ALCOR LIFE EXTENSION FOUNDATION

CRYONICS

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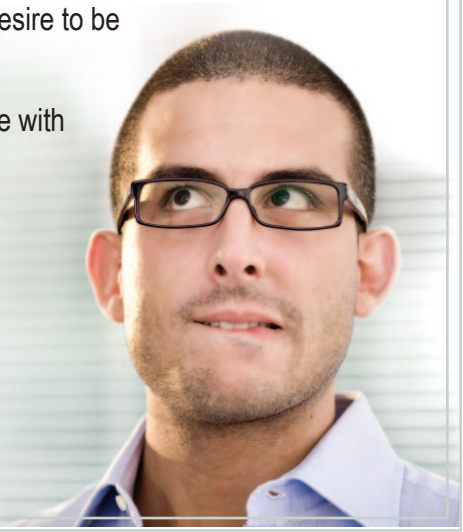

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COVER STORY: PAGE 7

Why does fracturing occur in cryonics patients? Which repair technologies are envisioned? What are the prospects for eliminating fracturing? In this comprehensive review, cryobiologist Brian Wowk reviews the topic and provides an update on Alcor's efforts to develop and validate Intermediate Temperature Storage (ITS).

Cover Photo: *Intermediate Temperature Storage (ITS) Neurodewar for safe storage at temperatures warmer than liquid nitrogen to reduce fracturing.*

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Alcor Life Extension Foundation
CRYONICS

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FROM THE EDITOR

Admittedly, there are times when it is a challenge to gather enough original and exciting materials for the next issue of *Cryonics*. When I considered devoting this issue of the magazine to research and development in cryonics I was not sure whether there was enough going on to fill the pages of the magazine. As it turned out, the materials that I received not only vastly exceeded the usual number of pages allotted to the magazine, but I had to stop soliciting for this issue. It also became clear that if I reported on the neural cryobiology research that Chana de Wolf and I conduct at Advanced Neural Biosciences the situation would become really unmanageable! As a result, this report will be published in another issue of the magazine or as a web exclusive.

Despite limiting the number of articles, we are still forced to publish some other material—research updates—as a web exclusive rather than in the magazine. In 2008, Alcor Staff member Michael Perry received a grant to research low cost alternatives to cryonics, then solicited experiments to develop an algorithm to estimate the degree of ischemic damage in electron micrographs of rodent brain samples. His first official report can be consulted here (www.alcor.org/Library/pdfs/Algorithmic_Estimation_of_Cortical_Autolysis.pdf). Mike also collaborated on a series of experiments to study the effects of chemical fixation on the *ischemic* brain. A report of this work will be published in the future as a broader update about low cost alternatives to cryonics.

I am thrilled that our cover article for this issue is an update on Intermediate Temperature Storage (ITS). Since learning that most patients will experience fracturing during their descent to liquid nitrogen temperature, Alcor has made efforts to document, investigate and resolve this issue to offer improved human cryopreservation technologies. Since Alcor published the last update on ITS there have been some new developments, including the acquisition of our first custom-designed ITS unit for neuro patients. As the article shows, our knowledge about ITS and fracturing events remains incomplete but we hope this article will spark interest to resume R&D in this area and trigger debate as to whether and how ITS should be made available to Alcor members.

Stopping or reversing the aging process will be an intrinsic component of cryonics for most members. This issue of *Cryonics* features an article by bio-gerontologist Michael Rose, Ph.D. in which he presents a novel theory about the aging process and why he believes it can be halted mid-age by adopting a lifestyle comparable to those of our hunter-gathering ancestors, a topic that is explored in more detail in his new co-authored book, *Does Aging Stop?*

Just before the first draft of this issue of the magazine was completed, the "father" of cryonics, Robert Ettinger was cryopreserved at the Cryonics Institute. Look forward to a lot more about Robert Ettinger in the next issue of *Cryonics*.

Aschwin de Wolf

CEO Update

By Max More

Fasten your seatbelt; tighten up your cryonics arrangements

I just survived my second car wreck. Having returned from giving a cryonics talk in Southern California, I was driving home from the Phoenix airport when I got into a situation that caused me to swerve to avoid a collision. At freeway speed, that swerve was hard enough to send my car out of control. It spun around and ran head first into the high concrete divider wall of the 51 freeway. I remember thinking, "This is it."

My car was totaled. To my astonishment, I stepped out of the car and found myself almost completely uninjured.

Praise be to seat belts and airbags. My old car had no side air bag, so it was fortunate that I slammed into the wall head on.

The first time I survived the thorough wrecking of a car was 600 miles south of Tijuana in Baja California during a return trip from observing the total solar eclipse of July 1991. That time, I was asleep in the back of a truck when it rolled over and I was thrown out, somehow landing almost unhurt. (Having survived twice practically unscathed tempts me to believe I'm like Bruce Willis in *Unbreakable*. If only.) Mike Perry, who was in the passenger seat, was not so lucky. Among other damage, he suffered dangerous head injuries. Thanks to an air ambulance and a San Diego hospital, he made a full recovery. (For more details on this incident, see: http://www.depressedmetabolism.com/2008/11/01/interview-with-alcor-readiness-coordinator-regina-pancake/)

No doubt everyone reading this uses a seat belt and drives in a car with at least a front air bag. But what if they aren't enough? Are all your cryonics arrangements fully in place and up to date? Do you wear your emergency neck tag or wristband? I confess that I was not wearing my neck tag. It was in my pocket but I hadn't been wearing it because the nickel in the chain makes my skin break out. The bracelet is too loose and annoying. Some of you probably have the same problem. If so, get in touch with Diane Cremeens. We're ordering new bracelets that use a snug and more stylish black band.

In case you crash and *don't* walk away, also ensure that your paperwork is current. Although Diane has been contacting members with the oldest paperwork, plenty of you still should update your forms, or complete a fresh set.

Are there more Relatives' Affidavits you should get signed? Do you have a medical power of attorney? Is your funding at the current *minimum* levels or, preferably, higher? If you can afford it, have you provided funding for an air ambulance?

Updates: My updates appear in three different forms: monthly in brief reports to the board, monthly in *Alcor News*, and quarterly in *Cryonics* magazine. From now on, *Alcor News* will come out right after a board meeting. My Updates for *Cryonics* will include some information from those monthly updates, but will always include new material.

Declaration of Intent: Do you know someone who seems interested in and favorable to cryonics but who hasn't made any arrangements yet? If it's something you think they want to do, but they aren't willing to put everything in place, you might at least urge them to execute a Declaration of Intent. (This is available on the Alcor website in the "Become a Member" section.) We recently had a frustrating case where an Alcor member offered to pay for a friend's cryopreservation but it never happened because the friend could no longer make decisions and her S.O. and family were not interested. If the person had signed a Declaration of Intent, it might not have been sufficient to enable us to proceed, but it would have made it more likely.

Cryopreservations: In late June, it looked likely that Alcor would have to conduct *three* cryopreservations in one week. I asked resident math genius Mike Perry to calculate the odds of this, given our current membership size. Based on numbers of cases over the past few years, he estimated this should occur once every 27 years per thousand members. (Alcor's current membership stands near a thousand.) Two patients stabilized, at least for a while, so we ended up calling off a standby (supported by Sandra Russell and Joan O'Farrell from Critical Care Research) while conducting just one cryopreservation.

The case that did go ahead in May was Alcor member A-1408 (the patient's wish is for anonymity). This was a classic example of how a patient can have unpredictable ups and downs in condition. A few days earlier, the patient was talking, smiling and shaving. On Tuesday May 24th everyone agreed that the "patient is doing much better." Two days later, clinical death was declared. We are especially grateful that Suspended Animation did the standby, stabilization, and transport on this case. This was especially taxing for the SA team since the standby began the day immediately following their conference in Florida.

One of the other three cases, Arizona member A-2357, held on for a while, but was finally cryopreserved on June 17. The heavy case load in 2010 led to a backlog of case reports. We've accelerated the preparation of these reports, which you can find on the website.

Improvements: We're making im-

provements to the building, security, energy efficiency, and other areas. We're exploring options for further improving patient protection and overall security. In my last update I talked about the problems with perfectionist thinking. It's just not possible to achieve perfect security. Attempts to do so would drain all of Alcor's resources. For obvious reasons, I'm not going to detail existing weaknesses, and will only report on new security measures once they are fully in place.

Improvements will be made to the roof insulation and sun shielding to reduce the air conditioning bill inevitable in Arizona's heat. Other continuing facility improvements include the reception area and to the floors in the OR and other areas. There will be a full report on these upgrades in a month or two, once complete.

Infrastructure improvements include progress with redesigning and cleaning up the hardware and software of the database and server, and fixes to the website making it possible to apply for membership online and to directly print the info pack.

I'm making it a priority to study critical evaluations of Alcor's practices written over the last ten years, with an eye to prioritizing the most high-payoff, practical, and affordable measures. You will find regular updates on improvements at Alcor in my *Cryonics* columns.

