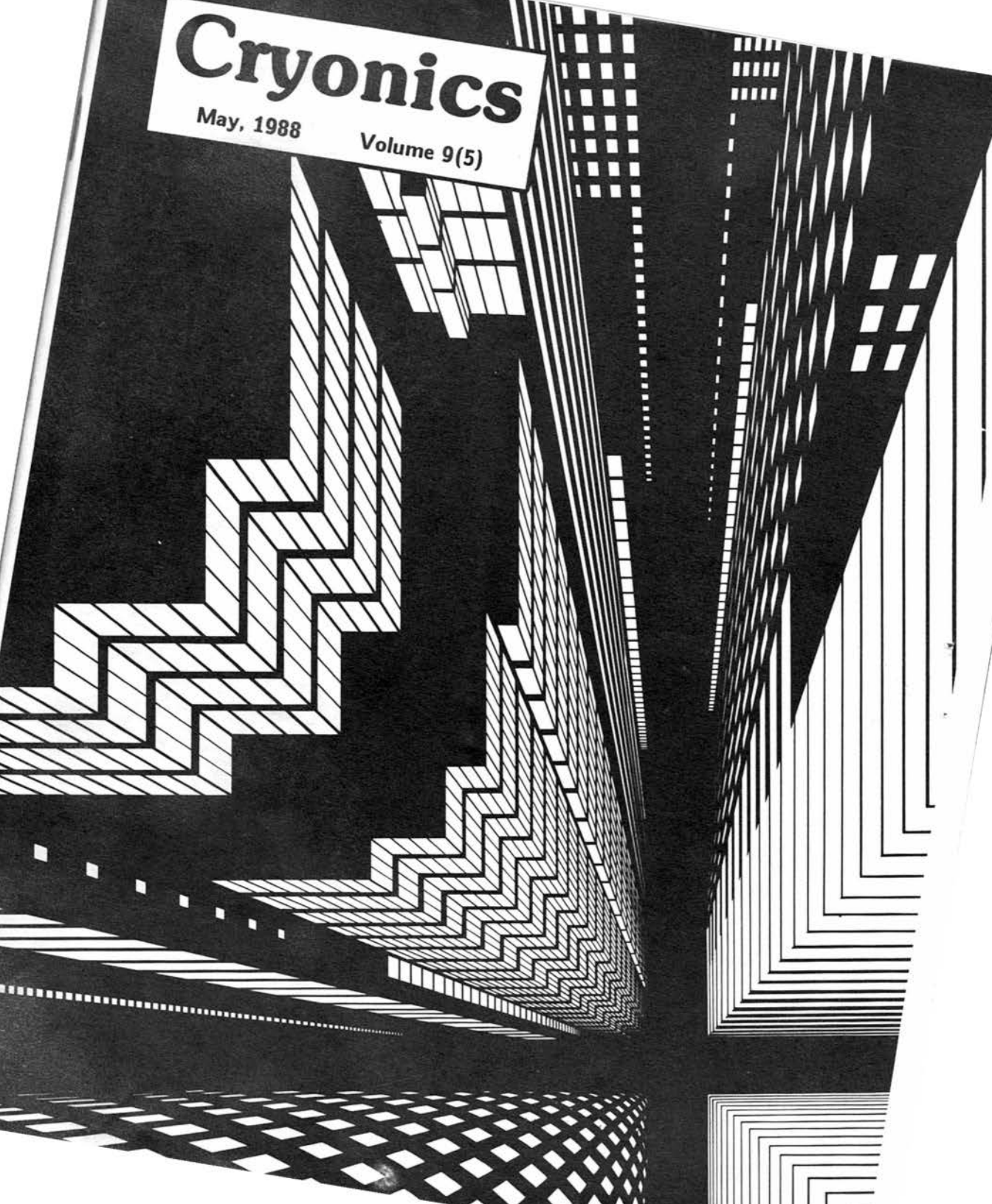
Cryonics

May, 1988 Volume 9(5)



Volume 9(5) May, 1988 Issue #94

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EDITORIAL MATTERS

The last few months have no doubt left most of our readers as stunned as they have us. It has been an interesting exercise in concentration to put out *Cryonics* under such conditions. In particular it has been hard to *write* for the magazine. We could use a little help. One of the side effects of the Coroner seizing our computers was that the normal backlog of work scheduled to fill up the pages of *Cryonics* simply vanished! Several lengthy articles by Mike Darwin and a case report on the Alcor member suspended in June of 1987 were lost (and as of this time we have been unsuccessful in getting copies of any of our patient records returned to us).

The message here is that we could use some help. If you have thought about writing something for *Cryonics*, consider sending it our way. It would help to take the load off us here more than you can imagine.

STATUS REPORT: ACT IV: ENTER THE RIVERSIDE POLICE

The "homicide" investigation of Dora Kent's death has taken on a new dimension. According to the April 3, 1988 Riverside *Press-Enterprise*, Raymond Carrillo, Riverside County Coroner, requested that the Riverside Police Department (RPD) take over the investigation of Dora Kent's "death". A detective has been assigned to the case and we understand that the RPD is investigating the matter in conjunction with the District Attorney's office and the Coroner's office. We have reprinted the newspaper account of this development on the next page. We have no information beyond what we read in the paper. Make of it what you will!

UCLA "STOLEN" PROPERTY INVESTIGATION: HOME AGAIN!

On April 5th, after weeks of waiting, a 16 ft. truck of Alcor property was returned to the facility. The property constituted over 90% by volume of what was taken from us. Only items for which we had uncontested receipts were returned. As the accompanying pictures show, this was a considerable volume of material, consisting of over 100 items seized during the raid on the Alcor facility on February 12-13.

As of this writing UCLA is currently holding 19 items of property for which we either have no receipt (in most cases because the property was purchased over 10 years ago!) or for which they refuse to accept the receipts we have provided. In particular, UCLA police are maintaining that a 5-shelf stainless steel utility cart which was purchased from UCLA Surplus and Excess Property is stolen. We purchased this item last August and we have

Coroner hands Dora Kent investigation to police

By DON BABWIN
The Press-Enterprise

The Riverside County Coroner's Office has handed the investigation of the death of 83-year-old Dora Kent over to the Riverside Police Department, officials said yesterday.

"They have classified the death as a homicide that occurred within the city limits and requested we assume an investigative role," said police Capt. Michael Figueroa.

A formal request was made last week by coroner Raymond Carrillo to Chief Linford L. "Sonny" Richardson, Figueroa said.

Coroner's officials have been investigating since they first learned about the woman's death in December at the Alcor Life Extension Foundation laboratory in Riverside.

In February, the coroner's office ruled the woman's death a homicide and that she had been killed by a lethal dose of barbiturates. Alcor officials contend the woman was already dead when a procedure to remove her head was begun, and that cardiopulmonary resuscitation after death distributed the drugs throughout Kent's body.

Yesterday, Figueroa said there was no reason for the delay in taking the case other than it took that long for police investigators and coroner's officials to sit down and discuss the case.

Richardson said of the request: "The only thing we were told was that they felt we were better prepared to investigate it (the death) as a crime." He said the police are better equipped to "interview potential witnesses, interview potential suspects" than is the coroner's office.

Also, said Richardson, the department was simply responding to a coroner's office request. "We can't take an investigation away from the coroner," he said. "They could have kept jurisdiction."

Supervising Deputy Coroner Daniel Cupido said the investigation was turned over because the coroner's office had "completed the duties of determining cause and mode of death."

Figueroa said the department did not become involved until the coroner's office made its ruling that the woman was a homicide victim. "We chose not to muddy the investigation," he said. "At the time, the cause of death was not determined."

When the coroner's office ruled the woman's death a homicide, the case was referred to the Riverside County District Attorney's Office. Yesterday, Assistant District Attorney Jay Thompson Hanks said the police investigation does not change the district attorney's office involvement in the case.

"They (the police department) have more resources than we do and certainly than the coroner's office does" in conducting criminal investigations, he said.

"If the police are going to assist, it is a great benefit," he said.

Police investigators will review the material gathered by coroner's investigators, according to Figueroa, who said he did not know how long that would take.

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several witnesses to this effect, as well as a receipt and the cancelled check! In addition, none of our prescription medications or our reagents which were seized during the raid have been returned -- this despite the fact that their warrant did not authorize the removal of these items!

We also reproduce a part of the Affiant's declaration by Deputy Coroner Allen Kunzman which allowed them to get the warrant to enter our facility and seize our property without even giving us an opportunity to prove ownership. You will note that the Affiant's declaration states that UCLA shows the electron microscope which we purchased from them to be "stolen, missing or destroyed." We also reproduce a copy of the UCLA receipt and canceled Cryovita check for this item dated April 3, 1981. The UCLA claim on the electron microscope is particularly bemusing on several counts, not the least of which is that it weighs over half a ton and normally occupies a room by itself.

We are still trying to adjust to the reality of what happened to us. On the basis of information from Lieutenant Cueba of the UCLA police, a warrant was issued which allowed the *Coroners* to come into the Alcor facility and seize a truckload of our property and cart it away along with the receipts that would allow us to prove we own it. And

(Continued on page 7)

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The following is a reproduction of parts of the Affiance Declaration sworn to establish the grounds of the January 12, 1988 raid on Alcor.

IN THE SUPERIOR COURT OF THE STATE OF CALIFORNIA
IN AND FOR THE COUNTY OF RIVERSIDE

Oral Affidavit of Allen Eugene Kunzman
Honorable Thomas E. Hollenhorst, Judge
January 11, 1988

APPEARANCES:
For the Petitioner: OFFICE OF THE DISTRICT ATTORNEY
BY: KIM PURBAUGH, Deputy
4080 Lemon Street, Suite 200
Riverside, California 92501

ALLEN EUGENE KUNZMAN, Affiant

....

Page 3, line 10 continues.

ALLEN EUGENE KUNZMAN,
having been sworn as the affiant herein, testified as follows.

EXAMINATION BY MR. PURBAUGH:

....

Page 11, line 1 continues

Q. ....
During your search of the ALCOR facility on January 7th of 1988, you said you located an electron microscope there --

A. Yes.

Q. -- with a U.C.L.A. property tag on it with a number; is that right?

A. Right.

Q. What did Mr. Cueba, Lt. Cueba, tell you about that particular microscope?

A. Okay. After he had a chance to get back to his Police Department and contact representatives from different departments that would be in control of that equipment, he called me and informed me that that particular piece of equipment had not been sold. They are carrying it as a piece of equipment either lost, stolen or destroyed, because it was never reported stolen, but it has never been sold, either.

Q. All right. So, they said they are carrying it as lost, stolen, or destroyed?

A. Correct.
Q. Okay. Obviously you are aware from seeing it at ALCOR it is not destroyed?

A. Correct.

....

Page 12, line 25 continues,

MR. PURBAUGH: What we can do on the record is, of the court reporter could designate her transcript as Attachment "A" --

THE COURT: All right, at this time I will

(page 13)

designate the transcript from these proceedings as Attachment "A" to the affidavit for the search warrant.

The court at this time is authorizing the search, as evidenced by the Court's signature as a magistrate; and I will attach hereto the original warrant dated January 6th as Attachment "B".

MR. PURBAUGH: The only thin we need do then on this second form that you signed, Deputy Kunzman, I will fill in, "The facts establishing the grounds for issuance of the search warrant are set forth under Attachments "A," and I am writing in "B".

THE COURT: All Right. Very well.

You swear the contents of that are true, so help you God?

THE AFFIANT: I do.

THE COURT: Okay.

(Proceedings concluded.)

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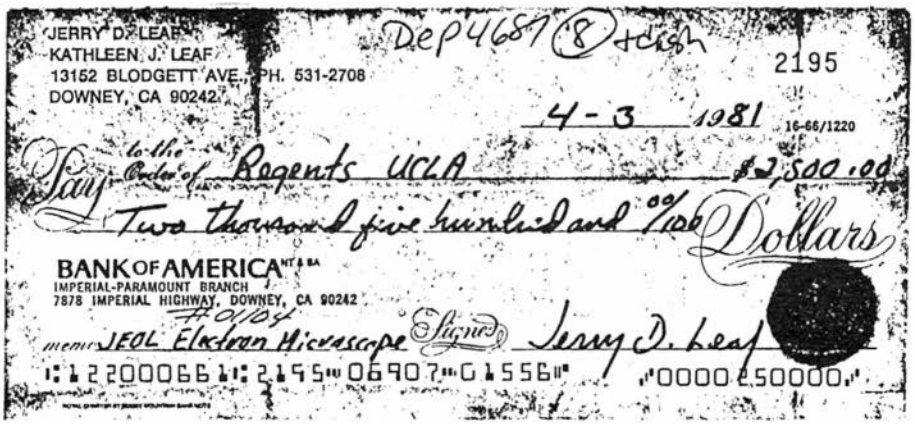

JERRY D. LEAF
KATHLEEN J. LEAF
13152 BLODGETT AVE., PH. 531-2708
DOWNEY, CA 90242

Dep 4687 (8) +disk

2195

4-3 1981

16-66/1220

Pay to the Order of Regents UCLA $2,500.00

Two thousand five hundred and 00/100 Dollars

BANK OF AMERICA NT & SA
IMPERIAL-PARAMOUNT BRANCH
7878 IMPERIAL HIGHWAY, DOWNEY, CA 90242

#0104

memo JEOL Electron Microscope

Signature Jerry D. Leaf

1:122000661: 2195 06907 01556 0000250000

UNIVERSITY OF CALIFORNIA – LOS ANGELES
EQUIPMENT MANAGEMENT
752 CIRCLE DRIVE SO.
LOS ANGELES, CALIFORNIA 90024

CASH RECEIPT
No. 01104

Date 4-3 19 81

Received from Jerry D. Leaf PHONE NO. 531-2708

Address 13152 Bloomfield Ave CUSTOMER'S ORDER NO.

