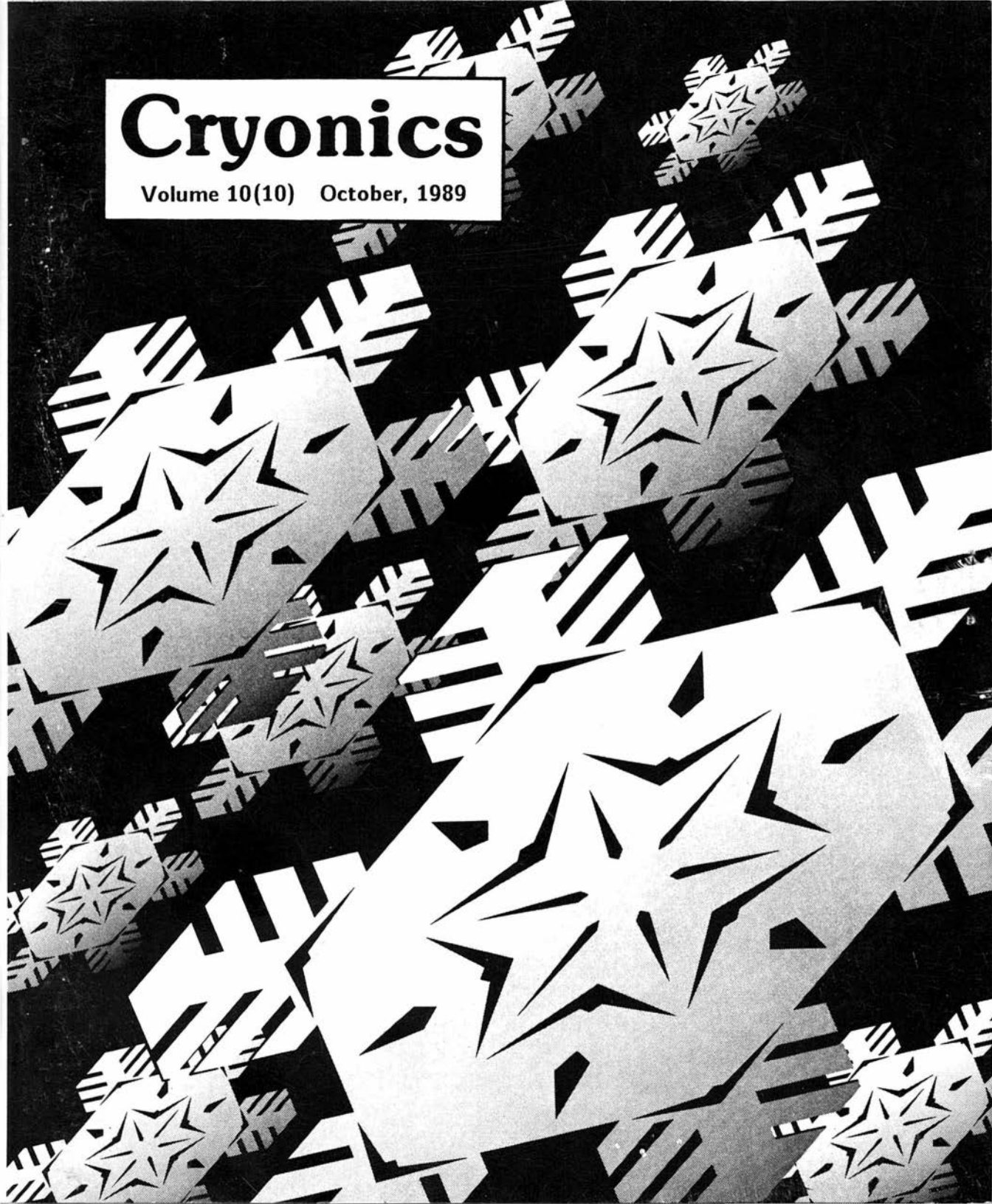
Cryonics

Volume 10(10) October, 1989



CRYONICS ■ Volume 10(10) ■ October, 1989 ■ Issue 111

CRYONICS is the newsletter of the Alcor Life Extension Foundation, Inc. Mike Darwin (Federowicz) and Hugh Hixon, Editors. Published monthly. Individual subscriptions: $25 per year in the US; $35 per year in Canada and Mexico; $40 per year all others. Back issues are $2.50 each in the US, Canada, and Mexico; $3.50 each all others.

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EDITORIAL MATTERS

We had planned on being back on track with magazine production. No such luck. There's been another human suspension and several companion animal suspensions (more on both below). We've also had our share of legal actions (more on those below too). Nevertheless, we're still trying!

This issue may seem a little one-dimensional to many of our readers. There are several reasons for this. First and foremost is the 24 pages occupied by Dr. Ralph Merkle's paper *Molecular Repair Of The Brain*. This paper isn't for everyone. **But it is important.** As far as we know, this is the first detailed examination of the computational requirements/-feasibility of repair of the brain on a molecular level. We are very proud to be publishing it.

Dr. Merkle's paper is only a beginning. Tremendous amounts of additional detail need to be put in place to shore up the argument that molecular-level repair of the brain is not only a distant theoretical possibility but a practically achievable reality. Dr. Merkle's paper will no doubt serve as an invaluable starting point for such future endeavors.

This issue has also suffered from a lack of diversity due to the pace of events in California. It is a paradox of *Cryonics* publication that the busier we are, the longer it takes us to tell you about it. The furious pace of activity here also means less time for reflection and analysis by the core Alcor staff (this is no doubt why so many busy people wait to write their memoirs until after retirement!). We apologize, and hope that the results are worth the wait.

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EDITORIAL POLICY

Perhaps no aspect of *Cryonics* editorial policy, or lack of it, has exacted more criticism and dissatisfaction than allowing rebuttal to appear in the same issue as a contributor's material. Many have felt this policy grossly unfair since it in effect gives the last word to *Cryonics* or Alcor staff.

Because of the unfairness of this, we have decided to adopt an editorial policy which will hopefully guarantee that contributors to *Cryonics* will have an opportunity to see and to reply to rebuttals or letters of comment. This policy is effective immediately.

We ask that all of our contributors bear with us as this policy is implemented. We also ask that you

understand that despite our fairly professional production values, *Cryonics* remains a very amateurish and spare-time affair. Please allow extra time for your comments on material published in *Cryonics* to appear: it will take time to copy the original contributors as well as to enter their response, if any.

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WALLET CARDS

Several years ago Alcor updated its wallet cards and issued new ones. Apparently a lot of people didn't get them, despite the fact that a comprehensive mailing was done to Suspension Members at that time. If you don't have a wallet card for whatever reason (never got one, lost, stolen, or a victim of "wallet rub" or "purse fungus") let us know. Reproduced below is a facsimile of one side of the card. The reverse side has an area for your signature. If you do not have a card, you need one and should call us or write us now!

URGENT INSTRUCTIONS

THE BEARER OF THIS CARD IS AN ANATOMICAL DONOR UNDER SECTION 7153.5(a) OF THE HEALTH AND SAFETY CODE OF CALIFORNIA AND HAS MADE ARRANGEMENTS FOR POST MORTEM CRYOGENIC PRESERVATION UNDER SECTION 7100 OF THE HEALTH AND SAFETY CODE OF CALIFORNIA. **PLEASE FOLLOW THE INSTRUCTIONS BELOW:**

1) IF UNCONSCIOUS, SERIOUSLY INJURED, OR CLINICALLY DEAD, **IMMEDIATELY** CALL (COLLECT) 714 736-1703 AND NOTIFY THE ALCOR FOUNDATION. STAY BY THE TELEPHONE TO RECEIVE INSTRUCTIONS. ALCOR PERSONNEL WILL BE PAGED.

2) IF CLINICALLY DEAD, START AND MAINTAIN CARDIOPULMONARY (HEART-LUNG) RESUSCITATION (CPR).

3) MAINTAIN ARTIFICIAL CIRCULATION AND VENTILATION AND ADMINISTER APPROPRIATE PARENTERALS TO MINIMIZE ACIDOSIS.

4) IF LEGAL DEATH HAS BEEN PRONOUNCED AND IT IS POSSIBLE TO DO SO, CONTINUE CPR AND PACK THE BODY IN ICE (ESPECIALLY HEAD, THROAT, AXILLA AND GROIN) OR PLACE ON A COOLING BLANKET AT 2 TO 4 DEGREES CENTIGRADE.

5) IF EXTENDED CPR IS NOT POSSIBLE OR INAPPROPRIATE (DONOR DEAD MORE THAN ONE HOUR) PACK THE BODY IN ICE.

6) **DO NOT UNDER ANY CIRCUMSTANCES ALLOW THE BODY TO FREEZE OR BE EXPOSED TO SUBFREEZING TEMPERATURES (i.e., BELOW 0 DEGREES CENTIGRADE OR 32 DEGREES FAHRENHEIT).**

DO NOT AUTOPSY OR EMBALM.

Call ALCOR (714) 736-1703 DONOR NUMBER

URGENT INSTRUCTIONS INSIDE

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THE GIFT OF A LIFETIME

We are offering introductory gift subscriptions again, at $10 each, less than 1/2 the regular subscription price. The recipient cannot previously have been on our mailing list as either a subscriber to *Cryonics* or as a member of Alcor. This offer applies only in the U.S., due to the much higher price of non-domestic mailings. We are actually taking a loss on the gift subscriptions at this rate, but we consider that finding new cryonicists is well worth it. If you have a friend or acquaintance who has expressed any interest in cryonics, a gift subscription to *Cryonics* may well be the gift of a lifetime.

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MEMBERSHIP STATUS

Alcor now has 136 Suspension Members, 261 Associate Members, and 13 members in suspension.

SUSPENSIONS REPORTED

There have been two recent cryonic suspensions that we know about. One was conducted by Trans Time for the American Cryonics Society on August 18, 1989. According to the *American Cryonics Society Journal* (June-July, 1989 issue), the patient was the father of an ACS Suspension Member who was dying from a work-related lung cancer (probably mesothelioma as a result of asbestos exposure). The patient was a former sheet metal worker who had been a Bay Area resident since 1934.

Arrangements for the suspension were made less than 24 hours in advance of the patient's legal death. Resuscitation and stabilization of the patient were apparently initiated sometime after cardiac arrest and the patient appears to have been removed from the hospital using a mortuary for pick-up. Perfusion was reportedly carried out at the Trans Time facility in Oakland with assistance from Dr. Ronit ben-Abraham, the physician-sister of ACS president Avi ben-Abraham. Surgery was performed by Trans Time consultant and UC Davis physiologist Dr. Eugene Bresnock.

According to Trans Time President Art Quaife, the California Department of Health Services is refusing to issue a death certificate on this patient (as they have also refused to do in the case of Alcor patient Dick Jones). The DHS is refusing to issue death certificates on cryonic suspension patients because "cryonic suspension does not constitute a legal means of disposition in the State of California."

Additional details about the Northern California suspension were not available as of this writing.

The most recent suspension was carried out by Alcor in early September. The patient was a 21-year-old woman from Spain who experienced sudden cardiac arrest in late August. This suspension was undertaken under *very* adverse legal, bio-

logical, and emotional conditions. This was the most problematic suspension we have carried out. A full discussion of the circumstances and conditions of this case will hopefully be presented in the next issue of *Cryonics*. Suffice it to say that the patient was a Coroner's case in Spain and that Spanish coroners can apparently be every bit as bureaucratic as their Riverside, California counterparts.

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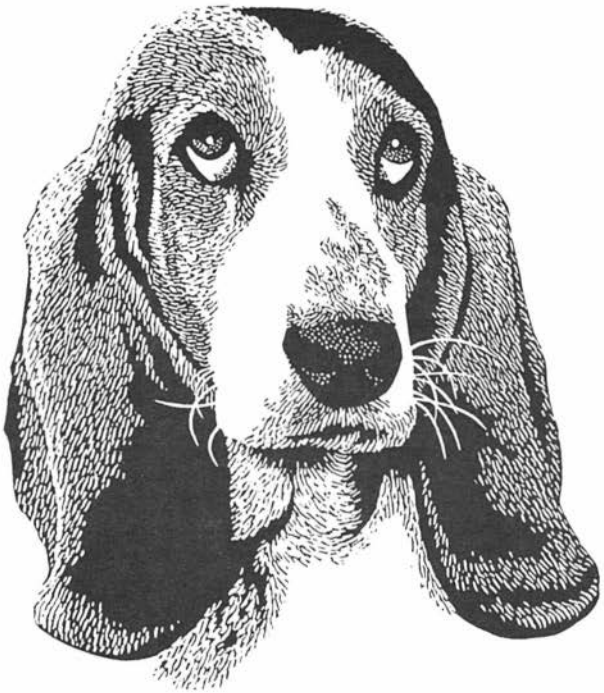
A FRIENDLY FACE IN A FOREIGN PLACE



In addition to human suspensions, the Alcor staff has been kept busy with the cryonic suspension of several members' pets; both domestic and foreign.

The first of these cases came on April 21st when we received a call from an Alcor member living in Melbourne, Australia. This member had been in contact with us for sometime about making arrangements for the neurosuspension of his pet Labrador Retriever, Rebecca. Unfortunately, Rebecca experienced congestive heart failure and cardiac arrest unexpectedly early. The member called Mike Darwin from the animal hospital and Mike was able to provide some simple instructions for heparinization (to prevent blood clotting) and cooling. With further long distance communication between Mike Darwin and a cooperative Australian mortician (yes, that's right, *mortician*) a decision was made to perfuse Rebecca's head with a formalin/glycerol/saline mixture. Glycerol, saline and reagent grade formaldehyde were obtained from a pharmacy and the veterinary clinic. The mortician carefully prepared a flush solution of saline and glycerol (following instructions from Mike Darwin by phone) in order to carry out blood washout before introducing fixative. Following blood washout with three liters of saline/glycerol, nine liters of formalin/saline/glycerol were slowly perfused through both carotid arteries.

Penetration of fixative was deemed excellent and the animal was then chilled to dry ice temperature. Fixative perfusion was used in this case because of the impossibility of getting good cryoprotective perfusion (fixatives stabilize tissue ultrastructure during freezing) and because of the legal difficulty of transporting unfixed canine tissue into the United States from Australia. Even with an embalmer's certificate, the bureaucratic paperwork was not completed until late May and Rebecca did not arrive until June 9th!

A few days later on the 15th of June, an ill and aged French Poodle named Pierre belonging to Alcor member Jo Ann Martin was placed into whole-body suspension under controlled conditions. Pierre was treated very similarly to Alcor suspension patients and

was glycerolized to 4M.

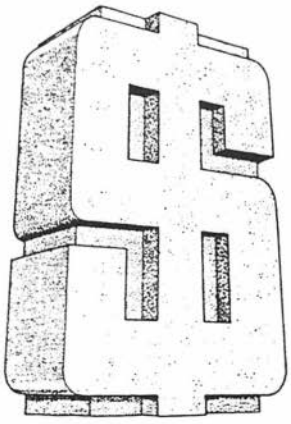
On the 23rd of August, Buddy, a five year old German Shepherd became the sixth companion animal to enter suspension at Alcor. Buddy is the dog of Alcor member Al Lopp and he experienced shock and cardiac arrest secondary to a previously undiagnosed disseminated lymphatic cancer. Buddy also had a special place in the hearts of some of the "old timer" Alcor staff since he lived at the lab in Fullerton for nearly a year and half. He was a gentle, affectionate, obedience-trained dog who won over the heart of anyone who spent time with him. Buddy was also perfused with glycerol and placed into neurosuspension using techniques very similar to those employed in human cryonic suspensions.

Alcor now has roughly half as many companion animals in suspension as it has people. Why this should be so is not surprising. Animals can be awfully good company and can provide great emotional comfort in people's lives. Sadly, sometimes they are the most decent and nonjudgemental beings in a person's life. We have received criticism and been the butt of some media jokes because we have pets in suspension. Somehow it is seen as "flaky" or "eccentric" to have suspended a dog or cat. But this is not the case. If an animal represents a powerful value in a person's life, wanting to preserve that value is both understandable and healthy. Cryonic suspension for pets makes no less sense than

What does it Cost?

Having companion animals placed into cryonic suspension isn't inexpensive. Storage for animals can be as costly or more costly than storage for human patients. Generally speaking the storage cost for pet neurosuspensions can be assumed to be $7,500 per 1000 cubic inches. This figure includes long-term storage but does not include money for revival or contingencies. It is important to realize that the volume figure quoted here includes packaging of the animal. Thus, if we are working with a large canine head which consumes 80% of the volume of a standard human neurocan, the charge would be for the full volume of the neurocan (i.e., roughly 0.5 cubic foot = $7500. Charges for whole-body pet suspensions will be based only in part on the volume rule quoted above. Depending upon the mass and shape of the animal, additional charges may be levied. Thus, if one wanted to place a Bull-Mastiff into whole-body suspension, the cost would be considerably higher than the per-volume figures quoted for pet neurosuspensions, since one human whole-body slot would be used. This would greatly increase the cost. In the case of a hypothetical Bull-Mastiff the cost would be in the vicinity of $40,000.

Perfusion of pets is optional and varies in cost with the size of the animal. A variety of perfusion options are available. Generally speaking, costs for glycerol perfusion for neurosuspension can be assumed to be in the range of $750 to $1,500 and the cost for whole body perfusion from $1,500 to $2,500. These figures are tentative and will probably be revised as we gain experience.



Members contemplating suspension for pets are urged to contact us well in advance. We are giving consideration to creating a pre-need program similar to that in place for people. If you are interested in such a program, please call or write us and let us know. The feedback from the marketplace will be helpful in allowing us to determine if we should proceed.

medical care for pets.

But I believe there is another reason why members have chosen to place deeply loved pets in suspension. Of all the things you can take with you to comfort you in the future, nothing will be as powerful as a familiar face. Some cryonicists are working on *Lifepact* arrangements, trying to convey personal property into the future so they will not be alone and bereft of memories of the past. This seems a reasonable undertaking.

But it is not likely to be as effective as taking a loved one along who will be just plain glad to see you. Anyone who has lost a dog or cat understands well the emotional hole that is left when suddenly there isn't anyone sitting attentively by the door to welcome you home.