Other news: I've been giving talks in diverse venues to raise awareness and understanding of what we do at Alcor and to try to spur membership growth. Alcor was represented at the Humanity+ @ Parsons Conference in New York on the weekend of May 14 and 15. More than one speaker was an Alcor member, as were several attendees. Around 200 people showed up. The conference was co-organized by Alcor member Natasha Vita-More together with Ed Keller of the Parsons School of Design. The idea of cryonics seemed to receive a mostly friendly reception. Whether or not Alcor gets some new members out of the talk, awareness and appreciation of what we do and why we do it was definitely improved.

In Florida the following weekend, Alcor participated in the Suspended Animation conference. This was the first cryonics conference in a few years, so I was glad of the opportunity to report on new developments at Alcor. Other talks by Alcor-related speakers included Brian Wowk on "Reversible Solid State Suspended Animation," Steve Harris on a "New Portable Liquid Ventilation System," and Ralph Merkle on "Developing Technology for the Revival of Cryopreserved Humans," as well as panel contributions by Saul Kent and Michael Korns. Following the conference, Suspended Animation conducted tours of their facility. The event enabled me to get better acquainted with the principals at SA.

I also spoke to a receptive audience at the Atlas Society's Free Minds conference in Anaheim in July. In pursuit of the goal of presenting the idea of cryopreservation to new (carefully selected) audiences, I'll be speaking at least a couple more times this year on cryonics and related ideas. Among these are Aubrey de Grey's SENS conference in Cambridge. We would be delighted to hear from you if you can help Alcor grow by suggesting companies, forums, conferences, and other arenas where I or other Alcor representatives could give a presentation.

Besides talking at conferences, I aim to boost Alcor's relatively slow recent growth rate by other forms of communication. Later this year, I'll make use of Web video by posting short (no more than 5-minute) videos on YouTube and/or Vimeo, answering common questions, refuting common objections, and addressing misconceptions. We will also look into other forms of targeted social media.

I'd like to thank Cryonics Institute President Ben Best for inviting me to attend and participate in CI's annual general meeting in September. Ben and I are on good terms and agree that "co-opetition" rather than competition makes better sense for both our organizations.

Finally, I have begun very early planning of a proposed 2012 Alcor 40th Year Conference, and will be soliciting input over the next few months. ■

Systems for Intermediate Temperature Storage for Fracture Reduction and Avoidance

By Brian Wowk, Ph.D.

Introduction

Cryopreservation by vitrification partially replaces water inside cells and tissue with chemicals called cryoprotectants that prevent ice formation. At high enough concentrations, cryoprotectants can prevent freezing. Instead of freezing, the mixture of water and cryoprotectants becomes more and more viscous like syrup during cooling. At a temperature near 120°C the viscous solution solidifies, an event called the "glass transition." This solidification without freezing is the physical basis of cryopreservation by vitrification.

Liquid nitrogen provides an inexpensive, stable, and highly reliable storage environment for cryopreserved tissue at a temperature of -196°C. Unfortunately the process of cooling to this very cold temperature tends to cause cryopreserved tissues to fracture. Such fractures probably do not compromise the neuroanatomical information preservation goals of cryonics as long as tissue remains cold and solid. However fractures prevent future recovery of cryopreserved tissue by any simple means. They are also alarming by contemporary biomedical standards.

Fracturing can be reduced, and sometimes avoided, by cooling through the glass transition temperature slowly and stopping cooling at temperatures warmer than liquid nitrogen. Much progress has been made within the past decade at developing systems able to safely store tissue at temperatures warmer than liquid nitrogen. Such systems have come to be called "intermediate temperature storage" (ITS) systems because they store at temperatures intermediate between liquid nitrogen and the glass transition temperature. ITS technologies are more complex and expensive than simple immersion in liquid nitrogen. Although ITS technologies for cooling and storing tissue in relative safety at adjustable temperatures now exist, the basic science knowledge of how to control temperature to avoid fracturing in tissues as large as a whole human body still does not exist. Only fracture reduction is presently possible.

Physical Causes of Fracturing

The vibration of molecules gives rise to a characteristic volume, or density, of a liquid or solid material at a given temperature. As temperature decreases, the volume of an object slightly decreases. This is called thermal contraction. Figure 1 shows thermal contraction of a cryoprotectant solution cooled in a test tube. Warmer solution in the center of the test tube continues cooling and contracting after solution near the walls has solidified, creating a dimple.

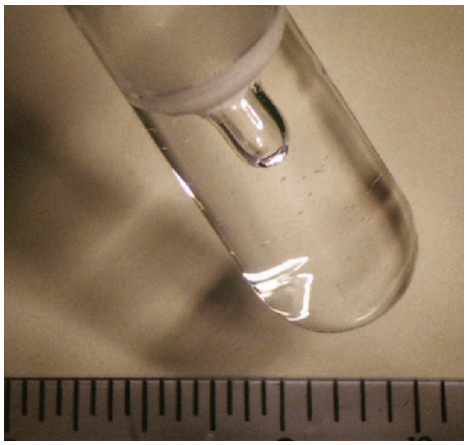

Fig. 1. *Differential thermal contraction of vitrification solution cooled in a test tube causes a dimple to form. The warmer inside of the solution continues contracting after the colder outside has solidified and begun cooling at a slower rate.*

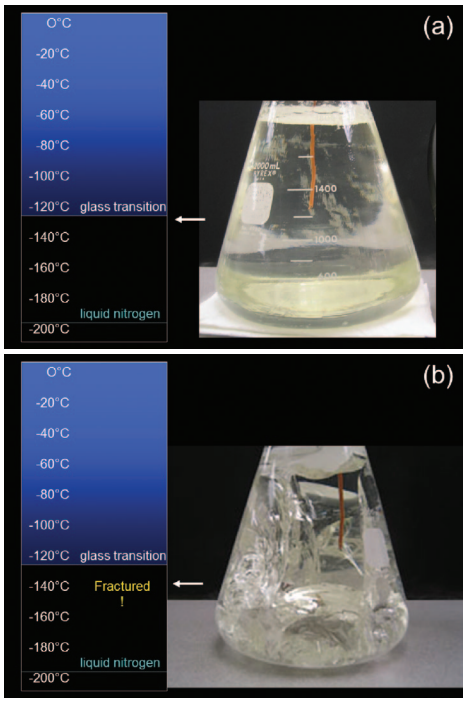

Fig. 2*. A two liter volume of solidified M22 vitrification solution shown (a) just below the glass transition temperature and (b) after further cooling. The solidified solution fractured during further cooling below the glass transition temperature.*

Thermal contraction can cause cryoprotectant glasses (solidified vitrification solution) to fracture by several different mechanisms (1). Figure 2 shows a cryoprotectant solution in a borosilicate glass flask fractur-

ing after vitrification and cooling. This fracturing occurred because the cryoprotectant solution adhered to the glass wall when it solidified. Cryoprotectant glasses have thermal expansion coefficients ten times greater than the flask container walls. Therefore cryoprotectant glasses will shrink ten times as much during cooling as glass containers that hold them. The cryoprotectant glass in Fig. 2 broke due to accumulated stress as it tried to retract away from the flask wall during cooling. Vitrified cryoprotectant solutions or tissues are less likely to fracture if held in containers made of hydrophobic materials that solutions don't adhere to, such as polyethylene plastic.

Cryoprotectant glasses or vitrified tissue can also fracture due to internal stress during temperature change regardless of container material. If different parts of tissue have different thermal expansion properties, the different parts will seek to contract by different amounts during cooling, causing stress that can result in fractures.

Even completely homogeneous tissue or pure cryoprotectant solutions can fracture during cooling. If different parts of a material cool at different rates, the rates of thermal volume contraction will be different. For example, near the end of cooling, the outside of an object may only contract at 0.1% per minute as its temperature nears that of the surroundings. However the inside of the object may be trying to contract at 0.2% per minute because it is warmer and still cooling faster. The core of the object therefore tends to pull away from the periphery, causing mechanical stress, which causes fracturing if the mechanical strength of the solid is exceeded. This phenomenon is illustrated schematically in Fig. 3.

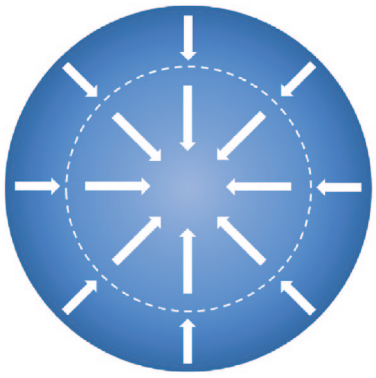

Fig. 3. *As cooling slows at the cold exterior of a vitrified object, the warmer interior will cool faster until a uniform temperature is reached throughout the object. Faster interior cooling causes faster thermal contraction of the interior, causing the interior to pull away from the exterior along the dotted line. These forces can cause the vitrified object to fracture.*

In practice, it's difficult to cool volumes of more than a few milliliters of vitrification solution to the temperature of liquid nitrogen without fracturing. This is because the thermomechanical properties of cryoprotectant glasses (thermal expansion coefficient 40 x 10^{-6} per °C, fracture strain 0.3%, fracture stress 3 MPa (5, 6)) make them much weaker than other glasses we are accustomed to. For example, window glass has a fracture stress of approximately 100 MPa due to its strong covalent chemical bonds.

