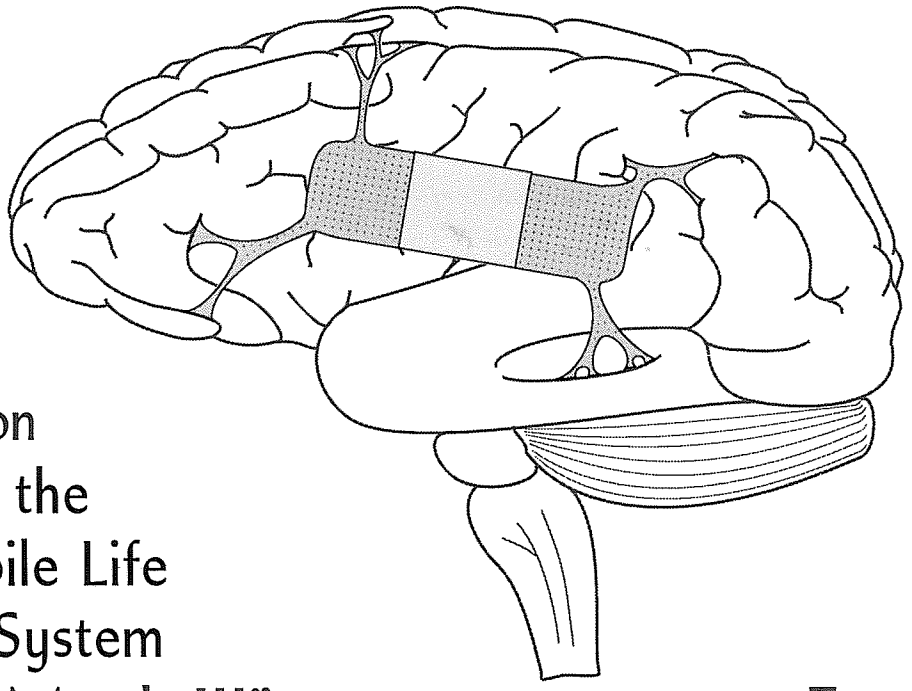
CRYONICS

1st Qtr, 1994 A PUBLICATION OF THE ALCOR LIFE EXTENSION FOUNDATION Volume 15:1

THIS ISSUE'S FEATURE:

The Molecular Repair *of the* Brain

By Ralph Merkle, Ph.D.



Hugh Hixon discusses the new Mobile Life Support System "MLSS Mark III"

Michael Perry explores the early days of immortalism in For the Record

PLUS: *Cryonics* interviews James Baglivo WINNER of the *Omni* /Alcor Immortality Contest

ISSN 1054-4305

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Cryonics is the ultra-low-temperature preservation (biostasis) of terminal patients. **The goal of biostasis and the technology of cryonics is the transport of today's terminal patients to a time in the future when cell and tissue repair technology will be available, and restoration to full function and health will be possible,** a time when cures will exist for virtually all of today's diseases, including aging.

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

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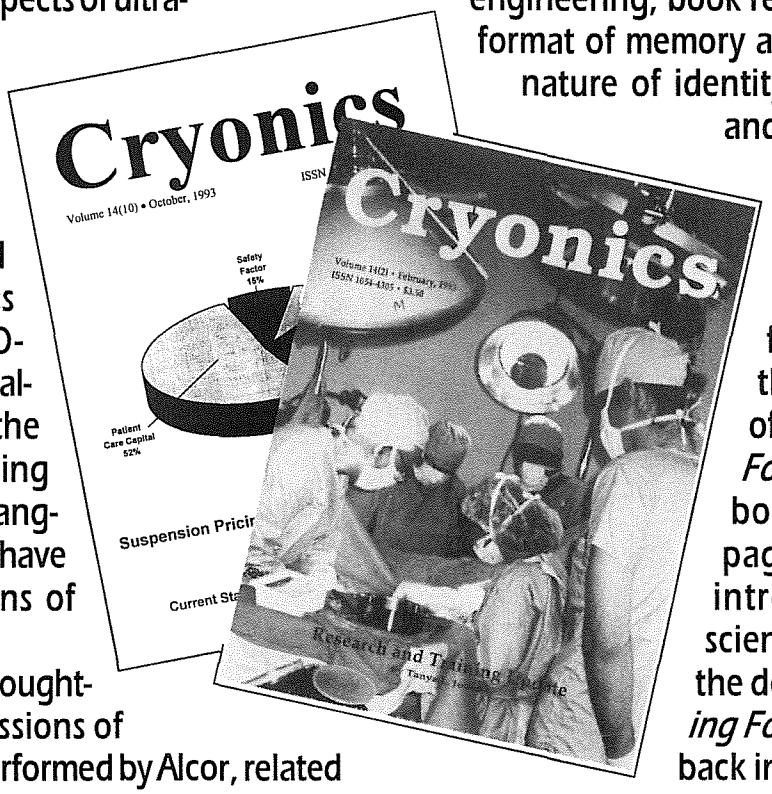
CRYONICS magazine explores the practical, scientific, and social aspects of ultra-low temperature preservation of humans.

As the quarterly publication of the Alcor Foundation—the world's largest and most advanced cryonics organization—CRYONICS takes a realistic, real-world approach to the challenge of maintaining (in a biologically unchanging state) patients who have reached the limitations of modern medicine.

CRYONICS contains thoughtful, provocative discussions of cryonic suspensions performed by Alcor, related research, nanotechnology and molecular engineering, book reviews, the physical format of memory and personality, the nature of identity, cryonics history, and much more.



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See the back inside cover for more information about the Alcor Foundation and Alcor Membership.

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CRYONICS

Editor: Ralph Whelan

Volume 15:1 • Issue #161
January (1st Quarter), 1994
ISSN 1054-4305

Cryonics is the Alcor Foundation quarterly.

Subscriptions:
$15/year U.S., Canada, and Mexico
$20/year all other countries

Back issues are $3.50 each.

Most of the first 150+ issues—#1 (September, 1977) through #160 (December, 1993)—were published on a monthly basis.

Letters and Correspondence

Please address all editorial correspondence to:

Editor, *Cryonics*
Alcor Foundation
12327 Doherty St.
Riverside, CA 92503

FAX: (909) 736-6917 **EMAIL:** info@alcor.org **PHONE:** (800) 367-2228

Letters intended for publication should be clearly marked as such.

UP FRONT

BY RALPH WHELAN, EDITOR

Whew!

So far, 1994 has been a good year for cryonics—if you can handle *change*, that is. The biggest (and most beneficent) change has been the Arizona Department of Health Services' (informal?) decision that cryonics is "medical research," rather than a funeral practice. Accordingly, they have agreed to issue Alcor the permits necessary for transfer of our 27 patients to Scottsdale, Arizona. We're now in high-speed make-like-a-tree mode, and likely will be as much in Arizona as California by the time you read this. The "dry run" test move of a patient-less (but full of liquid nitrogen) 4-person dewar is scheduled for the first week of February. Assuming the dry run isn't *too* educational, the 27 patients will follow soon after.

Other big changes: Alcor Members will have already received their "newsletter precursor," *The Alcor Phoenix*. To make the volume/issue numbers of the newsletter more intuitive (and to give the Editor a chance to make most of the obvious mistakes), this preliminary *Phoenix* is "issue number zero." The first *Phoenix* of 1994 will be Volume 1:1. (There will be 8 issues each year, two between each issue of *Cryonics*.) Since *The Phoenix* is printed in-house and mailed out First Class, we expect it to set a new standard for timely communication between Alcor Central and our hundreds of far-flung members.

The other big change is ... well, you're reading it. *Cryonics* is now a quarterly magazine. This less frequent release schedule allows us to print slightly longer magazines, to upgrade the printing quality, and to lay-out *Cryonics* in-house. (And all of this while saving roughly $10,000/year over the previous cost!) I suspect that this pleases no one so much as overworked Alcor Members Eric Geislinger and Jane Talisman, who have served as Production Editors for the past 40 issues with nothing but a hefty long-distance phone bill to show for it. *Thank you, Eric and Jane!*

The quarterly magazines get off to a roaring start with the first half of Dr. Ralph Merkle's "The Molecular Repair of the Brain." A shorter version of this impressive paper was recently published in *Medical Hypotheses*. Derek Ryan interviews the fascinating James Baglivo, winner of a free whole body suspension in the Omni/Alcor Immortality Contest. Get to know a little more about Jim—and read his winning essay—on page 32. Hugh Hixon tells the story of the new Mobile Life Support System Mark III, the new state-of-the-art in cryonics patient transport. And Thomas Donaldson joins Michael Perry and Steve Bridge as a regular columnist this issue with *The Donaldson Perspective*.

(On a related note: this issue of *Cryonics* and issue number zero of *The Alcor Phoenix* are my trial-by-fire at desktop publishing. Any missing pages or mysteriously unfinished articles will be filled in next quarter.)

Shaking things up still more was last week's earthquake, the 6.6 "Northridge Quake." Our thanks to the many Alcor Members who stumbled to their phones at 4:30am to place a nervous call to Alcor. Everybody's fine and nothing broke, but let's just say that *none of us slept through it*—and some of us now feel a good bit better acquainted with the undersides of our kitchen tables. (And a word to those Alcor Members who will still be living at or around X-Marks-The-Spot in the coming months: if you get shaken up, *call us as soon as possible* so we know you're okay.)

Donation acknowledgment letters have now been mailed out to everyone who donated to Alcor in 1993. If you were a donor in 1993 and have not yet received such a letter—or if the acknowledged total is different from what you recorded—please call Joe Hovey or Steve Bridge at Alcor. It's important to have such a letter for your records, to back-up the tax write-off.

The Last Paragraph of the Dick Jones Story?

On January 20, 1994, more than five years after Alcor placed Richard Clair Jones into cryonic suspension, the California Department of Health Services finally certified his death certificate and gave Alcor a disposition permit showing he is in cryonic suspension at our facility. Dick Jones' disposition and death certificate were the subjects of several years of legal action taken by Alcor against the Department of Health Services. Among other things, the DHS had argued that they could not give us disposition permits because there was no box on the disposition form (VS-9) labeled "cryonic suspension," and therefore (against all common law and the United States Constitution) cryonic suspension must be illegal.

In June, 1992, the Court of Appeal completely upheld Alcor's position, including our contention that the DHS was required by law to register death certificates and issue disposition permits on individuals in cryonic suspension. This decision became final in October, 1992, when the State chose not to appeal to the State Supreme Court.

Even so, it took months of detail work with the DHS, including another day in court and a stern warning from the judge, before progress was made. Over the last several months, Alcor President Steve Bridge and Alcor Member and volunteer Regina Pancake endured several fruitless trips to Los Angeles working on these problems, including about 18 hours sitting in the waiting room of Dick's doctor, who needed to sign a new death certificate. Eventually, the doctor ended up signing three death certificates—the first two were turned down by the DHS for technical errors.

Sometimes it seems that Dick Jones has worked as hard for cryonics after going into suspension as he did in his years of activism before that. But this part of Dick's story is finally over. Now he and the 26 other Alcor Members in suspension have a big move to Arizona ahead of them. And someday in the coming decades, if all goes well, a brand new story to begin.

About the Cover

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

LETTERS to the EDITOR

Dear Mr. Whelan:

Recently I have noticed a feeling among some cryonicists that my recent review of Eric Drexler's book *Nanosystems* was somehow motivated by dislike. While I don't wish to retract anything I said in that review, I feel that I should explain my motives.

As many readers know, I have felt skeptical about Drexler's ideas for some time. When I read *Nanosystems*, I hoped that some of my problems would at least be answered explicitly. I felt disappointed that (despite all the calculations presented) my questions were *not* dealt with. It seems to me, from reading *Nanosystems*, that answers to some of these questions, if done not experimentally but by computation and simulation, require more powerful computers than Drexler had access to. That is a pity and not a cause for anyone to feel joy.

Ultimately the possibility or nonpossibility (or perhaps practicality or nonpracticality) of *mechanical* nanodevices as described by Drexler is a matter of empirical test. A good simulation, though, would help to increase their possibility (or perhaps to show their impossibility, too). My own computing skills lie in the field of highly parallel computers, and I would be happy to help put these questions to the test.

If Drexler had recognized this issue, rather than simply giving the reader a wave of the hand or two, I would have said so. I could not find anywhere in his book where that was done; I would listen with interest to anyone who can point me there. But fundamentally, working machines need more than the designs of single parts, no matter how involved those single parts may be. And equally fundamental, we will not understand how to read ourselves off into machines (if indeed that ever becomes possible in the way that computer programs can be copied) without great attention to the workings of the machines we *now* are: which means understanding of memory, chemically, biologically, and physiologically, and understanding of our drives also.

Best, and long life to all,
Thomas Donaldson

Dear Investment Committee Members:

After resisting long and hard, as a new Alcor suspension member I find I cannot help but put in my two cents' worth. Please find enclosed a copy of the *Patient Fund Investment Goals Questionnaire.* I apologize for deviating from the form of the questionnaire, though I suspect I am not the only one to do so.

The main problem that I had with the questionnaire is the apparent assumption that the Fund be divided into different portfolios in fixed and somewhat arbitrary proportions. I completely support the idea of different portfolios with different strategies and risk levels, but would like to see the amounts apportioned to each fund have a more concrete basis. I would like to suggest a Fund something along these lines:

Emergency Portfolio:

$100,000. This is calculated based on the LN2 costs at a 2% rate of return if all the patients were converted to neuropreservation. All other costs of patient care are assumed to be donated. This is the dire extremes fund, to be used only in the event of the collapse of Alcor, loss of the other portfolios, or political or economic turmoil. It is invested in the most conservative instruments, with an eye to the possible collapse of the U.S. and/or world economies. (I do not agree with the argument that if the economy collapses, all is lost anyhow. My grandfather survived World War I, the collapse of the Austro-Hungarian Empire, the succeeding famine, the Depression, the German hyperinflation, Adolph Hitler, World War II, and a year in a POW camp.) My suggestions: T-bills, Swiss bank accounts, precious metals, cash. This portfolio is a good candidate for an outside trust, to provide the patients a last measure of protection against government confiscation or a legal judgment, or malfeasance in Alcor itself.

Operating Portfolio:

About $910,000. This is calculated based on the *current* total costs of patient care, at a 4% rate of return. For this example, I am using Ralph Whelan's figures from the October *Cryonics* of $17,235 for neuros and $61,634 for whole bodies. This portfolio is used for the normal and necessary expenses of patient care. Since effectively all the income is used for patient care, this portfolio will grow only when an additional patient is suspended. This portfolio is invested in instruments of moderate risk. My suggestions: money market funds, corporate bond funds, stock mutual funds, cryonics based real estate.

Growth Portfolio:

About $40,000 (?). This is whatever is left after the two other portfolios are established. This portfolio is used for more aggressive and risky investments. A goal of perhaps 8% growth (a little over the S&P 500 for the last 25 years) is not totally unreasonable. This portfolio assumes that the economy grows strongly (in the long run) as the result of new and powerful technologies, particularly of the sort needed to revive the patients. This will provide for the growth needed to pay for the revival and rehabilitation of the patients. My suggestions: stock mutual funds, technology funds, corporate bond funds, non-cryonics based real estate, individual technology stocks.

These portfolios are for the *current* Patient Care Fund. However, certain principles govern this plan as we move into the future. These principles dovetail nicely with the cost of the patient care system Ralph Whelan suggested in the October *Cryonics,* though they do not rely on it. It would work something like this:

Regularly, perhaps once a year, the *current* cost of patient care is calculated. This cost is used to determine the amount set aside for the Patient Care Fund (not counting safety margins and operating surpluses) from each suspension. This is also used to calculate the size of the Operating Portfolio using the 25x capital requirement. If any members have been suspended in the last year, the cost per patient should have decreased due to economies of scale. Since the

Operating Portfolio was funded at a higher per patient rate the previous year, it is now overfunded by some very small fraction. The Fund is now reapportioned. If the number of patients exceeds the number of neuros that can be cared for by the current Emergency Portfolio, then additional funds are transferred to it from the now over funded Operating Portfolio and the Growth Portfolio. If not, then the over funding of the Operating Portfolio is transferred to the Growth Portfolio. If all these assumptions are wrong, and one or more portfolios suffered losses, the Fund is still reapportioned, with first the Emergency Portfolio and then the Operating Portfolio brought up to strength. The Growth Portfolio is *always* what is left over after the Emergency and Operating Portfolios are at full strength.

As Alcor grows larger and stronger, a greater percentage of the Patient Care Fund is invested in higher return investments. And while it encourages growth, it always provides for the patients in *two* different ways, even if not another person is suspended and economies of scale never materialize. The Growth Portfolio absorbs the value fluctuations of all three funds, as well as helping provide for under funded suspensions. The Emergency and Operating Portfolios provide constant reassurance that expenses can be met.

Some quick and dirty calculations indicate that (using Ralph Whelan's scenario) if we have 200 patients in 10 years, well over half the Fund would be in the Growth Portfolio. If it takes longer to reach 200 patients, the proportion could be even higher due to longer growth time. I am currently writing a spreadsheet to further investigate the dynamics of this under various assumptions (remember, there are lies, damn lies, and spreadsheets).

Of course, all this planning is for naught if the portfolios are nōt strongly diversified, financially and geographically. But I feel it has a number of advantages over other methods I have heard of, though I must admit that in Georgia I am a bit out of the Alcor mainstream, and may have missed something.

Long Life,
Stephen J. Van Sickle

EXTRO 1

The First Extropy Institute Conference on Transhumanist Thought

Sunnyvale, California, April 30 - May 1 1994

PURPOSE: Extro 1 will be a rich, intellectually invigorating gathering designed to help push outward the boundaries of progress and possibility. It will be both a serious study and a joyful celebration of humanity's limitless potential and how it will be achieved. Besides presentations of accepted papers, the conference will feature lectures by leading thinkers, panel discussions, the first Extropy Awards banquet, and other events.

LOCATION:

The Sunnyvale Sheraton ballroom, Sunnyvale, California.

TIMES:

Saturday April 30, 8am-9am: Registration and welcome.

Saturday, 9am-8pm: Sessions.

Saturday 8.0-10.0pm: Banquet, Extropy Award Ceremony.

Sunday, 8.45am-1.0pm: Sessions.

SESSIONS:

Only those sessions currently (Jan 17) certain are listed here. Many others are under consideration and development.

Keynote speaker: Hans Moravec (*Mind Children*)

The Extropians E-mail List: Past, Present, & Future

Is There an Extropian Epistemology? Pan-critical rationalism and the Extropian Principles

SIMNET — a neural network simulator for modeling complex dynamical systems

Cryptographic Techniques for Resuscitation of Biostasis Patients

Life Extension Research

Extropy Awards presentation

ATTENDANCE FEES

	Before Mar 1	After Mar 1
Exl Members	$60	$70
Non-members	$75	$85

These rates include attendance at all talks and panel discussions, one copy of the conference Proceedings volume (which will include considerably more than just the papers delivered at the event), and light refreshments (coffee, juice, fruit), but not the banquet.

ACCOMMODATION:

Extro 1 attendees are responsible for making their own accomodation arrangements. If you are on tight budget, you might try asking local Extropians to take you in (but don't expect this for free). Bay Area Extropians can be contacted via Exl's local events e-mail list: exi-bay@gnu.ai.mit.edu

REGISTRATION DETAILS:

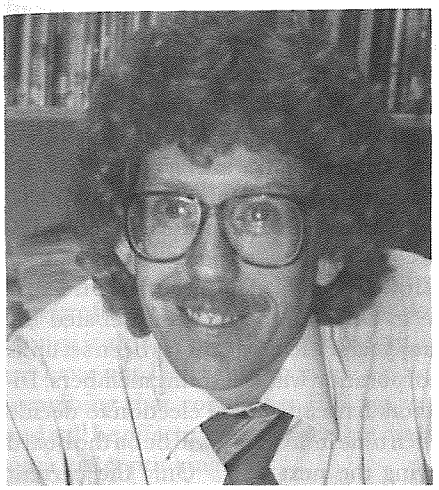
You may register immediately by mailing your payment (check, cash, or money order in U.S. currency) to:

Extropy Institute — Extro 1
11860 Magnolia Avenue, Suite R
Riverside, CA 92503-4911

Extropy Institute members will see further developments reported in *Exponent* — Exl's members' newsletter. To receive further information on Extro 1 as it becomes available, write to the same address, or phone 909-688-2323.

PROCEEDINGS:

If you do not expect to attend but want to reserve a copy of the Proceedings, contact us by April 1.



Notes from the President

Alcor and Cryonics Today

by Stephen W. Bridge

For many of you, this will be the first issue of *CRYONICS* magazine you have ever read. Many others have been reading about Alcor and cryonic suspension for only a few months. Since this is the beginning of a new year—and the end of my first year as Alcor's President and CEO—this looks like a good time for an overview of cryonics in general and Alcor in particular.

First, if you've just picked up this magazine at a newsstand or a friend's house and find you don't understand most of what it's about, call Alcor for a free information packet. If you want really comprehensive information, please order our detailed 110-page book, *Cryonics: Reaching for Tomorrow* (order information on the inside back cover), and perhaps some of the other fascinating books and articles available from Alcor. For the truly obsessed, we even have the entire 13-year run of *CRYONICS* Magazine available on computer disk and microfilm!

