Induction Ceremony

Challenges Facing a Global Society

On October 10, 2009, the American Academy of Arts and Sciences inducted its 229th class of Fellows and Foreign Honorary Members at a ceremony held in Cambridge, Massachusetts. **Terence Tao**, Professor of Applied Mathematics, University of California, Los Angeles; **Elizabeth G. Nabel**, President, Brigham & Women's/Faulkner Hospitals and former Director, National Heart, Lung, and Blood Institute; **Ronald M. George**, Chief Justice of California; **Edward Villella**, Founding Artistic Director and Chief Executive Officer, Miami City Ballet; and **Kent Kresa**, Chairman Emeritus, Northrop Grumman Corporation, addressed the audience. Their remarks appear below.

Terence Tao

Professor of Applied Mathematics, University of California, Los Angeles

The Future Impact of Internet-Based Technologies on Academia

Introduction

If I had to name the most significant technological development in recent decades, I would choose the Internet. By this, I mean not just the physical architecture of the Internet per se, which has been available to academics and government agencies since the 1960s, but the innovative technologies that flourished once the Internet matured: from tools as humble as the email mailing list to such unreasonably effective services as modern search engines or Wikipedia.

As the Internet has become more integrated into the mainstream of modern life, it has disrupted and revolutionized one sphere of human activity after another. We read in the news about how online media are thriving as "old" media stumble; how online medical information is transforming patient-doctor relationships; how blogs, tweets, and online videos are tipping the balance in closely fought elections; and so forth.

But to most of us in academia, the temptation is to view these changes with a certain detachment: sure, established for-profit companies may well face competition (as they ought to) from lower-cost Internet-based rivals, and it is only reasonable in a democracy that politics should be influenced by popular debate, both offline and online. But we, by contrast, should be secure in our ivory towers from any Internet revolution, with our tenure, our unique expertise, and our time-tested academic traditions.

Even when new technologies do hit close to home – by threatening the profit model of the academic journal system, say, or by greatly facilitating the ability of students to cheat on their homework (and also for professors to detect such cheating!) – we can still rationalize away these developments as requiring only superficial changes to adapt to: switching from physical journals to online journals, perhaps, or placing more safeguards on our homework formats. We still perform our "core" academic activities – teaching, advising, research – much as we have for over a century: classroom by classroom, student by student, and paper by paper. We may do more of these things online now rather than offline, but the professor, not the Internet, is still at the center of things. After all, it is not as if our classes can be replaced by a Wikipedia entry, or our research by a search engine query, right? Right?

Well, yes and no. Even the most advanced online resources available today are not nearly "smart" or sophisticated enough to render our academic services obsolete; not yet, at least. Unlike many other industries, academia does not currently face any real threat from a cheap Internet-based competitor. But I believe a hybrid form of academic activity is beginning to emerge, one in which Internet-savvy academics and

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their institutions harness the full power of online tools to initiate and organize large research collaborations and to disseminate and share their results at far more rapid and effective rates than were previously possible. In my discipline, mathematics, this type of Net-centric activity is still in its infancy, but it shows signs of potentially being substantially more efficient (and perhaps, more important, *open*, *cumulative*, and *responsive*) than traditional collaboration and dissemination, and is likely to become increasingly mainstream in the years ahead. This type of activity may not revolutionize

the way we work, the ambition of what we hope to achieve, or the academic culture we work in, but it is likely to transform them significantly.

Teaching

Consider teaching. Year after year, day after day, and in universities across the world, we stand in lecture halls and present the foundations of our subject to classrooms consisting of hundreds or even just dozens of students at a time. This keeps us engaged with our students, hones our skills, and makes us feel useful, but is it the most efficient way to do things?

The mathematical topic Möbius transformations is taught routinely in complex analysis classes in a thousand mathematics departments across the world, to classes of perhaps thirty or fifty students in size; I have done so myself several times. On YouTube a beautiful video explaining the geometric interpretation of these transformations has been viewed *one million six hundred thousand times* so far – more people than can be reached by even ten thousand mathematics lecturers. The video can be accessed by just about anyone on the Internet through a simple Web search on the topic. (Currently it is in the top three hits on all major search engines.)[1]

Now, one cannot hope to replicate the entire classroom experience as a sequence of YouTube videos. The quality of interactivity, depth of material, and availability of expert attention, in particular, are much poorer. Even professional efforts that are more organized, such as the online videotaped lectures offered by institutions such as MIT, are an imperfect substitute for being physically present at lectures. But the sheer numbers of people one can reach through the Internet shows the potential of tapping this medium to teach in the future.

