While reviewing the simulated molecular trajectories in the holographic visualization chamber, I selected a set of targets to input into our Molecular Design Toolbox. The Toolbox searches all the molecular databases and gives me a set of possible strategies to modify specific enzymes in the network in order to change their substrate specificity so they will act on one or more of the toxins present in our test site. I prioritized the strategies and readied them for distribution to my research teams for evaluation. The time passed quickly, and I suddenly realized that I must be at the school in 15 minutes to meet the children.

I arrived at the school by 4:30 p.m. to meet the kids, and we caught a maglev shuttle home. The overloaded car was noisy, and Jason was anxious to be home in time to see the next episode of the original *Star Trek* TV series that was still in perpetual reruns. His older sister Karen listened patiently to his prattle about Tribbles and such. After getting the kids some dinner and talking about their respective days with them, I settled them down in our communication center to work on their homework while I logged into the WSA library. I checked my log to see if there were any hot E-scripts published that day. It had been a relatively quiet day for science publishing: only 5000 manuscripts submitted to the network and only a couple of them flagged by my E-Sentry as important. We all finished early enough for Jason to watch *Star Trek* before it was time for him and Karen to get ready for bed and reading time. Their father arrived home in time to say good-night before they were asleep.

Over a late-night supper, Jack told me about his trip to Nevada where he was trouble-shooting for the U.S. Nuclear Energy Commission. The NEC came into being soon after the United States signed the international treaty requiring all nations to reduce their emissions from fossil fuels by 80%. They established our West Coast nuclear power reactor network in Nevada. Soon after, the Neutron Science Research Center was sited there with its facilities for reactor materials development, neutron scattering, and medical applications. Jack's contract was to find out what was wrong with the cold neutron source enhancement project at the research center.

His success would be a boon for our project. We were always hungry for more neutrons for our structural studies. Jack had good news for me—it seemed we might be doing experiments using the new cold source within the year.

We went to bed, and I enjoyed the feeling of being tired from a good day. I drifted asleep wondering where my journey might take me from here. We have the team and the tools to make the Asian project really go, and our success would have a huge impact for the future. I looked forward to being a part of making it happen.

The authors, a husband-and-wife team, collaborated on this project from the glorious mountains of Northern New Mexico. J. Trewhella arrived in the USA 20 years ago from Australia, and is a biophysicist. D. M. Parkin is from Utah, where he began his journey in condensed matter physics and went on to specialize in radiation effects. J. Trewhella, Mail Stop G758, and D. M. Parkin, Mail Stop K765, Los Alamos National Laboratory, Los Alamos, NM 87545, USA. E-mail: jtrewhella@lanl.gov and dmp@lanl.gov

Address to the 40th Annual Convention of the U.N.A.A.S.

by PAUL K. WOLBER

(Scene: A packed, windowless auditorium. A buzz of conversation fills the room, but individual voices are indistinct. A casually dressed, nut-brown man of indeterminate age walks to the podium and clears his throat. The crowd quiets, and the speaker begins …)

Speaker: Colleagues and friends, welcome to the 40th annual convention of the United Nations Association for the Advancement of Science. I thank the meeting organizers, both real-presence and virtual, for inviting me to deliver this opening address. Today, I would like to review the eventful first four decades of our history and then discuss the challenges which I believe will shape our next 10 years.

Many members of today's audience witnessed the sad events that caused the American Association for the Advancement of Science to transform into a truly international organization. I will not dwell on the tragic excesses of the international conspiracy of unemployed scientists that held the world hostage during the first 6 months of 2009, nor will I join the endless argument over whether the ultimate response of Hillary Clinton's administration was excessively brutal. Suffice it to say that one piece of good that emerged from those tragic times was the founding in 2010 of the U.N.A.A.S., an international scientific organization committed to policing the world's scientific communities and representing the interests of scientists of all nationalities.