Where We Came From

While the idea of suspended animation has been around since at least the 1920s, cryonics really got its start in 1964 with the publication of *The Prospect of Immortality* by Robert C.W. Ettinger. The first human freezing was that of Dr. James Bedford on January 12, 1967; and Dr. Bedford is still in suspension here at Alcor (although Alcor was not the organization which originally suspended him). The Alcor Life Extension Foundation was founded in 1972 and performed its first suspension in 1976.

In the early 1980s, several new cryonicists with medical and scientific backgrounds brought their expertise and viewpoints to Alcor, giving the field a scientific base and a new impetus for growth. Alcor began doing detailed evaluations of suspension procedures and significant research into methods to improve those procedures. The publication of Eric Drexler's book on nanotechnology *Engines of Creation* in 1986 interested many technical people in cryonics, since the book contained Drexler's speculations on how future technology might repair frozen patients.

The suspension of Dora Kent in December of 1987 brought Alcor to the pointed attention of the Riverside Coroner's Office and the California State Department of Health Services, resulting in a landmark series of legal actions over the following five years. These culminated in several court decisions which established the legal right of California residents to choose cryonic suspension and the right of Alcor to perform those suspensions and act as caretaker for the frozen patients.

While the bureaucratic "attention" we received during those five years was often painful and expensive, the media coverage eventually resulted in millions of people throughout North America and the world being exposed to Alcor's ideas. Over the past five years, thousands of people have written or called Alcor to find out more about cryonics.

Where We Are

Cryonics is populated by various hard-headed (they often prefer "rugged") individualists. The mere fact that they agree that they like being alive and think cryonics is a useful backup system does not mean they agree on much else. Consequently, over the years a number of cryonics organizations have been formed, often with very different ideas on what technology should be used, what organizational structure is appropriate, and how financial questions should be addressed. Currently, there are five organizations capable of performing or arranging for a cryonic suspension, at various levels of technology and capability, and a sixth is being formed.

Alcor now has approximately 375 Suspension Members around the world, fully signed up for cryonics protection should it become necessary. We also care for 27 patients who are already cryonically suspended and preserved in liquid nitrogen here at our facility.

I wish I could tell our readers that the problems of cryonics have all been solved, that we can guarantee that each of our patients will be repaired and revived, that we know the economy will hold together, and that the late 21st Century will be a time filled with advanced, life-affirming, long-lived individuals. I can't do that. We can only make guesses about the future, and there are many problems to be solved in cryonics today. That should not discourage us, however. Life is DEFINED by the problems that we must overcome in our everyday survival. The only people or organizations with no problems are those which no longer exist.

One of Alcor's major concerns in the past year has been to move our organization and our patients into a larger building, outside of Southern California's earthquake threat. In September, a limited liability company (an entity with elements of both a corporation and a limited partnership), *Cryonics Property, LLC*, was formed by Alcor and several Alcor suspension members to purchase a building in Scottsdale, Arizona. After several months of planning and of discussing various legal questions with Arizona authorities, it appears that we will begin the move within the next few weeks.

We think this move is the first step in a bright new era for Alcor. Not only will this provide better protection for our patients, but it will allow us to get away from Riverside's prohibition (enforced only on us) against animal research. In Scottsdale we will again be doing experiments to train

our suspension team and, over the next year, begin preparing for significant research into suspension and storage methods.

Cryonicists have debated the issues of cryonics for more than three decades now. The way cryonics groups are organized and the way suspensions are performed today bear little resemblance to the methods of 20 years ago. But we are a long way from having definite answers to many of the problems of cryonic suspension, most of which are the same as those pointed out thirty years ago in Ettinger's *The Prospect of Immortality*. The BIG QUESTIONS still cast mighty large shadows on the legitimacy of cryonics.

The Big Questions

This is not meant to be a definitive list or definitive summaries. Each of these could and have had many pages written about them, and more will be written in the coming years. We invite your comments as well.

1 How do we make sure that the right to provide for one's own cryonic suspension is established and protected? How do we make sure that the patients are legally protected from threats of removal or autopsy?

The United States is a country built on laws, creating an extremely complex maze for anyone trying to do something brand new. In many ways, laws, regulations, and the bureaucrats who blindly enforce them are as great a barrier to cryonics progress as lack of research. Hundreds of thousands of dollars in legal and court fees in California over the past five years have clearly established the legality of cryonics in this state. This decision has been made by the courts, since no cryonics-specific legislation has ever been passed (or seriously contemplated, as far as I know). We believe we are currently convincing the Arizona State Government of that as well, probably without the necessity of a court battle.

The only jurisdiction in the world (that we are aware of) in which cryonics is illegal is British Columbia, Canada. Several members of the Cryonics Society of Canada are actively working to have this law repealed. If you live in Canada and wish to assist with this effort, please contact Ben Best at P.O. Box 788, Station "A," Toronto, Ontario, M5W 1G3, CANADA.

Cryonics organizations today use the Uniform Anatomical Gift Act (in the laws of all 50 states) to gain legal custody of a patient for cryonic suspension. Basically, the Alcor Suspension Member agrees to donate his or her body to a *very* long-term research project. Under current law, cryonic suspensions may be performed only after legal death, and this may be true for many years to come. We can't prove that patients can be recovered from this frozen state; so we can't make any credible legal argument that they are really "alive."

If we ever DO prove our point, it will create dozens of new legal problems. If a patient is not legally "dead," could we use life insurance to fund suspensions? People cannot make anatomical gifts of their *living* bodies, so what mechanism could we use for legal custody? How will the laws dealing with inheritance and ownership of property be affected? If we are performing surgery on "living" people, we will be required to be a branch of *medicine*, which opens up its own Pandora's box of regulations and expenses. I could go on and on.

It is also possible that proposed legislation approving "physician-assisted suicide" will eventually be useful for some of our patients. Of course we do not view cryonic suspension as suicide; but as cryonicists have for the past three decades, we must use whatever laws give our members and patients an advantage. Dr. Jack Kevorkian has certainly focused a lot of attention on an individual's "right" to control his own life. We believe such a right should exist and it should include the right to opt for cryonic preservation when a disease or injury is clearly terminal.

2 How do we construct an organization flexible enough to survive as long as necessary without either moving wildly away from the central goals or becoming too sclerotic to change with the times?

Alcor is a non-profit, tax-exempt organization. Since we are only performing 2-5 suspensions a year, it appears that the tax and public relations advantages of this status are extremely important. Some other suspension organizations are for-profit and perhaps that arrangement will turn out to more practical in the future if cryonics begins a major growth spurt.

How members of the Board of Directors are to be selected has been debated for many years. Alcor has always been set up as a corporation without voting members. Directors have an annual election to decide which nine individuals will be on the Board during the next year. Only the current Directors vote. The purpose of this is to provide for only very slow change in the Board, to continue the "corporate culture" which emphasizes planning for the future and care for the patients. This also prevents sudden changes from a large influx of new members. However, many have complained that this system just as easily could result in entrenched incompetence and in few new people becoming involved in decision-making. I expect this issue to receive pointed examination this year.

Another area of recent debate is on the general structure of a cryonics organization. Should all activities (such as publications, transport, suspension services, patient care, and fund management) be kept "in house," or should they be "unbundled" to several separate organizations?

3 How do we plan financially for the survival of both the organization and the patients?

Cryonics is an expensive project. Just in basic operating funds, Alcor needs around $300,000 per year, and this includes paying our staff sub-marginal salaries (average *under* $14,000 per year). We have spent hundreds of hours over the past year examining our costs for providing transport, suspensions, and patient care. As a consequence of this, we have raised our minimum required donation for neurosuspension to $50,000 and raised our annual Emergency Responsibility Fee (ERF) to $324.00. We will still need to find other sources of money, including donations, or we will have to raise the ERF again, or cut back on basic programs.

The Patient Care Fund appears to be

financially solid, and much work has been done to improve our investment portfolio. We are confident we can keep earnings running ahead of expenses. For a year and a half we have been investigating the possibility of placing the Patient Care Fund into a trust arrangement of some kind; but this has proved extraordinarily difficult and costly. As far as our attorneys can tell, no trust like this has ever been created by a non-profit corporation, at least not with money it already owns. As of this writing, we have not been able to come up with something that could pass IRS approval and still be effective protection; but discussions are continuing.

4 *How do we communicate with and provide prompt cryonic suspensions for a membership spread out over the United States and several foreign countries?*

Some years ago Alcor began a program of appointing local coordinators in various areas of the U.S.A. and supplying them with "Transport Training" and equipment. As Alcor's membership has grown, this has expanded into a loose network of chapters and discussion groups, with many individuals trained as Transport Team Members. We will continue to train people for this purpose, with the eventual goal of having trained teams of volunteers in every area of the United States with very many Alcor members. I suspect that eventually many self-sufficient organizations will be formed as local membership grows.

A similar program has been attempted in Canada and Australia, but for now the distances between the few cryonicists in these immense countries still inhibit their ability to organize and get together. The Alcor organization in Great Britain has its own transport and preparation facility, due to the generosity of Alan Sinclair and others, and the British members are closer together; so they are better prepared for a suspension than anyone else outside the United States. Still, interest in cryonics in each of these countries must grow immensely before full self-sufficiency can be achieved.

5 *How can we know whether identity and memory survive freezing and thawing?*

This is the most crucial of research questions because survival of identity and memory is the entire point of what we are doing. It is also the most difficult, because we still don't know enough about what memory *is* to know if it survives. The goal of every cryonicist interested in research is to be able to train an animal, freeze it, thaw it, and show that it retains the memory of its training. Unfortunately, researchers cannot yet freeze and thaw even one organ and have it survive (although that goal appears to be getting closer by the month), much less any animal much more complex than a worm. There are many technical problems to be solved before the central question can even be examined—although it may be soon possible to show survival of memory in the worms. (Given the limited intellectual capacity of a worm, I suspect few people beyond us will be impressed.)

An immense amount of basic research needs to be done before we even know how to approach this question. Cryonicists have been depending too long on the ragged bits of related information casually dropped by researchers in other fields. We need to find ways to fund this basic research ourselves.

6 *How do we know if current procedures are good enough? If they aren't, how can we tell when they are?*

The easy answer is the hardest to accomplish, of course. We'll know when someone is thawed and tells us, "Yes, it's me." Being told we won't have the answer until we have the answer is hardly satisfying. Before we can begin to answer these questions, we need more basic information about how a cell operates, what makes it *stop* operating, and what changes occur at extremely low temperatures. Right now we are stuck with imprecise results from cryobiology that show some cells survive freezing well. Thanks to the research of dedicated cryonicists like Jerry Leaf, Michael Darwin, and Hugh Hixon over the past decade, we do know that our procedures from declaration of death through blood washout and cooling (down to about 4 degrees above freezing) have a high likelihood of preserving brain structure and memory. Dogs have been treated in this way and held at 4 degrees C (not frozen) for as long as five hours on occasion and survived, memories intact.

Beyond that we are theorizing with comparatively limited information. Answers could probably be obtained with a very few million dollars of research, but that kind of money is not available now.

7 *How will repair of frozen patients be accomplished?*

A number of possible solutions to this exist, some of which are explored in Alcor's basic literature. These range from biologically-engineered cell replacement devices to mechanical cell-repair machines to copying all of the person's identity into a computer and building a new brain. *[See "The Molecular Repair of the Brain," by Ralph Merkle, Ph.D. in this issue. —Ed.]* Which choices will be available in the future remain unknown, but it seems likely that at least one of these methods will be possible. I don't feel we should spend an inordinate amount of time worrying about this issue. For now, the most important thing is to work hard to insure that enough information is preserved, so there is something left to repair.

8 *How long will this all take? How long does an organization have to survive?*

I suspect that within the next 50 years some form of "suspended animation" will be possible. That is, scientists will be able to place a healthy individual into a kind of unchanging state (possibly via freezing or low temperature storage, but not necessarily), hold that individual for an appropriately long period of time, and revive him. That accomplishment will NOT mean that patients frozen with today's limited techniques can then be revived. Today's patients are far from healthy and we know we are inflicting additional damage on their bodies before we can reduce their tem-

peratures to an unchanging state.

A cryonics organization must survive *at least* until the following things are possible:

A. Most diseases are curable, and the damage caused by them and by traumatic injuries is repairable.

B. Medicine has the ability to accomplish at least some cell-by-cell repair, and to regrow any organ which is missing or which cannot be easily repaired. Such abilities probably include an advanced technology for manipulating individual molecules.

C. Aging is reversible and an indefinite lifespan is possible.

D. The damages caused by freezing injury are reversible. For some patients frozen under particularly difficult conditions, this may require advanced artificial intelligences with a near-total knowledge of normal brain structure and how it is disrupted by myriad ischemic and freezing scenarios.

E. All of the above advances can be *afforded* by the organization responsible for the patients.

If you are fortunate enough to survive another fifty years, you may reach a period where suspension (the word "cryonic" may not even be appropriate by then) is required only for victims of especially damaging accidents or sudden, rare diseases. But I wouldn't bet my life that medical technology will progress that fast—those of us in our forties and fifties thought we would be living on the Moon by now. If you are young and think you can just skip cryonics and go directly to biological immortality, you're taking an awful chance. I have known several otherwise healthy people who died under the age of 40 from cancer, sudden infection, "silent" heart disease, accident, or homicide.

The best advice I can give is: *hope* this will work in less than fifty years, but *prepare* for it to take 200 years.

9 How can we convince more people to accept our point of view, to join us in this activity, to support the research necessary to accomplish suspended animation?

Talk, talk, and more talk. Personal contact is still the one biggest key to convincing people that cryonics is a sensible thing to pursue. So Alcor employees and volunteers produce literature for distribution, give lectures, attend conferences which may attract similar individuals, and do dozens of media interviews and in-house tours each year.

All of our readers and members can help with this effort. Send copies of Alcor literature to any of your friends and family with open, inquisitive minds. Help us set up conference and lecture appearances. Some of you may learn enough about cryonics to do local interviews (but please don't do this without informing Alcor). Set up casual groups in your local area to discuss cryonics, perhaps combined with the other subjects most of us are fascinated by: life extension, artificial intelligence, future technology, space travel, etc.

Another factor is that we need more *facts* to talk about. We have to afford the research so we can be seen as making *progress*. Cryonics is currently a very well thought-out and presented idea. But the amount of *evidence* we have to back it up is painfully thin. You can help by supporting the beginning stages of research yourself.

10 How do we find the technical people capable of making progress in all areas of cryonics and increasing our ability to perform suspensions? How do we train them, pay them? How do we get the right people in the right jobs—and pay them what they are worth?

Actually, the answers to these questions, as well as 1 through 9, require the same things: more people, more ideas, more effort, more money. It is impossible to get the most talented people to manage Alcor, to perform suspensions, and to do research if we can only pay them $14,000 per year. We have had many volunteers over the decades who contributed mightily of their time and intellect; but full time people are required for anything major to be accomplished. I would love to say that you can invest in some cryonics company, make a lot of money for yourself and the company, and achieve our research goals. That's not true now and won't be true for a very long time.

Right Now

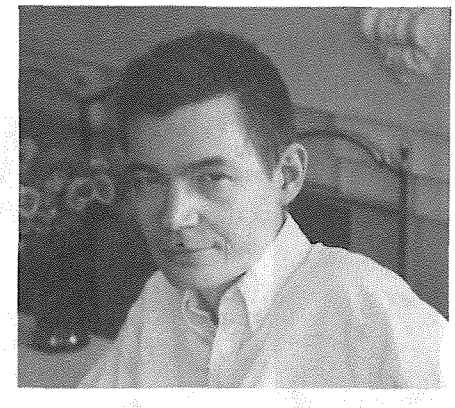
Right now, we need people who decide that staying alive is worth enough to them to provide their time and money to help run the organization and propel the research. Sitting around and thinking about cryonics has accomplished about all it's going to. The time for solid effort by a large number of people—as opposed to the handful who have been doing it for years—is long past.

Maybe it's time for *you* to step forward. You don't have to move to Arizona to help us make progress. With your own time and effort you can influence friends, writers, and scientists all over the world, merely by sending them our literature with your own comments. If you are able, contributing funds to research and to the daily progress of Alcor will put us closer to our goals. There are many other ways to help. Please call or write. *You* could be part of the answer to the Big Questions.

For the Record. . .

Trials of a Hopeful Immortal

The Life and Times of Origen



by Michael Perry, Ph.D.

Cryonics is a unique, 20th-century phenomenon, based on a scientific perspective of reality, and relying on human efforts and ingenuity to complete its mission of liberating the human frame from its biological limitations. It is only rendered possible, in turn, by the great advances that have been made in understanding and technology, so that the idea of effecting our own superhuman transition seems increasingly plausible and worthy of thought and effort.

We are indeed fortunate to be living in such times, yet it is worthwhile occasionally to look back to earlier times. In the past, there was little prospect of addressing the problem of death scientifically, yet people were still very much interested in freeing themselves of this burden and ascending to higher than human status. Some were so moved by a serene confidence in the desired outcome, by whatever means it might happen, that they spent their earthly lives, as far as possible, pondering what might lie in the infinite beyond and how to better direct one's life toward it. Their thoughts, stretching over millennia and exploring many avenues of the problem of becoming more than human, are worthy of attention today, even if our view of reality is different.

One of the greatest of these speculative transhumanists was the 3rd century Christian philosopher Origen, whose early life was spent mainly in the Greek-speaking Egyptian city of Alexandria. Origen (the name means "born of Horus" but was used by Christians as well as pagans) was mentioned in this column before, in connection with religion and cryonics[1]. However, there are certain features of his life and thought that call for more extended treatment, emphasizing those elements that extend across the boundaries of a particular world view. I think that we as immortalists can appreciate the problems he faced, despite our differences in outlook, and perhaps gain insight that will help in our own, hopeful transition to more-than-human status.

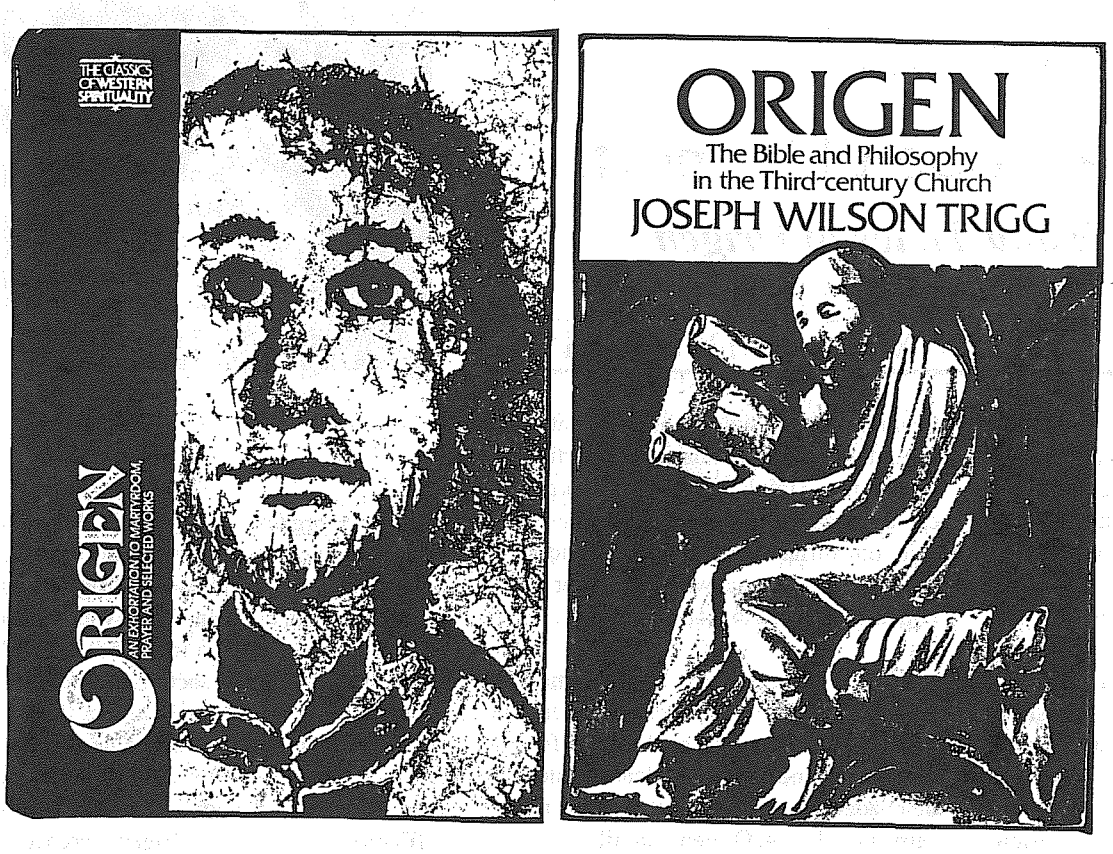
We may imagine then, the problems that would be confronted by a sensitive, intelligent child thrust into a world where life was often nasty and short, and death could not be evaded by human effort, however sincere and diligent. Origen's family had embraced Christianity, which, as citizens of the Roman Empire, placed them under threat of persecution. (Christianization of the Empire would not come until the accession of Constantine more than 100 years later.) Christianity offered an exalted view of a world beyond the mortal limits, and prescribed a code of conduct to attain it. Unfortunately some of its requirements ran afoul of the establishment and fostered continual harassment. For example, citizens were required to profess respect for the emperor as a divinity (done by offering a pinch of incense at a civic altar), something Christians refused to do. Refusal placed one's loyalty to the state under suspicion and might be treated very harshly.

