% of the purchase price will cost $100. Incident sunlight at the earth's surface provides a maximum of 1,353 watts per square meter, or 5.5×10^6 watts per acre. Making allowances for inefficiencies in the solar cells, atmospheric losses, and losses caused by the angle of incidence of the incoming light reduces the actual average power production by perhaps a factor of 15 to about 3.5×10^5 watts. Over a year, this produces 1.1×10^{13} joules or 3.1×10^6 kilowatt hours. The land cost $100, so the cost per joule is 0.9 nanocents and the cost per kilowatt hour is 3.3 millicents. Solar power, once we can make the solar cells cheaply enough, will be over several thousand times cheaper than electric power is today. We'll be able to buy over 10^{15} joules for under $10,000.

While the energy dissipation per logic operation estimated by Drexler[28] is about 10^{-23} joules, we'll content ourselves with the higher estimate of 10^{-22} joules per logic operation. Our 10^{15} joules will then power 10^{37} gate operations: 10^{12} gate operations for each bit in the structural data base or 5×10^{13} gate operations for each of the 2×10^{23} lipid molecules present in the brain.

It should be emphasized that in off-board repair warming of the tissue is not an issue because the overwhelming bulk of the calculations and hence almost all of the energy dissipation takes place outside the tissue. Much of the computation takes place when the original structure has been entirely disassembled into its component molecules.

How Much Is Enough?

Is this enough computational power? We can get a rough idea of how much computer power might be required if we draw an analogy from image recognition. The human retina performs about 100 "operations" per pixel, and the human brain is perhaps 1,000 to 10,000 times larger than the retina. This implies that the human image recognition system can recognize an object after devoting some 10^5 to 10^6 "operations" per pixel. (This number is also in keeping with informal estimates made by individuals expert in computer image analysis). Allowing for the fact that such "retinal operations" are probably more complex than a single "gate operation" by a factor of 1000 to 10,000, we arrive at 10^8 to 10^{10} gate operations per pixel—which is well below our estimate of 10^{12} operations per bit or 5×10^{13} operations per molecule.

"It should be emphasized that in off-board repair, warming of the tissue is not an issue because the overwhelming bulk of the calculations and hence almost all of the energy dissipation takes place outside the tissue."

To give a feeling for the computational power this represents, it is useful to compare it to estimates of the raw computational power of the human brain. The human brain has been variously estimated as being able to do 10^{13}[23], 10^{15} or 10^{16}[39] operations a second (where "operation" has been variously defined but represents some relatively simple and basic action)[4]. The 10^{37} total logic operations will support 10^{29} logic operations per second for three years, which is the raw computational power of something like 10^{13} human beings (even when we use the high end of the range for the computational power of the human brain). This is 10 trillion human beings, or some 2,000 times more people than currently exist on the earth today. By present standards, this is a large amount of computational power. Viewed another way, if we were to divide the human brain into tiny cubes that were about 5 microns on a side (less than the volume of a typical cell), each such cube could receive the full and undivided attention of a dedicated human analyst for a full three years.

The next paragraph analyzes memory costs, and can be skipped without loss of continuity.

This analysis neglects the memory required to store the complete state of these computations. Because this estimate of computational abilities and requirements depends on the capabilities of the human brain, we might require an amount of memory roughly similar to the amount of memory required by the human brain as it computes. This might require about 10^{16} bits (10 bits per synapse) to store the "state" of the computation. (We assume that an exact representation of each synapse will not be necessary in providing capabilities that are similar to those of the human brain. At worst, the behavior of small groups of cells could be analyzed and implemented by the most efficient method, e.g., a "center surround" operation in the retina could be implemented as efficiently as possible, and would not require detailed modeling of each neuron and synapse. In point of fact, it is likely that algorithms that are significantly different from the algorithms employed in the human brain will prove to be the most efficient for this rather specialized type of analysis, and so our use of estimates derived from low-level parts-counts from the human brain are likely to be conservative). For 10^{13} programs each equivalent in analytical skills to a single human being, this would require 10^{29} bits. At 100 cubic nanometers per bit, this gives 10,000 cubic meters. Using the cost estimates provided by Drexler[28] this would be an uncomfortable $1,000,000. We can, however, easily reduce this cost by partitioning the computation to reduce memory requirements. Instead of having 10^{13} programs each able to "think" at about the same speed as a human being, we could have 10^{10} programs each able to "think" at a speed 1,000 times faster than a human being. Instead of having 10 trillion dedicated human analysts working for 3 years each, we would have 10 billion dedicated human analysts working for 3,000 virtual years each. The project would still be completed in 3 calendar years, for each computer "analyst" would be a computer program running 1,000 times faster than an equally skilled human analyst. Instead of analyzing the entire brain at once, we would instead logically divide the brain into 1,000 pieces each of about 1.4 cubic centimeters in size, and analyze each such piece fully before moving on to the next piece.

This reduces our memory requirements by a factor of 1,000 and the cost of that memory to a manageable $1,000.

It should be emphasized that the comparisons with human capabilities are used only to illustrate the immense capabilities of 10^{37} logic operations. It should not be assumed that the software that will actually be used will have any resemblance to the behavior of the human brain.

More Computer Power

In the following paragraphs, we argue that even more computational power will in fact

[4] Despite the notorious difficulty in obtaining accurate information about specific aspects of brain "hardware," as discussed by Cherniak[40], it is still the case that rather rough bounds can be usefully derived.

be available, and so our margins for error are much larger.

Energy loss in rod logic—in Likharev's parametric quantron, in properly designed NMOS and CMOS circuits, and in many other proposals for computational devices—is related to speed of operation. By slowing down the operating speed from 100 picoseconds to 100 nanoseconds or even 100 microseconds we should achieve corresponding reductions in energy dissipation per gate operation. This will allow substantial increases in computational power for a fixed amount of energy (10^{15} joules). We can both decrease the energy dissipated per gate operation (by operating at a slower speed) *and* increase the total number of gate operations (by using more gates). Because the gates are very small to start with, increasing their number by a factor of as much as 10^{10} (to approximately 10^{27} gates) would still result in a total volume of 100 cubic meters (recall that each gate plus overhead is about 100 cubic nanometers). This is a cube less than 5 meters on a side. Given that manufacturing costs will eventually reflect primarily material and energy costs, such a volume of slowly operating gates should be economical and would deliver substantially more computational power per joule.

We will not pursue this approach here for two main reasons. First, published analyses use the higher 100 picosecond speed of operation and 10^{-22} joules of energy dissipation[28]. Second, operating at 10^{-22} joules at room temperature implies that most logic operations must be reversible and that less than one logic operation in 30 can be irreversible. Irreversible logic operations (which erase information) must inherently dissipate at least $kT\ln(2)$ for fundamental thermodynamic reasons. The average thermal energy of a single atom or molecule at a temperature T (measured in degrees K) is approximately kT where k is Boltzmann's constant. At room temperature, kT is about 4×10^{-21} joules. Thus, each irreversible operation will dissipate almost 3×10^{-21} joules. The number of such operations must be limited if we are to achieve an average energy dissipation of 10^{-22} joules per logic operation.

While it should be feasible to perform computations in which virtually all logic operations are reversible (and hence need not dissipate any fixed amount of energy per logic operation)[3, 10, 17, 26, 37, 41], current computer architectures might require some modification before they could be adapted to this style of operation. By contrast, it should be feasible to use current computer architectures while at the same time performing a major percentage (e.g., 99% or more) of their logic operations in a reversible fashion.