City Downey State Ca Zip 90242 RESALE CERT. NO.

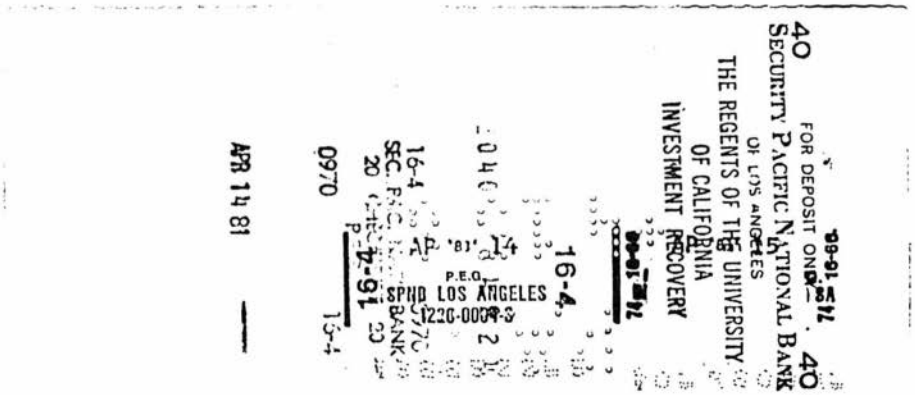
PROP. OR TAG NO.	DESCRIPTION	QUANTITY	PRICE	AMOUNT
	Electron Microscope (Leaf)	1	2500.00	2500.00
			TAX	
			TOTAL	2500.00

Invoice No. 10-6 Kubb

Cash Check No. 2195

RECEIVED BY Robb R Tuan

FORM NO. ICF-6 (6/78) WHITE – CUSTOMER COPY YELLOW – EQUIPMENT MGT. COPY PINK – ACCOUNTING COPY



UNIVERSITY OF CALIFORNIA POLICE
LOS ANGELES

PROPERTY REPORT

Non-Evidence — Evidence

RESIDENCE ADDRESS: 1. 12327 DOHERTY ST., RIVERSIDE, CA.	PERSON PROPERTY BOOKED TO: 1. ALCOR LIFE EXTENSION FOUNDATION
RESIDENCE ADDRESS: 2.	ARRESTEE'S NAME: 2.
RESIDENCE ADDRESS: 3.	VICTIM OR OWNER'S NAME: 3
RESIDENCE ADDRESS: 4. 601 Westwood Plaza, L.A., Ca. 90024	PERSON REPORTING TO POLICE DEPT (Last, First, Middle): 4. HUDDLESTON, D.L. #393 — BUS. PHONE 206-8136
DATE & TIME THIS REPORT: 1/15/88 — PROP BKD. AT: UCPD — DATE BKD: 1/15/88	DATE & TIME PROPERTY TAKEN INTO POLICE CUSTODY - LOCATION - CITY OR REPORTING DIST.: 1/12-13/88 RIVERSIDE, CA.
INV. DIV: UCLA DET. — IS THIS STOLEN PROPERTY? ☐ YES ☐ NO ☒ UNKNOWN	TYPE OF PREMISES: WAREHOUSE — TYPE OF PROPERTY: MISC. MEDICAL EQUIPMENT — DIV. RPTG.: 826
PROBABLE CRIME: 487.1PC GRAND THEFT — Prints · Photo · S.I.D. · Other	DIV. OR CITY & DATE CRIME OCCURRED: LOS ANGELES - UNKNOWN — LIST ANY CONNECTING REPORTS BY TYPE & DR

PROPERTY ON THIS REPORT SEIZED PURSUANT TO SEARCH WARRANT: ☒ ALL ITEMS ON THIS REPORT ☐ ONLY ITEM NOS.:

12327 DOHERTY ST. (SEARCH WARRANT NO.) | 1/11-12/88 (DATE) | JUDGE HOLLENHOST (ISSUED BY JUDGE) | COURT NO.

Separate reports are required for each classification of property: Evidence: Book to Arrestee. If none, Book to Victim. If neither, Book to Dept. Employee (Book as Evidence if connected to Crime, Possible Crime, or Arrest.) **Non-Evidence:** Book to Finder, Depositor, Owner or Person in lawful possession.

(1) IF STOLEN IN CITY OF LOS ANGELES EACH CASE MUST BE COVERED BY CRIME AND FOLLOW-UP REPORTS. (2) DESCRIBE CIRCUMSTANCES RESULTING IN BOOKING OF THIS PROPERTY. (3) GIVE ADDRESS, TIME AND/OR PHONE NUMBER WHERE CONCERNED PERSON(S) MAY BE CONTACTED BY DAY INVESTIGATORS IF NOT LISTED, OR OTHER THAN ABOVE. (4) ITEMIZE AND DESCRIBE ALL PROPERTY OMITTING DOLLAR VALUE. (5) LIST TOTAL VALUE OF U.S. CURRENCY BOOKED.

ITEM NO. | QUAN. | ARTICLE | SERIAL NO. | BRAND | MODEL NO. | MISC. DESCRIPTION (EG. COLOR, SIZE, INSCRIPTIONS, CALIBER, REVOLVER, ETC) | U.S. CURRENCY BOOKED

THE BELOW LISTED PROPERTY WAS SEIZED PURSUANT TO A SEARCH WARRANT SERVED AT THE ABOVE LOCATION ON 1/12-13/88. AFTER A THOROUGH INVESTIGATION FOR STOLEN PROPERTY. IT WAS DETERMINED THAT THE BELOW LISTED PROPERTY WAS NOT STOLEN AND, SHOULD BE RETURNED TO ALCOR LIFE EXTENSION FOUNDATION.

ITEM	QUANTITY	DESCRIPTION	ITEM NO. AS LISTED ON THE ORIGINAL RPT.
1	1	MONITOR, HEWLETT-PACKARD, SERIAL #1760PT08, MODEL #1061A.	H 11
2	1	RADIOMETER ACID BASE ANALYZER, SERIAL #149126, UCLA PROPERTY #70-400-2875.	15 OR
3	1	BLOCK AID MONITOR, UCLA ANES #18, SERIAL #2-665469.	7
4	1	GAGE, ETCHED ID #2-1722, PROPERTY #65-401-0920.	20 OR
5	1BOX	CONNECTING TUBING, 90498, H8294-00.	LA 24
6	1BOX	BLOOD VALVES.	LA 25

et cetera, for eight more pages and 60 entries

CC: CHS ✓ FCN CANCELED.

If additional space is required, use reverse side

SUPERVISOR APPROVING / SERIAL NO.	REPORTING EMPLOYEE'S SER. NO. DIV. DET.	PERSON REPORTING (Signature)
Sgt. R.A. Sanchez #331	HUDDLESTON, D.L. #393	X [signature]
DATE & TIME REPRODUCED · DIVISION · CLERK		INDEXED · CHECKED

* *

furthermore, we have been unable to get our property back unless we could produce a receipt showing that we bought it! Can you imagine someone coming into your home and seizing all your furniture and possessions and then demanding that you produce receipts to prove that you purchased it?!

In many instances property was taken which did not even have UCLA property stickers -- or any evidence whatsoever that it was related to UCLA. For instance, UCLA police are still holding 5 gallons of our silicone cooling liquid (which was purchased from Chemcentral, a local chemical supplier) as well as vials of injectable Mexican Hydergine (the labeling is in Spanish!) which is used in ischemia experiments and which it is legal to bring across the border. They also took reagents such as the amino acid taurine and fish oil capsules -- items UCLA is hardly likely to have -- and yet we have to come up with receipts for these items or forfeit them!

We have been told we will probably never get our medications back -- and even if we do they will probably be worthless as they are being stored outside in an unairconditioned tractor-trailer at over 120°F.

As it is we were lucky to get the equipment and disposables back that we did. All but three of our oxygenators have been returned and virtually all of our furniture except the rolling rack was given back. Of course, we had to spend nearly $230 renting a liftgate truck and driving 180 miles to pick our possessions up, not to mention 24 man-hours of lost time picking it up and putting it away once it arrived. And of course there will be no compensation for the scratches, dents, and damage done to the equipment during its seizure and transport to UCLA. We have discovered that damage inflicted during execution of a search warrant cannot be recovered. It's a lucky thing they didn't rip our doors apart and tear out our walls looking for illegal drugs!

The accompanying photo puts the lie to the Coroner's and UCLA's claims -- and shows our satisfaction at having our property back and seeing Alcor back to full capability. We can now do blood gas determinations and we have our remote standby total body washout capability up and running again. It doesn't take away the raped feeling, but as Jerry Leaf's quiet smile attests: It's good to have our stuff back!

* *

NO NEURO?

We understand that the American Cryonics Society (ACS) and Trans Time, Inc (TT) no longer will offer neurosuspension as a patient-selected option; according to ACS president Jack Zinn, their new policy is to suspend their current neurosuspension members as whole body patients and only convert them to neurosuspension later, when their suspension funding drops below that required to cover the costs of whole-body storage.

The Cryonics Institute in Detroit, Michigan has never offered neurosuspension. Thus, Alcor is now the only cryonics organization to offer neurosuspension at the patient's choice.

ACS President Jack Zinn has stated that neurosuspension was discontinued because Trans Time suspension personnel refused to perform neurosuspensions. A recent article by TT Suspension Team leader Dr. Paul Segall in the *ACS Journal* cited public relations objections as being paramount.

Alcor will continue to offer neurosuspension.

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PAYING FOR REMOTE STANDBY

If you have suspension arrangements with Alcor you should already know that Alcor will not start to respond until you are legally dead. If you live a good distance away from Los Angeles or Miami, this can be a serious problem. It means that Alcor personnel cannot be dispatched until after death has been pronounced and that translates into a long time delay. The reason for this policy (which is not new) is simply that we cannot be assured of payment in the event that you recover and do not "die". Since suspension is paid for by life insurance, there is no cash flow to Alcor until a member is declared legally dead.

One way around this problem which has been suggested is to obtain a credit card in Alcor's name which can be used to bankroll remote standby. Thus, if you recover from a life threatening illness against all odds, Alcor would still be assured of payment.

There are many problems with this approach and we believe we have come up with a simpler and better one. What we suggest you may want to do is to obtain a credit card in your own name to be used solely for the purpose of

Remote Standby. You then sign an undated credit card slip which is kept on-file with Alcor to be used in the event of need. A contract for Remote Standby is negotiated in advance, stating the conditions under which Alcor will respond and the financial "limit" you want put on it. If you do become critically (and apparently terminally) ill, Alcor can be assured of payment in the event a team is flown out before pronouncement of legal death.

Alternatively, remote standby can be arranged by establishing an escrow account with Alcor to in effect prepay for the service. If you are interested in a remote standby contract please contact us for additional information: (714) 736-1703.

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LIQUID NITROGEN: CHEAPER NOW THAN EVER

One of the happier side effects of the police action against Alcor and the crisis it precipitated is a sharp *reduction* in patient storage costs. At the height of the recent crisis we were told by our liquid nitrogen supplier that our "account was canceled" and that they did not wish to do business with us in the future. To remedy this situation we had to pay our liquid nitrogen bill months in advance and cough up $3000 for a deposit on the company's LS-160 liquid nitrogen containers. This left a sour taste in our mouth and prompted Mike Darwin to begin looking around for another supplier. After an aggressive search, a new supplier was located and a new contract executed. Much to our surprise the price we were able to get on liquid nitrogen was dramatically lower than the 37 cents per liter we have been paying. How much lower? 35% lower! We are now getting liquid nitrogen for 24 cents per liter. We believe this is the lowest price paid per liter by any cryonics organization anywhere.

Our new supplier is a large and reliable company. Additionally, we have purchased our own liquid handling equipment and are now immune from drivers' strikes and dependence on any one supplier. We can now drive up to a supplier here, there, or anywhere with our own liquid hauling containers, pay for the purchase in cash, and go. This frees us from threats of "canceled accounts" and "blackballing" by skittish cryogenics companies who don't want their trucks seen in the vicinity of any "body freezing" establishments.