Hundreds of academics (including myself) use a blog to post their course notes and encourage online discussion (in all directions) between the teacher and students in the classroom, as well as visitors from around the world. I have had classes with perhaps thirty local students but up to 100 other participants from a variety of backgrounds following (and commenting on) the blog. The quantity and level of questions asked is much higher, and the material in my notes is much improved because of this. From preparing blog materials and obtaining feedback from students and participating colleagues, I have learned more about a subject than if I had taught it in a traditional way.

The traditional classroom lecture will still play an indispensable role in the future but will do so in a rather different format than today, with its effects being vastly amplified and prolonged through its integration with the Internet.

Even after the physical class ends, the online class goes on. I have often had people wanting to learn a subject stumble onto year-old lecture notes on my blog through a search engine and continue the discussion afresh. Within a few years, the Internet might include valuable online content like this for nearly every commonly taught academic topic, all just one search query away for anyone with Internet access.

The technological level of online interactivity is certain to increase in the future. One can well imagine that classes will routinely (for instance) field questions by text message from students overseas who are watching the lecture in real time through video, with the discussion continuing online long after the class has ended. Not all experiments in online teaching will achieve their intended objectives, but only one clear success is needed to provide a model that can then be rapidly emulated by institutions and lecturers worldwide.

In my view, the traditional classroom lecture will still play an indispensable role in the future but will do so in a rather different format than today, with its effects being vastly amplified and prolonged through its integration with the Internet.

Collaboration

Another major area where profound changes are happening is collaboration in research. Only four decades ago the primary mode of communication among academics in distant institutions was physical mail. This was inconveniently slow, and it discouraged collaboration with anyone who was not in the same physical location. With modern communication tools such as email, the situation today is vastly different. In mathematics, to collaborate over long distances is now completely routine, with months of online communication punctuated by only a few (but crucial) days of physical contact each year. Perhaps as a consequence, the proportion of papers in mathematics that are jointly rather than singly authored has increased tremendously. As a related phenomenon, an increasing fraction of papers are also interdisciplinary rather than specialized to a single subfield.

Software tools have recently become available to allow easier collaboration by large numbers of authors from across the world. Unlike the sciences, pure mathematics in academia has never had large laboratories in which armies of graduate students, postdocs, and senior researchers work on a single goal. The technology to make such large-scale projects possible is just now becoming available. This year, for instance, by ad hoc usage of existing tools such as blogs and wikis, the first "polymath" projects were launched. These are massively collaborative mathematical research projects, completely open for any interested mathematician to drop in, make some observations on the problem at hand, and discuss them with the other participants. The first such project solved a significant problem in combinatorics after almost six weeks of effort and almost a thousand small but nontrivial contributions from dozens of participants. This was a novel way to do mathematics, as well as a novel way to locate the collaborators with the right expertise and interest to solve the problem. The project might serve as a model to begin collaborations through online rather than physical networking.

Online collaboration confers other unexpected benefits, too. Projects retain a fully available online record of all discussions,

[1] Douglas N. Arnold and Jonathan Rogness, *Moebius Transformations Revealed*, online video (2007), www.youtube.com/watch?v=JX3VmDgiFnY.

including false starts, dead ends, and incremental progress, that took place while the problem was not yet solved, giving a much richer, more dynamic, and more accurate picture of how mathematical research really takes place. The cut-and-dried presentations one sees in finished products such as papers and textbooks cannot do similar justice to this process.

By taking research online, it comes to life. One participant in an online polymath project compared his anticipation to see the latest developments to the suspense one might feel while watching a TV or movie drama. Veteran researchers are familiar with these tensions, frustrations, and joys, but conveying these experiences to the graduate students entering the field used to be quite difficult. Perhaps these open Internet projects, with their "show, don't tell" nature, may succeed in doing so in the future.

Academic Culture

As we adopt new technology, our culture of doing things subtly changes. In mathematics, for instance, research used to be a secretive activity. One would often not discuss what one was working on before it was ready for submission to a journal and would give out preprints only to a select few colleagues before the publication process was complete (which took months or even years). With the rise of preprint servers and search engines, mathematicians nowadays customarily put a preprint online as soon as it is submission-ready (sometimes even sooner). Experience has shown that doing so greatly increases the visibility, impact, and influence of one's work, and (perhaps counterintuitively) discourages excessively competitive behavior and even plagiarism because the time stamps given by preprint servers can help defuse arguments over precedence.