Various electronic proposals show that almost all of the existing combinational logic in present computers can be replaced with reversible logic with no change in the instruction set that is executed[37, 38]. Further, while some instructions in current computers are irreversible and hence must dissipate at least $kT\ln(2)$ joules for each bit of information erased, other instructions are reversible and need not dissipate any fixed amount of energy if implemented correctly. Optimizing compilers could then avoid using the irreversible machine instructions and favor the use of the reversible instructions. Thus, without modifying the instruction set of the computer, we can make most logic operations in the computer reversible.

Further work on reversible computation can only lower the minimum energy expenditure per basic operation and increase the percentage of reversible logic operations. Much greater reductions in energy dissipation might be feasible[35]. While it is at present unclear how far the trend towards lower energy dissipation per logic operation can go, it is clear that we have not yet reached a limit and that no particular limit is yet visible.

We can also expect further decreases in energy costs. By placing solar cells in space the total incident sunlight per square meter can be greatly increased (particularly if the solar cell is located closer to the Sun) while at the same time the total mass of the solar cell can be greatly decreased. Most of the mass in earth-bound structures is required not for functional reasons but simply to insure structural integrity against the forces of gravity and the weather. In space both these problems are virtually eliminated. As a consequence a very thin solar cell of relatively modest mass can have a huge surface area and provide immense power at much lower costs than estimated here.

If we allow for the decreasing future cost of energy and the probability that future designs will have lower energy dissipation than 10^{-22} joules per logic operation, it seems likely that we will have a great deal more computational power than required. Even ignoring these more than likely developments, we will have adequate computational power for repair of the brain down to the molecular level.

Chemical Energy of the Brain

Another issue is the energy involved in the complete disassembly and reassembly of every molecule in the brain. The total chemical energy stored in the proteins and lipids of the human brain is quite modest in comparison with 10^{15} joules. When lipids are burned, they release about 9 kilocalories per gram. (Calorie conscious dieters are actually counting "kilocalories"—so a "300 Calorie Diet Dinner" really has 300,000 calories or 1,254,000 joules). When protein is burned, it releases about 4 kilocalories per gram. Given that there are 100 grams of protein and 175 grams of lipid in the brain, this means there is almost 2,000 kilocalories of chemical energy stored in the structure of the brain, or about 8×10^6 joules. This much chemical energy is over 10^8 times less than the 10^{15} joules that one person can reasonably purchase in the future. It seems unlikely that the construction of the human brain must inherently require substantially more than 10^7 joules and even more unlikely that it could require over 10^{15} joules. The major energy cost in repair down to the molecular level appears to be in the computations required to "think" about each major molecule in the brain and the proper relationships among those molecules.

Determining the Healthy State

In the second phase of the analysis, determination of the healthy state, we determine what the repaired (healthy) tissue should look like at the molecular level. That is, the initial structural data base produced by the analysis phase describes unhealthy (frozen) tissue. In determination of the healthy state, we must generate a revised structural data base that describes the corresponding healthy (functional) tissue. The generation of this revised data base requires a computer program that has an intimate understanding of what healthy tissue should look like, and the correspondence between unhealthy (frozen) tissue and the corresponding healthy tissue. As an example, this program would have to understand that healthy tissue does not have fractures in it, and that if any

"It should be feasible to deduce the correct structural description even in the face of significant damage. Only if the structure is obliterated beyond recognition will it be infeasible to deduce the undamaged state of the structure."

fractures are present in the initial data base (describing the frozen tissue) then the revised data base (describing the resulting healthy tissue) should be altered to remove them. Similarly, if the initial data base describes tissue with swollen or non-functional mitochondria, then the revised data base should be altered so that it describes fully functional mitochondria. If the initial data base describes tissue which is infected (viral or bacterial infestations) then the revised data base should be altered to remove the viral or bacterial components.

While the revised data base describes the healthy state of the tissue that we desire to achieve, it does not specify the method(s) to be used in restoring the healthy structure. There is in general no necessary implication that restoration will or will not be done at some specific temperature, or will or will not be done in any particular fashion. Any one of a wide variety of methods could be employed to actually restore the specified structure. Further, the actual restored structure might differ in minor details from the structure described by the revised data base.

The complexity of the program that determines the healthy state will vary with the quality of the suspension and the level of damage prior to suspension. Clearly, if cryonic suspension "almost works," then the initial data base and the revised data base will not greatly differ. Cryonic suspension under favorable circumstances preserves the tissue with good fidelity down to the molecular level. If, however, there was significant pre-suspension injury then deducing the correct (healthy) structural description is more complex. However, it should be feasible to deduce the correct structural description even in the face of significant damage. Only if the structure is obliterated beyond recognition will it be infeasible to deduce the undamaged state of the structure.

Alternatives to Repair

A brief philosophical aside is in order. Once we have generated an acceptable revised structural data base, we can in fact pursue either of two distinctly different possibilities. The obvious path is to continue with the repair process, eventually producing healthy tissue. An alternative path is to use the description in the revised structural data base to guide the construction of a different but "equivalent" structure (e.g., an "artificial brain"). This possibility has been much discussed[4, 23], and has recently been called "uploading" (or "downloading")[11]. Whether or not such a process preserves what is essentially human is often hotly debated, but it has advantages wholly unrelated to personal survival. As an example, the knowledge and skills of an Einstein or Turing need not be lost: they could be preserved in a computational model. On a more commercial level, the creative skills of a Spielberg (whose movies have produced a combined revenue in the billions) could also be preserved. Whether or not the computational model was viewed as having the same essential character as the biological human after which it was patterned, it would indisputably preserve that person's mental abilities and talents.

It seems likely that many people today will want complete physical restoration (despite the philosophical possibilities considered above) and will continue through the repair planning and repair phases.

"The human brain has roughly 10^{12} nerve cells, plus perhaps ten times as many glial cells and other support cells. While simply encoding this complex a structure into the genome of a single embryo might prove to be overly complex, it would certainly be feasible to control critical cellular activities by the use of on-board nanocomputers."

Restoration

In the third phase of repair we start with an atomically precise description (the revised data base) of the structure that we wish to restore, and a filing cabinet holding the molecules that will be needed during restoration. Optionally, the molecules in the filing cabinet can be from the original structure. This deals with the concerns of those who want restoration with the original atoms. Our objective is to restore the original structure with a precision sufficient to support the original functional capabilities. Clearly, this would be achieved if we were to restore the structure with atomic precision. Before discussing this most technically exacting approach, we will briefly mention the other major approaches that might be employed.

We know it is possible to make a human brain, for this has been done by traditional methods for many thousands of years. If we were to adopt a restoration method that was as close as possible to the traditional technique for building a brain, we might use a "guided growth" strategy. That is, in simple organisms the growth of every single cell and of every single synapse is determined genetically. "All the cell divisions, deaths, and migrations that generate the embryonic, then the larval, and finally the adult forms of the roundworm *Caenorhabditis Elegans* have now been traced."[33]. "The embryonic lineage is highly invariant, as are the fates of the cells to which it gives rise"[32]. The appendix says: "Parts List: *Caenorhabditis elegans* (Bristol) Newly Hatched Larva. This index was prepared by condensing a list of all cells in the adult animal, then adding comments and references. A complete listing is available on request..." The adult organism has 959 cells in its body, 302 of which are nerve cells[34].