Fibrous material present in a vitrification solution will increase the vitrified solution's fracture strength, and reduce the likelihood and extent of fracturing. Tissue itself is fibrous, so tissues and organs generally do not fracture as easily or extensively as bare cryoprotectant solutions like the solution in Fig. 2(b). However organs are still capable of fracturing during cooling.

Prevelance of Fracturing in Cryonics

In late 1983 Alcor performed postmortem examinations of three whole body cryonics patients who had been transferred from another cryonics facility for conversion to neuropreservation and continued storage at Alcor. In every patient, several full thickness fractures of the skin were observed as well as multiple fractures of most internal organs. The spinal cord of one patient was cleanly fractured every 6 cm over a 20 cm length examined. These patients were frozen with low concentrations of cryoprotectant rather than vitrified, so fracturing is a phenomenon that can occur in either frozen or vitrified tissue during cooling to liquid nitrogen temperature. It is not unique to vitrification. These findings were documented in a report in the September 1984 issue of *Cryonics* magazine (7). There was further discussion of these findings on page 28 of the 1st Quarter 1995 issue of Cryonics (8).

In 1994 Alcor performed a postmortem examination of the brain of Alcor patient A-1242 who had been ordered removed from cryopreservation after a court overturned the 1990 cryopreservation arrangements made by her husband. It was discovered that the brain had fractured into five major pieces. Details were reported on page 29 of the 1st Quarter 1995 issue of Cryonics (8).

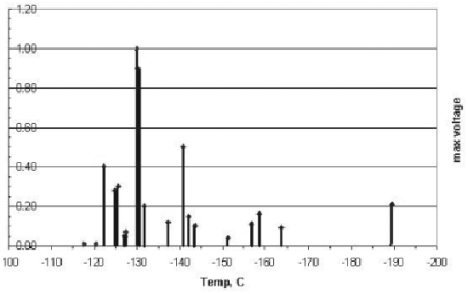

Fig. 4. *Acoustic events believed to be fractures detected in the brain of Alcor patient A-2063 during cooling after perfusion with B2C vitrification solution. Such events are detected in all patients during cooling between the glass transition temperature (-123°C) and liquid nitrogen (-196°C).*

In 1997 Alcor brought into regular use an acoustic fracture detection system called the "crackphone." The crackphone is a custom designed system that performs digital data processing of sound signals recorded by microphones placed in contact with the brain during deep cooling of cryonics patients. It detects and records acoustic events believed to correlate with fracturing.

Acoustic events consistent with fracturing were found to be universal during cooling through the cryogenic temperature range. They occurred whether patients were frozen or vitrified. If cryoprotection is good, they typically begin below the glass transition temperature (–123°C for M22 vitrification solution). If cryoprotective perfusion does not go well, then fracturing events begin at temperatures as warm as -90°C. Higher fracturing temperatures are believed to occur when tissue freezes instead of vitrifies because freezing increases the glass transition temperature of solution between ice crystals. The temperature at which fractures begin is therefore believed to be a surrogate measure of goodness of cryoprotection, with lower temperatures being better.

The crackphone is believed to be highly sensitive to fractures, but its specificity is not clear. Cracking sounds can often be heard during cooling of vitification solutions or vitrified tissue with no fractures later being found (unpublished observations of the author). So it is not clear whether every acoustic event detected during cooling is necessarily a fracture. Studies correlating acoustic events with physical fracturing have not been done. Still, it is believed that the brain and other major organs of every cryonics patient cooled to the temperature of liquid nitrogen

to date have some fractures.

Significance of Fracturing

Fracturing does not cause tissue to break into widely separated pieces at the time of fracture. As shown in Fig. 5, fractures are not macroscopically obvious at cryogenic temperature. The actual physical displacements associated with fracturing are small, and are believed to remain small as long as tissue remains solid. Future repair strategies for fracturing are therefore anticipated to begin at low temperature with the tissue still in the solid state (2, 3).

Factures in bare cryoprotectant solutions such as those in Fig. 2 are observed to be optically smooth. In other words, the fracture surfaces are smooth on a scale smaller than a wavelength of light, which is less than one millionth of a meter. Although the fracture faces of vitrified tissue have not been specifically studied, it is assumed that they are also relatively smooth. When frozen tissue is fractured for microscopy in a procedure called "freeze fracture," the resulting faces are smooth enough for electron micrographic study of cell membranes. From an information theoretic standpoint, it seems likely that fracturing does not cause loss of neural connectivity information provided that tissue remains vitrified, and provided that some future means exists to match and restore structure across fracture faces. However further study is needed.

Unfortunately fracturing excludes any future repair strategy that might begin by simple warming and reperfusion. It's therefore a barrier to the development of reversible suspended animation of large organs or humans no matter how good cryoprotectant technology becomes. Fracturing underscores that cryonics as currently practiced is an information archiving technology that will require very arcane technology to reverse. It is not anything close to suspended animation.

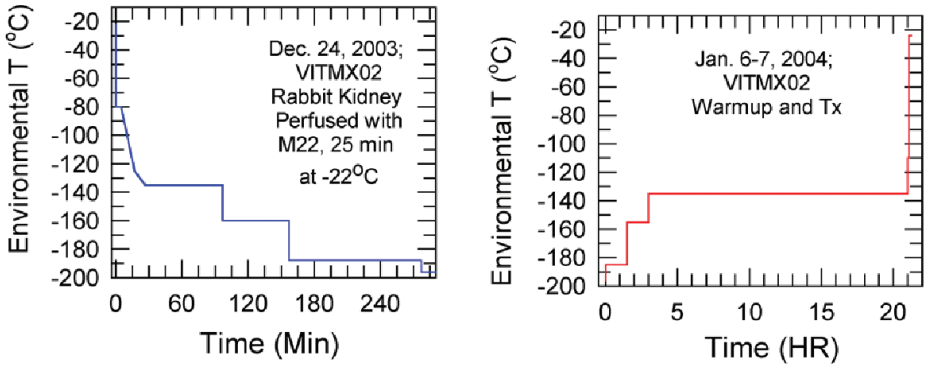

Fig. 6. *Slow cooling and warming protocol followed for a vitrified rabbit kidney that was successfully stored under liquid nitrogen for two weeks prior to transplantation without fractures. (Data courtesy 21st Century Medicine, Inc.)*

Reduction and Elimination of Fracturing

To prevent fracturing, stresses such as those shown in Fig. 3 need to be minimized. This can be achieved by slowing cooling as the glass transition is approached so that the temperature is as uniform as possible within tissue during descent through the glass transition. Holding for a period of time near or just below the glass transition to allow stress relaxation before further cooling is especially helpful. Figure 6 shows a cooling protocol that permitted storage of a rabbit kidney under liquid nitrogen with no evidence of fracturing during later transplantation (4). Faster cooling has been observed to result in fracturing.

Another strategy has allowed even bare vitrification solutions, which are highly susceptible to fracturing, to reach liquid nitrogen temperature without fracturing. That strategy is to cool slightly below the glass transition temperature, then rewarm above it, and then finally resume cooling

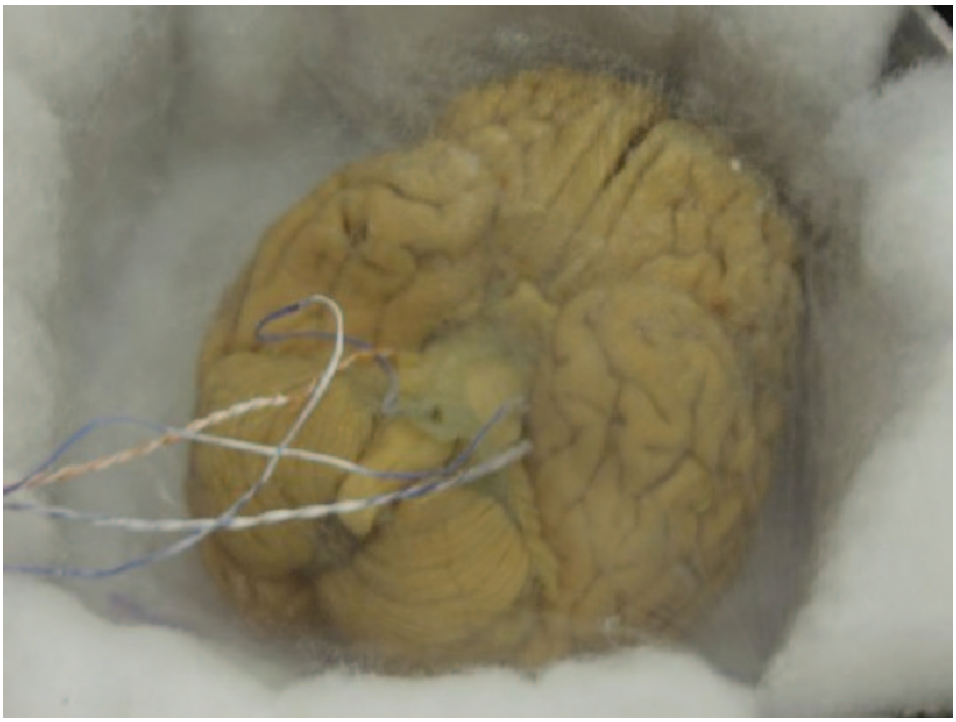

Fig. 5. *Vitrified brain of Alcor patient A-2077 under liquid nitrogen. This brain is almost certainly fractured, yet it remains an integrated whole. Movements between fracture planes appear to remain microscopic provided that tissue stays cold and solid.*