This journey that we cryonicists are set to embark upon is one with many anxiety-provoking unknowns. The vagaries of circumstance and law may separate husbands from wives, children from parents; temporarily or forever. We hope not. We plan not. But it is one of great ironies that cryonic suspension for pets is not being called illegal. It is perfectly acceptable to the state to freeze one's dog or cat. Similarly, pets entering suspension may do so under far more controlled and optimum conditions than people can. Indeed, euthanasia for pain-wracked and/or dying animals is considered almost mandatory: To fail to do to a dying animal what the law criminally punishes us to do to a dying human would be considered an unspeakable act of cruelty.

It's a strange world.

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A PET PROGRAM

Despite the fact that we have placed half as many pets in suspension as people, we do not have any kind of formal, structured program to do this: or even any comprehensive set of policies or procedures to guide us. We do restrict the suspension of pets to Alcor Suspension Members, but beyond that, we haven't given the matter much thought. We'd be especially interested in hearing from anyone who would be interested in taking on the responsibility of structuring a companion animal suspension program using the existing Alcor human suspension contract as a *very rough* starting point. Anyone interested in doing this should contact Mike Darwin at (714) 736-1703.

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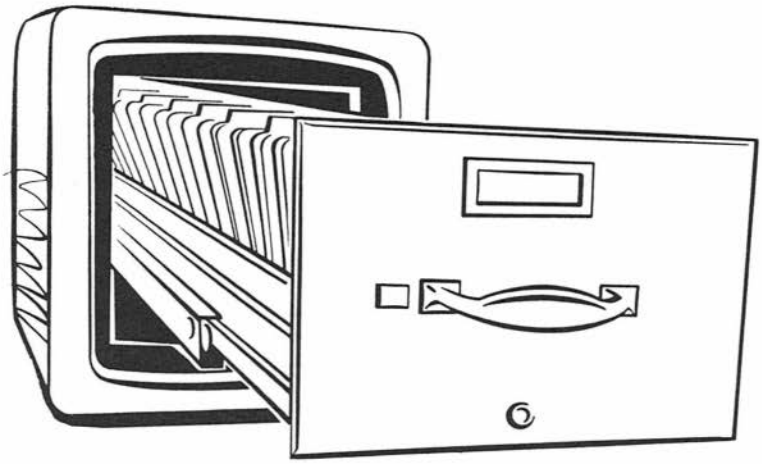
NOW WE'RE FIRE RESISTANT!

We have for some time provided fire protection for our neurosuspension patients (and once the legal battles subside will do so for our whole-body patients as well) and now we've extended that protection to suspension patient records and **member records.**

Remember all that dreadful paperwork you filled out? Remember that forklift load of documents you sent in to get suspension coverage? Have you thought about having to go through all that again? Well we have, and we've done what we can to protect all that work by purchasing fire-proof files. A few days ago virtually all of the Alcor membership records/suspension paperwork was loaded into top-of-the-line Meilink *Hercules* fire-resistant filing cabinets. The cabinets also have both combination and key locks to provide extra security for the documents. Patient records have been stored in fire-



resistant files for nearly a year.

Fortunately, we were able to obtain these files for a small fraction of the $1000 (each!) new purchase price. Two of the four four-drawer files purchased were obtained for $100 each, and two were obtained for $250. The files, although used, are in excellent condition.

Alcor thus becomes the first (and to our knowledge the only) cryonics organization to offer fire protection for suspension documents and patient records.

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LEGAL UPDATE

Well, if anyone thought government harassment of Alcor was over with, think again. In early September, we received word through a leak at the Board of Medical Quality Assurance (BMQA) that the Riverside County District Attorney's Office was preparing to file 19 counts of felony practice of medicine without a license against several Alcor Suspension Team members. The physician who accepted the anatomical gift on Dora Kent and who was her treating physician in the last days of her life was also reportedly going to be charged with "aiding and abetting the practice of medicine without a license".

What is interesting in all of this is that we have been told that a significant number of the 19 counts are for things done **after** Dora Kent was legally dead! Furthermore, we were informed by the Board of Medical Quality Assurance investigator handling the case that they intended to bring charges rela-

tive to cryonic suspensions where **independent** physicians first pronounced the patient legally dead before Alcor did anything! It appears that cryonics just got reclassified as medicine. That's the good news. The bad news is that we've all been practicing medicine without a license! Oh well, every silver lining must have a cloud.

It seems the California medical community wants to have it both ways. Even after they give up and pronounce you **dead** (a situation which normally rather abruptly ends the doctor-patient relationship!) anything *we* do to you is still considered medicine.

Do you ever get the feeling these folks just plain don't like us?

Well, as usual we didn't take it lying down. As the press release and newspaper articles which follow detail, we were in court yet again.

(Text cont'd on page 11)

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FOR IMMEDIATE RELEASE
Contact: Carlos Mondragon
(714)736-1703

ALCOR FILES SUIT TO BLOCK GOVERNMENT HARASSMENT

Current Action

Riverside, CA, Sept. 16th. On September 15th the Alcor Life Extension Foundation in Riverside, California filed a lawsuit against the District Attorney of Riverside County to attempt to force him to stop wasting the taxpayer's money on acts of harassment and terrorism against Alcor.

This action was taken because the California Board of Medical Quality Assurance has informed us that the Riverside County District Attorney is planning to file charges against Alcor for "practicing medicine without a license". This absurd charge is the latest in a series of immoral and unjustified attacks on Alcor and cryonics which were initiated by the Riverside County Coroner **over 21 months ago.**

This planned action by the District Attorney's office is a continuation of the malicious acts and systematic harassment begun by the Coroner's Office against innocent people. We feel it important to stop such acts not only for the peace of mind of Alcor members and for the safety and well being of the people in cryonic suspension which Alcor is caring for, but to stop needless waste of tax dollars on such persecution. Even now, the cost to the taxpayers as a result of these actions could amount to **millions of dollars.**

Background

The assault against Alcor began in January of 1988 when the Riverside County Coroner attempted to remove 83-year-old Dora Kent from cryonic suspension and autopsy her brain. Mrs. Kent had been placed into cryonic suspension because she believed that future medical technology might be able to restore her to life, health and youth. (Cryonics has been practiced in California for 23 years and has, in recent years, been gaining increasing support from scientists and physicians around the world.)

The search warrants that were obtained to enter the Alcor facility and remove Mrs. Kent from cryonic suspension on January 7th and 12th, were obtained by acts of perjury on the part of the Coroner. When the Coroner was challenged in court, he was unable to provide any evidence in support of his desire to autopsy her. A consequence of our legal action against the Coroner to block the autopsy of Mrs. Kent was the issuance of a Temporary Restraining Order prohibiting the destruction of Mrs. Kent, or any of the other patients being cared for by Alcor. This ruling is now a permanent order.

To attempt to desecrate anyone's remains is despicable. To attempt to do so to a woman who thought she might live again is even worse!

In the 21 months since the cryonic suspension of Dora Kent, Alcor has been systematically harassed and terrorized. We have been subjected to two raids during which records, furniture, personal property of staff members, and tens of thousands of dollars worth of computers and medical equipment were taken. We have been publicly accused of grand theft, (only to have all of the so-called "stolen" property returned to us) and of homicide! The reputation of the Alcor staff has been dragged through the mud, and the career of one Alcor staff member, Jerry Leaf (Alcor's Suspension Team Leader), formerly of the UCLA Medical Center, has been destroyed. Jerry was discharged from UCLA at the time of the Kent affair after 17 years of exemplary service and 13 years of outstanding work as a researcher in the Division of Thoracic Surgery.

We have been arrested and taken to jail hand-cuffed in front of television cameras and photographers. We have had a SWAT team deployed against us and been told that the very act of trying to save the lives of ourselves and our loved ones with cryonic suspension is illegal!

Why?

Now, nearly two years after the sensational charges of homicide, theft and brutality to Mrs. Kent have failed to materialize, the Riverside District Attorney has decided to accuse Alcor of the practice of medicine without a license. And what is more, to accuse us of doing so on people who have been pronounced legally dead by a duly licensed and independent physician. In fact, we have reliable information that an attempt was made by the District Attorney's Office to execute a search warrant, arrest staff and disrupt the cryonic suspension of TV comedy writer and producer Dick Clair, who was placed into suspension by Alcor on December 11th, 1988.

Why are such actions being taken? Why is Alcor being terrorized in this way? Why are we being forced to spend hundreds of thousands of dollars to defend ourselves? Why are the taxpayers of Riverside County and the State of California being forced to pay for such useless and destructive government action?

We wish we knew the answers to those questions. But, regardless of the reasons, regardless of the attempts of the District Attorney to destroy both Alcor and the practice of cryonics, **we've had enough.**

Isn't it time for this outrage to end? Isn't it time to stop wasting money on malicious acts against innocent people simply because you don't agree with them?

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INLAND ♦ The Sun
Empire

WEDNESDAY
September 20,
1989 ★★★

Cryonics laboratory loses bid to freeze investigation

By TONY SAAVEDRA
The Sun's Fontana Bureau

RIVERSIDE — A cryonics group that freezes the dead lost the first round Tuesday in its battle to kill an investigation by Riverside County prosecutors.

Riverside Superior Court Judge Robert J. Timlin refused to grant an emergency order protecting group members from being charged with practicing medicine without a license.

Timlin said there was no evidence that Alcor Life Extension Foundation would be harmed by waiting for a full hearing on Oct. 19.

The Riverside cryonics laboratory is suing District Attorney Grover C. Trask to block his office from charging Alcor members with illegally practicing medicine. The potential charges stem from the 1987 death of Dora Kent, an 83-year-old woman whose head was surgically removed and frozen in Alcor's Doherty Street lab.

During a hearing in the judge's chambers, Alcor attorney Christopher Ashworth argued that members were being persecuted by the threat of criminal charges.

"It's not dynamically any different from threatening to prosecute black people for voting or Scientologists for practicing their religion," Ashworth said.

Alcor members insist they have the constitutional right to be frozen after death in hopes of being resurrected by future technology — a process called cryonic suspension. The practice is dismissed as fantasy by most scientists, but supported by others.

To protect the civil rights of its members, Alcor should be allowed to perform whatever medical procedures are necessary — before or after death — to preserve the body, Ashworth said. Fear of prosecution could force Alcor members to renege on their contracts with people who wish to be frozen, he added.

"Something that may look like practicing medicine has got to be permitted to ease someone into cryonic suspension," Ashworth said.

Prosecutors argued that Alcor was staging an attempt to kill an ongoing criminal investigation into the group's alleged medical practices. There are no immediate plans to file the 19 charges recommended about a year ago by the state Medical Board of Quality Assurance, prosecutors said.

The medical-related charges were

See CRYONICS/B2

Continued from/B1

put on hold so prosecutors could concentrate on the long-running homicide investigation into Kent's death.

Charges of illegally practicing medicine stem from the 36-hour period that Kent spent at the laboratory before she died.

Robert G. Spitzer, supervising deputy district attorney, disputed that Alcor members have the constitutional right to sidestep medical law.

Spitzer also accused Ashworth and the cryonics lab of filing a frivolous suit that amounts to a publicity stunt. Another prosecutor called Ashworth "the Zsa Zsa Gabor of Riverside County."

If Alcor loses, Spitzer said he will ask that Ashworth and the cryonics firm be fined and ordered to reimburse the county for legal expenses.

Alcor members denied the case was à grab for media attention, saying that they want to end harassment by Riverside County authorities.

"It's costing us beaucoup bucks to defend ourselves against this kind of petty action," said Carlos Mondragon, Alcor president. He estimated the group has spent $120,000 to fight county officials, including a 1988 lawsuit that prevented the coroner from thawing Kent's head.

The latest suit has become a sideshow to the larger homicide case, which ran into a roadblock last month in appellate court. Justices ruled that Alcor members do not have to testify before the grand jury unless they receive full immunity, meaning that they can't be charged for Kent's death.

Spitzer said he is preparing to send the case to the state Supreme Court, hoping to get an order forcing the cryonics members to testify under limited immunity.

Under that plan, the witnesses still could be prosecuted, but their testimony cannot be used as evidence against them.

(Continued from page 8)

On the Immunity front, we won solidly (see the San Bernardino *Sun* article on the next page). Deputy D.A. Curt Hinman's performance was so bad in court it is hard to put into words. *Use immunity* can be considered a contractual agreement between prosecutors and witnesses. Mr. Hinman had considerable problems with this idea, insisting that his offer must be accepted by the Alcor witnesses, as would be the case with the broader, court-sanctioned *transactional immunity*. Finally, the presiding judge explained to him, "But they didn't agree to testify, Mr. Hinman. They told you to stick it in your ear." After which Hinman launched into another cycle of argument, as if repetition could make his point. And was again counseled by the judge as to where his offer for limited immunity had been placed. Eventually, the Court got tired of the repetition, and cut him off.

By contrast, Alcor *pro bono* attorney Ephriam Margolin performed beautifully. The decision by the Appellate Court mirrored his brief almost exactly.

Hinman, in a remarkable display of misplaced optimism (or desperation), asked the court for a rehearing. It was summarily denied. Seeking even more punishment, he has decided to appeal the decision to the Supreme Court of the State of California. One shudders at the thought of our tax dollars at "work" in this useless and destructive fashion.

Riverside
The Press-Enterprise
Saturday, August 26, 1989

Ruling halts action on frozen head case

By RONNIE D. SMITH
The Press-Enterprise

SAN BERNARDINO — An appellate court has ruled against prosecutors in a case related to the death of a woman whose head was frozen by a Riverside cryonics lab.

For now, the ruling on an immunity issue by the 4th District Court of Appeal in San Bernardino halts the homicide investigation of Alcor Life Extension Foundation by the Riverside County District Attorney's Office.

"Yes, we are dead in the water right now," said Riverside County Deputy District Attorney Curtis R. Hinman.

Hinman said a change in state law regarding immunity from prosecution is needed to get the case back on track.

He was unsure whether the ruling, released yesterday, would be appealed.

The criminal investigation of the death of 83-year-old Dora Kent began 1½ years ago after her son, Saul Kent of Woodcrest, said he took his ailing mother to the Alcor laboratory, where she died Dec. 11, 1987.

Alcor officials said her head was surgically removed and placed in sub-zero storage.

The unusual case propelled the obscure cryonics movement to national attention.

Devotees of cryonics say they freeze remains of the dead with the idea that once science finds a cure for whatever killed those people, they can be revived though cell re-generation procedures. Most scientists dismiss cryonics as fantasy.

After Kent's death, county coroner officials concluded that she had died from a lethal dose of barbiturates pumped into her body to prepare her for freezing. Alcor officials have insisted that Kent was dead when the drugs were administered.

Investigators are trying to find who administered the drugs and when.

They have focused on a dozen Alcor members, including Michael Federowicz, Alcor's research director, and Jerry D. Leaf, who worked in the division of thoracic surgery at UCLA and surgically removed the head.

The appellate decision released yesterday stemmed from a Riverside Superior Court judge's ruling in March. Judge Victor Miceli refused to force three Alcor members to testify with limited immunity before the grand jury.

Prosecutors had offered Hugh Hixon, R. Michael Perry and Scott Green limited federal-type immunity for their testimony about Kent's death and the freezing of her head.

The federal-type immunity, like that given to Col. Oliver North in the Iran-Contra affair, means a person cannot be prosecuted for what he says but nevertheless can be prosecuted.

The Alcor members refused to testify before the county grand jury. Miceli then ruled that that they could not be forced to testify unless given total immunity from prosecution as provided by state law.

State law allows what is called "transactional" immunity. Under it, once a witness testifies, he cannot be prosecuted at all.

Riverside prosecutors appealed Miceli's ruling and asked the three-judge appellate court to recognize the federal-type immunity in California. Prosecutors said such immunity would be an added tool in fighting crime.

Associate Justice Thomas Hollenhorst, in writing the appellate opinion — which can be cited as existing law — stated that the state penal code does not recognize the federal-type immunity.

"We therefore conclude the trial court (Miceli) was correct in its finding that the order to compel testimony must be accompanied by a grant of transactional immunity as provided in the statute," he wrote.

Hollenhorst is a former Riverside Superior Court judge and Riverside County assistant district attorney. He was joined in the opinion by Justice Howard M. Dabney, a former Riverside assistant district attorney, and Joseph Campbell, the presiding justice.

An Alcor official said he was pleased by the ruling but it was irrelevant.

"Their investigation has always been dead in the water because there has never been any guilty people around here and there was never a crime," said Carlos Mondragon, president of Alcor.

He said Alcor has a dozen people in sub-zero storage. Mondragon said the last freezing, a 71-year-old physician from the Midwest, occurred in April.

In a related matter, Mondragon said Alcor is still waiting to receive about $3 million from the estate of Emmy Award-winning television writer Richard C. Jones, who left Alcor half of his $10 million estate last December. Jones' frozen body is at Alcor

Cryonics in Europe

by Saul Kent

Bill Faloon, Jo Ann Martin, and I recently spent about 16 days in Europe. One reason for our trip was to make arrangements to set up *The Reanimation Foundation*, a charitable foundation in Liechtenstein that will enable members to invest the money they'd like to take with them when they are placed in cryonic suspension. This is possible in Liechtenstein because they have no *Rule Against Perpetuities*, unlike the United States and most other countries. You'll be hearing more about *The Reanimation Foundation* in the future.

Another reason was to meet cryonicists in Europe. We were unable to go to Austria, where Dr. Ernst Fasan, an attorney whom I had met previously, resides. But we did travel to Munich, Germany, where we met with Petr Bucur-Volk. Since there was recently a report by Mike Darwin (*Cryonics*, April, 1989) in which he discussed cryonics in Europe in depth, I'll just discuss it briefly in this article.

Petr -- who is quite knowledgeable about a broad range of subjects -- told us how his interest in cryonics developed and about the others in his country who would very much like to see cryonic services available in Europe. The problem in Germany is that the four people interested in such services are scattered throughout the country and none of them currently has enough money to promote cryonics effectively.