Restoring a specific biological structure using this approach would require that we determine the total number and precise growth patterns of all the cells involved. The human brain has roughly 10^{12} nerve cells, plus perhaps ten times as many glial cells and other support cells. While simply encoding this complex a structure into the genome of a single embryo might prove to be overly complex, it would certainly be feasible to control critical cellular activities by the use of on board nanocomputers. That is, each cell would be controlled by an on-board computer, and that computer would in turn have been programmed with a detailed description of the growth pattern and connections of that particular cell. While the cell would function normally in most respects, critical cellular activities, such as replication, motility, and synapse growth, would be under the direct control of the on-board computer. Thus, as in *C. Elegans* but on a larger scale, the growth of the entire system would be "highly invariant." Once the correct final configuration had been achieved, the on-board nanocomputers would terminate their activities and be flushed from the system as waste.

This approach might be criticized on the grounds that the resulting person was a "mere duplicate," and so "self" had not been preserved. Certainly, precise atomic control of the structure would appear to be difficult to achieve using guided growth,

for biological systems do not normally control the precise placement of individual molecules. While the same atoms could be used as in the original, it would seem difficult to guarantee that they would be in the same places.

Concerns of this sort lead to restoration methods that provide higher precision. In these methods, the desired structure is restored directly from molecular components by placing the molecular components in the desired locations. A problem with this approach is the stability of the structure during restoration. Molecules might drift away from their assigned locations, destroying the structure.

An approach that we might call "minimal stabilization" would involve synthesis in liquid water, with mechanical stabilization of the various lipid membranes in the system. A three-dimensional grid or scaffolding would provide a framework that would hold membrane anchors in precise locations. The membranes themselves would thus be prevented from drifting too far from their assigned locations. To prevent chemical deterioration during restoration, it would be necessary to remove all reactive compounds (e.g., oxygen).

In this scenario, once the initial membrane "framework" was in place and held in place by the scaffolding, further molecules would be brought into the structure and put in the correct locations. In many instances, such molecules could be allowed to diffuse freely within the cellular compartment into which they had been introduced. In some instances, further control would be necessary. For example, a membrane-spanning channel protein might have to be confined to a specific region of a nerve cell membrane, and prevented from diffusing freely to other regions of the membrane. One method of achieving this limited kind of control over further diffusion would be to enclose a region of the membrane by a diffusion barrier (much like the spread of oil on water can be prevented by placing a floating barrier on the water).

While it is likely that some further cases would arise where it was necessary to prevent or control diffusion, the emphasis in this method is in providing the minimal control over molecular position that is needed to restore the structure.

While this approach does not achieve atomically precise restoration of the original structure, the kinds of changes that are introduced (diffusion of a molecule within a cellular compartment, diffusion of a membrane protein within the membrane) would be very similar to the kinds of diffusion that would take place in a normal biological system. Thus, the restored result would have the same molecules with the same atoms, and the molecules would be in similar (though not exactly the same) locations they had been in prior to restoration.

To achieve even more precise control over the restored structure, we might adopt a "full stabilization" strategy. In this strategy, each major molecule would be anchored in place, either to the scaffolding or an adjacent molecule. This would require the design of a stabilizing molecule for each specific type of molecule found in the body. The stabilizing molecule would have a specific end attached to the specific molecule, and a general end attached either to the scaffolding or to another stabilizing molecule. Once restoration was complete, the stabilizing molecules would release the molecules that were being stabilized and normal function would resume. This release might be triggered by the simple diffusion of an enzyme that attacked and broke down the stabilizing molecules. This kind of approach was considered by Drexler[1].

Low Temperature Restoration

Finally, we might achieve stability of the intermediate structure by using low temperatures. If the structure were restored at a sufficiently low temperature, a molecule put in a certain place would simply not move. We might call this method "low temperature restoration."

In this scenario, each new molecule would simply be stacked (at low temperature) in the right location. This can be roughly likened to stacking bricks to build a house. A hemoglobin molecule could simply be thrown into the middle of the half-restored red blood cell. Other molecules whose precise position was not critical could likewise be positioned rather inexactly. Lipids in the lipid bi-layer forming the cellular membrane would have to be placed more precisely (probably with an accuracy of several angstroms). An individual lipid molecule, having once been positioned more or less correctly on a lipid bi-layer under construction, would be held in place (at sufficiently low temperatures) by van der Waals forces. Membrane bound proteins could also be "stacked" in their proper locations. Because biological systems make extensive use of self-assembly it would not be necessary to achieve perfect accuracy in the restoration process. If a biological macromolecule is positioned with reasonable accuracy, it would automatically assume the correct position upon warming.

Large polymers, used either for structural or other purposes, pose special problems. The monomeric units are covalently bonded to each other, and so simple "stacking" is inadequate. If such polymers cannot be added to the structure as entirely pre-formed units, then they could be incrementally restored during assembly from their individual monomers using the techniques discussed earlier involving positional synthesis using highly reactive intermediates. Addition of monomeric units to the polymer could then be done at the most convenient point during the restoration operation.

The chemical operations required to make a polymer from its monomeric units at reduced temperatures are unlikely to use the same reaction pathways that are used by living systems. In particular, the activation energies of most reactions that take place at 310 K (98.6 degrees Fahrenheit) can not be met at 77 K: most conventional compounds don't react at that temperature. However, as discussed earlier, assembler based synthesis techniques using highly reactive intermediates in near-perfect vacuum with mechanical force providing activation energy will continue to work quite well, even if we assume that thermal activation energy is entirely absent (e.g., that the system is close to 0 Kelvins).

An obvious problem with low temperature restoration is the need to re-warm the structure without incurring further damage. Much "freezing" injury takes place during rewarming, and this would have to be prevented. One solution is discussed in the next two paragraphs.

Generally, the revised structural data base can be further altered to make restoration easier. While certain alterations to the structural data base must be banned (anything that might damage memory, for example), many alterations would be quite safe. One set of safe alterations would be

Because biological systems make extensive use of self-assembly it would not be necessary to achieve perfect accuracy in the restoration process. If a biological macromolecule is positioned with reasonable accuracy, it would automatically assume the correct position upon warming.

those that correspond to real-world changes that are non-damaging. For example, moving sub-cellular organelles within a cell would be safe—such motion occurs spontaneously in living tissue. Likewise, small changes in the precise physical location of cell structures that did not alter cellular topology would also be safe. Indeed, some operations that might at first appear dubious are almost certainly safe. For example, any alteration that produces damage that can be repaired by the tissue itself once it is restored to a functional state is in fact safe—though we might well seek to avoid such alterations (and they do not appear necessary). While the exact range of alterations that can be safely applied to the structural data base is unclear, it is evident that the range is fairly wide.

An obvious modification which would allow us to re-warm the structure safely would be to add cryoprotectants. Because we are restoring the frozen structure with atomic precision, we could use different concentrations and different types of cryoprotectants in different regions, thus matching the cryoprotectant requirements with exquisite accuracy to the tissue type. This is not feasible with present technology because cryoprotectants are introduced using simple diffusive techniques.