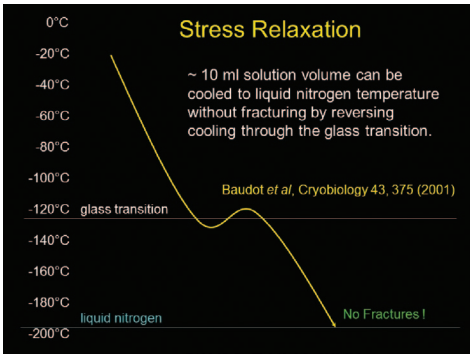

Fig. 7. *Warming above the glass transition temperature after descending slightly below it can reduce temperature gradients and associated stress, allowing 10 mL solution volumes to reach liquid nitrogen temperature without fracturing.*

as shown schematically in Fig. 7. This allows interior temperatures to catch up to the cooler exterior temperature so that the whole object passes through the glass transition at a more uniform temperature and cooling rate. This avoids "locking in" stresses that would otherwise result from non-uniform passage through the glass transition.

Molten silicate glass (window glass) that is cooled too quickly will also fracture for the same reasons that cryoprotectant glasses do. To prevent this, silicate glasses are held during manufacturing for a period of time near their glass transition temperature to reduce stress. This process is called annealing. After annealing and slow cooling to a lower temperature, called the strain temperature, silicate glass can be quickly cooled to room temperature without fracturing. A similar annealing process allowing cooling of large volumes of cryoprotectant glasses to liquid nitrogen temperature without fracturing is theoretically possible. Unfortunately, due to the physical weakness of cryoprotectant glasses compared to silicate glass, very long annealing times may be necessary.

Whether for long periods of annealing or permanent storage, systems for storing cryopreserved tissue at temperatures between the glass transition temperature and liquid nitrogen temperature are necessary if fracturing is to be avoided. In cryonics, such systems have come to be called Intermediate Temperature Storage (ITS) systems.

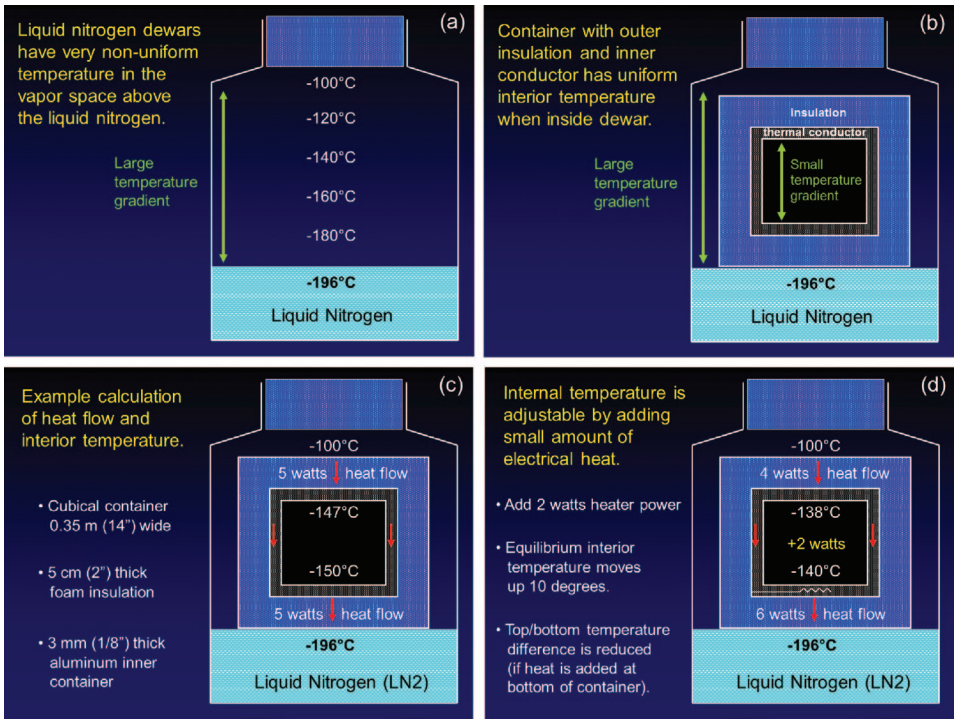

Fig. 8. *(a) The temperature in the vapor space above liquid nitrogen. (b) More uniform temperature inside an insulated storage container with a thermally-conductive inner liner. (c) Calculated heat flows inside container. (d) Adjustment of container temperature with electrical heat.*

Progress in Development of Intermediate Temperature Storage (ITS) Systems

For decades mechanical laboratory freezers have been available that are capable of maintaining temperatures as low as -140ºC. They've been sold under names such as Queue and CryoStar. In the year 2000 a 10 cubic foot CryoStar freezer was acquired for testing by Alcor for possible use storing neuropatients. It included a liquid nitrogen backup system able to maintain temperature in the event of a power failure, and was also filled with dry ice as thermal ballast. Alcor used it for two patients between 2002 and 2006 before advancing to newer liquid nitrogen ITS systems. The newer systems had much lower power consumption, no temperature cycling, and other advantages described below.

"Vapor phase" storage systems that store at temperatures warmer than liquid nitrogen in the vapor space above liquid nitrogen have long been available. However as shown in Fig. 8(a), they suffer from large uncontrolled temperature differences in the vapor space. They are used in cryobiology not because of their warmer temperature, but because they prevent transfer of pathogens between samples stored under a common pool of liquid nitrogen.

Figures 8(b) and 8(c) show that if an insulated container with a conductive inner liner is placed above liquid nitrogen, the non-uniform temperature outside the container becomes converted into a more uniform temperature inside the container. The addition of a small thermostat-controlled electric heater inside the container as shown in Fig. 8(d) allows the uniform interior temperature to be adjustable. 21st Century Medicine, Inc., obtained US Patent 7,278,278 for this and related types of intermediate temperature storage systems in 2007.

In 2003, Alcor acquired the prototype "neuropod" storage device shown in Fig. 9 for testing. Using the principles explained in Fig. 8, the neuropod was designed to hold a single neuropatient at an adjustable, uniform, and stable intermediate temperature. The neuropod itself could be placed

Fig. 9. *Prototype neuropod suitable for maintaining single neuropatients at a stable and adjustable intermediate storage temperature, (a) showing neurocan inside, (b) with top insulation in place, (c) and (d) inside a small dewar with 8 liters of liquid nitrogen at the bottom able to maintain -140°C inside the neuropod for 90 hours between refills. Longer times between refills are possible with larger dewars. The blue cable connects to a small temperature controller that supplies electrical heat to the inside of the neuropod to maintain the desired interior temperature. The neuropod requires 0.15 watts heating for each °C temperature difference between the interior and mean exterior temperature.*

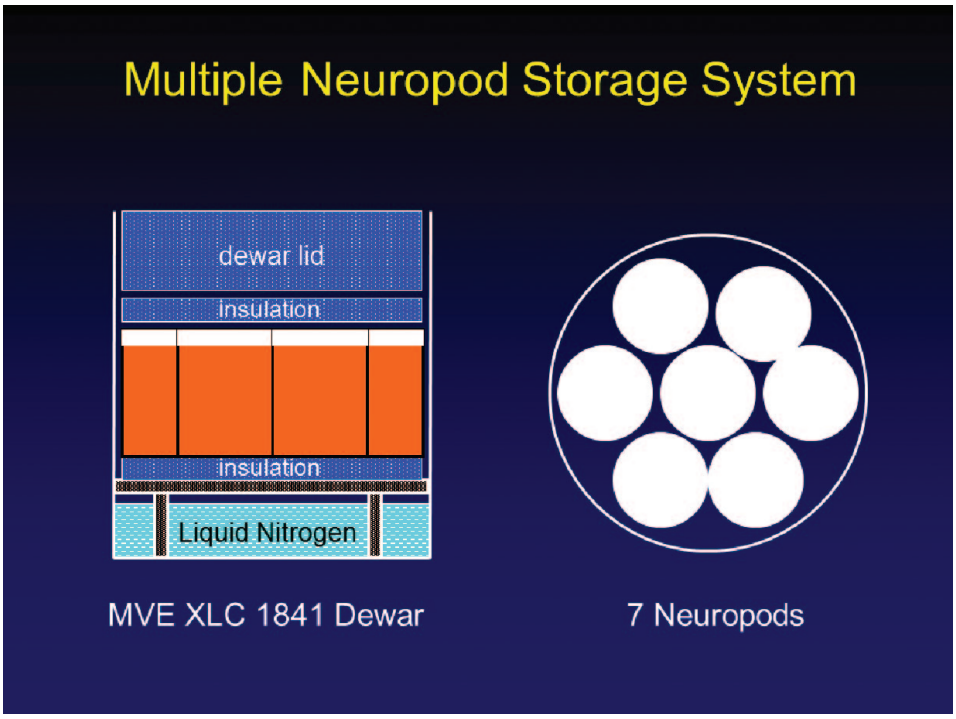

Fig. 10. *Collections of neuropods could be stored in the vapor space of conventional liquid nitrogen dewars. The temperature inside each one could be individually controlled to manage complex cooling plans for annealing protocols lasting years if necessary.*

into any uncontrolled cryogenic environment, such as the vapor space above liquid nitrogen in a conventional storage dewar. An electric heater supplied by a temperature controller added small amounts of heat as necessary to maintain the desired temperature inside the neuropod. The heat automatically adjusts to maintain a stable internal temperature even when the outside temperature fluctuates, such as during dewar refilling (temperature drop) or transfer through ambient air between dewars (temperature rise). The power requirements of the controller are so low (<10 watts) that they can easily be met by small battery backup systems.