Nevertheless, if the vigor and intelligence that Petr exhibited is shared by his German colleagues, the future of cryonics in Germany will be a bright one.

A Visit To France

I was looking forward to meeting with Anatole Dolinoff, whom I had corresponded with in the 1960s, and I wasn't disappointed. Dolinoff, his wife Elisabeth, his mother Raisa, and their six dogs proved to be warm and friendly hosts. I was also impressed with the youthful vigor of his mother, who is over 90 and as active as anyone I've ever seen at that age.

The most important subject I discussed with Dolinoff was his notion that cryonics is "illegal" in France because of a decree imposed by Jean-Marcel Jeanneney, that country's Minister of Health, in April, 1968. Dolinoff kept on insisting that -- even today -- this decree has the power of law in France, but I refuse to believe that its 60 million citizens are to be denied their right to cryonic suspension because of a few words by a petty bureaucrat more than 20 years ago.

I finally got Dolinoff to find a copy of this anti-cryonics polemic in his voluminous, but fragmented, files, that are balanced precariously on a ledge on the second story of his house. I intend to have this copy translated into English and will then show it to an attorney in this country with a knowledge of French law.

If it turns out that the decree actually does have the force of law in France, we'll start looking for a strategy to challenge it effectively. If it does not, we'll attempt to find out how attractive cryonics is to the French. It could be very attractive. In the late 60s, when Dolinoff was active in the *Cryonics Society of France*, they had the largest group of cryonicists outside the United States. Dolinoff showed me several of their publications, which rekindled memories of the past. He also showed me a mailing list of 250 people who had expressed interest in cryonics at that time.

External view of English facility now being constructed

* * *

We also met Luigi Warren, an English cryonicist, who was in Paris attending a Libertarian convention, and spent an evening with him. Luigi has spent considerable time in the U.S., and has a wide-ranging acquaintance with cryonics and cryonicists on both continents. He whetted our appetite for our impending visit to England, where we had heard that Alan Sinclair was in the process of putting up a cryonics facility.

The New Facility In England

The facility in England will be housed in a new industrial building that is currently under construction in an area near the English Channel, about 40 miles south of London. It is quite near Sinclair, who will be financing it out of his own pocket.

When the building is completed, Alan plans to construct the interior walls to provide working space for cryonic suspension services and research, and then to start purchasing equipment and supplies from us in the United States. We also discussed the possibility of a training session, directed by Alcor personnel, to be held at the facility after it's completed. Everyone thought it would be a good idea to invite one or more of the German cryonicists to this training session.

We were driven to the new facility by Garrett Smyth and Mike Price, two Alcor Suspension Members who were among the founders of *Mizar*, the company that was formed in England to help promote cryonics. Later in the day, we were joined by Andrew Blackall and a friend of his interested in cryonics.

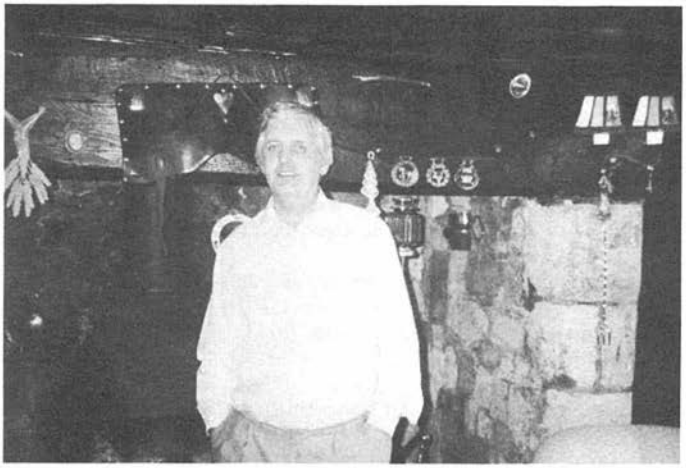
A Possible Conference

I also discussed the possibility of holding a European Cryonics Conference, in

September, 1990. If this conference comes off, it will probably be held in England, close enough to the new cryonics facility to permit a tour of it.

Such a conference would permit cryonicists from all the European countries to meet and would also be a good opportunity for Americans to meet their European brethren. It could also be used to promote cryonics throughout Europe in an effort to recruit new members.

Alan Sinclair



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Why Suspension Members Should Videotape Their Wishes

by Saul Kent

Shortly after Dick Jones (The TV producer suspended by Alcor in December, 1988) found out he had AIDS (in 1986), he wanted to make a videotape about his wishes regarding cryonics "while he was still lucid and rational". But he repeatedly put off doing so because he "didn't look good enough" and wanted to get better before appearing before the camera.

His plan backfired. Instead of getting better, he got worse. By the time he got over his concern about how he looked, he was very weak and his mental condition had deteriorated significantly. The videotape was never made.

At the end, Dick was victimized by his sister, Claire Martin, his business partner, Jenna McMahon, and attorney Barrett McInerney. The three of them conspired to get his signature on new legal documents to radically change his estate plan 56 hours before he died.

When Dick was rational, he said repeatedly that he didn't trust Jenna or his sister Claire and that he didn't want them, or anyone else, to have any of his money. He even set up two trusts to make sure it was absolutely clear what was going to his family and what was going to Alcor.

If Dick had made the video he had planned to make, it might have stopped his scheming sister in her tracks. If he had said on videotape what he had frequently said about Claire in real life, she might never have had the guts to steal his money. And if she had still tried, the video might have swayed the judge (presiding over the ensuing court fight

over Dick's estate) in our favor.

Alcor Will Fight For Your Rights

We have to learn a lesson from what happened to Dick Jones. Don't expect the best of people around you, even people you think are on your side. Sometimes a person changes radically when you're no longer strong enough or sharp enough to influence them. And even if you're fortunate enough to be able to control their actions while you're still alive, you'll lose all control over them when you are in suspension.

This is especially true for wealthy people. Henry Ford II took tremendous pains to prevent a court fight over his estate after he died. He failed: as soon as he died, his relatives were at each other's throats. There was so much fighting over J. Paul Getty's money after he died that, at one hearing, there were 400 attorneys (representing various relatives) jousting with each other in the courtroom.

In your case, things will be even more complicated because you want to be suspended, rather than buried or cremated. If your relatives are generally opposed to cryonics, they could wind up united against your wishes (at least on that issue) even as they continue to fight over your money.

But you'll have Alcor on your side no matter what. Alcor will fight for your rights more vigorously than anyone, even the attorney for your estate. We'll even fight your attorney if he turns on you. Once you're in suspension, you see, we may be the only ones who really think you have any rights at all!

Taking Preventive Measures

The best strategy is to take as many protective measures as possible while you're still lucid and in good health. Preventing a potential problem is always easier, less expensive, and more effective than depending on others to cure it.

One measure that is quite useful is to make a videotape of your wishes regarding your cryonic suspension and reanimation, and to update this tape on a regular basis. This will provide Alcor and your attorneys with clear-cut evidence that you were in your right mind when you executed your legal documents and that your wishes were long-standing.

A videotape provides far better proof of your sanity in choosing cryonic suspension than written documents because it enables the audience to see (and hear) for itself what shape you were in at the time and how strongly and passionately you felt about your wishes.

The Power Of Greed

The making of a videotape will help to protect you against *anyone* who tries to steal your money, not just your relatives, friends, and business associates. Your biggest enemy could turn out to be a creditor, a government agency, or even a foreign government. Sometimes people have enemies they didn't even know they had, especially if they have a lot of money.

One lesson we learned in the Dick Jones case is that greed is even more powerful than we thought it was. Claire Martin was clearly intimidated by Alcor's attempts to protect

Dick against her. On two occasions, she was almost stopped. but, in the end, greed won out. Dick simply had too much money for her to give up.

Anyone Is A Possible Enemy

Another lesson we learned in the Dick Jones case is that greed can transform otherwise nice people into dirty "streetfighters". Claire Martin was (and is) a nice, intelligent, entirely respectable person. She probably never acted before as she did in stealing Dick's money, and she'll probably never act that way again. Under different circumstances, I probably would have gotten along very well with her and enjoyed her company greatly.

Dick liked his sister Claire a good deal, far more than his other sisters (who had died years before). He had been quite close to her in childhood, and had always gotten along well with her throughout his life. Although she had ceased to be an important part of his life for many years, he still kept in touch and felt kindly toward her.

This may have been his undoing. If his other sisters had been alive, he would have been more on guard. Perhaps he would have taken measures that would have stopped them (and Claire) in their tracks when they attempted to attack his estate.

But Claire was so "nice" and "sweet" that he never really thought she was capable of acting like a common thief. Claire probably never thought so either, till it happened. And probably has completely rationalized her actions.

Videotaping For Reanimation

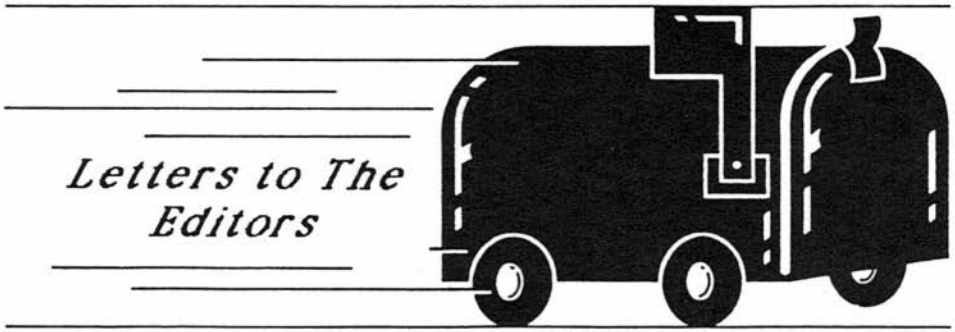
Another reason Alcor members may want to make videotapes is to provide information for attempts to reanimate them after they are in suspension. If it turns out there is a problem in re-establishing your identity during reanimation, every bit of information about you will help. The more future doctors know about who you were and what you wanted, the easier it will be for them to reconstruct your identity.

What is needed here is autobiographical material. There's probably nothing better for this purpose than a videotape that shows how you look and act. When you talk about yourself on videotape, it's more revealing than anything you write about yourself, because the camera shows *how* you say things, not just what you say. Moreover, in talking about yourself, you're more likely to reveal yourself as you really are, rather than when you express your thoughts in a stylized medium such as writing.

A New Service From Alcor

Alcor now offers videotaping to its members. The cost of this service is $35 per half hour, with a $35 minimum. The first opportunity for Alcor members to make videotapes will will be at the annual Turkey Roast on Sunday, Dec. 3, 1989, which will be at the home of Saul Kent and Jo Ann Martin, at 16280 Whispering Spur in Riverside.

A special room will be set aside for this service. Members will be offered guidance in making videotapes to protect their wishes regarding cryonic suspension, and it will also be possible to tape autobiographical material. Anything said on videotape will be private and confidential and will only be revealed to the Alcor personnel involved in this project.



Dear Editors:

With improved survival from heart disease and cancer, the likelihood of developing some kind of brain disease in old age has increased. Also, for some members of Alcor there must be a significant likelihood of developing psychosis or other disease in which their judgement is impaired and they may not act in their best interests. The onset of these illnesses is often insidious, and considerable damage could be done to suspension arrangements befor they would be declared legally unfit to manage their own affairs. The recent problem with Dick Jones' estate is a case in point.

I was wondering what we can do *now* to improve our standing in such circumstances? The libertarian attitudes of many cryonicists may be inimical to the interests of people who sever their ties with cryonics while in a state of mind which distorts personality and judgement.

In a recent discussion with two cryonicists who are proponents of libertarianism, one advocated a non-interventionist attitude to people who, while not hurting others, were behaving in a manner dangerous to themselves. He appeared not to understand the insidious nature of brain diseases which may change personality and emotion and leave "rational" faculties intact so that their actions can be defended with appearent reason. An abstract idea of "rights" was invoked to justify this. Thus I am led to observe, from experience, that the "rights" of a brain tumour patient vary with the location of the tumour. The patient with a tumour that causes violence had some chance of being cured -- he was lucky enough to threaten others and be hospitalized. The one with the tumour which caused apathy and neglect, so he refused an operation, died, his "rights" respected.

The other cryonicist stated that libertarian societies are tough and don't tolerate weakness -- can we look forward to an absence of medicine in the future? Or is this a selective discrimination against brain disease? I think such a society would suffer a diminution of creativity. If we extend the idea -- well, isn't cryonics for the weak? but this is an aside. It is the attitude that concerns me.

I am thinking about this problem. I am aware that in this small space I have stated it simplistically -- for instance, what about those who do not have brain disease and decide against cryonics? Sanity is a murky issue. I don't want to force existence on anyone, but want to be protected from situations such as those described above. I welcome ideas. We shouldn't remain smug in our sanity -- who knows what lies ahead?

Sincerely,
Cath Woof
Sunnyvale, CA

To the Editors:

On page 5 of *Cryonics*, June, 1989, Alcor president Carlos Mondragón asked for input on Alcor providing for the concerns raised by LIFEPACT. I have a question.

Before cryonicist Richard Clair Jones was put into cryonic suspension, he stored a lot of mementos of his life, in case they might be needed for future memory stimulation upon his revival. And now LIFEPACT is thinking of setting up a Museum-Library for revocable donations of personal property for cryonicists (personal items and financial resources).

"Taking it with you" seems to be a common concern among many cryonicists, including myself.

Is Alcor planning to set up a storage facility, an "Alcor Memory Bank", so that cryonicists signed up with Alcor could each bring into the future, say, even a 3'x3' box of some personal items and financial resources?

David G. Johnson
Higganum, CT

David -- Yes we are, and there will be more on this in the future. --MD

* * *

Dear Editor:

Dave Pizer

Thank you for the very flattering article in the July issue of *Cryonics*. However, you have given me too much credit. As far as I know, the Pizer Tank was originally Mike Darwin's idea. He designed it, and although I did add a few finishing touches, he deserves the credit for most of it.

The first tank was assembled by my employee, Ron Nickels, who may be considering cryonics for himself someday. Ron worked off Darwin's drawings and a few of my suggestions and some of the input were his.

The newer, more refined versions were built by *Fitwell* manager and newest Alcor Suspension Member Don Ward, and *Fitwell* Master Trimmer Russ Wailand. Don supervised Russ, who did most of the work and who is very skilled at upholstery and has other talents in arts and crafts.

The Pizer Tanks are therefore mostly the products of these other individuals. All I did was minor facilitation and supply the money.

Sincerely,
David Pizer
Fitwell Manufacturing
Phoenix, AZ

* * *

Dear Sirs:

I have just returned from a trip to Germany. I read back-issues of *Cryonics*, including Mike Darwin's comments on Europe and Germany. I was also in Asia this summer. I assure you, if one of those two overtakes us (U.S.), it won't be Germany -- especially with their tribal altruistic attitudes.

By the way -- I certainly hope Alcor will suspend me for the money. I hope Alcor will make lots of bucks by freezing me; if Alcor members are not greedy and are apologetic to some alturistic Europeans, then there is no hope -- some "saint" may end up thawing me out "for the good of society".

Sincerely,
Krzysztof Ostaszewski
Louisville, KY

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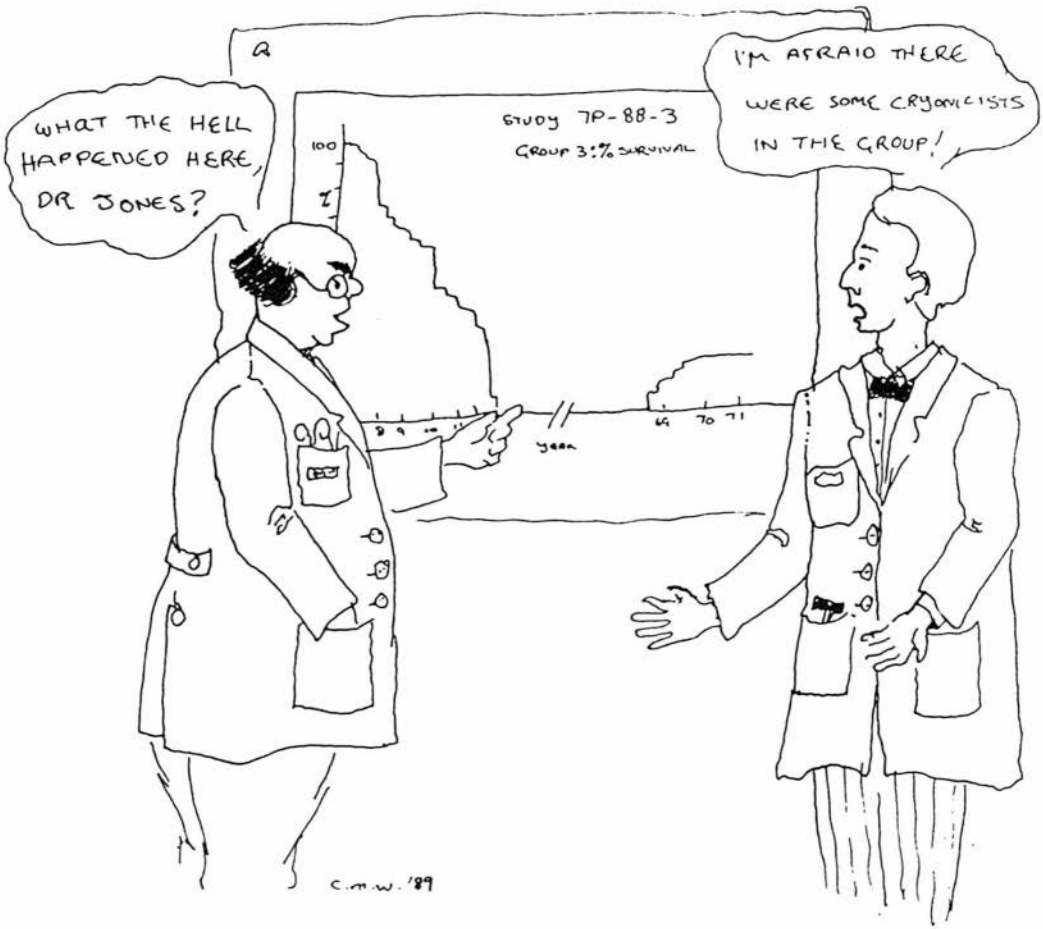

Molecular Repair Of The Brain

by
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Xerox PARC
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Palo Alto, CA 94304
merkle@xerox.com

INTRODUCTION

Tissue preserved in liquid nitrogen can survive centuries without deterioration [22,42]. This simple fact provides an imperfect time machine that can transport us almost unchanged from the present to the future: we need merely freeze ourselves in liquid nitrogen. This might at first seem unwise: being frozen is bad for your health -- at least today. Perhaps, however, this condition might someday be cured, which would permit time travel to the era when the cure was available. While perhaps unappealing to the healthy, this possibility is more attractive to the terminally ill, whose options are somewhat limited. Far from being idle speculation, this option is in fact available to anyone who so chooses. Three organizations in the U.S. now provide such "cryonic suspension" services.