In many parts of mathematics there is now a social expectation that one's work should be readily available online, and journals have largely abandoned attempts to enforce a monopoly on the dissemination of their authors' work. As a result, research developments propagate at a significantly faster speed than in previous decades.

I can imagine further cultural shifts of this type. Currently, the actual problem-solving process in mathematical research is usually obscured from view until the problem has been solved and a polished, publication-quality draft is available. With the rise of open collaborative projects such as polymath, this culture may begin to change. (For instance, I circulated a draft of this talk on my blog weeks in advance, both to obtain valuable feedback and to encourage me to continue working on the text. A few years ago, I might have shown a draft to only one or two trusted friends, with perhaps a single round of revisions.)

In the future, some of the more technical and specialized subfields of mathematics may encounter increasing societal pressure from their peers to make their work more accessible and transparent to wider audiences.

Similarly, the advent of mathematical blogs and other semiformal outlets for discussion is reinforcing an existing trend in mathematics in which the intuition and motivation behind a mathematical topic are emphasized as much as the definitions, theorems, and proofs. In the future, some of the more technical and specialized subfields of mathematics may encounter increasing societal pressure from their peers to make their work more accessible and transparent to wider audiences.

In teaching mathematics, the current model is that of a nearly one-way street: the lecturer does almost all of the talking. Apart from a few questions from the bolder students, one receives feedback only days or weeks after the class has ended, from the assignments, evaluations, and exams the students turn in.

With improvements in technology, students might come to expect classes to be significantly more interactive, both during the "actual" class and in the online discussions before and after. An expectation of near-instant feedback may become the norm.

Such changes will encounter resistance from some academics – consider the ongoing debate on whether to allow laptops in classrooms – and many changes will not be fully successful; we still have only a partial understanding of what makes one online experiment flourish and another fail. Nevertheless, I doubt that we will keep the status quo indefinitely in the presence of such technological and social changes.

Conclusion

One can draw an analogy between pre-Internet academia and preindustrial manufacturing. Before the industrial revolution, manufacturing was the province of individual craftspeople or secretive guilds working painstakingly on each individual piece of work, with each master passing down his or her carefully hoarded insights and tricks to just a handful of disciples. Finding parallels to each of these phenomena in academia is not hard.

But after the Industrial Revolution, specialization and mass production became the paradigm in manufacturing – less intimate, surely, but vastly more efficient and reliable. One might bemoan the loss of creativity and individuality that each craftsperson exhibited, but eventually, as the Industrial Revolution matured into the modern era, the outlets for creativity were dispersed to a wider group of people. Thanks to the division of labor, design, invention, entrepreneurship, manufacturing, marketing, training, and management could now be performed by whoever was best qualified to do each task, rather than the same individual having to handle all of them. The best practices in these areas could be adopted widely rather than being confined to their originators, and a select number of followers.

Academia has not experienced change on the scale of the Industrial Revolution since the invention of the printing press. With the advent of the Internet – the modern-day analogue of the printing press, among other things – could it be revolutionized once again? ■

Elizabeth G. Nabel

President, Brigham & Women's/Faulkner Hospitals; former Director, National Heart, Lung, and Blood Institute

Scientific and Medical Discovery – in Service of Human Health

While we come from different backgrounds and have different research interests, for those of us in the biological sciences, we share a passion for science and a responsibility to put intellectual contributions to humanitarian use. Our nation's citizens and leaders are in the midst of a vitally important discussion on health care. This debate has provided insights into who we are as Americans and what we value. All people deserve to be healthy. Unfortunately, for many middle-class Americans good health has become increasingly unaffordable because of lost jobs, a lack of insurance, and/or insufficient income. My belief, which is shared and has been articulated by many in the audience, is that health is a basic human right, and my comments today focus on two dimensions of this discussion from the perspective of a physician-scientist.

While issues of access, quality, and affordability are complex and difficult to solve, they do not negate the underlying principle that Americans should have the ability to enjoy good health. The intensity of our national health care debate offers the scientific and medical community an important opportunity.

Many of us have worked in impoverished areas in this country and abroad. We understand the close association between poverty, a lack of decent housing and education, and poor health. How should we respond? What is our duty to our fellow citizens? A recent survey confirms that the vast majority of physicians consider it a professional obligation to address societal and health-policy issues.[1] Health care professionals, for the most part, are eager to serve. And so these efforts, many begun by members of this class of new Fellows, must continue: our voices must be heard as we, as scientists and physicians, advocate for health as a human right. We must continue to reach out to those in need and to those who are most vulnerable, those whose voices may be muffled to society's ears.