"We may imagine, then, the problems that would be confronted by a sensitive, intelligent child thrust into a world where life was often nasty and short, and death could not be evaded by human effort, however sincere and diligent."

At intervals persecutions against Christians were organized on a scale that was large and violent. It was during one of these, about 202 A.D. when Origen was seventeen, that his own father was put to death for the beliefs he followed and had taught his son. The precocious and devoted youth, already acquiring a reputation for scholarship and interest in the deep questions of life, wanted to join his father in martyrdom, and was only dissuaded with difficulty by his mother. Origen's preoccupations then, though esoteric, were far from purely academic, and he was willing to suffer as necessary for the ideals he upheld.

There is, in fact, an interesting contrast with the general run of attitudes seen in the pre-Christian Roman state, and those who would eventually supplant it. The state would have been concerned with citizens en masse, with each citizen "doing his duty," remaining loyal and productive through his or her natural lifespan. When that was over, the state would have no further interest, except insofar as there should be progeny so life could go on, more or less as before.

On the other hand Christians, in the formative period a century or so before Origen, had an apocalyptic vision in which Jesus was expected soon to return to earth and lead his movement to a new and unprecedented condition, the "kingdom of heaven." Though opinions varied, the hope was seriously entertained that this would be the start of truly more-than-human, immortal existence. This hope was preserved and nurtured in the new faith as it developed, and continued to burn fiercely after expectations of an imminent return had faded.



INTEREST IN ORIGEN CONTINUES, AS THESE MODERN TITLES ATTEST

The "kingdom"—a community of immortals—would obviously differ radically from existing society, many of whose institutions and demands were consequently seen as unimportant.

In fact, in the New Testament that was a product of this formative period one finds some rather startling anticipations of issues that would only be expected to surface if death could be eliminated. Jesus, it says in a remarkable passage,[3] was disputing some Sadducees who denied that people would be resurrected. Their arguments were not along the lines of saying resurrection was impossible *in principle* ("all things" would have been possible to God, for instance), but that it would never happen because it would violate the established, sanctioned order. That is, if a woman had remarried after the death of her husband (this is iterated to seven successive husbands to underscore the point) then at the resurrection, they ask, whose wife would she be? Polyandry being disallowed in society of the time, this was an impossibility.

Viewed a little more generally, we see what appears to be recognition of a biological fact: people don't just "live," they grow up, marry, produce families, die, and *that's it*. They are part of a cyclic chain of events: life goes on though individuals do not; to have it otherwise would be improper.

In expressing an alternative possibility, Jesus hits on something of no small significance to us, as we contemplate a literal end to death through scientific means. He says that the woman and her husbands would no longer be married but would live "like angels," i.e., the biological imperatives would no longer apply. *After immortality, procreation, having served its purpose, essentially must cease.* (In view of the mores of the times, this meant sex must cease also, something I'll say a little more about later.)

It seems likely, in fact, that sex can be entirely decoupled from reproduction. People may continue to be fully active, sexual beings yet have full control of the "population problem."

In general one frequently finds in the Christian literature a disparagement of sexuality. Sometimes Christianity has been severely taken to task for this hostility toward something that is so strongly rooted in human nature and so widely seen as necessary for joy and fulfilment. However, I think there are larger issues at stake that are bravely being addressed, and much of the negativity is at least understandable. Immortality will surely bring major changes.

So, to return to the overstressed, brilliant young man who had recently endured the murder of his father and others among his people, it may not seem surprising that thoughts of an otherworldly existence would very largely dominate his thinking. True to this pattern, his personal life became a study in austerity, while he spent his hours in research, teaching and writing.

Some of this austerity no doubt was fostered by his now-serious financial plight—the death of his father, who had been fairly prosperous, left Origen to provide for his widowed mother and eight younger siblings. He fasted often, wore no shoes and subsisted with little sleep and without a bed. This however was not enough and, following a Biblical exhortation to make oneself a eunuch "for the sake of the kingdom of heaven,"[4] he castrated himself (or had the operation performed; it was a routine surgical practice,[5] eunuchs having their uses). Such an act was not viewed favorably and would be used against him, many years later, in a dispute with the local bishop, in which Origen was banished from Alexandria. (He then spent much of his time in Caesarea, Palestine.) Ironically, Origen himself would comment that doing violence to the body was not the road to "true purity" and would perfect a nonliteral approach to interpreting passages from the Bible.[6] (He continued, however,

to advocate sexual renunciation for those so inclined, including himself.)

Despite the hardships of his youth, Origen, with the help of a wealthy patron, would go on to become one of the most prolific writers of all time, and one of the most compassionate thinkers in the history of Christianity. In fact, when a long lull in the persecutions allowed a flowering of creative output, Origen found himself in trouble with his own people. He was too kind-hearted, asserting that the goodness of God would result in the salvation of all rational beings in the end. (A later detractor would rail that "he has dared to pay great honor to the devil"[7] who would be among the beneficiaries.)

And eventually, there was another persecution. Origen, now in his sixties, was arrested and tortured severely, the object being not to kill him but make him renounce his beliefs. His feet were stretched far apart, a chain was fastened around his neck, and he was repeatedly brought to the brink of death, then revived. But Origen held firm, and the death of the emperor ended the ordeal. The severities had broken his health, however, and he died soon afterward, around 253.

Later, when Christianity became the state religion, Origen's writings came under increasing scrutiny and attack. They were finally condemned at the Fifth General Council in Constantinople, in 553, and most of his vast output was subsequently destroyed or lost (about a third survives, mainly in translations). One remarkable work that we still possess in reconstructible form is *On First Principles*. Here Origen lays out a system of the world and speculates on transhuman and posthuman existence. Essentially, life in the future is seen as a vast educational process, in which the secrets of the universe will be revealed in all their depth and clarity, and in addition, each participant will experience an "unspeakable joy."[8] This process will never be finally consummated for, no matter how far the understanding extends, there is always more to be learned. There will always be something worth living for, and the means to live life as it should be lived.

In the long history of thought about what sort of life ought to follow this one—if something other than oblivion is possible—there are those who concentrated on the punishments some might receive, and others who focused more on the rewards and benefits. I think it is the latter, among whom Origen is prominent, who have more to say that is of interest to us. It seems unlikely, for example, that long and ingenious punishment would be the best way to deal with anyone's problems, in the transition from mortal to immortal, but everyone will want to enjoy benefits. What will the "good life" of the future be like? No doubt there will be many changes, among the most fundamental of which, one suspects, being those connected directly with the elimination of death.

In particular, without the attrition of older individuals, procreation will indeed lose its urgency, and in fact become a liability. Today we already see this happening, with the world population burgeoned by increasing life expectancy, but also indications that the problem may be less severe than once thought. Improved methods of birth control, increasingly encouraged and accepted, allow limiting of childbearing without the austerities of the past. It seems likely, in fact, that sex can be entirely decoupled from reproduction. People may continue to be fully active, sexual beings yet have full control of the "population problem." (It is worth pointing out, too, that procreation could actually continue for a long time to come at the rate of two children per couple without exhausing the resources likely to be available.)

I suspect, though, that in the immense changes and increased options that will accompany our progress to posthumans, concepts like sexuality and procreation will largely lose their meaning. Hopefully, we will all engage in reasoned activity to promote our immortality and happiness. Sometimes this may involve creation of other beings with whom we hope to share eternity, though the process may differ greatly from its biological precursor. But exactly how it will be, and what we might discover about the true nature of life and death, and the possibilities of immortality, only time can tell.

Sources:

A: Brown, P. *The Body and Society: Men, Women, and Sexual Renunciation in Early Christianity*, Columbia University Pr., 1988.

B: Eusebius, *The History of the Church*, Williamson tr., Penguin, 1981.

C: Origen, *On First Principles*, Butterworth tr., Peter Smith, 1973.

D: Origen, *On First Principles,* Crombie tr., in *The Ante-Nicene Fathers,* vol. IV, T & T Clark, 1885, Eerdmans reprint.

E: Payne, R. *The Fathers of the Eastern Church*, Dorset, 1989.

F: Trigg, J. W. *Origen: The Bible and Philosophy in the Third-century Church*, Knox, 1983.

Notes:

1: Perry, M. "For the Record" *Cryonics* Jun. 1993, 5; **2:** F, 21; **3:** Matt. 22.23-30; **4:** Matt. 19.12; **5:** A, 168; **6:** E, 46; **7:** C, 251, footnote 1; **8:** D, 299 col. 1.

Membership Status

Alcor has 374 Suspension Members, 546 Associate Members (includes 105 in the process of becoming Suspension Members), and 27 members in suspension. These numbers are broken down by country below.

Country	Members	Applicants	Subscribers
Argentina	0	1	1
Austria	1	0	1
Australia	13	1	4
Brazil	0	0	1
Canada	11	5	50
Costa Rica	0	0	1
Denmark	0	0	1
Estonia	0	0	1
Finland	0	0	2
France	0	0	2
Germany	1	1	1
Holland	0	0	2
Ireland	0	1	1

Country	Members	Applicants	Subscribers
Italy	0	2	1
Japan	2	0	2
Lichtenstein	0	0	1
Lithuania	0	0	2
New Zealand	0	0	1
P. D'Andorra	0	0	1
Russia	0	0	4
Sri Lanka	0	0	1
Sweden	0	0	1
Switzerland	0	0	1
U.K.	13	4	7
U.S.A.	327	88	350
Ukraine	0	0	1
TOTALS	**374**	**105**	**441**

The MLSS We Wanted To Build:

The Mobile Life Support System
Mark III

by Hugh Hixon

From *Cryonics*, March, 1987:

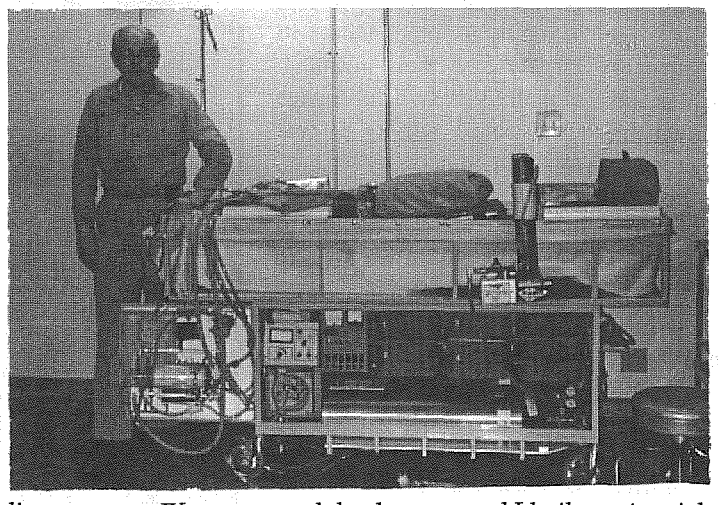
Early in 1985 a decision was made by Cryovita Laboratories with support from the Alcor Life Extension Foundation to develop an easily transportable, fully self-contained extracorporeal perfusion and cooling unit for use in the transport of biostasis patients. The objectives to be met in the design of this unit were that it be readily transportable, relatively straightforward to operate, fully self-contained in terms of power requirements and supporting supplies (disposables, surgical instruments, medications, etc.), and that it be capable of meeting the normothermic metabolic demands of the average adult.

The primary purpose of the MALSS is to allow for field cardiopulmonary support by extracorporeal perfusion. However, because of the necessity to await the pronouncement of clinical death imposed by current legal constraints, preparation of the patient for extracorporeal support must begin after respiratory and cardiac arrest. In order to minimize ischemic damage during the interval between pronouncement of legal death and the start of extracorporeal support it is necessary to administer CPR. While it is anticipated that under most circumstances femoral cutdown and initiation of bypass can be undertaken with 15 to 30 minutes of legal death, it is still necessary to have mechanical adjuncts for CPR available in order to maximize use of the extremely limited number of personnel available in a field setting.

And so we did.

Jerry Leaf had had this project in mind for some time, and had acquired from somewhere a 24-volt tubing (or roller) pump (probably designed for the Army, which still uses that voltage). He had seen in perfusionist professional literature several custom-built perfusion carts and so had a good idea of what he wanted—except for the price. Estimates of the cost of the prototype carts ran in the neighborhood of $150,000 to $250,000; not unreasonable for something designed and built by a custom engineering company but far beyond our means.

Shopping around, Jerry and Mike Darwin located a Travenol *Life Support Litter*, which in a folding tubular aluminum frame accomodated a Brunswick *HLR 50-90* thumper, a cardiac monitor-defibrillator, two 22 ft^3 oxygen "E" cylinders, and three storage drawers. */See the issue of Cryonics quoted above for pictures. –Ed./* These they turned over to me.

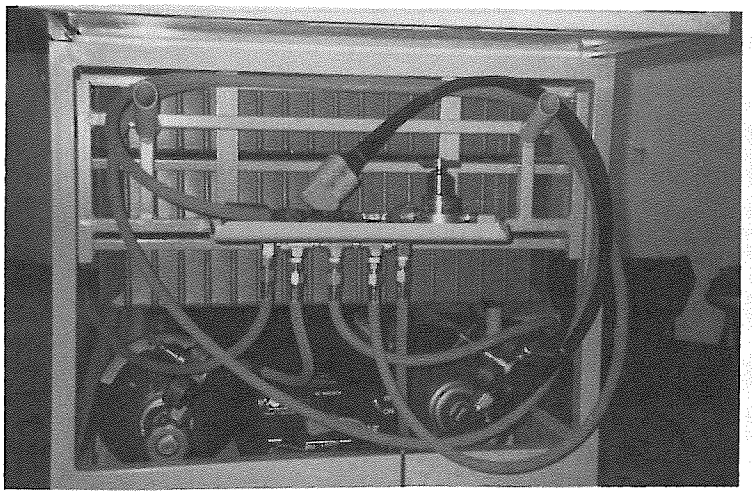


We remounted the drawers, and I built support frames for the tubing pump, two 12-volt batteries, a weird 2 x 12-volt battery charger to provide 24-volt power, a (very noisy) air/vacuum pump modified from a 12-volt auto tire pump, a water pump, and a power distribution panel for the whole thing. We also grafted on a collection of struts and clamps to mount an oxygenator, monitoring instruments, and the like. And it didn't fold any more.

One problem was immediately obvious: the main frame was very noticeably bowed from the weight of all the equipment on it (the batteries totaled 90 lbs alone). Jerry took the frame away and brought it back with the bottom struts replaced with chrome-moly steel tubing. It was still a bit springy, but OK. I now estimate that at that point it weighed about 450 lbs, without a patient. This impression of overloading was reinforced a few years ago when I replaced the

Mark III?

For nomenclature purposes, the first MLSS, constructed at Cryovita Laboratories by Jerry Leaf, Mike Darwin, and myself, is the Mark I. It has gone through a number of major modifications, and I would now call it, somewhat arbitrarily, the Mark I, Model III MLSS. The Mark II MLSS is an uncompleted frame built by Keith Henson. Its salient points are a welded- steel frame and separate ice bath, mechanical section, and dolly, in order to get it into Keith's station wagon. The Mark III is the MLSS recently completed at Alcor, and is the logical extension of the Mark I, mated with the steel frame of the Mark II, all done on a clean slate.



The "squid" surface cooling spray system.

wheels. The rims of the original wheels had been progressively deformed by the rolling weight, so that the solid tires were no longer tight on the rims. With a patient and ice bags, the MLSS easily topped 650 lbs.

It was NOT "easily transportable," as we had originally called for. Getting it into the Cryovita van, and later the Alcor ambulance, was a gut-busting strain-everything operation as two or three men lifted first one end and then the other into the two-foot-high vehicle bed, with inadequate support and handholds. We didn't do it very often, and in fact never did it with a patient this way. The real advance in transportability came when we had a 1000-lb lift gate installed on the ambulance. I think the final straw that led to that being done was our first experience in using the MLSS, in the "Carl Harper" suspension in June, 1987. Because of (among other things) the weight problem, we transported the patient on a regular gurney with HLR in the ambulance to Alcor, and then moved him onto the MLSS in the facility for extracorporeal washout and cooldown. After that, I investigated the power lifts used on the vehicles of handicapped persons. What we eventually got was a modified pickup truck lift gate. Jerry, with a bad back, was particularly appreciative of the $2,500 investment.

In the following years, we made several major modifications to the MLSS: The Brunswick HLR was replaced by a more effective and reliable Michigan Instruments HLR; the cardiac monitor was removed and a modified ice bath was mounted on the top, replacing ice bags heaped on the patient in an unstable, dripping pile; an icewater circulating system was added; and various changes were made for the use of different perfusion circuit components.

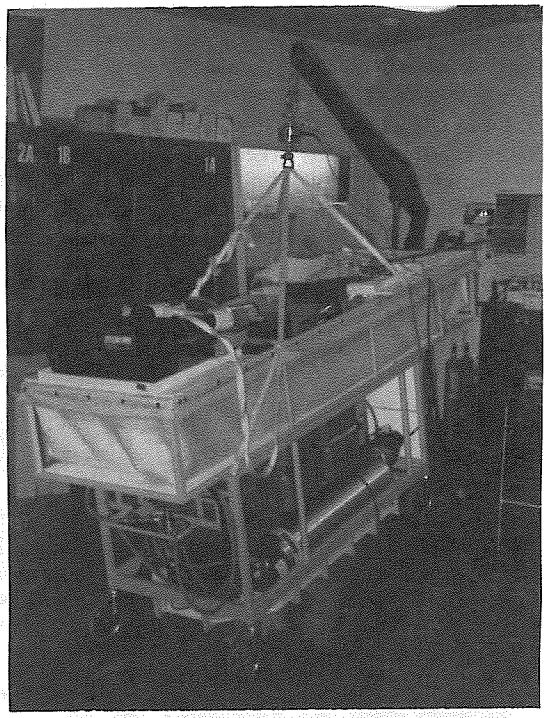
As noted above, the first use of the MLSS was in 1987, and as is expected for a prototype, it had some problems; which were addressed by some modifications. The next use was in the Dick Jones suspension of December, 1988. By this time we had the lift gate on the ambulance and the Michigan Instruments HLR had replaced the failure-prone Brunswick. Dick was removed from the hospital on the HLR, and was placed on bypass at a local mortuary.

In June, 1990, the seed of another improvement was invented. For Arlene Fried's suspension, Fred Chamberlain put together a spray system to improve surface cooling while extracorporeal circulation was being established. (See picture above.) Referred to as a "squid" for all its distribution legs, it worked well but was not very efficient, since Fred put it together from available pieces on very short notice. I reworked the idea for the MLSS, and since it required an ice bath to operate, Mike Darwin put a modified ice bath on the MLSS, along with a more effective Michigan Instruments *High Impulse* HLR. The MLSS was not used again, however, until December, 1991. There we found out that my system was a bit too enthusiastic, and put icewater on people that didn't need it. Robert Cardwell in Australia subsequently came up with a better diffuser design and I incorporated it into the MLSS.

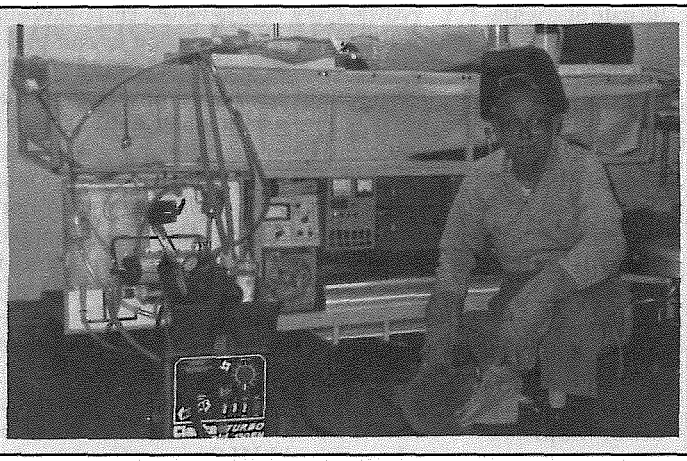
Also along the way, we underwent a number of modifications in the perfusion circuit. Probably the most important one was procedural. Jerry Leaf was an experienced perfusionist, and the extracorporeal perfusion tubing packs he built for both the MLSS and the cryoprotective perfusion reflected that. They had just the basic components, and Jerry would complete the circuit in the field with bits and pieces from other sources. The upshot of this was that only Jerry could string the circuits; a problem that caused us no end of trouble if Jerry was away. And by monumental bad luck, two suspensions occurred when he was on vacation. On the second of these, in December, 1990, the problem was dropped in my lap, and I was not even aware that the tubing pack was incomplete. If stringing the perfusion circuit was an intelligence test, I failed it miserably. (Fortunately, the patient was just an hour from Alcor's lab, so another washout method was used.)

After Jerry's suspension, responsibility for the MLSS and perfusion circuit packs fell to me. *My* packs have all the components, a build-up diagram, an assembly diagram, a list of additional required components, and extensive markings on the tubing and other components as to what tube goes where. I also have a complete non-sterile tubing package for training people, and have done so. I would not pronounce it idiot-proof (idiots are much too clever), but setup of the circuit is much simpler now. (Using it in the field is a whole 'nother can of worms, but I'm working on it.)