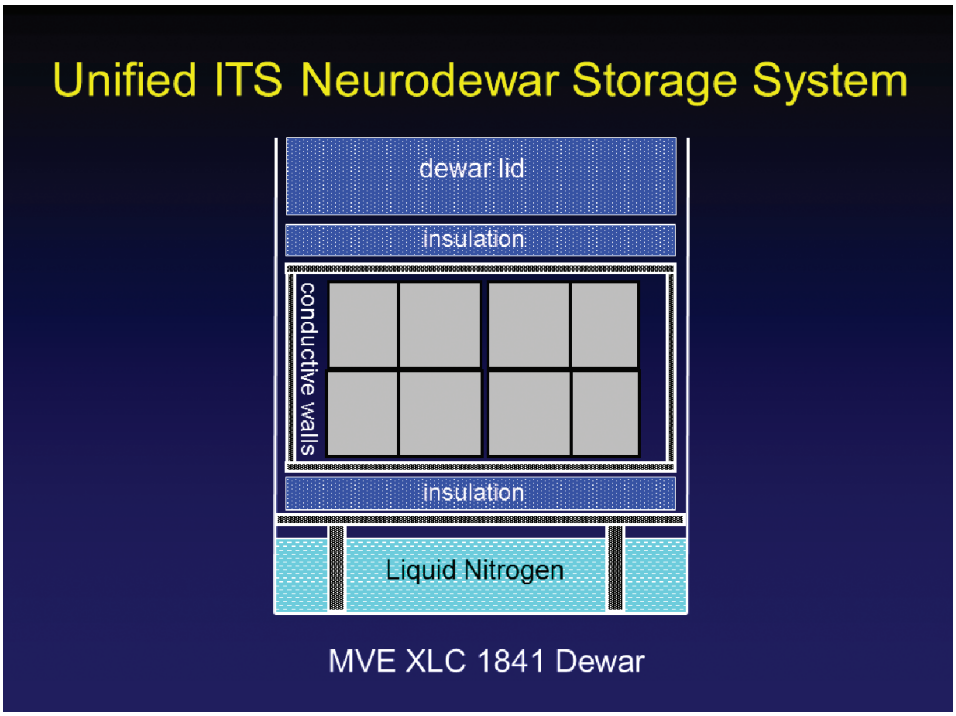

Fig. 11. *Instead of containers with individual environment control, the ITS Neurodewar system stores 14 smaller uninsulated neurocontainers in a common temperature environment inside a liquid nitrogen dewar. One large storage chamber with thermally-conductive walls ensures a uniform shared storage temperature. Like the neuropod system, small amounts of electrical heat under active control maintain the desired storage temperature in the shared environment.*

The advantages of this type of ITS system are numerous.

- No moving parts
- Low power requirements
- Individual temperature control
- Power failure results in cooling rather than warming
- Temperature stability in presence of external instability or non-uniformity
- Storage flexibility (containers will function in any cryogenic environment that is on average colder than the target interior temperature)

In 2004 Alcor acquired and began testing another neuropod that was designed to be "patient rated." It incorporated dual redundant temperature controllers and heaters, and other safety features.

The advantage of individual storage pod temperature control is a disadvantage in terms of complexity and cost. An alternative approach is to construct an intermediate temperature storage system that maintains a large common volume at the same temperature. In 2003 21st Century Medicine, Inc., developed and constructed an ITS storage dewar for cryobiology applications capable of maintaining adjustable and uniform storage temperatures in the -120°C to -150°C range using liquid nitrogen. Since then, such dewars have been used at 21st Century Medicine instead of laboratory freezers. Unlike mechanical freezers, ITS dewars have very low power consumption, no heat output, no moving parts, no noise, and limited temperature excursion if they fail.

In 2005 Alcor placed an order with 21st Century Medicine for an ITS dewar large enough to hold 14 neuropatients. After tedious development efforts, the ITS Neurodewar shown schematically in Fig. 11 and photographically in Figs. 12 and 13 was delivered to Alcor in 2008. The unit has been

in uneventful operation and evaluation at Alcor since then. The specifications are:

Storage Volume:	15.5 cubic feet
Temperature Uniformity (top-to-bottom):	3°C
Temperature Stability (empty chamber):	2°C during 2″ liquid nitrogen fill
Operating Temperature Limits:	-159°C to -124°C
Lower Failsafe Temperature:	-159°C (0 watts heater power)
Upper Failsafe Temperature:	-124°C (48 watts heater power)
Maximum Liquid Nitrogen Capacity:	6.0″ or 118 liters
Liquid Nitrogen Consumption at -159°C:	0.6″ or 12 liters per day
Liquid Nitrogen Consumption at -145°C:	1.0″ or 20 liters per day
Liquid Nitrogen Consumption at -140°C:	1.2″ or 24 liters per day
Rate of Warming Following LN_2 Depletion:	1°C per hour

Comparision of ITS vs. Liquid Nitrogen Immersion Storage

The storage method traditionally used in cryonics is immersion in liquid nitrogen at a temperature of -196°C. Storage vessels that hold liquid nitrogen are kept almost full to the top. ITS systems use dewars that are only partially filled with liquid nitrogen. For example, the ITS dewar of Fig. 13 contains only about 120 liters of liquid nitrogen in a pool at the bottom. This is sufficient to last only 5 days when operating at a temperature of -140°C. In contrast, the tall "Bigfoot" dewars used by Alcor for liquid nitrogen immersion storage contain more than 1000 liters of liquid nitrogen that can last weeks between refills without catastrophic warming. As shown in Fig. 13, ITS dewars can automatically refill themselves from external liquid nitrogen tanks (or be manually refilled if electric power is unavailable), but this is intrinsically less reliable than having the liquid nitrogen already in the dewar.

Fig. 12. *(Left) ITS Neurodewar under construction, showing storage chamber with seven storage compartments. (Right) Neurodewar in operation with main lid open, showing closed storage compartment lids.*

Fig. 13. *(Left) ITS Neurodewar with dual redundant temperature controllers and displays on the right side of the unit. (Right) Neurodewar in operation at Alcor, maintaining an internal temperature of -140°C. The unit automatically refills itself from the connected liquid nitrogen tank.*

The ITS Neurodewar of Fig. 13 costs as much as a Bigfoot dewar, but has only one third the neuropatient holding capacity. When operated at -140°C it consumes liquid nitrogen at twice the rate of a Bigfoot dewar. (Liquid nitrogen consumption can be reduced in future units if the operating temperature range is made smaller.) Transfer losses are also expected to be larger due to more frequent filling. Therefore the cost of ITS storage is at least three times that of conventional liquid nitrogen immersion storage.

Whole Body ITS Systems

The same concepts of individual temperature-controlled storage pods, and common temperature storage dewars, can be applied to the design of whole body ITS storage systems. Cryogenic engineer Michael Iarocci and architect Stephen Valentine of the Timeship Project have designed several different whole body ITS systems. Some systems even consume less liquid nitrogen per patient than Bigfoot dewars, but at greater capital cost.

Unresolved Issues

The most important unresolved issue of intermediate temperature storage is how to use it to avoid fracturing. Despite some attempts to avoid fracturing over the last decade, some including months of annealing, acoustic data indicated that fracturing was still occurring during descent to target intermediate storage temperatures. Therefore ITS is presently a means to reduce fracturing, not avoid fracturing. Perhaps ITS is best characterized as a necessary tool to develop future protocols to avoid fracturing.

However presently it is not even possible to say whether pod-type storage systems permitting individual temperature control are cost-justified over common temperature environments because it is not known how to use either system to avoid fracturing. There is only a general presumption that a future fracturing avoidance protocol may require lengthy individual temperature conditioning.