The first challenge facing the U.N.A.A.S. was the formidable task of reversing the conditions that had produced such an ample supply of unemployed, disaffected scientists and engineers. The task was complicated by funding problems: the governments of the world found it difficult to muster the political will to provide the money needed to employ so many specialists, especially given the events of the preceding year. But, as often happens, adversity inspired a creative solution to the problem. Over the previous decade, the astronomy, physics, and molecular biology communities had experimented with virtual telepresence across high-bandwidth networks as a means of sharing important resources. The utilization of telescopes, accelerators, and automated sequencing facilities had already been improved by such connections. The long-distance collaborations enabled by the Internet in the late 20th century had also expanded to fill some of the new bandwidth. The key insight made by the architects of the original U.N.A.A.S. Virtual Science Initiative was that most of the infrastructure necessary to extend telepresence links into individual public and private laboratories was already in place. All that was needed was the will to spend the relatively small amount of money needed to integrate the system.

The results of that first bold experiment have been called the "Internet Miracle." However, my laboratory at the Madras Institute of Technology was an early participant, and I believe that a better name would be the "Night-Shift Miracle." The sharing of laboratory resources via robotics and virtual telepresence allowed the scientific community to establish collaborations that operated around the clock, to use key resources at all times, and to double or triple the number of minds working on important problems. The point is well illustrated by the effort to develop synthetic endosymbionts, which began in my laboratory in 2014 when I. J. Sorkovsky engineered a version of *Chlamydia pneumoniae* that could be chemically primed to induce programmed cell death in cultured human cells.

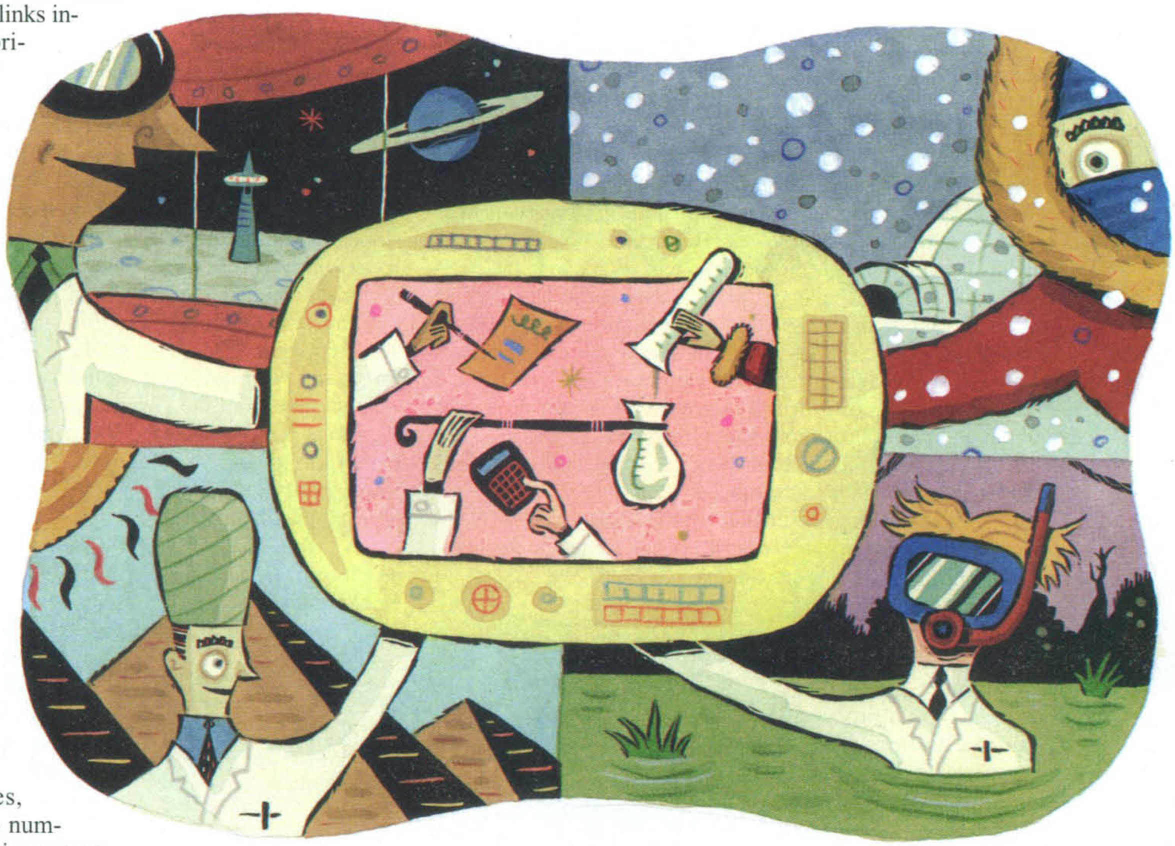

ILLUSTRATION BY ADAM MCCAULEY

(A large diagram appears in place of the wall behind the speaker. The speaker fades and reappears inside the diagram.)