Perhaps the most important question in evaluating this option is its technical feasibility: Will it work?

Given the remarkable progress of the past few centuries, it is difficult to dismiss cryonics out of hand. The structure of DNA was unknown prior to 1953; the chemical (rather than "vitalistic") nature of living beings was not appreciated until early in the 20th century; it was not until 1864 that spontaneous generation was put to rest, when Louis Pasteur demonstrated that no organisms emerged from heat-sterilized growth medium kept in sealed flasks; and Sir Isaac Newton's *Principia* established the laws of motion in 1687, just over 300 years ago. If progress of the same magnitude occurs in the next few centuries, then it becomes difficult to argue that repair of frozen tissue must inherently remain infeasible.

Hesitation to dismiss cryonics is not a ringing endorsement, and still leaves the basic question in considerable doubt. Perhaps a closer consideration of how future technologies might be applied to the repair of frozen tissue will let us draw stronger conclusions -- in one direction or the other. Ultimately, cryonics will either: (a) work, or (b) fail to work, and it would seem useful to know in advance which of these two outcomes to expect. If it can be ruled out as infeasible, then we need not waste further time on it. If it seems likely that it will be technically feasible, then a number of non-technical issues should be addressed in order to obtain a good probability of overall success.

The reader interested in a general introduction to cryonics is referred to other sources [23,24]. Here, we focus on technical feasibility.

Given the nature of the damage caused by cryonic suspension, any technology capable of reversing it might well have to go through the damaged structure molecule by molecule. Such molecular repair should be possible with nanotechnology. We will not consider the feasibility of nanotechnology here -- this issue is considered elsewhere [1,2,3,4,5,6,7,8,10,19,41]. We will give a brief introduction to nanotechnology, and will then clarify the technical issues involved in applying it to the repair of damaged tissue.

NANOTECHNOLOGY

Broadly speaking, the central thesis of nanotechnology is that almost any chemically stable structure that can be specified can in fact be built. This possibility was first advanced by Richard Feynman in 1959 [4] when he said: "The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom." (Feynman won the 1965 Nobel prize in physics.)

Recently Drexler [1,10,19,41] has made more specific proposals about how such molecular manipulation might be done. In particular, Drexler has proposed the assembler, a small device resembling an industrial robot which would be capable of holding and positioning reactive compounds in order to control the precise location at which chemical reactions take place. This general approach should allow the construction of large, atomically precise objects by a sequence of precisely controlled chemical reactions.

Ribosomes

The plausibility of this approach is perhaps best illustrated by the ribosome. Ribosomes manufacture all the proteins used in all living things on this planet. A typical ribosome is relatively small (a few thousand cubic nanometers) and is capable of building almost any protein by stringing together amino acids (the building blocks of proteins) in a precise linear sequence. To do this, the ribosome has a means of grasping a specific amino acid (more precisely, it has a means of grasping a specific transfer RNA, which in turn is chemically bonded by a specific enzyme to a specific amino acid), of grasping the growing polypeptide, and of causing the specific amino acid to react with and be added to the end of the polypeptide [14].

The instructions that the ribosome follows in building a protein are provided by mRNA (messenger RNA). This is a polymer formed from the four bases; adenine, cytosine, guanine, and uracil. A sequence of several hundred to a few thousand such bases codes for a specific protein. The ribosome "reads" this "control tape" sequentially, and acts on the directions it provides.

Assemblers

In an analogous fashion, an assembler will build an arbitrary molecular structure following a sequence of instructions. The assembler, however, will provide three-dimensional positional and full orientational control over the molecular component (analogous to the individual amino acid) being added to a growing complex molecular structure (analogous to the growing polypeptide). In addition, the assembler will be able to form any one of several different kinds of chemical bonds, not just the single kind (the peptide bond) that the ribosome makes.

It seems unlikely that an assembler must inherently be very large. Enzymes "typically" weigh about 100,000 amu's (atomic mass units), while the ribosome itself is about 3×10^6 amu's [14]. The smallest assembler might be a factor of ten or so larger than a ribosome. Current design ideas for an assembler are somewhat larger than this: cylindrical "arms" about 100 nanometers in length and 10 nanometers in diameter, rotary joints to allow arbitrary positioning of the tip of the arm, and a worst-case positional accuracy at the tip of perhaps 0.1 to 0.2 nanometers, even in the presence of thermal noise [18]. Even a solid block of diamond as large as such an arm weighs only sixteen million amu's, so we can safely conclude that a hollow arm of such dimensions would weigh less. Six such arms would weigh less than 10^8 amu's.

The assembler requires a detailed sequence of control signals from some outside source, just as the ribosome requires mRNA to control its actions. Such detailed control signals can be provided by a computer. A feasible design for a molecular computer has been presented by Drexler [2,19]. This design is mechanical in nature, and is based on sliding rods that interact by blocking or unblocking each other at "locks." This design has a size of about five cubic nanometers per "lock" (roughly equivalent to a single logic gate). Quadrupling this size to 20 cubic nanometers (to allow for power, interfaces, and the like) and assuming that we require a minimum of 10,000 "locks" to provide minimal control results in a volume of 200,000 cubic nanometers (0.0002 cubic microns) for the computational element. Assuming that each cubic nanometer is occupied by roughly 100 atoms of carbon, this 2×10^5 cubic nanometer computer will have a mass of about 2×10^8 amu's.

An assembler might have a kilobyte of high speed (rod-logic based) RAM, and 100 kilobytes of slower but more dense "tape" storage, and might have a mass of 10^8 amu's. Some additional mass will be used for communications (sending and receiving signals from other computers) and power. In addition, there will probably be a "toolkit" of interchangable tips that can be placed at the end of the assembler's arm. When everything is added up, a small assembler, with arms, computer, "toolkit," etc., should weigh less than 10^9 amu's.

Feynman said: "The problems of chemistry and biology can be greatly helped if our ability to see what we are doing, and to do things on an atomic level, is ultimately developed -- a development which I think cannot be avoided." The assembler is the smallest embodiment of this dream.

A repair device is an assembler which is specialized for repair of tissue in general, and frozen tissue in particular. We assume that a repair device also has a mass of 10^9 amu's.

Cost

One consequence of the existence of assemblers is that they are cheap. Because an assembler can be programmed to build almost any structure, it can in particular be programmed to build another assembler. Thus, self-reproducing assemblers should be feasible, and in consequence the manufacturing costs of assemblers would be primarily the cost of the raw materials and energy required in their construction. Eventually, the price of assemblers (and of the objects they build) should be no higher than the price of other complex structures made by self-replicating systems. Potatoes -- which have a staggering design complexity involving tens of thousands of different genes and different proteins directed by many megabits of genetic information -- cost well under a dollar per pound.

MATTER AND THE BRAIN

We make the simplifying assumption that only the brain will require repair at the atomic and molecular level. Although we could require repair of the entire body one molecule at a time, this seems unnecessary. Faithfully repairing each and every molecule of the liver appears to offer no benefit over simpler techniques -- such as replacement. The calculations and discussions that follow are therefore based on the size and composition of the brain. They could be extended in the obvious way to the rest of the body for those who feel molecular repair of such secondary tissue is essential.

The brain, like all the familiar matter in the world around us, is made of atoms. It is the spatial arrangement of these atoms that distinguishes an arm from a leg, the head from heart, and sickness from health. This view of the brain is the framework for our problem, and it is within this framework that we must work. Our problem, broadly stated, is that the atoms in a frozen brain are in the wrong places. We must put them back where they belong if we expect to restore the natural functions of this most wonderful organ.

While we could view this statement as simply a broad philosophical truism, we can also take it quite literally. Viewed thus, it raises three major questions: how can we tell where the atoms are; how can we tell where they should go; and how do we go about moving them from the former location to the latter?

Rather than consider these questions at once, we shall instead first consider a simpler problem: how would we go about describing the position of every atom if somehow this information was known to us? This answer will let us better understand the harder questions.

Each atom has a location in three-space that we can represent with three coordinates: X, Y, and Z. Atoms are usually a few tenths of a nanometer apart. If we could record the position of each atom to within 0.01 nanometer, we would know its position accurately enough to know what chemicals it was a part of, what bonds it had formed, and so on. If the brain is roughly 0.1 meters across, then 0.01 nanometers represents one part in 10^{10}. That is, we would have to know the position of the atom in each coordinate to within one part in ten billion. A number of this size can be represented with about 33 bits. There are three coordinates, X, Y, and Z, each of which requires 33 bits to represent, so the position of an atom can be represented in 99 bits. An additional few bits are needed to store the type of the atom (whether hydrogen, oxygen, carbon, etc.), bringing the total to slightly over 100 bits. While we could argue that some additional information might be required (ionization state, for example) the grand total will still be about 100 bits -- a conveniently round number.

Thus, if we could store 100 bits of information for every atom in the brain, we could fully describe its structure in as exacting and precise a manner as we could possibly need. A memory device of this capacity appears to be quite literally possible. To quote Feynman [4]: "Suppose, to be conservative, that a bit of information is going to require a little cube of atoms 5 x 5 x 5 -- that is 125 atoms." This is indeed conservative. Single-stranded DNA already stores a single bit in about 16 atoms (excluding the water that it's in). It seems likely we can reduce this to only a few atoms [1], but even if we assume that the laws of chemistry inherently require 10 atoms to store a single bit of information, we still find that the 100 bits required to describe a single atom in the brain can be represented by about 1000 atoms. Put another way: if we encode the position of an atom in other atoms, we inflate the number of atoms we need by perhaps as much as 1000. If we encoded the location of every atom in the brain, we would need 1000 times as many atoms to hold this encoded data as there are atoms in the brain. This means we would require roughly 1,000 times the volume. The brain is somewhat over one cubic decimeter, and so it would require somewhat over one cubic meter of material to encode the location of each and every atom in the brain.

While this much memory is remarkable by today's standards, it appears inevitable that at some time in the future it will be feasible. That is, it will literally be possible to store a description of each and every atom in the brain in a memory device that we will be able to build.

While such a feat is remarkable, it is also much more than we need. The title of

this paper is "*Molecular Repair Of The Brain*," not "*Atomic Repair Of The Brain*." Chemists do not often think of atoms by themselves, they usually think of them in groups -- called molecules. For example, water is a molecule made of three atoms: an oxygen and two hydrogens. If we describe each atom separately, we will require 100 bits to describe each atom, or 300 bits. If, however, we give the position of the oxygen atom and give the orientation of the molecule, we need: 99 bits for the location of the oxygen atom plus 20 bits to describe the type of molecule ("water", in this case) and perhaps another 30 bits to give the orientation of the water molecule (10 bits for each of the three rotational axes). This means we can store the description of a water molecule in only 150 bits, instead of the 300 bits required to describe each atom. (The 20 bits to describe the type of the molecule can be used to describe up to 1,000,000 different molecules -- many more than are present in the brain).

As the molecule we are describing gets larger and larger, the savings in storage gets bigger and bigger. A whole protein molecule will still require only 150 bits to describe, even though it is made of thousands of atoms.

We can do even better: the molecules in the brain are all bunched in next to each other. Having once described the position of one, we can describe the position of the next molecule as being such-and-such a distance from the first. If we assume that two molecules are within 10 nanometers of each other (a reasonable assumption) then we need only store 10 bits of "delta X," 10 bits of "delta Y," and 10 bits of "delta Z" rather than 33 bits of X, 33 bits of Y, and 33 bits of Z. This means our molecule can be described in only 10+10+10+20+30 or 80 bits.

We can compress this further by using various other clever strategems (50 bits or less should be quite achievable), but the essential point should be clear. We are interested in molecules, and describing a molecule is much easier than describing an atom.

A further point will be at once clear to any biologist. Describing the exact position and orientation of a hemoglobin molecule within a red blood cell is completely unnecessary. Each hemoglobin molecule bounces around within the red blood cell in a random fashion, and it really doesn't matter exactly where it is, nor exactly which way it's pointing. All we need do is say, "It's in that red blood cell!" So, too, for any other molecule that is floating at random in a "cellular compartment." We need only say which compartment it's in. For most molecules that are "membrane bound," i.e., are part of the cell wall or are in some other lipid membrane, it likewise does not matter where in the membrane they are. The lipid membrane is a "two dimensional fluid" because molecules in the membrane are free to move about to other places in the membrane (though they usually can't escape from the membrane). Just as we need only describe a hemoglobin molecule as being in a red blood cell, so too we need only describe most membrane-bound proteins as being in the membrane.

How much further does this reduce our storage requirements? Quite a bit. Can we go even further? Yes, but only if we first address some profound philosophical questions. Could we, perhaps, describe an entire cell with only a sketchy description of the function it needs to perform? Could we describe an entire group of cells in terms of their high-level function, omitting all "unnecessary" detail?

To avoid a lengthy digression into such philosophical issues we will, for purposes of this paper, adopt the narrowest possible philosophical stance about successful tissue repair. We require that repair restore the molecules of the brain to their original positions. We neglect a modest amount of change in molecular structure during the repair process as being unavoidable and insignificant. The molecular structure of the human brain is in a constant state of change during life -- molecules are synthesized, utilized,

and catabolized in a continuous cycle. Cells continuously undergo slight changes in morphology. Changes of a similar magnitude introduced by the repair process can reasonably be viewed as insignificant.

We must ask if changes in molecular structure introduced by cryonic suspension itself are of such an extent that they would block faithful repair at the molecular level. It seems unlikely that freezing damage causes sufficient disruption to obscure the molecular structure. Cryonic suspension "almost" works. Many tissues have been frozen to liquid nitrogen temperatures and, upon re-warming, have functioned correctly (including early-stage human embryos -- now healthy children). It seems unlikely that repair of frozen tissue will prove infeasible for this reason. We will discuss this issue further after a more detailed description of the repair process, and in the next section will explicitly discuss the probable impact of freezing on human memory.

Our philosophical criteria are quite fastidious. It is not at all obvious that the preservation of awareness, consciousness, and "self" requires the physical repair or even the preservation of the brain [11,12]. Although the brain is made of neurons, synapses, protoplasm, DNA, and the like, most modern philosophers of consciousness view these details as no more significant than hair color or clothing style. An "artificial brain" that was functionally the same as the more conventional biological design would still house a living, conscious human being [15, page 36].

While molecular repair is technically more difficult than the construction of an artificial brain, it should be more generally acceptable. Most people accept the idea that restoration of the brain to a healthy state in a healthy body is a desirable objective.

Another issue is not so much philosophical as emotional. Major surgery is not a pretty sight. There are few people who can watch a surgeon cut through living tissue with equanimity. So, too, with molecular repair. If we intend to examine and repair every major molecule in the brain, then we must gain access to them, remove them from their surrounding matrix, examine their structure, determine if repair is required, make the repair to the isolated molecule, and then return the molecule to its proper position. The mechanics of this process might make the strongest queasy. Yet, as with surgery, we must judge the process by the final result -- the restoration to complete health of a human being.

The reaction of "Bones" McCoy, the (rather conservative) doctor aboard the starship *Enterprise* in the "*Star Trek*" television series, might be common. As he described the transporter: "That's a heck of a way to travel, scattering your molecules all over space." Despite his opinion, the good doctor appeared none-the-worse for wear following his excursions, for the transporter faithfully restored his structure down to the last scattered molecule. While the repair process we will describe here is not as exact as the fictional transporter, the basic idea is the same. We take each molecule and put it back where it belongs.

MEMORY

It is reasonable to ask whether the important structural elements underlying human memory and human personality are likely to be preserved by cryonic suspension. Clearly, if human memory is stored in a physical form which is destroyed by freezing, then cryonic suspension won't work. In this section we briefly review what is known about memory, and whether known or probable mechanisms are likely to be preserved by freezing.

To see the Mona Lisa or Niagara Falls changes us, as does seeing a favorite television show or reading a good book. These changes are both figurative and literal, and it is is the literal (or neuroscientific) changes that we are interested in: what are the physical alterations that underlie memory?

Briefly, the available evidence strongly supports the idea that memory is stored by alterations in the synapses between nerve cells.

> Shepherd in "*Neurobiology*" [38, page 547] said: "The concept that brain functions are mediated by cell assemblies and neuronal circuits has become widely accepted, as will be obvious to the reader of this book, and most neurobiologists believe that plastic changes at synapses are the underlying mechanisms of learning and memory."
>
> Kupfermann in "*Principles of Neural Science*" [13, page 812] said: "Because of the enduring nature of memory, it seems reasonable to postulate that in some way the changes must be reflected in long-term alterations of the conections between neurons."
>
> Alkon, in "*Memory Storage and Neural Systems*," [35] says: "The formation of associative memories appears to involve a sequence of molecular changes at specific locations in systems of neurons."
>
> Lynch, in "*Synapses, Circuits, and the Beginnings of Memory*" [34, page 3] said: "The question of which components of the neuron are responsible for storage is vital to attempts to develop generalized hypotheses about how the brain encodes and makes use of memory. Since individual neurons receive and generate thousands of connections and hence participate in what must be a vast array of potential circuits, most theorists have postulated a central role for synaptic modifications in memory storage."
>
> Greenough and Bailey in "*The anatomy of a memory: convergence of results across a diversity of tests*" [39] say: "More recently it has become clear that the arrangement of synaptic connections in the mature nervous system can undergo striking changes even during normal functioning. As the diversity of species and plastic processes subjected to morphological scrutiny has increased, convergence upon a set of structurally detectable phenomena has begun to emerge. Although several aspects of synaptic structure appear to change with experience, the most consistent potential substrate for memory storage during behavioral modification is an alteration in the number and/or pattern of synaptic connections."

