# Trust and Accountability in Science and Technology

Summary of Discussions from the California Council on Science and Technology (CCST) Council Meeting

October 19, 2010

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## Introduction

On October 19, 2010, members and guests of the California Council on Science and Technology (CCST) gathered at the Arnold and Mabel Beckman Center of the National Academies in Irvine, California. After a brief update about CCST's current portfolio of initiatives and activities, the group heard from speakers exploring the issues of trust and accountability from different perspectives. These included:

- Scoping the issues of trust and accountability,
- What modeling of complex systems — from climate change to engineering to public education pipelines — can and cannot tell us,
- The science of trust (as illustrated by a neuroscientist's research on oxycotin), and
- From the cosmos to the legislative chamber — highlights from the experiences of CCST's first cohort of science and technology fellows completing a year in various legislative offices in Sacramento.

Each of these is summarized below, along with comments and questions from other participants. A list of participants and a brief list of resources and background papers are provided in appendices.

## CCST Overview — Susan Hackwood

***Susan Hackwood, Ph.D.**, is CCST's Executive Director and Professor of Electrical Engineering at the University of California, Riverside, where she also served as founding Dean of the school's Bourns College of Engineering.*

Dr. Hackwood launched CCST's fall meeting with an overview of the organization and its current portfolio of activities. The non-profit Council brings together California's pre-eminent science and technology leaders, who collectively provide credible, independent and objective guidance on public policy issues involving science and technology.

Current initiatives include:

- The new **Science and Technology Fellows Program**, which is a 5-year pilot program modeled after the national American Association for the Advancement of Science (AAAS) Congressional Science and Technology Fellows Program. In California's version (the first such state-level program), Ph.D.-level or equivalent scientists and engineers from all over the country receive specialized training and support to serve for a year in Assembly and Senate legislative offices. (Three of the 2009-2010 Fellows joined the Council meeting; they shared their experiences during a panel discussion that is summarized later in this report.) In this role, they answer questions from legislators and their staff, help interpret scientific (and pseudo-scientific) studies and data, develop ideas and language for bills, and prepare reports on specific topics.

- A **Personalized Healthcare** pilot program involves a prototype of electronic health record (EHR) platforms that incorporates genomic and genetic information as part of the records — with the information accessible not only to clinicians, but by patients themselves. The initial prototype is testing the domain of breast cancer diagnosis and treatment, with an Ontology Panel convened to explore how information on this domain could be aggregated, integrated, and evaluated. The initial results, which should be available early in 2011, will include an open-source application ontology that will form the basis for integrating clinical and genomic data, for breast cancer as well as other diseases and conditions.

- A project assessing **California's Energy Future** is in its final stages, with a final report on its way through the peer review process. The report addresses the gap between existing and needed technological solutions required if

California intends to meet its aggressive 2050 target of reducing greenhouse gases to 80% below 1990 levels.

- Another successful California initiative modeled on a national one is the **California Teacher Advisory Council (Cal TAC)**, which convenes 12 outstanding science and mathematics teachers to bring the voice of classroom teachers into education policy debates and decisions. The group's second symposium, to be held just after the CCST meeting, addresses formative and summative assessments. On the roster for 2011 is a project to inform innovation work on digitally designed education, inside and outside the classroom.

- An unusual bipartisan, bicameral request asks CCST to assess **California's innovation infrastructure.** In response, CCST is convening a series of regional meetings across the state this fall that will culminate in a report and briefing for the legislature and California's new governor. The meetings and reports will explore barriers to innovation and productivity and ways to overcome these with "game-changing" strategies designed to improve the state's competitive edge in science and technology innovation.

- Two legislators have asked CCST to answer the question: "Are there health and safety issues regarding the new **SmartMeters** being installed by utilities?" CCST has convened a group of over two dozen technical experts to provide their input, with a project team chaired by CCST Board Member Rollin Richmond. In this effort, particular attention is being paid to conflicts of interest.

- CCST took advantage of a recent report on NASA's future and ongoing budget discussions to visit Washington, DC and inform California's Congressional delegation about the instrumental role that **NASA Federal Laboratories** play in the state's economy. A similar visit to the Department of Energy to heighten awareness of the California laboratories' role and contributions is scheduled for the spring of 2011.

Dr. Hackwood ended her overview with a picture of CCST members — *incognito* behind their 3-D glasses — joining 250 policymakers and staff from the California Space Authority on an outing to a private screening of Hubble 3D at the Sacramento Imax theater. Dr. Hackwood urged those who have not yet seen the film to find a nearby venue without delay, noting how effective the film's "wow factor" was in conveying both the complexity of the science that went into building the Hubble and what it is revealing from an intimate look at galaxies 800 million light years away, as well as the human side of the effort.

## Setting the Scope

To set the stage for a discussion about trust and accountability in science and technology, Charles Kennel, Bruce Alberts, and Gary Marchant offered some of their reflections.

### The Climate Debate — Charles Kennel

***Charles Kennel, Ph.D.,*** *Council Chair, is Distinguished Professor of Atmospheric Science, Scripps Institution of Oceanography and Founding Director and Chairman, International Advisory Board, Environment and Sustainability Initiative, University of California, San Diego*

Dr. Kennel gave the group an overview of the history of climate change research and some of the more recent events collectively referred to as "Climategate," both as a personal reflection on issues of trust and accountability in science and as a preview to later comments by Ben Santer on climate change models.

*Measuring Climate Change: The Origins of the Discipline of Earth Sciences*

Dr. Kennel's timeline and story begin in 1957, when Charles David Keeling — soon to become the Director of the Scripps Institution of Oceanography — developed the first instrument to measure carbon dioxide ($CO_2$) in atmospheric samples and began collecting data.

Three years into his data collection, Dr. Keeling documented increasing levels of $CO_2$, consistent with the atmospheric input of burning fossil fuels. Despite these early results, it would be another 22 years before controversy over the quality of these measurements was resolved, in the form of a 1979 National Academy of Sciences report from a committee chaired by Massachusetts Institute of Technology meteorologist Jule Charney.

In the 1979 report, Dr. Charney and his colleagues predicted that if current rates of $CO_2$ emissions continued, we could expect an increase in temperatures to exceed natural climate fluctuations — i.e., global warming — by the year 2000. The report stimulated a great deal of scientific inquiry and activity, led in part by NASA, to better understand contemporary climate conditions and forecast changes in these conditions more accurately into the coming decades. These efforts became a new earth sciences discipline (and its offshoot, earth systems science), which together examined the ways that components of the earth, atmosphere, oceans and solar observations could be understood in terms of their implications for forecasting climate change.