A related question is what storage temperature is appropriate for ITS. The lower the temperature the more stable the storage, but the more difficult it is to avoid fracturing. Viscosity at and below the glass transition is so high that chemical reactions can probably be neglected over less than geologic timescales. However a phenomenon called ice nucleation happens at high a rate near the glass transition temperature, and in some studies doesn't become undetectable until 20 degrees below it. Ice nucleation-- the local reorientation of water molecules into nanoscale ice crystals --doesn't cause immediate structural damage. However it can make avoiding ice growth and associated structural damage during future rewarming more difficult. The extent and significance of ice nucleation in highly concentrated cryoprotectant solutions is still poorly understood (1).

More research is required on fracturing avoidance for large cryopreserved organs and tissues. Valuable research may continue to come from mainstream cryobiology, but some research will need to be specific to cryonics. In the meantime, cryonics organizations face difficult decisions in whether to make an expensive and complex technology that is still unsuccessful in its final objective clinically available. ITS is not unlike cryonics itself. ■

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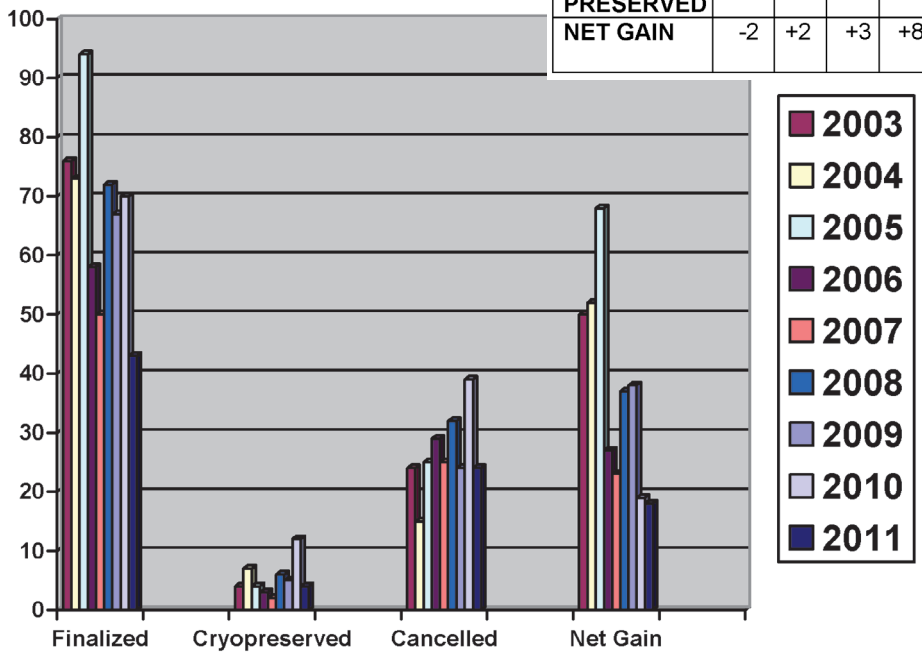
Membership Statistics

2011	01	02	03	04	05	06	07	08	09	10	11	12	
TOTAL	930	932	935	943	945	948							948
FINALIZED	3	7	8	10	4	6							38
REINSTATED	1	2	0	0	2	0							5
CANCELLED	6	7*	4	2	3	2							24
CRYO-PRESERVED	0	0	2	0	1	1							4
NET GAIN	-2	+2	+3	+8	+2	+3							+18



On June 30, 2011, Alcor had 948 members on its Emergency Responsibility List. Thirty-eight (38) memberships were approved during the first six months of 2011, five (5) memberships were reinstated, twenty-four (24) memberships were cancelled and four (4) members were cryopreserved. Overall, there was a net gain of eighteen (18) members this year to date.

Chronology of Developments Related to Fracturing and Intermediate Temperature Storage

1966: Kroener and Luyet observed fracturing in vitrified glycerol solutions. (C. Kroener, B. Luyet, "Formation of cracks during the vitrification of glycerol solutions and disappearance of the cracks during rewarming," Biodynamica 10, (1966) 47-52.

1984: Alcor noted fractures in human cryopreservation patients. (Federowicz, M., Hixon, H., and Leaf, J. Postmortem Examination of Three Cryonic Suspension Patients. Cryonics, September, 16-28 (1984)

1990: Fahy published a detailed study of fracturing in large volumes of vitrification solution. (Fahy, G., Saur, J., and Williams, R. Physical Problems with the Vitrification of Large Biological Systems. Cryobiology 27, 492-510 (1990)

1993 March: A detailed discussion and design exercise for a -130ºC "Cold Room" of 100-person capacity took place on the CryoNet email list.

1994: Alcor noted fractures in the brain of a patient following removal from cryopreservation. Various other aspects of the fracturing problem were discussed in the same article, including possible intermediate temperature storage systems, and the development of a new acoustic fracturing monitoring device, the "crackphone." (Hixon, H. Exploring Cracking Phenomena, Cryonics 1st Qtr. 1995 pags 27-32)

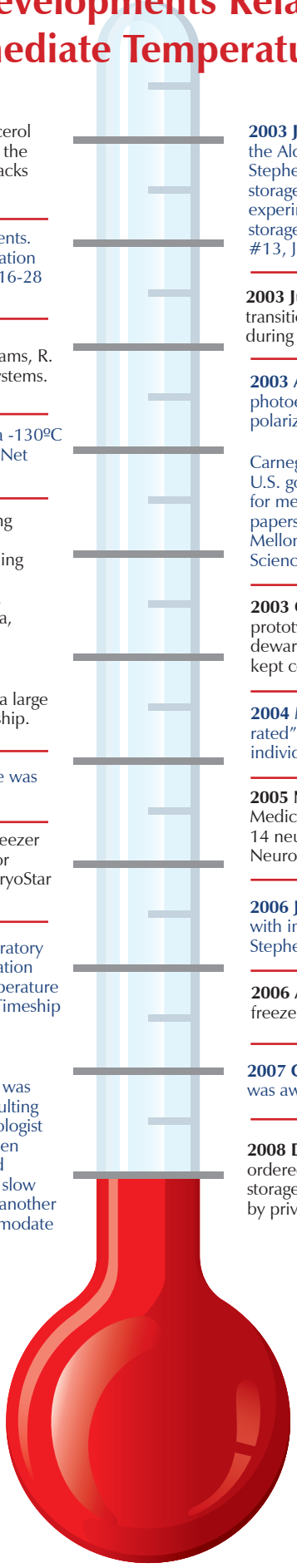
Architect Stephen Valentine began studying Cold Room intermediate temperature storage design concepts as part of a large cryonics facility design that would eventually be called Timeship.

1997: The crackphone acoustic fracturing monitoring device was brought into clinical use by Alcor.

2000: Alcor acquired a -130ºC Harris CryoStar laboratory freezer from GS Laboratory Equipment and began testing its utility for possible storage of neuropatients. (BioTransport Purchases CryoStar Freezer, Cryonics 3rd Qtr. 2000, page 11)

2002: Physicist Brian Wowk and Brookhaven National Laboratory cryogenic engineer Mike Iarocci began an intensive collaboration with architect Stephen Valentine to design intermediate temperature storage systems suitable for cryonics in connection with the Timeship Project.

In summer 2002 an Alcor neuropatient reached the lowest temperature ever recorded without fracturing, –128°C. This was attributed to a uniformly low glass transition temperature resulting from excellent cryoprotective perfusion. Professional cryobiologist consultants expressed the opinion that the case may have been the best cryopreservation of any cryonics patient to date, and recommended transfer to the CryoStar freezer for continued slow cooling and annealing for fracture avoidance. In December another patient, A-1034, was also placed into the CryoStar to accommodate wishes of the family for this type of storage.



2003 June: In Ontario, California, presentations were made to the Alcor board of directors by Brian Wowk, Mike Iarocci, and Stephen Valentine on new designs for intermediate temperature storage systems. Alcor purchased and took delivery of an experimental single-patient "neuropod" intermediate temperature storage system developed by Brian Wowk at 21CM.(Alcor News #13, July 1st, 2003 and Alcor News #14, August 1st, 2003)

2003 July: The first patient transferred to the CryoStar freezer was transitioned to liquid nitrogen storage because fracture avoidance during slow cooling to -140°C was not successful.

2003 August: Alcor Research Fellow Hugh Hixon began photoelasticity studies of fracturing using a polariscope and polarized light to image stress in cryoprotectant glasses.

Carnegie Mellon University received a $1.3 million grant from the U.S. government to study fracturing during vitrification of tissue for medical applications, resulting in many new and valuable papers in the scientific literature about this subject. (Carnegie Mellon Researchers Developing New Ways to Store Tissue,Organs, Science Daily, August 13, 2003)

2003 October: 21st Century Medicine, Inc., constructed a prototype laboratory ITS dewar in which most of the volume of the dewar was converted into a uniform-temperature storage space kept cold by liquid nitrogen.

2004 March: Alcor purchased and took delivery of a "patient rated" neuropod intermediate temperature storage unit for individual neuropatients.