Extremely precise control over the heating rate would also be feasible, as well as very rapid heating. Rapid heating would allow less time for damage to take place. Rapid heating, however, might introduce problems of stress and resulting fractures. Two approaches for the elimination of this problem are (1) modify the structure so that the coefficient of thermal expansion is very small and (2) increase the strength of the structure.

One simple method of insuring that the volume occupied before and after warming was the same (i.e., of making a material with a very small thermal expansion coefficient) would be to disperse many small regions with the opposite thermal expansion tendency throughout the material. For example, if a volume tended to expand upon warming the initial structure could include "nanovacuoles," or regions of about a nanometer in diameter which were empty. Such regions would be stable at low temperatures but would collapse upon warming. By finely dispersing such nanovacuoles it would be possible to eliminate any tendency of even small regions to expand on heating. Most materials expand upon warming, a tendency which can be countered by the use of nanovacuoles.

Of course, ice has a smaller volume after it melts. The introduction of nanovacuoles would only exacerbate its tendency to shrink upon melting. In this case we could use vitrified H_2O rather than the usual crystalline variety. H_2O in the vitreous state is disordered (as in the liquid state) even at low temperatures, and has a lower volume than crystalline ice. This eliminates and even reverses its tendency to contract on warming. Vitrified water at low temperature is denser than liquid water at room temperature.

Increasing the strength of the material can be done in any of a variety of ways.

Proteins are one class of strong polymers that could be incorporated into the structure with minimal tissue compatibility concerns. Any potential fracture plain would be criss-crossed by the newly added structural protein, and so fractures would be prevented.

A simple method would be to introduce long polymers in the frozen structure. Proteins are one class of strong polymers that could be incorporated into the structure with minimal tissue compatibility concerns. Any potential fracture plain would be criss-crossed by the newly added structural protein, and so fractures would be prevented. By also including an enzyme to degrade this artificially introduced structural protein, it would be automatically and spontaneously digested immediately after warming. Very large increases in strength could be achieved by this method.

By combining (1) rapid, highly controlled heating; (2) atomically precise introduction of cryoprotectants; (3) the addition of small nanovacuoles and the use of vitrified H_2O to reduce or eliminate thermal expansion and contraction; and (4) the addition of structural proteins to protect against any remaining thermally induced stresses; the damage that might otherwise occur during rewarming should be completely avoidable.

Conclusion

Cryonic suspension can transport a terminally ill patient to future medical technology. The damage done by current freezing methods is likely to be reversible at some point in the future. In general, for cryonics to fail, one of the following "failure criteria" must be met:

1.) Pre-suspension and suspension injury would have to be sufficient to cause information theoretic death. In the case of the human brain, the damage would have to obliterate the structures encoding human memory and personality beyond recognition.

2.) Repair technologies that are clearly feasible in principle based on our current understanding of physics and chemistry would have to remain undeveloped in practice, even after several centuries.

An examination of potential future technologies[28] supports the argument that unprecedented capabilities are likely to be developed. Restoration of the brain down to the molecular level should eventually prove technically feasible. Off-board repair utilizing divide-and-conquer is a particularly simple and powerful method which illustrates some of the principles that can be used by future technologies to restore tissue. Calculations support the idea that this method, if implemented, would be able to repair the human brain within about three years. For several reasons, better methods are likely to be developed and used in practice.

Off-board repair consists of three major steps: (1) Determine the coordinates and orientation of each major molecule. (2) Determine a set of appropriate coordinates in the repaired structure for each major molecule. (3) Move them from the former location to the latter. The various technical problems involved are likely to be met by future advances in technology. Because storage times in liquid nitrogen literally extend for several centuries, the development time of these technologies is not critical.

A broad range of technical approaches to this problem are feasible. The particular form of off-board repair that uses divide-and-conquer requires only that (1) tissue can be divided by some means (such as fracturing) which does not itself cause significant loss of structural information; (2) the pieces into which the tissue is divided can be moved to appropriate destinations (for further division or for direct analysis); (3) a sufficiently small piece of tissue can be analyzed; (4) a program capable of determining the healthy state of tissue given the unhealthy state is feasible; (5) that sufficient computational resources for execution of this program in a reasonable time frame are available; and (6) that restoration of the original structure given a detailed description of that structure is feasible.

It is impossible to conclude based on present evidence that either failure criterion is likely to be met.

Further study of cryonics by the technical community is needed. At present, there is a remarkable paucity of technical papers on the subject[5]. As should be evident from this paper multidisciplinary analysis is essential in evaluating its feasibility, for specialists in any single discipline have a background which is too narrow to encompass the whole. Given the life-saving nature of cryonics, it would be tragic if it were to prove feasible but was little used.

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[5] A literature search on cryonics along with personal inquiries has not produced a single technical paper on the subject that claims that cryonics is infeasible or even unlikely. On the other hand, technical papers and analyses of cryonics that speak favorably of its eventual success *have* been published. It is unreasonable, given the extant literature, to conclude that cryonics is unlikely to work. Such unsupported negative claims require further analysis and careful critical evaluation before they can be taken seriously.

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Cool Heads Prevail

Fiction by Linda J. Dunn

This story was originally published in The Semi-Circular of Janus, the newsletter of the "Circle of Janus" SF Fan Club. Our thanks to Ms. Dunn for authorizing its republication here. —Ed.

Steve disappeared on Thursday. Or at least, I think it was Thursday. We don't keep track of time very well here in heaven.

When you're facing infinity, noting the days of the week seems as pointless as counting drops of water in the ocean.

But I'm still pretty sure it was Thursday because we had one good reason for staying tuned to earth's time: WorldCon.

Shortly after my arrival here, I discovered that heavenly residents can go anywhere they want in their astral bodies. Well, naturally the one place every one of us SF fans want to go as frequently as possible is WorldCon. I haven't missed one in at least seventy-five years.

Since we travel via heavenly Port and don't have to worry about reservations, traffic, and all those other-worldly hassles, we usually leave the morning WorldCon begins. That's usually Thursday.

I think the saints are finally beginning to get used to our schedule. They still think we're demented and would love to forbid our yearly pilgrimage, but He has become somewhat of a fan since our arrival. That means they have to take a "hands off" policy towards us.

But that doesn't mean they don't make their displeasure known. They tend to roll their eyes, clasp their hands together, and mumble in Latin if they see us returning with replicas of what we admired on earth.

(We had a special problem that one time when one of the guys replicated a particularly attractive fan he'd seen in a mermaid costume. Saint Peter didn't want to let him through the port with it.)

But like I said, they're starting to get used to us now. They usually go off when WorldCon begins and leave some of the lesser saints in charge of the port. In fact, I think guarding the port during the time of our departure and return has become something of an initiation rite for the newer additions to sainthood.

This particular time our group was short one long-time member.

I knew Steve wouldn't miss the convention for anything in—well, heaven—so I was concerned when he didn't show up. In fact, we were all so worried about his absence that as soon as Monday rolled around and the living started tearing down the displays, we got together and started a search through all of heaven.

He was nowhere to be found.

It's a rare thing for someone to be cast out and we certainly couldn't imagine Steve doing something to justify such a thing; but just to be on the safe side we decided to check out Hell.

Hell may be a nasty place for the residents, but it's a great tourist attraction for us heavenly guests.