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GUIDELINES FOR INITIATING SUSPENSION

As a result of the recent controversy and conflict associated with the cryonic suspension of Dora Kent, Alcor has drafted and adopted guidelines for initiating cryonic suspensions. We intend to follow these guidelines in future Alcor suspensions and we believe that they will virtually eliminate the possibility of a repeat of the recent crisis. The guidelines are reproduced below:

ALCOR GUIDELINES FOR INITIATING CRYONIC SUSPENSION

The Alcor Life Extension Foundation will observe the following medical and legal standards in initiating cryonic suspension of clinically dead members:

1) Alcor will notify the Coroner's Office of the potential cryonic suspension of any member as soon as we become aware of the situation. We understand this to mean that we will notify the Coroner's Office of the clinical death or impending clinical death of a member*.

2) Pronouncement of legal death shall be by a physician not associated with Alcor (i.e., not a staff member, Director or Officer) or the Coroner or Medical Examiner of the appropriate county.

3) Alcor patients will not be brought into the Alcor facility before pronouncement of clinical death per #2 above. No medical procedures shall be performed by anyone not legally licensed to do so prior to declaration of legal death by a physician.

4) Appropriate documentation of patients in Alcor's care (death certificates and Public Health Service VS-9 forms) shall be provided to the Coroner's Office and the Public Health Service.

5) With the consent of the member*, the Coroner's Office shall be notified by Alcor of the arrival of any "high risk" members who intend to take up residence in Riverside County in anticipation of imminent clinical death as soon as Alcor becomes aware of this action or intended action.

6) In any case where Alcor personnel are present at the apparent death of a member when a medical doctor is *not* in attendance, we will initiate resuscitation and activate the Emergency Medical System to bring the patient to a hospital and/or competent medical care to the patient. Only after an independent physician has certified death will Alcor begin suspension procedures.

* This has been requested of us by the Riverside County Coroner's Office. However, due to legal considerations regarding confidentiality of medical history/records Alcor cannot disclose details concerning a living patient's condition without the consent of that patient.

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ALCOR CRYONICS DISCUSSION GROUP FORMS IN NEW YORK

Cryonics groups as such got their start in New York City in the mid 1960's. Indeed, the term "cryonics" was coined by a New Yorker, a young engineering student named Carl Werner. The Cryonics Society of New York was the first cryonics group and throughout the late '60's and into the mid '70's led the way both in terms of press coverage and actual accomplishments.

However, by the late '70's CSNY had virtually ceased to exist and since that time New York has been a peculiarly quiet area for cryonics activity. This has always seemed puzzling since the other three major coastal U.S. metropolitan areas have spawned and supported significant amounts of cryonics activity: ACS/Trans Time (TT) near San Francisco, Alcor near Los Angeles and near Miami. New York City and its environs, with a population in excess of 15 million people, surely ought to be able to support a cryonics group.

Recently, Irving Rand of Lake Success, L.I. (who is associated with ACS/TT) announced formation of a New York group -- although no details have been forthcoming. More recently still, a number of New York Alcor members have been agitating to form a group -- and have succeeded in doing so. On March 19th the first meeting the New York Cryonics Discussion Group was held and five people attended. On April 16th a second meeting was held with

eight people in attendance. The concentration of Alcor suspension members in the New York City/Long Island area has been rising sharply and the odds look good for the beginnings of a renaissance of New York cryonics.

The principal leaders of this effort have been Jerry Arthus, Curtis Henderson (the former president of the Cryonics Society of New York), and Al Roca. A more recent addition to the Alcor contingent is trust and estate planning attorney Charles Butin, who recently became an Alcor Suspension Member.

The New York group plans to meet monthly and they have as their immediate goals:

1) To establish a Coordinator capability with full emergency response capabilities (i.e., medications, heart-lung resuscitator, and related transport equipment).

2) Create an informal discussion group so that interested people can familiarize themselves with cryonics and Alcor and obtain information and assistance about how to obtain cryonics protection.

3) Serve as a resource base for information about research and developments in cryonics and life extension.

The group plans to meet on the the third Saturday of each month at 5:30 PM. A temporary meeting place has been established at the Laissez Faire Book Store in New York City (Bookstore phone #: (212) 925-8992 -- ask for Al Roca). Following the meeting, members adjourn to a local restaurant for dinner.

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

Gerard Arthus	(516) 273-3201
Al Roca	(201) 352-5268
Curtis Henderson	(516) 589-4256

A Final Note

We have had personal contact with Al Roca, Jerry Arthus, Curtis Henderson, and Charles Butin. All of them strike us as sincere, competent, and committed people. We have high hopes for the future of this group in part because two of these people have a track history of being real "doers" with a broad base of practical skills.

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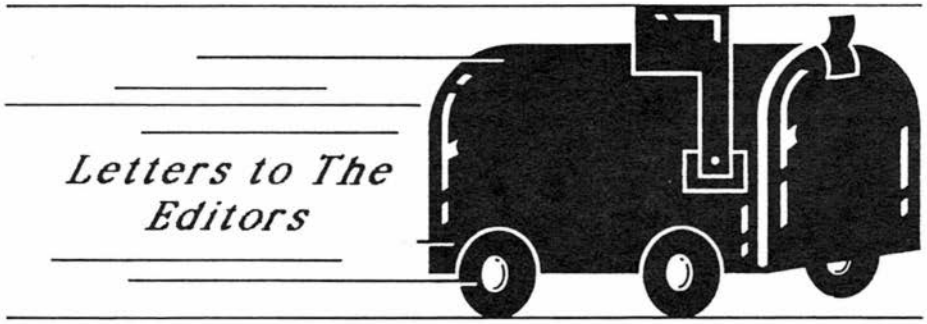

Editors:

I would like to respond to a few of the misconceptions in the article "The Glories of Biochemistry" by Thomas Donaldson. (*Cryonics*, April, 1988).

1. The article suggest that a question on the Foresight Institute questionnaire -- asking for the reader's estimate on when we will be able to build assembler-based devices capable of replicating themselves when immersed in a suitable mix of chemicals -- is silly to ask, since natural replicators obviously already exist. The interesting question, however, is when we will be able to build new ones not found in nature. Far from being silly, this is one of the most frequent questions asked by technical audiences at presentations on nanotechnology.

2. I have checked only one of the numbers given in the article, but that one is incorrect. It is asserted that normal enzymes are, in linear dimensions, 10 to 50 times the scale of the nanomachines proposed by Eric Drexler. A factor of 50 in linear dimension converts to a factor of 125,000 in volume. The article gives the size of a large enzyme as 100,000 atoms; it therefore says that Drexler proposes nanomachines which have a volume of under one atom. Obviously this isn't correct; readers are advised to check the other numbers given in the article before using them.

3. The article suggest that the decreased size seen in nanomachine designs, as compared to existing natural active molecules, is due to scientific arrogance. Actually, the modest reduction in size falls out of the designs, which have at this point been presented by Eric Drexler to many technical audiences and are now being covered by him in teaching a course on nanotechnology at Stanford University. It is not surprising that we should be able to do better than nature at designing for compactness -- life hasn't had small size as a primary goal, and has generally worked with (bulky) amino acids as building blocks, not individual atoms.

4. The article asserts that Drexler's rod logic nanocomputer "will soon go down" due to cosmic rays, chemical attack by trace contaminants, and external vibration. Let's look at these effects one by one:

> *Cosmic rays*: As the book *Engines of Creation* points out, these nanocomputers have such a small cross-section that radiation damage incidents will be very rare. Calculations show that a half-life for a microprocessor-equivalent device should be over a century.

Trace contaminants: The design assumes that the nanocomputer is a sealed system built to contain only what it is supposed to contain.

External vibration: The rods move at such high accelerations (*billions* of gees) that external vibrations are negligible in comparison.

5. The article states that we may not need molecular-scale computers to do medical cell repair tasks, pointing out that enzymes work by pattern recognition and that great computational power is not needed to assemble crystals. However, some of us suffer from medical problems beyond the abilities of any conceivable stand-alone enzyme, unaided by computation, and repairing these medical problems will be more complex than assembling crystals.

I agree with many points made in the article. For example, it observes that nanomachines will be able to operate in harsher environments than proteins (it mentions different solvents and high temperatures as examples of this). Quite right; this was noted in Chapter 1 of *Engines of Creation* (1986).

I wish I could promise readers that I would try to correct all errors in this and later articles in nanotechnology published in *Cryonics*, but it just isn't possible. The payoff in human understanding gained by writing letters like this is just too low: my responses cannot be attached directly to the article I'm responding to, and therefore will be missed by some readers, while others will read both but fail to revise months-old impressions. This is why the Foresight Institute advocates building a hypertext publishing system to improve public (and scientific) debate on a wide range of topics. Criticisms and criticisms of criticisms could then be found in the same place at the same time.

One last comment: some of the problems with the article critiqued above are based on terminology. I've appended three definitions from *Engines of Creation* which have been used since before 1986 when the book came out. These are useful definitions in part because they make relevant distinctions between artificial and natural devices, such as ribosomes vs. assemblers.

Sincerely,
Chris Peterson
Editor, *Foresight Update*

Assembler: A molecular machine that can be programmed to build virtually any molecular structure or device from simpler chemical building blocks. Analogous to a computer-driven machine shop.

Cell Repair Machines: A system including nanocomputers and molecular-scale sensors and tools, programmed to repair damage to cells and tissues.

Nanotechnology: Technology based on the manipulation of individual atoms and molecules to build structures to complex, atomic specifications.

* * *

To the editor, CRYONICS

Reply to "Cryonics as a Religion" --

Readers of CRYONICS should know that Alcor does not have an official policy regarding religion and cryonics. The articles which appeared in the April issue, as well as this reply -- and any others the Editors may wish to print, are the personal opinions of the writers.

My position on the matter is as follows: Alcor is definitely not a religion. Cryonics is not a religion, it is a science. There is no reason why the science of cryonics cannot or should not be a part of anyone's religion. There may be advantages to cryonics being a part of, or even the core of an organized religion.

Mike was right in adding to the dictionary definition of religion the concept of *faith*, -- which he then goes on to correctly define as "belief in the absence of rational proof". Of course there is no rational proof that cryonics *will* work -- only a fair chance, based on what is known now. We don't peddle certainties, religions do.

But wait -- Mike goes on to assert that we freeze people when they die because we *believe* that "Life has a physical basis - we are a pattern of interchangeable atoms". True enough, but what is left out of that statement is that we have no rational proof that that is all life is. Was I asleep when someone proved that awareness has a *purely* physical basis? Until we have such proof, those cryonicists who hold that belief (many, but not all of us) are committing an act of *faith*. Let he who is without sin...

Further, without any rational proof, Mike states that the chance of courts or legislatures extending protections to cryonics based on our belief in it is "nonexistent". I would refer him to a recent decision by the Superior Court of the State of California in the case of Saul Kent, *et al* vs. Raymond L. Carrillo, *et al*. While making no mention of religious beliefs, the court held that their removal from cryonic suspension would constitute a "violation of the rights of the decedents". That decision was made, at least in part, because in this society it is more than just "impolite" to challenge others' beliefs. As Keith Henson recently pointed out to me, we have a "mega-meme" out there that says you just don't [mess] with people on the basis of what they believe. I can draw another example of this from personal experience: when it became necessary for me to explain my involvement in cryonics to my employer, I made it a point to emphasize that while cryonics is not strictly speaking, a religion, it does take the place of religion in my life and is my way of dealing with mortality. I didn't have to articulate the word "lawsuit". I'm sure it occurred to my employer if he considered any option other than tolerance. Many suspension members execute Certificates of Religious Belief because it might get them some extra measure of protection, not only in a court of law, but possibly when in a hospital with a terminal diagnosis. My estimation is that those who are attempting to secure for cryonics the protections of religion -- specifically Venturists -- have a good chance of success.

Finally, Mike argues that any connection with religion damages our credibility in the eyes of "rational, competent" people and alienates these "thoughtful" people whom we supposedly "need to reach the most". Just who are these models of rationality? Why, they're the medical and scientific establishment. Well if these folks are so bloody smart, why aren't they signed-up? Rationality, and the lack of it, can be found in all walks of life in roughly equal proportions. I submit that the people we need to reach the most are the people we have been reaching: those who love life, have open minds, and are honest enough to see the reasonableness of the cryonics "gamble" in spite of all socialization to the contrary. Most of our members are *not* libertarian atheists who love science fiction

and have degrees in computer science. Personally, I don't fit any of those categories.

Have no fear that an association with religion will be a turn-off to people with MD's or PhD's. My guess is that as with everyone else, you'll have a better chance of convincing them of the divinity of christ, than of the rationality of cryonics.

Keep the faith,
Carlos Mondragon.

* *

INCORPORATING CRYONICS IN RELIGION

by Dave Pizer

I would like the opportunity to respond to the article by Mike Darwin, "Cryonics as a Religion", in the April issue.