### *The Intergovernmental Panel on Climate Change (IPCC)*

At the same time, parallel efforts were underway at the international level to consolidate the data streaming in from different subdisciplines of earth science, in order to make more reliable statements about the present and future climate. These efforts coalesced under the aegis of the Intergovernmental Panel on Climate Change (IPCC), convened by the United Nations, whose first report was released in 1988.

The IPCC's 1988 report took the stance that climate change accelerated by human activity was a plausible idea, consistent with the basic science, but that the evidence for this conclusion did not yet exist. The panel recommended areas of inquiry that could yield such evidence in the future, and recommended periodic assessments to continue to examine and document the issue. Nearly two decades later, the most recent of these assessments, released in 2007, pronounced the evidence for human causes of climate change "undeniable." (The next assessment and report, now underway, will be completed in 2012.)

Anticipating challenges to the IPCC's work and conclusions, the panel's founders went to great lengths to avoid the appearance of conflicts of interest. They recruited experts from the relevant fields, each of whom had a track record of peer-reviewed research and publications, but they tried to balance the composition of each panel with a diversity of views within the scientific subdisciplines in each field. Panelists were recruited from both oil-producing and oil-consuming nations, and turnover of individual panelists — to avoid accusations that they were permanent, vested (and therefore biased) IPCC members — was built in, with relatively few scientists serving continuously from one panel to the next.

The 2007 panel included 800 members, who labored for 2 years to produce the report that garnered them (with Al Gore) the Nobel Peace Prize that year. Thousands of peer-reviewed publications were reviewed rigorously, with strict rules about which of these passed scientific muster for inclusion.

### *Climate Change "Auditors" and "Denialists" Join the Fray*

In retrospect, the Nobel Peace Prize represents a pinnacle from which climate change science soon plummeted, perhaps irrevocably. Vigorous opposition to the IPCC findings, which had been brewing during the report's release and attendant publicity, reached a crescendo as attention turned to the 2009 Copenhagen Conference on Climate Change. For the most part, those who objected to the IPCC's climate change conclusions did not pursue these arguments in the scientific, peer-reviewed literature, but instead turned to the public media.

In the public media, unlike the scientific literature, standards of ethics and fairness dictate a "hearing" for alternate points of view, even if the validity of each side's evidence or arguments may not be comparable. Certainly, the science underlying global models of climate change was (and remains) far from perfect, so individual strands of reasoning or particular conclusions were vulnerable to scrutiny and dissent.

Dr. Kennel noted that those who question particular aspects of the science in this way can be thought of as "auditors." Like the auditors of publicly held companies, they have enough training and skills to examine the scientific credibility underlying various conclusions. (However, they may not have the skills or capacity to judge the complexity and interactions of the systems involved in climate change.)

While the "auditors" challenged pieces of the climate change science from a scientific (or at least quasi-scientific) perspective, another group objected to the IPCC's conclusions for very different reasons. This group, the "denialists," would prefer that the problem of climate change did not exist (because they see the costs of intervention as unacceptably high, or do not believe in interfering with market forces, or hold similar philosophical and ideological beliefs). While the "auditors" might amplify a particular flaw or chain of evidence while ignoring the overall weight of the evidence and conclusions, the "denialists" would amplify any evidence that minimized the importance or very existence of climate change.

Together, the "auditors" and "denialists" were able to use the public media to sow doubt about the IPCC's conclusions and the implications of the scientists' work. In contrast to the scientific community, the court of public opinion — and many politicians — concluded that there was legitimate scientific controversy about the existence and degree of climate change.

### *The University of East Anglia e-mails*

In 2009, before the Copenhagen Conference, hackers obtained internal e-mails among members of the Climate Science Group at the University of East Anglia. The e-mails, covering approximately 10 years of back-and-forth exchanges among the scientists and their colleagues, were selectively released — and made to look as if the scientists had manipulated data to fit their foregone conclusions about climate change.

Upon closer examination, Dr. Kennel said, the e-mails revealed something quite different, and more human than sinister. First, they demonstrated a high level of frustration and resentment as the scientists responded to repeated requests for data from various "auditors" questioning their work. Second, the scientists had deleted some data in which they had little confidence, which had altered the curve from what it would have been with the data included.

In the public press, the hacked e-mails were presented as evidence of unreliable and suppressed climate change data, leading to suspect conclusions.

In response, several panels were convened to investigate the accusations, including one within the British Parliament and others from within the university. The Parliamentary panel members said they were not equipped to judge the validity of the science, but did find that the university had not provided adequate support to the scientists dealing with a barrage of Freedom of Information Act (FOIA) requests for their data.

### *Painful Lessons — and New Questions*

Although most of the investigative panels released their results quickly, within months of the Copenhagen Conference, the damage was done — and appears to be persisting. A Pew Center on Public Opinion poll tracking trust in scientists recorded a steep 25-point drop in the 3-month period following the Conference. The investigative panels may have reassured the scientific community, Dr. Kennel noted, but they did not restore the public's trust in scientists.

To Dr. Kennel, the example of climate change is only the latest example of historical clashes between how scientists interact with society, going back to Galileo and Darwin, among others. "It is a much broader issue than climate change," he noted, but "climate change is a revealing test case."

## The National Academies — Bruce Alberts

***Bruce Alberts**, Ph.D., a biochemist and CCST Board Member, serves as Editor-in-Chief of* Science *and as a United States Science Envoy. Dr. Alberts is also Professor Emeritus in the Department of Biochemistry and Biophysics at the University of California, San Francisco, to which he returned after serving two 6-year terms as the president of the National Academy of Sciences (NAS).*

Dr. Alberts emphasized three imperatives that struck him as he reflected on the topic of trust and accountability in science:

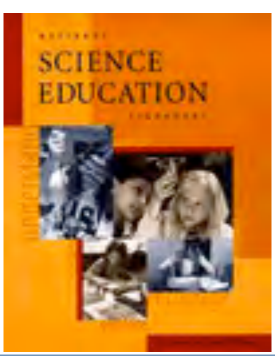
- **science education** needs,
- the need to **"make a science" of answering questions about increasing the public's trust in science**, and
- the need to do more to stress and inculcate **ethics** within our scientific communities.