The devil loves it, too. After all, what could be more hellish than to have a visit from your ex-spouse gloating over his or her election to an infinity of contentment while you're up to your eyeballs in some slime pit surrounded by alligators? ... And that's only one of the situations I've seen my ex-husband in when I've dropped by for a visit. They've got some real nifty tortures in their AI library that even I wouldn't have wished upon that rotten jerk.

In case you didn't know, Satan did away with all the fire and brimstone when Virtual Reality became available. He's got Hell's AI system hooked up via virtual connection in feedback mode and the library is crammed full of some of the most bizarre and awful things imaginable. The Hell system managers told me their biggest problem was getting sufficient on-line storage for Hell's large database. They said Satan likes to keep their acquisition budget unbelievably small as a constant reminder that this IS Hell.

As a former computer system manager, I had a particular interest in the computer set-up and I shuddered when I saw their operations and realized what a hellish experience those poor managers were enduring.

But the AI hookup did make it easy for us to look for Steve and we were both relieved and disappointed when we didn't find him. If he wasn't in Heaven or Hell, where else could he possibly be?

That's when we remembered about Alcor. Steve left our local SF club in Indianapolis to assume management of Alcor, and he'd made arrangements to have himself frozen upon his death in the hope that he could be brought back when technology was sufficiently advanced.

Well, if you were in charge of the operation, who would you bring back first? Someone whose loss would cost the organization lots of money, such as a multi-millionaire with stipulations in his contract, or someone whose awakening would be wildly popular if successful and inexpensive if it failed?

Steve was on Earth. We found him at the next WorldCon giving a panel discussion on cryonics and how it felt to be back. We rejoiced and sat down for the discussion. Naturally, we expected him to talk about life after death and his great times with us, but we were rudely disappointed. He didn't remember anything. Or at least, he claimed

"Satan did away with all the fire and brimstone when Virtual Reality became available. He's got Hell's AI system hooked up via virtual connection in feedback mode, and the library is crammed full of some of the most bizarre and awful things imaginable."

not to remember anything except a moment of panic when his parachute didn't open and then waking up in the recovery room at Alcor.

We left then and roamed the halls for awhile. Finally, we bumped into another heavenly resident and gaped as we realized it was Himself—the Supreme Being.

He looked a little embarrassed and asked us not to tell the saints.

So we asked him about Steve and his lack of memory. He said He was responsible for that. It wouldn't do, he explained, for people to know what to expect when they die. It seems He wants people to be good because it's the right way to be, not because they want to be guaranteed a spot in heaven.

Besides, he pointed out, heaven is getting a little crowded.

We all nodded in agreement and then Dave pointed out that it really didn't matter much. With today's lifespans, Steve would be joining us in three or four hundred years.

But He halted our rejoicing. It was, He reminded us, getting a little crowded in heaven. With the world government finally getting off its rump and colonizing Mars, it would be only a matter of time until humans moved ouside the Solar System and started finding all those habitable worlds He'd set up for them. Then the population growth would really take off!

I think He also mumbled something about how He should have just said "go," and left out the part about "being fruitful and multiplying," but I could be mistaken.

Steve would be immortal, He informed us. As would everyone else who underwent the procedure of regeneration. It was growing so crowded in Heaven that He had decided it was time to allow this scientific advancement. He chuckled a little, too. Said the only people dying now would be those killed in accidents, and a large number of those would be going straight to Hell.

I thought that was a little extreme, but He assured me Satan had always reserved a special place in Hell for drunk drivers. According to Him, it's right next to the place for politicians.

I was impressed, but then Bob piped up with "Well, I don't think this is at all fair. If we'd known you planned this, we would have had our heads frozen too." We told him to be quiet, bowed a few times to Him, and backed away.

When we got back to the party hotel, Bob whined that we should have let him file a complaint with Him, but Greg just grinned and said he had a better idea.

You know, Heaven's full of engineers and technicians. The Supreme Being always said He reserved a special place in Heaven for them because the scientists always got all the credit when it was really the engineers and technicians who did all the work. Greg's idea was to build a modifier for the Port which takes us to Heaven, Hell, Earth, and whatever other plane we want to visit. Only this modifier would take us backwards in time to the point we desired.

So we built it. But being souls without form or substance, we couldn't talk to ourselves and convince ourselves that we needed to set up an account with Alcor. It didn't matter; we found another avenue.

Have you ever had a near-miss situation where you've jokingly said that your Guardian Angel was looking after you? Or have you ever been somewhere allegedly haunted and felt a presence watching you? And haven't you heard stories from people about how they'd wake up one morning after the death of a loved one and feel as though that person was nearby and attempting to comfort them?

Well, forget all that; it's all psychological nonsense and wishful thinking upon the part of mere mortals. We can't do any of that. But we could borrow Satan's AI system and connect it to our device. With a small change, we managed to send output back in time to the Macintosh one of our members used for writing.

We asked the original owner to write this story, so it would be in her style. The owner refused, claiming she couldn't possibly write as badly now as she had in those days. But those of us forced to occasionally listen to the stories she composes now were certain she could, in fact, write even worse than she had while alive.

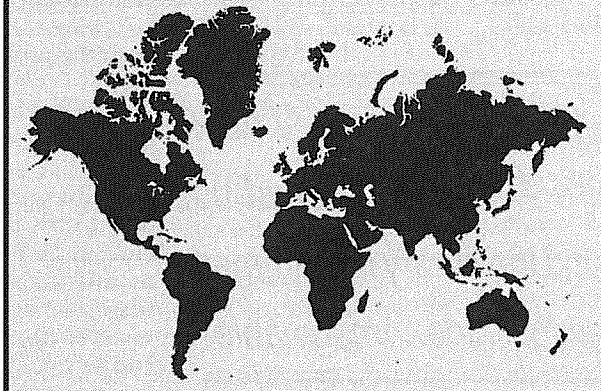
She walked off in a huff when we said that, so we had to get someone else to write it; then we sent it over the Port via the time distorter. You're reading it now.

With a little luck, the Macintosh owner will wake up in the morning and manage to convince herself that she wrote this during the night while she was half asleep. If we're really lucky, she may even get it printed in some small press publication where people will read it several times, exclaiming over how badly some stories are written.

Most of you read this will simply ignore the message at the end, but the members of our local club will not. Once you've changed the past, your memories change too. We know we paid attention to the following message from Heaven: Invest in Alcor. And make arrangements to have yourself frozen.

Membership Status

Alcor has 331 Suspension Members, 557 Associate Members (includes 112 in the process of becoming Suspension Members), and 28 patients in suspension. These numbers are broken down by country below.



Country	Members	Applicants	Subscribers
Argentina	1	0	1
Austria	1	0	1
Australia	12	0	6
Brazil	0	0	1
Canada	8	5	43
Costa Rica	0	0	1
Denmark	0	0	1
Estonia	0	0	1
Finland	0	0	2
France	0	0	2
Germany	1	1	1
Holland	0	0	2
Ireland	0	1	2

Country	Members	Applicants	Subscribers
Italy	0	2	1
Japan	2	0	2
Lithuania	0	0	2
New Zealand	0	0	1
Russia	0	0	4
Spain	6	2	0
Sri Lanka	0	0	1
Sweden	0	0	1
Switzerland	0	0	1
U.K.	14	4	3
U.S.A.	292	97	357
Ukraine	0	0	1
TOTALS	331	112	445

Through Our Eyes Only? The Search For Animal Consciousness

by Marian Stamp Dawkins, WH Freeman and Co., Ltd., 1993

Reviewed by Thomas Donaldson, Ph.D.