This past summer, I had an opportunity to witness such advocacy in rural Rwanda when I visited the Partners in Health program at the Rwinkwavu District Hospital. Rwanda is a war-torn land that is now rebuilding itself after decades of politically motivated atrocities. Here is a place where divisive acts in 1994 shredded the fabric of a country where Tutsi, Hutu, and Twa residents once peacefully coexisted. During the 1994 genocide, neighbor turned against neighbor, and the country was literally destroyed. The country's infrastructure is being rebuilt thanks to the vision and leadership of Rwanda's president, Paul Kagame. Access to quality health care in Rwanda, as in many impoverished or politically unstable regions, is far from guaranteed. But the advocacy of organizations like Partners in Health is making a difference, and hope and optimism are growing.

I visited with government and health leaders in Rwanda, and I was impressed by what is being done and by the potential for what can be done. For example, Partners in Health is making great progress in caring for sick Rwandans, rebuilding the medical care infrastructure, and training local people to do vital work. I acknowledge in particular the vision and on-the-ground efforts of my colleague and fellow inductee Dr. Paul Farmer, the medical anthropologist and physician who is Partners in Health's founding director. He has accomplished similar gains in Haiti.

We can and should use the urgency of the current health care discussion as an opportunity to focus on the role of biomedical research and medical discovery in laying the foundation for better human health.

One of the most profound and lasting ways we can serve our fellow citizens in places where poverty and political oppression vanquish the right to good health is through biomedical research. The results of such research are multiplicative – extending benefit that is not possible through individual contact. Basic discoveries, translation to clinical medicine, and implementation into urban and rural communities have been the story line of medical advances for decades, sparing millions from infections, cancer, and heart disease. Much of this work is supported by taxpayer investments in biomedical research in this country through the National Institutes of Health (NIH), the National Science Foundation, and other government agencies.

President Franklin Delano Roosevelt foresaw the power that basic research could bestow on human health when on October 31, 1940, he dedicated the newly established NIH on the Bethesda campus where I am now privileged to work: "We cannot be a strong nation unless we are a healthy nation. And so we must recruit not only men and materials but also knowledge and science

[1] R. M. Antiel, F. A. Curlin, K. M. James, and J. C. Tilburt, "Physicians' Beliefs and U.S. Health Care Reform – A National Survey," *New England Journal of Medicine*, September 14, 2009 (epublication ahead of print).

in the service of national strength. . . . The ramparts we watch must be civilian in addition to military."[2]

The NIH came to be during a time in which this country was suffering, in the wake of the Great Depression. President Roosevelt appreciated the necessity of this investment in research, and we can attest today that he was correct in his vision. I am continually inspired by the many outstanding minds that have devoted their talents to public service in the worlds of science and medicine. A perfect embodiment of this ideal is fellow Academy member, and my colleague at the NIH, Dr. Tony Fauci, with whom I work closely and often on a range of policy issues that make a mark on national and global health.

As physicians and scientists, we carry deep within us a belief that health is a human right and an understanding that when our health system does not adequately serve many of our fellow Americans we must change it.

This is a special and challenging time for our biomedical community. We are in another period of economic hardship, and the NIH was fortunate to be the recipient of a multibillion-dollar investment from the American Recovery and Reinvestment Act of 2009 to create jobs and accelerate the pace of medical discovery. We can and should use the urgency of the current health care discussion as an opportunity to focus on the role of biomedical research and medical discovery in laying the foundation for better human health. This is also a time for physicians to renew their commitment to advocating for health as a human right.

We are optimistic that knowledge from important fields of NIH-funded research will contribute significantly to our progress in achieving affordable and high-quality health care for all Americans. Research gives us the mechanism to improve health outcomes by developing and disseminating evidence-based information to patients, clinicians, and other decision-makers about which interventions are most effective for which patients under specific circumstances. Research in the areas of health economics, health systems, health disparities, and personalized medicine will also undoubtedly inform the health care discussion in unique and important ways.

As physicians and scientists, we carry deep within us a belief that health is a human right and an understanding that when our health system does not adequately serve many of our fellow Americans we must change it. Biomedical research offers hope to improve vaccines, therapeutics, devices, and health system approaches that will bring health and security to the nation. This health care discussion is not solely about our nation's health; it is also a testament to our commitment to civility and to the protection of core human values. ■

[2] "History of Medicine," in Box 6, MS C 186, Elizabeth Pritchard Papers, National Library of Medicine, Washington, D.C.