I think I understand what Mike is trying to say and I agree with a lot of his reasoning. Mike makes some very good points in his sincere concern for the cryonics movement and the safety of the Alcor members. Mike has been an outstanding leader and an advanced analytical thinker in the cryonics movement. His record for being right more than wrong is impressive. His boldness for speaking up on tough issues demonstrates his courage and sincerity.

The main question I have with the article is the hypothesis that theistic or mystical beliefs are required in the definition of a religion. Mike is correct in that all the presently existing, major religions have supernatural beliefs, "but the times, they are a changin'".

To say that all collies are dogs is not to say that all dogs are collies. To say that all philosophical systems that depend on theistic and mystical beliefs are religions does not have to mean that all religions *must* have theistic and mystical beliefs.

Religion, like politics and art, is a human construct: We made it, we can correct it.

To say that humans can't change the concepts and beliefs in their religions might be to infer that religion was more powerful than man.

Over the years, there have been many treatises by scholars more discerning than me on whether a non-theistic philosophy can, or cannot, be reasonably called a religion. And although I cannot answer the question to everyone's satisfaction, as one of the founders of Venturism, I would like to explain my position. First I would like to point out that Venturism is the religion that deals with science, cryonics and physical immortality, *but Venturism is*

a religion of people, not cryonics.

Now I would like to address the following questions, which are also the most important concerns of Venturism:

Can there be a non-theistic religion?

Why do we want to be a religion?

Why is a cryonics-concerned religion worthwhile?

Can there be a non-theistic religion?

1. Venturism, like conventional religions, is concerned with the problem of death. Most religions. however, only address the fear of death. Venturism hopes to be able to help competent cryonics research/suspension organizations, like Alcor, *eliminate the fact of death.* It thus has something "extra" to offer -- a very big something, we think -- and for this reason is deserving of the most sincere commitment.

2. In 1965, The United States Supreme Court, in the case of U.S. versus Seeger, ruled that "a sincere and meaningful belief that occupies a place in the lives of its possessors parallel to that filled by orthodox beliefs in God is, in effect, a religious belief."

3. The times are changing and changing times bring changing definitions. In the case of Reynolds v. the U.S., the Supreme Court concluded that "in order to ascertain the meaning of the word "religion" as used in the Constitutional prohibition against interfering with religious freedom, the court should consider the history of the times..."

4. The are several lawyers and law scholars along with the many other astute cryonicists who are members or supporters of Venturism.

5. A prominent Constitutional lawyer has given a very tentative preliminary opinion that religious standing will create some advantages for us. He has offered (for a reasonable fee) to come up with a coherent and useful opinion. We may find it helpful to the cryonics movement to employ him to explore this in the future.

6. Alcor and other cryonic suspension organizations at one time realized the potential value of having a cryonics-based religious belief *and asked their members to sign just such a certificate indicating just such a belief.*

7. In March of this year, I met with a senior IRS Officer, Jim Stephens, whose department has done a study of Venturism over the last year and Mr. Stephens said that Venturism was a religion and shall be accorded all the rights and privileges of any other religion in the United States.

8. Venturism is not the first religion that is concerned with science. The prominent philosopher Auguste Compte, the founder of Positivism, started the "religion of Humanity". Compte and his followers believed in science, not theism. In the religion of Humanity they wanted to honor men of science as their "saints." (In the future, Venturism will honor men and women of cryonics.) At one time, the religion of Humanity was very popular with many prominent men of science. Although there are still a few of their "churches" said to exist, their religion died out because they did not have a strategy for eternal life as Venturism does.

9. There presently exist several non-theistic religions like the Unitarian Atheists and the Fellowship of Religious Humanism, to which some of the brightest living atheists from the fields of science, medicine, and philosophy belong. Two quotations from their magazine "Religious Humanism" follow:

> *"It is right that men of science and industry should be at the back of all efforts to progress; but religion should be there also, and should be the inspiring force; and religion would be there, if it were the religion of Humanism."*
>
> ---Dietrich Sermons, Vol I.

> *"...Any religion so called, any creed or faith... that does not embody a sense of truth yet to be discovered, of mystery yet to be penetrated, or love yet to be realized, lacks this essential quality of religiousness. But if one's humanism has this dimension, it has achieved a religious quality, whatever one may prefer to call it."*
>
> ---Peter Samsom

10. Cryonics and religion will be intermixed even without Venturism. Dr. James Southard, a cryobiologist at the University of Wisconsin, has stated he feels cryonics, in general, is a religious belief. Rather than wasting valuable time and resources denying these assertions, I think it would be more honest to say that the concerns of cryonics are a religion for some and not a religion for others.

11. Dr. Russell Willis, professor of religion at Arizona State University, was kind enough to give me an interview on March 11, 1988. After I briefly explained the principles of Venturism, he agreed that Venturism is a religion. In paraphrasing Paul Tillich, Dr. Willis said, "Religion is defined as that which is ultimately real."

Dr. Willis also added, "That which ultimately gives life meaning is one's religion, or to put it another way, the concern of religion is to respond to what ultimately gives life meaning. To a theist, what gives life meaning is God. To a Venturist, what gives life meaning is the Venture."

Why do we want to be called a religion?

Traditionally when a person states that a particular conviction is his religion, he is making the strongest possible classification for his philosophy. When we say the philosophy of cryonics and physical immortality is the basis for our religion we are telling the theist that cryonics/physical immortality is of ultimate significance to us; that there is nothing more important in this world. Theists traditionally have a hard time realizing that the non-theists' beliefs might be consequential to them. We are trying to get the listener's attention and give him a reference point he is familiar with by making such a strong statement. In other words, Venturists are saying in eleven countries that cryonics/physical immortality is as important to us as Jesus, Buddha, or Mohammed might be to him.

By calling our beliefs our religion, we hope the theist might better understand and *respect* our beliefs just as he wants others to respect his deepest religious beliefs.

Venturists do not say that cryonics is a religion, only that Venturism is a religion. (Venturism is also recognized by the government as a scientific and educational movement.) Venturism does involve some faith: Faith that if we can eliminate aging, diseases, and the usual accidents, we will someday find a way to escape an exploding solar system, a dying galaxy, or the collapsing universe. We have faith that man will not destroy the world while we are in our dewars awaiting rescue. We have faith that men of the future will take the time to unfreeze and restore us. And finally, we have faith that the future is worth striving for, a future of limitless possibilities for those who care.

Why is a Cryonics Religion Worthwhile?

Simply put, some cryonicists want to help other humans live forever. Humans traditionally have looked to religion to facilitate that goal. (And even theists are worth saving!) I have long believed that a frontal attack against an enemy that outnumbers you a million to one is not the best strategy.

In my investigation as to why people are religious I have come in contact with the concept of "Civil Religion." Civil Religion is a prevalent desire of people to be religious in general. They may not be as concerned with exactly what they believe; they just want to be religious. Perhaps instead of attacking the religious community's existing beliefs head-on we can recruit some of their ranks by offering to gratify in another way, rather than trying to destroy, their need for religion.

Speaking for Alcor should be reserved for those few who have the scientific and technical background. But those of us without these skills also need a forum from which to speak. In my zeal to promote cryonics, I find myself talking to various newspapers, radio talk shows, and college classes along with many people on an individual basis. There are times I talk as an Alcor Coordinator, and there are times when I feel more comfortable talking as a Venturist. I am not as qualified to speak on the very technical specifics of biology and chemistry that are involved in cryonics as I should be as a representative of Alcor, and I do not want to make any statements that are in scientific error when speaking as an Alcor member.

When speaking as a Venturist, I make it clear that I am not an expert in science but am very committed to my philosophy nonetheless. The listener seems to be more open-minded when the subject is presented in this light. He expects me to be sincere in my discussion

of the cryonics philosophy but he can be forgiving if I do not know all the technical answers or if I make a mistake in discussing some scientific or medical detail.

There is another disadvantage when speaking as an Alcor Coordinator in that the opposition often brings up the $100,000 payment that Alcor receives in a whole body suspension. Although I can overcome this if given enough time by explaining and proving that cryonics organizations are not in it for the money, on a thirty or sixty minute radio talk show I do not want to waste precious time defending that position, nor do I want to have to be in a defensive posture at all. I want to use the time talking specifically about the possibility of cryonics working and the beauty of life in the future. If I get someone who wants to call me later and discuss at length all the other aspects of cryonics, I can then take the time to explain the justification for the price and explain the other options. By speaking as a Venturist, the opposition can not attack my philosophy on grounds that I am "in it for the money."

Perhaps the title of the article by Max O'Connor that followed Mike's article entitled "Why Are There so Few Of Us" accents my point. I would like to suggest that by allowing a cryonics-concerned religion to exist, for those who want it, cryonics will acquire a much larger following than if it is restricted to only those with an extensive scientific background. I agree the leaders in cryonics should be of the highest scientific and medical caliber, but I feel that the benefits of cryonics should be for anyone who can find a way to accept them. The average person on the street simply does not have the medical knowledge, scientific consciousness, or analytical skills to pass a strict test for entry into the school of immortalism. Do we want to make the entrance requirements so tough that only a few can be admitted?

Also I would like to mention that one of our goals in the future is to establish a care facility for cryonicists. Elderly cryonicists might become the target of attack from non-cryonicist relatives and might need a protected environment to spend their patriarchal years. Elderly, perhaps incapacitated cryonicists could best be protected in the custody of their own religious organization. If a relative tried to attack their cryonic suspension arrangements, Venturism might be better able to defend them from its more financially-uninvolved position than a cryonic suspension organization that stood to receive $100,000 or more. Venturism would receive no financial benefit if a member were cryonically suspended.

In closing I would like to restate that I don't know if a non-theistic belief can become a major religion. I respect those who have sincere concern in accepting the concept of a cryonics religion. I will do all in my power to help the cryonics movement in general and as an Alcor suspension member I will try to do all that I can to help build and advance Alcor independently of my activities in Venturism.

There are numerous other good reasons for having a separate, non-suspension, not-for-profit cryonics organization and Venturism is an attempt to establish such an unrelated organization. Whether this cryonics-concerned religion can exist and be of benefit is in the hands of the people.

In the meantime, I pledge:

If Venturism becomes a detriment to the cryonics movement, I will be the first to move to eradicate it.

* *

Misadventure As A Cause Of Death In An Immortal Population

by Hugh Hixon

A year or two ago, I got hold of a galley proof for an article on *Longevity*, the life extension oriented newsletter put out by *Omni*. The piece was kind of a short overview of the quest for immortality and was apparently intended to appear in *Penthouse*, *Omni's* parent magazine. What caught my eye was the last paragraph:

> *Among the visionaries are those who talk of achieving immortality. But eliminating death doesn't seem very likely. After all, with a five percent probability for accidents, the longest we could hope to live -- even absent disease and decrepitude -- would be 600 years.*

Not true! In fact, on close inspection, about all you can get from this statement is that there is a crisis in science education among journalists.

Among other things, this seems to invoke some Cosmic Accountant who comes along and zeros out everyone celebrating their 600th birthday, an absurd thought. And as to how the calculation was made in the first place, I can't even guess.*

It does raise an interesting question, though. How long *can* we expect to live? As it turns out, this is not a difficult question to answer, in a statistical sense. We can use current mortality tables to supply real-world numbers. Arguably, our life-styles will change in the future, but it seems reasonable that our lives should not be *more* hazardous than they now are.