After the separation of Cryovita Laboratories from Alcor in 1992, Alcor continued to lease the old MLSS from Cryovita; but given the circumstances, this was obviously a fragile arrangement. About this time for other reasons, (engineer and Alcor board member) Keith Henson began construction of a MLSS of his own. It has never been completed, but Keith fabricated it by gas-welding mild steel tubing. Most medical equipment is made of stainless steel or aluminum, or chrome-plated steel, for resistance to corrosion, lightness, looks, and combinations of these reasons. The joining technologies involved with these materials are not for beginners. However, given that the MLSS is a low-use item (reducing corrosion problems), and that because of the equipment on it, it is already beyond the ability of four big paramedics (or even four gorillas) to lift when loaded (cancelling any particular advantage for the lower weight of aluminum in the frame), mild steel, with its ease of fabrication, becomes a good choice for a frame material, and



The Mark III outweighs the Mark I by 115 lbs.



A Welding Shop

I eventually settled on a a wire-feed metal-inert-gas (MIG) welder. Scott Herman, who is a journeyman electrician, convinced me that 220-volt power is readily available in almost every home, so I got the biggest hobby welder available. Compared to commercial MIG welders it looks like a toy, but it turned out to be a little monster. A test showed that it is fully capable of good penetration in 3/4" steel plate, and that its nominal 20% duty cycle is a generous underestimate. The inert gas shield produces easily cleaned, slag-free welds. A surface grinder allows me to grind my welds smooth and wire-wheel rust away. An abrasive cutoff saw allows me to cut steel tubing quickly. And a split-leg leather apron keeps me from putting any more tiny burn holes in my pants.

Keith's work made that obvious. Finally, since I had taken an adult-education welding class for fun several years previously, I knew what I would need for equipment to do the job.

Eventually, I bought most of the equipment for a small welding shop and set to work (See Box, top of next page). My first project was a steel-frame ice bath to replace the plywood-and-PVC-pipe one in our Remote Kit (the air-shipment package that allows us to do a wash-out and cooldown outside the range of our ambulance; it has been used six times.) The new ice bath folds into a reasonably compact package for air shipment and is a great deal stronger and more durable than the old ice bath. The second was a new MLSS, the schedule being somewhat accelerated by Cryovita's termination of our lease on the old one, for undisclosed reasons.

I will not go into the design decisions that resulted in the new MLSS, but among the parameters were: fabricating equipment available, component cost and availability, the possibilities in a moderately large hardware catalog collection, the interior dimensions of a certain almost-too-small hospital elevator, (Alcor Suspension Services Manager) Tanya Jones' height (5'2"), caster design, oxygen cylinder dimensions, the height of the door of the ambulance, modifications possible to an extracorporeal tubing pump, the width of doorways, the critical dimensions of the old MLSS, the size of the HLR, oxygen supply logistics, ambulance power output, the memory of various curses by Jerry and Mike laid upon the old MLSS in moments of inadequacy, and personal experience with the old MLSS on two transports.

And so we now have the Alcor Mobile Life Support System, Mark III, the MLSS we *really* wanted in 1985. Weight ready-to-go, 625 lbs; parts cost, approximately $6,500; construction time, several hundred man-hours, spread out over four months.

Details of improvements as follows:

■ The new steel frame is stronger and more durable than the aluminum, steel and PVC tubing combination of the original, and it is custom designed and constructed around essential features of the whole unit. And it is designed to integrate into the ambulance.

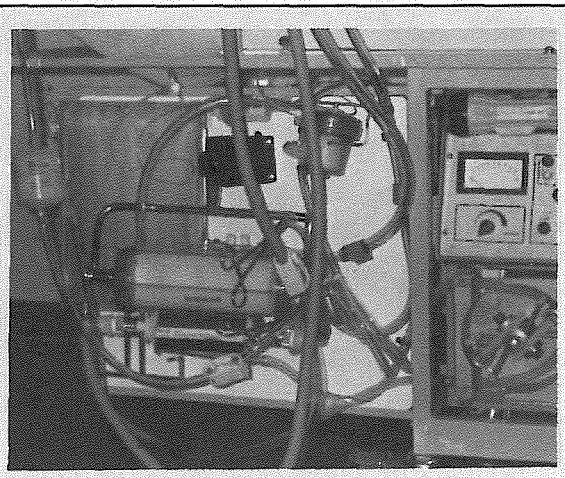
■ The frame is constructed such that the 7'1" ice bath can be shortened by nearly a foot on the spot. (A tight elevator ride on one patient transport convinced us that this is a good idea.) Because of the steel frame, the PIB has a larger internal capacity (for bigger patients), despite having almost identical external dimensions as the old MLSS.

■ All components with the exception of the HLR are secured within the frame profile; this prevents the perfusion circuit and equipment from being scraped off going through doorways and from the inevitable collisions with walls and furniture.

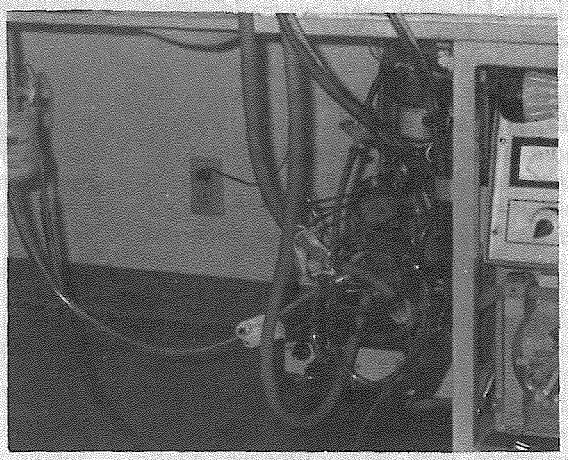
■ The blood pump has been modified and placed to ease stringing of the perfusion

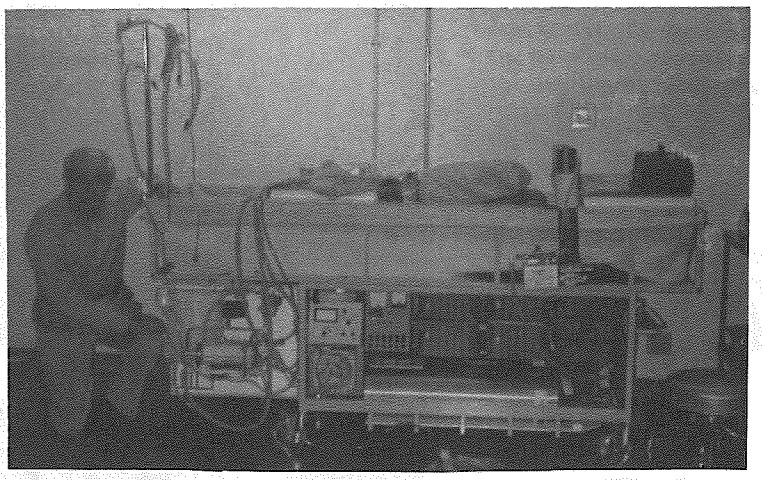
If We Meant It To Fly, We Should Have Put On Wings

Jerry had in mind that the Mark I would be air-transportable in a helicopter. As it turned out, this was a fantasy; none of the common passenger helicopters in commercial service was able to accomodate its length (85 inches). Arguably, the pilot also would not have been pleased by the weight of the MLSS plus patient plus ice plus attendents, which could easily have topped 1,000 pounds. (Where helicopters are now used for medical transport, they are usually intermediate-to-large troop transport 'copters of military origin.)



The perfusion circuit mounting board can be swung out for stringing and locked back within the profile while strung.





circuit; and the adjacent perfusion circuit mounting board can be swung out for stringing and locked back within the profile while strung (See Box below). The consequence of this is that the perfusion tubing circuit can be strung when time is less critical, in advance of the pronouncement of the patient's legal death. (On the old MLSS the circuit stood in continual danger of being left on a random doorknob. Thus, it was strung in the confusion of the surgical cutdown, the HLR banging away, people shouting over the noise, the perfusionist in a race with the surgeon, etc. Don't tell me about the good old days.)

■With the more efficient configuration of equipment and a larger frame profile, more on-board storage capacity is available in shallow, large-capacity removable drawers.

■The oxygen cylinders hold 7,000-liters of oxygen (compared to 1,256 liters previously). This gives the HLR of the Mark III an unsupported endurance of about an hour. This can be readily extended by connecting the MLSS to hospital oxygen, the ambulance oxygen system, or separate cylinders.

■The Mark III's electrical components all use 110-volt power, supplied either from the wall or from a 1200-watt inverter powered by an 80-ampere-hour, 12-volt gel battery, or by the ambulance 12-volt system. This is a major improvement over the perverse and inflexible 12/24-volt system demanded by the 24-volt roller pump of the Mark I, and allows the Mark III to be fully supported either from wall power or from the ambulance. An on-board ammeter allows estimation of battery drain.

■The icewater circulating pump pumps faster, and the distribution system contains Robert Cardwell's non-splashing flow diffusers.

■The orientation of the original MLSS (with the patient's head at the rear of the ambulance) has been reversed, so that activities in the ambulance are a lot easier. Also because of this, the ambulance lift gate has been shortened 17", easing the strain on its mounts. (This was a good example of

Text concludes on page 30

Credits

The Mark III MLSS was designed and built entirely in-house at Alcor. Tanya Jones, Scott Herman, and Keith Henson were major contributors to the effort, which was spearheaded by Hugh Hixon. Hugh also gets many thanks for having advanced most of the cost out-of-pocket (this allowed the project to proceed without regard to transient cash flow concerns). Hugh also purchased the equipment for a small but complete welding shop in aid of this and other development and prototyping projects at Alcor. (One of these is a much-improved portable ice bath (PIB) design.)

Thoughts On MLSS's Unbuilt

I do not expect that there will ever be another MLSS similar to the one Cryovita built. It was and is a prototype, with all the problems that implies. Its service has been adequate, but between the compromises of the engineers at Travenol who designed the original gurney, and the compromises we made building it with our preconceptions and the materials at hand, there are "frictional losses" in its use that are much less in the Mark III. The aluminum frame was clearly marginal for the equipment and patient load we placed on it, the mechanical functions were poorly located, and the use of the 24-volt roller pump resulted in a perverse and inflexible power system.

Likewise, a MLSS more capable (and more massive) than the Mark III is not going to be built either. First, it is hard to imagine a scenario where the Mark III cannot be connected to external O_2 and electrical support (in the hospital, the operating theatre, or the ambulance) for over an hour. And second, compressed gas and batteries are very inefficient ways of storing energy. It would be a minor modification to double the unsupported endurance of the Mark III, but the addition of another two lightweight oxygen cylinders and another battery would increase the weight by 150 lbs (and incidentally eliminate all the on-board storage).

I had not thought that such a need would exist, but there is a move afoot in St. Petersburg (Russia) to start a cryonics group, and in the less well-appointed monuments to Soviet medical care, a long-endurance MLSS might fill a real need.

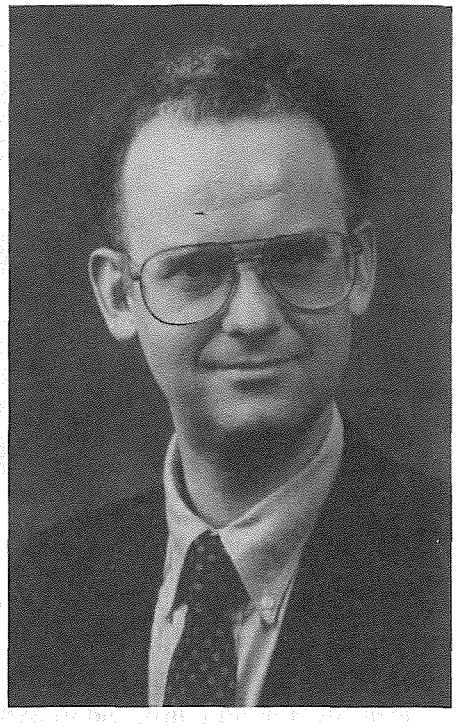
There is only one solution here: an on-board gasoline engine driving both a 12-volt, 100 ampere alternator and an air compressor. Even with good silencing of the engine and compressor, the weight of such a power pack should be under 100 lbs. In a U.S. hospital, such a unit would cause the administration and nursing staffs to go through the ceiling; in a Russian hospital, they would probably want to buy it. The electrical system would be entirely 12-volt, and a small compressed oxygen cylinder would suffice to support the oxygenator.

There is no particular weight advantage to a MLSS using batteries and 12-volt components, even though one appears to save weight by getting rid of the 38 lb., 1200-watt inverter. In order to power the 12-volt DC functions indefinitely in a 110-volt AC environment such as a building, a very large battery charger/power supply is needed, and the weight saving from dispensing with the inverter is eaten up.

I expect I will be building an air-shippable MLSS for Alcor's Remote Standby Kit. The peculiar design problem here is that we cannot ship full gas cylinders and big batteries by air freight due to safety regulations. Instead, the mechanical section will go inside the folding steel-frame ice bath I have recently built, and at the destination, the mechanical section will be removed and wheels added, the ice bath unfolded and mounted on it, and a standard steel H-cylinder and car battery added. In remote situations we have to operate out of a mortuary, and in our experience, morticians have no trouble finding these items, given reasonable warning.

Very likely, the next MLSS improvement will be an on-board computer for monitoring and data collection. This will be somewhat expensive ($3,000 – $4,000) and will take up space in the mechanical section now used for storage.

The Molecular Repair of the Brain



by Ralph C. Merkle, Ph.D.

A short version of this paper entitled "The Technical Feasibility of Cryonics" appeared in *Medical Hypotheses* Vol. 39, 1992; 6-16.

Abstract

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

Introduction

Tissue preserved in liquid nitrogen can survive centuries without deterioration[1]. 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. If freezing damage can someday be cured, then a form of time travel to the era when the cure is available would be possible. While 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 available to anyone who so chooses. First seriously proposed in the 1960's by Ettinger[80] there are now three organizations in the U.S. that provide cryonic suspension services.

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

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

Given the remarkable progress of science during 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 by Louis Pasteur, who 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 the repair of frozen tissue is inherently and forever 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. 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[17, 18, 51]. Here, we focus on technical feasibility.

While many isolated tissues (and a few particularly hardy organs) have been successfully cooled to the temperature of liquid nitrogen and rewarmed[35], further successes have proven elusive. While there is no particular reason to believe that a cure

[1]Peter Mazur, a well known cryobiologist and critic of cryonics, has said: "Cryobiologists are often asked how long cells can remain viable at -196 degrees 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 degrees C and back without killing them."[26] The record for storage is held by Leonard Hayflick, who has kept normal fibroblasts from embryonic human lungs in liquid nitrogen for 28 years (as of June 1990) without noticeable deterioration[63].

for freezing damage would violate any laws of physics (or is otherwise obviously infeasible), it is likely that the damage done by freezing is beyond the self-repair and recovery capabilities of the tissue itself. This does not imply that the damage *cannot* be repaired, only that significant elements of the repair process would have to be provided from an external source. In deciding whether such externally provided repair will (or will not) eventually prove feasible, we must keep in mind that such repair techniques can quite literally take advantage of scientific advances made during the next few centuries. Forecasting the capabilities of future technologies is therefore an integral component of determining the feasibility of cryonics. Such a forecast should, in principle, be feasible. The laws of physics and chemistry as they apply to biological structures are well understood and well defined. Whether the repair of frozen tissue will (or will not) eventually prove feasible within the framework defined by those laws is a question which we should be able to answer based on what is known today.

Current research (outlined below) supports the idea that we will eventually be able to examine and manipulate structures molecule by molecule and even atom by atom. Such a technical capability has very clear implications for the kinds of damage that can (and cannot) be repaired. The most powerful repair capabilities that should eventually be possible can be defined with remarkable clarity. The question we wish to answer is conceptually straightforward: will the most powerful repair capability that is likely to be developed in the long run (perhaps over a few centuries) be adequate to repair tissue that is frozen using the best available current methods?[2]

The general purpose ability to manipulate structures with atomic precision and low cost is often called *nanotechnology* (also called molecular engineering, molecular manufacturing, molecular nanotechnology, etc.). There is widespread belief that such a capability will eventually be developed [1, 2, 3, 4, 7, 8, 9, 15, 25, 28, 30, 54, 55, 56, 67, 68, 69, 73, 74, 75, 76, 77, 78] though exactly how long it will take is unclear. The long storage times possible with cryonic suspension make the precise development time of such technologies noncritical. Development any time during the next few centuries would be sufficient to save the lives of those suspended with current technology.

In this paper, we give a brief introduction to nanotechnology and then clarify the technical issues involved in applying it in the conceptually simplest and most powerful fashion to the repair of frozen tissue.

"In deciding whether such externally provided repair will (or will not) eventually prove feasible, we must keep in mind that such repair techniques can quite literally take advantage of scientific advances made during the next few centuries."

Nanotechnology

Broadly speaking, the central thesis of nanotechnology is that almost any structure consistent with the laws of chemistry and physics 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.)

This concept is receiving increasing attention in the research community. There have been two international research conferences directly on molecular manufacturing [54, 55, 73, 77] as well as a broad range of conferences on related subjects. *Science* [28, page 26] said "The ability to design and manufacture devices that are only tens or hundreds of atoms across promises rich rewards in electronics, catalysis, and materials. The scientific rewards should be just as great, as researchers approach an ultimate level of control—assembling matter one atom at a time." "Within the decade, [John] Foster [at IBM Almaden] or some other scientist is likely to learn how to piece together atoms and molecules one at a time using the STM [Scanning Tunneling Microscope]."

Eigler and Schweizer[30] at IBM reported on "...the use of the STM at low temperatures (4 K) to position individual xenon atoms on a single-crystal nickel surface with atomic precision. This capacity has allowed us to fabricate rudimentary structures of our own design, atom by atom. The processes we describe are in principle applicable to molecules also. In view of the device-like characteristics reported for single atoms on surfaces [omitted references], the possibilities for perhaps the ultimate in device miniaturization are evident."

J. A. Armstrong, IBM Chief Scientist and Vice President for Science and Technology[67] said "I believe that nanoscience and nanotechnology will be central to the next epoch of the information age, and will be as revolutionary as science and technology at the micron scale have been since the early '70's.... Indeed, we will have the ability to make electronic and mechanical devices atom-by-atom when that is appropriate to the job at hand."

The New York Times said[68]: "Scientists are beginning to gain the ability to manipulate matter by its most basic components—molecule by molecule and even atom by atom." "That ability, while now very crude, might one day allow people to build almost unimaginably small electronic circuits and machines, producing, for example, a super computer invisible to the naked eye. Some futurists even imagine building tiny robots that could travel through the body performing surgery on damaged cells."

Drexler[1,9,15,25,56] 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.

The best technical discussion of nanotechnology has recently been provided by Drexler[56].

Ribosomes

The plausibility of this approach can be illustrated by the ribosome. Ribosomes manufacture all the proteins used in all living things on this planet. A typical ribo-

[2]There is no implication here that the most powerful repair method either will (or will not) be used or be necessary. The fact that we can kill a gnat with a double-barreled shotgun does not imply that a fly-swatter won't work just as well. If we aren't certain whether we face a gnat or a tiger, we'd rather be holding the shotgun than the fly-swatter. The shotgun will work in either case, but the fly-swatter can't deal with the tiger. In a similar vein, we will consider the most powerful methods that should be feasible rather than the minimal methods that might be sufficient. While this approach can reasonably be criticized on the grounds that simpler methods are likely to work, it avoids the complexities and problems that must be dealt with in trying to determine exactly what those simpler methods might be in any particular case and provides additional margin for error.

some 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 selectively 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[13].

The instructions that the ribosome follows in building a protein are provided by mRNA (messenger RNA). This is a polymer formed from the 4 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" sequentiall, and acts on the direction 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.

Calculations indicate that an assembler need not inherently be very large. Enzymes "typically" weigh about 10^5 amu (atomic mass units[3]), while the ribosome itself is about 3×10^6 amu[13]. 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 30 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[56]. Even a solid block of diamond as large as such an arm weighs only sixteen million amu, 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.

Molecular Computers

The assembler requires a detailed sequence of control signals, 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, 15, 56]. This design is mechanical in nature, and is based on sliding rods that interact by blocking or unblocking each other at "locks."[4] This design has a size of about 5 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 10^4 "locks" to provide minimal control results in a volume of 2×10^5 cubic nanometers (.0002 cubic microns) for the computational element. This many gates is sufficient to build a simple 4-bit or 8-bit general purpose computer. For example, the 6502 8-bit microprocessor can be implemented in about 10,000 gates, while an individual 1-bit processor in the Connection Machine has about 3,000 gates. 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.

An assembler might have a kilobyte of high speed (rod-logic based) RAM, (similar to the amount of RAM used in a modern one-chip computer) and 100 kilobytes of slower but more dense "tape" storage—this tape storage would have a mass of 10^8 amu or less (roughly 10 atoms per bit—see below). 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 interchangeable tips that can be placed at the ends of the assembler's arms. When everything is added up a small assembler, with arms, computer, "toolkit," etc. should weigh less than 10^9 amu.

E. coli (a common bacterium) weighs about 10^{12} amu[13, page 123]. Thus, an assembler should be much larger than a ribosome, but much smaller than a bacterium.

Self Replicating Systems

It is also interesting to compare Drexler's architecture for an assembler with the von Neumann architecture for a self replicating device. Von Neumann's "universal constructing automaton"[27] had both a universal Turing machine to control its functions and a "constructing arm" to build the "secondary automaton." The constructing arm can be positioned in a two-dimensional plane, and the "head" at the end of the constructing arm is used to build the desired structure. While von Neumann's construction was theoretical (existing in a two dimensional cellular automata world), it still embodied many of the critical elements that now appear in the assembler.