Ronald M. George

Chief Justice of California

The Perils of Direct Democracy: The California Experience

I am honored to speak as a representative of the new class of Academy members. I would like to share some thoughts on a matter that has been of recent and continued professional concern to me but that I believe may be of general interest to members of the Academy because it fundamentally implicates how we govern ourselves. This is the increasing use of the ballot initiative process available in many states to effect constitutional and statutory changes in the law, especially in the structure and powers of government.

A not-too-subtle clue to my point of view is reflected in the caption I have chosen for these remarks: "The Perils of Direct Democracy: The California Experience." Although two dozen states in our nation permit government by voter initiative, in no other state is the practice as extreme as in California.

By the terms of its constitution, California permits a relatively small number of petition signers – equal to at least 8 percent of the voters in the last gubernatorial election – to place before the voters a proposal to amend any aspect of our constitution. (The figure is only 5 percent for a proposed nonconstitutional statutory enactment.) If approved by a simple majority of those voting

at the next election, the initiative measure goes into effect on the following day.

The legislature (by two-thirds vote of each house) shares with the voters the power to place proposed constitutional amendments before the electorate. California, however, is unique among all American jurisdictions in prohibiting its legislature, without express voter approval, from amending or repealing even a statutory measure enacted by the voters unless the initiative measure itself specifically confers such authority upon the legislature.

The process for amending California's Constitution thus is considerably easier than the amendment process embodied in the United States Constitution, under which an amendment may be proposed either by a vote of two-thirds of each house of Congress or by a convention called on the application of the legislatures of two-thirds of the states. An amendment can be ratified only by the legislatures of (or by conventions held in) three-quarters of the states.

The relative ease with which the California Constitution can be amended is dramatically illustrated by the frequency with which this has occurred. Only seventeen amendments to the United States Constitution (in addition to the Bill of Rights, ratified in 1791) have been adopted since that document was ratified in 1788. In contrast, more than 500 amendments to the California Constitution have been adopted since ratification of California's current constitution in 1879.

Former United States Supreme Court Justice Hugo Black was known to pride himself on carrying in his pocket a slender pamphlet containing the federal Constitution in its entirety. I could not emulate that practice with California's constitutional counterpart.

One bar leader has observed, "California's current constitution rivals India's for being the longest and most convoluted in the world. . . . [W]ith the cumulative dross of past voter initiatives incorporated, [it] is a document that assures chaos."

Initiatives have enshrined a myriad of provisions into California's constitutional charter, including a prohibition on the use of gill nets and a measure regulating the confinement of barnyard fowl in coops.

This last constitutional amendment was enacted on the same 2008 ballot that amended the state constitution to override the California Supreme Court's decision recognizing the right of same-sex couples to marry. Chickens gained valuable rights in California on the same day that gay men and lesbians lost them.

Perhaps most consequential in their impact on the ability of California state and local government to function are constitutional and statutory mandates and prohibitions – often at cross-purposes – limiting how elected officials may raise and spend revenue. California's lawmakers, and the state itself, have been placed in a fiscal straitjacket by a steep two-thirds-vote requirement – imposed at the ballot box – for raising taxes. A similar supermajoritarian requirement governs passage of the state budget. This situation is compounded by voter initiative measures that have imposed severe restrictions upon increases in the assessed value of real property that is subject to property tax, coupled with constitutional requirements of specified levels of financial support for public transportation and public schools.

Frequent amendments – coupled with the implicit threat of more in the future – have rendered our state government dysfunctional, at least in times of severe economic decline.

These constraints upon elected officials – when combined with a lack of political will (on the part of some) to curb spending and (on the part of others) to raise taxes – often make a third alternative, borrowing, the most attractive option (at least until the bankers say "no").

Much of this constitutional and statutory structure has been brought about not by legislative fact-gathering and deliberation but by the approval of voter initiative measures, often funded by special interests. These interests are allowed under the law to pay a bounty to signature-gatherers for each signer. Frequent amendments – coupled with the implicit threat of more in the future – have rendered our state government dysfunctional, at least in times of severe economic decline.

Because of voter initiatives restricting the taxing powers that the legislature may exercise, California's tax structure is particularly dependent upon fluctuating types of revenue, giving rise to a "boom or bust" economic cycle. The consequences this year have been devastating to programs that, for example, provide food to poor children and health care for the elderly disabled. This year's fiscal crisis also has caused the Judicial Council, which I chair, to take the reluctant and unprecedented step of closing all courts in our state one day a month. That decision will enable us to offset approximately one-fourth of the more than $400 million reduction imposed by the other two branches of government on the $4 billion budget of our court system.