The author of this book says some very interesting things to us as cryonicists, even though she wrote it from a viewpoint quite different from our own. The major question which seems to have driven Ms. Dawkins to write her book comes from *morality*: if some animals are conscious, can we morally treat them the way we often do now, experimenting on them or eating them?

Regardless of the reasons for which *she* wrote her book, its interest to us comes direct from our interest in finding out, somehow, just how much damage before and during suspension would destroy us entirely. Could our consciousness survive even with a total loss of memory? For that matter, could it even survive suspension? Some cryonicists, from an attitude close to despair, believe that even after a perfect suspension we may never regain our consciousness: they decided to choose suspension because nothing else exists. Other cryonicists believe that consciousness *with* no memory at all means nothing; that opinion may be very well as it stands, but given how sloppy the world is, just how little memory counts as no memory at all? Do we survive if we can only remember a few scenes from our early childhood? The gulf between no memory at all and only a little may be very wide.

Dawkins begins by examining a related question, which she clearly distinguishes from consciousness. Are animals capable of learning and complex behavior? Do not be put off by her purposes in making this investigation; she is determined to do it rigorously, with close attention to experimental data. By doing so, she knowingly raises issues that a more sentimental approach would ignore. For instance, bees can achieve quite surprizing feats in locating flowers. We know, however, that bees are individually far too simple to have much in the way of thoughts. The entire process by which bees search for sources of nectar works like a very finely tuned machine. In this context, Dawkins also discusses the evidence for language in chimpanzees; her conclusion is that although chimpanzees can clearly learn individual words, they fail completely to learn any grammar. (Instances to the contrary, she argues, come from the chimpanzee's ability to respond based on a close watch of how nearby humans respond). So it's not so easy to decide that animals can learn based solely on their behavior.

Yet some psychologists have produced experimental evidence that almost certainly indicates learning. Dawkins discusses, for instance, the behavior of rats, which involves not only recognition of other rats, but decision as to whether or not to eat what the other rat has eaten on the basis of just how healthy that rat remains afterwards. And psychologists have shown that rats do even more than that: once they learn that something is unhealthy to eat, they somehow teach their pups not to eat it too. Experimenters have found that even after several generations, and the death of all the rats that initially learned that one food was unhealthy, the rat colony would still refuse to eat it. Her discussion of these abilities of animals is particularly interesting because she focuses not on whether or not an animal can pass laboratory tests of "intelligence" but instead on the role that learning and thinking play to help the animal survive in the wild. In this context, experimenters have shown that some birds have a memory for where they have hidden nuts which extends to tens of thousands of locations; ostriches recognize individual ostrich *eggs*, ... in general, animals in their normal habitat have specialized intellectual abilities which far exceed our own.

As Dawkins says herself, it's not that this is consciousness, but that it may come close. We do, after all, consider any species capable of complex and learned behavior to be more likely to have consciousness than one able to only carry out stereotyped, simple behavior.

From an ability to learn complex behaviors, we can pass to an even more distinct ability, the ability to think. There is a fairly explicit definition of what thinking might consist of: that we (or an animal) have some model of the world, and rather than work out what will happen if we do X rather than Y by trial and error, we predict the result from our model. So can animals have such models of the world? To test such abilities, we present the animal with a *novel* situation.

Dawkins discusses several experiments of this kind. In each of them, the animal must somehow learn a concept of number or order independent of the particular objects involved. For instance, one experimenter has trained rats to always choose the 3rd tunnel in a series, regardless of how it looked or smelt, or its position in relation to where the rat was placed at the start. (This scientist took a great deal of trouble to make sure that his rats had no other cue about how to behave). She also discusses one parrot, Alex, specifically trained to recognize *meanings* of the words it had learned.

And finally, perhaps the easiest (or hardest?) question of them all: do some animals have feelings? Dawkins here points out that even among human beings, words are considered far less weighty indicators of feelings than actions. Dawkins suggests that we examine animals' actions to find out their feelings, and cites several experiments showing how animals can feel hungry (how hard they work for food) or not, or lonely (at least among social animals: how hard they work to visit a companion). As one very suggestive example, she cites an experiment with sweet liquids. Human beings will find such liquids less pleasant right after they've eaten than when they are hungry. Rats also will drink less of a sweet liquid after eating. The suggestiveness comes from graphing the response of both humans and rats: they match closely.

So finally, after all this data, Dawkins discusses it in the light of her main question: are these animals conscious? She makes one obvious critical point about consciousness: we judge that a *person* is conscious from their behavior also, not from any special access to their mind. Hence if we show that ani-

mals have quite similar behavior, it becomes illogical to decide that they lack consciousness while people do not. And then she makes another critical point which deserves serious attention. If we believe that consciousness has some kind of *use* (that is, it gives conscious animals an advantage over nonconscious ones) then we must also believe that it will show itself somehow in behavior.

That is, consciousness should be just as testable as weight.

True, its advantages may be subtle, but they must show themselves explicitly to those who know how to look. We cannot logically decide that the question of consciousness is unanswerable (though of course we may not *now* know how to answer it. A short discussion of the evidence suggests that consciousness provides an ability to work out what to do in novel situations. Furthermore, for most animals (including most human beings) social relations give the main field in which it shows its value. (She does *not* claim that it has no use otherwise).

As cryonicists this tells us also how we might test survival of consciousness: very simply, it will most likely survive so long as our brains retain some integrity. If suspension or events before it destroy our forebrain, then perhaps consciousness would not survive ... though new forebrains might certainly be regrown. At this point, Dawkins rests her case; but for us, the question has only begun. Yet this emphatically does *not* mean that animal consciousness has no bearing at all on our concerns. For if we can test for consciousness in animals, we can also test for its survival. By doing so, we will therefore bring some empirical data into a field that has remained the sole province of metaphysics and philosophy for too long. Were Suda's cat brains conscious? Experiments can decide such questions just as they can decide whether or not life continues.

Can this data affect our behavior toward nonhuman animals? Unfortunately, if we base our morality on consciousness alone, then any rights we give for consciousness will extend many times too far. Consider the real consequences of deciding that every mammal and bird is morally equal: then our response to nature should resemble that of a witness to a murder. We would necessarily have to bring *all* predation of *whatever kind* to an end. The real *moral* problem remains that of choosing between different relative goods, a far harder problem. Dawkins assumes that consciousness will bear on this issue, without discussing how in any detail ... quite unlike her discussion of consciousness itself. But cryonicists should not allow this lapse to blind them to the interesting ideas and data she presents.

Reversing Memory Loss: Proven Methods for Regaining, Strengthening and Preserving Your Memory, by Vernon H. Mark, M.D.

Reviewed by Russell Cheney

Many believe that memory is a critical component of life and of self; these individuals are likely to find this book both fascinating and useful.

Briefly, this gem is a surprisingly-readable, up-to-date, practical guide on what's currently known about retaining your maximum brain capacity. It's written by an authority in the field, and on the vast majority of issues appears to provide clear, scientific information in a domain traditionally complicated by unsubstantiated assertions.