It seems likely, therefore, that human memory is encoded by changes in synaptic structure. Sometimes this encoding involves the presence or absence of a synapse, and other times it involves structural and functional changes to an existing synapse.

What, exactly, might these changes be? Very strong statements are possible in simple "model systems". Bailey and Chen, for example, actually recovered learned memories from sea slugs (*Aplysia californica*) by direct examination of the changed synapse with an electron microscope [36].

> "Using horseradish peroxidase (HRP) to label the presynaptic terminals (varicosities) of sensory neurons and serial reconstruction to analyze synaptic contacts, we compared the fine structure of identified sensory neuron synapses in control and behaviorally modified animals. Our results indicate that learning can modulate long-term synaptic effectiveness by altering the number, size, and vesicle complement of synaptic active zones." Examination by transmission electron microscopy in vacuum of

sections 100 nanometers thick recovers little or no chemical information. Lateral resolution is at best a few nanometers, and depth information (within the 100 nanometer section) is entirely lost. Specimen preparation included removal and desheathing of the abdominal ganglion which was then bathed in seawater for 30 minutes before impalement and intrasomatic pressure injection of HRP. Two hours later the ganglia were fixed, histochemically processed, and embedded. Following this treatment, Bailey and Chen concluded that "...clear structural changes accompany behavioral modification, and those changes can be detected at the level of identified synapses that are critically involved in learning."

The following observations about this work seem in order. First, several different types of visible changes were present. This provides redundant evidence of synaptic alteration. Inability to observe one type of change, or obliteration of one specific type of change, would not be sufficient to prevent recovery of the "state" of the synapse. Second, examination by electron microscopy is much cruder than proposed nanotechnological techniques which literally propose to analyze every molecule in the structure. It can reasonably be presumed that further alterations in synaptic chemistry will be detectable at the molecular level. Third, it seems unlikely that freezing would destroy all trace of the changes actually observed.

Such satisfying evidence is at present confined to "model systems;" what can we conclude about more complex systems, e.g., humans? Certainly, it seems safe to argue that synaptic alterations are also used in the human memory system, that synaptic changes of different types are likely to take place when the synapse "remembers" something, and that these changes probably involve mechanisms similar to those used in lower organisms (evolution is notoriously conservative).

Perhaps, however, some fundamentally new long-term memory system has been evolved only in humans? Even if this unlikely possibility were to prove true, any such hypothetical system would be sharply constrained by the available evidence. It would have to persist over the lifetime of a human being, and thus would have to be quite stable. It would have to tolerate the natural conditions encountered by humans and the experimental conditions to which primates have been subjected without loss of memory (presuming that primate memory is fundamentally very similar to human memory). And finally, it would almost certainly involve changes in tens of thousands of molecules to store each bit of information. Functional studies of the human memory system suggest it has a capacity of only 10^9 bits (somewhat over 100 megabytes) [37] (though this excludes motor memory, e.g., the information storage required when learning to ride a bicycle). Such a low memory capacity suggests that, independent of the specific mechanism, a great many molecules are required to remember each bit. It even suggests that many synapses are used to store each bit (recall there are about 10^{15} synapses -- which implies some 10^6 synapses per bit of information stored in long term memory).

Given that nanotechnology will allow the molecule-by-molecule analysis of the structures that store memory, and given that such structures are large on the molecular scale (involving tens of thousands of molecules each) then it appears unlikely that such structures will survive the lifetime of the individual only to be obliterated without trace by freezing.

TECHNICAL OVERVIEW

We now give an overview of the technical issues that must be dealt with in molecular repair of the brain: what must be done, and how it might be accomplished.

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 [30, 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 [16, 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 anticipate molecular repair, 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's. 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 0.002 moles. One mole is 6.02×10^{23} molecules, so 0.002 moles is 1.2×10^{21} molecules. Therefore, the brain has about 1.2×10^{21} protein 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's, 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 an atomic 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. There are more water molecules than anything else, both because there is more water in the brain by mass and because the molecular weight of water is smaller than that of the other molecules.

These numbers are fundamental. Molecular repair of the brain will require that we cope with them in some fashion.

How Much Time

Another parameter whose value we must decide is the amount of time required to repair each 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. The total time required for repair is just the sum of the repair times for all the molecules, 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 time required for a ribosome to manufacture a protein molecule of 400 amino acids is about ten seconds [14, 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 seven milliseconds [14, page 289]. In both cases, synthesis takes place in solution and involves significant delays while the needed components diffuse to the reactive sites. Faster methods of transport than random diffusion seem possible in principle (e.g., conveyor belts), and there is no reason to believe that such methods cannot be reduced to nanometer scale. The speed of assembler-directed reactions should also be faster than current biological systems. The arm of an assembler should be capable of making a complete motion in under a microsecond. 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. It seems unlikely that such analysis will require substantially longer than the synthesis time involved, so it seems reasonably conservative to multiply the synthesis time by a factor of a few to provide a time estimate of the overall molecular repair. 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. Thus, we will assume that analysis and repair takes 100 seconds per protein molecule.

It seems likely that repair will take place while the tissue is still frozen. In this case, the times for the various biological synthesis steps given here must be viewed as general "proof of principle" times rather than specific estimates of the actual time that will be required by an assembler operating at (perhaps) liquid nitrogen temperatures. We know that the synthesis of the biological molecules of interest can be done in a certain time frame using diffusive chemical reactions at 98.6°F -- it seems unlikely that reducing the temperature will create a barrier that will inherently require longer synthesis times. Assemblers are basically mechanical in nature, and so they can be designed to operate across a broad range of temperatures. If anything, the reduction in thermal vibration as a consequence of reduced temperature should allow more accurate positioning and facilitate, rather than hinder, the assembler-based synthesis process.

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. If we adopted nature's philosophy we would simply discard and replace any damaged molecules, greatly simplifying molecular "repair".

Discarding even parts of the original structure might be philosophically disturbing for some people. This philosophical problem can be entirely avoided by adopting the more difficult approach of actually analyzing a damaged molecule, and then repairing it. However, for those who view the simpler removal and replacement of damaged molecules as acceptable, the repair process can be substantially simplified. Informal discussions suggest most people view replacement of damaged molecules as acceptable. 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.

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's, 100 times less than a protein) is about 100 times less than the repair time for a protein, while the "repair time" for a water molecule will be almost 3000 times less than the repair time for a protein. That is, the repair time for one lipid molecule is assumed to be 1 second, while the "repair time" for a water molecule is assumed to be 36 milliseconds. While "repair" of water molecules is in all probability unnecessary, it seems likely that some time will be required to clear them away while analyzing other molecules and some additional time required to restore tissue water levels. While it should be possible to handle water molecules in "bulk", in view of the uncertainties involved we will adopt the more conservative estimate. The repair time would be reduced by a factor of about five if we did not allocate time for the removal, "repair" and replacement of water molecules.

We have implicitly assumed that the time required to analyze and synthesize an individual molecule will dominate the time required to determine its location and the time required to restore it to its correct position (with the possible exception of the small molecules, such as water). These assumptions appear 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 1.2×10^{21} protein molecules plus 1 second times 2×10^{23} lipids plus 0.036 second times 4×10^{25} water molecules, or 1.8×10^{24} 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's 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 1.8×10^{24} repair-machine-seconds, then we require 1.8×10^{16} repair machines for complete molecular repair of the brain. This corresponds to $1.8 \times 10^{16} / (6.02 \times 10^{23})$ or 3×10^{-8} moles, or 30 nanomoles of repair machines. If each repair device weighs 10^9 amu's, then the total weight of all the repair devices is 30 grams: about one ounce.

Thus, the weight of repair devices required to repair each and every molecule in the brain, assuming the repair devices operate no faster than current biological methods, is only one ounce. This is only about 2% of the total mass of the brain.

It seems unlikely that either more or larger repair devices are required. However, it is comforting to know that errors in these estimates of even three or four orders of magnitude can be easily tolerated. A requirement for 30 kilograms of repair devices (1,000 times more than we compute is needed) or 300 kilograms (10,000 times more than we compute is needed -- over 600 pounds) 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 300 kilograms of repair devices, a number of other repair scenarios would still work -- one such approach is discussed later in this paper. Given that nanotechnology is feasible, manufacturing costs for repair devices will be small. The cost of even 300 kilograms of repair devices should eventually be a few hundred dollars or less. The feasibility of molecular repair 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 bringing each molecule, in turn, to the attention of a repair device.

We shall presume that analysis takes place while the tissue is still frozen. While the exact temperature is left open, it seems better 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 developed if analysis were to take place after warming. We will not explore these possibilities here (although this is worthwhile).

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 then reassembled 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 computational resource 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 [18]. We will give a brief outline of the on-board repair scenario here, but will not consider it in any depth.

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 ultimately produce a device capable of repairing frozen tissue.

It is interesting to note that a team of Japanese scientists at Tokyo University's Research Center for Advanced Science and Technology have already begun developing a "...tiny robot to move inside the human body to treat diseased tissue...". Iwao Fujimasa said their objective is a robot less than 0.04 inches in size that will be able to travel through veins and inside organs [17]. They hope to have a working prototype in a year [20]. While substantially larger than the proposals considered here, the direction of future evolutionary improvements is already clear.

The 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 molecular repair in which the disassembly and reassembly processes are more visible. Ultimately, though, correct restoration of the structure is the overriding concern.

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 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 repair every molecule in its assigned volume.

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 advantage of this approach is obvious -- any 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. In addition, 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 (legs) and navigational abilities. Off-board repair scenarios have been discussed informally [18], but have not previously been written down.

Off-board repair scenarios can be naturally divided into four 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 of gathering this information it will be necessary to move tissue aside to allow access to structures that would otherwise be hidden. Various methods of gaining access to and analyzing the overall structure are feasible -- in this paper we shall consider only one approach.

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. No tissue movement occurs during this phase -- it involves only computation based on the information provided by the analysis phase.

The third phase is repair planning. In this phase, a plan must be developed which takes into account both the current (damaged, non-functional) state of the tissue and the desired healthy state, and describes how to convert the the former into the latter. Repair planning requires a substantial amount of computation, but again no tissue need actually be physically moved.

The fourth and final phase is actual repair. In this phase, the repair plan has been determined and is used to control repair devices that actually physically repair the affected tissue.

Now that we have discussed the four main phases involved in off-board repair, we consider one off-board repair method in greater detail: divide-and-conquer.

Divide And Conquer

Divide-and-conquer is a general purpose problem solving method frequently used in computer science. 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. Propst and Ko in "*Correlations between active zone ultrastructure and synaptic function studied with freeze-fracture of physiologically identified neuromuscular junctions*" [40] said: "Freeze-fracture techniques provide *en face* views of presynaptic membranes and are therefore a more direct and accurate way of studying the length, spacing, and intramembrane particles of AZs [Active Zones -- specialized parts of the pre-synaptic membrane]." In other words, you can see the individual molecules on the exposed faces of the fracture. It seems unlikely that the fracture itself will result in the loss of structural information. The freshly exposed faces can now be analyzed by various surface analysis techniques.

Current Work In Electron Microscopic Reconstruction Of Nerve Tissue

It is interesting to note that current research in 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. 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, and 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 [27,28], and even finer detail [29]. 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.

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 1.8×10^{16} repair devices and pieces. If the 1350 cubic centimeter volume of the brain is divided into this many cubes, each cube would be about 0.4 microns (422 nanometers) on a side. Each such 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.

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 one meter in length, and can easily handle objects from one to ten centimeters in size (0.01 to 0.1 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 0.1 micron or 100 nanometers. (Note that an assembler has arms of 100 nanometers). Thus, we would need to design eight 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.

Output Of The Analysis Phase

The analysis phase of divide-and-conquer will produce two things. First, it will provide a detailed description of the location, orientation, and type of each molecule. That is, the analysis will produce a detailed structural data base that contains information about every molecule in the brain. Second, it will produce the actual molecules, sorted and indexed.

Memory And Computational 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 easily 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] appear quite feasible. Given that there are about 2×10^{23} "significant" molecules in the brain (we do not bother to record the locations of the water molecules, simple ions, and the like -- anyone concerned about this omission can increase the size of the structural data base to hold this rather uninteresting information), and assuming 50 bits are required to encode the location and description of each molecule then we require 10^{25} bits -- or about 1000 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 10^{14} cells and that each cell stores 10^{10} bits in its DNA [14]. 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.

In addition, the computational power required to analyze a data base with 10^{25} bits is well within known theoretical limits [9,25,32]. The rod-logic molecular model of computation dissipates roughly 10^{-21} joules per gate operation when operating at 50 picoseconds [2,19]. Extrapolation of current trends in miniaturization suggest that such energy dissipations will be achieved by the year 2020 [31, fig. 1]. There is no presently known reason to expect the trend to stop or even slow down at that time [9,32]. 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 ten cents per kilowatt hour. Even ignoring future decreases in the cost of energy (which might be dramatic over a period of one to two centuries) this implies that 10^{12} joules can be purchased for $30,000 dollars. This much energy would support 5×10^{14} gates operating at 50 picoseconds per gate operation for three years. This is a total of 10^{33} gate operations: 10^{8} gate operations for each bit in the structural data base, or 5×10^{9} gate operations for each of the 2×10^{23} lipid molecules present in the brain.

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 1000 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. Allowing for the fact that such "retinal operations" are probably more complex than a single "gate operation" by a factor 100 to 1000, we arrive at 10^{7} to 10^{9} gate operations per pixel -- which is quite in keeping with our estimate of 10^{8} operations per bit or 5×10^{9} operations per molecule.

It is likely that this estimate of the computational power required is conservative (too large), and therefore that we have more than adequate computational power available. In the following paragraphs, we argue that even more computational power will in fact be available, and so our margins for error are much larger.

Energy loss in rod logic is related to speed of operation. By slowing down the operating speed from 50 picoseconds to 50 nanoseconds or even 50 microseconds we should achieve corresponding reductions in energy dissipation per gate operation. This should allow substantial increases in computational power for a fixed energy budget. If we increase the number of gates, we can both decrease the energy dissipated per gate operation (by operating at a slower speed) and maintain the same 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^{12} (to approximately 5×10^{26} gates) would still result in a total volume of only 10 cubic meters (recall that each gate plus overhead is about 20 cubic nanometers). 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 do not adopt this approach here for two main reasons. First, published analyses [2,19] use the higher 50 picosecond speed of operation. Second, normal logic gates cannot operate at energy levels below thermal noise. The average thermal energy of a single atom or molecule at a temperature T (measured in degrees Kelvin) is expressed as kT, where k is Boltzman's constant. At room temperature, kT is about 4×10^{-21} joules. Normal logic gates ("AND" and "OR" gates, for example) must inherently dissipate at least this much energy for fundamental thermodynamic reasons. This does not impose a fundamental limit on computation because we can build a computer out of other types of gates. The major problem with normal gates is that they are "irreversible." That is, the output of an "AND" gate does not necessarily uniquely specify the input: if the output is a logic "0", then either or both inputs might be "0". To overcome this deficiency, and to allow operation far below kT, it is necessary to make the computation reversible. That is, any state in the computation must have a unique predecessor state. Computational states that have two or more predecessor states must inherently dissipate about kT energy, and must be banned. A fully reversible computer can be built from "Fredkin gates." These are three-input, three-output Boolean logic elements that are reversible. That is, given the three outputs, it is possible to determine the unique set of three inputs that produced that output. Fredkin gates are logically complete, for it is possible to build the normal

"AND", "OR" and "NOT" gates from them. However, designing and building a computer with Fredkin gates introduces a new set of design problems that have not been widely considered. Theoretical design work and several different computational models strongly support the idea that building reversible computers is quite feasible [9,25,32]. Likharev in particular proposed a computational element based on Josephson junctions operating at 4° Kelvin in which energy dissipation per switching operation was 10^{-24} joules with a switching time of 10^{-9} seconds [33]. Further work on reversible computation can only lower the minimum energy expenditure per basic operation. While it is at present unclear how far this can continue, it is clear that we have not yet reached a limit, and that no particular limit is yet visible.

If we allow for the decreasing future cost of energy and the probability that future designs will have lower energy dissipation, 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 molecular repair of the brain.

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^{12} joules. When lipids are burned, they release about nine kilocalories per gram. (Calorie conscious dieters are really 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 four 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 10^5 times less than the 10^{12} joules that one person can reasonably purchase at today's prices. 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^{12} joules. The major energy cost in molecular repair appears to be in the computations required to "think" about each major molecule in the brain.

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 cracks in it, and that if any cracks 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 these cracks. 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.

The complexity of this program 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 remarkable fidelity down to the molecular level. Indeed, the structure is almost (though not quite) functional. It is not difficult to deduce the location and function of a molecule when the molecule is present and either functional or almost functional. If, however, the suspension went badly and there was significant pre-suspension damage, 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 extensive damage.

The full power of molecular repair should now be evident: almost any damage that can be understood can be repaired. Almost any damage that can be identified -- "The mitochondria are swollen and non-functional," "The cell wall is ruptured," "The cell has been split," "The level of ATP in the cell is too low to support metabolism," "The cell is dehydrated," etc., can now be repaired. For example, it would be theoretically possible to repair a cell even if it had been almost obliterated, provided that there were sufficient clues in the surrounding tissue to support the inference that the cell had been there, and what its function had been. For a nerve cell, it would be sufficient to know little more than the locations and types of the synapses and the courses of its axons and dendrites.