*Science Education*

Recently, in preparation for a third edition of a series of books NAS has published on science and creationism, NAS commissioned focus group research in an attempt to understand why these books — and other science education efforts — appeared to be so ineffective.

Behind a one-way glass mirror, just as if the subject at hand were the pros and cons of a new brand of soap, a professional moderator led groups of 10 college-educated adults (all of whom had at least some high school or college-level science education) in discussions that explored their beliefs about religion and science.

Most striking, said Dr. Alberts, was the fact that many of the adults in these focus groups made no distinction between how scientists determine what is right, and how religious people do. According to the focus group participants, both scientific and religious "findings" are a kind of dogma — comparable but mutually exclusive dogma — and people are essentially free to choose one or the other. As one participant put it, "Science is revealed truth from scientists; religion is revealed truth from prophets."




For decades, the National Academies have been very active in science education, Dr. Alberts said, producing a report setting forth national science education standards in 1996. A 2007 update of the proposed standards, noting the lack of progress, proposed a framework for science education anchored by four fundamental science learning goals for students:

1. They should be able to **know, use, and interpret scientific explanations of the natural world.** Dr. Alberts pointed out that while almost all students are exposed to the "know" part of this equation, few are stimulated or encouraged to move beyond this to using and interpreting what they learn.

2. They should be able to **generate and evaluate scientific evidence and explanations.** The "Climategate" scandal shows how relevant — and rare — this set of skills is among the general public.

3. They should be able to **understand the nature and development of scientific knowledge.** Again, "Climategate" is a telling example of how gaps in understanding the scientific process make people vulnerable to misinformation.

4. They should be able to **participate productively in scientific practices and discourse.**

The second and fourth of these strands, Dr. Alberts observed, can only be taught through active inquiry. They cannot be conveyed by what has become the default mode for science education today: a teacher lecturing in front of a class, handing out fill-in-the-blanks study sheets for students to fill out after consulting a textbook (as, he lamented, is the case in his grandchildren's science classroom).

*"College defines what science education is. If we don't change the college level, we can't change the lower levels of science education."*

Dr. Alberts is optimistic that variations based on these common science education standards will be adopted by many states, as comparable mathematics standards have been. Even though these standards are focused on K-12 education, Dr. Alberts pointed out that the most profound implications are for college-level science education, because "College defines what science education is. If we don't change the college level, we can't change the lower levels of science education."

Dr. Alberts foresees many advantages of meeting this challenge, beyond science education itself. First, he said, the more active engagement in learning helps to retain the curiosity and energy for learning that young children naturally bring to kindergarten, but often lose as they move into higher grades. Dr. Alberts described a room full of second graders thrilled with the mystery of magnetic filings, contrasted with a bored group of eighth-grade science students, dreading science class. "It's completely unnecessary," Dr. Alberts said, "but you can see why they feel that way, when you see what's going on in those classes."

A different approach to science education also opens up more possibilities for children to excel at something in class — critical for their motivation (and particularly so for minority and low-income students). In addition, a generation of energized, curious, and motivated science students can grow into a nation of "can-do" problem solvers — who, in addition to their problem-solving skills, have the critical thinking skills to insulate and protect themselves from the deluge of misinformation presented in scams, televised rants, and talk radio. Of the 20-plus Republican Senatorial candidates, Dr. Alberts commented, only one had gone on the record as believing that human activity has played a role in climate change.

*Making a Science of Answering Questions About How to Increase the Public's Trust in Science*

> ***"These are researchable questions that have not been well researched."***

Whether and how a different approach to science education makes a difference — for instance, in being able to assess and weigh arguments and information, a belief in scientific discoveries, and general trust in science — requires some experiments. "These are researchable questions," Dr. Alberts said, "that have not been well researched."

The NAS focus group research he mentioned earlier is part of the effort to understand what people believe and why they are not more trusting of science, its methods, and its conclusions. Experiments could be devised to see whether those trends and outcomes could be shifted. Dr. Alberts believes this is potentially a very important role for CCST — especially because no one else is focusing on it.

*Stressing and Inculcating Ethics into Our Scientific Communities*

Although the vast majority of scientists are honest, the steady news about scientific scandals — from Korean claims of human cloning to manipulated data in a Harvard laboratory — takes its toll on the public's trust. "We need to do a lot more to really bring down the wrath of the scientific community on people who violate that trust," Dr. Alberts concluded. "Scientists *must* be able to trust each other's reporting of data."

## Public Understanding of Science and the Government's Role — Gary Marchant

***Gary Marchant**, J.D., Ph.D., is an Associate Professor of Law at Arizona State University, where he also serves as the Executive Director of the Center for the Study of Law, Science, and Technology. Prior to joining the ASU faculty in 1999, he was a partner at the Washington, D.C. office of the law firm of Kirkland & Ellis, where his practice focused on environmental and administrative law. Dr. Marchant's research and teaching interests include environmental law, risk analysis, genetics and the law, and law, science and technology.*

Dr. Marchant's observations about the public's understanding of science centered on the ways the government engages in science — or tries to. Although the public assumes and expects that the government will apply science to ensure our safety and protect us, Dr. Marchant said, in fact there are many inherent limitations in the government's ability to do so.

> ***"From safe saccharin levels to mad cow disease to the safety of genetically modified foods, the public looks to government for definitive answers that it cannot provide."***

- **Uncertainty**. The inherent uncertainty of science, Dr. Marchant said, poses a dilemma for regulators, who often seek much more definitive answers than data and analytic tools can provide. In some cases, we even have different branches of the same government agency arriving at opposite conclusions — as was the case with the FDA and the diabetes drug Avandia.
- **Expectations**. When regulatory agencies look to science for guidance on setting a particular standard (such as what level of air pollution is safe), they are in essence using scientific "cover" to insulate decision makers from the courts or other challenges. In the long run, Dr. Marchant believes, this ends up undercutting science, because people feel let down. When science is asked to resolve questions that are more political or ethnical in nature, expectations are not met. The mismatch between what science is asked to do and what it can deliver has been described as the "science charade."
- **Quality** (or lack thereof). The funding levels for science within government agencies are going down, not up — even as the number and complexity of issues continues to increase. Funding aside, Dr. Marchant said, the quality of science within government agencies is uneven (as documented in the recent *Safeguarding the Future report*). The status of science within agencies as varied as the Environmental Protection Agency (EPA) and Food and Drug Administration (FDA) is quite precarious, to the degree that these and other agencies are not in a position to meet their responsibilities for ensuring health and safety.