The original strain, CP888, was crude by today's standards. Its pathogenic characteristics had been disarmed, and it had been rendered dependent on even more host pathways than its wild-type progenitor. Cell invasion required viral priming of the host, and host death was triggered by a combination of three chemical signals. But CP888 was indiscriminate. It had no capacity to assess the state of its host.

(As the speaker lectures, elements and bulleted points are added to the diagram.)

Dr. Sorkovsky was smart enough to see the potential of his invention for remodeling human cells and wise enough to realize that he could not exploit it by himself. He and I mulled over the problem and then initiated the formation of a virtual research group that eventually spanned six continents, utilized dead time at 11 of the world's premier research locations, and spawned the investigations that resulted in 12 Nobel Prizes. The daughters of CP888 have yielded multiple cancer cures, tools for permanently ridding cells of retroviral infections, tools for performing site-specific gene therapy, means for programming neurons to form bio-electronic interfaces, and other cost-effective technologies that have made life happier, healthier, and longer for all of us.

(The original diagram has shrunk; arrows have grown from it, pointing to each innovation.)

In preparation for this talk, I telemet with Dr. Sorkovsky in St. Petersburg and prepared a short accounting of resources exchanged during the first 20 years of the collaboration. Less than 5 kilograms of physical material was transferred. Approximately 40 scientists physically traveled to other laboratories. And about 10^{18} bytes of information flowed over high-bandwidth trunks.

(The diagram with arrows has been replaced by a log-scale bar graph illustrating each point.)

More recently, the evolutionary biology and space exploration communities have collaborated electronically to understand the implications of fossil life found on Mars and active life found within Europa. Their efforts have produced the startling hypothesis that life on Earth was assembled from terrestrial, martian, and Europan components. This hypothesis, in turn, has spawned the concept of information ignition in emergent systems. Finally, information ignition has been demonstrated experimentally in artificial life simulations run on hardware spanning several continents and connected by high-bandwidth networks.

Not only have the life sciences benefited from virtual science, a virtual research group produced the unexpected solution to the solar neutrino deficit and its technological child, warm fusion. During the late twenties, the revolution accelerated itself with the invention of the first "3rd Eye®" bio-electronic virtual-reality interfaces. In 2038, the U.N.A.A.S. conference crossed the watershed of hosting more virtual than real-presence attendees. Today, I speak to an audience estimated at 15,000; fewer than 200 of you are present in the flesh at the conference site.

The U.N.A.A.S. has played important roles in all of these advances. The association has served as a catalyst, bringing scientists from across the world together as an electronic community, and has worked, quietly but firmly, to encourage constructive uses of new knowledge and to discourage misanthropic applications of discoveries. Finally, the association has convinced the nations of the world to support and fund science cooperatively. This cooperation has resulted in a safer and more stable world order.

(The speaker is standing in front of an image of the Earth from space. The image and speaker dissolve, and the speaker reappears before the podium.)

What challenges does science face over the next decade? I will discuss two, which fit into the general categories of bioethics and the social organization of science. I feel qualified to explore these challenges because they are both derived from the invention of synthetic endosymbionts. However, I also recognize that the greatest challenges will be the ones that we cannot yet see. But I cannot explore what is not yet known, so I will instead extrapolate from what I do know.

The major bioethical challenge that I foresee is the quandary of whether the human germ line should be altered to include synthetic endosymbiont progenitors. Such progenitors have already been introduced into the germ lines of several important plant and animal species, without ill effects. Progenitors prepare the organism for the introduction and removal of more specialized endosymbionts. They make endosymbiont-based medical therapies safer, better, and less costly. So far, they present no disadvantages.