This truly remarkable repair capability makes repair possible under conditions that would today be immediately dismissed as hopeless. It also makes all current estimates of tissue "viability" based on functional criteria irrelevant. Injury caused by a lack of blood flow (ischemic injury) is today the primary cause of mortality, and its mechanism of action is of great interest [21]. Efforts aimed at determining the "...proximate causes of cell death" are intended to guide work aimed at reversing non-lethal damage. The search for the "...critical events in ischemic cell injury..." is serious, and might well provide near-term improvements in health care. This work is also completely misleading about the ultimate degree of damage that tissue can tolerate and still be repaired. Proposed mechanisms of "...irreversible cell damage..." include such obviously repairable injuries as: elevated intra-cellular calcium, ATP depletion, membrane damage (holes), mitochondrial dysfunction, and others. This work forms the backdrop against which tissue damage to cryonically suspended patients is measured by most biologists, cryobiologists, doctors, and other health care workers. Clearly, this work pre-disposes such workers to dismiss cryonics because, by these criteria, much "irreversible" damage has occurred in the cryonically suspended patient. The implications of molecular repair have simply not been considered, and we can reasonably expect a delay of several years to a few decades before they are. This would be consistent with historical data concerning the slow acceptance of the bacterial theory of disease. Despite the demonstration by Ignaz Semmelweis in 1848 that washing your hands in chlorinated lime after leaving the autopsy room and before entering the maternity ward reduced maternal deaths from childbed fever from as high as 25% to essentially zero, his proposal was widely ridiculed and little practiced for several more decades -- even in the hospital where he carried out his study.

Molecular repair does have limits. If it is impossible to deduce a reasonably accurate picture of the tissue structure that was present before injury, then molecular repair will fail. Given the redundant nature of the biological structures that make up the individual cells and the additional redundancy introduced at a higher level by the structure of the nervous system, the level of damage required to make such deductions infeasible in principle must be truly massive. Even if significant loss of structure did occur at the cellular level (an unlikely event when cryonic suspension takes place under favorable circumstances) it would still be possible to recover much if not most of the higher level structure. To quote "*Principles of Neural Science*" [13, page 813]:

"Although the physical changes representing learning are likely to be localized to specific neurons, the complex nature of learning ensures that these neurons are widely distributed in the nervous system. Therefore, even after extensive lesions, some trace can remain. Furthermore, the brain has the capacity to take even the limited information remaining, work it over, and reconstruct a good reproduction of the original."

Alternatives To Completing 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 in the philosophical literature [11], and has recently been called either "uploading" or "downloading" [26]. Whether or not such a process preserves what is essentially human is sometimes 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 grossed in the billions of dollars) 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.

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.

Determining A Feasible Assembly Sequence

In the third phase of repair, repair planning, we must generate a plan for reassembly of the tissue components (the molecules) back into the healthy state described by the revised structural data base. That is, we must determine how to actually rebuild the healthy tissue. This problem is similar to generating an assembly sequence for a complex human-made structure, such as an airplane. The assembly sequence must satisfy certain constraints, both physical and having to do with the specific assembly technology. For example, you can't put large structural elements through small hatches -- so they'd better be built into the structure early in the assembly sequence.

It is worthwhile noting that the revised structural data base can be further altered to make reassembly easier. While certain alterations to the structural data base must be banned (anything that might damage memory, for example), many alterations would seem to be quite safe. One set of safe alterations would be 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, gently pushing aside tissue to open a small space should 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, that a fairly wide range exists should be evident.

One possible assembly sequence is to rebuild and repair the individual pieces into which the tissue was originally broken, and then reverse the sequence of steps used to generate the pieces. That is, each repair device would not only analyze the piece of tissue for which it was responsible, it would also restore that piece of tissue. Then, the original sequence of steps involved in dividing the tissue would be reversed in the construction of an intact whole.

It seems unlikely that this will prove to be the most attractive possibility. It is probable that during the division process some large molecules will have been split. In particular, long molecules of DNA will probably have crossed a fracture boundary, and therefore will have been split into two parts. While arranging matters so that individual molecules that are split by fractures during the division process are properly repaired during the assembly process does not seem infeasible, it would appear easier to avoid the problem entirely. Given that we have a complete description of the location of every molecule in the brain in the revised structural data base, it would seem simpler to generate a new set of synthetic "fractures" that systematically avoid dividing any molecules. That is, a DNA molecule would fall entirely within a single "piece" in the new arrangement. The locations of these new "fractures" would bear no relationship to the locations of the old fractures, nor would they need to bear any such relationship. The new "fractures" would be deliberately selected to minimize reassembly difficulties. They might, for example, follow cell boundaries whenever feasible. There is no need for the assembly sequence to have any relationship at all to the disassembly sequence.

A number of fundamentally different assembly sequences are possible.

We will not examine the problem of generating a feasible assembly sequence here. This problem is clearly important, and deserves further research. We expect that further work on the general problem of building large, atomically precise objects should be applicable to this special case, and we look forward to such work as interest in nanotechnology grows. Even though we do not consider the problem of generating a feasible assembly sequence here, it should be clear that it is indeed possible to build living tissue. It is, after all, done by every living creature on the planet. It also follows from the general thesis of nanotechnology: that the construction of almost any chemically stable object that has been specified to the atomic level is feasible. The revised structural data base clearly specifies such an object (the brain) and specifies its structure in precise molecular detail. Its construction should therefore be feasible, particularly when we consider that existing biological systems already demonstrate "proof of principle."

CONCLUSION

Molecular repair of the brain should eventually prove technically feasible. Divide-and-conquer is particularly attractive in view of the relative simplicity of the assumptions on which it is based. It 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 by 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 finding a feasible reassembly sequence given a description of the healthy state of the tissue is possible.

No particular constraints are placed on the number, size, energy dissipation, or speed of the needed repair devices. They also need not be mobile, nor have any navigational ability. Immobility also simplifies the power and communication networks.

In short, should nanotechnology prove feasible, then repair of frozen tissue can be readily accomplished. Indeed, the margins for error are sufficiently large that it would require a gross failure of projected technical capabilities to render such repair infeasible.

APPENDIX

Approximate values of interesting numbers. Numbers marked by a "*" are extrapolations based on projected technical capabilities (nanotechnology and molecular computing).

Volume of the brain:	1350 cubic centimeters
Weight of the brain:	1400 grams
Weight of proteins in the brain:	100 grams
Weight of a ribosome:	3×10^6 amu's
*Weight of a repair machine:	10^9 amu's
*Length of a repair machine arm:	100 nanometers
Weight of water in brain:	1100 grams
Weight of protein in brain:	100 grams
Weight of lipids in brain:	175 grams
Weight of "other solids":	35 grams
Weight of "typical" protein:	50,000 amu's
Weight of "typical" lipid:	500 amu's
Weight of water molecule:	18 amu's
Weight of carbon atom:	12 amu's
Density of carbon (diamond):	3.51 grams/cubic centimeter
Number of proteins in brain:	1.2×10^{21}
Number of lipid molecules in brain:	2×10^{23}
Number of water molecules in brain:	4×10^{25}
Time to synthesize a protein:	10 seconds
*Time to repair one protein molecule:	100 seconds
*Time to repair one lipid molecule:	1 second
*Time to "repair" one water molecule:	0.036 seconds
*Time to repair all brain molecules:	1.8×10^{24} repair-machine seconds
*Number of repair machines to repair all brain molecules in three years:	1.8×10^{16} repair machines
*Weight of that many repair devices:	30 grams
Number of bits needed to store the molecular structure of the brain:	10^{25} bits
*Energy dissipated by a single "rod logic" (gate) operation:	10^{-21} joules
*Speed of a single "rod logic" (gate) operation:	50×10^{-12} seconds

Cost of 10^{12} joules of energy at current rates:	30,000 dollars
*Number of gate operations 10^{12} joules can support:	10^{33} gate operations
*Size of a single "lock" (gate) plus overhead (power, etc):	20 cubic nanometers
*Volume of gates that can deliver 10^{33} operations in three years (cooling neglected!):	0.01 cubic millimeters
Power of 10^{12} joules dissipated over a three year period:	10 kilowatts (100 light bulbs for 3 years)
Water flow required to cool a 10 kilowatt thermal source:	5 liters per minute
Normal blood flow through the brain:	0.75 liters/minute
Chemical energy stored in the structure of the brain:	8×10^{6} joules (2,000 kilocalories)
Boltzman's constant *k*:	1.38×10^{-23} joules/degree Kelvin
Thermal energy of one atom at room temperature (300 degrees K): joules	4.14×10^{-21}
One watt:	one joule per second
One kilowatt hour:	3.6×10^{6} joules
Avogadro's number (the number of atoms in one mole):	6.0221367×10^{23}
Joules per (dietary) Calorie:	4,186

One mole of a substance: that quantity of the substance that weighs (in grams) the same as its molecular weight amu (atomic mass units): By definition, one atom of carbon 12 weighs 12 amu's.

REFERENCES

1. *Engines of Creation* by K. Eric Drexler, Anchor Press, 1986.

2. *Nanotechnology: wherein molecular computers control tiny circulatory submarines*, by A. K. Dewdney, *Scientific American*, January 1988, pages 100 to 103.

3. *Foresight Update*, a publication of the Foresight Institute.

4. *There's Plenty of Room at the Bottom* a talk by Richard Feynman (awarded the Nobel Prize in Physics in 1965) at an annual meeting of the American Physical Society given on December 29, 1959. Reprinted in *Miniaturization*, edited by H.D. Gilbert (Reinhold, New York, 1961) pages 282-296.

5. *Where the next fortunes will be made.* by Brett Duval Fromson, *Fortune*, December 5, 1988, page 185.

6. *Molecular Engineer Eric Drexler: Manipulating Nature Atom by Atom.* by Ed Regis, in *Omni*, January 1989, page 66.

7. *Scanning Tunneling Microscopy and Atomic Force Microscopy: Application to Biology and Technology* by P.K. Hansma, V.B. Elings, O. Marti, and C.E. Bracker. *Science*, October

14, 1988, page 209-216.

8. *Molecular manipulation using a tunnelling microscope*, by J.S. Foster, J.E. Frommer and P.C. Arnett. *Nature*, Vol. 331, 28 January 1988, pages 324-326.

9. *The fundamental physical limits of computation* by Charles H. Bennet and Rolf Landauer, *Scientific American*, Vol. 253, July 1985, pages 48-56.

10. *Molecular Engineering: An Approach to the Development of General Capabilities for Molecular Manipulation*, by K. Eric Drexler, *Proceedings of the National Academy of Sciences (USA)*, Vol 78, pp 5275-78, 1981.

11. *The Mind's I*, by Douglas R. Hofstadter and Daniel C. Dennett. Bantam, 1982.

12. *Matter and Consciousness: A Contemporary Introduction to the Philosophy of Mind*, by Paul Churchland, second edition, 1988, the MIT press.

13. *Principles of Neural Science*, second edition, by Eric R. Kandel and James H. Schwartz. Elsevier, 1985.

14. *Molecular Biology of the Gene*, fourth edition, by James D. Watson, Nancy H. Hopkins, Jeffrey W. Roberts, Joan Argetsinger Steitz, and Alan M. Weiner. Benjamin Cummings, 1987. Although available last year only as a two volume set, it can now be purchased as a large single volume.

15. *Death, Dying, and the Biological Revolution*, by Robert M. Veatch, Yale 1976.

16. *Human Biochemistry* by James M. Orten, Tenth Edition, Mosby 1982.

17. *Tiny surgical robot being developed*, in *San Jose Mercury News*, Feb. 18, 1989, page 26A

18. Eric Drexler, private communication.

19. *Rod Logic and Thermal Noise in the Mechanical Nanocomputer*, by K. Eric Drexler, *Proceedings of the Third International Symposium on Molecular Electronic Devices*, F. Carter, Ed., Elsevier, 1988.

20. *Submarines small enough to cruise the bloodstream*, in *Business Week*, March 27, 1989, page 64.

21. *Calcium and Ischemic Injury*, by Joseph Y. Cheung et. al., *The New England Journal of Medicine*, Vol. 314, No. 26, page 1670.

22. *Freezing of living cells: mechanisms and implications*, by Peter Mazur, *American Journal of Physiology*, Vol 247, (Cell Physiology 16): C125-C142, 1984.

23. *Alcor: Threshold to Tomorrow*, available from Alcor, 12327 Doherty St. Riverside, CA 92503.

24. *Many are cold, but few are frozen: A Humanist looks at Cryonics*, by Steven B. Harris, M.D., *Free Inquiry*, Vol. 9, No. 2, Spring 1989, pages 19-24.

25. *Conservative Logic*, by Edward Fredkin and Tommaso Toffoli, *International Journal of Theoretical Physics*, Vol. 21, Nos. 3/4, 1982, pages 219-253.

26. *The Tomorrow Makers*, Grant Fjermedal, MacMillan, 1986.

27. *Computer analysis of neuronal structures* by Robert D. Lindsay, Plenum, 1977.

28. *The microcomputer in cell and neurobiology research* by R. Ranney Mize, Elsevier, 1985.

29. *Intracellular control of axial shape in non-uniform neurites: a serial electon microscopic analysis of organelles and microtubules in AI and AII retinal amacrine neurites*, by Sharon E. Sasaki-Sherrington, J. Roger Jacobs, John K. Stevens, *Journal of Cell Biology* 98, April, 1984, 1279-1290

30. *Guinness Book of World Records*, Donald McFarlan et. al., Bantam 1989.

31. *Dissipation and noise immunity in computation and communication* by Rolf Landauer, *Nature*, Vol. 335, October 27, 1988, page 779.

32. *Notes on the History of Reversible Computation* by Charles H. Bennett, *IBM Journal of Research and Development*, Vol. 32, No. 1, January 1988.

33. *Classical and Quantum Limitations on Energy Consumption in Computation* by K.K. Likharev, *International Journal of Theoretical Physics*, Vol. 21, Nos. 3/4, 1982.

34. *Synapses, Circuits, and the Beginnings of Memory*, by Gary Lynch, MIT Press, 1986.

35. *Memory Storage and Neural Systems*, by Daniel L. Alkon, *Scientific American*, July 1989, pages 42-50.

36. *Morphological basis of long-term habituation and sensitization in Aplysia* by Craig H. Bailey and Mary Chen, *Science* 220, April 1, 1983, pages 91-93

37. *How Much Do People Remember? Some Estimates of the Quantity of Learned Information in Long-term Memory*, by Thomas K. Landauer, in *Cognitive Science* 10, 477-493, 1986

38. *Neurobiology*, by Gordon M. Shepherd, Oxford, 1983.

39. *The anatomy of a memory: convergence of results across a diversity of tests*, by William T. Greenough and Craig H. Bailey, *Trends in Neuroscience*, 1988, Vol. 11, No. 4, pages 142-147.

40. *Correlations between active zone ultrastructure and synaptic function studied with freeze-fracture of physiologically identified neuromuscular junctions*, by Jon W. Propst and Chien-Ping Ko, *Journal of Neuroscience*, November 1987, 7(11), 3654-3664.

41. *Machines of Inner Space* by K. Eric Drexler, *1990 Yearbook of Science and the Future*, pages 160-177, published by *Encyclopedia Britannica*, Chicago 1989.

42. *Stopping Biological Time: The Freezing of Living Cells* by Peter Mazur, *Ann. N.Y. Acad. Sci.* 541: 514-531, 1988. "Cryobiologists are often asked how long cells can remain viable at -196°C, the temperature of boiling liquid nitrogen (which is the usual cryogenic fluid). The answer is clear -- more than 1000 years. The reason is that direct ionizations from background radiation are the only source of damage at such temperatures. Ordinary chemical reactions cannot occur. The pertinent question then is not storage stability, it is how can one get cells down to -196°C and back without killing them."

THE ALCOR SURVEY 1988-9

tabulated by Max O'Connor
comments by Max O'Connor and Mike Perry

Part 2 of 2

Question 33: Which of these books have you read?

A. *The Prospect of Immortality* (Ettinger): SM:51 AN:21
B. *Engines of Creation* (Drexler): SM:56 AN:27
C. *Man Into Superman* (Ettinger): SM:28 AN:12
D. *The Immortalist* (Harrington): SM:25 AN:11
E. *Prolongevity* (Rosenfeld): SM:26 AN:13
F. *Cryonics* (Sheskin): SM:13 AN:3
G. *Suspended Animation* (Prehoda): SM:11 AN:6
H. *We Froze the First Man* (Nelson): SM:22 AN:5
I. *The Life Extension Revolution* (Kent): SM:34 AN:15
J. *The Age of the Pussyfoot* (Pohl): SM:20 AN:4
K. *The Door Into Summer* (Heinlein): SM:36 AN:13

Engines rates tops, closely followed by *Prospect*. These two books appear to be the most influential in cryonics.

Question 34: Are you currently taking any anti-aging drugs? If so, which ones? (Do not include vitamins or minerals in this section.)

Yes: SM:6 AN:6 No: SM:53 AN:27

Hydergine: SM:4 AN:3
Co-enzyme Q10: SM:6 AN:2
Centrophenoxine: SM:1 AN:1
Deanol: SM:1
Aspirin: SM:1 AN:1
Ethoxyquin: SM:1
L-Dopa: AN:1
GH-3: AN:1
DMAE: AN:1
Estrogen: AN:1

Despite the very serious interest in (ultimately) defeating the aging process, cryonicists are relatively uninterested in "anti-aging" drugs today. A guess would be that they think "we ain't there yet", that aging will be cured, but not until nanotechnology is far more advanced.

Question 35: Have you taken any anti-aging drugs in the past? Which ones?

Yes: SM:4 AN:6 No: SM:44 AN:16

BHT: SM:10 AN:1
Hydergine: SM:5 AN:4
DMAE: SM:4 [2 Deanol, 1 Deaner, 2 DMAE] AN:1 [DMAE]
Centrophenoxine: SM:2
Ethoxyquin: SM:1 AN:1
Co-enzyme Q10: SM:1
Piracetam: SM:1 AN:2
GH3/Procaine: SM:1 AN:1
Estrogen: SM:1
Progesterone: SM:1
Gerimal: AN:1
Nootropil: AN:1
Lucidril: AN:2

Again, not much interest, considering.

Question 36: Do you take vitamin/mineral supplements? Which ones and what amount?

