ON THE 40TH ANNIVERSARY OF THE FIRST MANNED MOON LANDING TODAY'S SCIENTISTS POINT TO NEW FRONTIERS

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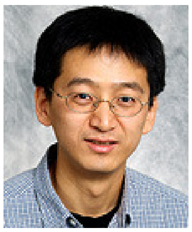
Ling Qi, Assistant Professor of Nutritional Sciences, Cornell University



Area of research/field of work:
Metabolic regulation and diabetes

Current work/research and its relevance:
The cause or set of causes of obesity and diabetes. Delineating the characteristic nature and function of cells and genes involved in obesity and diabetes will establish a pivotal mechanism for the interplay between obesity/diabetes and other associated diseases such as cancer, and may provide one or more candidate targets for drug intervention in conditions marked by chronic inflammation.

Federal research grants:
Our work is funded by NIH NIDDK

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
The next great scientific frontier is finding cures for many human diseases. Our generation has witnessed a great many breakthroughs in science and medicine. Nonetheless, many human diseases—including cancer and neurodegeneration—remain incurable and lethal. Within the next decade, we will gain new insights into more diseases and thereby design more effective vaccines and drugs to prevent or treat them. This can only be accomplished through research and discovery, which in turn require increased focus on—and funding for—science and science education.

Additional Links:
http://www.human.cornell.edu/che/DNS/qilab/index.cfm

EMORY UNIVERSITY

Rafi Ahmed, PhD, Director, Emory Vaccine Center, Professor & GRA Eminent Scholar, Department of Microbiology & Immunology, Emory University

Area of research/field of work:
Dr. Ahmed's work focuses on understanding the mechanisms of immunological memory in infection and vaccination. This is the most exciting frontier area of research in the field of Immunology.

Current work/research and its relevance:
Understanding the finer details of immunological memory at the cellular and molecular level has far-reaching consequences for confronting both emerging and re-emerging infections and for ultimately devising preventive strategies (vaccines and immuno-therapeutics) against some of the insidious pathogens (HIV/AIDS, Malaria and TB) that extract a heavy human toll around the globe.

A remarkable recent finding by Dr. Ahmed's group -- that a therapeutic immunosuppressive drug, rapamycin, enhanced immunological memory -- could potentially revolutionize and broaden treatment options in acute viral infections.

Furthermore, Dr. Ahmed's laboratory has recently identified a novel immune pathway activated in chronic microbial infections (viral, bacterial and parasitic), having the ability to prevent the immune system from generating functional immune responses against pathogens. A successful therapeutic intervention targeting this pathway would likely pay huge dividends in ameliorating the disease burden due to acute and chronic infections that devastate the human population in the developing world.

In order to achieve these goals, the research team led by Dr. Ahmed has devised novel cloning strategies for the generation of high affinity human monoclonal antibodies (mAbs) and this technology is being applied to indentify high affinity mAbs against H1N1 swine flu. This approach, combined with vaccination, will go a long way towards achieving effective control and prevention of viral infections in humans.

Federal research grants:
Dr. Ahmed's research is funded by several grants from the National Institutes of Health focused on the problem of immunological memory in both experimental model systems and humans. Also, Dr. Ahmed's work is supported by the Bill & Melinda Gates Foundation under

their Grand Challenges in Global Health (GCGH) and Collaboration for AIDS Vaccine Discovery (CAVD) Grant Programs, focusing on novel approaches to designing effective vaccines and immuno-therapeutics against chronic infections (HCV/hepatitis and HIV/AIDS).

JOHNS HOPKINS
UNIVERSITY

Peter Agre, MD, Nobel Laureate, University Professor and Director, The Johns Hopkins Malaria Research Institute, The Johns Hopkins Bloomberg School of Public Health

Area of research: Agre's research focuses on the biology of malaria. In 2003, Agre shared the Nobel Prize in Chemistry with Roderick MacKinnon for his discovery of aquaporins — channels that regulate and facilitate water molecule transport through cell membranes, a process essential to all living organisms. In 2004, Agre turned his research attention toward malaria when he was awarded a pilot grant from JHMRI. In addition, in February, he was inducted as the 163rd president of the American Association for the Advancement of Science, the nation's largest scientific organization.

Current work/research and its relevance:
Our laboratory is now focused specifically on the biology of malaria. Current projects involve studying agents that protect against malaria in the brain, a common and often deadly manifestation of the infection. We are also at work studying the aquaporins, the proteins that control cellular movements of water, and that are expressed in mosquitoes that carry malaria. In addition to work in our laboratory, I am charged with directing the Johns Hopkins Malaria Research Institute, a wonderful program that received generous support from the Michael Bloomberg Family Foundation. In this capacity, I serve, guide, and advocate on behalf of our twenty faculty members and their teams of young scientists as they work on malaria. Finally, I use every opportunity to use the bully pulpit that came with my Nobel Prize to bring malaria to the attention of science students throughout the U.S. and abroad. By exciting young people, I feel the chance of attracting the ones that will provide the critical information needed to bring malaria to an end worldwide.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?

In May 1961, President Kennedy announced the objective of landing a man on the moon and returning him safely before the decade ended. This ambitious goal was important for several reasons. First, it raised the international respect for our aerospace preeminence. Second, it was also a scientific adventure into the unknown; despite the exceedingly advanced level of science in our country, no one on earth really knew what would be found on the moon. Third, it sparked our national pride. And after completion of the Apollo missions, it was probably our national pride that benefitted the most, for almost everyone my age remembers the immortal words of Neil Armstrong:

> "That's one small step for man, one giant leap for mankind."

A contemporary event of this dramatic nature is difficult to contemplate, but the possibility of a major investment with breathtaking returns is fun to imagine. Possibilities include redesign of the American educational system to rekindle the precious human capital of our youth. Another would be to develop a new national system of mass transit including high-speed rail. A third would be to develop novel forms of environmentally friendly energy. But as admirable as these goals may be, my own scientific excitement lies elsewhere.

My personal dream is to unleash the finest minds in the world on the problems of the killer diseases of the developing world. These infectious diseases cause deaths of approximately 10 million small children each year worldwide. And these are diseases that we could and should conquer including the big four: malaria, respiratory disease including tuberculosis, diarrheal disease, and HIV AIDS. Often children are infected by more than one at any time, and most also suffer concomitantly from malnutrition. While great efforts are being invested by aid agencies on behalf of each, the basic scientific understanding is still far from complete.

It is believed that more than half of all humans who ever lived died of malaria. Malaria in particular needs more scientific analysis, since it is the most complicated organism of the group — 5,300 genes encoding thousands of proteins expressed in at least three distinct stages of a complicated life cycle. While effective medicines have previously been invented, they are of short-lived value since drug resistance invariably occurs. A complete understanding of the proteins and biological pathways will certainly identify many new candidates, each being an opportunity for design of new human therapies and even new methods to combat malaria in the mosquito stage of the disease. What is needed is more than research dollars or laboratory space. We need bright young scientists to embrace this as their life's work. The conscience of our nation will be lifted mightily if we could end this dreaded scourge affecting the world's least fortunate

Federal research grants:
Dr. Agre's work is supported/has been supported by grants from the National Institutes of Health.