However, the decision to permanently alter human biology is not to be taken lightly. I propose that, over the next decade, the scientific community should strive to set the ground rules for performing such alterations and to define the hurdles to be overcome before allowing human germ line changes. We should proceed with caution and preserve, whenever possible, the option of reversing course. But we should proceed. The human genome is riddled with the scars of an evolution shaped by millennia of disease and starvation. I firmly believe that we can learn to drive our own evolution by more humane means.

The second challenge that I see affects me personally. Science must face the effects of the marked increase in human longevity on how scientific careers begin and progress. My own life as a scientist offers a case in point.

In 2029, I underwent my first treatment. Soon, I was in the grips of "second adolescence," the period of profound physical and mental change that accompanies rejuvenation therapy.

As a result of our work on synthetic endosymbionts, I. J. Sorkovsky and I were honored with the Nobel Prize in Physiology or Medicine in 2027. I was 68 years old, about to retire to emeritus status and the twilight of a productive and satisfying life. After I received the Nobel, my colleagues persuaded me to delay my retirement in order to exercise whatever influence I might have gained to aid the institute. However, in 2028 the first form of endosymbiont-based rejuvenation therapy was approved for human use. In 2029, I underwent my first treatment. Soon, I was in the grips of "second adolescence," the period of profound physical and mental change that accompanies rejuvenation therapy. I switched fields and became an experimental informationist. I had the good luck to join the field as the community began its search for a coherent description of information ignition. The result of that work was another Nobel, awarded last year. I am now 91. But I am more energetic and clear-headed today than I was at age 55, when I. J. Sorkovsky and I began our program to exploit CP888.

So, you might ask, "Why is this a problem?" Scientists live longer, more productive lives, and the world profits. Perhaps that is so, but our children do not profit. Instead, they live in our shadows, unable to shine on their own. Again, you might ask, "Is this really bad?" After all, quality and truth should triumph in science. However, science also needs a steady infusion of iconoclastic creativity, of minds that are not quite educated enough to "know" that their wildest ideas are impossible.

Mainstream science has been increasingly dominated by the rejuvenated. But it is worth noting that the three most unexpected discoveries of the past 20 years were made by scientists under the age of 30.

Therefore, I will end with two modest proposals. First, I urge the Nobel Committee to follow the lead of the MacArthur and Gates Foundations, by limiting individuals to two lifetime awards. It is important to maintain the option of rewarding younger researchers, and I can attest to the fact that two Nobel Prizes assure one of a lifetime at the podium. Second, I urge the U.N.A.A.S. to double its support for young scientists over the next decade. Some of the increase should come from the governments of the world, who should, after all, invest in their children. But some of the increase should come from the budgets of older researchers. Over the years, we have learned how to do science efficiently. It is time for us to show what we can do with those skills.

(As the speaker finishes, the audience freezes in place. The auditorium fades and is replaced by a conference room. A young woman sits at a console in one corner. Her skin is marbled with swirls of silver and gold.)

Speaker: How was I for time?

VT Technician: The time was good. The translator programs had some trouble at the end; you departed a bit too far from the guide text. I'll try to add a warning nimbus to the heads-up display. At least, if I can figure out how to use your ancient software.

Speaker: When you grew up with PowerPoint, it's hard to change.

VT Technician: Power-what?

Speaker: (sighing) Never mind. Let's try it one more time. From the top …

(*Scene*: A packed, windowless auditorium. A general buzz of conversation fills the room …)

The author is a 48-year-old physical chemist turned molecular biologist who works on nucleic acid arrays. He is interested in the future because he has two daughters and because it has been so much fun watching science change and grow during his lifetime. He reads a lot of science fiction and has taken Arthur C. Clarke's words to heart: "What's the best way to prepare for the future? Read science fiction!" P. K. Wolber, M/S 25U-5, Agilent Technologies, Palo Alto, CA 94304, USA. E-mail: paul_wolber@agilent.com