Life Extension Mix: SM:22 AN:10
Multivitamin/mineral: SM:19 AN:13
Extend: SM:2
Vitamin C: SM:16 AN:6
Vitamin E: SM:8 AN:8
Magnesium: SM:8
Selenium: SM:7 AN:3
B Complex: SM:5
Zinc: SM:5 AN:2
Co-enzyme Q10: SM:6 AN:4
Amino Acids: SM:3 AN:3
Calcium: SM:3 AN:1
Niacin: SM:3 AN:1
Ginseng: SM:2
RNA: SM:2
Vitamin D: SM:2
Cognitex: SM:2 AN:2
Garlic: SM:2 AN:2
BHT: SM:1 AN:1
Beta Carotene: SM:1 AN:1
Carnitine: SM:1
Folic Acid: SM:1
Vitamin B6: SM:1 AN:1
Antioxidants: SM:1 AN:1
Rutin: SM:1
Iron: SM:1
Vitamin A: SM:1 AN:1
Choline Chloride: SM:1 AN:1
Phosphatidyl choline: AN:1
Vitamin B5: SM:1 AN:2
Glutathione: SM:1
B complex: AN:1
Vitamin B1: AN:1
Vitamin B12: AN:1
Cysteine: SM:1
Ascorbyl Palmitate: SM:1
Bioflavinoids: SM:1
Potassium: SM:1 AN:1
GTF: SM:1
Twin EPA: AN:1
Onion powder: AN:1
EPR-1000: AN:1
Gamma linoleic acid: AN:1
Papain bromelain: AN:1
PABA: AN:1
Max EPA: AN:1
Biotin: AN:1
Evening primrose oil: AN:1

Again, some people indicated that they took a number of supplements but were unwilling to list them.

Overall, this response is very interesting compared to the previous two questions. Many more cryonicists are interested in vitamin supplements than in anti-aging drugs. The efficacy of vitamin supplements is more convincing than is that of anti-aging drugs.

Question 37: Are you a vegetarian? Vegan? Chicken and fish only?

Vegetarian: SM:6 (2 of these eat a little fish) AN:1
Vegan: SM:1 (but eats fish) AN:0
Chicken and fish only: SM:11 AN:3

A few cryonicists are vegetarians, a larger number, still a minority, avoid high-cholesterol meats.

Question 38: Do you modify your diet in any other way?

No: SM:16
Low fat: SM:32 AN:12
High Fiber: SM:11 AN:8
Low calorie: SM:8 AN:5
Low/no sugar; SM:6 AN:7
Low cholesterol: SM:3 AN:6
High cruciferous vegetables: SM:2
Low salt/no added salt: SM:2 AN:3
Moderate alcohol: SM:2
No alcohol: SM:0 AN:1
Low/no caffeine: SM:1 AN:2
Low meat: SM:1 AN:3
Bran: SM:1 AN:1
Non-fat diary products: SM:1 AN:1
Control snacking: SM:1
High sugar: SM:1
Lots of curries: SM:1
Dr. Atkins diet: AN:1
Plenty of fruit: AN:1
Plenty of vegetables: AN:1
Fasting: AN:1
Low saturated fat: AN:1
Avoid mutagens: AN:1
Avoid carcinogens: AN:1

Most cryonicists modify their diet in some way.

Question 39: Do you get regular exercise? What kind?

Yes: SM:49 AN:28 No: SM:12 AN:4

Running/jogging: SM:18 AN:10
Walking: SM:17 AN:8
Weights: SM:16 AN:3
Swimming: SM:8 AN:3
Aerobics: SM:5 AN:0
Aerobic (unspecified): SM:4
Calisthenics: SM:3 AN:2
Tennis: SM:3 AN:3
Cycling: SM:3
Irregular: SM:3 AN:1
Yoga: SM:2 AN:2
Stairs: SM:1
Climbing: SM:1
Treadmill: SM:1
Construction work: SM:1
Volleyball: SM:1
Moving heavy objects for work: SM:1
Sex: SM:1
Rowing: SM:1
Table tennis: SM:1
Trampoline: SM:1 AN:1
House/garden work: AN:3
Racquetball: AN:1
Martial arts: AN:2
Soccer: AN:2
Golf: AN:2

Softball: SM:1
Basketball: SM:1 AN:4
Stationary cycling: SM:1
Biking: SM:1
Baseball: AN:1
Rowing machine: AN:1
Dancing: AN:1

Most cryonicists are regular exercisers, with running, walking, swimming and weights being especially popular.

Question 40: Is there anything else you do as an anti-aging or pro-health measure?

No: SM:27 AN:19
Don't smoke: SM:4 AN:4
Calorie/weight control: SM:3 AN:1
Don't drink: SM:3 AN:2
No drugs: SM:3 AN:1
Avoid the sun: SM:3
Reduce risks: SM:2
Won't get in car with drunk driver: SM:2
Aspirin: SM:2
Almonds: SM:2
Regular medical check-ups: SM:2 AN:1
Stay intellectually active: SM:2 AN:1
Get adequate sleep: SM:2
Follow life extension developments: SM:2 AN:1
Stress control: SM:2 AN:2
Regular dental check-ups: SM:1
Plenty of sex: SM:1
Use a life extension doctor: SM:1
Safe sex: SM:1
Meditation: SM:1 AN:1
Laugh a lot: SM:1
Don't drive drunk: SM:1
Avoid prescription drugs: SM:1
Lots of pleasure: SM:1
Avoid auto accidents: SM:1
Regular aging measurements: AN:1
Anti-dandruff shampoo: AN:1
Filter water: AN:2
"Biowater": AN:1
Bee pollen: AN:1
Filter air: AN:1
Self-defense: AN:1
Drink very little: AN:1

A major oversight was to forget to specifically ask if and how many cigarettes respondents smoked.

In general, a large percentage of SM's and AN's do "something else" as an anti-aging or pro-health measure, often a form of avoidance (e.g. no drugs).

Question 41: DO you know CPR (cardiopulmonary resuscitation)?

Yes: SM:44 AN:14
No: SM:25 AN:21

That so many know CPR is encouraging, except that CPR's effectiveness is now being questioned.

Question 42: Do you use seatbelts?

Yes: SM:65 AN:31 **No**: SM:3 AN:3 **Sometimes**: SM:1 AN:1

It's "no accident" that almost everyone in the survey uses seatbelts!

PERSONALITY PROFILE

Question 43: How many books do you own?

0-49.....SM:6 AN:0
50-99.....SM:3 AN:2
100-149....SM:2 AN:5
150-199....SM:0 AN:0
200-299....SM:6 AN:5
300-399....SM:7 AN:3
400-499....SM:2 AN:1
500-599....SM:1 AN:3
600-699....SM:0 AN:0
700-799....SM:1 AN:1
800-899....SM:2 AN:0
900-999....SM:2 AN:0
1000+.....SM:19 AN:8
(SM: 7 had 2000 or more, and 2 of these have 10,000 or more; AN: one had 2000.)

Very few... SM:1
Dozens..... SM:1
Hundreds....SM:9 AN:4
Thousands SM:1 AN:1
Tons/many/lots: SM:5 AN:1

Working out an average requires assumptions to be made, since some answers are not specific. I will ignore the "tons/many/lots" category as hopelessly vague. "Very few" will count as 25; "dozens" will count as 70; "hundreds" as 400; and "thousands" as 2,000. Take the result with two pinches of salt and call the statistician in the morning.

Average: SM:942 AN:482

Perhaps there is some significance in the fact that on the average SM's own twice as many books as AN's but read books at about the same rate (actually a slightly lower rate; see next question). Owning books is a way of preserving information, which is generally of interest to cryonicists. (Indeed a brain or other preserved remains are like books.)

Question 44: How many books do you read per year?

0-5.....SM:8 AN:1
6-10.....SM:6 AN:4
11-20....SM:14 AN:8
21-30....SM:8 AN:2
31-40....SM:4 AN:6
41-50....SM:6 AN:4
51-60....SM:4 AN:0
61-70....SM:1 AN:1
71-80....SM:3 AN:1
81-90....SM:1 AN:1
91-100...SM:0 AN:2
Over 100..SM:6 AN:3
(4 of these over 200)
Dozens...SM:0 AN:1

Ignoring the vague answers, the average is 45 for SMs, 52 for ANs, roughly a book a week.

Question 45: To how many magazines do you subscribe?

0-3	SM:16 AN:8	16-19.	SM:6 AN:0
4-6	SM:22 AN:11	20-25.	SM:5 AN:3
7-10	SM:11 AN:6	25+.	SM:4 AN:0
11-15	SM:3 AN:6		

That's an average of just over seven for SMs, and nearly 7.5 for ANs.

Question 46: Have you ever been a regular reader of science fiction? If "yes", at what times in your life?

Yes	SM:28 AN:18	Now occasionally.	SM:6
No	SM:20 AN:11	Various times	SM:2
Always/from childhood on.	SM:24 AN:10	Childhood only.	SM:1
Teen-ager	SM:14 AN:9	Recently.	SM:2 AN:2
Off and on	SM:4	High school	SM:1

(Other SM answers - 15-30:1; 18-35:1; from 20 to present:1. AN: one from 12 until 30, and one from 20 to the present.)

A majority of the respondents have been science fiction readers, and most of these in turn were hooked for life.

Question 47: List the three most important books in your life.

By "important" it was intended that the respondent list the most influential in their thinking or course of life. Some people seem to have thought it meant their favorite books, which may not be the same. Often the title but not the author was listed. I have filled these in where I can.

K. Eric Drexler: *Engines of Creation*: SM:17 AN:7
Ayn Rand: *Atlas Shrugged*: SM:17 AN:4
The Fountainhead: SM:4 AN:3
The Virtue of Selfishness: SM:1 AN:1
General works: SM:1
Robert Ettinger: *The Prospect of Immortality*: SM:16 AN:3
Man Into Superman: SM:4 AN:1
Harry Browne: *How I Found Freedom in an Unfree World*: SM:3
Robert Heinlein: Complete works: SM:3 AN:1
: *Have Space Suit Will Travel*: SM:2
: *The Door Into Summer*: SM:1
: *Methuselah's Children*: SM:1
: *The Moon is a Harsh Mistress*: SM:0 AN:1
: *Time Enough for Love*: SM:0 AN:2
: *Stranger in a Strange Land*: SM:0 AN:1
Richard Dawkins: *The Selfish Gene*: SM:3
Bible: SM:3 AN:1
Arthur C. Clarke: *Profiles of the Future*: SM:2
: *The Sands of Mars*: SM:1
Robert Anton Wilson: *Universe Next Door* trilogy: SM:1
Prometheus Rising: SM:1
& R. Shea: *The Illuminatus Trilogy*: SM:1

Bertrand Russell: *Why I Am Not a Christian*: SM:2
Gerard K. O'Neill: *The High Frontier*: SM:2 AN:2
Alfred Korzybski: *Science and Sanity*: SM:2 AN:1
Murray Rothbard: *For a New Liberty*: SM:1 AN:1
Russell & Whitehead: *Principia Mathematica*: SM:1
Mark Twain: *The Adventures of Huckleberry Finn*: SM:1
Morris & Linda Tannenhill: *The Market for Liberty*: SM:1
Isaac Asimov: *Foundation Trilogy*: SM:1
Douglas Hofstadter: *Godel, Escher, Bach*: SM:1
Ernest Holmes: *The Science of Mind*: SM:1
Robert Ardrey: *African Genesis*: SM:1
Gibbon: *Decline and Fall of the Roman Empire*: SM:1
James P. Hogan: *Voyage to Yesteryear*: SM:1
Pearson & Shaw: *Life Extension*: SM:1 AN:3
John Mann: *Secrets of Life Extension*: SM:1
Harold T. Meryman: *Cryobiology*: SM:1
Ludwig von Mises: *Human Action*: SM:1
Friedrich Hayek: *The Constitution of Liberty*: SM:1
Nathaniel Branden: *Honoring the Self*: SM:1
Friedrich Nietzsche: *The Will to Power*: SM:1
Andrew S. Tanenbaum: *Structured Computer Organization*: SM:1
Marilyn Ferguson: *The Aquarian Conspiracy*: SM:1
Robert Nelson: *We Froze the First Man*: SM:1
Adrian Berry: *The Next Ten Thousand Years*: SM:1
John Cage: *Silence*: SM:1
Timothy Leary: *The Game of Life*: SM:1
Harlan Ellison: *The Glass Teat*: SM:1
Roger Callaghan: *Five Minute Phobia Cure*: SM:1
Encyclopedia Britannica: SM:1
Brian Wowk & Mike Darwin: *Tomorrow's Medicine Today: Alcor*: SM:1
Homer Smith: *Kamongo*: SM:1
G. Gordon Liddy: *Will*: SM:1
Woody Allen: Short story collection: SM:1
E.R. Burroughs: *Tarzan of the Apes*: SM:1
Mario Puzo: *The Godfather*: SM:1
Anne McCaffrey: *Crystal Singer*: SM:1
George Orwell: *1984*: SM:1
Dale Carnegie: *How to Win Friends and Influence People*: SM:1
Maxwell Maltz: *Psycho-cybernetics*: SM:1
G.& S. Tanner: *Mormonism: Shadow or Reality?*: SM:1
Pool: *Technologies of Liberty*: SM:1
Nathaniel Hawthorne: *The Scarlet Letter*: SM:1
J.R.R. Tolkien: *Lord of the Rings*: SM:1
Lewis Carroll: *Alice in Wonderland*: SM:1
Herman Wouk: *The Caine Mutiny*: SM:1
Arthur Conan Doyle: *Sherlock Holmes stories*: SM:1
First calculus book: SM:1
Lorrie Hull: *Strasberg's Method As Taught by Lorrie Hull*: SM:1
Beeton's Book of Needlework: SM:1
Dr. Suge: *Live to be 100 and Enjoy It*: SM:1
F. Scott Fitzgerald: *Tender is the Night*: SM:1
The Story of Harold: SM:1
Balzac: *Works*: SM:1
Karl Menninger: *The Human Mind*: SM:1
J.D. Salinger: *Catcher in the Rye*: SM:1

Shipbuilding: SM:1
Physics books: SM:1
I.S. Shklovskii: *Intelligent Life in the Universe*: SM:1
Biophysics of Organ Preservation: SM:1
A Music Anthology for the Piano: SM:1
Saul Kent: *The Life Extension Revolution*: AN:2
Frank Wallace: *The Neo-Tech Discovery*: AN:2
Napoleon Hill: *Think and Grow Rich*: AN:2
Dr. Seuss: *The Lorox*: AN:1
Fritz Perls: *Gestalt Therapy Verbatim*: AN:1
Alan Harrington: *The Immortalist*: AN:1
Roy Walford: *Maximum Lifespan*: AN:1
Thomas Wolfe: *The Right Stuff*: AN:1
Robert Nozick: *Philosophical Investigations*: AN:1
Petr Beckmann: *The Health Hazards of Not Going Nuclear*: AN:1
Robert Ringer: *Looking Out For #1*: AN:1
Webster's Dictionary: AN:1
Funk & Wagnall's Encyclopedia: AN:1
F.M. Esfandiary: *Optimism One*: AN:1
Milton & Rose Friedman: *Free to Choose*: AN:1
Feynman, Leighton, & Sands: *Feynman Lectures on Physics*: AN:1
Julian Jaynes: *The Origin of Consciousness. . .*: AN:1
Alvin Toffler: *Future Shock*: AN:1
R. Buckminster Fuller: *Critical Path*: AN:1
Rand-McNally Road Atlas: AN:1
Ward Dean: *Biological Aging Measurement*: AN:1
Lelord Kordel: *Eat and Grow Younger*: AN:1
Gaylord Hauser:*Look Younger, Live Longer*: AN:1
Adelle Davis: *Let's Eat Right to Keep Fit*: AN:1
Students Agains Tyranny: *The White Rose*: AN:1
Screenwriters' Workbook: AN:1
APL: An Interactive Approach: AN:1
Lonnie Barbach: *Pleasures*: AN:1
George Clason: *The Richest Man in Babylon*: AN:1
Urantia Foundation: *The Urantia Book*: AN:1
Jude Wanniski: *The Way the World Works*: AN:1
Martin & Ramanavski: *We Don't Die*: AN:1
Goodman & Gillman: *The Pharmacologic Basis of Therapeutics*: AN:1
Chad Oliver: Science fiction: AN:1
Adam Smith Institute: *The Omega Report*: AN:1
David Friedman: *The Machinery of Freedom*: AN:1
Frank Buck: *Bring 'Em Back Alive*: AN:1
Manual for the Adventurer and Traveler: AN:1
Ernest Becker: *The Denial of Death*: AN:1
Jean Craighead George: *My Side of the Mountain*: AN:1
Punt: AN:1
Liberty Primer: AN:1
Partial Differential Equations of Mathematical Physics: AN:1
Celestial Mechanics: AN:1
Relativistic Field Theories: AN:1

Well, as many seem to have known beforehand, the books holding by far the most votes (though only a plurality) are *The Prospect of Immortality*, *Engines of Creation* and *Atlas Shrugged*. These three books are nearly equal in popularity, and no other book comes close to them. Otherwise there is a wide but thin sprinkling. Certain classes stand out:

science fiction, libertarian philosophy and economics, scientific and technical, health and longevity, along with an expected handful of cryonics books.

Question 48: Do you like travel?

Yes.....SM:55 AN:30
No.....SM:9 AN:3
It's okay. SM:3 AN:2
Indifferent. ..SM:1

Yes, cryonicists are venturesome.

Question 49: Do you collect anything?

Yes: SM:26 AN:9 **No**: SM:35 AN:20

Books.....SM:14
Coins.....SM:8 AN:4
Encyclopedias SM:4
Videos.....SM:4
Comic books SM:3 AN:2
Stamps.....SM:2 AN:1
Memories.....SM:2
Pictures. SM:2
Guns/weapons....SM:2
Antiques.....SM:2
Journals. SM:2
Computers SM:1
Cryonics newsletters SM:1
Genealogical data. SM:1

Medical transcription notes. ..SM:1
Chess sets. SM:1
Libertarian buttons ..AN:1
WWII Materials. ..AN:1
Old music videos: AN:1
Old books.....AN:1
Erotica. SM:1
Pottery. SM:1
Life ext stuff ..SM:1
Articles SM:1
Matchbooks SM:1 AN:1
Baseball cards ..SM:1
Friends. SM:1

Cameras.. .....SM:1
Software.....SM:1
Photos.....SM:1
Antique bottles: SM:1
Art.....SM:1 AN:1
S.F. Books SM:1
Audio tapes. SM:1
Frozen indian dinner boxes SM:1
Spice cans SM:1
Art books. SM:1
Stocks.....AN:1
Historical manuscripts :AN:1
Health books AN:1
Post cards AN:1
Old elec. equip.: AN:1

A large minority of cryonicists are collectors, and someone wants about everything, books and coins topping the lists.