JOHNS HOPKINS
UNIVERSITY

Charles Bennett, Ph.D., Professor, the Henry A. Rowland Department of Physics and Astronomy, Zanvyl Krieger School of Arts and Sciences, The Johns Hopkins University

Area of research/field of work:
Bennett's research interests include cosmology, sub-millimeter and radio astronomy, astronomical instrumentation (especially for space flight), and the large-scale studies of the properties of the Milky Way galaxy. Bennett is the Principal Investigator of the Wilkinson Microwave Anisotropy Probe (WMAP) mission. WMAP was competitively selected in 1996 as a NASA medium-class Explorer (MIDEX) mission. WMAP was launched June 2001 and its first scientific results were made public in February 2003. WMAP quantified the age, content, history, and other key properties of the universe with unprecedented accuracy and precision. This was recognized by Science magazine as the 2003 "Breakthrough of the Year." The National Academy of Sciences awarded the 2009 Comstock Prize in Physics to Bennett, and shared the Peter Gruber Foundation's 2006 Cosmology Prize. That same year, he was awarded the Harvey Prize by the Technion-Israel Institute of Technology. In 2005, Bennett won the prestigious Henry Draper Medal of the National Academy of Sciences.

Current work/research and its relevance:
In my own research, I am pursuing the nature of the dark energy that fills the universe, and exploring what happened at the very beginning of the universe. My research has mostly been supported by small grants from NASA. I also lead the WMAP space mission and previously worked on the Cosmic Background Explorer (COBE) space mission.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
Putting a man on the moon seemed like an impossible task when President Kennedy declared that it would be done within a decade. Kennedy himself acknowledged that we, as a country, would do it because it is a difficult challenge. That was 40 years ago. Since that time our nation has accomplished much in space, and there is now the pressing question of what to do next.

One of the greatest accomplishments of the space age has been the launch and repeated astronaut-servicing of the Hubble Space Telescope. While astronomers were accustomed to placing telescopes on high mountain tops, space flight provided the opportunity to put telescopes above the Earth's atmosphere. From space, the Hubble Space Telescope has peered across the universe, revealing regions where solar systems are now in the process of forming. It has looked at galaxies billions of light years away, and it has measured the expansion of the universe.

Other NASA space missions have studied our planet Earth, our solar system, our Milky Way galaxy, and the depths of the universe. The Wilkinson Microwave Anisotropy Probe (WMAP) mission determined the age and contents of our universe. It is 13.7 billion years old, and filled with 5 times more dark matter than atoms. We do not yet know what the dark matter is. Our universe is also filled with a mysterious "dark energy" that is causing the expansion of our universe to accelerate, expanding faster and faster as time goes on. Why? We do not yet know.

Two of the most fundamental questions we can ask about the universe are: (1) Are we alone? and (2) How did the universe begin? Along with carrying out the space observations of our universe needed to answer these questions, we also need space missions to monitor our climate and deteriorating health of our planet Earth, and to understand our Sun and its connection with the Earth.

The ability to send astronauts to new destinations beyond the Moon is limited by our ignorance about how to do it. What are the adverse health effects of long-term space travel? We don't know. Research is needed to better understand both the radiation environment as well as the radiation effects on astronauts. Research is also needed to understand effects on bones, muscles and other tissue. All of this research must be done before we can seriously contemplate long-term space travel beyond the protective environment of near Earth orbits. In the meantime NASA has used robots, like the rovers on Mars, to explore the planets – using machines to extend our reach.

The modern world has been defined by machines (robots) enhancing human capabilities. This will be the future of space flight as well. The astronaut-servicing of the Hubble Space Telescope is an excellent example. Now we should build on this hard-won knowledge and success. We should use our human presence in space not so much to "go places", but to "do things" and "learn things." How about building an enormous new telescope in space? Astronauts learned how to build an enormous structure in space when they built the Space Station. Let's use that knowledge to build a great new telescope – one too big to launch in one piece. Let's use it to answer fundamental questions, like whether or not we are alone in the universe, and to study how the universe began.

If America decides to accept the challenge, we could answer these questions, and accomplish a range of other great research and discovery within the next decade, which in turn would spur innovation and create jobs here on Earth. We could do all this in partnership with other countries, not only to share the costs, but as a means of peaceful international cooperation.

Federal research grants:
Bennett's work is currently supported/has been supported by NASA grants.

JOHNS HOPKINS
UNIVERSITY

Adam Riess, Ph.D., Professor, the Henry A. Rowland Department of Physics and Astronomy, Zanvyl Krieger School of Arts and Sciences, The Johns Hopkins University

Area of research/field of work:
In 1998 Dr. Riess led a study for the High-z Team which provided the first direct and published evidence that the expansion of the Universe was accelerating and filled with dark energy (Riess et al. 1998, AJ, 116, 1009), a result which, together with the Supernova Cosmology Project's result, was called the "Breakthrough Discovery of the Year" by *Science Magazine* in 1998. Riess was elected to the National Academy of Sciences in April 2009 and shared two of cosmology's most prestigious prizes – the 2006 Shaw Prize and the Peter Gruber Foundation's 2007 Cosmology Prize – for the discovery of dark energy. He continues to explore the mysterious nature of dark energy.

Current work/research and its relevance:
"I am actively trying to deduce the nature of dark energy through measurements with telescopes. Dark energy is presently one of the biggest mysteries in physics. Understanding its nature may provide a clue to developing a deeper understanding of gravity and quantum theory. If that occurs, there is no telling how far reaching the results might be!"

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
The issue of global warming is a major concern whose understanding falls on the shoulders of science. Right now the focus is on Plan A; reducing our production of carbon dioxide, which is as it should be. However, the range of uncertainty in our models of the future atmosphere is large and the potential peril is great. I believe in the coming decade, we will learn a great deal about the quality of our understanding by comparing the current predictions to future data. In the face of such risk, I think it will be prudent for science to begin developing a "Plan B" for global warming. This could take the form of more aggressive interventions if the efforts to cut back on carbon output are not enough. For example, active blocking of sunlight above the atmosphere might be necessary. Achieving this would be an enormous scientific and engineering challenge but likely something America could achieve if necessary.

Federal research grants:

Riess’s work on the nature of dark energy is currently supported/has been supported by NASA grants through the Hubble Space Telescope program.

JOHNS HOPKINS

UNIVERSITY

Akhilesh Pandey, M.D., Ph.D., Associate Professor at the Institute of Genetic Medicine and the Departments of Biological Chemistry, Oncology and Pathology, The Johns Hopkins School of Medicine

Area of research/field of work:
Pandey studies how proteins talk together within cells and how cells talk to each other. His lab uses computers and large scale analytical techniques to identify and study molecular communication pathways in healthy and cancer cells.

Current work/research and its relevance:
As a small team, we can only do so much. At one end, we are creating the resources and tools that will help us find diagnostic and therapeutic targets faster. We are able to do this by creating databases that help prevent duplicating research that has been done earlier and help us prioritize what to focus on based on all that we have learnt as a community about a given disease or pathway. On the other extreme, we are using advanced proteomic methods to discover therapeutic targets in cancer, which would make personalized treatment possible, at least in some cancer patients. This is the next great forward for science, because we need to stop thinking of being able to treat all patients with the same label (i.e. a given cancer) with the same drugs. This is because cancers are heterogeneous and we need to find individual aberrations that drive them. Drug companies might not necessarily be the most enthusiastic about doing this because it might mean a smaller patient base, which is shortsighted because the same drug might be helpful in smaller numbers of many cancers.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
I think that the next big frontiers in science are to be able to diagnose diseases early and accurately and to be able to cure them. Apart from infectious diseases, we are still unable to 'cure' most diseases - the best we can do is to 'control' some of them. Also, for some diseases such as cancers, it might be possible to provide individualized therapy - the concept of 'personalized medicine' is still in its infancy and a lot more still needs to be done.