- **Conflicts of Interest**. Both the perception and reality of conflicts of interest are rife, with a revolving door between industry and government, members of government advisory panels funded by the drug companies whose products they are asked to assess, and accusations of junk science quickly leveled when conclusions are inconvenient.

- **Addressing Social and Ethical Concerns**. The advent of new technologies and genetic engineering raises concerns for the public that fall outside the realm of health and safety, and have more to do with moral, religious, and ethical issues. The "yuck factor," as Dr. Marchant described it, drove 50,000 people concerned about cloning animals to write to the FDA — which then responded that these issues are not its responsibility. Technically, that is true, Dr. Marchant conceded, but dismissing this outpouring of concern "is no way to run a railroad." Part of the problem, he noted, is that within science, we lack some of the expertise — from lawyers, economists, and ethicists — who could help frame and discuss these difficult issues more fruitfully. "We know cancer is bad," he said, "but is making big or small farms good or bad?" By avoiding these questions, science and government are left in the untenable position of saying that the public's concerns are out of bounds. "We have a real gap here," Dr. Marchant said, "and we have to figure out how to address what the public cares about."

- **Keeping Pace.** Science and technology are moving ahead so quickly, Dr. Marchant observed, that it is difficult for would-be monitors — ethicists and regulators — to catch up. As the Microsoft anti-trust case wound its way through the DC District Court system, Dr. Marchant pointed out, it was presenting arguments about an operating system that was already three generations old. Likewise, the Clean Water Act of 1972 defined water pollution from point sources common at that time — such as the pipes spewing wastewater from factories. Today, most water pollution stems from non-point sources (such as agricultural run-off) — yet these were not covered by the Clean Water Act and thus the main regulatory mechanism we rely on to control water pollution, while obsolete, remains in place because no one can figure out how to fix it.

What can be done to address these issues? Increased funding for science within federal agencies is needed, but that alone wouldn't solve the problem, Dr. Marchant said. Scientific integrity policies and efforts to require statutes or regulations to meet scientific criteria are also areas of current activity and attention.

Dr. Marchant would like to see scientific governance models that reflect more of a partnership with industry, non-governmental organizations, environmental groups, and the public in making these decisions, rather than relying on governmental rules and pronouncements. He described an effort in Europe to develop a scientific body to address food safety issues across the European Union (EU). The EU version functions much like the IPCC — it deals only with scientific issues and does not take on risk management, regulatory policy, or other implications of its work. In Dr. Marchant's view, this immunizes the scientists from political corruption to a much greater degree than is the case in the United States.

## What Modeling of Complex Systems Can and Cannot Tell Us

CCST Board Member Miriam John introduced three speakers — Ben Santer, Howard Hirano, and Chris Roe — each of whom made some observations about the potential and limitations of modeling.

### What Climate Change Models Can and Cannot Do

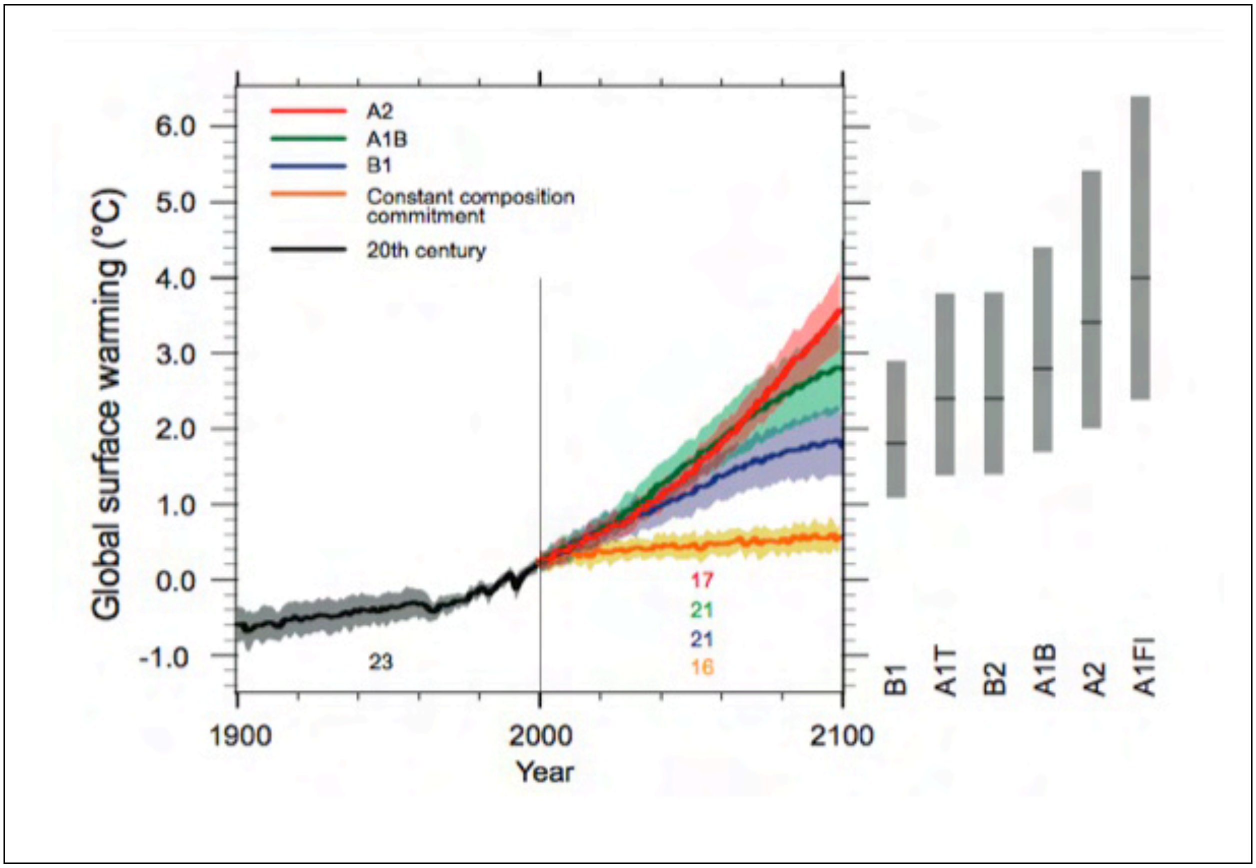
*Ben Santer is a research scientist at the Program for Climate Model Diagnosis and Intercomparison at the Lawrence Livermore National Laboratory, where he specializes in statistical analysis of climate data sets and the detection and attribution of climate change forcings. His research on global warming has been recognized with awards from the U.S. Department of Energy, World Meteorological Association, and MacArthur Foundation.*

Dr. Santer has had a long association with climate change research, serving as lead author of the detection chapter for the IPCC's 1995 report. That report, he noted, after years of deliberation, said that "the balance of the evidence suggests a discernible human influence on global climate." Subsequent reports in 2001 and 2007 found — and announced — even stronger evidence and conclusions. "I wish I could tell you it's all a hoax and a conspiracy," Dr. Santer said, "but it's not. Beyond the shadow of a doubt, we have changed the chemistry of the earth and its climate."