2005 November: Alcor placed an order with 21st Century Medicine, Inc., for a custom ITS dewar large enough to hold 14 neuropatients at a stable intermediate temperature ("ITS Neurodewar").

2006 January: US Patent 6,988,370, Cryogenic storage system with improved temperature control, was awarded to Mike Iarocci, Stephen Valentine, and Brian Wowk.

2006 April: Alcor transferred patient A-1034 from the CryoStar freezer to the validated neuropod purchased in 2004.

2007 October: US Patent 7,278,278, Cryogenic storage system, was awarded to Brian Wowk and Mike Iarocci.

2008 December: Alcor took delivery of the ITS neurodewar ordered in 2005. Patient A-1034 was transferred into the new storage unit, and three cryopreserved brains that had been stored by private individuals were accepted into ITS storage.

2011 Q3 Readiness Update

By Aaron Drake, NREMT-P CCT

Alcor's Recent Cryopreservations

This past quarter, Alcor cryopreserved two of its members. The first member lived just north of the Tampa, FL area. Alcor team members initiated a standby at the hospital for three days during the time the individual was listed as critical and medical providers anticipated that he might stop breathing. The member stabilized and Alcor ended the standby while continuing to monitor the patient's condition remotely. When his medical condition deteriorated again, Alcor was on the verge of initiating a standby for another member and therefore decided to request Suspended Animation to provide the standby this time.

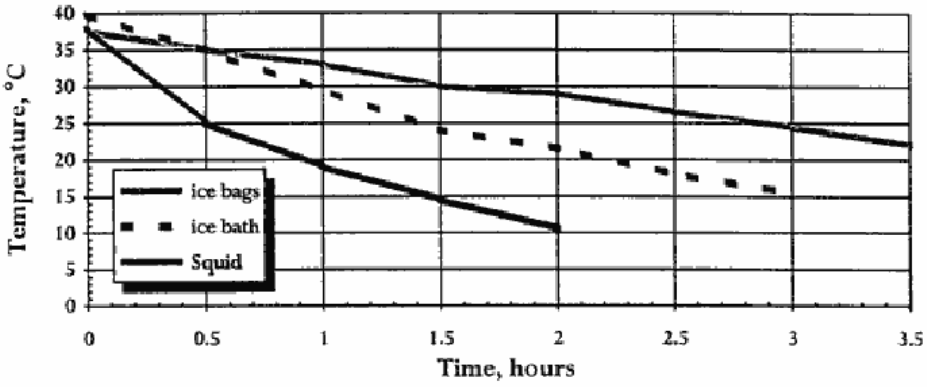
On the afternoon of the fourth day of the standby, the member was pronounced, stabilized and cooled on-site, followed by a field washout. The transport commenced the next morning by commercial airlines and the patient was brought to Alcor with the surgical team at the ready. After the neuro cryopreservation ensued, member A-1408 became Alcor's 105th patient.

Alcor's Arizona response team provided standby services twice at the home of A-2357 on the west side of the Phoenix valley, approximately 50 miles from Alcor in Scottsdale. The first standby lasted six days before the member's condition improved enough for the team to stand down. While continuing to monitor the individual's health through a very supportive hospice organization, the attending physician determined that it was time to restart the standby just a mere two weeks later. On the second day of the standby, despite relatively strong vital signs, the member's breathing became weaker until he finally just ceased to take a breath.

At the prior request of the hospice physician, both she and a hospice nurse assisted Aaron Drake and Steve Graber in administering the medications, cooling and preparing the patient for transport. They both followed the rescue vehicle back to Alcor so they could observe the procedure and see the facilities. Being impressed with the overall process, the physician expressed the desire to provide services for future Alcor members. This new relationship, along with the existing hospice that we have used in the past, will provide us with a stronger network of hospice options in the greater Phoenix area. A-2357 is now Alcor's 106th patient.

Alcor's Redesigned SQUID

What's a SQUID? This device, resembling the marine animal characterized by multiple tentacles, is designed to accelerate the speed at which a patient is cooled.



Immediate cooling is very important as it reduces the metabolic demand of the body. The more rapidly this occurs, the less ischemic damage is incurred.

This graph shows that:

1. surrounding the patient with ice bags will provide cooling at about 5°C per hour;
2. immersing the patient in a portable ice bath filled with a water/ice slurry will increase that rate to about 10°C per hour;
3. adding the Squid to circulate the water/ice slurry increases the rate to about 15°C per hour.

Alcor's Readiness Coordinator, Steve Graber, redesigned and built a compact, high output portable ice water recirculation system, better known as a "SQUID." This system is designed for a small sump pump to sit near the feet of the patient. Tubing from the pump runs up the legs and across the torso, and wraps over the neck and on the head. Chilled ice water then circulates around the patient to dramatically increase the cooling rate.

This new unit was tested in Alcor's ice bath to determine flow characteristics and battery duration. Based on the battery and pump specifications we expected around 850 gallons per hour flow with a power duration of 2.5 hours. Not only did we achieve our expected flow rate but were also surprised when the pump was still flowing strong at 3.5 hours.

12v Battery Powered SQUID features:

- ◊ Small and highly portable ice water recirculation system. Total system weight: 11.5Lbs.
- ◊ Single 12v 7Ah Gel Cell Battery mated to a powerful micro-sized pump with 1-1/4" outlet.
- ◊ Greater than 3.5hr run-time (tested).
- ◊ Hugh Hixon-designed water dispersal system with high volume flow and multiple flow branches using separate drain line.
- ◊ Double tubing slit-cover design with negligible splash characteristic.
- ◊ Compact design fitting into a small water resistant soft-sided carrying case with handle.
- ◊ Additional 115v power charger with intelligent charging/maintenance mode.

Team Training

The Pacific Northwest team, based in Portland, OR, hosted a two day training session at the home of former Alcor president Carlos Mondragon. Along with team leader Aschwin de Wolf, Aaron Drake instructed the twelve who attended. The first day consisted of classroom and practical training on the equipment, supplies and medications. On the second day, everyone reviewed the objectives and then participated in a scenario-based exercise on a mannequin, in real-time, to test the newly acquired skills. Up until now, the team has only had a partial kit with zero training and would have been unable to provide much support if called upon. Now that a full response kit is in place and there are multiple people who have been through Alcor's training, they feel comfortable and willing to assist in an emergency.

Dewars

Alcor has acquired three new Bigfoot dewars from a new vendor. They were shipped in an enclosed 40' semi-trailer, well wrapped and strapped to custom pallets. Alcor used two forklifts in tandem to unload and upright the dewars. We were immediately pleased with the high quality of the welds and attention to detail throughout their construction. The dewars now await testing for boiloff rates before being put in service. ■

About the Author

Aaron Drake
NREMT-P, CCT, Medical Response Director

Aaron Drake is a Nationally Registered EMT-Paramedic (NREMT-P) and a Certified Cardiovascular Technologist (CCT) who serves as Alcor's Medical Response Director. In this position he is responsible for the standby, stabilization and transport operations of the Alcor Foundation.

A New Choice for Immortalists

By Michael R. Rose
Department of Ecology and Evolutionary Biology, University of California

Everyone whom I know to be registered for cryopreservation does so because they don't want to die, for good and forever. That is to say, they are some type of immortalist. They may not be cyber-immortalists waiting to be uploaded to a successor to the present world-wide web. But basically they want the prospect, at least the possibility, of living forever. Like an agnostic contemplating the possibility that God does in fact exist, and a God in the business of providing accommodations comfortable or uncomfortable in the afterlife, immortalists are confronted with a menu of relatively stark, and often unappealing, alternatives, given that no one has yet brought a cryopreserved human, as body or head, back from the freezer alive.

I am not going to argue against cyber-immortality or cryo-immortality here. After all, the value of back-up plans is self-evident. Instead, what I am going to offer is an informal introduction to a third possibility. This possibility is one in which aging is stopped, and then repair and refurbishment are used to achieve immortality by the simple expedient of not dying in the first place.

Let me confess straightaway that if somebody had proposed this possibility to me just three years ago, I would have laughed at them outright. But I have spent the last two years reinterpreting my life's work, at least my research since 1976, when Brian Charlesworth first started working me over to get me to do my doctoral thesis on the evolution of aging.

Here is one of the key points, really the central intuitive idea that the present article hinges on. Since Aristotle, virtually everyone who has worked on the biology of aging has conceived of it in terms of an underlying cumulative physiological process. The most famous, and indeed notorious, present-day proponent of this view is the inimitable Aubrey de Grey. Aubrey characterizes aging as a process of cumulative damage, chiefly at the cell and molecular levels. As such, notwithstanding his media reputation as a wild-eyed radical, Aubrey is thoroughly conventional. In this respect, he more or less agrees with the National Institute on Aging, of the NIH, and innumerable other cell and molecular biologists. While some of these cell-molecular aging researchers think that free-radical damage is the central cause of cumulative damage, others think that progressive dysregulation is more important. Classical-era biologists, from 2500 to 1600 years ago, thought that aging was due to a progressively worsening balance between the earth, water, fire, and air that were thought to make up the human body. In effect, classical thinking was that these four elements were combined to yield life in an unstable mixture, whereby aging involves the drying out and cooling of the body's physiology. Modern-day cell biologists instead write about cumulative damage and/or dysregulation of pathways controlled by sirtuins, TOR, and the like. Regardless of details, all of these people agree with Aristotle's original hypothesis that aging is a cumulative physiological process of some type.