A decade is not a long time, yet if the proper strategy is adopted, one can accelerate discoveries that impact medicine. An example in recent times is HIV, where both NIH and drug companies pushed hard and we already have the results as far as treatment goes. Even then, we have been less 'lucky' in terms of developing a successful vaccine. If America took on the challenge, we could still make significant progress. Teaming up as a community, we can do 'systematic science' - which is not how things are generally done in science. We can also do 'large-scale science' in the next decade, which when coupled to systematic science would essentially make the next decade a 'data gathering' phase. With this mindset, we can go a long way in developing an infrastructure for programs for early detection of diseases and for identifying therapeutic targets within a decade. Large centralized repositories for everything need to be created - right now, there is an enormous duplication of effort at almost every academic medical center.

As a nation, we need to recognize that NIH has done exceedingly well to further altruistic science. We also have to realize that it is now time to revamp the system. We need to bring oomph into research. It is the only discipline I know where trained people are justifying what they do on a regular basis in order to get paid (through grants)! They ask for permission (in terms of grants) from agencies to let them do their work. No wonder, young smart people try to avoid such fields. We need more researchers -- not less. Only at the highest levels can research be prioritized appropriately. We should not talk about doubling the budget - it should be 10 times higher - which is still a pittance in the big picture. Only then are we allowed to dream about widespread 'breakthroughs' in biomedical research. I would argue that it is the financial part (and to a smaller extent the question of academic credit) that is a barrier to true collaboration. We need to unite hospitals with researchers better and we need to unite different researchers at different places better - they should work together and not compete (as it is now). Academics talk about 'publish or perish' - instead we need to change the environment such that they try to focus on the real problems - diagnosing and curing diseases. Finally, without active involvement of companies, translating such findings to impact patient care the clinic is still difficult, if not impossible. We could integrate the academic and commercial enterprises better as we ultimately do have common goal - of improving health.

Federal research grants:
Pandey’s work is currently supported/has been supported by grants from the National Institutes of Health and the National Heart, Lung and Blood Institute.

JOHNS HOPKINS
UNIVERSITY

Peter C. Searson, Ph.D., Joseph R. and Lynn C. Reynold Professor of Materials Science and Engineering, The Whiting School of Engineering, Director of Johns Hopkins Institute for NanoBioTechnology, The Johns Hopkins University

Area of research/field of work:
Searson studies nanoscience, surfaces and interfaces, and the applications of nanoscience to biology and medicine.

Current work/research and its relevance:
Our research is in applications of nanoscience to biology and medicine. For example, collaborating with colleagues in medicine, we are developing semiconductor quantum dots for targeting and treatment of pancreatic cancer. Pancreatic cancer is the fourth leading cause of cancer death in the US and the survival rate amongst pancreatic cancer patients is extremely low, primarily due to the fact that a large fraction of tumors are metastatic at the time of diagnosis. Therefore, to improve survival of pancreatic cancer patients, there is an urgent need for detection at an early, and hence potentially curative, stage. Our approach is based on targeting molecular markers associated, and may lead to a new approach for early detection and identification of the stage of progression of pancreatic cancer.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
What are the next great scientific frontiers? The interface between nanoscience and medicine is emerging as one of the next great scientific frontiers. This is a rapidly growing, multidisciplinary field spanning physical sciences / engineering and the biological sciences / medicine.

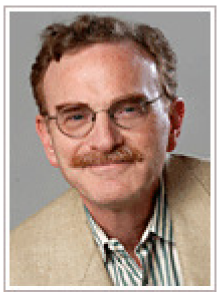
What could be accomplished through science, research, and discovery within the next decade? Nanoscience is emerging as an enabling technology in the basic biological sciences, as well as in clinical medicine. In the biological sciences, nanoscience has resulted in new tools and techniques that have led to advances in understanding of cell function and signaling. Examples of new techniques include real-time, 3D imaging in live cells; single molecule imaging; new bioanalytical assays, such as microarrays and microfluidic devices; and new biosensors such as QD-tagged antibodies. In clinical medicine, nanoscience is beginning to have impact in the diagnosis and treatment of disease. Over the next decade, research at the interface of nanoscience and medicine will likely contribute to significant breakthroughs in our understanding of cell biology and disease at the molecular level, and hence provide a roadmap for new diagnostic and therapeutic strategies that could revolutionize healthcare and medicine.

What do we need to do as a nation to accomplish this? To be successful at this interface between nanoscience and medicine, future leaders must be trained across traditional disciplinary boundaries and be conversant with developments in nanoscience and understand the scientific and clinical problems in biology and medicine. This is a significant challenge since universities are configured for highly specialized, disciplinary training, and are only beginning to develop strategies for interdisciplinary training. There are two main strategies in creating interdisciplinary education programs. One approach is to train students within conventional disciplinary boundaries; the second approach is to create a new interdisciplinary program, independent of existing disciplines.

At Johns Hopkins we believe that a strong disciplinary grounding is crucial, especially in such rapidly evolving, interdisciplinary fields. We have created pre-doctoral and post-doctoral training programs that build a community of researchers across traditional disciplinary boundaries, providing specialized lectures, seminars, and workshops in nanoscience and biology. Courses within disciplines taught at the highest level, and not watered down versions. To ensure that the research is of the highest quality, students have two co-advisors, one in the physical sciences / engineering and one ion the biological sciences / medicine.

Federal research grants:
Searson's work is supported by the National Science Foundation and the National Institutes of Health.

Randy W. Schekman, Ph.D., Professor of Cell and Developmental Biology, Department of Molecular and Cell Biology, University of California Berkeley; Adjunct Professor, Biochemistry and Biophysics, University of California, San Francisco; investigator, Howard Hughes Medical Institute; and, Editor-in-Chief, *Proceedings of the National Academy of Sciences of the United States of America*



Area of research/field of work:
Prof. Schekman studies membrane assembly, vesicular transport, and membrane fusion among organelles of the secretory pathway and his research is currently being supported and has been supported by grants from the National Institutes of Health. . Basic principles that emerged from his lab's past and on-going studies in yeast are now being applied to studies of genetic diseases of protein transport. His work earned him one of the most prestigious prizes in science, the Albert Lasker Award for Basic Medical Research, which he shared with James Rothman in 2002. He is the founding director of the Berkeley Stem Cell Center which includes faculty, students and staff of seven UC Berkeley colleges and departments, Lawrence Berkeley National Laboratory, and Children's Hospital Oakland Research Institute. The Center offers laboratory research opportunities in basic cell, molecular and developmental biology, chemistry, bioengineering and chemical engineering. He was elected to the National Academy of Sciences in 1992. Schekman's path to award-winning researcher began with a youthful enthusiasm for science and math, which he attributes to his father, an engineer who helped develop the first online program for real-time stock quotes. High school science fairs—and winning them—further whetted his appetite for competitive science. Biology's power hit him more personally, though, when his teenage sister died of leukemia.

Current work/research and its relevance:
In my own area of research of cell biology, the great breakthroughs are in controlling cell fate during embryonic development. Learning how cells differentiate from a stem cell to a developed tissue will offer great insights and medical applications in tissue repair and replacement. In my lab we study how cells assemble themselves and how this process can be disrupted in diseases such as birth defects and Alzheimer's Disease.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
I would say that the great Moon Landing equivalent of our time is to greatly reduce our use of fossil fuels. This requires a significant federal investment in science and engineering, much as the Apollo project of the late 60s. In all areas of fuel development, from biofuel alternatives to fossil fuel and ethanol, to solar cells that capture more sunlight, to batteries that store power more efficiently and with greater long term stability, and nuclear power that is safer and generates less radioactive waste.