The voter initiative process places additional burdens upon the judicial branch. The court over which I preside frequently is called upon to resolve legal challenges to voter initiatives. Needless to say, we incur the displeasure of the voting public when, in the course of performing our constitutional duties as judges, we are compelled to invalidate such a measure.

On occasion, we are confronted with a pre-election lawsuit that causes us to remove an initiative proposal from the ballot because, by combining insufficiently related issues, it violates our state constitution's single-subject limitation on such measures. At other times, a voter initiative – perhaps poorly drafted and ambiguous or faced with a competing or "dueling" measure that passed at the same election – requires years of successive litigation in the courts to ferret out its intended meaning and ultimately may have to be invalidated in whole or in part.

One thing is fairly certain, however. If a proposal, whatever its nature, is sufficiently funded by its backers, it most likely will obtain the requisite number of signatures

to qualify for the ballot; if it does qualify, the chances are good that the measure will pass. The converse certainly is true: poorly funded efforts, without sufficient backing to mount an expensive television campaign, are highly unlikely to succeed, whatever their merit.

This dysfunctional situation has led some to call for the convening of a convention to write a new constitution for California to replace our current 1879 charter, which in turn supplanted the original 1849 document. Yet, although a recent poll reflects that 79 percent of Californians say the state is moving in the wrong direction, only 33 percent believe that the state's constitution requires "major" changes, and approximately 60 percent are of the view that decisions made by Californians through the initiative process are better than those made by the legislature and the governor.

Californians may need to consider some fundamental reform of the voter initiative process. Otherwise, I am concerned we shall continue on a course of dysfunctional state government, characterized by a lack of accountability on the part of our officeholders as well as the voting public.

Add to this mix a split among scholars concerning whether a constitutional convention, if called, could be limited in the subject matter it is empowered to consider. Some argue that a convention would be open to every type of proposal from any source, including social activists and special interest groups. There also is controversy over the most appropriate procedure for selecting delegates for such a convention.

A student of government might reasonably ask: Does the voter initiative, a product of the populist movement that reached its high point in the early twentieth century in the midwestern and western states, remain a positive contribution in the form in which it now exists in twenty-first-century California? Or, despite its original objective – to curtail special interests, such as the railroads, that controlled the legislature of California and of some other states – has the voter initiative become the tool of the very types of special interests it was intended to control, and an impediment to the effective functioning of a true democratic process?

John Adams, who I believe never would have supported a voter initiative process like California's, cautioned that "democracy never lasts long . . . There is never a democracy that did not commit suicide." The nation's Founding Fathers, wary of the potential excesses of direct democracy, established a republic with a carefully crafted system of representative democracy. This system was characterized by checks and balances that conferred authority upon the officeholders of our three branches of government in a manner designed to enable them to curtail excesses engaged in by their sister branches.

Perhaps with the dangers of direct democracy in mind, Benjamin Franklin gave his much-quoted response to a question posed by a resident of Philadelphia after the adjournment of the Constitutional Convention in 1787. Asked the type of government that had been established by the delegates, Franklin responded, "It would be a republic, if you can keep it." As Justice David Souter recently observed in quoting this exchange, Franklin "understood that a republic can be lost."

At a minimum, in order to avoid such a loss, Californians may need to consider some fundamental reform of the voter initiative process. Otherwise, I am concerned we shall continue on a course of dysfunctional state government, characterized by a lack of accountability on the part of our officeholders as well as the voting public. ■

Edward Villella

Founding Artistic Director and Chief Executive Officer, Miami City Ballet

The Art of Life

I can divide my life into two distinct periods: life before my exposure to the arts and life after my exposure to the arts. Before the arts, I was a feisty kid with an abundance of physicality from the blue collar community of Bayside, Queens. I channeled my physicality into sandlot baseball and high school and college varsity athletics. While attending the New York State Maritime College, I added to my constant need to learn, move, and be physical a higher education in commerce and the military. However, it wasn't until George Balanchine invited me to join his company, the New York City Ballet, that I had my first serious exposure to art and a completely different kind of physicality. What I experienced and learned there utterly transformed my life. I discovered a mind-driven physicality: dance, what Balanchine called "the poetry of gesture." Once that discovery crossed my horizon and I began my sojourn as a dancer in Balanchine's singular world, my life was unalterably changed, and I never looked back.

As a dancer, I could live the Greek ideal of a balanced life of the mind and the body. And I had the rare privilege of working with two of the twentieth century's greatest cre-

ative minds: George Balanchine and Igor Stravinsky. Their collaborations produced masterworks, and when I had the opportunity to approach these works as a dancer I knew I was in the presence of their minds and an articulation of their remarkable genius. That opportunity was both exhilarating and terrifying.