First, the math. Given that you are part of a fixed group, say, everyone born in 1942, the death rate is normally expressed as deaths per 100,000 population per year. If the death rate does not vary with age (actually, it does, but one of the goals of immortalists is to eliminate aging; and besides, it's not relevant to this example), the death rate from some cause is, say, 500 per 100,000 population per year, and the population size is 100,000, then in the first year of the example, about 500 people will die. The next year, the population is 99,500, and 498 will die, etc. 139 years in the future, half the population will still be alive, and of those, 250 will die in that year. In 276 years, one-fourth the population will still be alive, and in that year, 125 will die. In 459 years, one-tenth will still be alive, and in that year, about 50 will die. Et cetera. It should be obvious from this example that it will be a long time before the last person in the group dies. The probability of it being you is, of course, one in 100,000. The proper mathematical expression is an exponential decay curve, which has the form,

$$(1 - R_d)^t = N$$

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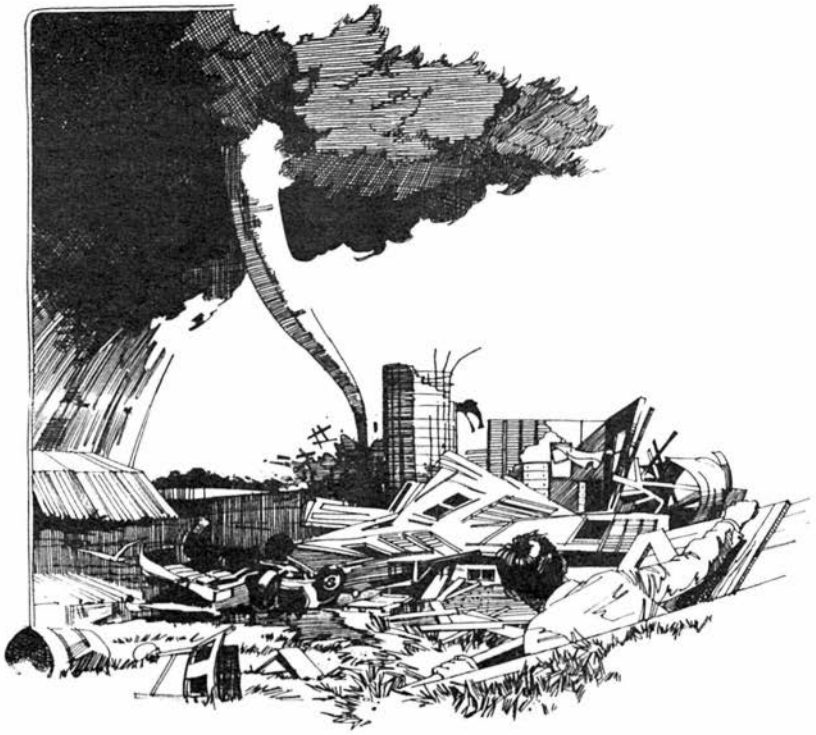
*An estimate of 700 years is made by Dr. Alex Comfort in his *The Process of Aging*, (New American Library, New York, 1964):

> "If we could stay as vigorous as we are at 12, it would take about 700 years for one-half of us to die, and another 700 years for the survivors to be reduced by one-half again."

Dr. Comfort does not show how he arrived at this figure. The death rate (1981, *all* causes) for the 10-14 year age group is 29.6 per 100,000 per year. This rate does not yield Dr. Comfort's result (see below to make calculation). He would have had to use pre-1964 statistical figures that may include much higher childhood disease mortality.



where:

N = the fraction of the original group still alive
t = time in years
R_d = death rate per year, expressed as a fraction

To conform with established convention, I will set N = 0.5, and find the time *t* at which one-half the population is still alive. This is commonly referred to as the *half-life* ($t_{1/2}$) of the population. The concept of a half-life is used very commonly as a simple measure of exponential decrease. Perhaps the measure seen most often is that of radioactive decay, where one refers to the half-life of radioactive isotopes. Please note that the concept of half-life is independent of the number of people, atoms, etc., in the sample. Whether one is working with a group of ten people or a million, all other things being equal, both groups have the same half-life. The only differences are that the random nature of statistics will make the decrease of the smaller group proportionally much more irregular, and that it is much easier to determine accurately the half-life of a large group.*

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* For other fractions of the population, use the following conversion table with the half-life values:

For a remaining population of:	90%	70%	50%	30%	10%	1%
Multiply the half-life time by:	0.1520	0.5416	1.0000	1.737	3.322	6.644

To do the actual arithmetic, even with a scientific calculator it is easier if the expression is changed to the form,

$$t_{1/2} \ln (1 - R_d) = \ln 0.5$$

or,

$$t_{1/2} = (\ln 0.5)/\ln (1 - R_d) = -\ln 2/- R_d$$

since

$$\ln (1 - R_d) = -R_d, \text{ as } R_d \text{ approaches zero}$$

thus,

$$t_{1/2} = 0.693147.../(r_d/100{,}000) = 69315/r_d$$

where r_d is the death rate per 100,000 population per year, which is the normal mode of expression for the mortality tables I will use.

We are now ready to crunch some numbers.

For the year 1981 (Why 1981? -- because I could get tables for it), from *Vital Statistics of the United States**, the tables are listed by cause of mortality, and by age group in five year blocks. I assume that our conquest of disease will be total, leaving only accidents, suicides, and homicides as causes of death. I further assume that suicide is a treatable disease process, and eliminate that as a cause of death.

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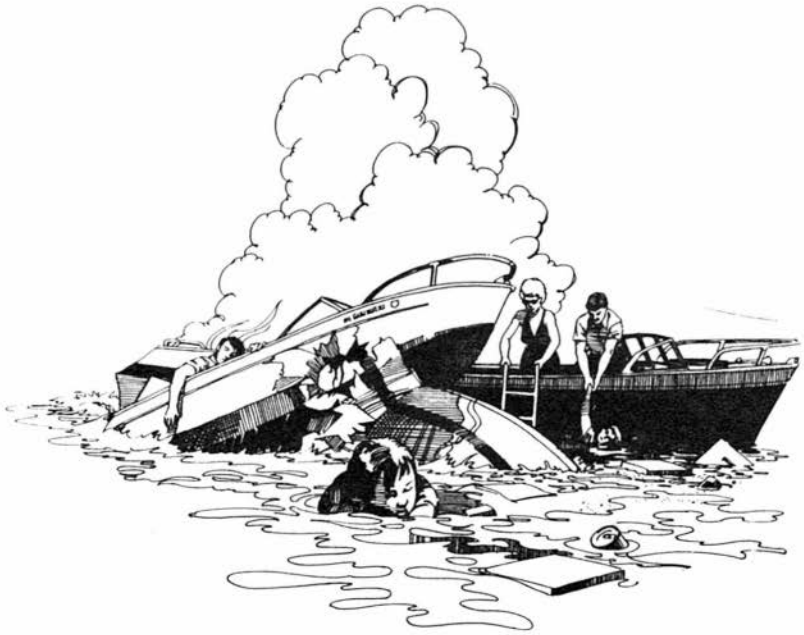
* National Center for Health Statistics: *Vital Statistics of the United States, 1981* Vol. II, Mortality, Part A. U.S. Department of Heath and Human Services (DHHS) Pub. No. (PHS) 86-1101. Public Health Service, Washington. U.S. Government Printing Office, 1986.



Death rate varies with age. The two major factors seem to be experience and infirmity. The older we get, the more experienced we are at avoiding accidents; and the older we get, the slower we get at avoiding accidents. The curve bottoms out at the 40-44 year age group. I will also use that age group for the homicide figures, even though the minimum is in the 70-74 year age group, on the grounds that at that age, who's *doing* anything that would make it worthwhile to kill them. I also ignore the lower death rates for children and teenagers. They're not out in the real world, yet, and besides which, we're only *that* young once. And the number is, . . . 41.9 deaths per 100,000 in the white population (64.9 for males, 19.5 for females. I do not wish to predict the future distribution of women into more hazardous occupations, or the appearance or disappearance of more or less hazardous occupations). Which gives us a *half-life* for our population of 1654 years.

So much for a maximum life span of 600 years!

But this figure is based on *current* mortality. Let's consider the impact of future medical technology (including nanotechnology) and squeeze the figures a bit. A population half-life of 1654 years is for our current resuscitation technology (actually, for 1981), whether the accident occurs in the emergency room of a major metropolitan trauma center, or in the most inaccessible portion of Alaska's Brooks Range. If, as at least one space satellite company proposes, a person can be located anywhere in the world with an accuracy of about 12 feet, with a cigarette-pack sized transmitter, and if everybody is equipped with vital-function monitors, about the only people who will slip through the net are those with truly massive head trauma. This is not a large fraction of accidents. In fact, a short conversation with a friend of mine who works in Emergency Rooms confirms that actual destruction of the structure of the brain is not particularly common. This leaves only serious homicides as a factor to consider.

Estimating the rate on this kind of homicide is very difficult. I do not believe that in any society with competitive forces that homicide will disappear. It certainly will get less common. So I will grab a figure out of the air, more or less, and say that the sum of truly permanent fatal accidents and homicides will be *one* per 100,000 population per year (the aggregate figure (male and female) for white homicides is 8.9 in the 40-44 year age block.). This gives a population half-life of *69,315* years. However, anyone who quotes this figure without including a statement of its very speculative nature is on their own.

So much for the good news. The bad news is that we are still in a time where most people die as a result of disease processes. The calculations I have made here obviously apply to a benign future that (along with cryonics) may never come to pass.

It *is* possible, however, to exert some choice. A close examination of the causes of death in whatever population you may find yourself may allow you to take actions that will isolate you somewhat from the sources of risk (*thus placing you in a subgroup with a longer half-life!*) while still allowing you to enjoy life. You can never get away from statistics, but as a thinking being, you can often choose which set of statistics will apply to you. Thus cryonics.

Finally, it should be pointed out that whatever death rate may apply to you, your chances of dying either last *or first* are equal, and equally unsatisfactory.

Y'all be careful, hear?

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NANOTECHNOLOGY

by Brian Wowk

CONTENTS

* *

"Protein engineering... represents the first major step toward a more general capability for molecular engineering which would allow us to structure matter atom by atom."

--- Kevin Ulmer, Director of Exploratory Research, Genex Corporation

INTRODUCTION

Reversal of cryonic suspension will require a highly sophisticated future technology. Interestingly, though, the technology required will not result from developments specific to cryobiology, or even medicine in general. The required technology is instead related to a far more general trend in technological progress -- a trend relevant not only to reversal of cryoinjury, disease, and aging, but also to the kind of world the 21st century has the potential to bring. The future technology the success of cryonics will depend on is called *nanotechnology*.

Nanotechnology is a term that in recent years has come to be identified with projected means of detailed engineering on the molecular level. Nanotechnology differs from all present technology (which might be called bulk technology) in that it will allow precise control over the molecular structure of manufactured materials. Because of this, nanotechnology is also sometimes called molecular technology or molecular engineering.

The closest approximation to nanotechnology today is synthetic chemistry. Following well-understood principles of chemical bonding, it is possible to design on paper a large range of chemical structures (molecules and aggregates of molecules) which do not exist in nature, but that *can* exist according to the laws of nature. By mixing together various reagents in solution, synthetic chemists are able to physically produce many of these structures.

Synthetic chemists are sharply limited, however, in their present abilities to assemble chemical structures. The range of structures that can be produced by simple random collisions of molecules in solution is a very small subset of those which are physically possible. If it were possible to individually "pick up" atoms and assemble them like building blocks -- with site-specific control of assembly reactions -- a *far* larger range of molecular structures would be physically realizable. *Some of these structures are of tremendous technological significance.*

Nanotechnology is the hypothetical (at present) ability to assemble atoms according to general specifications -- like building blocks. Such a capability would open the possibility of physically assembling virtually any stable arrangement of atoms that could ever be designed, *regardless of scale or complexity.* Nanotechnology, then, is synthetic chemistry carried to the ultimate -- the ability to synthesize *anything.*

It will be argued here that nanotechnological capabilities are essentially inevitable within the next several decades; that they are an implicit consequence of general technological progress. The technological consequences of nanotechnology itself will be briefly explored and will be seen to dwarf in significance the consequences of all technological progress to date. Indeed, developments more profound than the industrial revolution, antibiotics, and nuclear weapons all put together can be shown to result from one basic capability: the ability to structure matter atom by atom.

ROUTES TO NANOTECHNOLOGY:

Nature's Nanotechnology

What evidence is there matter can be assembled according to general and complex atomic specifications? It seems appropriate to start with the recognition that biological systems *already* assemble matter according to extremely complex (though not general) atomic specifications.

Consider a seed that grows into a tree. Using energy from sunlight, a single seed is able to assemble several tons of dirt and air into into a large tree, richly detailed with all its cells and their complex constituents. Yet other than its sheer complexity, there is no special magic to this process. Fundamentally, biological growth is just complex synthetic chemistry. Yet biological systems perform feats of chemical synthesis *far* more complex than any chemist could perform in a laboratory today. What is their secret?

The answer is that biological systems do not rely just on random thermal motion to perform chemical reactions. Cells use *enzymes* and enzyme systems to expedite chemical processes. Enzymes are special large molecules that control the course of chemical reactions without being consumed in reactions themselves.

Enzymes are often described as agents which "speed up" chemical processes. Although technically correct, such a characterization is actually a gross over-simplification of what enzymes really do. Enzymes are best thought of as *molecular machines* -- machines constructed to atom-level specifications -- that are able to *specifically recognize* and *physically manipulate* complex molecular structures. Within the organized environment of living cells, enzymes form part of a sophisticated system that assembles molecules not by accidental collision, but by deliberate physical construction. Indeed, in terms of complexity and mode of operation, single cells are equivalent to entire factories with enzymes as dexterous assembly-line workers.

This, then, is the secret of how cells out-perform synthetic chemists: cells do not simply mix chemicals together, they *guide* chemical synthesis by *controlled* and *programmable* physical manipulation of molecular structures. This is the essence of nanotechnology.

Protein Engineering

Cells can actually be thought of as natural chemical synthesis machines with DNA controlling what chemical structures will be assembled. By manipulating the DNA content of cells, genetic engineers are able to direct cells to produce molecules more complex than can be produced by ordinary synthetic chemistry. This novel approach to chemistry opens up a world of possibilities that are only just beginning to be realized.