But I don't. Not anymore. And this break with the long Western academic tradition of aging theory is the key to the new choice I wish to offer here.

I should be clear that my present view is also not one generally held, at least not yet, even by most evolutionary biologists who work on aging. Like them, I spent more than thirty years thinking that William Hamilton's declining forces of natural selection, which he published in 1966, showed that evolution by natural selection would allow cumulative processes of physiological deterioration to proceed unchecked, provided they killed off their victims at sufficiently late ages. And thus my very definition of aging, which I published in my 1991 book *Evolutionary Biology of Aging,* assumed that endogenous processes of physiological deterioration, whether due to damage or dysregulation, would proceed without remit until all members of a sheltered cohort given good conditions die.

My turning on the Road to Damascus started one day in 1992 when my good colleague Larry Mueller showed me two articles from the journal *Science*, articles from the laboratories of our colleagues Jim Curtsinger and Jim Carrey. The data in those articles were mind-blowing. They showed the complete cessation of the acceleration in age-specific death-rates that evolutionary biologists like Larry and myself regarded as the hallmark of aging. It looked as if aging came to a stop.

Both Larry Mueller and I were intensely skeptical about these results, and we voiced some of our skepticism in print, in correspondence that was published in *Science* together with our colleagues Joe Graves and Ted Nusbaum, as well as in other articles that involved Larry and Joe Graves only. But I was deeply troubled by these findings from the two Jim's, and thought about them intermittently throughout the next two years.

By 1994, I was thinking that perhaps evolutionary biologists had misconceived the problem of the evolution of aging. Perhaps it was NOT natural selection just letting go, but something that specifically tracked Hamilton's forces of natural selection.

This led me to convince Larry Mueller to do some explicit simulations of evolution, simulations in which we looked at what happened at very late ages, long after Hamilton's forces of natural selection bottom out and stabilize. What the simulations generated were late-life plateaus in mortality, just as the Curtsinger and Carrey labs had found. We published this result in *PNAS* in 1996.

With this result in hand, we then checked how changes in Hamilton's forces would change the age at which mortality plateaus occur, based on explicit simulations. These simulations showed that changing the *last* age of reproduction in a biological population, the parameter that Hugh Hefner is working on as I write, would tune the age at which mortality rates would plateau.

So Larry Mueller, my then graduate student Casandra Rauser, and many undergraduate students working in my laboratory tested populations that had been evolving in my laboratory for this predicted relationship between the last age of reproduction and the start of the plateau in mortality rates. Qualitatively, it worked. Shifting the last age of reproduction, which is when Hamilton's force of natural selection acting on mortality itself plateaus, produces the qualitatively predictable shift in observed mortality plateaus in our fruit fly experiments. Not immediately, as a physiological effect, but eventually, over many generations, as a result of evolution occurring in my laboratory under controlled conditions.

Not only is the rate of aging, considered demographically, readily tuned by evolution, so is the age at which aging stops demographically readily tuned by evolution. And this is true not only of those aspects of aging that affect survival. It is also true of reproductive aging, the main theme of the doctoral research of Cassie Rauser in my laboratory. Reproductive aging is tuned by Hamilton's other force of natural selection, the one that tunes age-specific fecundity.

Still for more than a decade I thought of aging as a physiological process, just one that comes to an end when the late-life plateaus in mortality and fecundity are reached. But I now think that this was the wrong conclusion to draw from our work.

Consider the following point. If aging is a physiological process, however multifarious, why should it come to a halt just when the organism is most debilitated? In the human case, demographic aging stops when the death rate is between 30 and 50 % per year, particularly among centenarians. These are very frail people, yet their aging abruptly stops. How is this supposed to make sense?

Instead, imagine an entirely different view. Suppose instead that aging only seems like a physiological process, but actually is no such thing. Suppose instead that aging is the age-dependent tuning of Darwinian adaptation, where the tuning is determined by the patterns of Hamilton's forces of natural selection. Not a physiological process at all.

On this view, what seems like a physiological process is a scientific illusion, fully parallel to the illusion of the sun rising in the morning, crossing the sky, and setting in the evening. Because, of course, the sun does no such thing. Sunrise and sunset are optical illusions produced by the rotation of the Earth.

So why is this physiological illusion so convincing, and so reliable? It is convincing and obvious because the falls in Hamilton's forces of natural selection are so predictable and so intense, at least in most animal species. Hamilton's evolutionary forces are as strongly determinative of deterioration as any acute disease process. Only the illusory 'physiological aging processes' that they produce is extremely protracted in the human case.

If this view is correct, then those species in which Hamilton's forces of natural selection do NOT fall should be free of aging. Even if they have the same basic cell biology as we do, and even if they are as subject to mechanical injury and oxidation as we are. This alternative view thus makes some strong predictions, predictions which are readily falsified by comparative data. IF, a big if, this theory is wrong.

And the comparative data show that such species DO indeed exist. For example, sea anemones that reproduce only by symmetrical fission are animal species that are thought to be free of aging, from experiments culturing them in aquaria. Similar results have been found among other fissile coelenterates, particularly in the work of Daniel Martinez. And Graham Bell has found results like these in flatworms that can also reproduce by splitting in two. So, not only can aging stop, sometimes it doesn't even get started.

The problem for people is that when our aging normally stops, we are about a hundred years old, very fragile, and often demented. So who would want to sustain that state indefinitely?

But I kept on thinking about the cessation of aging. In the last two years I started thinking about some data that Cassie Rauser had collected on the cessation of reproductive aging in our fruit flies. She showed that the timing of this cessation, and the reproductive function of flies that have stopped reproductive aging, depended on their environment. These findings raised the possibility, in my mind, that we might be able to manipulate when mortality declines stop too, using environmental manipulation, in fruit flies or humans.

A few fruit fly experiments later, we are already seeing signs of such an opportunity: declining and stabilizing mortality too can be manipulated environmentally. This work is by Marta Santos and her team in my lab, and will be submitted for publication soon.

So, how to manipulate humans so as to stop our aging sooner, and in better condition? How to find a third option for immortalists, a less drastic choice before cryonic or cyber immortality?

As we explain in some detail in our book *Does Aging Stop?* (Mueller, Rauser, & Rose, 2011; Oxford University Press), shifting back to lifestyles that are physiologically comparable to those of hunter-gatherers provides a possibility of stopping aging at earlier ages, and in better shape. [For those who aren't scientists, I have presented this possibility in some detail at the website Rob Patterson has built for me: 55theses.org.] This possibility is particularly available for those whose ancestors have never adapted to agriculture, such as the northern First Nations of Canada or the non-agricultural tribes of tropical rainforests. For them, Larry Mueller's calculations suggest that they may be able to stop aging in middle-age in particularly good shape.

For the rest of us, the prospects are not quite as good, if we switch to hunter-gatherer lifestyles. But the possibility does present itself that we may be able to stop our aging phase, not our "aging process," by an age like 70, and do so in much better condition than present-day 70 year-olds can sustain.

Then, as medicine becomes still better at rescuing us from the accidents of thromboses, malignancies, and car collisions, we could remain on this aging-arrested plateau indefinitely.

Something for you all to think about. ■

I am grateful to Max More for suggesting that I write this article, and to Joseph L. Graves Jr. and Marta Santos for their comments on an earlier draft.

About the Author

Michael R. Rose

Michael Rose went to the University of Sussex in 1976 for his doctoral studies on aging in *Drosophila melanogaster.* There he began his work on the evolution of aging and created *Drosophila* stocks with postponed aging. In 1991, his **Evolutionary Biology of Aging** appeared, offering a view of aging that was a complete departure from the views that had dominated the aging field since 1960. **Evolution** described the field of gerontology as now "after Rose."

What is Cryonics?

Cryonics is an attempt to preserve and protect human life, not reverse death. It is the practice of using extreme cold to attempt to preserve the life of a person who can no longer be supported by today's medicine. Will future medicine, including mature nanotechnology, have the ability to heal at the cellular and molecular levels? Can cryonics successfully carry the cryopreserved person forward through time, for however many decades or centuries might be necessary, until the cryopreservation process can be reversed and the person restored to full health? While cryonics may sound like science fiction, there is a basis for it in real science. The complete scientific story of cryonics is seldom told in media reports, leaving cryonics widely misunderstood. We invite you to reach your own conclusions.

How do I find out more?

The Alcor Life Extension Foundation is the world leader in cryonics research and technology. Alcor is a non-profit organization located in Scottsdale, Arizona,founded in 1972. Our website is one of the best sources of detailed introductory information about Alcor and cryopreservation (www.alcor.org). We also invite you to request our FREE information package on the "Free Information" section of our website. It includes:

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