Question 50: Did you suffer any bereavements before getting involved in cryonics?

Yes: SM:25 AN:6 **No**: SM:34 AN:30

Parents. SM:10 AN:2
Husband.....SM:1
Son.....SM:1
Uncle.....SM:1
Friend.....SM:2

Grandparent. SM:2 AN:1
Sibling. SM:2
Pet. SM:5
Boyfriend. SM:1
Neighbor SM:1

A large number, but less than half of SM's suffered bereavements, with parents the most common. For AN's the fraction suffering bereavements is much smaller, which seems to be of significance. If others close to you have died you are probably more likely to think seriously about your own death.

Question 51: Do you think a lot about being rich?

Yes.....SM:24 AN:19
No.....SM:36 AN:11
Occasionally SM:5 AN:5

Several people commented that they not only thought about it, they planned for it.

Question 52: Before getting involved in cryonics did you, or do you now, feel alienated from family, school, society?

Used to:	Yes.....SM:36	AN:14	Now:	Yes.....SM:28	AN:7
	No.....SM:27	AN:16		No.....SM:29	AN:15
	A little SM:5	AN:4		A little SM:8	AN:5

Alienation from society seemed to be more common than alienation from family, though few people gave details. This is another question that would have benefited from more explanation. There are different types of alienation; you may feel alienated but able to cope and function effectively, or you may be alienated and feel trapped and inefficacious. Several people noted feelings of alienation but said it didn't stop them enjoying life or functioning well. A degree of alienation seems highly likely for people who challenge deeply entrenched traditional views of death and who long for more understanding. The growth of the cryonics community may be expected to provide an alternative community which can compensate for feelings of deprivation.

Question 53: Do you read bodybuilding magazines?

Yes: SM:8 AN:3 **No**: SM:58 AN:27 **Sometimes**: SM:1 AN:5

At 13.4% (for SMs), the proportion of cryonicists who read bodybuilding magazines is probably higher than the general population. However, I expected it to be even more since many of us are attracted to the idea that we will become more than human in the future. Bodybuilders seem to represent the physical side of this in that they are far bigger and stronger than the average human.

Question 54: Have you ever had cosmetic surgery? If not, would you if you had the money?

Had cosmetic surgery:	Yes.....SM:6	AN:4	Would have:	Yes.....SM:17	AN:10
	No.....SM:58	AN:30		No.....SM:38	AN:17
				Maybe...SM:11	AN:4

Like question 53, this question was intended to reveal our attitudes towards physical alterations. Though I have no control figures, it's likely that cryonicists are more conducive to the idea of making changes in their appearance through surgical procedures.

Question 55: Would you say that you are generally:

A. Very optimistic. SM:20	AN:8	D. Pessimistic. SM:2	AN:2
B. Optimistic SM:40	AN:20	E. Very Pessimistic SM:2	AN:0
C. Neutral. SM:6	AN:6	Depends on mood SM:2	AN:1

I know of no study of optimism and pessimism in the general population, though the majority of people claim to be satisfied with their lives. Cryonicists are usually much more optimistic than others, being interested in the possibilities of a greatly extended lifespan, expansion into space, and the absence of resource constraints. You are not likely to become a suspension member unless you expect life in the future to be worth living. Of course, you might think *anything* to be better than death, but this may not be sufficient motivation to get signed up.

Question 56: Do you:

A. Prefer new buildings to old SM:26 AN:12
B. Prefer old buildings to new SM:15 AN:6
C. No preference SM:28 AN:18

Somewhat more cryonics people "prefer new buildings to old" than the other way around, which suggests that the desire for novelty somewhat dominates the urge for preservation of the past, but even more have "no preference". In short, the issue does not seem of much significance.

Question 57: Have you ever served in the military?

Yes: SM:19 AN:7 No: SM:51 AN:31

A large majority of both SM's and AN's have not served in the military, which does not seem surprising in view of other factors such as the prevalence of libertarian philosophy (versus the military regimen), and belief in overcoming death (making warmaking especially unpalatable).

Question 58: Do you belong to any community groups?

Yes: SM:16 AN:11 No: SM:52 AN:23

In general cryonicists do not seem to be "pillar of the community" types.

Question 59: Do you give money to:

A. Humanitarian causes. SM:37 AN:18
B. Political causes SM:28 AN:13
C. Cultural organizations SM:13 AN:4
D. Religious organizations. SM:8 AN:2
Write-ins: Alcor. SM:8
Foresight Institute. SM:3
Scientific SM:1
Consumers' Union SM:1
Wildlife conservation. ..SM:1

The Venturists accounted for at least two of the religious organization donations. Clearly cryonicists are not insular people interested only in prolonging their own lives regardless of what goes on the world, despite not belonging to community groups. Especially through humanitarian and political causes they are concerned to improve the world they live in. After all, if we don't keep an eye on what goes on, the world may not be a very pleasant place to come back to -- and maybe we won't be *able* to come back.

Question 60: Are you a registered voter? Have you ever run for political office?

Registered voter:	Yes	SM:59 AN:20	Run for office:	Yes	SM:8 AN:3
	No.	SM:10 AN:11		No.	SM:59 AN:33

Especially considering how many cryonicists are libertarian, it's remarkable how may have run for office. Several non-Americans noted that registering to vote was compulsory in their country. Suspension members are more politically active than non-members, if these results are representative.

Question 61: On the issue of altering *your own* consciousness with chemicals (such as marijuana, hashish, LSD, amphetamines, cocaine, alcohol, barbiturates, nicotine or any subset of these):

A. Are you opposed to doing this SM:28 AN:16
B. Believe it to be a good idea in certain circumstances. SM:29 AN:12
C. Believe it to be a bad idea SM:29 AN:15

Nearly half the SM's and AN's are opposed to psychoactive drugs. The only drugs significantly favored were alcohol (in small amounts), and the psychedelics (LSD, marijuana). There was almost universal opposition to or lack of interest in the physically harmful drugs like amphetamine, cocaine, barbiturates, and nicotine, though a few admitted to smoking despite believing it to be a bad idea. Cryonicists are much more likely than the general population to consider each chemical on its merits and demerits rather than to support or oppose all chemical modifications of brain states. Several people said that A and C were hard to distinguish. I'm not sure what happened when I was formulating the question; either of A or C is redundant. Virtually everyone who said "yes" to one said "yes" to the other.

Question 62. There wasn't one. A slip which both I and the editors missed.

Question 63: What do you think is the most important issue confronting cryonics today?

A. Need to lower prices SM:1 AN:4
B. Need to expand membership..... SM:23 AN:13
C. Need to increase technical capability and standards SM:13 AN:8
D. The legal status of cryonics SM:47 AN:15
E. Need to expand research. SM:14 AN:13
F. Need for co-operation. SM:3 AN:2
G. Other:
   More scientific plausibility SM:1
   Educate the public SM:1 AN:1
   Social acceptance. SM:1 AN:1

There is a heavy emphasis of concern over the legal status of cryonics, which reflects the crises of '88 (Dora Kent case, California Health Department objections).

Question 64: What suggestions do you have for reaching new members?

Generally, the suggestions were of the sort of things that have been tried, or are being tried -- literature, media appearances, appearances at conventions and conferences, etc.

Question 65: What do you feel are the chances of cryonics or suspended animation working for you?

A. Very high. SM:16 AN:3
B. Fairly good. SM:19 AN:9
C. Possible SM:27 AN:21
D. Highly unlikely. SM:8 AN:3

Source of doubts:

Social/legal/political. SM:28 AN:9
Organization may fail SM:8 AN:5
Current techniques crude. SM:5 AN:5
Delay before suspension SM:5 AN:1
Accident.....SM:4 AN:2
Scientific/technical. SM:3
Memory may not be preserved...SM:2
Autopsy.....SM:2 AN:2
Distance from Alcor SM:2 AN:1
Nanotech may destroy us SM:1
Ontological doubts. SM:1
Money might run out.....SM:1
Philosophical SM:1
War vandalism.....SM:1
Mistakes made.....SM:1
Lack of research. SM:1
Revival may be impossible SM:1 AN:2
Won't be necessary. SM:1
Emotional aversion. SM:0 AN:1
Nuclear war.....SM:0 AN:1
Who will want to revive us? SM:0 AN:1

These results were interesting. They are objective evidence that should lay to rest the idea that cryonics is a cult. Cryonicists, even those signed up, are not "true believers". Opinions vary widely about the chances of making it.

Question 66: What age do you think you will be when you are suspended?

30-39.....SM:1 AN:0
40-49.....SM:0 AN:0
50-59.....SM:1 AN:1
60-69.....SM:2 AN:2
70-79.....SM:11 AN:8
80-89.....SM:11 AN:8
90-99.....SM:10 AN:3
100-109.....SM:9 AN:1
110-119.....SM:4 AN:1
120-129 .....SM:1 AN:0
130-139 .....SM:0 AN:1
140-149 .....SM:1
Well over 100 .....SM:2
Don't know. SM:7 AN:1
Don't think about it.SM:1
Probably won't be SM:3 AN:6
Possibly never. SM:1

The median age range is 90-99 for SM's and 80-89 for AN's, showing they both expect to live into ripe old age.

Question 67: In what year do you expect *your* revival to be possible?

2000-24...SM:2 AN:3	2100-09...SM:13 AN:5	2180-89...SM:2 AN:1
2025-39...SM:1 AN:0	2110-19...SM:2 AN:0	2190-99...SM:0 AN:0
2040-49...SM:1 AN:2	2120-29...SM:1 AN:1	2200.....SM:3 AN:2
2050-59...SM:2 AN:2	2130-39...SM:0 AN:1	2300.....SM:1 AN:0
2060-69...SM:4 AN:1	2140-49...SM:1 AN:0	2400.....SM:0 AN:1
2070-79...SM:2 AN:0	2150-59...SM:3 AN:3	2500.....SM:2 AN:1
2080-89...SM:7 AN:1	2160-69...SM:1 AN:0	3000.....SM:1 AN:0
2090-99...SM:1 AN:0	2170-79...SM:1 AN:0	

Other answers: 2241 - SM: 1; Few centuries - SM: 1; 12,000 - AN: 1; 500 years - AN: 1; Never - AN: 1.

There is a wide sprinkling of estimates, with the decade 2100-2109 getting the median and plurality votes for both SM's and AN's.

Question 68: In what year do you think someone suspended with current techniques could be revived?

2010-19...SM:1 AN:0	2100-09...SM:13 AN:4	2190-99...SM:0 AN:0
2020-29...SM:2 AN:2	2110-19...SM:2 AN:0	2200.....SM:5 AN:1
2030-39...SM:1 AN:2	2120-29...SM:2 AN:0	2250.....SM:1 AN:0
2040-49...SM:3 AN:2	2130-39...SM:0 AN:0	2400.....SM:0 AN:1
2050-59...SM:3 AN:5	2140-49...SM:1 AN:0	2500.....SM:1 AN:1
2060-69...SM:4 AN:2	2150-59...SM:5 AN:4	3000.....SM:1 AN:0
2070-79...SM:4 AN:0	2160-69...SM:0 AN:0	12000.....SM:0 AN:1
2080-89...SM:5 AN:0	2170-79...SM:1 AN:0	Don't know: SM:7 AN:2
2090-99...SM:0 AN:1	2180-89...SM:2 AN:0	

Other answers: SM: 2463: 1, 3080: 1, within 500 years: 1; AN: 2007: 1, 2222: 1, Never: 2, Probably never: 2.

Again, 2100-2109 gets the median and plurality votes among SM's, and the median vote among AN's. (It is tied for plurality among AN's, with 2150-59. In general there seems to be a slight tendency for a later estimate among AN's.)

Question 69: When do you expect the prevention and reversal of aging to be possible?

By 2000.....SM:1 AN:1	2050-59.....SM:10 AN:5	2120-39.....SM:1 AN:1
2000-09.....SM:1 AN:2	2060-69.....SM:5 AN:3	2140-59.....SM:1 AN:0
2010-19.....SM:6 AN:5	2070-79.....SM:1 AN:2	2160-79.....SM:0 AN:1
2020-29.....SM:4 AN:2	2080-89.....SM:8 AN:0	2180-99.....SM:0 AN:0
2030-39.....SM:4 AN:2	2090-99.....SM:1 AN:0	2200.....SM:1 AN:2
2040-49.....SM:1 AN:1	2100.....SM:6 AN:3	Don't know..SM:5 AN:1

Other answers: SM: Soon: 1, within 500 years: 1, 2500-3000: 1.
AN: 2230: 1, 12,000: 1

In general, it is estimated that aging will be prevented and reversed some decades before revival from cryonic suspension is possible, with the median estimate at 2050-59, some 50 years earlier than for cryonic revival.

Question 70: How much injury do you think is done with existing perfusion and and suspension techniques?

A. Permanent and irreversible.	SM:1	AN:3
B. Severe, but potentially reversible in future.	SM:33	AN:15
C. Severe, but almost certainly reversible	SM:30	AN:15
D. Moderate.	SM:3	AN:1
E. Insignificant	SM:1	AN:0
Don't know.	SM:1	AN:1

As might be expected, cryonicists are cautiously optimistic.

Question 71: Do you expect any memory loss or other specific damage as a result of freezing?

Yes.	SM:25	AN:14	Possibly.	SM:5	AN:3
No.	SM:14	AN:10	Maybe short term.	SM:4	AN:2
A little.	SM:9	AN:1	Probably.	SM:1	AN:1
Don't know.	SM:8	AN:2			

There is a large degree of uncertainty here, which may be partly attributed to the vagueness of the permitted responses. (For instance, note how "a little", "probably", "maybe short term" and "possibly" overlap.) Curiously, the AN's seem more optimistic than the SM's. A majority, however, of both AN's and SM's favors the opinion that memory loss will not be too severe.

CONCLUSIONS

Cryonicists have certain marked traits. They are venturesome, but at the same time interested in preserving the past. They are nonreligious, non-family oriented, non-society oriented yet optimistic and interested in making a better world through more as well as less conventional means. Though optimistic, they are not dogmatists, particularly when it comes to cryonics. Though generally hopeful, cryonicists also acknowledge a healthy element of doubt whether their particular approach, cryonics, will serve as their means of deliverance. They do, of course, consider life important, including their own. They believe in human solutions to human problems, and that technology holds the key to the betterment of mankind even on such a fundamental problem as mortality. They want a world where life will not slide predictably to oblivion but be open-ended. They are willing to make a serious, rational commitment to the attainment of that dream.

As cryonicists we are interested in reaching others who would find our ideas agreeable and join our ranks. Thus far the single, greatest success in spreading the word on cryonics seems to have come from one well-written book, Ettinger's *The Prospect of Immortality*. Many people, at least among the "older guard" who were active in cryonics (or actively contemplating) in the '60's, seem to have first heard about the idea through this book either directly, through a chain of intermediaries, or as a consequence of promotional efforts growing out of the book's success. More recently, another brilliantly written book, Drexler's *Engines of Creation*, has greatly improved the credibility of cryonics by suggesting, in broad outline at least, a physical mechanism for resuscitation of frozen humans. Well-written books make great promotional tools, though they are not easy to generate, so that other approaches also need to be considered. One possibility is

to collect data of the "psychological profile" variety from a large pool of volunteers and then try to identify those who might be predisposed to favor the cryonics idea, based on responses of a control group of known cryonicists. (Such people might then be sent Alcor information packs or otherwise contacted.) The present survey could provide a starting point for such a project, although we would want to conduct a new survey with a more "generic" questionnaire not specifically slanted toward those who have already embraced cryonics.

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PERSONALS

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Meeting Schedules

Alcor business meetings are usually held on the first Sunday of the month. Guests are welcome. Unless otherwise noted, meetings start at 1 PM. For meeting directions, or if you get lost, call Alcor at (714) 736-1703 and page the technician on call.

ALCOR

The OCTOBER meeting will be held at the Alcor facility:

(SUN, 1 OCT, 1989) Alcor Life Extension Foundation
12327 Doherty St.
Riverside, CA

There will be a YARD SALE of furniture and things from Dick Jones' house.

The NOVEMBER meeting will be held at the home of:

(SUN, 5 NOV, 1989) Marcelon Johnson
8081 Yorktown
Huntington Beach, CA

The DECEMBER meeting is the Annual Turkey Roast, at the home of:

(SUN, 3 DEC, 1989) Saul Kent and Jo Ann Martin
16280 Whispering Spur
Riverside, CA

* * *

Alcor members in the San Francisco Bay area have formed an Alcor chapter, and are aggressively pursuing an improved rescue and suspension capability in that area. Meetings are generally held on the second Sunday of the month, at 4 PM. Meeting locations can be obtained by calling the chapter's Secretary-Treasurer, Thomas Donaldson, at (408) 732-4234 (home), or at work, (415) 593-3200 (ask for Thomas Donaldson).

The OCTOBER meeting will be held at the home of:

(SUN, 8 OCT, 1989) Keith Henson and Arel Lucas
1794 Cardel Way
San Jose, CA

* * *

The New York Cryonics Discussion Group of Alcor meets on the the third Saturday of each month at 6:30 PM, at **72nd Street Studios**. The address is 131 West 72nd Street (New York), between Columbus and Broadway. Ask for the Alcor group. Subway stop: 72nd Street, on the 1, 2, or 3 trains.

The meeting dates are as follows:

OCTOBER 21 NOVEMBER 18 DECEMBER 16 JANUARY 20

If you live in the New York, Philadelphia, New Jersey, or Boston areas and would like to participate in the rebirth of New York cryonics please contact one or more of the following people:

Gerard Arthus (516) 273-3201
Curtis Henderson (516) 589-4256

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