Federal research grants:
Research activities are supported by individual grants from the NIH and CIRM, private foundations, a training grant from the California Institute for Regenerative Medicine and private philanthropic donations.

Additional Links:
http://stemcellcenter.berkeley.edu/message.html;

Satya Atluri, Samueli/Von Karman Professor of Aerospace Engineering, Mechanical & Aerospace Engineering, University of California – Irvine, Henry Samueli School of Engineering, Director, Center for Aerospace Research and Education

Area of research/field of work:
Dr. Atluri's interests lie in the disciplinary areas of applied mathematics; theoretical, applied, and computational mechanics of solids and fluids at various length and time scales; computer modeling in engineering and sciences; meshless and other novel computational methods; structural longevity, failure prevention, and health management.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
Dr. Atluri's research focuses on the mechanics of solids, structures, and engineered materials, to analyze and synthesize low-mass aerospace structures, for their strength, stiffness, stability, toughness, damage tolerance, longevity, life-cycle costs, self-adaptivity, smartness, and self-healing properties. He also conducts research on computer modeling and near- real-time simulation of physical phenomena in fluids, solids, structures, transport processes, and engineered materials, etc., at various length and time scales.

Dr. Atluri believes that the engineering of structural as well as functional materials, need to be understood from both bottom-up and top-down perspectives, with emphasis on their (nano-micro) structure-property (strength, stiffness, fracture-toughness) relationships. Knowledge of multi-functional and smart materials, nano-structured materials, and biomimetic materials will be important both for future space-missions and for the future of earthbound infrastructure. Structural failure results in trillions of dollars of loss to the global economy each year. Dr Atluri conducts extensive research on failure prevention and damage tolerance of load-bearing as well as functional structures, as well as research into the fundamental nano-scale level mechanisms of corrosion, and ways to slow-down corrosion. In order to reach our goals as a nation, Dr Atluri believes we need a National Department of Engineering, Science, & Technologies (DEST), parallel to the Departments of Commerce and Defense, with a prominent and Secretary, to integrate and coordinate research currently funded and supervised by various government agencies(incl. NIH, DoD, FAA, NSF, NIST, DARPA). The Secretary of DEST should be held accountable for developing and nurturing the human-resources needed in science, engineering and technology in order to ensure the economic security of our country.

Federal research grants:
Dr. Atluri's work has been supported by: NSF, DARPA, the Office of Naval Research, The Air Force Office of Scientific Research, The Army Research Office, The Army Research Labs, NASA, the Federal Aviation Administration, The Department of Energy, The Nuclear Regulatory Commission, The Edwards Air Force Base, The Wright-Patterson Air Force Base, and more.

Anthony James, Distinguished Professor, Microbiology & Molecular Genetics, School of Medicine Distinguished Professor, Molecular Biology and Biochemistry, School of Biological Sciences, University of California – Irvine

Area of research/field of work:
Dr. James works on vector-parasite interactions, mosquito molecular biology, and other problems in insect developmental biology.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
Dr. James and his colleagues are researching genetic methods to control the spread of mosquito-borne diseases. The recent call for eradication of malaria stimulated debate as to whether or not this is possible, and if so, what will be needed to actually achieve such a monumental event in the history of human health. Those willing to entertain this possibility recognize that one method alone, such as vaccines or mass administration of drugs, is not going to accomplish this end, and therefore we are faced with the complex task of integrating disparate approaches and tools to control malaria, while at the same time being alert to new developments that could supplement current technologies. While current control and elimination efforts are based on drugs and vector control, and planning for the availability of a vaccine, eradication can be expected to take several decades. It is certain that tools that are viewed now as "in the future" will be needed to meet this challenge. We envision a role for genetically-modified mosquitoes as part of the tool-set that will help achieve eradication.

The fundamental target of any control program is to stop transmission of the pathogen. This halts the spread of the disease and allows resources to be used to clear the pathogens from existing reservoirs, and in the case of vaccines, establish a population that is no longer susceptible to infection. Clearly, stopping transmission is a difficult task. The ecological and epidemiological circumstances that characterize transmission are heterogeneous, with geographic and seasonal differences influencing variation in humans, pathogens and the vector mosquitoes. Coupled with near-, mid, and long-term non-cycling patterns of changing human demography and anthropogenic impacts on the environment, the goal of stopping transmission is a moving target with a somewhat unpredictable trajectory. However, the known challenges are a place to start and these include grappling with the aforementioned heterogeneity, creating robust and sustainable solutions, and having tools that are effective, efficacious and safe, and that are economically-feasible. We don't know yet in an integrated program what the overall balance is going to be between tools that can be applied generally and those that need implementation in specific transmission locales. Current tools and sufficient resources in control efforts can take transmission to low levels. However, cost-effectively sustaining these low levels while figuring out how to manage refractory transmission foci and imported cases to take the next step to elimination will take new tools. Looking into the future, genetically-modified mosquitoes may play a key role in control, elimination, and the eventual eradication of mosquito-borne pathogens.

The development of integrated effective control approaches for disease eradication is non-trivial. It calls upon scientific discoveries and social development to co-evolve and contribute to a common goal. While there may not be as many "moving parts" as there were in the rockets, capsules and communication components that allowed us to go to the moon, the precise interplay and need for coordinate action of both the science and social aspects of disease control require a similar commitment of intellectual strength, emotional commitment, and resources. New ways of thinking, and in some cases, novel scientific and social methods will need to be discovered and developed to achieve disease eradication.

America, more importantly, Americans, have accepted to some extent the challenge of disease eradication. We have had a "war on cancer", concerted efforts to stem the ravages of HIV, and a spectrum of other programs targeting specific diseases. A number of diagnoses that were once death sentences no longer pose the same threats. These changes were brought about by science, research and discovery, and it is reasonable to expect that similar efforts put to the major infectious disease can have similar outcomes. In the case of mosquito-borne diseases, it is not too much to expect local elimination of some of these diseases, malaria and dengue fever in particular, in many parts of the world.
Social, political and scientific commitment coupled to a realization that difficult challenges take time to address. We need to use better the tools we have now while at the same time maintaining the pipeline for innovation that will brings us new tools. Education and communication are critical components of all aspects of these endeavors.

Federal research grants:
Dr. James' research program has been funded continuously since 1989 by grants from the National Institutes of Health, Burroughs-Wellcome Fund, John D. and Catherine T. MacArthur Foundation and the Bill and Melinda Gates Foundation.

Hans Keirstead, Associate Professor, Anatomy & Neurobiology, School of Medicine, University of California – Irvine, Associate Professor, Reeve-Irvine Research Center, Co-Director, Sue and Bill Gross Stem Cell Research Center

Area of research/field of work:
Dr. Keirstead's research focus is on stem cell-based approaches to treat spinal cord injury.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
Stem cells are the origin of every cell in the human body. Their isolation outside of the human body provides us with an unprecedented opportunity to generate individual populations of every human tissue type in high purity, in virtually unlimited amounts, for use in cell replacement strategies to treat disease and injury in which that cell population is lost, for use in the discovery of drugs to treat diseased tissues, and for use in research laboratories to understand human development.

In 2005, for the first time, human embryonic stem cells were directed to become one human cell type in high purity, in a manner compatible with clinical and commercial use. This achievement enabled the first clinical trial using this cell type, which was approved by the FDA for human testing in 2009. One cell type, one clinical trial, but still a giant leap for mankind. If America decided to accept the challenge, the basic and clinical research communities could develop techniques to direct human stem cells to generate virtually unlimited amounts of every single human cell type. As one cell type provided the medical community with the opportunity to treat one human condition, unlimited quantities of every single human cell type would provide the medical community with the material to treat and study every human disease and injury. Such an accomplishment would spur untold biotechnological advances, the genesis of a new sector in the biotechnology industry, save the government billions of dollars annually, and alleviate immeasurable human suffering.