Genetic engineers are now, for example, able to direct cells to produce any protein desired. (Although, ironically, synthetic chemists have recently developed a similar capability without relying on cells for help.) This capability has given rise to the field of protein engineering. Protein engineering is the field concerned with the design and assembly of useful protein structures. And protein structures can be *very* useful, for enzymes are composed primarily of protein. Enzymes are the very molecular machines that allow cells to outdo synthetic chemists in the first place, so the ability to design enzymes again opens a whole new field of chemistry. In particular: *Creation of artificial enzymes via protein engineering opens a route to chemical synthesis technologies not seen in nature.*

Truly complex chemical synthesis (the kind exhibited by whole cells) requires that diverse enzymes act as part of a coordinated system within organized environments such as cells. In order, then, for protein engineering to reach its full potential for novel chemical synthesis, protein engineers will have to learn to incorporate their artificial enzymes into cell-like machines. Genetic engineering shows a path to this as well.

By inserting appropriate DNA sequences (manufacturing instructions) into cells, it is possible to generate not only complex molecules, but even *complex aggregates of molecules* that perform useful functions. It is possible, for example, to create complete working viruses by inserting the appropriate DNA sequences into cells -- DNA sequences produced by purely non-biological methods. (Accomplishments such as this render questions of whether humans can "create life" archaic and irrelevant: of course we can.) So not only can cells be directed to produce novel enzymes, but even novel *enzyme systems* of cell-like complexity, with cell-like characteristics such as *self-replication.*

In fact, cells are not even strictly necessary for production of complex molecular machines. As mentioned, synthetic chemists are now able to produce proteins -- hence artificial enzymes -- without using cells. This in itself allows cells to be dispensed with. Why? Because all cells really do is produce individual protein molecules. After cells produce them, protein molecules *self-assemble* into the aggregates that make up more complex molecular machines such as viruses. This self-assembly occurs because of properties intrinsic to protein molecules themselves (notably shape and surface charge distribution) and does not depend on machinery within cells. For example, ribosomes (complex molecular machines which cells use to make protein) themselves self-assemble from more than 50 separate protein molecules. Even working viruses can be similarly assembled from non-living molecular components by simple mixing inside a test tube.

The key is constructing the correct molecular components: once molecules of the correct shape and surface properties are synthesized (even by non-biological methods) chemistry takes over, and self-assembly into complex aggregates becomes possible even by simple mixing in solution. Such aggregates can be as complex as ribosomes, viruses, or even larger molecular machines. In fact, *the level of machine complexity attainable by sequential addition and self-assembly of engineered protein components into solution is in principle unlimited. Protein engineering therefore opens a route to the creation of molecular machines as complex as living organisms, but with human-engineered functions.*

The chief obstacle to such engineering efforts at present is the difficulty of designing protein molecules which possess the desired characteristics. This difficulty is *purely technical* and is rapidly disappearing with advances in computer simulation and protein science. The route to molecular machines of life-like complexity is therefore clear, and *there are tremendous economic incentives to exploit it.* If civilization continues over the next several decades, *it will be exploited.*

Before examining the capabilities which lie at the end of this route, there are other relevant developments to consider as well.

Microtechnology

Genetic engineers, protein engineers, and synthetic chemists are developing molecular machines by working from the molecular level upward. Yet *the same technology appears achievable by working from the macroscopic level downward.*

In 1959, Nobel laureate Richard Feynman outlined a route to molecular machine technology that begins with existing normal-scale machines. He proposed that large

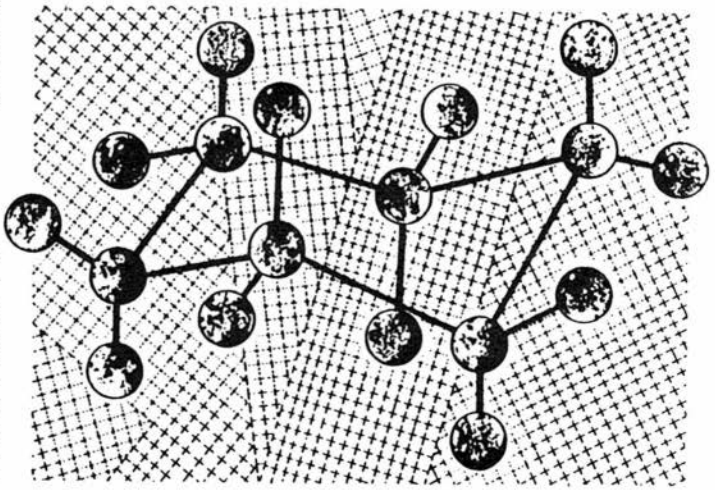
machines could be used to build smaller machines, which in turn could build still smaller machines, etc., all the way down to the molecular level. The end result would be an apparatus whereby human operators could control robotic machines that, like enzymes, operated at the molecular level.

Although rather outlandish at the time, many of Feynman's predictions have since been realized. Using electron beam lithography methods similar to those employed in the manufacture of integrated circuits, engineers are now able to fabricate gears, actuators, and sensors (of many varieties) only a few microns across. *These are machine parts so small that electron microscopy is required to see them clearly.* Devices constructed from such parts will have powerful applications in areas as diverse as medicine, remote monitoring, and manufacturing (including the manufacture of even smaller devices). Like protein engineering, this technology is also driven by the promise of great near-term benefits.

Scanning Tunneling Microscopes

Perhaps the most remarkable tool in the microtechnology arsenal today is the recently-developed scanning tunneling microscope (STM). *STMs accomplish in a single step what Feynman assumed would require a lengthy series of developments.* STMs incorporate an atomically-sharp sensing tip positioned with sub-angstrom precision by piezoelectric crystals (piezoelectric materials change size with the application of voltage to them). When held a few angstroms above a conducting surface, electrons are able to tunnel across the surface-to-tip gap, creating a current that is extremely sensitive to small variations in gap size. By scanning the tip across a surface so as to maintain a constant current, STMs are able to "feel" the shape of materials at an atomic level. With rapid computer-controlled scanning it is even possible to obtain detailed images of atomic structure in *real time.*

Most profoundly, however, not only can STMs "see" individual atoms, *they can also physically manipulate them.* STMs therefore constitute true remote telepresence on the molecular level. They provide a vehicle by which engineers can both perform and monitor construction tasks involving even single atoms. Although the manipulative abilities of STMs are still primitive, the technology is progressing extremely rapidly. Like protein engineering and micromachine technology, STMs represent the beginning of yet another approach to complex engineering on the molecular level.



The Destination

Synthetic chemistry (particularly protein engineering) and microfabrication technology are converging pincer-like on detailed molecular assembly capabilities. Neither technology appears limited by any natural laws from culminating at the construction of

molecular machines of life-level complexity. Such machines would be able to manipulate and assemble molecular structures with the same degree of dexterity and sophistication demonstrated by biological systems today.

What does this mean? Trivially, it means we will soon be able duplicate any of the molecular synthesis feats seen in nature by molecular machines of our own design. More significantly, once we possess molecular assembly tools as sophisticated as those in nature *we will assemble things that don't exist in nature.*

Nature's protein-based machines are designed to build other protein machines. Ours will do more. Natural enzymes demonstrate that protein molecules can chemically bind and direct reactions involving metal ions and other non-protein structures. Appropriately designed protein machines can therefore be used to assemble complex non-protein structures.

For example, protein machines can be used to build molecular machines made of components tougher than protein (so-called second generation nanotechnology). Molecular machines made of protein can only operate within a very narrow range of temperature and moisture conditions. In contrast, molecular machines based on complex covalently-bonded structures will be able to function in extreme temperatures and pressures, and even in powerful acids. Just as we have used the protein machinery of our own bodies to build large machines made of steel, so too will we use microscopic protein machines to build other molecular machines with a wider range of application.

Clearly protein engineering opens a route to complex chemical and materials synthesis technology. How complex? *The synthesis power and versatility of natural enzymes is already so vast that it seems difficult to conceive of any stable molecular structure that could not be assembled by enzyme systems designed to custom specifications.* (The only exceptions would seem to be certain highly contrived structures of no great technological significance.) *Protein engineering, synthetic chemistry, and microfabrication technology therefore all open routes to capabilities for the assembly of matter according to general and complex atomic specifications.*

IMPLICATIONS

Complex man-made molecular machines seem at least several decades away, yet the route to them is clear. If we are to understand anything of future technology, we must first understand the implications of detailed molecular assembly capabilities.

Fortunately this is not particularly difficult. Nanotechnology, for all its sophistication, is based on components we already understand quite well: atoms and molecules. Many of the consequences of nanotechnology can therefore be foreseen on the basis of known physics and chemistry. Although we are still far from the *tools* that will comprise nanotechnology, we already have the ability to *design* (in broad terms) many of the specific materials and devices it will make possible.

Indeed, we are at present much like a child with a set of toy blocks in front of him, but with his hands still tied. While the protein engineers and microtechnologists continue to untie our hands, let's think about what we are going to build. Our survival -- both personally and as a species -- may depend on it.

Materials Technology

Nanotechnology will advance materials technology in two ways. First, it will allow

great improvements in properties which engineers strive to enhance today, such as strength and durability. Second, it will allow the development of materials with properties unlike any *even seen* in technology today.

Consider the problem of strength. When great strength is required for specific applications, molecular machines will allow the assembly of arbitrarily-large networks of covalently bonded carbon atoms. In other words: *diamond*.

Nor is such a capability very far off. Crude diamond synthesis could probably be performed by relatively simple enzyme systems, or perhaps even by a single engineered enzyme. Even the beginnings of such a capability, such as an ability to manufacture fine diamond fibers, would lead to composite materials with *fifty times* the strength-to-weight ratio of aluminum. (Such materials would revolutionize the aerospace industry, among many others.) As the technology becomes more refined, there is no reason why pure diamond structures of *any size* or shape could not be synthesized from raw carbon.

More profoundly, nanotechnology will make possible the manufacture of materials with properties we don't even normally associate with "materials". Some of these are properties usually associated with *living tissue*.

Recall that nanotechnology means abilities to fabricate materials according to *complex atomic specifications*. Unlike the simple static materials used in technology today, materials engineered in full molecular detail could incorporate a myriad of active microscopic components. These components, like cells in living tissue, could confer novel properties to materials, such as *muscle-like movement*, *self-renewal*, and even *abilities to metamorphose*.

Imagine an automobile that could change its shape or color according to an owner's slightest whims. Its body, incorporating an active microstructure, could flex or fold, harden or soften, all subject to sophisticated computer direction. Dents and scrapes would not require a repair shop -- they would *heal themselves*. Yet dents would not be expected to occur often. If diamond microstructures were used to provide strength, the strength could exceed that of today's strongest steel.

These are just a few of the materials possibilities inherent in a technology which operates at the molecular level.

Computer Technology

Since its inception, computing technology has followed a steady trend toward greater degrees of miniaturization and speed. This trend has seen several transitions in hardware design and manufacturing techniques. The vacuum tubes of the first electronic computers gave way to discrete semiconductor components, which in turn gave way to the integrated semiconductor circuits which still dominate today. Further transitions seem likely.

The miniaturization limits of semiconductor-based computing are being approached rapidly. To overcome them, engineers have begun turning to biotechnological methods of constructing circuits based on molecule-scale components. These explorations constitute the field of molecular electronics, or "biochip" technology. Nanotechnology will carry molecular electronics to the ultimate: computers constructed to precise atomic specifications. Because nanotechnology will be required to manufacture them, we might call such computers *nanocomputers*.

What would be the performance level of computers with atomic-scale components?

Estimates are difficult at present because of the complex quantum mechanical behavior of electrons in ultra-small circuits. To simplify the task of estimating the performance of nanocomputers, some theorists have investigated a form of nanocomputing which would seem to constitute a *lower bound* on future computing capabilities.

Rather than *electronic* nanocomputers, it is possible to conceive of computers which rely on the purely *mechanical* interaction of molecular components for information processing. Although mechanical nanocomputers would not be much faster than today's fastest computers (in contrast to electronic nanocomputers, which might be a *million times* faster), they dramatically illustrate the *extreme miniaturization* nanotechnology will make possible.

Using simple physics and chemistry, mechanical nanocomputers have been designed which would store binary bits on a nanometer scale. (A cubic nanometer holds roughly a thousand atoms.) Larger molecular structures (consuming about 5 cubic nanometers) would serve as active logic elements able to store and retrieve individual bits on a nanosecond timescale. Smaller structures, such as single-atom side groups on a flexible polymer, would allow highly-compact "tape" storage with microsecond access time.

How much smaller is this than today's computers? About a *trillion times smaller*, since not only would such components be smaller in linear dimensions than their contemporary counterparts, but they could also be built in three dimensions. Using these components, a computer with 10 megabytes of RAM, 1000 megabytes of storage, and a gigahertz processor could fit inside little more than a cubic micron. *This is a mainframe computer the size of a bacterium!*

What would such computers be used for? Outrageous possibilities such as storing the sum total of human knowledge (even a century from now) inside a wristwatch come to mind. Many other applications, both frivolous and profound, are foreseeable (especially since the cost, as well as size, of computers will likely continue declining in the decades ahead). The most important applications would seem to be in the fields of manufacturing and medicine.