***"Beyond the shadow of a doubt, we have changed the chemistry of the earth and its climate."***

#### *What Climate Models **Can** Do*

Climate models offer a way to obtain information about the climatic shape of things to come, Dr. Santer explained, and really are the only tool available for understanding how these changes could unfold over a century. One of the most famous figures from the IPCC's 2007 report does just that, showing the projected changes in different scenarios between 2000 and 2100, starting with business as usual.




Unlike some other types of scientific inquiry, climate researchers cannot conduct systematic experimentation in the real world. Here, too, climate models can help, by performing the types of experiments that alter natural factors — the sun's energy output, levels of volcanic dust — and human forces, to see how these differ. When we use these models to try to explain the observed warming that has occurred in this century, Dr. Santer said, the models that include a combination of both natural and human forces match the observed effects. (Einstein would have loved climate models, Dr. Santer said.)

Climate change models also help us to estimate and understand the climate "fingerprints" caused by individual factors such as sulfate and volcanic aerosols, stratospheric and troposheric ozone, solar energy, well-mixed greenhouse gases — and all of these combined. The models conform to changes observed over the 20th century, and also validate some predictions from early experiments in the 1960s, which predicted but could not then measure the combination of a pronounced cooling of the upper atmosphere with a warming of the lower atmosphere. (This also refutes the often-cited explanation for observed global warming being caused solely by a slight increase in the sun's energy output — which does not fit the available data about cooling of the upper atmosphere.)

Models also help us understand whether human activities have changed the likelihood of unusual climate events such as the recent floods in Pakistan, or extreme heat waves in Europe and Siberia. By performing simulations that compare the likelihood of these events with and without human influence built into the model, we can confirm that human interventions do increase the risk of these events.

### *What Climate Models **Can't** Do*

Because of the uncertainty built into the models (both climate model uncertainty, and scenario uncertainty), the models cannot yield exact answers. Dr. Santer explained that since the most recent IPCC Assessment Report (from 2007), scientists have continued to develop innovative ways to reduce uncertainty and understand year-to-year fluctuations.

Another limitation is that no single model can do it all. The world now has over three dozen climate models developed by dozens of institutions from at least 20 different countries, but they are not of equal quality. Which are the most reliable for decisions about policies to stem or reverse climate change? Should differences in the models be reflected in "weighted" computer projections of future climate change? These questions already have become huge political issues for the next IPCC Assessment Report, Dr. Santer said, which is due in 2012.

A 2009 study by Dr Santer and his colleagues ranked two dozen models on the basis of 20 different performance metrics — and then repeated the process with a more complex set of 50 measures. In the first run, the top four models — American, Japanese, German and British — performed well in simulating average climate change today, but less so when the more complex set of performance metrics was used. For the time being, Dr. Santer said, although it is difficult to identify the best models, there appears to be enough virtue in having a collection of models to warrant their continued use.

### *Conclusions*

Climate models are the only credible tools we have for trying to understand the rate and magnitude of changes in climate as they unfold over the next century, what these changes will mean in terms of seasonal and geographic changes, the relative contributions of human and natural factors to these changes (historically, and looking ahead), and how human factors alter the likelihood of extreme climate events.

Despite these many virtues, climate models also have some limitations. For example, they can provide probabilities, but not exact answers. They cannot provide reliable information on regional-scale details of future climate change, which Dr. Santer believes will be an important issue. Currently, climate models also cannot provide reliable information on the contributions of ice sheet dynamics to sea level rise. "This is key, but we're not there yet," Dr. Santer said. And since there are many models and no single one does it all, we do not yet know which models will yield the most reliable climate change projections, Dr. Santer added.

Climate change models may have some limitations, but these do not in any way call into question the IPCC's (and others') conclusions that the earth is warming and that humans are culpable in some of that warming, Dr. Santer said. Moreover, despite claims to the contrary, the models have repeatedly and routinely been confronted with observations. Far from its portrayal during Climategate as a secretive, closed enterprise, climate modeling and the analysis of climate model situations is an open endeavor, Dr. Santer said, exposed to the world community.

Dr. Santer has spent most of the last two years defending his climate modeling work and that of his colleagues, responding to endless and time-consuming FOIA requests. He described the many and unprecedented tetrabytes of archived data now open to world scrutiny and expressed his frustration that that part of the Climategate story — and the exoneration of the scientists involved by five separate investigations — has never made it to the front pages of newspapers, the way the initial allegations did.

"Accountability is a two-way street," Dr. Santer said as he concluded his remarks. "When you accept government funding, you have to do the best science you can and publish the results in peer-reviewed literature." But funding agencies and professional societies have obligations, too, he added. "It's not enough to say, 'Here, do some research,' and then leave the scientists to fend for themselves under unjustified, politically motivated attacks." If we do not find ways to resolve this, Dr. Santer warned, "We risk not having our best and brightest there on the issues where we need them the most. They will be afraid and intimidated, unwilling to spend years of their careers being harassed."

Dr. Santer's presentation generated a number of comments about the fallout from Climategate. Some proposed making FOIA requests more costly — perhaps by charging a nominal fee to at least deflect some of the costs incurred by institutions. ("Freedom of information isn't free," as one participant put it.) The responsibility of institutions to support scientists — on this specific issue, and in other ways — was reiterated. And Dr. Santer's concern that anticipated harassment might drive scientists away from certain fields (such as climate research) was shared by others. "The way to solve this is to make climate science a national security issue," one suggested, only partly in jest, to make climate change research classified. Indeed, several participants noted that the Department of Defense takes climate change very seriously in its scenario planning all over the world.