Federal research grants:
As he developed stem cell technologies during the Bush Administration, Dr. Keirstead could not use federal money to study the 'non-federally approved' stem cell lines that he created and used in his research. He funded his studies with multiple foundation grants, collaborative research agreements with stem cell companies, and State funding from the California Institutes of Regenerative Medicine.

Michael Rose, Professor, Ecology and Evolutionary Biology, School of Biological Sciences, University of California – Irvine, Director, Network for Experimental Research on Evolution, A University of California Multicampus Research Program

Area of research/field of work:
Dr. Rose uses experimental evolution to build Drosophila (fruit flies) that live longer, healthier, and more vigorous lives.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
The slowing and eventual cessation of human aging is a major focus of Dr. Rose's research, and accomplishing this goal would be a transformative event for humankind comparable to landing on the Moon.

After the development of the Copernican model for the solar system, the idea of traveling to the Moon and back became a commonplace technological vision. Pieces were written about it in the 18th, 19th, and 20th Centuries, long before it was accomplished. Naturally, during most of this time-period many thought that travel to the Moon would never be achieved.

Within biology and medicine, the idea of defeating human aging is even older. Some of the earliest recorded thoughts of both Western and Eastern civilizations concern means by which our aging could be slowed or arrested, and the topic has been discussed ever since.

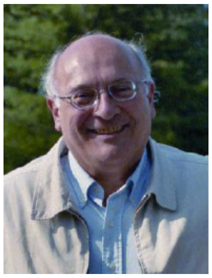
In the 1970s, Dr. Rose deliberately produced animals with enhanced lifespans that didn't involve mutilation or deprivation, the first time this had ever been done. Since then, chiefly at the University of California Irvine, Dr. Rose has been pursuing the idea of accomplishing the same goal for human subjects. While Dr. Rose hasn't succeeded yet, he and his team are getting very close. Accomplishing this goal is perhaps now at a similar point in its development as the idea of astronauts traveling to the moon was in 1961, when President Kennedy made it a national goal for the United States.

Federal research grants:

Dr. Rose’s research on aging has been supported by the British Commonwealth, NATO, the Natural Sciences Research Council of Canada, the National Institute on Aging, the University of California, and the National Science Foundation, as well as several private donors.

UCIRVINE

William Sirignano, Professor, Electrical Engineering & Computer Science, The Henry Samueli School of Engineering, University of California – Irvine



Area of research/field of work:
Dr. Sirignano's current research focuses on problems of fuel spray and droplet combustion; breakup of injected liquid streams; formation, injection, and burning of emulsified fuels; liquid-film combustors; turbine burners.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
Dr. Sirignano muses that a future scientific achievement that could rival (in the public's minds) the Apollo project, which put men on the Moon, would be putting women on Mars. His pick, however, for an engineering achievement, is not that one but another that would have wider impact although less (or at least more diffuse) front-page news. The major challenges of the future, they are not focused on new technologies alone. Rather, we are challenged to manage technologies and people as part of a large system. Such large systems can be scientifically categorized as "complex systems" because they have certain characteristics, including limited ability to manage from above because of a very large number of semi-autonomous decision makers and the ability to self-organize structures. So, these are more than just highly complicated systems such as an aircraft or a spacecraft. Examples of complex systems include a health-care system, an energy-supply-and-consumption system, a financial market, an air-traffic-control system, and a military force employed in a battle. The engineering/scientific challenges are to characterize these systems and to develop means to optimize their performances and/or the performance of certain elements/agents within the system.

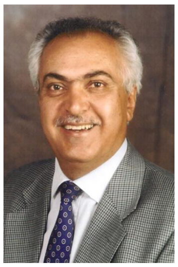
This is a field that requires very advanced mathematical science and approaches, leaning more towards observational than laboratory science. Interest in this area would require some turning away from the reductionist approach that has dominated much of natural science and engineering in the past. The reductionist approach gives less attention to the interactions and synergisms among components of a system which actually might be the most important characteristics of a complex system. With some accuracy, social scientists and biologists can argue that they have worked on complex systems for generations. That is a true but incomplete statement of the situation; in general, biologists and social scientists have not brought the mathematical skills, training, or perspective that engineers could contribute to moving beyond characterization to improvement through design and control.

Federal research grants:

In recent years, Dr. Sirignano's research has been supported by the Army Research Office, Air Force Office of Scientific Research, and Siemens Power Corporation.

UCIrvine

Soroosh Sorooshian, Distinguished Professor Civil & Environmental Engineering, Henry Samueli School of Engineering, Distinguished Professor, Earth System Science, School of Physical Sciences



Area of research/field of work:
Dr. Sorooshian works on Hydrology, hydrometeorology and hydroclimate modeling, remote sensing and water sources management.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
The technological and scientific breakthroughs in space exploration which led to Apollo mission moon landings created many opportunities for research in diverse fields. Since the Apollo days many advanced satellites have been launched to explore the outer space as well as the study of our own planet.

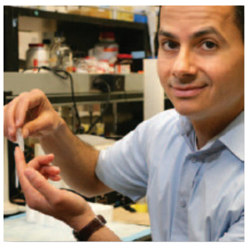
Dr. Sorooshian's research group has focused on the application of space observations for better characterization of the Earth hydrologic cycle. In specific, accurate measurement of rainfall throughout the globe with adequate spatial and temporal resolutions is of paramount importance for a number of applications, including climate change, flood hazard mitigation, and water resources management. Through the observations made by numerous weather and environmental satellites Dr. Sorooshian and his team have been able to make significant progress in mapping global precipitation patterns with a resolution of a few kilometers in real time. The future looks even brighter as new generations of satellites are being developed and launched. This provides new capabilities to observe and better understand one of the most important elements of the Earth system, namely the hydrologic cycle. Through this understanding, predictions can be made for future extreme events such as floods and droughts. These predictions enable the development of policies that empower authorities to take action in adapting to and mitigating the impacts of climate change.

As the United States is one of the major economic powers in the world, it has an obligation to take a leading role in addressing the climate change issue. In the next decade new tools should be developed to better predict regional climate changes and provide policy makers with the data needed for better management

Federal research grants:

Dr. Sorooshian's research is currently supported by grants from NASA, National Oceanic and Atmospheric Administration, NSF, and the United Nations Educational, Scientific and Cultural Organization.

Omar Yaghi, Professor, UCLA Department of Chemistry and Biochemistry, Director, UCLA Center for Reticular Chemistry, Founder, UCLA Clean Energy Network



Current work/research and its relevance:
My research is on capturing carbon dioxide before it reaches the atmosphere. My research group and I have invented one of the most extensive classes of materials named metal-organic frameworks (MOFs). They have wide uses in cleaning the air and environment. More significant is that MOFs are the products of minds that were originally directed to acquisition of basic knowledge through basic research. The research is fun and continues to have important positive impact. We have invented a way of putting together a molecular moving block into any type transformative which has led to large number of new material that have many applications.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
The pressing questions that will be with us for sometime to come are those pertaining to energy. Specifically, clean energy...how do we clean the air we breath from over 100 years of neglect and abuse? How do we create new concepts for harnessing the energy of the sun and other renewable sources?

Not surprisingly the answer is in unlocking the power of molecules and large chemical structures where one potentially can create the very conditions under which it would be possible to use sunlight to convert carbon dioxide (emitted from power plants and automobiles that burn fossil fuels) to clean fuels that recycle carbon. Ultimately how do we produce hydrogen economically and store it safely for use with only water as a byproduct.