Further work on self-replicating systems was done by NASA in 1980 in a report that considered the feasibility of implementing a self-replicating lunar manufacturing facility with conventional technology[29]. One of their conclusions was that "The theoretical concept of machine duplication is well developed. There are several alternative strategies by which machine self-replication can be carried out in a practical engineering setting." They estimated it would require 20 years (and many billions of dollars) to develop such a system. While they were considering the design of a macroscopic self-replicating system (the proposed "seed" was 100 tons) many of the concepts and problems involved in such systems are similar regardless of size.

"Synthesis under these conditions is somewhat like placing the parts of a radio into a box, shaking, and pulling out an assembled radio. The ability of chemists to synthesize what they want under these conditions is amazing."

[3] An atomic mass unit is the same as a Dalton. Different authors in different fields have different preferences for the name used to describe this unit, and so no single abbreviation will satisfy everyone. The use in this paper of the atomic mass unit, abbreviated as amu, was a compromise intended to be most easily understood by the widest audience.

[4] A wide variety of mechanical computer designs are feasible. Perhaps the most famous proposal for a mechanical computer was made by Charles Babbage[65] in the early to mid 1800's. Mechanical systems can be scaled down to the molecular size range and still function, although the analysis of such molecular mechanical systems requires the use of (appropriately enough) molecular mechanics: a thriving field which models molecular behavior by the use of force fields to describe the forces acting on the individual nuclei[66]. The time evolution of the locations of the nuclei can be followed using relatively straightforward computational methods.

Positional Chemistry

Chemists have been remarkably successful at synthesizing a wide range of compounds with atomic precision. Their successes, however, are usually small in size (with the notable exception of various polymers). Thus, we know that a wide range of atomically precise structures with perhaps a few hundreds of atoms in them are quite feasible. Larger atomically precise structures with complex three-dimensional shapes can be viewed as a connected sequence of small atomically precise structures. While chemists have the ability to precisely sculpt small collections of atoms, there is currently no ability to extend this capability in a general way to structures of larger size. An obvious structure of considerable scientific and economic interest is the computer. The ability to manufacture a computer from atomically precise logic elements of molecular size, and to position those logic elements into a three-dimensional volume with a highly precise and intricate interconnection pattern, would have revolutionary consequences for the computer industry.

A large atomically precise structure, however, can be viewed as simply a collection of small atomically precise objects which are then linked together. To build a truly broad range of large atomically precise objects requires the ability to create highly specific positionally controlled bonds. A variety of highly flexible synthetic techniques have been considered by Drexler [56]. We shall describe two such methods here to give the reader a feeling for the kind of methods that will eventually be feasible.

We assume that positional control is available and that all reactions take place in a hard vacuum. The use of a hard vacuum allows highly reactive intermediate structures to be used, e.g., a variety of radicals with one or more dangling bonds. Because the intermediates are in a vacuum, and because their position is controlled (as opposed to solutions, where the position and orientation of a molecule are largely random), such radicals will not react with the wrong thing for the very simple reason that they will not come into contact with the wrong thing.

It is difficult to maintain biological structures in a hard vacuum at room temperature because of water vapor and the vapor of other small compounds. By sufficiently lowering the temperature, however, it is possible to reduce the vapor pressure to effectively 0.

Normal solution-based chemistry offers a smaller range of controlled synthetic possibilities. For example, highly reactive compounds in solution will promptly react with the solution. In addition, because positional control is not provided, compounds randomly collide with other compounds. Any reactive compound will collide randomly and react randomly with anything available (including itself). Solution-based chemistry requires extremely careful selection of compounds that are reactive enough to participate in the desired reaction, but sufficiently non-reactive that they do not accidentally participate in undesired side reactions. Synthesis under these conditions is somewhat like placing the parts of a radio into a box, shaking, and pulling out an assembled radio. The ability of chemists to synthesize what they want under these conditions is amazing.

"Much of current solution-based chemical synthesis is devoted to preventing unwanted reactions. With assembler-based synthesis, such prevention is a virtually free by-product of positional control."

Much of current solution-based chemical synthesis is devoted to *preventing* unwanted reactions. With assembler-based synthesis, such prevention is a virtually free by-product of positional control.

To illustrate positional synthesis in vacuum somewhat more concretely, let us suppose we wish to bond two compounds, A and B. As a first step, we could utilize positional control to selectively abstract a specific hydrogen atom from compound A. To do this, we would employ a radical that had two spatially distinct regions: one region would have a high affinity for hydrogen while the other region could be built into a larger "tip" structure that would be subject to positional control. A simple example would be the 1-propynyl radical, which consists of three co-linear carbon atoms and three hydrogen atoms bonded to the sp3 carbon at the "base" end. The radical carbon at the radical end is triply bonded to the middle carbon, which in turn is singly bonded to the base carbon. In a real abstraction tool, the base carbon would be bonded to other carbon atoms in a larger diamondoid structure which would provide positional control, and the tip might be further stabilized by a surrounding "collar" of unreactive atoms attached near the base that would limit lateral motions of the reactive tip.

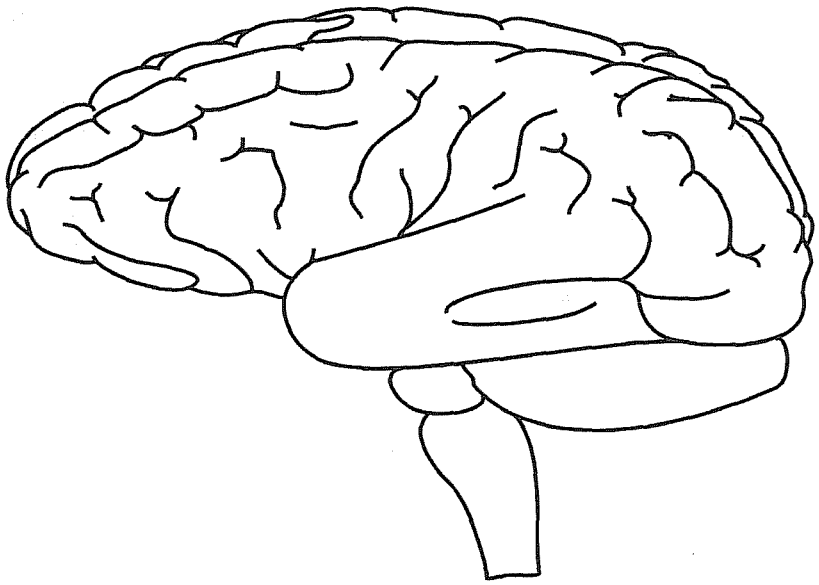
The affinity of this structure for hydrogen is quite high. Propyne (the same structure but with a hydrogen atom bonded to the "radical" carbon) has a hydrogen-carbon bond dissociation energy in the vicinity of 132 kilocalories per mole. As a consequence, a hydrogen atom will prefer being bonded to the 1-propynyl hydrogen abstraction tool over being bonded to almost any other structure. By positioning the hydrogen abstraction tool over a specific hydrogen atom on compound A, we can perform a site specific hydrogen abstraction reaction. This requires positional accuracy of roughly a bond length (to prevent abstraction of an adjacent hydrogen). Quantum chemical analysis of this reaction by Musgrave et. al.[69] show that the activation energy for this reaction is low, and that for the abstraction of hydrogen from the hydrogenated diamond (71) surface (modeled by isobutane) the barrier is very likely zero.

Having once abstracted a specific hydrogen atom from compound A, we can repeat the process for compound B. We can now join compound A to compound B by positioning the two compounds so that the two dangling bonds are adjacent to each other, and allowing them to bond.

This illustrates a reaction using a single radical. With positional control, we could also use two radicals simultaneously to achieve a specific objective. Suppose, for example, that two atoms A1 and A2 which are part of some larger molecule are bonded to each other. If we were to position the two radicals X1 and X2 adjacent to A1 and A2, respectively, then a bonding structure of much lower free energy would be one in which the A1-A2 bond was broken, and two new bonds A1-X1 and A2-X2 were formed. Because this reaction involves breaking one bond and making two bonds (i.e., the reaction product is not a radical and is chemically stable) the exact nature of the radicals is not critical. Breaking one bond to form two bonds is a favored reaction for a wide range of cases. Thus, the positional control of two radicals can be used to break any of a wide range of bonds.

A range of other reactions involving a variety of reactive intermediate compounds (carbenes are among the more interesting ones) are proposed in [56], along with the results of semi-empirical and ab initio quantum calculations and the available experimental evidence.

Another general principle that can be employed with positional synthesis is the controlled use of force. Activation energy, normally provided by thermal energy in conventional chemistry, can also be pro-



vided by mechanical means. Pressures of 1.7 megabars have been achieved experimentally in macroscopic systems[19]. At the molecular level such pressure corresponds to forces that are a large fraction of the force required to break a chemical bond. A molecular vise made of hard diamond-like material with a cavity designed with the same precision as the reactive site of an enzyme can provide activation energy by the extremely precise application of force, thus causing a highly specific reaction between two compounds.

To achieve the low activation energy needed in reactions involving radicals requires little force, allowing a wider range of reactions to be caused by simpler devices (e.g., devices that are able to generate only small force). Further analysis is provided in [56].

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." Drexler has provided the substantive analysis required before this objective can be turned into a reality. We are nearing an era when we will be able to build virtually any structure that is specified in atomic detail and which is consistent with the laws of chemistry and physics. This has substantial implications for future medical technologies and capabilities.

Repair Devices

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 has a mass of between 10^9 and 10^{10} amu (e.g., we assume that a repair device might be as much as a factor of 10 more complicated than a simple assembler). This provides ample margin for increasing the capabilities of the repair device if this should prove necessary.

A single repair device of the kind described will not, by itself, have sufficient memory to store the programs required to perform all the repairs. However, if it is connected to a network (in the same way that current computers can be connected into a local area network) then a single large "file server" can provide the needed information for all the repair devices on the network. The file server can be dedicated to storing information: all the software and data that the repair devices will need. Almost the entire mass of the file server can be dedicated to storage, it can service many repair devices, and can be many times the size of one device without greatly increasing system size. Combining these advantages implies the file server will have ample storage to hold whatever programs might be required during the course of repair. In a similar fashion, if further computational resources are required they can be provided by "large" computer servers located on the network.

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 (after amortization of possibly quite high development costs), 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.

Describing the Brain at the Molecular and Atomic Level

In principle we need only repair the frozen brain, for the brain is the most critical and important structure in the body. Faithfully repairing the liver (or any other secondary tissue) molecule by molecule (or perhaps atom by atom) 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. It should be clear that if repair of the brain is feasible, then the methods employed could (if we wished) be extended in the obvious way to the rest of the body.

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 the 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 (with perhaps some minor additions and removals, as well as just rearrangements) if we expect to restore the natural functions of this most wonderful organ.

In principle, the most that we could usefully know about the frozen brain would be the coordinates of each and every atom in it (though confer footnote 5). This knowledge would put us in the best possible position to determine where each and every atom should go. This knowledge, combined with a technology that allowed us to rearrange atomic structure in virtually any fashion consistent with the laws of chemistry and physics, would clearly let us restore the frozen structure to a fully functional and healthy state.

In short, we must answer three questions:

1.) *Where are the atoms?*
2.) *Where should they go?*
3.) *How do we move them from where they are to where they should be?*

Regardless of the specific technical details involved, any method of restoring a

person in suspension must answer these three questions, if only implicitly. Current efforts to freeze and then thaw tissue (e.g., experimental work aimed at freezing and then reviving sperm, kidneys, etc.) answer these three questions indirectly and implicitly. Ultimately, technical advances should allow us to answer these questions in a direct and explicit fashion.

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

How Many Bits to Describe One Atom

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 nanometers, we would know its position accurately enough to know what chemicals it was a part of, what bonds it had formed, and so on. The brain is roughly .1 meters across, so .01 nanometers is about 1 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[5].

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 should 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]. The work at IBM[30] suggests a rather obvious way in which the presence or absence of a single atom could be used to encode a single bit of information (although some sort of structure for the atom to rest upon and some method of sensing the presence or absence of the atom will still be required, so we would actually need more than one atom per bit in this case). If we conservatively 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 1,000 atoms. Put another way, the location of every atom in a frozen structure is (in a sense) already encoded in that structure in an analog format. If we convert from this analog encoding to a digital encoding, we will increase the space required to store the same amount of information. That is, an atom in three-space encodes its own position in the analog value of its three spatial coordinates. If we convert this spatial information from its analog format to a digital format, we inflate the number of atoms we need by perhaps as much as 1,000. If we digitally encoded the location of every atom in the brain, we would need 1,000 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, so it would require somewhat over one cubic meter of material to encode the location of each and every atom in the brain in a digital format suitable for examination and modification by a computer.

"We are nearing an era when we will be able to build virtually any structure that is consistent with the laws of chemistry and physics. This has substantial implications for future medical technologies and capabilities."

While this much memory is remarkable by today's standards, its construction clearly does not violate any laws of physics or chemistry. That is, it should literally be possible to store a digital description of each and every atom in the brain in a memory device that we will eventually be able to build.

How Many Bits to Describe a Molecule

While such a feat is remarkable, it is also much more than we need. Chemists usually think of atoms 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 per atom, or 300 bits total. 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 + 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 the three atoms separately. (The 20 bits used to describe the type of the molecule can 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. The canonical position of every atom in the molecule is specified once the type of the molecule (which occupies a mere 20 bits) is given. A large molecule might adopt many configurations, so it might at first seem that we'd require many more bits to describe it. However, biological macromolecules typically assume one favored configuration rather than a random configuration, and it is this favored configuration that we will describe[6].

We can do even better: the molecules in the brain are packed in next to each other. Having once described the position of one,

[5] To fully specify the state of each atom would, strictly speaking, require that we specify the states of all its electrons. For the most part, however, these states are known or can be readily inferred once the type of atom is given. For example, a sodium atom in solution will normally be the ion, Na^+. Likewise, the bonding structure of two carbon atoms separated by a certain distance can normally be inferred from the distance. The state of magnetization, while relevant for computers (the state of magnetization of a floppy disk is obviously of importance) is of negligible importance in biological systems. People are routinely exposed to magnetic fields of several Tesla to make diagnostic images, and appear none the worse for the experience. While coordinate information should be sufficient in almost all cases, we can always add a few bits of additional information if there is some ambiguity. This won't increase our estimate of 100 bits per atom by very much, and because 100 bits is a conveniently round number we'll continue to use it.

[6] Because proteins are always produced as a linear chain, they must of necessity be able to adopt an appropriate three dimensional configuration by themselves. Usually, the correct configuration is unique. If it isn't, it is usually the case that the molecule will spontaneously cycle through appropriate configurations by itself, e.g., an ion channel will open and close at appropriate times regardless of whether it was initially started in the "open" or "closed" configuration. If any remaining cases should prove to be a problem, a few additional bits can be used to describe the specific configuration desired.

we can describe the position of the next molecule as being such-and-such a distance from the first. If we assume that two adjacent 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 stratagems (50 bits or less is quite achievable), but the essential point should be clear. We are interested in molecules, and describing a molecule takes fewer bits than describing an atom.

Do We Really Need to Describe Each Molecule?

A further point will be obvious 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. Many other molecules, even though they do not diffuse freely within a cellular compartment, are still able to diffuse fairly freely over a significant range. The description of their position can be appropriately compressed.

While this reduces our storage requirements quite a bit, we could go much further. Instead of describing molecules, we could describe entire sub-cellular organelles. It seems excessive to describe a mitochondrion by describing each and every molecule in it. It would be sufficient simply to note the location and perhaps the size of the mitochondrion, for all mitochondria perform the same function: they produce energy for the cell. While there are indeed minor differences from mitochondrion to mitochondrion, these differences don't matter much and could reasonably be neglected.

We could go still further, and describe an entire cell with only a general description of the function it performs: this nerve cell has synapses of a certain type with that other cell, it has a certain shape, and so on. We might even describe groups of cells in terms of their function: this group of cells in the retina performs a "center surround" computation, while that group of cells performs edge enhancement. Cherniak[115] said: "On the usual assumption that the synapse is the necessary substrate of memory, supposing very roughly that (given anatomical and physiological "noise") each synapse encodes about one binary bit of information, and a thousand synapses per neuron are available for this task: 10^{10} cortical neurons x 10^3 synapses = 10^{13} bits of arbitrary information (1.25 terabytes) that could be stored in the cerebral cortex."

How Many Bits Do We Really Need?

This kind of logic can be continued, but where does it stop? What is the most compact description which captures all the essential information? While many minor details of neural structure are irrelevant, our memories clearly matter. Any method of describing the human brain which resulted in loss of long term memory has rather clearly gone too far. When we examine this quantitatively, we find that preserving the information in our long term memory might require as little as 10^9 bits (somewhat over 100 megabytes)[22]. We can say rather confidently that it will take at least this much information to adequately describe an individual brain. The gap between this lower bound and the molecule-by-molecule upper bound is rather large, and it is not immediately obvious where in this range the true answer falls. We shall not attempt to answer this question, but will instead (conservatively) simply adopt the upper bound.

Criteria of Death

> "**death** \'deth\ *n* **[ME** *deeth*, fr. **OE** *death*; akin to **ON** *dauthi* death, *deyja* to die—more at DIE] **1:** a permanent cessation of all vital functions **:** the end of life"
> *Webster's New Collegiate Dictionary*

Determining when "permanent cessation of all vital functions" has occurred is not easy. Historically, premature declarations of death and subsequent burial alive have been a major problem. In the seventh century, Celsus wrote "... Democritus, a man of well merited celebrity, has asserted that there are in reality, no characteristics of death sufficiently certain for physicians to rely upon."[57, page 166].

Montgomery, reporting on the evacuation of the Fort Randall Cemetery, states that nearly two percent of those exhumed were buried alive[57].

"Many people in the nineteenth century, alarmed by the prevalence of premature burial, requested, as part of the last offices, that wounds or mutilations be made to assure that they would not awaken ... embalming received a considerable impetus from the fear of premature burial."[57].

New Criteria

Current criteria of "death" are sufficient to insure that spontaneous recovery in the mortuary or later is a rare occurrence. When examined closely, however, such criteria are simply a codified summary of symptoms that have proven resistant to treatment by available techniques. Historically, they derive from the fear that the patient will spontaneously recover in the morgue or crypt. There is no underlying theoretical structure to support them, only

a continued accumulation of ad hoc procedures supported by empirical evidence. To quote Robert Veach[14]: "We are left with rather unsatisfying results. Most of the data do not quite show that persons meeting a given set of criteria have, in fact, irreversibly lost brain function. They show that patients lose heart function soon, or that they do not "recover." Autopsy data are probably the most convincing. Even more convincing, though, is that over the years not one patient who has met the various criteria and then been maintained, for whatever reason, has been documented as having recovered brain function. Although this is not an elegant argument, it is a reassuring." In short, current criteria are adequate to determine when current medical technology will fail to revive the patient, but are silent on the capabilities of future medical technology.

Each new medical advance forces a reexamination and possible change of the existing ad hoc criteria. The criteria used by the clinician today to determine "death" are dramatically different from the criteria used 100 years ago, and have changed more subtly but no less surely in the last decade[7]. It seems almost inevitable that the criteria used 200 years from now will differ dramatically from the criteria commonly employed today.

These ever shifting criteria for "death" raise an obvious question: is there a definition which will not change with advances in technology? A definition which *does* have a theoretical underpinning and is *not* dependent on the technology of the day?

The answer arises from the confluence and synthesis of many lines of work, ranging from information theory, neuroscience, physics, biochemistry and computer science to the philosophy of the mind and the evolving criteria historically used to define death.

When someone has suffered a loss of memory or mental function, we often say they "aren't themselves." As the loss becomes more serious and all higher mental functions are lost, we begin to use terms like "persistent vegetative state." While we will often refrain from declaring such an individual "dead," this hesitation does not usually arise because we view their present state as "alive" but because there is still hope of recovery to a healthy state with memory and personality intact. From a physical point of view we believe there is a chance that their memories and personalities are still present within the physical structure of the brain, even though their behavior does not provide direct evidence for this. If we could reliably determine that the physical structures encoding memory and personality had in fact been destroyed, then we would abandon hope and declare the person dead.

"Historically, premature declaration of death and subsequent burial alive have been a major problem ... Montgomery, reporting on the evacuation of the Fort Randall Cemetery, states that nearly two percent of those exhumed were buried alive."

The Information Theoretic Criterion of Death

Clearly, if we knew the coordinates of each and every atom in a person's brain then we would (at least in principle) be in a position to determine with absolute finality whether their memories and personality had been destroyed in the information theoretic sense, or whether their memories and personality were preserved but could not, for some reason, be expressed. If such final destruction had taken place, then there would be little reason for hope. If such destruction had *not* taken place, then it would in principle be possible for a sufficiently advanced technology to restore the person to a fully functional and healthy state with their memories and personality intact.

Considerations like this lead to the *information theoretic criterion of death*[8]. A person is dead according to the information theoretic criterion if their memories, personality, hopes, dreams, etc. have been destroyed in the information theoretic sense. That is, if the structures in the brain that encode memory and personality have been so disrupted that it is no longer possible in principle to restore them to an appropriate functional state then the person is dead. If the structures that encode memory and personality are sufficiently intact that inference of the memory and personality are feasible in principle, and therefore restoration to an appropriate functional state is likewise feasible in principle, then the person is not dead.