## Models and Human Decision-making — Howard Hirano

***Howard Hirano*** *is manager of Sandia Laboratories' Advanced Technologies department, which develops tools to assist decision-makers involved in emergency response.*

In his systems analysis work at Sandia National Laboratories, Dr. Hirano explained, he and his colleagues define their job as researching and formulating a problem and then evaluating the relative value of various alternatives. Although the alternatives involve technology, the decisions and alternatives they test are not based on technology alone. For example, in the homeland security arena where Dr. Hirano does most of his work, the team is very aware that their adversaries are constantly innovating — and that this lends their efforts an extra layer of urgency. In this time-compressed environment, models are extremely useful in testing the performance of various alternatives.

In Dr. Hirano's work, his definition of a system includes scientific and technical features as well as the people who make decisions, because their thinking and reactions are crucial to the success of any scenario.

To illustrate how these different aspects of systems interact, Dr. Hirano described some work he completed recently for the Department of Homeland Security (DHS) and the Transportation Security Administration (TSA). The task was to analyze the optimal types of technology that TSA could acquire and deploy to detect threats (in response to the airline passenger who hid explosives in his clothing last Christmas, yet was able to board international flights).

Using standards analytic techniques, Dr. Hirano and his team conducted a gap analysis, identified priorities for investment in new technology, and began assembling the information to make recommendations. However, the environment in which this technology would be deployed — U.S. airports — is a complicated one, with competing priorities beyond 100% detection. As Dr. Hirano pointed out, the stakeholders include not only the federal agencies concerned with terrorist threats, but also the airlines themselves and of course the flying public. Although everyone in theory wants the best security, Dr. Hirano said, there's a point where it becomes inefficient.

At a technical level, the decision involves the quality of an x-ray device and its images, but once this decision leaves the isolation of the lab, subject to human interpretation and decision-making, it becomes far more complicated. The same situation arose recently with the deployment of whole body imagers in airports. Airports have finite budgets for their checkpoint systems, and it turned out that the performance of an entire system is affected when new technology is introduced, because the personnel who left the existing checkpoints for training on the new imaging machines were not replaced during their training days, so the entire system bogged down. Fortunately, Dr. Hirano noted, that particular obstacle — while unanticipated — could be fixed with budgets that allowed for additional staff deployments during training time.

Dr. Hirano and his colleagues develop conceptual models and try to install uncertainty and variability. They recognize that when they run sensitivity analyses, they are not seeking a single bounded answer. Instead, they are looking at the trade-offs of choosing one course of action over another. “We don’t know what our adversaries will do next,” he said, “but we have to make some decisions regardless” — and these models help make those decisions more informed than they would otherwise be.

## Modeling Education Systems — Christopher Roe

***Christopher Roe** is Deputy Director of the Business-Higher Education Forum (BHEF), where he oversees BHEF initiatives focused on improving college readiness and strengthening science, technology, engineering and mathematics (STEM) education.*

The Business-Higher Education Forum (BHEF) is an organization of the CEOs of large companies that employ scientists and engineers, as well as university presidents. A BHEF Working Group was convened to figure out ways to increase the number of students interested and proficient in the STEM disciplines. Because the group was co-chaired by Cal Poly President Emeritus Warren Baker and Raytheon CEO William Swanson, it is perhaps not surprising that they decided to apply systems thinking and modeling to this problem.

Unlike climate change, with its dozens of models and decades of modeling history, the education system has not been thought of or analyzed in this way before. Through the generosity of funders such as the William and Melinda Gates Foundation and Raytheon (which donated 15,000 system engineer training hours to the effort), a four-year process was launched to build a working systems model of the U.S. educational system, and then use the model to identify high-leverage approaches to generating more students interested in STEM careers.

The first part of this venture — cataloguing the components of the U.S. public education landscape and linking the components as parts of a system — was a huge venture in and of itself, given the system's size and complexity. Once this work was done, however, it helped to explain why so many promising education reforms (such as the millions the Gates Foundation invested in piloting small high schools and reducing class sizes) were far less effective when taken to scale.

One aspect of the climate modeling that the BHEF group particularly took to heart was a commitment to make the model and its supporting data widely available. Indeed, the work to create the model was donated by Raytheon on the condition that it remain open source. "Anybody can go look at the data, coefficients, variables and structures of the model," Mr. Roe explained, adding that this was done in the hopes of increasing confidence and overcoming mistrust.

As it turned out, making the data available through a technical software platform was a step in the right direction, but it was still too technical for general use. (Nevertheless, thousands of people tried to download the model.) Again borrowing from the climate change community, the team built a version that could be run from a Smartphone, with prepared scenarios available through the

Web site. The extra effort not only helped build trust, but also increased awareness of this new and unique tool.

Within the education community, most research has drawn from social science research and looked back in time, not forward. The BHEF tool is the first to look to the future. The Department of Education has used it to strategize about national goals, as have communities around the country. The next challenge is to secure the funding to make it even more broadly available.

In response to a question about whether the STEM model had produced any insights or predictions yet, Mr. Roe offered a few — with the caveat that the model was still very much an early, 1.0 prototype. One strategy that could have significant impact on increasing the number of students to persist through STEM majors until graduation is the use of cohort programs. Another is to focus on the K-12 system to increase interest among students, with small investments in particular intervention points potentially leading to significant increases in system performance overall.

## The Science of Trust — Paul Zak

***Paul Zak, Ph.D.**, is Professor of Economics and Department Chair at Claremont Graduate University, as well as the founding Director of the Center for Neuroeconomics — a term he coined to describe the integration of his two fields of research and study, neuroscience and economics.*

"We trust strangers all the time," Dr. Zak said, addressing an audience that had just finished a catered lunch, and many of whom had flown to the meeting as well. "The people who prepare our food . . . the ones fly our airplanes . . . "

Curious about variations in levels of trust that played out in many different spheres of daily life, Dr. Zak began examining trust from a neuroscientist's perspective. "The short answer," he said, isl that trust is chemical." He and his colleagues designed an experiment to prove the chemical basis for trust, using a task called the trust game that was developed in the mid-1990s by experimental economists.

The trust game places two players in a situation where they have the option of transferring money to a complete stranger. The players, who never interact face-to-face and are unknown to one another, each receive a $10 payment for participating. The first player can transfer some, all, or none of this sum to the second player. If he or she chooses to transfer funds to the second player, that amount is tripled. (So, for example, if the first player chooses to transfer $6 of his or her original $10, that amount is tripled to $18 and then credited to the second player's account.) Upon receiving the tripled sum, which is added to his or her original $10, the second player then has the option of returning some portion of this total (including zero) to the first player.