We need to understand the current energy situation we are in and then make it a priority. We spend an astonishingly tiny, tiny fraction of our GNP on basic research that could very well lead to the unlocking and harnessing the power of molecules and large structures composed of great beauty but indeed hold the secrets to saving our planet.

Another very important aspect of a sustainable future is for us to start considering higher education (post graduate) as what it really is – the transformation of the mind to create knowledge and transform the individual and thus society. Currently, we only mentor less that a tenth of a percent of those students in the world who are hungry to be mentored in the art and science of solving problems in energy, medicine and other fields. Many of such students either go on to do nothing truly transforming or sadly hopeless acts of violence and dedication to unworthy causes. Why are we not able to cooperate with other countries on a fundamental level to bring mentoring to the betterment of peoples?

Federal research grants:
U.S. Department of Energy, U.S. Department of Defense, National Science Foundation, BASF Global

Additional Links:
http://www.research.ucla.edu/UCLAinvents/03/issue.pdf
http://yaghi.chem.ucla.edu/
http://www.spotlight.ucla.edu/here-now-stories/omar-yaghi/

Alexander Raikhel, Distinguished Professor of Entomology, Member of the Academy of Sciences, University of California, Riverside

Area of research/field of work:
Molecular biology, immunology, insect vector research

Current work/research and its relevance:
Immune defense against pathogens causing malaria and Dengue fever and transmitted by mosquitoes.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?

We have urgent and enormous tasks for improvement of human lives here on Earth. Our environment is being threatened by the use of fossil fuels, and yet we are still grappling with inefficiency of alternative energy sources.

Major scientific efforts must be devoted to achieve breakthroughs in this area. Another great scientific frontier should be in the dramatic improvement of diagnosis and treatment of major chronic diseases, such as cancer, diabetes and heart disease. More funding should be directed towards accomplishment of this goal. Malaria, tuberculosis and AIDS are three major contributors of mortality and suffering in the developing world, particularly in sub-Saharan Africa. We must do more to overcome these and other devastating infectious diseases. We as a society have greatly benefited from advances in science and their applications to our lives.

However, we as a nation must realize that without a dedicated continuous support of scientific endeavors, ours and our children's well-being cannot be sustained and improved. America must preserve its leadership in creativity by increasing funding for research and even more importantly by educating its children.

Many devastating human diseases are transmitted by mosquitoes. Disease causing pathogens have successfully adapted to survive the immune defense of mosquito vectors. Hence, the understanding of the interactions between a pathogen and its vector host is essential for developing novel methods for disrupting disease spread. My laboratory aims to decipher mosquito immune responses during the invasion by pathogens. It is my hope that my work will contribute to the fight against malaria, Dengue fever and other diseases threatening humans.

Federal research grants:
Dr. Raikhel's work on immunity and reproduction of mosquitoes is currently supported by grants from the National Institutes of Health.

David, Reznick, Professor of Biology, University of California, Riverside

Area of research/field of work:
Evolutionary biology

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
Research over the last few decades has taught us that evolution is not just a historical process whose footprint can be found in living organisms. It is a rapid process that can be studied experimentally in natural populations and can reveal significant change in short intervals of time, on the order of months to years. If evolution is a contemporary process that can result in rapid adjustment to environmental change, then it becomes relevant to consider the roles that it might play in our day-to day-lives. The importance of evolution has been recognized, but not fully evaluated, in the role it plays in emerging diseases and other human health issues, but also in interactions between humans and other organisms in ways that can affect the long-term welfare of humanity. Because of the potential rapidity of evolution, it is now within our grasp to wed the maturing field of systems biology/genomics with population and evolutionary biology. This synthesis will allow us to use evolution as a tool to study how the genome works and genomics as a tool to study how evolution works. Genomics is already used to make inferences about evolution, but it almost invariably does so in the traditional fashion, by trying to reconstruct the changes that occurred in the past. We are proposing instead that it is now possible to harness the power of genomics for experimental studies of evolution in natural populations, to directly observe the mechanisms of genetic change that underlie the processes of evolution. By doing so, we will be able to see in real time how genetic changes are associated with specific modes of evolution. Seeing evolution in action avoids the many confounding factors that make it so difficult to infer evolutionary processes from merely looking at its modern outcome.

My argument is best illustrated with an example. I study guppies (*Poecilia reticulata*). Their closest relative is *Poecilia picta*. A traditional application of genomics to evolution would be to generate complete genome sequences for both species, compare them, then try to draw inferences about how differences in their genome relate to differences between species. This same exercise is now being executed for chimps and humans. The limitation is that these two species last shared a common ancestor millions of years ago, so any differences that we see between their genomes that are correlated with differences in the species could be causal, or could be a consequence of chance correlations that have arisen over the millions of years that have passed since they shared a common ancestor. In my current research on guppies, I am studying replicate, evolving populations in a natural setting. I am marking and archiving total genomic DNA from every individual, then using a small subset of it to construct the pedigree for the population. If we could generate whole genome sequences for large numbers of individuals with known attributes in evolving populations, then the task of defining cause and effect relationships between trait evolution and change in the genome would be far more accessible than in comparisons among species.

Seeing evolution in action is distinct from inferences derived from evolution that occurred in the past because the genetic basis of evolutionary change can have unpredictable consequences that cannot be inferred from the traditional, more historical study of evolution as a process. We know enough now to realize that the key to evolution is not simply to change individual genes that produce proteins that play some specific role in growth, development and maintenance. There are instead multiple keys, including the regulation of when and where a gene is expressed and how much gene product is made. We also know that our genomes are dominated by DNA that produces no gene products; there is some indication that this seemingly silent DNA is under selection, but its role in evolution is not well understood. At present, we cannot gauge the magnitude or nature of the roles played by the direct modification of gene products or gene regulation in evolution, nor do we have a good understanding of the role of untranscribed DNA. By wedding genomics with experimental studies of evolution, we can develop a complete understanding of all of the genomic mechanisms that underlie evolution and a superior understanding of how the genome works.

Within a decade, we could map out the genetic changes that cause specific types of evolution to occur in a natural setting. There is a prevalent sense that there is a "gene for" specific traits, but in fact we know that this is not true. Individual genes can affect individual traits, but they can also affect many other traits, many other genes can affect a trait in question, and genes can interact with one another in unpredictable fashions. Thus, genes and their effects cannot be seen in isolation, but one always needs to consider their overall effects—a genetic change that might predispose us to a certain disease might at the same time protect us from other ailments. We also know that the static development of a trait can give us a distorted image for the role that individual parts of the genome play in defining a trait. Over the next decade, we could instead define the dynamical change in the genome that are associated with the evolution of a trait and develop an enhanced concept for how the genome works and how it is modified to allow organisms to adjust to changes in their environment. The basic information that would emerge from such studies would have wide application to many fields that are of direct value to humanity. For example, I have documented the evolution of the size at birth, development rate and age at maturity, growth rate, rate of production of offspring, rate of aging and senescence, performance (acceleration and endurance) and behavior, among many other traits in my research on guppies. The genetic basis of all of these traits would be revealed if we could also study how guppy genomes change as these traits evolve. The kinds of genetic mechanisms that are revealed by such dynamic studies are certain to be different from those that are revealed by more traditional approaches to studying the genetic basis of traits like aging and senescence since more traditional studies most often begin with lab derived mutants and the presumption that it is the mutated genes that control the trait in question. Any trait that can be shown to evolve would become accessible to genomic analysis via the proposed approach.