When Balanchine gave me the extraordinary role of his and Stravinsky's Apollo to prepare for performance, I could not have achieved what I did without first absorbing the wealth of information and experience that he had to impart about his creation. In the time-honored custom of our field, passing knowledge and experience from body to body and mind to mind, the genius conveyed to the neophyte his insights and thoughts about the role. Imagine what it was like for me as a young artist, filled with an enormous desire to learn, to be the beneficiary of what the master had to teach me about his Apollo. He provided his points of departure, made sense of abstract gesture, and then helped me to understand it. During this transmittal of knowledge, Balanchine demonstrated one gesture that was completely revelatory, a gesture that both built the characterization and defined the character of Apollo. The characterization of a choreographic master's Greek god was ripe with images of swooping eagles, matadors, chariot drivers, soccer players, and bicycle riders. This process of teaching and learning, giving and receiving, provided me with an artful approach to prepare for my future roles.

As an athlete, I could lift. As a dancer, I had to lift, but more particularly, to partner and look after another dancer colleague. Partnering is an intimacy of physical conversation, a mutual exchange of dependence and trust. Two bodies and two minds working together as one whole.

For the past fifty years, I have devoted myself to the art form of dance, particularly classical ballet, first as a dancer, then as a teacher and artistic director. Dance has taught me so many lessons and enriched my life in more ways than I can ever describe; it gave me the ability to speak in silence, to animate movement in the most sophisticated ways, to physicalize music, to see the honesty of art, and to know what is correct, the one possibility that is right. Dance has inspired me to seek what is ideal, what is unattainable – perfection. Dance required me to understand human behavior and develop the ability to express it theatrically and to express human relationships in the context of historical period and style and then to link this understanding back to line and form. Dance showed me how to swim in time through designated space with gestures of integrity. Dance taught me how to respond to the music with a keen understanding of the intimacies of timing in relationship to the architecture of the score. Dance illuminated how abstraction is an idea reduced to its essence, and how the physical expression of that essential idea through qualitative entertainment can produce human pleasure. Dance revealed clarity by teaching me to recognize what is not necessary and how to be economical with gesture. Dance taught me how to portray emotion, and in the process I learned a way to be aware of and help control life's emotions. Dance gave me discipline and formal structure, but it also gave me the freedom and knowledge to move with artistic ease, removing all tensions in both body and mind. A good life lesson.

Dance gave me the ability to speak in silence, to animate movement in the most sophisticated ways, to physicalize music, to see the honesty of art, and to know what is correct, the one possibility that is right.

Time eventually deprives us of the pleasure of active portrayal. This inevitability, however, provides us with a different type of pleasure and an opportunity to repay an accumulated debt. I have traveled a great distance from the position in which I started – that of the neophyte receiving precious information from the master – to one filled with an enormous desire to preserve that information as authentically as possible and to pass it on to the next generations of dancers. Twenty-five years ago, this desire coupled with my desire to repay a debt to a genius and the teachers and mentors who gave me a life, a life of art, led me to create another entity, Miami City Ballet, as a vehicle to continue sharing with the world what these masters taught.

Fifty years ago, when I started my career as a dancer, it seemed clear to me, as it still does now, that to live with an understanding of music, dance, art, elegance, and nobility could be a point of departure for a life role, the art of life. ■

Kent Kresa

Chairman Emeritus, Northrop Grumman Corporation

Space Robots Deserve More Respect

As you may have noticed from media reports, on October 9, 2009, NASA successfully carried out an important research mission on the moon using a two-component satellite named LCROSS (Lunar Crater Observing and Sensing Satellite). One part of this unmanned vehicle was designed to crash into a moon crater while the other monitored the twenty-five-mile-high debris plume created by the collision. The objective was to assess lunar soil for the possible existence of hydrated minerals, ice crystals, and hydrocarbons.

I have been thinking about LCROSS and NASA's many other impressive robotic missions in my preparations for this talk. It occurred to me that a brief consideration of what sort of value we place on robots might be a good way to engage both the arts and the sciences communities within the Academy. Doing so would also enable me to touch on a subject currently much discussed: the respective roles of robotic and human exploration activities in America's future space program.

Many with a strong humanities bias see unmanned systems as primitive and unexciting. In contrast, some in the science and engineering community view the human space programs envisioned by NASA as too costly when compared to what might be achieved with robots. Both these extreme positions contain valid arguments as well as misconceptions.