A simple example from computer technology is in order. If a computer is fully functional then its memory and "personality" are completely intact. If it fell out the seventh floor window to the concrete below, it would rapidly cease to function. However, its memory and "personality" would still be present in the pattern of magnetizations on the disk. With sufficient effort, we could completely repair the computer with its memory and "personality" intact[9].

In a similar fashion, as long as the structures that encode the memory and personality of a human being have not been irretrievably "erased" (to use computer jargon) then restoration to a fully functional state with memory and personality intact is in principle feasible. Any technology independent definition of "death" should conclude that such a person is not dead, for a sufficiently advanced technology could restore the person to a healthy state.

On the flip side of the coin, if the structures encoding memory and personality *have* suffered sufficient damage to obliterate them beyond recognition, then death by the information theoretic criterion has occurred. An effective method of insuring such destruction is to burn the structure and stir the ashes. This is commonly employed to insure the destruction of classified documents. Under the name of "cremation" it is also employed on human beings and is sufficient to insure that death by the information theoretic criterion takes place.

More Exotic Approaches

It is not obvious that the preservation of life requires the physical repair or even the preservation of the brain[10,11]. Although the brain is made of neurons, synapses, protoplasm, DNA and the like; most mod-

[7]"For many years, it was thought that irreversible cellular damage unavoidably occurs after only a few minutes of complete cerebral ischemia. This opinion has been modified during the past decade [omitted reference]. Provided that the conditions for recovery are optimal, short-term restoration of brain functions may be achieved after periods of ischemia lasting as long as 60 minutes..."[60].
"Most clinical and experimental studies suggest that the normothermic brain is not able to withstand complete ischemia of >8 to 10 min. There is, however, firm experimental evidence of functional and biochemical recovery of a substantial part of the brain after complete cerebrocirculatory arrest of one hour [omitted references]"[64].
"It turned out in fact that appropriate treatment of post-ischemic recirculation disturbances led to recovery of energy metabolism and neuronal excitability after complete cerebro-circulatory arrest of as long as 1 hour at normal body temperature [omitted reference]"[62].

[8]Definitions that are similar or identical to the one given here are well known in the cryonics literature[17].

[9] This issue is of great concern to computer users. A variety of tools and techniques exist for recovering information from damaged or otherwise inoperative disk drives, with the intent of recovering the memory and "personality" of the computer so that the user will not suffer a (sometimes traumatic) loss.

ern philosophers of consciousness view these details as no more significant than hair color or clothing style. Three samples follow.

The ethicist and prolific author Robert Veatch said, in *Death, Dying, and the Biological Revolution*, "An 'artificial brain' is not possible at present, but a walking, talking, thinking individual who had one would certainly be considered living."[14, page 23].

The noted philosopher of consciousness Paul Churchland said, in *Matter and Consciousness*, "If machines do come to simulate all of our internal cognitive activities, to the last computational detail, to deny them the status of genuine persons would be nothing but a new form of racism."[11, page 120].

Hans Moravec, renowned roboticist and Director of the Mobile Robot Lab at Carnegie Mellon said, "Body-identity assumes that a person is defined by the stuff of which a human body is made. Only by maintaining continuity of body stuff can we preserve an individual person. Pattern-identity, conversely, defines the essence of a person, say myself, as the *pattern* and the *process* going on in my head and body, not the machinery supporting that process. If the process is preserved, I am preserved. The rest is mere jelly."[31, page 117].

We'll Use the Conservative Approach

Restoration of the existing structure will be more difficult than building an artificial brain (particularly if the restoration is down to the molecular level). Despite this, we will examine the technically more exacting problem of restoration because it is more generally acceptable. Most people accept the idea that restoring the brain to a healthy state in a healthy body is a desirable objective. A range of increasingly less restrictive objectives (as described) are possible. To the extent that more relaxed criteria are acceptable, the technical problems are *much* less demanding. By deliberately adopting such a conservative position, we lay ourselves open to the valid criticism that the methods described here are unlikely to prove necessary. Simpler techniques that relax to some degree the philosophical constraints we have imposed might well be adopted in practice. In this paper we will eschew the more exotic possibilities (without, however, adopting any position on their desirability).

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. In a heart transplant, for example, surgeons cut open the chest of a dying patient to rip out their dying heart, cut open a fresh cadaver to seize its still-beating heart, and then stitch the cadaver's heart into the dying patients chest. Despite this (which would have been condemned in the middle ages as the blackest of black magic), we cheer the patient's return to health and are thankful that we live in an era when medicine can save lives that were formerly lost.

The mechanics of examining and repairing the human brain, possibly down to the level of individual molecules, might not be the best topic for after dinner conversation. While the details will vary depending on the specific method used, this could also be described by lurid language that failed to capture the central issue: the restoration to full health of a human being.

A final issue that should be addressed is that of changes introduced by the process of restoration itself. The exact nature and extent of these changes will vary with the specific method. Current surgical techniques, for example, result in substantial tissue changes. Scarring, permanent implants, prosthetics, etc. are among the more benign outcomes. In general, methods based on a sophisticated ability to rearrange atomic structure should result in minimal undesired alterations to the tissue.

"Minimal changes" does not mean "no

FIGURES OF INTEREST

Approximate values of interesting numbers. Numbers marked by * 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
*Weight of a repair machine:	10^9 to 10^{10} amu
*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
Weight of "typical" lipid:	500 amu
Weight of water molecule:	18 amu
Weight of carbon atom:	12 amu
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 all brain macromolecules:	3.2×10^{23} repair-machine seconds
*Number of repair machines to repair all brain molecules in three years:	3.2×10^{15}
*Weight of that many repair devices:	53 to 530 grams
Number of bits needed to store the molecular structure of the brain:	10^{25} bits
*Energy dissipated by a single "rodlogic" (gate) operation (including a few percent of irreversible operations):	10^{-22} joules
*Speed of a single "rod logic" (gate) operation:	100×10^{-12} seconds
Estimated cost of 10^{15} joules of energy generated on earth in the future:	10,000 dollars
*Number of gate operations 10^{15} joules can support:	10^{37}
*Size of a single "lock" (gate) plus overhead (power, etc.):	100 cubic nanometers
*Volume of gates that can deliver 10^{37} operations in three years (a larger volume will in fact be required to accommodate cooling requirements):	1 cubic centimeter
Power of 10^{15} joules dissipated over a three year period:	10 megawatts (100,000 light bulbs for three years)
Chemical energy stored in the structure of the brain:	8×10^6 joules (2,000 kilocalories)
Boltzmann's constant k:	1.38×10^{-23} joules/Kelvin
Approximate thermal energy of one atom at room temperature (kT at 300 degrees K):	4.14×10^{-21} joules
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}
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
Joules per (dietary) Calorie:	4,186

changes." A modest amount of change in molecular structure, whatever technique is used, is both 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. Cells also make small errors in building their own parts. For example, ribosomes make errors when they build proteins. About one amino acid in every 10,000 added to a growing polypeptide chain by a ribosome is incorrect[14, page 383]. Changes and errors of a similar magnitude introduced by the process of restoration can reasonably be neglected.

Does the Information Theoretic Criterion Matter?

It is normally a matter of small concern whether a physician of 2190 would or would not concur with the diagnosis of "death" by a contemporary physician applied to a specific patient in 1990. A physician of today who found himself in 1790 would be able to do little for a patient whose heart had stopped, even though he knew intellectually that an intensive care unit would likely be able to save the patient's life. Intensive care units were simply not available in 1790, no matter what the physician knew was possible. So, too, with the physician of today when informed that a physician 200 years hence could save the life of the patient that he has just pronounced "dead." There is nothing he can do, for he can only apply the technologies of today—*except in the case of cryonic suspension.*

In this one instance, we must ask not whether the person is dead by today's (clearly technology dependent) criteria, but whether the person is dead by all future criteria. In short, we must ask whether death by the information theoretic criterion has taken place. If it has not, then cryonic suspension is a reasonable (and indeed life saving) course of action.

Experimental Proof or Disproof of Cryonics

It is often said that "cryonics is freezing the dead." It is more accurate to say that "cryonics is freezing the terminally ill. Whether or not they are dead remains to be seen."

The scientifically correct experiment to verify that cryonics works (or demonstrate that it does not work) is quite easy to describe:

1.) Select N experimental subjects.
2.) Freeze them.
3.) Wait 100 years.
4.) See if the technology available 100 years from now can (or cannot) cure them.

The drawback of this experimental protocol is obvious: we can't get the results for 100 years. This problem is fundamental. The use of future technology is an *inherent* part of cryonics. Criticisms of cryonics based on the observation that freezing and thawing mammals with present technology don't work are irrelevant, for that is not what is being proposed.

This kind of problem is not entirely unique to cryonics. A new AIDS treatment might undergo clinical trials lasting a few years. The ethical dilemma posed by the terminally ill AIDS patient who might be assisted by the experimental treatment is well known. If the AIDS patient is given the treatment prior to completion of the clinical trials, it is possible that his situation could be made significantly worse. On the other hand, to deny a potentially life saving treatment to someone who will soon die anyway is ethically untenable.

In the case of cryonics this is not an interim dilemma pending the (near term) outcome of clinical trials. It is a dilemma inherent in the nature of the proposal. Clinical trials, the bulwark of modern medical practice, *are useless in resolving the effectiveness of cryonics in a timely fashion.*

Further, cryonics (virtually by definition) is a procedure used only when the patient has exhausted all other available options. In current practice the patient is suspended after legal death: the fear that the treatment might prove worse than the disease is absent. Of course, suspension of the terminally ill patient somewhat before legal death has significant advantages. A patient suffering from a brain tumor might view suspension following the obliteration of his brain as significantly less desirable than suspension prior to such obliteration, even if the suspension occurred at a point in time when the patient was legally "alive."

In such a case, it is inappropriate to disregard or override the patient's own wishes. To quote the American College of Physicians Ethics Manual, "Each patient is a free agent entitled to full explanation and full decision-making authority with regard to his medical care. John Stuart Mill expressed it as: 'Over himself, his own body and mind, the individual is sovereign.' The legal counterpart of patient autonomy is self-determination. Both principles deny legitimacy to paternalism by stating unequivocally that, in the last analysis, the patient determines what is right for him." "If the [terminally ill] patient is a mentally competent adult, he has the legal right to accept or refuse any form of treatment, and his wishes must be recognized and honored by his physician."[59]

If clinical trials cannot provide us with an answer, are there any other methods of evaluating the proposal? Can we do more than say that (a) cryonic suspension can do no harm (in keeping with the Hippocratic oath), and (b) it has some difficult-to-define chance of doing good?

Failure Criteria

Trying to prove something false is often the simplest method of clarifying exactly what is required to make it true. A consideration of the information theoretic criterion of death makes it clear that, from a technical point of view (ignoring various non-technical issues) there are two and only two ways in which cryonics can fail[10].

Cryonics will fail if:
(1) Information theoretic death occurs prior to reaching liquid nitrogen temperature[11].
(2) Repair technology that is feasible in principle is never developed and applied in practice, even after the passage of centuries.

The first failure criterion can only be considered against the background of current understanding of freezing damage, ischemic injury and mechanisms of memory and synaptic plasticity. Whether or not memory and personality are destroyed in the information theoretic sense by freezing and the ischemic injury that might precede it can only be answered by considering both the physical nature of memory and the nature of the damage to which the brain is subjected before reaching the stability provided by storage in liquid nitrogen. The following sections will therefore provide brief reviews of these subjects.

The second failure criterion is considered in the later sections on technical issues, which discuss in more detail how future technologies might be applied to the repair of frozen tissue.

As the reader will readily appreciate, the following reviews will consider only the most salient points that are of the greatest importance in determining overall feasi-

[10]Cryonics will also fail if a person is prematurely thawed. This failure mode, however, is not an argument against cryonics, rather it is an argument for reliable refrigerators. A person injured in a car crash might die if their ambulance was struck by a train. This is not an argument that we should cremate accident victims rather than use an ambulance to transport them to a hospital!

[11]There is fairly general agreement that death by the information theoretic criterion will not occur during storage of tissue at the temperature of liquid nitrogen, confer footnote 1. For this reason we neglect the possibility that significant information loss occurs during storage even though this might be viewed as theoretically possible.

bility. They are necessarily too short to consider the topics in anything like full detail, but should provide sufficient information to give the reader an overview of the relevant issues. References to further reading are provided throughout[12].

Freezing Damage

There is an extensive literature on the damage caused by both cooling and freezing to liquid nitrogen temperatures. Some reviews are[5, 6, 42, 43]. *Scientific American* had a recent and quite accessible article[33]. In this section, we briefly review the nature of such damage and consider whether it is likely to cause information theoretic death. Damage, *per se*, is not meaningful except to the extent that it obscures or obliterates the nature of the original structure.

While cooling tissue to around 0° C creates a number of problems, the ability to cool mammals to this temperature or even slightly below (with no ice formation) using current methods followed by subsequent complete recovery [36, 37] shows that this problem can be controlled and is unlikely to cause information theoretic death. We will, therefore, ignore the problems caused by such cooling. This problem is discussed in [5] and elsewhere.

Further, some "freezing" damage in fact occurs upon re-warming. Current work supports this idea because the precise method used to re-warm tissue can strongly affect the success or failure of present experiments even when freezing conditions are identical[5, 6]. If we presume that future repair methods avoid the step of re-warming the tissue prior to analysis and instead analyze the tissue directly in the frozen state then this source of damage will be eliminated. Several current methods can be used to distinguish between damage that occurs during freezing and damage that occurs while thawing. At present, it seems likely that some damage occurs during each process. While significant damage does occur during slow freezing, it does not induce structural changes which obliterate the cell.

Present Day Successes

Many types of tissue including human embryos, sperm, skin, bone, red and white blood cells, bone marrow, and others [5, 6, 35] have been frozen in liquid nitrogen, thawed, and have recovered. This is not true of whole mammals[13]. The brain seems more resistant than most organs to freezing damage[34, 50]. Recovery of overall brain function following freezing to liquid nitrogen temperature has not been demonstrated, although recovery of unit level electrical activity following freezing to -60° C has been demonstrated[50].

Fractures

Perhaps the most dramatic injury caused by freezing is macroscopic fractures[32]. Tissue becomes extremely brittle at or below the "glass transition temperature" at about 140K. Continued cooling to 77K (the temperature of liquid nitrogen) creates tensile stress in the glassy material. This is exacerbated by the skull, which inhibits shrinkage of the cranial contents. This stress causes readily evident macroscopic fractures in the tissue.

Fractures that occur below the glass transition temperature result in very little information loss. While dramatic, this damage is unlikely to cause or contribute to information theoretic death.

Ice

The damage most commonly associated with freezing is that caused by ice. Contrary to common belief, freezing does not cause cells to burst open like water pipes on a cold winter's day. Quite the contrary, ice formation takes place outside the cells in the extracellular region. This is largely due to the presence of extracellular nucleating agents on which ice can form, and the comparative absence of intracellular nucleating agents. Consequently the intracellular liquid supercools.

Extracellular ice formation causes an increase in the concentration of the extracellular solute, e.g., the chemicals in the extracellular liquid are increased in concentration by the decrease in available water. The immediate effect of this increased extracellular concentration is to draw water out of the cells by osmosis. Thus, freezing dehydrates cells.

Damage can be caused by the extracellular ice, by the increased concentration of solute, or by the reduced temperature itself. All three mechanisms can play a role under appropriate conditions.

The damage caused by extracellular ice formation depends largely on the fraction of the initial liquid volume that is converted to ice[6, 33]. (The initial liquid volume might include a significant amount of cryoprotectant as well as water.) When the fraction of the liquid volume converted to ice is small, damage is often reversible even by current techniques. In many cases, conversion of significantly more than 40% of the liquid volume to ice is damaging[43, page 134; 44]. The brain is more resistant to such injury: conversion of up to 60% of the liquid volume in the brain to ice is associated with recovery of neuronal function[34, 37, 40, 53]. Storey and Storey said "If the cell volume falls below a critical minimum, then the bilayer of phospholipids in the membrane becomes so greatly compressed that its structure breaks down. Membrane transport functions cannot be maintained, and breaks in the membrane spill cell contents and provide a gate for ice to propagate into the cell. Most freeze-tolerant animals reach the critical minimum cell volume when about 65 percent of total body water is sequestered as ice."[33].

Appropriate treatment with cryoprotectants (in particular glycerol) prior to freezing will keep 40% or more of the liquid volume from being converted to ice even at liquid nitrogen temperatures.

Fahy has said "All of the postulated problems in cryobiology—cell packing [omitted reference], channel size constraints [omitted reference], optimal cooling rate differences for mixed cell populations [omitted reference], osmotically mediated injury[omitted references], and the rest—can be solved in principle by the selection of a sufficiently high concentration of cryoprotectant prior to freezing. In the extreme case, all ice formation could be suppressed completely by using a concentration of agent sufficient to ensure vitrification of the biological system in question [omitted reference]"[46]. Unfortunately, a concentration of cryoprotectant sufficiently high to protect the system from all freezing injury would itself be injurious[46]. It should be possible to trade the mechanical injury caused by ice formation for the biochemical injury caused by the cryoprotectant, which is probably advantageous. Current suspension protocols at Alcor call for the introduction of greater

[12]Criticisms of cryonics are not supported by the extant literature. Interestingly (and somewhat to the author's surprise) there are no published technical articles on cryonics that claim it won't work. As one might suspect, there are also no articles in the neuroscience literature that address the issue of erasure of memory in the information theoretic sense, and there are no articles in the cryobiological literature that address the impact of freezing on the retention of long term memory in the information theoretic sense. There is an almost absolute conceptual failure to either understand or consider the implications of the information theoretic criterion of death. This conceptual failure is a severe impediment to research in this area.

Even worse, the Society for Cryobiology has gone so far as to adopt by-laws calling for the expulsion of members who support cryonics. Members in good standing who support cryonics have been threatened with firing if they discuss their views publicly. Open discussion and review has proven to be a remarkably effective engine for driving scientific advance. The suppression of open discussion by a scientific society runs counter to one of the most central principles of scientific research and seriously impedes progress.

[13] Many non-mammalian animals can be frozen to temperatures as low as -50 degrees C and survive[33].

than 6 molar glycerol. Both venous and arterial glycerol concentrations have exceeded 6 molar in several recent suspensions. If this concentration of cryoprotectant is also reaching the tissues, it should keep over 60% of the initial liquid volume from being converted to ice at liquid nitrogen temperatures[14].

Concentration Effects

"Dehydration and concentration of solutes past some critical level may disrupt metabolism and denature cell proteins and macromolecular complexes"[43, page 125]. The functional losses caused by this mechanism seem unlikely to result in significant information loss. One qualification to this conclusion is that cell membranes appear to be weakened by increased solute concentration[5, page 92]. To the extent that structural elements are weakened by increased solute concentrations the vulnerability of the cell to structural damage is increased.

Denaturing

Finally, denaturing of proteins might occur at low temperature. In this process the tertiary and perhaps even secondary structure of the protein might be disrupted leading to significant loss of protein function. However, the primary structure of the protein (the linear sequence of amino acids) is still intact and so inference of the correct functional state of the protein is in principle trivial. Further, the extent of protein denaturation caused by freezing must necessarily be limited given the relatively wide range of tissues that have been successfully frozen and thawed.

Intracellular Freezing

Intracellular freezing is another damaging event which might occur[6]. If cooling is slow enough to allow the removal of most of the water from the cell's interior by osmosis, then the high concentration of solute will prevent the small amount of remaining water from freezing. If cooling is too rapid, there will be insufficient time for the water within the cell to escape before it freezes. In the latter case, the intracellular contents are supercooled and freezing is abrupt (the cell "flashes"). While this correlates with a failure to recover function[5, 6, 42, 43] it is difficult to believe that rapid freezing results in significant loss of information.

"The damage most commonly associated with freezing is that caused by ice. Contrary to common belief, freezing does not cause cells to burst open like water pipes on a cold winter's day. Quite the contrary, ice formation takes place outside the cells in the extracellular region."

Intracellular freezing is largely irrelevant to cryonic suspensions because of the slow freezing rates dictated by the large mass of tissue being frozen. Such freezing rates are too slow for intracellular freezing to occur except when membrane rupture allows extracellular ice to penetrate the intracellular region. If the membrane does fail, one would expect the interior of the cell to "flash."

Loss of Information versus Loss of Function

Spontaneous recovery of function following freezing to liquid nitrogen temperatures using the best currently available techniques appears unlikely for mammalian organs, including the brain. Despite this, the level of structural preservation can be quite good. The complexity of the systems that *have* been successfully frozen and rewarmed is remarkable, and supports the claim that good structural preservation is often achieved. The mechanisms of damage that have been postulated in the literature are sufficiently subtle that information loss is likely to be small; that is, death by the information theoretic criterion is unlikely to have occurred. Further research aimed specifically at addressing this issue is needed.

Ischemic Injury and Pre-Suspension Injury

Although modern cryonic suspensions can involve minimal delay[15] and future suspensions might eliminate delay entirely[16], delay is sometimes unavoidable[17]. The most significant type of damage that such delay causes is ischemic injury.

Broadly speaking, the structure of the human brain remains intact for several hours or more following the cessation of blood flow, or ischemia. The tissue changes that occur subsequent to ischemia have been well studied. There have also been studies of the "postmortem" changes that occur in tissue. Perhaps the most interesting of these studies was conducted by Kalimo et. al.[39].