We not only need to continue to expand on the great progress that has been made in genome sequencing to make it ever cheaper and faster to obtain such information, but we also have to appreciate how important it is to work with entire communities of organisms in their natural settings. To achieve our vision, we need to focus attention on the integration of disciplines that currently have limited or no overlap. Genomics and the computer sciences are now well integrated. Genomics and evolution are partially integrated. We propose a much more extensive integration of genomics with evolution and ecology so that we can learn to study the evolution of the genome as a contemporary process and can better relate all of the ways in which the genome can be modified to cause evolutionary change.

Federal research grants:

Dr. Reznick's work has been continually supported by grants from the National Science Foundation since 1978.

His current research is supported by a grant from the Population Biology Division to study the evolution of placentas in the fish family Poeciliidae and a second grant from the Frontiers in Integrative Biological Research program to study the interaction between evolutionary and ecological processes in a natural ecosystem.

Michael Turner, Bruce & Dianna Rauner Distinguished Service Professor in Astronomy & Astrophysics, University of Chicago, former Chief Scientist, Argonne National Laboratory

Area of research/field of work:
Theoretical astrophysics, cosmology and elementary particle physics, cosmology

My research focuses on the application of modern ideas in elementary-particle theory to cosmology and astrophysics. I believe that this approach holds the key to answering the most pressing questions in cosmology.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
Our place in the Universe.

We are poised to answer some of the most profound and most persistent questions that humankind has asked: How did the Universe begin? Are we alone? What is our cosmic destiny? We know that the Universe began from a big bang 13.7 billion years ago, but we don't know what triggered the big bang, or if there were other big bangs. We too know that most stars have planets, that there are 100 billion stars in our Milky Way galaxy and 100 billion galaxies in the observable Universe – a tremendous number of possibilities for life.

However, we don't know how common earth-like planets are, how often that they are the right distance from their star to support life, or how common life is (let alone intelligent life). Finally, we know that the Universe is expanding at an accelerating pace, caused by the action of a mysterious dark energy, but we don't know what dark energy is, and until we do, we can only speculate about
our cosmic destiny.

Together, powerful instruments that have been built and are being imagined and bold ideas have placed of these questions within reach today. We have a theory for what triggered our big bang – a burst of acceleration know as cosmic inflation. The next step is to test the theory and discover its underlying details by making very precise measurements of the radiation left over from the big bang itself – the cosmic microwave background. Experiments to make these measurements both on the ground and in space have been designed, but await funding. Recently, NASA launched a space telescope called Kepler dedicated to searching for Earth-like planets within our galaxy. Space telescopes capable of imaging planets discovered by Kepler and searching them for signs of life are in the process of being invented and likely could be built within 20 years.

While there are no guarantees when working at the frontiers of knowledge, a sustained commitment over the next two decades and an investment in both people and equipment of 20 billion dollars might well succeed in answering these big questions, or at the very least make dramatic progress. Like putting a man on the moon, answering these big questions would be part of a journey to find our place in the Universe as well as preparing to extend our presence beyond Earth. Few investments would leave a greater legacy to future generations or say more about our species.

Professor William F McDonough, Department of Geology, University of Maryland

Area of research/field of work:
Geochemistry

Current work/research and its relevance:
My research expertise is in geochemistry and the analysis of material (solids and liquids). I am developing methods for forensic identification of materials, environmental analysis and the analysis of materials that give us insights into how the Earth and inner planets were formed and operate. My research programs spans the realms of practical science for society (environmental, national security and metrology) to fundamental scientific research that tells us about the Earth and the planets.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
Global climate change, water resources and the energy economy are our next great scientific frontiers. The Apollo mission, like the Manhattan project, was conceived in a sense of a national need to address a global challenged real (in the case of the Manhattan project) or perceived. Both projects were in response to culturally driven, politically charged "wars" (WWII and Cold War). The collective pressures of Global climate change and its consequences on water resources and its concomitant health issues will affect many nations and the world economy. The demand that energy resources places on national budgets, national security and the global climate is recognized and understood to demand immediate attention, particularly in the case of energy resource diversity. Perhaps more than anything, we need to address the scientific challenge or providing more effective, efficient and diverse sources of energy to drive the global economy, its citizens and its infrastructure.

We need to invest in understanding the interplay between climate change, water resources and the energy economy. We need to invest in all three areas of science and its associated areas of policy. Understanding the nature of water resource and its shifting distribution as a function of global climate change are likely to be a significant challenge to society in the future.

Federal research grants:
NSF, Earth and Environmental Sciences; NASA, Meteoritics and Planetary Sciences; DIA, Forensic Analysis, remote sensing

Lucy McFadden, Research Professor, Department of Astronomy, University of Maryland, College Park

Area of research/field of work:
Professor McFadden explores the physical properties of asteroids and comets in our solar system using robotic spacecraft. She was a co-investigator on NASA's historic NEAR and Deep Impact missions and is a co-investigator on the agency's current Dawn and EPOXI missions.

Area of research/field of work:
My current scientific research involves learning as much about Vesta and Ceres as we can to prepare for the Dawn mission's orbiting of Vesta (2011-2012) and Ceres in 2015. To that end, I have acquired multi-color images of Vesta with Hubble Space Telescope to map its surface and to explore what constraints can be placed on its composition. My colleague, Jian-Yang Li and I have used Hubble Space Telescope to measure the ultraviolet spectrum of Ceres to characterize an absorption band that Li found in his work in 2006. It will be interesting to see if we can pinpoint the material that causes this feature now that there are data with higher spectral resolution than were previously available.

The Deep Impact spacecraft carried an imager with filters designed to detect fluorescent light from comet Tempel 1. I am working on the analysis of these data to see if we can learn anything about the gas emission at close range to the comet.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
Neil Armstrong and Buzz Aldrin's landing on the moon was a landmark day in human history and it ushered in a new age in the exploration of our solar system. As a rising high -school senior on July 20, 1969, I found myself in a campground outside of Leningrad, then the U.S.S.R. With a group of my peers and three adult leaders we were washing dishes and watching Armstrong set foot on the Moon. Like most high school students I was focused on my immediate surroundings; my friends there with me, the people we encountered on our

travels in two Volkswagen mini-buses, and the seminars we were attending through the program called Traveling Seminars Abroad. Watching the men land on the moon was as awesome to me as it was to everyone around us. A few days later, in the subway in Leningrad, a babooshka came running after us and congratulated *us* for landing on the moon. Little did I know that I would be participating in the space program three years later as an undergraduate researcher and eventually as a co-Investigator of robotic missions exploring asteroids and comets.

Today, exploration of the solar system and the universe beyond has changed our view of ourselves, our home planet and the Universe beyond. We now know that the moon formed during a violent collision over 4 billion years ago that ejected a malleable chunk of Earth. That mass was captured into earth orbit and spun into the moon. Today seek answers to questions of how life formed on Earth by exploring planets both near and far that contain water and organic material that seeds life on Earth, and we are characterizing planets around other stars. NASA currently has 65 active robotic spacecraft exploring both the solar system and beyond. Our colleagues around the world are doing the same with active spacecraft built by the EU, Japan, Russia and India. University researchers in partnership with aerospace companies and NASA initiate, design and implement the great observatories and robotic space craft that have lead the revolution in astronomy and astrophysics of the past five decades. Students working with us in our university research laboratories gain the ability to ask questions and design a plan of action to address them. In most cases we learn things that were totally unanticipated. And like the Apollo 11 landing on the moon, forty years ago, it changes the way we see ourselves, our community and our culture.