As an engineer, I'll try to present the unmanned case and leave it to others to explain manned space exploration. However, I won't try to predict or influence policy decisions. My objective today is far less ambitious. I simply want to encourage more respect for robots from their skeptics.

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The obstacle I face is clear if you consider how we human beings view ourselves. Most of us think Shakespeare's Hamlet was on target when he said, "What a piece of work is a man! How noble in reason, how infinite in faculty." This view of humanity has given robots a serious image problem, even from their earliest days.

I remember that my grandfather didn't want to ride in an elevator that wasn't run by a human operator. And my father would never trust an unmanned train. They had their concerns about reliability and safety, which are well resolved by now. For my own and later generations, elevators are no problem, and the only weak link in unmanned trains is the inability of human riders to remember their exit stations.

Most of us are not prepared to fly in an unmanned airplane, however, although the capability exists. This mode of transport could become commonplace for our children or grandchildren, though, as they get comfortable with that vehicle's safe performance.

Today's robots have transcended the simple heavy-lifting roles of elevators and trains and even the more complex assembly tasks of automated factories. They now manage networked systems that perform higher-level human functions like surveillance, decision-making, and communication and do so with far more effectiveness than human operators are capable of.

One thinks, for instance, of a fighter plane's fire control system that, without human assistance, rapidly collects surveillance input from the battlespace, uses GPS data to generate coordinates of enemy targets, and communicates this information by satellite to air and ground platforms best positioned to prosecute an attack. These higher-level functions will increasingly be performed by unmanned aircraft able to operate where human pilots cannot, in battlespaces that pose extraordinary risks or are situated at distances exceeding human endurance levels.

Unmanned systems are also capable of ad hoc adaptability: they can be reconfigured for alternative tasks by remote programmers. This sophisticated technology has only recently been available, and the level of adaptability is increasing as fast as Moore's Law has increased computer memory.

Over the last twenty to thirty years, unmanned systems have accomplished a sizable portion of the explorer's dream. Satellites have taken long-distance measurements. Space probes landing on or flying by all of the planets in our solar system have collected information and sent it back to analysts on Earth. The Voyager interstellar mission and others have sent unmanned systems beyond our solar system. Until recently, however, some scientists saw these efforts as more limited than what would

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have been achieved had human explorers, with their superior investigative powers and flexibility, been able to go on these voyages.

Today, however, this picture is changing. Greatly increased computer power, fuzzy logic, and software advances enable engineers remotely managing a telescope like Hubble to reprogram complex observations. Similarly, robots exploring or digging samples on the surface of a planet are sophisticated enough to adapt their approaches to unexpected circumstances. The Martian rovers *Spirit* and *Opportunity* come to mind. This adaptability still falls short of human levels, but the gap is closing fast.

Other important considerations that favor robots are cost and endurance. As one would expect, the cost of human voyages is dramatically higher than for robots. A rocket carrying human beings must launch and transport far more weight because it must carry a life-support system that provides all the sustenance and protections of an Earth environment and must support a round-trip journey. Because unmanned systems have such a huge design and cost advantage, they become an increasingly serious exploration alternative, particularly as their investigative abilities move closer to those of human beings.

At present, unmanned systems represent the *only* option for deep-space exploration. Space, like the military battlespace, presents dangers and distances that human beings cannot deal with, at least not for the foreseeable future. For example, until technology evolves, human beings cannot realize NASA's hope of exploring Jupiter's Europa system because it sits in the Jovian radiation belt. Distances are a major impediment to human space travel if we assume no advance over current chemical propulsion technology. Travel to Mars now takes a year with current technology, four or five years to get to Jupiter, and thirty to reach Pluto. Given the extreme difficulty of sustaining life support for long-distance journeys, consideration of any objective beyond Mars is at present out of the question. Recruiting explorers will also become tougher when they are being asked to travel for several decades before coming home.

Robots face no such difficulties, however; they have few limits on their travel, research, and reports. In fact, a robot might even undertake the multigenerational voyage that would be required for reaching another solar system. Upon reaching its destination, it would carry out its investigation designed many years earlier and communicate the results – with some communication delay – to engineers on Earth.

Robots may not be Shakespeare's "paragon of animals," though their resume has expanded. Nor are they heroic explorers like Columbus, Magellan, or the Apollo astronauts. Still, for those of us who value a healthy integration of the humanities and sciences, robots are an extension of ourselves. They represent humanity's questing spirit but leverage science to reach places and see worlds that human hands will never touch. I encourage you to join me in respecting and honoring them for their exciting discoveries, reliable expertise, and ability to go the distance. ■