Optimism

Dr. Mark's positive approach to retaining brain function will be comfortable to many cryonicists, who tend to be optimists themselves. Typically, from page 139:

Brain sciences have made fantastic progress in the last three decades, in both the diagnosis and treatment of brain diseases and injuries. When pinpointed early, the causes of brain symptoms, especially memory loss, can in many cases be reversed. This fact is important for you to know because many people, when faced with the symptoms of memory loss, become quite depressed. Their first thought is that, like their fathers or grandmothers before them, they've got Alzheimer's disease, that everything is lost, and there's nothing that can be done for them. Fortunately, that's not true in the vast majority of cases.

Repeatedly, Dr. Mark emphasizes that memory-loss diagnoses due to Alzheimer's disease or "simple" old age should not be accepted lightly. For example, from page 169:

An important message I want to convey is not to take the diagnosis of Alzheimer's disease as final until a very thorough and accurate history has been taken. With multi-infarct dementia ... it is possible to treat such patients and prevent future problems if the disease is found early enough.

Vital Memory

The first, three-chapter, section of the book—"What Is Vital Memory?"—discusses Dr. Mark's term "vital memory," as well as memory processes and testing. His pragmatic term, "vital memory" equates roughly to sufficient mental capacity to perform daily functions and to enjoy life.

Treatment

The next, five-chapter section, "Reversal of Memory Loss," discusses major causes and their treatment, including depression (identified as the single most-common cause of reversible vital memory loss), alcohol, hallucinogens, stimulants, depressants, and prescription medications.

Memory loss symptoms are clearly delineated that are normal (should not be of special concern), and that require medical investigation.

Dr. Mark believes that a surprisingly wide variety of commonly-used drugs have both short-term and permanent deleterious effects on memory and intellectual functions. Recommended for minimal use are drugs as well-known as

Daily Supplementation

Supplement	Minimum	Optimal
Vitamins:		
A	5000 IU	10,000 IU
D	400 IU	400 IU
E	30 IU	100 IU
C	60 mg	1,000 mg
B1 (thiamine)	1.5 mg	20 mg
B2 (riboflavin)	1.7 mg	10 mg
B3 (niacin)	20 mg	250 mg
B5 (pentothenic acid)	10 mg	20 mg
B6 (pyridoxine)	2 mg	20 mg
B9 (folic acid)	400 mcg	400 mcg
B12 (cobalamines)	6 mcg	100 mcg
H (biotin)	n/a	300 mcg
Choline	n/a	3 g
Minerals:		
Calcium	1 g	1.6 g
Phosphorus	1 g	1.6 g
Iodine	150 mcg	150 mcg
Iron	18 mg	20 mg
Magnesium	400 mg	400 mg
Copper	2 mg	3 mg
Zinc	15 mg	25 mg
Other:		
Spring Water	n/a	45-60 oz

Extracted from Table 2, page 210.

Important note: Prior to using this list as a guide, please study the related material in Dr. Mark's book.

Valium, Ativan, Halcyon, and alcohol, among many others specifically identified here. A check-off list for the use of new prescription drugs is included (page 95).

Nutrition

The next, four-chapter section, "Diet and Reversible Memory Loss," discusses brain nutrition and chemistry, memory versus brain metabolism, and thyroid dysfunction. This section is good news for those wishing to help take charge of the health of their own brain.

In addition to a complete chapter on the subject, one of the most comprehensive and practical discussions of beneficial brain supplementation culminates in specific recommendations, shown here in the box "Daily Supplementation." Before using this extract, it is recommended the reader study Dr. Mark's accompanying notes in his book.

A quick evaluation by Dr. Steve Harris rated the supplementation schedule as "Very good," although Dr. Harris stated that choline has not been proven to result in anything except the consumer smelling fishy.

Dr. Mark stressed that good nutrition is low-fat nutrition; "Many strokes can be prevented by reducing fat in the diet."

Diseases/Injuries

The next, six-chapter section, "Diseases and Injuries That Cause Memory Loss," discusses problems caused by infections, closed-head injuries, epilepsy, strokes and degenerative brain diseases. One entire chapter is devoted to surgery-treatable causes of memory loss.

Hope

The next, two-chapter section. "Hope for the Future," discusses prevention and predictions. The chapter on prevention is most helpful because of the practical nature of the recommendations, including the following:

Exercises:

Physical

Dr. Mark recommends daily exercise to reduce the risk of strokes associated with hardening of the arteries, as well as for general fitness to help avoid falling accidents that cause severe head injuries.

Gentle jogging for twelve to fifteen minutes a day is recommended, as are other alternative exercises at varying length of times to achieve equivalent benefits.

Brain

Examples of preventive exercises include learning to print, shave, and brush teeth with the nondominant hand.

Slowing down the brain's aging process by practicing all aspects of intellectual function is recommended, including math skills, drawing with either hand, and reading aloud.

Honing memory skills is recommended via specific exercises focused on attention, concentration and distraction-avoidance, including the development of mnemonic (association) and relaxation methods.

Injury-Prevention

Over 100,000 serious brain injuries occur each year from automobile accidents. Air bags used with three-point seat-belt restraints would, "... markedly reduce the incidence of brain injury." Appropriate helmets in contact sports and bikes would be of great help.

Conclusion

This book is recommended to become part of every cryonicist's tool-kit to help deal positively with the future.

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All prices include postage and handling and are in U.S. dollars. Minimum order: $5.00. Overseas orders must be paid with U.S. dollars by Traveler's Cheques or International Money Order, and must include an additional 20% (of total) for shipping. All orders are subject to availability and all prices are subject to change.

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About the Alcor Foundation

The Alcor Foundation is a non-profit tax-exempt scientific and educational organization dedicated to advancing the science of cryonics and promoting it as a rational option. Alcor currently cares for 28 patients in cryonic suspension, and has hundreds of signed up Members. Being an Alcor Member means knowing that—should the worst happen—Alcor's Emergency Response Team is ready to respond for you, 24 hours a day and 365 days a year.

Alcor's Emergency Response capability includes equipment and trained technicians in Arizona, New York, Indiana, Northern California, Southern California, and England, and a cool-down and perfusion facility in Florida.

Alcor's Arizona facility includes a full-time staff with employees present 24 hours a day. The facility also has a fully equipped research laboratory, an ambulance for local response, an operating room, and a patient care facility using state-of-the-art storage vessels.

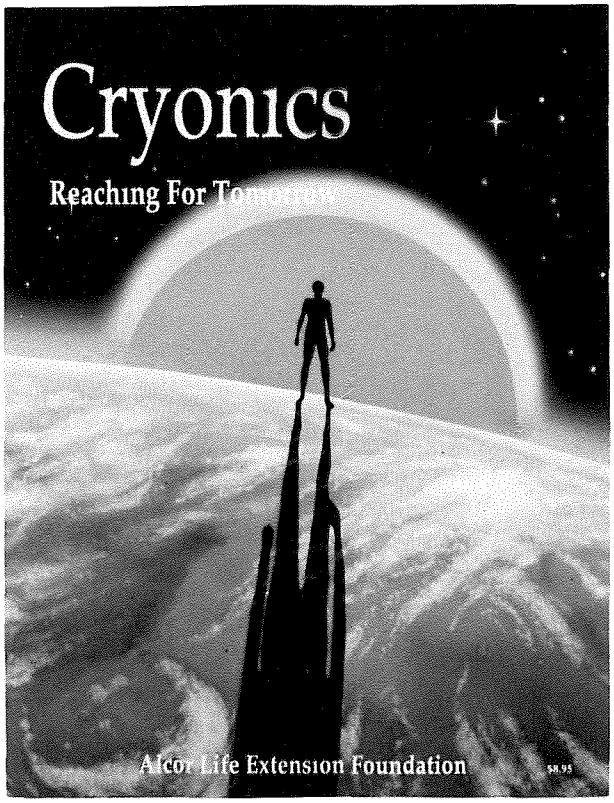
New Handbook Now Available!