Game theory models would predict that the second player, maximizing his or her gains, would have no reason to return any of the money. But in the trust game experiments, this is not what happened. Instead, 90% of the first players forwarded some money to the second player (a random and unseen stranger with whom they would have no contact, before or after the experiment), and 95% of the second players returned some money to the first player, violating the model's predictions.

The participants who sent money to a stranger could not explain why they took the actions they did, but Dr. Zak and his colleagues found a clue when they began measuring elevated levels of oxycotin, a unique mammalian hormone and neurochemical. (Dr. Zak hastened to distinguish oxytocin from the painkiller oxycontin.) Oxytocin is a difficult substance to measure, because it is synthesized in the brain on an as-needed basis — and released during events such as childbirth, breastfeeding, and sex (all too messy for laboratory conditions, Dr. Zak conceded). It can be measured in blood, if the subject is stressed to produce oxytocin.

In the trust game experiments, Dr. Zak and his colleagues found strong correlations between oxytocin levels in their subjects and the act of trusting a stranger by sending him or her money. They then manipulated oxytocin levels even further with nasal inhalers (first tested, Dr. Zak said, in the great tradition of "scientific autoexperimentation"). Comparing trust game players receiving oxytocin squirts versus a placebo, the proportion of oxytocin-enhanced players who sent money to a stranger was double that of the placebo group.

Other experiments revealed that the emotion associated with an oxytocin state is empathy. The response, Dr. Zak explained, is more emotional than cognitive, originating in the amygdala where our brains balance fear and trust. When oxytocin levels are elevated, people are more likely to give to charity. Moreover, these levels are constantly fluctuating as we respond to individuals, movies, music, art, and a variety of other stimuli and situations.

Oxytocin levels vary, but are generally higher in women (and are associated with attachment to mates and maternal care for offspring in monogamous mammals). It is a multipurpose chemical, sometimes triggered by stress — for example, striking up a conversation with a stranger in the next seat on an airplane that is undergoing turbulence.

Testosterone levels inhibit oxytocin, Dr. Zak noted. He hasn't looked at patterns within families, but noted that there are strong developmental influences and oxytocin levels can become dysregulated early in life. Among the five percent of trust game subjects who demonstrate perfect self-interest and decide to keep their money, Dr. Zak believes are many with dysregulated baseline oxytocin levels who perhaps share some attributes with the five percent of the population that could be characterized as psychopaths — i.e., lacking empathy and trust, deceptive (to themselves and others), and failing to bond or attach to others. Low oxytocin levels may also be related to social anxiety disorders.

Dr. Zak commented on several implications of his research for trust and science, noting that transparency, empathy and autonomy are critical for both scientists and policy-makers. He also suggested that research should be presented to the public in ways that induce trust and promote accountability (rather than dictating conclusions). "Involving citizens in public science can help with this," he said.

Meeting participants commented on how oxytocin and trust might help explain how those inside and outside climate science see themselves as competing tribes, leading one observer to note that those attending the CCST Council meeting may have experienced an oxytocin buzz just by entering the room.

## From the Cosmos to the Legislative Chambers

***Bryan Hannegan, Ph.D.,*** *CCST Council Member and Vice President of Environment and Renewables for the Electric Power Research Institute (EPRI), moderated a panel discussion featuring three of the first CCST Science and Technology Fellows:* ***Amber Hartman, Ryan McCarthy, and Jessica Westbrook.***

Dr. Hannegan opened the panel discussion by reflecting on some of his own experiences communicating science to policymakers — first as an AAAS Congressional Science Fellow, and then as Staff Scientist for the U.S. Senate Committee on Energy and Natural Resources and Chief of Staff for the White House Council on Environmental Quality. To him, it all boils down to three things: process, people, and preparation.

The process of communicating science to policymakers has become more and more contentious and technically complex, with a disconnect between the black-and-white answers that policymakers demand and the shades of gray that scientists deliver. This complexity and contentiousness make it even more imperative for scientists to be able to translate their findings and provide a context for them, fitting them into a framework that feels more familiar to public policymakers.

The communications task is formidable: only 5 of the 535 members of Congress have advanced degrees in science or math. It is no wonder that they have so much difficulty differentiating the science that streams into debates from trade associations, think tanks, advocacy groups and others from science that meets more rigorous standards. Whether at the federal or state level, the science and technology Fellows play an important role in helping elected officials and their staff gauge the quality of scientific findings and help them avoid at least some bad decisions or flawed legislation.

Dr. Hannegan wished he had been more prepared to tackle some of the communication and other challenges he faced as a Congressional Science Fellow. He posed a similar question to the Fellows finishing their first year in Sacramento.

*What do you wish you had known, or what might have made you more effective?*

**Amber Hartman** wished she had been more politically aware, subscribing to the Sacramento *Bee* and Washington *Post* and keeping up with political e-mail lists and listservs. Even though she did her doctoral work in a cross-cutting program that spanned different biology disciplines, she wished she had trained even more broadly, particularly in physics and economics. In retrospect, she also would have attended the AAAS annual meeting. She expressed gratitude for the academic advisor who encouraged her to pursue her interest in policy work, noting that this was probably quite uncommon in the sciences.

**Jessica Westbrook** agreed. She had not known about the many opportunities — including this fellowship as well as other placements — for which she was qualified. "I hadn't had a civics class since high school," she said, although she made the most of her 3-week crash course in navigating the capitol. On the science front, she knew that she would be unlikely to find herself working in her field of plant genetic engineering. However, she did feel well prepared for the task she undertook throughout her time in Sacramento: reviewing studies outside her field of expertise with a critical eye.

**Ryan McCarthy** (who prefaced his comments with a heartfelt "Go, Giants!"), also said he could have used a civics lesson, but felt he was able to learn on the fly. Management and leadership training would have been helpful, as well as more practice in distilling messages into a quick "elevator pitch."

*What surprised you the most?*

"The way politics trumps science," answered Amber Hartman. She described a proposal to implement regulations prescribing the type of paint used on cars to reflect more solar energy, use less air conditioning, and thus lower carbon emissions. Suddenly, seemingly out of nowhere, the issue became a public safety issue when a legislator was contacted by law enforcement groups maintaining that the coating would interfere with cell phone reception, GPS positioning devices, and the signals from prisoners' ankle bracelets. To her, a simple experiment could have resolved the question, but this was not contemplated — and legislators were afraid to appear soft on crime. "It changed the whole conversation," she said, shaking her head. "It was probably the most surprising and frustrating experience throughout the year."