Medicine

An indication of nanotechnology's ultimate impact on medicine can be gleaned from the effect nanotechnology's dual enabling technologies -- biotechnology and microtechnology -- are beginning to have in this field.

Biotechnology is now allowing the synthesis of complex new drugs and bioregulatory molecules which are increasing medicine's control over cells at the molecular level. On another level, microtechnology is allowing the development of microscopic biosensors and other tools for analysis and treatment of tissue in unprecedented detail (even remotely, such as by catheter.)

Looking ahead over the next several decades, it seems clear that biotechnologists will learn to design and assemble increasingly complex molecular aggregates ("molecular machines"), and microtechnologists will develop increasingly smaller and more sophisticated biosensory and microsurgical tools. These two technologies, then, would seem to have a common destination: autonomous microscopic devices capable of detailed *in situ* monitoring and control of cells and tissue (much like the body's own immune cells). The future tools of medicine, then, will be "microbes" designed to custom specifications.

Such medical microbes might be called *cell repair devices*, since one of their most

dramatic functions will be the detailed analysis and repair of individual cells. It may seem inconceivable that something the size of a cell, or smaller, could function with any degree of medical sophistication. Yet future nanocomputers the size of bacteria (one thousandth the volume of a typical cell) could contain the information processing power of today's room-filling computers. Nanocomputer-equipped repair devices, then, could function *extremely* intelligently. Obtaining power from the same nutrient molecules that supply natural cells, cell repair devices could be deployed to examine and repair virtually every molecule of a patient's body, if necessary.

The medical potential of such technology would be almost unlimited. Infectious diseases could be completely eliminated by roving repair devices which recognized and destroyed infectious agents with an effectiveness far surpassing natural immune mechanisms. Severe injuries (even loss of limbs and organs) would be completely reversible by manipulating the appropriate genes in cells at wound sites to induce controlled tissue regeneration. Even the aging process itself could be reversed by a technology capable of analyzing and repairing cells in complete molecular-level detail. And, of course, the potential of general cell repair technology for reversing severe freezing injury even opens a doorway for *today's* patients to reach this medicine.

That nanotechnology will have such staggering medical implications should not be surprising. Since we are all made of molecules, it follows that a technology which operates at the molecular level should have profound medical consequences.

Agriculture

Food production today consists of spreading natural molecular machines (crops) across large areas of land to collect sunlight which is used to energize the synthesis of carbohydrates, proteins, fats, and various trace nutrients. These products are then harvested and consumed directly, or passed on to other molecular machines (livestock) which synthesize a greater variety of food products.

Yet sunlight and soil are not inherently necessary for production of food. These are simply the forms of energy and raw materials nature's food chain has evolved to use for food synthesis (and not very efficiently at that). By allowing the construction of molecular machines to custom specifications, nanotechnology will allow the development of systems capable of food production starting only from the barest essentials of energy and raw materials in any form.

Indeed, from the standpoint of nanotechnology, food production is just a manufacturing process like any other. Starting with raw materials from a garbage dump, and energy from the same electrical power grid that supplies other industries, a nanotechnological food synthesis plant could directly manufacture *in finished form* any of the food products we rely on plants and animals for today. The ultimate agricultural consequence of nanotechnology, then, is that *it will allow us to dispense with crops and livestock completely.*

Why we would want to do such a thing might not be obvious. (Just as the advantages of trading horses for automobiles might not have been obvious at one time.) Yet the advantages of pulling food production out of the biosphere are important and many. Doing so would free up large areas of land for either wilderness or residential use (land area that right now is being used for little more than extremely inefficient solar energy collection). More importantly, nanotechnologically manufactured food would be produced under *completely controlled conditions*: its composition would be known to the last molecule, and it would be completely free of herbicides, pesticides, or any other toxins.

And most important of all, *food production would no longer be vulnerable to insects, drought, soil erosion, or any other unpredictable elements of nature.*

The possibility of releasing food production from constraints such as arable land leads to a natural question: *Just how many people can this planet support, anyway?* From the perspective of nanotechnology, this depends on just two considerations: energy availability and living space. Assuming that a century from now 1% of the Earth's surface area is devoted to solar energy collection (a modest goal in view of the manufacturing potentials discussed below) with only 20% efficiency, the resulting energy would be sufficient to support *100 billion people* in the same style of living enjoyed by U.S. citizens today (with 20% of that energy going into food production, assuming 10% efficient conversion to food energy). Global population densities not exceeding present suburban levels would still leave ample room for wilderness areas in such a scenario.

So with a little ingenuity, the Earth is a far more fertile place than most people imagine.

Manufacturing

The onset of the industrial revolution marked the beginning of an era in which increasingly less human effort has been producing increasingly more material wealth. (In a broader philosophical sense, it might be said that human minds are beginning to control steadily greater amounts of matter and energy in the Universe). This trend shows no signs of abating.

One of the more remarkable facets of technology today is the phenomenon of machines making other machines. Or, more profoundly, the phenomenon of machines making more of themselves (such as assembly line robots which build other assembly line robots). This has prompted some to ask whether a time will come when machines will be able to build copies of themselves without any human assistance. Yet it is often not realized that such machines already exist: molecular machines in the form of living organisms have been building copies of themselves for billions of years.

Machines which operate at the molecular level are particularly well-suited to self-replication. Since everything is made of atoms, a technology which controls individual atoms has at its disposal a complete set of standard components from which essentially anything can be built. In particular, it is clear that any molecular machine capable of assembling atoms according to detailed specifications would as a subset of that ability be able to assemble copies of itself.

What does this mean? *Virtually any of the tools and devices we build with nanotechnology could be self-replicating.* Once a molecular machine (or system of molecular machines) was constructed and programmed for a set of manufacturing tasks, one of its tasks could be to manufacture more of itself. And as natural replicators (such as bacteria or rabbits) demonstrate, self-replicating machines could rapidly make themselves available in great quantity. It therefore follows that anything nanotechnology could manufacture (i.e., anything made of atoms) would similarly be available in near-unlimited quantities once a single self-replicating manufacturing system was assembled.

It seems then that nanotechnology will complete the transition from a labor-oriented economy to a pure information economy. Ultimately a technology level is foreseeable in which the only human effort required to manufacture vast quantities of a product will be the effort required to design a single prototype (and even design will be greatly assisted by artificial intelligence systems). Wealth in a nanotechnological economy will therefore

depend on only three primary values: energy, raw materials, and information (particularly engineering information).

This technology may bring to mind images of the Earth's limited resources being rapidly exhausted by madly replicating machines bent on filling unlimited human wants. Yet it must be realized that nanotechnology will open a vastly larger resource frontier: The material and energy resources of the solar system dwarf those of Earth, and self-replicating factories spread among the asteroids and beyond -- like seeds on the wind -- could reshape the whole of solar space to suit human needs. So the Earth's limited resources do not preclude a future of great abundance indeed.

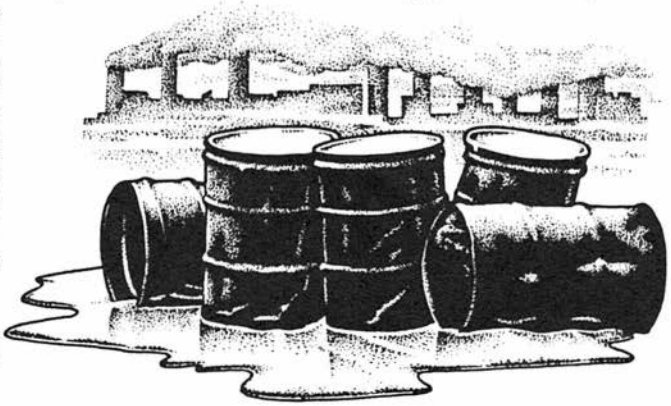
Ecology

Heavy industry today is cumbersome, noisy, and fills the environment with toxic wastes. We tolerate such industries only because, on balance, our quality of life is much higher with them than without them. Yet is pollution truly *essential* to industrial production?

Imagine an industry that produced construction materials for homes and buildings. It would mine raw materials from deep inside the ground and process the materials into finished product inside huge chemical factories. Imagine this industry producing billions of tons of construction materials a year. Surely such an industry would be highly disruptive and polluting. Yet we already have such industries. We call them *forests.*

Today's industries pollute simply because non-molecular technology is not suited to detailed control and design of manufacturing processes. In contrast, nature's nanotechnology already demonstrates that "manufacturing activities" can be carried out on a *massive global scale* without adverse ecological consequences. Just as existing biological systems manage (indeed consume!) each other's wastes, so too could human-designed nanotechnological manufacturing systems. A century from now, entire cities may be manufactured as quietly, cleanly, and *effortlessly* as forests grow today.

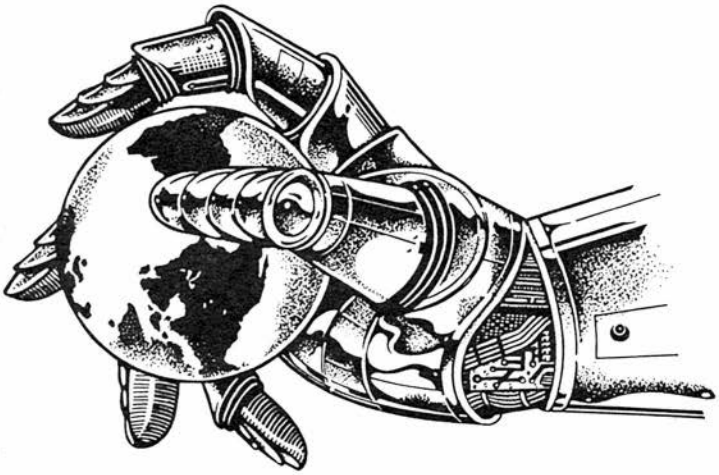
In fact, not only will nanotechnology make possible perfectly clean (or at least self-cleaning) industries, it will also allow us to *clean up* messes made by more primitive technologies. The carbon dioxide produced by burning fossil fuels today, for example, could be dissociated back into carbon and oxygen by widely deployed molecular machines powered by sunlight. Functioning like natural plants, but *much* more efficiently, such devices could within a decade reduce atmospheric CO_2 back to 18th century levels. (Indeed, since carbon is the most important element to nanotechnology, excessive *depletion* of atmospheric CO_2 might even be a problem by the late 21st century!) Other organisms could be designed which would replicate and spread though the biosphere like bacteria. Their mission: seek out and de-toxify (digest) toxic chemical wastes wherever found. Nanotechnology could in principle even regenerate extinct species, as long as intact DNA samples could be found.



While future technologies should never be used as an

excuse for mismanagement of today's, they do underscore the *sheer absurdity* of predicting future ecological problems on the basis of blind extrapolation. Consider the common admonition that rising CO_2 levels will soon cause melting of the polar ice caps and widespread coastal flooding by the mid 21st century (the so-called "greenhouse effect"). By a similar line of reasoning, one might have concluded a century ago that residents of today's large cities would have to contend with unmanageable quantities of horse manure!

Dangers



A recent movie in the *Star Trek* series featured a contrivance called the "Genesis Device". Activated on a lifeless planetary body, the device would in short order transform the surface of the planet into a life-bearing environment as lush as that on Earth. Although fictional, this is *exactly* the kind of power that nanotechnology will place in human hands.

Imagine a molecular device the size of a pollen grain. Constructed to precise atomic specifications, it could incorporate a data bank rivaling the information content of the U.S. Library of Congress and a set of sophisticated tools for assembling atoms according to programmed instructions. Introduced into the atmosphere of a suitable planet, and coming to rest in an appropriate environment, it could via a process of replication and differentiation (like any ordinary seed) reshape the surface of the planet into a complete biosphere just as the fictional Genesis Device did.

Like the Genesis Device, the danger of such technology is obvious. Devices far less sophisticated than the above -- even as simple as voracious, omnivorous bacteria -- could lay waste to the entire surface of the Earth within a matter of weeks if designed to do so. Advanced nanotechnology carries other unprecedented dangers. These include microbes designed for selective genocide, surveillance *par excellence*, mind-control, and many others largely limited only by the imagination. Most of these threats can be understood by considering nanotechnology's most audacious implication: *The ability to create any life form that could in principle exist.*

In the face of such coming developments, the future of humanity may seem grim. How could such technology be controlled? Who could be trusted with it? What about accidents? Although there are no simple answers to these questions, there are hopeful possibilities.