The new edition of *Cryonics: Reaching For Tomorrow* is back from the presses! *Reaching For Tomorrow* is *the* "textbook" introduction to cryonics. Over 100 pages long, *Reaching For Tomorrow* is a fantastic and unique examination of the social, practical, and scientific arguments that support the continuing refinement of today's imperfect cryonic suspension techniques, in pursuit of perfected suspended animation.

This edition features a new Appendix based on the "Suspension Pricing and the Cost of Patient Care" article by Ralph Whelan in the October, 1993 issue of CRYONICS, as well as a considerably lengthened and updated chapter on "Revival."

Order your copy for $7.95, or receive it FREE when you subscribe to CRYONICS magazine for the first time. (See the offer on the inside front cover.)

*Still the **only** comprehensive introduction to cryonics procedures and philosophy on the planet!*



For those considering Alcor Membership. . .

If you're intrigued enough with cryonics and Alcor that you're considering Membership, you might want to check out *The Alcor Phoenix*, Alcor's Membership newsletter. *The Phoenix* is a Membership benefit, so it's free to Members and Applicants, but anyone can receive it for $20/year ($25/year if you're overseas). It's released 8 times each year, on the "off months" of the quarterly CRYONICS (February, March, May, June, August, September, November, and December). *The Phoenix* is shorter than CRYONICS, but appears twice as often and is mailed First Class. Being a Membership newsletter, *The Phoenix* focuses on Membership issues such as financing cryonics, staff and management matters, developments in Patient Care and Emergency Response, etc. These issues will impact you directly if you decide to become a Member, and may help you make a more informed decision in the meantime.

Alcor Foundation
7895 E. Acoma Dr., #110
Scottsdale, AZ 85260-6916
(602) 922-9013

Meetings

Board of Directors Meetings

Alcor business meetings are held on the first Sunday of every other month: January, March, May, July, September, and November. (The July and September meetings are on the second Sunday.) Guests are welcome. Meetings start at 1 PM. For more information, call Alcor at (602) 922-9013.

Sunday, July 10, 1994:

ALCOR
7895 East Acoma Dr., #110
Scottsdale, AZ 85260

Directions: *Take the 10 to the 17 Northbound, exit Thunderbird Road heading East. Thunderbird will turn into Cactus St, stay on Cactus until you reach Scottsdale Road, turn left on Scottsdale Road, then right on Thunderbird (which will quickly become Redfield), then (after about a quarter mile) left on 76th Place. 76th Place turns into Acoma Drive; Alcor is on the right at 7895 Acoma Dr., Suite 110.*

Bay Area

Alcor Northern California meetings: Potluck suppers to meet and socialize are held the second Sunday of the month beginning at 6:00 PM. All members and guests are welcome to attend. There is a business meeting before the potluck at 4:00. The June meeting information is as follows:

Sunday, June 12, 1994:

Paul Genteman
905 S. Winchester Blvd, Apt 228
San Jose, CA
Tel: 408-296-3298

Directions: *Take 280 South, exit Winchester Blvd, go South (right), enter Winchester Park Apt's (first right after Toys R Us). Paul's apt is at the South end of the complex in quad 905. Apt 228 is the first apt at the top of the stairs.*

Colorado

A cryonics group will be forming in Colorado. Further information may be obtained by contacting Walter Vannini at 111 East Drake Rd, Suite 7046, Fort Collins, CO 80525, or 71043.3514@compuserve.com (email).

Midwest

Alcor Midwest is in full swing. It produces a monthly newsletter and holds monthly meetings. It has a state-of-the-art stabilization kit and responds to six states: MI, IL, OH, MO, IN, and WI. For meeting information or to receive the Alcor Midwest Newsletter, contact Brian Shock at (317) 769-4252, or 670 South State Road 421 North; Zionsville, IN 46077.

Boston

There is a cryonics discussion group in the Boston area meeting on the second Sunday each month. Further information may be obtained by contacting Tony Reno at (508) 433-5574 (home), (617) 345-2625 (work), 90 Harbor St., Pepperell, MA 01463, or reno@tfn.com (email). Information can also be obtained from David Greenstein at (508) 879-3234 or (617) 323-3338 or 71774.741@compuserve.com (email).

District of Columbia

Life Extension Society, Inc. is a new cryonics and life extension group with members from Washington, D.C., Virginia, and Maryland. Meetings are held monthly. 1994 meetngs are scheduled for May 15, June 12, July 17, September 11, October 16, November 13, and December 11. Call Mark Mugler at (703) 534-7277 (home), or write him at 990 N. Powhatan St.; Arlington, VA 22205.

Las Vegas

Cryonics Laughlin meets the third Sunday of the month at 1:00 PM at the Riverside Casino in Laughlin, Nevada. FREE rooms at the Riverside Casino on Sunday night are available to people who call at least one week in advance. The time and place of these meetings sometimes changes, so before you come, *please* call Eric Klien at (702) 897-4176.

Directions: *Take 95 south from Las Vegas, through Henderson, where it forks between 95 and 93. Bear right at the fork and stay on 95 past Searchlight until you intersect with 163, a little before the border with California. Go left on 163 and stay on it until you see signs for Laughlin. You can't miss the Riverside Casino in Laughlin, Nevada.*

Southern California

The Southern California chapter of Alcor meets every month in an informal setting in one of our member's homes. The May meeting (on the fourth Sunday of the month) is now scheduled. For more information, call Michael Riskin at (714) 879-3994. The April 24 meeting will be at the home of Nance Clark at 4201 Via Marina in Marina Del Rey. For directions, call Alcor or call Nance at 310-306-3129.

England

There is an Alcor chapter in England, with a full suspension and laboratory facility south of London. Its members are working aggressively to build a solid emergency response, transport, and suspension capability. *Meetings are held on the first Sunday of the month* at the Alcor UK facility, and may include classes and tours. The meeting commences at 11:00 A.M., and ends late afternoon.

The address of the facility is:

Alcor UK
18 Potts Marsh Estate
Westham
East Sussex
Tel: 0323 460257

Directions: *From Victoria Station, catch a train for Pevensey West Ham railway station. When you arrive at Pevensey West Ham turn left as you leave the station and the road crosses the railway track. Carry on down the road for a couple of hundred yards and Alcor UK is on the trading estate on your right.*

Victoria Station has a regular train shuttle connection with Gatwick airport and can be reached from Heathrow airport via the London Underground tube or subway system.

People coming for AUK meetings must phone ahead—or else you're on your own, the meeting may have been cancelled, moved, etc., etc. For this information, call Alan Sinclair at 0323 488150. Near metropolitan London, contact Garret Smyth at 081-789-1045 or Garret@destiny.demon.co.uk, or Mike Price at 081-845-0203 or price@price.demon.co.uk.