"Postmortem" Changes in the Human Brain

In order to study immediate "postmortem" changes, Kalimo et. al. perfused the brains of 5 patients with aldehydes within half an hour of "clinical death". Subsequent examination of the preserved brain tissue with both light and electron microscopy showed the level of structural preservation. In two cases, the changes described were consistent with approximately one to two hours of ischemic injury. (Ischemic injury often begins prior to declaration of "clinical death," hence the apparently longer ischemic period compared with the interval following declaration of death and prior to perfusion of fixative.) Physical preservation of cellular structure and ultrastructure was excellent. It is difficult to avoid the conclusion that information loss was negligible in these cases. In two other cases, elevated intraparenchymal pressure prevented perfusion with the preservative, thus preventing examination of the tissue.

[14] Unpublished work by Darwin, Leaf and Hixon suggests that penetration of glycerol into the axonal regions of myelinated nerve cells is poor, and that increased damage to the axon results. This is consistent with the observation that penetration of glycerol through the many layers of the myelin sheath would presumably be slowed. However, myelinated axons are relatively large and serve a relatively well defined function: the transport of information. Even significant damage to the axon would not obliterate the fact of its existence or the path over which it carried its signal. As a consequence, this damage is unlikely to result in information theoretic death.

[15] Suspension usually begins immediately upon pronouncement of legal "death." If legal death is pronounced upon cessation of heartbeat in a terminally ill patient who is being continuously monitored, then the ischemic interval can be kept under 5 minutes.

[16] Thomas Donaldson has sought the legal right to be cryonically suspended shortly before, rather than shortly after, a tumor destroys his brain[64]. Had he been (or should he be) successful in his legal action, his suspension would involve no ischemic interval and hence no injury from this source.

[17] There are various reasons for delay when a person is cryonically suspended, ranging from purely pragmatic issues such as delay following abrupt and unexpected accidents to legal and social forces that mandate that suspension not be started until after a legal declaration of "death." Whatever the cause, the effect is to increase the level of damage that takes place prior to suspension.

Without such an examination, it is difficult to draw conclusions about the extent of information loss. In the final case, "...the most obvious abnormality was the replacement of approximately four-fifths of the parenchyma of the brain by a fluid-containing cavity that was lined by what seemed to be very thin remnants of the cerebral cortex." Cryonic suspension in this last case would not be productive.

As an aside, the vascular perfusion of chemical fixatives to improve stability of tissue structures prior to perfusion with cryoprotectants and subsequent storage in liquid nitrogen would seem to offer significant advantages. The main issue that would require resolution prior to such use is the risk that fixation might obstruct circulation, thus impeding subsequent perfusion with cryoprotectants. Other than this risk, the use of chemical fixatives (such as aldehydes and in particular glutaraldehyde) would reliably improve structural preservation and would be effective at halting almost all deterioration within minutes of perfusion[41]. The utility of chemical preservation has been discussed by Drexler[1] and by Olson[58], among others.

Ischemia

The events following ischemia have been reasonably well characterized. Following experimental induction of ischemia in cats, Kalimo et. al.[47] found "The resulting cellular alterations were homogeneous and uniform throughout the entire brain: they included early chromatin clumping, gradually increasing electron lucency of the cell sap, distention of endoplasmic reticulum and Golgi cisternae, transient mitochondrial condensation followed by swelling and appearance of flocculent densities, and dispersion of ribosomal rosettes." Energy levels within the cell drop sharply within a few minutes of cessation of blood flow. The chromatin clumping is a reversible early change. The loss of energy results fairly quickly in failure to maintain trans-membrane concentration gradients (for example the Na^+K^+ pump stops working, resulting in increased intracellular Na^+ and increased extracellular K^+). The uneven equilibration of concentration gradients results in changes in osmotic pressure with consequent flows of water. Swelling of mitochondria and other structures occurs. The appearance of "flocculent densities" in the mitochondria is thought to indicate severe internal membrane damage which is "irreversible."[18]

Ischemic changes do not appear to result in any damage that would prevent repair (e.g., changes that would result in significant loss of information about structure) for at least a few hours. Temporary functional recovery has been demonstrated in optimal situations after as long as 60 minutes of total ischemia[60, 61, 62]. Hossmann, for example, reported results on 143 cats subjected to one hour of normothermic global brain ischemia[64]. "Body temperature was maintained at 36° to 37°C with a heating pad. ... Completeness of ischemia was tested by injecting ^{133}Xe into the innominate artery immediately before vascular occlusion and monitoring the absence of decay of radioactivity from the head during ischemia, using external scintillation detectors. ... In 50% of the animals, even major spontaneous EEG activity returned after ischemia.... One cat survived for 1 yr after one hour of normothermic cerebrocirculatory arrest with no electrophysiologic deficit and with only minor neurologic and morphologic disturbances." Functional recovery is a more stringent criterion than the more relaxed information theoretic criterion, which merely requires adequate structural preservation to allow inference about the pre-existing structure. Reliable identification of the various cellular structures is possible hours (and sometimes even days) later. Detailed descriptions of ischemia and its time course[45, page 209 et sequitur] also clearly show that cooling substantially slows the rate of deterioration. Thus, even moderate cooling "postmortem" slows deterioration significantly.

"Present evidence supports but does not prove the hypothesis that information theoretic death does not occur for at least a few hours following the onset of ischemia."

Lysosomes

The theory that lysosomes ("suicide bags") rupture and release digestive enzymes into the cell that result in rapid deterioration of chemical structure appears to be incorrect. More broadly, there is a body of work suggesting that structural deterioration does not take place rapidly.

Kalimo et. al.[47] said "It is noteworthy that after 120 min of complete blood deprivation we saw no evidence of membrane lysosomal breakdown, an observation which has also been reported in studies of in vitro lethal cell injury[omitted references], and in regional cerebral ischemia[omitted references]."

Hawkins et. al.[48] said "...lysosomes did not rupture for approximately 4 hours and in fact did not release the fluorescent dye until after reaching the postmortem necrotic phase of injury. ... The original suicide bag mechanism of cell damage thus is apparently not operative in the systems studied. Lysosomes appear to be relatively stable organelles...."

Messenger RNA and Protein

Morrison and Griffin[79] said "We find that both rat and human cerebellar mRNAs are surprisingly stable under a variety of postmortem conditions and that biologically active, high-molecular-weight mRNAs can be isolated from postmortem tissue. ... A comparison of RNA recoveries from fresh rat cerebella and cerebella exposed to different postmortem treatments showed that 83% of the total cytoplasmic RNAs present immediately postmortem was recovered when rat cerebella were left at room temperature for 16 h [hours] postmortem and that 90% was recovered when the cerebella were left at 4° C for this length of time.... In neither case was RNA recovery decreased by storing the cerebella in liquid nitrogen prior to analysis. ... Control studies on protein stability in postmortem rat cerebella show that the spectrum of abundant proteins is also unchanged after up to 16 h [hours] at room temperature...."

20 Million Year Survival of DNA

The ability of DNA to survive for long periods was dramatically illustrated by its recovery and sequencing from a 17 to 20 million year old magnolia leaf[52]. "Sediments and fossils seem to have accumulated in an anoxic lake bottom environment; they have remained unoxidized and water-saturated to the present day." "Most leaves are preserved as compression fossils, commonly retaining intact cellular tissue with considerable ultrastructural preservation, including cell walls, leaf phytoliths, and intracellular organelles, as well as many organic constituents such as flavonoids and steroids[omitted references]. There is little evidence of post-depositional (diagenetic) change in many of the leaf fossils."

[18] It should be clear that the claim of "irreversibility" is unsupported. Mitochondrial function is well understood: mitochondria provide energy for the cell. Even their complete absence would not cause death by the information theoretic criteria.

Cell Cultures taken after "Death"

Gilden et. al.[49] report that "...nearly two-thirds of all tissue acquired in less than six hours after death was successfully grown, whereas only one-third of all tissue acquired more than six hours after death was successfully grown in tissue culture." While it would be incorrect to conclude that widespread cellular survival occurred based on these findings, they do show that structural deterioration is insufficient to disrupt function in at least some cells. This supports the idea that structural deterioration in many other cells should not be extensive.

Information Loss and Ischemia

It is currently possible to initiate suspension immediately after legal death. In favorable circumstances legal death can be declared upon cessation of heartbeat in an otherwise revivable terminally ill patient who wishes to die a natural death and has refused artificial means of prolonging the dying process. In such cases, the ischemic interval can be short (two or three minutes). It is implausible that ischemic injury would cause information theoretic death in such a case.

As the ischemic interval lengthens, the level of damage increases. It is not clear exactly when information loss begins or when information theoretic death occurs. Present evidence supports but does not prove the hypothesis that information theoretic death does not occur for at least a few hours following the onset of ischemia. Quite possibly many hours of ischemia can be tolerated. Freezing of tissue within that time frame followed by long term storage in liquid nitrogen should provide adequate preservation of structure to allow repair[19].

Memory

It is essential to ask whether the important structural elements underlying "behavioral plasticity" (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 obliterated by freezing, then cryonic suspension won't work. In this section we briefly consider a few major aspects of what is known about long term memory and whether known or probable mechanisms are likely to be preserved by freezing.

It appears likely that short term memory, which can be disrupted by trauma or a number of other processes, will not be preserved by cryonic suspension. Consolidation of short term memory into long term memory is a process that takes several hours. We will focus attention exclusively on long term memory, for this is far more stable. While the retention of short term memory cannot be excluded (particularly if chemical preservation is used to provide rapid initial fixation), its greater fragility renders this significantly less likely.

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 the literal (or neuroscientific) changes that we are interested in: what are the physical alterations that underlie memory?

Briefly, the available evidence supports the idea that memory and personality are stored in identifiable physical changes in the nerve cells, and that alterations in the synapses between nerve cells play a critical role.

Shepherd in "Neurobiology"[23, 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"[12, page 1005] 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 connections between neurons."

Eric R. Kandel in "Principles of Neural Science" [12, page 1016] said: "Morphological changes seem to be a signature of the long-term process. These changes do not occur with short-term memory (Figure 65-6 [not reproduced here]). Moreover, the structural changes that occur with the long-term process are not restricted to the [sic] growth. Long-term habituation leads to the opposite change—a regression and pruning of synaptic connections. With long-term habituation, where the functional connections between the sensory neurons and motor neurons are inactivated (Figure 65-2[not reproduced]), the number of terminals per neuron is correspondingly reduced by one-third (Figure 65-6[not reproduced]) and the proportion of terminals with active zones is reduced from 40% to 10%."

Squire in "Memory and Brain"[70, page 10] said: "The most prevalent view has been that the specificity of stored information is determined by the location of synaptic changes in the nervous system and by the pattern of altered neuronal interactions that these changes produce. This idea is largely accepted at the present time, and will be explored further in this and succeeding chapters in the light of current evidence."

Lynch, in "Synapses, Circuits, and the Beginnings of Memory"[20, 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."

Turner and Greenough said "Two non-mutually exclusive possible mechanisms of brain information storage have remained the leading theories since their introduction by Ramon y Cajal [omitted reference] and Tanzi [omitted reference]. The first hypothesis is that new synapse formation, or selected synapse retention, yields altered brain circuitry which encodes new information. The second is that altered synaptic efficacy brings about similar change."[16].

Greenough and Bailey in "The anatomy of a memory: convergence of results across a diversity of tests"[24] 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

[19]Much current work advances the (correct) claim that cellular, organ, and body function is lost under certain conditions. This loss of function is incorrectly and misleadingly labeled "death," "irreversible injury," etc. 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 predisposes such workers to dismiss cryonics because, by these criteria, much "irreversible" damage has occurred in most cryonically suspended patients. The implications of adopting the information theoretic criterion of death 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 new ideas. Ignaz Semmelweis demonstrated 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 about 1%. Despite this, his proposal was widely ridiculed and little practiced for several more decades[80].

Interestingly, few of even the most severe critics of cryonics claim that death by the information theoretic criterion is likely to have occurred when the question is posed to them directly.

and/or pattern of synaptic connections."

It seems likely, therefore, that human long term memory is encoded by detectable physical changes in cell structure and in particular in synaptic structure.

Plastic Changes in Model Systems

What, exactly, might these changes be? Very strong statements are possible in simple "model systems." Bailey and Chen, for example, identified several specific changes in synaptic structure that encoded learned memories from sea slugs (*Aplysia californica*) by direct examination of the changed synapse with an electron microscope[21].

"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 vesical complement of synaptic active zones."

Examination by transmission electron microscopy in vacuum of sections 100 nanometers (several hundred atomic diameters) thick recovers little or no chemical information. Lateral resolution is at best a few nanometers (tens of atomic diameters), 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 changes were present. This provides redundant evidence of synaptic alteration. Inability to detect 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 the techniques considered here which literally propose to analyze every molecule in the structure. Further alterations in synaptic chemistry will be detectable when the synapse is examined in more detail at the molecular level. Third, there is no reason to believe that freezing would obliterate the structure beyond recognition.

Implications for Human Memory

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 say that synaptic alterations are also used in the human memory system, that synaptic changes of various types take place when the synapse "remembers" something, that the changes involve alterations in at least many thousands of molecules and probably involve mechanisms similar to those used in lower organisms (evolution is notoriously conservative).

It seems likely that knowledge of the morphology and connectivity of nerve cells along with some specific knowledge of the biochemical state of the cells and synapses would be sufficient to determine memory and personality. Perhaps, however, some fundamentally different mechanism is present in humans? Even if this were to prove true, any such 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 and personality (presuming that the primate brain is similar to the human brain). And finally, it would almost certainly involve changes in tens of thousands of molecules to store each bit of information. Functional studies of human long term memory suggest it has a capacity of only 10^9 bits (somewhat over 100 megabytes)[22] (though this did not consider 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 perhaps 10^{15} synapses — which implies some 10^6 synapses per bit of information stored in long term memory).

Given that future technology 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 at least tens of thousands of molecules each) then it appears unlikely that such structures will survive the lifetime of the individual only to be obliterated beyond recognition by freezing. Freezing is unlikely to cause information theoretic death.

End Part I of II

conclusion (from page 15) of ***"The Mobile Life Support System Mark III"****:*

an engineer's nightmare: a propagating design error. The handedness of the Mark I was carefully considered when it was built, but there was little apparent difference, and it was pretty much a coin flip. When we got the ambulance, it made a lot of difference, and we had guessed wrong; but the alternative was to completely rebuild the MLSS, and that was more trouble than we had time for, so we carried on and lived (uncomfortably) with the consequences.)

■And finally, the professional paint job is not only durable, it makes the Mark III MLSS look very professional! (Credit to Mike Darwin for suggesting powder coating.)

These advances did not come without some sacrifices: Unassisted battery endurance is less (about an hour and a half under full load); however, we have never experienced, nor do we expect, an MLSS transport where the trip from the point of disconnection from AC power to the ambulance—or vice versa—would take more than a few minutes. Due to a design error, the wheels are smaller than preference (by 2"), but they yield more manueverability than we had with the original model because they and the frame are not overstressed. Finally, the Mark III weighs more than the original (625 lbs. vs. 510).

We'll take it.

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A Conversation with...

Omni/Alcor Immortality Contest Winner

James Baglivo

by Derek Ryan

Jim Baglivo was born in Hammonton, New Jersey, and has lived there most of his life. He did well in school early on, but saw his grades drop in later years in tandem with his waning interest in the monotony and busywork imposed on him by that dinosaur known as the American Public School System. Instead of the homework which dominated the lives of so many of us, Jim found himself enraptured by his books, his drawings, and his friends. Eventually, he simply dropped out of school, rebelling against the notion that he should spend some arbitrarily dictated amount of time appeasing a system whose most important requirements were not that you learn and grow, but that you show up and follow the rules. That Jim left school should not *mislead the reader into viewing him as simply another rebellious, uneducated product of urban America. Quite the contrary, Jim is a bright, articulate, affable individual. But this seeming paradox between his lack of formal education and his obvious intelligence is not the most remarkable story to be found in Jim's life. Not even close.*

In February, 1991 Jim was injured in a nearly fatal auto accident which left him comatose for a month, and completely paralyzed for four more. Against steep odds he has learned to walk again, but his body will never be the same. Or, at least, that's what a lot of people would think. Not Jim, though. He expects that mankind will one day achieve a level of medical technology sufficient to repair his body completely.

In fact (and here we find the most interesting story in Jim's remarkable life), he finds the possibilities of future medicine so compelling that he knew the moment he heard about the OMNI/Alcor Immortality Contest that he would enter. A chance at being freed from physical pain and discomfort by the doctors of tomorrow was an opportunity he couldn't pass up, an opportunity certainly worth entering an essay contest for.

As is obvious by now, he won. The judges of the Contest were moved both by the physical tragedy he had to endure and by his positive expectations for being healed by advanced technology. Derek Ryan recently interviewed Jim over the telephone, and what follows are excerpts from that conversation.

Cryonics: *When did you first hear about cryonics?*

JB: Oh, I don't remember the original time. I'd heard rumors of Walt Disney. I'd seen it in science fiction, like in *Aliens*. But it was always fiction. I didn't think of it as a viable opportunity until I got a hold of *OMNI* and read about the contest.

Cryonics: *How long did it take you to decide to enter?*

JB: As soon as I saw the headline I knew that I had to enter it. I want to live forever.

Cryonics: *You know, even cryonicists very often shy away from saying "forever." You don't seem to have any such reservations.*

JB: No. I don't know how the world will progress, exactly, and I won't even speculate. But, I'd like to be a first hand witness to all of it, or even play a key role, if possible.

Cryonics: *So you don't have clear expectations about how the world will evolve?*

JB: No. It's too hard to tell. I do believe that, the further into the future we go, the more enlightened people there will be.

Cryonics: *And by "enlightened" you mean what, exactly?*

JB: Enlightened about the value of human life. About human dignity. About how we should treat one another. Also about our animal nature, and where that leads us. You know, "I've got bigger bombs than you." I don't know who will win, the smart or the barbarically powerful.

Cryonics: *Interesting distinction there.*

JB: Yeah. Actually there's an interesting entity in the world where the smart and the barbarically powerful sort of blend together. It's known as the military. That's where the ramifications of things like cryonics and nanotechnology scare me. When you think about things like general assemblers and cellular regeneration, it boggles the mind. The kinds of weapons that will be possible are frightening even before they exist.

Cryonics: *So bearing in mind the dangers of nanotechnological weaponry, how should humanity be proceeding at this point?*

JB: Well, we shouldn't be limiting it, I know that. It's clear that research would just go underground if we did that. Prohibition makes for the bloodiest wars. I think that people should be educated about it. I think that it should be put in their faces. "This is your future. Here's what is happening, and here are some of the millions of ways that things could go. Things are going to happen whether you want them to or not." Right now, nanotechnology is a joke, or a dream, or a good movie to most people.

Cryonics: *So you don't think that most people are looking that far ahead?*

JB: No. I've heard some pretty ludicrous, off-the-wall things from the people who I've talked to since I won the contest. Their reactions lead me to believe that they haven't been seriously exposed to these ideas. Cryonics is a joke to most of them. It's Walt Disney in an ice castle.

Cryonics: *Do you see any reason for cryonics to appeal more to individuals like you who have been cheated by life, so to speak, than people who are physically healthy?*

JB: Sure. With people who have AIDS, for instance, it's like someone put death on a plate in front of them and said, "Here's your dinner," and they're forced to look at it. Whereas people who are quote unquote healthy tend to push death towards the back of their minds, because it's not such a pleasant picture.

Cryonics: *My impression is that you tend to fall on the atheist side of the religious equation. Is that right?*

JB: Generally, yes. I'm not going to believe that something is so just because you say so. That's the essence of religion. "This is God. He says don't do this or you'll go to hell forever." No proof. Just assurances. I think that the American public wants to be fooled constantly. They want to believe *something*, regardless of how pointless or irrelevant to life it may be. They want to feel *sure*, and that's why they buy into that kind of stuff.

Cryonics: *Do you think this desire to be sure has anything to do with why cryonics hasn't completely caught on yet?*

JB: Certainly. It's not guaranteed. Cryonics is a bunch of new ideas that cause you to question and confront your old, set ideas. If you believe in God, cryonics throws doubt on the whole thing. What happens to my soul? If I come back, did I go to heaven? Where is heaven, then? It throws the whole thing into question. Most people can't deal with that. It's not safe, and secure, and sure. In fact, that's probably one of the

reasons I like it.

Cryonics: *Let's backtrack here for a second and talk about your accident. When did it happen?*

JB: February, 1991.

Cryonics: *Describe what you know of the actual accident.*

JB: Actually, I know nothing of the accident first hand. Everything from two weeks before the accident until about a month afterwards was basically wiped from my memory by a traumatic head injury. From what I've been told, I was with one of my friends in his car. We left the road doing about 80, hit some trees, and flipped over a bunch of times. They found my body about 30 feet from the car. I had multiple fractures, including five vertebrae. In fact, I now have one less vertebra than everyone else. My brother jokes that I must be a reptile or something now since I don't have enough vertebrae to be human anymore. (Laughs.) I was just generally racked up. I laid on my back for six months, which turned out to be a positive thing. I came out of it mentally stronger and physically weaker.

Cryonics: *So describe your physical status today.*

JB: Well, I have metal rods affixed to my spine so my lower back flexibility is pretty much lost. My right calf muscle is basically non-functional due to the spine injury. My left rotator cuff was torn and leaves me with a limited range of movement. I can still walk and I can still work, though.