Although the *sudden* emergence of advanced nanotechnology would indeed be difficult to deal with, it is unlikely that creations such as "omnivorous bacteria" will come about overnight. With foresight and implementation of co-evolving technologies, a route to the safe implementation of nanotechnology does seem to exist. This route can be appreciated by noting that *nanotechnology carries awesome potential for defense as well as offense.*

Just as present technology allows the creation of antibiotics and vaccines which augment our body's immune defenses against nature's own "nanomechanical" invaders (viruses and bacteria), advanced nanotechnology will allow further augmentation -- *vast* augmentation -- of natural immune mechanisms. A century from now, our bodies -- and the biosphere as a whole -- may incorporate nanotechnological defense systems far beyond any in nature today.

It is possible, then, to conceive of a world of advanced nanotechnology whose citizenry and natural life forms both would be protected from accidents or malice involving such technology. The true challenge would seem to be navigating the difficult course that would get us to such a world safely.

INEVITABILITY

Nanotechnology is not a single technology. There are no "nanotechnology labs", only genetic engineering labs, protein engineering labs, synthetic chemistry labs, molecular electronics labs, STM labs, and a host of others *all* engaging in work ultimately leading to means for sophisticated molecular manipulation.

Nanotechnology is simply a word coined by theorists who are currently exploring where all these present technologies are leading. It is a word that may or may not still be with us when the destination -- in all its diverse manifestations -- is finally reached. Nanotechnology, then, is not a technology, but rather *an expression of where technology as a whole is heading.*

Research directions leading to nanotechnological capabilities are many and diverse. Also, technologies such as protein engineering and microfabrication technology are driven by tremendous short-term payoffs which exist at short intervals *every step of the way* to full fledged nanotechnology. It would seem, then, that if technological progress continues -- if humanity's efforts to improve its material well-being continue -- nanotechnology is inevitable.

The message should be clear: no one can be "for or against" nanotechnology unless one is similarly "for or against" the continued existence of civilization itself. Technological progress and innovation are natural elements of any civilization (at least any non-totalitarian one), and the endpoint of technological progress appears to be general control on the molecular level. Thus, our task today is not to bicker about the wisdom of developing such technology, but to ensure it will be used wisely once it is developed -- and to ensure that *we personally* will be in a position to benefit from its use.

NOTES AND REFERENCES

"Protein engineering... represents..." is a quote from *Protein Engineering*, by Kevin Ulmer, *Science, 219*, 666-671 (Feb. 11, 1983).

In some circles, particularly in the UK, "nanotechnology" is used to refer to present techniques for manufacturing on the scale of 0.1 to 100 nanometers. This is *not* the meaning intended here. Nanotechnology, as used in this book, refers to future technologies for detailed engineering directly at the molecular level.

ROUTES TO NANOTECHNOLOGY

Molecular Engineering: An Approach to the Development of General Capabilities for Molecular Manipulation, K. Eric Drexler, *Proceedings of the National Academy of Sciences (USA), 78(9)*, 5275-5278 (Sept. 1981). This paper outlines the complete technical case for the development of nanotechnological capabilities via protein engineering.

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There's Plenty of Room at the Bottom, Richard P. Feynman, in *Miniaturization*, H.D. Gilbert, Ed., New York: Reinhold, 1961.

From ICs to Microstructures: Materials and Technologies, Richard S. Muller, in *Proceedings of the IEEE MicroRobots and Teleoperators Workshop*, Hyannis (Cape Cod), November, 1987.

Scanning Tunneling Microscopy, by G. Binnig and H. Rohrer, *Physica 127b*, 37-45 (1985). (A rapidly growing body of STM literature now exists which is too extensive to summarize here.)

IMPLICATIONS

By far the best look at the implications of nanotechnology to date is *Engines of Creation*, K. Eric Drexler, Anchor Press/Doubleday, Garden City, NY, 1986. This book covers in greater detail most of the ideas in this appendix.

A detailed study of a specific mechanical nanocomputer design, addressing issues such as energy dissipation and thermal noise, is *Rod Logic and Thermal Noise in the Mechanical Nanocomputer*, by K. Eric Drexler, in *Proceedings of the Third International Symposium on Molecular Electronic Devices*, Forrest L. Carter, Ed., Elsevier Science Publishers, B.V., North Holland, 1987.

A possible design for computers a million times faster than today's is proposed in *Quantum Mechanical Computers*, by Richard P. Feynman, *Optics News, 11*, 11-20 (Feb. 1985).

As an example of how nanotechnology could manufacture food, one might imagine steaks grown in the form of an isolated column of meat supplied with "blood" manufactured elsewhere in a factory. An electrochemical process could be used to synthesize an ATP-like "energy currency" for molecular machines which would then assemble all the nutrients

required in the blood supply.

Supporting 100 billion people from solar energy falling on 1% of the Earth's surface assumes an insolation (solar radiation flux) of one kilowatt per square meter, and average energy use on the order of 5-10 kilowatts per person. A more practical (and likely) energy source a century from now, though, will probably be nuclear fusion and/or fast-breeder fission (assuming public misinformation concerning the safety of nuclear power is eliminated by then).

INEVITABILITY

It is notable that nearly half of the Nobel prizes awarded for physics and chemistry within the last four years (1984-1987) were for technologies directly related to the development of nanotechnological capabilities. These include:

* The 1984 prize for chemistry to Bruce Merrifield for developing the "Merrifield method" of synthesizing complex polymers vital to biotechnology.

* The 1986 prize for physics to Gerd Binnig and Heinrich Rohrer for developing the scanning tunneling microscope (STM).

* The 1987 prize for chemistry to Charles Pedersen and Donald Cram for developing a class of synthetic molecules with selective binding properties like those of natural enzymes.

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Science Updates

by Thomas Donaldson

HUMAN GENE THERAPY IMMINENT

Most progress must overcome many obstacles. At the time these obstacles may seem insurmountable. Five years later people wonder why it took so long, since the solution was so obvious. Recently R. Hock and A.D. Miller have transferred a gene for drug resistance to *human* bone marrow cells (*Nature*, **320**, 275 (1986)). It seems very likely that their methods will see clinical application in only a few months.

The particular molehill over which scientists have had to struggle with this problem is that of how to use viruses to transfer genes without at the same time leaving these viruses *infectious*. Infectious transfer viruses would create a danger to the patient. Up to now, experiments on gene transfer haven't worried about this problem. The subjects were animals and we merely wanted to prove that transfer occurred, not that it was helpful to the animal.

The basic method for transfer remains the same as that used before. It involves specially engineered viruses. These must be unable to reproduce on their own once inserted into the target cells. At the same time, we must have good means of growing them artificially, since almost all bone marrow target cells must receive a dose of the new gene.

About two years ago we described one method for doing this. Hock and Miller used essentially the same method for their human gene experiments. The transfer virus contains three elements: the gene which it carries to the target cell, gene sequences necessary to insert itself into the target cell and cause replication once inside, and a packaging

sequence which tells another virus to make a "coat" for it. But what it lacks to become infectious in its own right is the genes for the "coat" itself. Without these genes, it cannot create virus particles able to spread on their own to other cells.

The crucial coat genes come from another virus, the *helper* virus. Previous attempts at gene transfer involved helper viruses able to replicate on their own. These helper viruses would then *also* enter the target cells. They would become infectious. Hock and Miller have created a special helper virus which lacks the special packaging sequence. This means that the pair (transfer plus helper) can replicate together, but neither one can replicate alone.

There are further problems before we apply this technology. For clinical use we want to infect the bone marrow stem cells. These cells multiply and differentiate into many blood elements. Hock and Miller have actually infected another type of cell one cell generation descended from the stem cells (they are called CFU-GM cells). Hock and Miller did succeed in transferring drug resistance to the stem cells too. But unfortunately their means turned out to be infectious. Secondly, it could turn out that the stem cells will try to turn off expression of their new genes. This can happen and would mean a new delay while we sought for means to get around it.

Finally there is one major problem we must solve for full control. The virus mechanism now used to insert foreign genes into cells doesn't put those genes in their normal place. It leaves them floating within the cell. Cell *regulation and control* of genes depends on their location in the chromosome. If we could actually cause *replacement* of the existing gene in defective cells then we could cure many conditions such as thalassemia which require not only a new gene, but also correct regulation and control.

Nevertheless, this work is very close to giving us a way to cure or treat a small number of serious genetic defects. The two leading candidates for treatment are ADA deficiency (which causes a severe immune deficiency) and Lesch-Nyhan syndrome, a kind of mental deficiency.

The accompanying commentary in *Nature* about this experiment (by *Nature* editor Miranda Robertson) claims that "No one expects in the foreseeable future to be interfering with human fetuses"). In my own experience, only six years ago no one expected "in the foreseeable future" to be inserting genes into human cells with a view to curing illness. It seems, in fact, that by the time scientists are loudly saying that something is impossible "in the foreseeable future" we may expect its arrival within the hour.

The scientific report, in *Nature*, arrives with another "ethical" report on human gene therapy. This of course is still further evidence that direct intervention in the human genome is very close (if even ethicists have started to worry!). Of course there is another way to think about this problem. Until we could actually modify our own genes, people believed that our genes somehow contained the "essence" of our individuality and humanness. Interfering with these genes therefore constitutes interference with the order of nature. But look! If we can change our genes, they cannot contain our essence after all, can they?

Organic Magnets

Many readers may have already heard of the *organic* chemicals which conduct electricity like a metal. *Polyacetylene* was one of the first such chemicals. Now there are others, and a significant prospect of commercial application. There are also organic

superconductors. All of these substances attain their electrical properties because of their chemical structure. They contain only hydrogen, oxygen, carbon, and nitrogen.

Quite recently a group of chemists in the Soviet Union (Yu. V. Korshak, A.A. Ovchinnikov, *et al*, *Nature*, **326**, 370 (1987)) has synthesized one more organic chemical with properties formerly thought to exist only in metals. They have created a magnetic polymer (of hydrogen, oxygen, carbon, and nitrogen, no less!). Their polymer contains only trace (impurity) amounts of iron. This is definitely not another polywater: their work comes from a long theoretical investigation in Russia and in the West of how to compose an organic chemical so that it would have magnetism. This magnetic chemical makes a black powder. Although it hasn't got any immediate use in itself, it's likely that later magnetic chemicals may have a lot of use. Among other things, they would be far lighter than iron magnets.

Magnetism occurs when the electron spins of the atoms in a substance ar aligned. That alignment is exactly what Korshak, Ovchinnikov, and their coworkers have worked out how to do.

What does this *prove*? Well, it proves nothing. However, some cryonicists feel that out present organic form is somehow deficient (agreed!) and that deficiency derives from the materials of which it is made (not agreed!). If electrically conducting organic chemicals exist, then the fact that we do not use them for our nerve impulses suggests that there is some selective *reason* why they are not used. It's not just a simple inability of the materials. In fact, organic compounds show a vast diversity of properties, among which are the only currently existing true molecular machines.

Our deficiencies most likely have much more to do with past selective pressure and past conditions of life than they have anything at all to do with our materials. Those conditions which produced aging and death as *evolutionary phenomena* would act just as strongly on machines made of glass and metal. A desire for immortality involves a desire to move *out* of conditions where natural selection promotes a longevity of 70 years. Once out of that prison, the exact materials of our bodies and minds become a technical detail. Given the diversity of carbon-hydrogen-oxygen-nitrogen compounds, we may stay in that form indefinitely.

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Meeting Schedules

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

ALCOR

The MAY meeting will be held at the home of:

(SUNDAY, 8 MAY 1988) Bill Seidel and Candy Nash
10627 Youngworth
Culver City, CA

The JUNE meeting will be held at the home of:

(SUNDAY, 12 JUN 1988) Paul Genteman
535 S. Alexandria, #325
Los Angeles, CA

The JULY meeting will be held at the home of:

(SUN, 10 JUL 1988) Brenda Combest
8150 Rhea
Reseda, CA

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The Alcor Cryonics Supper Club is an informal dinner get-together in the Greater Los Angeles area. These meetings are for newcomers and old-timers alike -- just an opportunity to get together and talk over what's happening in cryonics -- and the world!

If you've wanted an opportunity to ask lots of questions about cryonics, or if you just want a chance to spend some time with some interesting and nice people, pick a date and come! All dinners are scheduled for Sundays at 6:00PM.

DUE TO THE LIFE AGAINST DEATH WEEKEND MAY 27-30,
NO SUPPER CLUB MEETING IS SCHEDULED FOR MAY

SUNDAY, 26 JUNE

Los Arcos*
722 N. Pacific Ave.
Glendale
(818) 246-8175

*Take the 134 to Glendale, exit at Pacific Ave., and go north about one block.

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The New York Cryonics Discussion Group of Alcor has recently formed.

The group plans to meet on the the third Saturday of each month at 5:30 PM. A temporary meeting place has been established at the Laissez Faire Book Store in New York City (Bookstore phone #: (212) 925-8992 -- ask for Al Roca). Following the meeting members adjourn to a local restaurant for dinner.

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

Gerard Arthus	(516) 273-3201
Al Roca	(201) 352-5268
Curtis Henderson	(516) 589-4256

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