Dr. Cool

by DANIEL ROBIN BOOTH

ILLUSTRATION BY ADAM MCCAULEY

Dr. Sam Toohey kicked his desk drawer shut and leaned back in his chair. Science, who needed it? A pile of half-read, skimmed, or just plain unread papers lay on his desk. They could wait. Most of them were the usual directives: Do this, go there, find this, prove that, translate it into plain Global Communication System Two (Western dialect). They would have to wait. It wasn't even as if GCS2 was his native tongue. He'd grown up speaking a minor dialect derived from Global Communication System Seven. He laughed. Seven! No one used seven any more. In fact, everything from four upward had died out over the past 10 years. Three was only used by the more pedantic type of older statesman. Two was given official sanction for purely political reasons. Global Communication System One was the only variant that actually meant anything these days. Anything else spoken by adults was looked upon as a little eccentric; teaching of any other system was strictly forbidden. And still he had to translate everything he did into GCS2. Simply making his work accessible to 98% of the population wasn't sufficient. "Science must be open to all," was the decree from on high. He was lucky he didn't have to do GCS3 as well, but they had specialists for that sort of thing.

This was a different office. Cleaner than Sam's; fewer empty bottles lying on the floor, less of that peculiar smell associated with ... what was it called now? "Cigarette smoke." Yes, that was it: cigarette smoke. Well, whatever it was, there was none of it here. Just the gentle whirr of the environmental conditioning and the occasional hum as a vehicle zipped past the window. Two men stood and stared out of the window in question.

"Do you have to work on the 48th floor?" said one.

"Yes," said the other, "I think I do. I like the view."

"I don't."

"You should try looking out instead of down."

"But there's such a lot of 'down' to look at. I..." he was interrupted by the sound of the room entry-shield disengaging briefly to let their boss enter.

"Men," she said, "we have a problem."

Back in his less-than-sterile office, Sam sat with a small paper tube in his hand. He turned it over and over, as if trying to find the motivation to do what came next. Eventually he put it into his mouth and picked up the silver metallic object lying underneath a pile of *Series Three Cycle—Technical Specifications* documents. He flicked at it until a yellow flame was produced. Slowly, very slowly, he applied the flame to the tube in his mouth. Thick, toxic smoke appeared, which Sam tried unsuccessfully to avoid inhaling. He placed the silver object back on the desk, coughed a little, and wiped his slightly watering eyes.

This couldn't possibly be "cool." No way on Earth, or what was left of it, was this activity cool in the slightest. This worried him. Beneath all the mission directives and GCS wrangling, "cool" was Sam Toohey's job. His training had been somewhat hit and miss. The science part, that was the hit. He was a genius ... OK, he was a decent scientist; he'd done his time in the lab, gained his Global Qualification Level Eight (Science) permit. He could have been a brilliant ... reasonably good ... researcher. So what was he doing here with this tube full of vegetation gently smoldering in his mouth? Being cool, that's what. Government Agent 225476, Doctor Sam Toohey. Responsible for public understanding of science and, more importantly, making science fashionable again. Which meant being cool. Or, at least, behaving in a manner that some government history researcher had decided represented a lost era of "coolness." This represented the "miss" part of his training.

A sharp pain from his left leg made him change his position slightly in the chair. He opened the drawer of the desk and pulled out a bottle of amber-colored liquid. He was about to remove the top when a thought struck him. He removed the paper tube and placed it carefully in the glass dish on his desk. He then put the top of the bottle in his mouth, levered it open with his teeth and spat the top across the room. He gulped some of the liquid down. It tasted filthy but it was officially cool and, remarkably, it did seem to ease the pain in his leg.

The pain in question stemmed from the various test programs for the Series Three Cycle, not to mention the Series One and Two Cycles. Your average car was deemed unsuitable for him; it just wouldn't be cool enough. Sam would have been quite happy with an average car, or even a slightly under-average one if he was being completely honest, but the department wouldn't have it. So they cooked up the Series One Cycle, which damn nearly cooked Sam.

The Series Two had performed quite well, at first. Unfortunately, no one had told Sam that the two–thrust nozzle configuration made it distinctly more unstable than the standard four-nozzle car. Sam discovered this for himself ... at 100 meters up, hence the pains in his leg. The Series Three seemed to have all these little problems ironed out. At least, it hadn't killed him yet ....

"Gentlemen, this is a job for Sam Toohey."

There was a muffled ringing noise from somewhere on his desk.