Cryonics: *Okay, what about your mental status? What was it like for you at first?*

JB: For a while, I was probably clinically insane. I don't really remember that time, though. My first real memory after the accident is of waking up in a white room to see a lady all in white who was obviously a nurse. She said, "You've been in an accident." I said, "Oh, no!" and passed out. After that I was really disoriented for a while, to say the least. So I guess it was despair and hopelessness at first.

Cryonics: *How long were you in the hospital?*

JB: Well, I was actually in the hospital for four months. After that I was in a physical/mental rehabilitation center for a couple of months.

Cryonics: *What was it like in the hospital?*

JB: I had a couple of roommates, but mostly I ignored them. I was self-absorbed, wondering if I was ever going to walk again, when I was ever going to get out of there, if I was ever even going to be able to sit up. I was totally frightened.

Cryonics: *When did that change?*

JB: When they moved me across the street from the hospital to Maple Leaf Physical Therapy. I switched from this sadness and despair to an almost all-consuming anger. I would probably have drowned myself in self-pity if I hadn't had a buoyant float of anger. I was sick of lying down. I was sick of hearing that I couldn't do anything. One of the first things my doctor said to me was that he could list several reasons why I should be dead, and not one reason why I should be alive. I said, "It's because I want to be!" I told him that, "I'm gonna walk out of here and you're gonna watch me!" And that's exactly what happened.

I'm not going to believe that something is so just because you say so. That's the essence of religion. "This is God. He says don't do this or you'll go to hell forever." No proof. Just assurances. I think that the American public wants to be fooled constantly.

Cryonics: *Now that you are walking and living again, how does the accident figure in?*

JB: Well, I think it's very unfortunate that it happened, at least physically. As far as my mind goes, mentally, psychologically, I'm glad it happened. There's nothing I could have planned that would have woken me up so fast. A lot of unimportant things that I thought were important now take the place in my life that they should. I value reflection, meditation, discussion and thought a lot more because of all that time while my body was completely stopped and my mind was the only way to free myself. It gave me plenty of time to think about all there is to think about, and believe me, there's a lot to think about.

Cryonics: *This brings up one of the hardest concepts for non-cryonicists to swallow: the notion that our minds and our bodies are not irrevocably connected, that your consciousness is the most fundamental aspect of your identity, not your body.*

JB: Yeah. One of the harder things about lying on my back all of that time was trying to rid myself of this image of being trapped in my own body. "My mind is still capable, but my body is non-functional. Why am I trapped? Because this casing I'm in is insufficient for the task I need to accomplish." If you could've somehow transferred all of my thoughts and memories onto a chip, and installed them in something else, that would've been fine by me.

Cryonics: *And we humans may be doing exactly that at some point in the future.*

JB: Bring it on! I'm ready for it, anyway.

Cryonics: *If none of this had happened to you, do you think you'd still be signing up for cryonics right now?*

JB: No. More than anything else, the accident made me realize that the one tenuous thing you can really call your own is your life. Your house, your car, all your stuff, that's all meaningless at some point. But no matter what stuff you have, as long as you're alive, you have the ability to change things. It doesn't matter whether you're a prince or a pauper right now. All that really matters is whether you're alive. You can become a prince if you want to, but you'll have to stay alive to do it.

The Winning Essay...

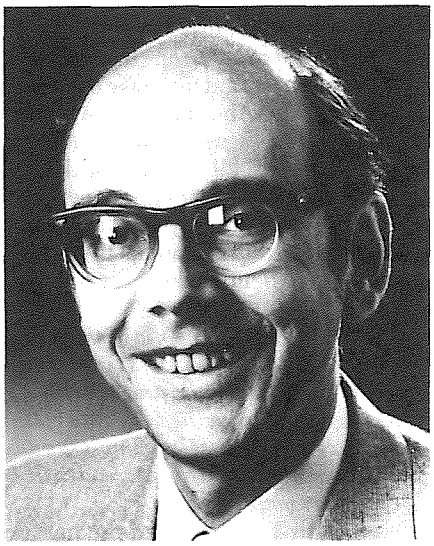
I am twenty-one years old. When I was nineteen, I was involved in a very serious automobile accident. I was gravely injured. Thanks to modern medical technologies and techniques, I survived. Modern technology, however, is unable to return my physical form to its once healthy state. I am sore each day and (most likely) will be until my existence ends. (I have more metal within my body than most people have in their silverware drawers!)

When I close my eyes for the "final" time, I want to die with a smile on my face, both knowledge and hope in my heart. This smile will be brought about by both the knowledge that I will be cryonically suspended, and also by the hope that I will awaken healthy and healed.

I look forward to the future. I have hope that it will not be the ignorant, opinionated, and prejudiced world of today, but rather an enlightened age. I carry no sad old traits as such in my heart, and refuse to bring them with me. I will however, bring knowledge of such things. To know the mistakes of your forefathers is to prevent them from happening again.

I will bring with me hope; hope for my future and hope for all the world. I will also bring love and understanding, the two most important things I can bring.

—James Baglivo



The Donaldson Perspective

Thoughts on Christmas Day

by Thomas Donaldson, Ph.D.

Like many cryonicists, I do not consider myself religious; but probably again like many cryonicists, Christmas brings up many memories of my childhood, not to mention dinners with relatives, exchange of Christmas gifts, and all the other activities for which Christmas is known. In that sense it becomes difficult, if not impossible, to escape—and someone raised in a family that celebrates Christmas might seriously wonder, every year, whether they really wish to escape it completely at all.

In my own case, this year, Christmas consisted almost entirely of memories. Everyone who remains in my birth family lives far away: Massachusetts or Kentucky. My wife is now in Australia. And so, laying in some supplies, I cooked myself a somewhat more elaborate Christmas meal than usual, and spent Christmas by myself. My major Christmas activity consisted of a short trip to a cliff on Highway One overlooking the Pacific, where I went to think about Christmases and immortality, cryonics and Christ.

Christmas came from a pagan holiday, and most customs of Christmas don't really need Christianity: the Christmas tree, the gifts, the meetings with relatives. Even "The Twelve Days of Christmas" need not be read as a Christian song. And even the basic notion of Christianity comes directly from mythology: the dying and reviving gods, Adonis, Attis, Osiris, Tammuz. (Poinsettias, the Christmas plant, symbolize both the green of spring and the new god and red the death of the old god.) Both Christmas and Easter, complete with virgin birth, came directly from such older festivals.

And so we now have cryonicists, who break with these old myths. Not only do we say that we seek immortality by our own efforts (not by the grant of some god) but we say, also, that it is for *everyone*. To anyone raised to believe that only very special people might achieve immortality, these ideas might well seem not only improper but *unclean*. How often have people complained of us that we set ourselves up as special? And when someone questions cryonics by asking: why should anyone bother to revive you? Behind their question lies the story of Christ and all the other dying and reviving gods.

That myth may touch many people much more deeply than they know. After all, most people still come to humanism not because they were raised in it, but because they came to question the beliefs in which they were raised and found them deficient. But those beliefs still keep their hold. Nor is this story of virgin birth, death, and revival unique to Christianity.

These myths don't merely concern Christmas and Easter. The myth of the dying and reviving god is a myth about the seasons, about the regularity of Nature, and a statement of how human beings fit into that Nature. Even if not in detail, many people plan out their whole lives on these patterns: education as a child and youth, marriage in young adulthood, production and raising of children. In short, they hope someday to preside as grandparents over their family on Christmas day.

To suggest immortality is to suggest that all of that planning and all those happy visions not only will not but ought not to occur. To anyone who has been molding their life to fit these seasons, immortality may feel deeply disturbing. It calls their whole life into question, making them ask: Have I spent all these years, then, chasing after a fading dream?

The reach of these myths goes very far. Even cryonicists can remember being asked by adults: what are you going to *be* when you grow up? The myths of death and revival, the seasons, the whole notion of "growing up" into some *fixed* condition are central to most of literature, either as something to reach toward or to flee from. A story should have a plot: it begins, it describes some changes, which then lead to an end. Someone dies, someone may be born, someone "grows up." Behind that notion of death lies a notion of completion, that after some events no more can happen: they "live happily ever after" ... or die in some general holocaust.

When we became immortalists we decided to strive for something quite new: a story, our own story, that will never reach completion, and never have an end. And the only myths about such a life, in the world at large, are unpleasant ones: the Wandering Dutchman, *aimlessly* travelling about the Earth. (That myth says, implicitly: how can you have an aim if it is not Death?). Even Christians who believe in Heaven, and so tell us so blithely that they "do not need cryonics", have no answer for what they will actually *do* in Heaven. Nor for that matter do those cryonicists, who cast their visions of the future into shapes much like those of the Christian apocalypse, really tell us what will happen *after* the "Discontinuity". Yet the myth of an imminent "Discontinuity" suffers from the same problem as the myth of Heaven: what, then, do we *do* with ourselves afterwards? It is a myth of completion and ending.

I strongly suspect, in fact, that our inability to tie our goals to any popular myth may help explain the relative unpopularity of cryonics (and even immortalism). And myths come out of the life of people, they aren't invented as if they were stories. If we succeed, as I hope, then we will create such myths out of our own lives. And myths have power even over people who deny them: we not only will but *must* create such myths.

For what it is worth, I will say what I aim to do, which is to grow and explore the directions of growth. Of course there are many such directions, most of which can't be described by a simple physical dimension. Nor would I find growth in weight, height, girth, etc of much interest. Even growth of my brain would be a means to an end rather than an end in itself. But I would like to increase my abilities and understanding in many ways.

And here I may speak for many cryonicists. Yet in making any such choice we should be aware of the *metaphysical* problems it implies (certainly we must solve many other problems, too). To grow is also to lose something you once had; with enough growth, you will no more remember your present life than you now remember your very early childhood. Are you then still "the same person"? A deep concern with continuity of our "Self" quite often becomes a topic among cryonicists. Such a concern doesn't come merely from questions about how well we can survive suspension. It will come even if our suspension succeeds completely. It is the *other* side of immortality.

We live now in a world made by myths of death and limitation. As immortalism grows, we will ring the changes on new myths too, of change and persistence amid change, growth and the losses that growth will cause.

And so it came to the day after Christmas, and my door bell rang. In front of me stood an older woman, a younger woman (her daughter), and a little girl, her daughter: three generations. They had brought along tracts about Christianity, and wanted to tell me about them. The older woman seemed a sweet old soul; the younger woman friendly, wanting to solve my problems. The little girl looked curious. I turned them away, of course, as gently as I could. I could say only: "Your message has nothing to say to me."

The Rediscovery of the Mind, by John R. Searle, MIT Press, 1992

Reviewed by Thomas Donaldson, Ph.D.

John Searle is known among students of the philosophy of mind for his Chinese Room story. He presented the Chinese Room story as an argument against the Turing Test for whether or not a computer could think. The story goes: let us suppose a room, with a man who does *not* know Chinese inside it. Even though this man does not know Chinese, by consulting a suitable table he knows that if presented with one sequence of Chinese ideograms he should respond with another, and does.

The implication is that if we were conducting our Turing Test of a thinking computer in Chinese, then this man would seem to fulfill all the necessary criteria to pass it. Yet at the same time he has only consulted a table, with no idea at all that these ideograms had or even might have had a meaning. It's possible to carp at this story: perhaps the table would be far too large for practical use, and the story therefore impossible. Yet as a philosophical exercise (where practicalities aren't needed) the Chinese Room does make an important point: no amount of skill in playing with tokens really captures the notions of intelligence or awareness. Both must exist on a nonsymbolic level or they do not exist at all.

And of course the problem becomes even worse. *We*, when working any computer program, attach a meaning to the output of that program (whether it is a Turing robot or not). The program itself is once more only a set of directions for changes to be made inside a machine. It is *human beings*, whether they designed the program or not, who decide that its output is really the choice of an optimal design for a bridge or a simulation of galaxies colliding.

The Chinese Room story, then, isn't just a story about the Turing Test, but a statement about one particular strategy, still often attempted, for constructing an "intelligent machine" ... or again, for explaining the workings of our own brains. In the normal sense of a computer program, by our essential nature we *cannot* be simulated by computer programs. (And note that this is definitely *not* an argument claiming the impossibility of making an artificially intelligent machine. It is an argument about one *strategy* for doing so. Searle himself points out, for instance, that neural nets may provide a means to create a conscious, intelligent device, though he believes that will take many years of research).

Nearly one quarter of Searle's book consists of a detailed discussion of the many varieties of philosophy of mind that differ from his on this key point. His title itself comes from that criticism. The problem comes from the problem of the existence and location of *consciousness* (and in fact his book might have better been titled *The Rediscovery of Consciousness*).

In terms of the beliefs of many about the material world, anything which cannot be perceived by outside, third party observers cannot be real. Consciousness and all of our inner feelings (including emotions and desires) suffer from the problem that no outside observer can examine *my* consciousness (or emotions, desires, etc). In the time of Descartes, this fact led to the conclusion that some entirely separate field of existence, the mental, must exist distinct from the material world. Now, however, no thoughtful person believes in such a separate world; this has led to many attempts to look for external signs of the phenomena which we call consciousness. Some people, realizing that by the nature of consciousness it can have no infallible external signs, have even raised questions about its *existence*, and argued that any statements we make about ourselves as "conscious" are merely turns of phrase, or even mistaken. Searle's solution to this problem is painfully simple: well, some physical phenomena, *by their nature*, simply cannot be perceived directly by third parties. This does not make them unphysical, mystical, mentalistic, or other such. It just makes them hard to study.

One implication of the Chinese Room is exactly this. It provides an example of external (observable by a third party) behavior, apparently understanding Chinese, but actually not. (Notice that Turing put forward his Test as a test of whether or not a computer could become aware just as we are. No one doubts that computers can do things we cannot. The issue is whether they can become self-aware).

How do people who are not philosophizing on the subject, or even scientists, study and speak of consciousness? Normally, we attribute consciousness to one another by assuming that similar causes give similar effects. You are close enough to me in appearance, physiology, neurology, and biochemistry for me to believe that you also are conscious. We decide that the "higher" animals are conscious for much the same reasons. In this way neurobiologists studying vision can go on to say that some animals perceive color while others don't, and even that human perceptions of color differ slightly in detail. But in terms of actually having the *feeling* of consciousness that you do, I cannot.

Again, a field called "cognitive psychology" provides one major strain of thinking in the study of brains. Many of those who practice it distinguish themselves by a belief that no understanding of how brains actually work is needed. They believe this because they think of our minds as working like a computer program. Searle argues very pointedly against such a thesis. Summarized, his argument works like this: we have seen that computer programs (in the sense used by these practitioners) consist basically of playing with symbols. As such they cannot explain how our brains work: just why and how one collection of neurons, for instance, sends signals to another. No amount of symbolic computation can *explain* that in itself; the most it could do is to suggest hypotheses for later verification on real brains. (I think Searle may be a little unfair here, though at the same time his point is well taken. Some cognitive scientists use computer programs as a means to help them understand brain physiology and activity, not dispense with it).

A similar problem arises when we try to explain language as based on some kind of inner language used by our brains (recall the works of Noam Chomsky!). The very most such a theory can do is take us back one more step, when what we really seek is the connection between language, our brains, and the world around us. Postulating yet *another* language gives no answer at all. (And note that neural nets, once more, provide a model for systems which *do not* create this eternal regress).

Finally, Searle discusses one feature of our experience as human beings perhaps essential to our abilities, including our consciousness. He calls it the Background. Though its name may seem unfamiliar, others have also discussed it. The later works of Wittgenstein concern this Background, for instance. Whenever we act, think, or talk, any understanding of our actions depends on a literally endless set of perceptions about the world. If we speak of shoes, the purpose, nature, and materials of shoes lies behind what we say *even though we make no conscious reference to it*. And because we are acting in the world rather than in some nicely limited (even if very large) set of symbols, our actions and thoughts can be conditioned by this Background.

An old philosophical puzzle about language summarizes this point. When the English first noticed the black swans in Australia, they had no hesitation in calling them black swans—though every dictionary at that time claimed that swans must be white. One test for the ability of a device (I do not say computer) to emulate human intelligence and consciousness might be, then, whether or not it can see black swans when it finds them.

Searle does not agree with either Patricia Churchland or Daniel Dennett on many details. He has and expounds his own viewpoint on similar questions. Any cryonicist interested in consciousness (and we all hope, by whatever means, that our consciousness will revive after cryonic suspension) might do well to read and think about what each of these authors has to say.

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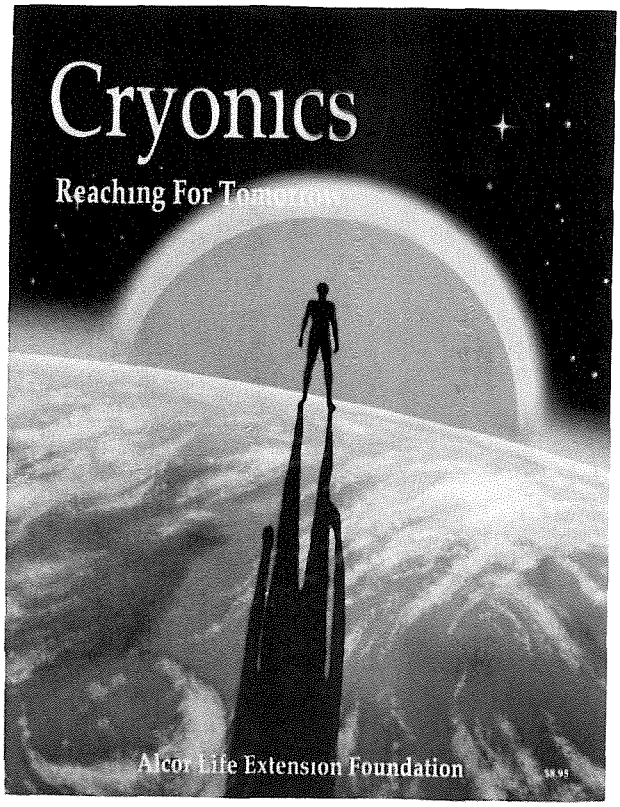

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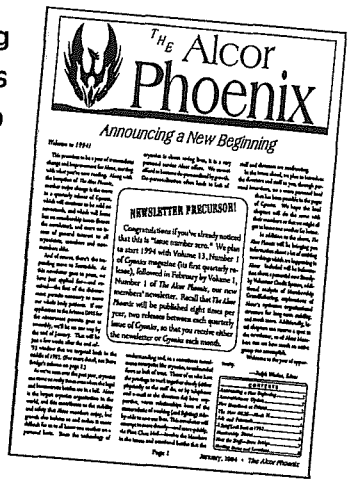
If you're intrigued enough with cryonics and Alcor that you're considering Membership, you might want to check out *The Alcor Phoenix*, Alcor's Membership newsletter. *The Phoenix* is a Membership benefit, so it's free to Members and Applicants, but anyone can receive it for $20/year. It's released 8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

Board of Directors Meetings

Alcor business meetings are held on the first Sunday of every other month: January, March, May, July, September, and November. (The July and September meetings are on the second Sunday.) Guests are welcome. Meetings start at 1 PM. For more information, call Alcor at (909) 736-1703.

Sunday, March 6, 1994:

ALCOR
12327 Doherty St.
Riverside, CA 92503

Directions: *Take the Riverside Freeway (State Hwy 91) east toward Riverside. Go through Corona (past the Hwy 15 interchange), and get off at the Pierce exit. Go right (south) on Pierce. Turn right (west) at the first intersection, Magnolia. Turn right (north) at the next intersection, Buchanan. Go about 200 yards on Buchanan and turn left onto the second side street, Doherty. Turn right between the first two buildings on your right (no street name). Alcor is the fifth unit on the right.*

Bay Area

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

Sunday, February 13, 1994:

Naomi Reynolds (408-264-1607)
1444 Jeffery Ave.
San Jose, CA

Speaker: Charles Musgrave (winner of the 1993 Feynman Award in Nanotechnology) speaking on Nanotechnology.

Directions: *Take Hwy 280 toward San Jose. Take the 87 Exit (guadalupe Pwky) South. Get off at the Almaden Expwy exit. Go to Foxworthy (there is a light) an turn right. Go to Plummer (stop sign). Go one block to Jeffrey and turn left. Jeffrey is a cul de sac with limited parking, so you may have to find a place on Plummer.*

Midwest

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

Boston

There is a cryonics discussion group in the Boston area meeting on the second Sunday each month. Further information may be obtained by contacting Walter Vannini at (603) 889-7380 (home) or (617) 647-2291 (work). E-mail at 71043.3514@Compuserve.com.

District of Columbia

Alcor DC is a new cryonics group with members from Washington, D.C., Virginia, and Maryland. The Alcor DC Board of Directors meets once a month. Alcor DC also sponsors discussion groups, speaker's bureaus, and seminars. Call Mark Mugler at (703) 534-7277 (home), or write him at 990 N. Powhatan St.; Arlington, VA 22205 for directions or for upcoming activities.

Las Vegas

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

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

Southern California

The Southern California chapter of Alcor meets every month in an informal setting in one of our member's homes. This group is now moving into high gear, in preparation for "Alcor Central's" departure scheduled to occur sometime in the next few weeks. The February, and March meetings (each on the fourth Sunday of the month) are now scheduled. The February meeting will be at the home of Alcor Director Michael Riskin. For more information, call Linda Chamberlain at (619) 757-3774.

England

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

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

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

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

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