Another surprise was the absence of scientists in many discussions. "Where is the UC? Where are the Council members?" she asked. "We need to have more of us in the room!"

Ryan McCarthy was surprised by the whole process — the volume of bills, the pace at which they move through, how quickly (and seemingly randomly) opposition and support can be mobilized. "Some things go through without a lot of notice, and others don't. It's not a very uniform process, but that's part of the fun of it, too," he said.

*When and how did your science background make a difference?*

Amber Hartman worked on a bill attempting to legalize alkaline hydrolysis, a process that she summarized for the lay person (using her communication skills) as the "Granny-to-goo" alternative to burying human remains. Touted as environmentally friendlier than burial or cremation, it seemed a viable alternative — until she scrutinized the process more closely. She emerged from her review with six major scientific concerns. The manufacturer claimed the liquid by-product of the process was as safe as water to drink, and yet it also dissolved a human body in just three hours. "How could that be true?" she asked. "It wasn't that I made a bill better or that a great environmental law passed," she said, "but that a bad thing got stopped." She still believes it could be done correctly in the long run, with more advanced technology that better meets environmental codes — but in its current form, the manufacturer's scientific claims for the process's safety did not pass muster.

Jessica Westbrook related an example of butchers and supermarkets trying to eliminate animal remains through composting, instead of the more expensive meat rendering process. Potentially, this allowed the introduction of pathogens such as avian flu and anthrax that are eliminated during the rendering process. Composting was in one agency's jurisdiction (recycling), while rendering was in another's (agriculture), leading to a clash between two departments. A lobbyist was maintaining that composting, with proper procedures, would be safe. With help from another fellow, who happened to be a veterinarian, she was able to obtain accurate information on the relationship between rendering and pathogens — and kill the bill.

*Did you learn any lessons about communicating science to lay people?*

Amber Hartman tries to personalize the story — bringing to life the farm worker, Maria, who can't have children because of her exposure to pesticides — and uses metaphors and analogies whenever possible. To explain genetic modification to her boss, she said, "DNA is a book — it has all the DNA in your cells. Each chapter tells one piece of the story, a very specific thing — and the paragraphs are even smaller subsets. The letters come out in a huge compilation of ideas. Each makes an organism — a book. You can rearrange the letters, to get different books. Geneticists move the chapters, or the paragraphs, or reverse sentences."

Ryan McCarthy pretends he's explaining something to his mother.

*Do you believe California is governable?*

The fellows expressed guarded optimism, despite their ringside seat to some of California's most intractable problems. "I'm Pollyanna," said one, "I believe it will work out somehow — but I have no idea how!"

## Appendix: 2009-2010 Fellowships

### Inaugural Fellows Placement in the California State Legislature

**Daniel R. Ballon – Assembly Minority Leader/Republican Caucus:** Daniel received his Ph.D. in molecular and cell biology from the University of California, Berkeley, and a B.A. in molecular biology and biochemistry, Russian language and literature from Wesleyan University. He previously served as a senior policy fellow, technology studies at the Pacific Research Institute for Public Policy in San Francisco.

**Amber Laura Hartman – Senate Environmental Quality Committee:** Amber received her Ph.D. in biology from The Johns Hopkins University and a B.S. in biology from Davidson College. Recently, she was a graduate researcher at the Genome Center, University of California, Davis, where she has also held teaching assistance and lecturer positions. She is fluent in the Spanish language.

**Byron Kennedy – Assemblymember Sandré Swanson's Office**: Byron received his M.D. and Ph.D. in chronic disease epidemiology, and a M.P.H. in chronic disease epidemiology from Yale University. He also received a B.S. in biological sciences from California State University, Sacramento. He has an active medical license in both California and New York. He completed his residency in preventive medicine and previously served as a public health medical officer at the California Department of Public Health.

**Igor Lacan – Assembly Water, Parks, & Wildlife Committee:** Igor received his Ph.D. in urban ecology, a M.S. in aquatic ecology, and a B.S. in ecology from the University of California, Berkeley. He is an ecologist specializing in sustainable environmental management of urban areas.

**Ryan McCarthy – Assemblymember Wilmer Amina Carter's Office:** Ryan received his Ph.D. in civil and environmental engineering from UC Davis in 2009. He received a M.S. in civil and environmental engineering from UC Davis and a B.S. (cum laude) in structural engineering from UC San Diego. He previously served as a graduate researcher in the Sustainable Transportation Energy Pathways (STEPS) Program at the University of California, Davis.

**Katharine Moore – Senate Natural Resources and Water Committee:** Katharine received her Ph.D. in atmospheric science from Colorado State University, a M.S. in environmental engineering from the University of California, Berkeley and a B.S. in mechanical engineering from the Massachusetts Institute of Technology. Previously, she was a research assistant professor at the University of Southern

California Department of Civil and Environmental Engineering.

**Maurice Pitesky – Senate Energy, Utilities & Communications Committee:** Maurice received his Masters of Preventative Veterinary Medicine degree at the University of California, Davis. He also received a Doctorate in Veterinary Medicine (DVM) from UC Davis, a M.S. in agriculture from Cal Poly, San Luis Obispo, and a B.S. in biology from the University of California, Los Angeles. He previously served as a veterinarian with a focus in epidemiology and biostatistics, and has a background in agricultural sustainability, food systems, and the environment.

**Janice Tsai – Senate Majority Leader Dean Florez**: Janice received her Ph.D. in engineering and public policy from Carnegie Mellon University in August 2009. Her educational background also includes a Master of Library and Information Science, Rutgers, and a B.A. in mathematical methods in the social sciences, Northwestern University. The recent focus of her research was in the areas of salient privacy and decision-making, and the impact of privacy concerns on the adoption of mobile-location sharing technologies.

**Jessica Westbrook – Assembly Natural Resources Committee:** Jessica received her Ph.D. from the Department of Horticulture at Cornell University with a minor in plant biology, and a B.S. in plant biology at the University of California, Davis. She recently served as a graduate research assistant at Cornell University in the Department of Horticulture.

**Amber Wright – Senate Office of Research:** Amber received her Ph.D. in population biology from the University of California, Davis. She received a M.A. in conservation biology from Columbia University and a B.S. in biological sciences (cum laude) from Cornell University. She recently served as a graduate student researcher at the University of California, Davis and she has also held teaching assistant positions at UC Davis and Columbia University.