Steven L. Salzberg, Ph.D., Phillip H. and Catherine C. Horvitz Professor, Department of Computer Science, Directory, Center for Bioinformatics and Computational Biology, University of Maryland, College Park

Area of research/field of work:
Bioinformatics, genomics, genetics

Current work/research and its relevance:
My research focuses on the development of computational algorithms for analyzing DNA sequences. One of my main interests is the use of "next-generation" DNA sequencing technology to map the genomes of a broad range of species, from viruses to bacteria to mammals. We are also using this technology to study the diversity of microscopic life found in the human body, in the soil, and in other environments.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
The United States could map the genome of every man, woman, and child in the entire country. With the complete DNA sequences of every citizen in hand, we would have an unprecedented ability to study the entire range of human diseases, to determine how diet and lifestyle factors interact with our genes to affect our health, to understand precisely how genes influence our risk for cancer and infectious diseases, and a host of other questions related to human health. We could also start to deliver on the promise of "personalized medicine," in which treatments could be customized to each person's genome. And because the United States has long been a melting pot for different nationalities, the genetic variation we would uncover in the population would include a snapshot of the genes for the entire human race.

The technology for creating this national genome map is already available. The latest DNA sequencers can sequence the entire genome of a human being in about a week, at a cost of only a few thousand dollars. By launching such an ambitious project, the U.S. would allow technology developers to reach economies of scale that might drive this cost down ten-fold or even 100-fold. New, very large data warehouses will be needed to store and search the data, but these too can be built by scaling up existing technology, with the expectation that costs will drop as the technology improves. The resulting database will be a resource for biomedical research that will dwarf anything in existence today, and that will provide an incredibly powerful tool for solving the major human health problems we face as a species.

Federal research grants:
My work on genome sequencing and mapping is currently supported by grants from the National Library of Medicine at the National Institutes of Health (NIH), the National Institute of General Medical Sciences at NIH, the National Institute of Allergy and Infectious Diseases at NIH, the U.S. Department of Agriculture, the National Science Foundation, and the Department of Homeland Security.

UNIVERSITY OF MICHIGAN

Dennis Assanis, Director of the Michigan Memorial Phoenix Energy Institute and of the W.E. Lay Automotive Laboratory

Area of research/field of work:
Assanis is an international authority in the field of power and energy. His research is driven by the imperative to gain new understanding of the basic energy conversion processes so as to develop systems with significantly improved fuel economy and dramatically reduced emissions. His expertise encompasses both modeling methodologies and experimental techniques.

Current work/research and its relevance:
At the University of Michigan, research spans from the most basic of research to find new fuels, new materials and new storage systems for more sustainable vehicles, as well as expansive research on internal combustion, on how electric grids will interface with electric-powered vehicles, how vehicles can make electric grids more robust. There also is research understanding market forces and policy.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
The nation's – and the world's – next great scientific frontier faces one of mankind's greatest risks with one of technology's greatest opportunities.

The frontier: Energy – specifically ending the world's devastating addiction to fossil fuels. The challenge is changing ingrained habits and technologies that have resulted, in the United States alone, in the consumption of nearly 7,000 gallons of petroleum per second, and its catastrophic damage to the environment, the acceleration of global warming and the destabilization of security.

The opportunity: Instead of looking for a single innovation to transform transportation, the next great challenge will be a revolutionary and holistic reinvention of vehicles. The next "moon landing" will be a new science-driven way of approaching automobiles and other means of transportation that go beyond slashing mpg or substituting gas with electricity. The next great discovery will in fact be a series of tightly coordinated discoveries that will transform transportation systems towards sustainability.

The future: Carbon Neutral Vehicles (CNV) – breaking down each element and function of the vehicle to find ways to eliminate greenhouse gases. This means from its fuels, to how it runs, to how it interacts with other systems like the electrical grid, to the parts that make the vehicles to the policies that guide the vehicles use – there is a revolution to find new ways to give that vehicle throughout its life cycle a tiny environmental footprint.

New stuff starts here: In pursuit of CNVs, "blends" of renewable biofuels and low-carbon electricity will be integrated in highly-efficient propulsion technologies that incorporate novel energy conversion, harvesting and storage via advanced energy materials and components. This will require not only transformative research through discovery and co-design of new biofuels and engine cycles, energy storage materials, electrified vehicle propulsion technologies and controls, but also translation of research results into highly efficient and clean components and systems.

This will mean rapid, tightly coordinated and vastly multidisciplinary work beyond innovative technologies. Economic, social and policy strategies will be needed to evaluate various policy options and the economic impact of transforming our transportation system. Finally, in order to truly transform the various modes of transportation, the transportation and building infrastructure needs to be optimized for accessibility and mobility.

In other words, it's vast. It's different than anything we've known. And it's achievable. The work already is in progress.

The opportunity in the next decade is new vehicles that truly don't contribute to climate change or pollution – not vehicles that just shift the environmental impact elsewhere. It means something new that from start to demise becomes a solution, not a problem. It's a series of developments and achievements that use research and data to guide decisions.

Federal research grants:
His work is supported by the Department of Defense and Department of Energy.

Wayne Knox, Director, The Institute of Optics, Professor of Optics, Professor of Physics, University of Rochester, Senior Scientist, Laboratory for Laser Energetics

Area of research/field of work:
Ultrafast Sciences and Technology, Telecommunications, Ultrafast Biomedical Optics and Optics Education

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
Certainly one of the greatest challenges we face today is to eliminate the large-scale use of fossil fuels through aggressive research into renewable energy sources that are safe, clean, and improve the environment, as a whole. Optical technologies such as improved solar energy collection and more efficient lighting and displays are just a few examples where we can see future advancements. In order to make theseviable, the combined expertise of scientists and engineers from many diverse fields across the globe will be required.

Elissa L. Newport, George Eastman Professor, Brain & Cognitive Sciences and Linguistics, Chair, Brain & Cognitive Sciences, University of Rochester

Area of research/field of work:
My primary research interest is in the acquisition of language, and in the relationship between language acquisition and language structure.

Current work/research and its relevance:
My own research is focused on understanding learning in infants and young children - why infants can learn so much more effectively than adults - and on understanding how the brain rapidly acquires new information and recovers from damage during early life. If we can understand how the human brain is so exceptionally 'plastic' in early life, we will be able to restore this plasticity to the adult brain. Within the next few decades, we will be able to stimulate the brain to re-grow and repair itself after damage - just as the skin or the liver naturally grow back when injured.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
In my opinion, the 21st century equivalent to putting a man on the moon will be our understanding of the human brain - and in particular, achieving the ability to stimulate the brain to repair itself, including restoring old memories and learning new information, after damage and disease.

We're on the brink of understanding how to achieve this goal, and that understanding will revolutionize the way we treat devastating neurological injuries and disease, such as stroke and Alzheimers, which are predicted to be the number one diseases of the next decades. Under ordinary circumstances, the human brain does not create new neurons after injury and, once childhood is over, does not extensively re-map the functions that are lost onto other brain areas. However, extensive remapping of function does occur in infants and young children, and both of these recovery processes - remapping and neurogenesis - occur in other species. We are learning from study of these processes, in infants and in other species, how to stimulate human brain repair.

To achieve this goal, America needs to continue its recent increase in funding for biomedical science. We're almost there - if we merely stop cutting science funding, these discoveries are around the corner.

WAYNE STATE UNIVERSITY

Douglas Barnett, Ph.D., Associate Professor of Psychology, College of Liberal Arts and Science, Wayne State University

Area of research/field of work:
Child Development, parenting, clinical psychology

Current work/research and its relevance:
Understanding how parents promote positive or resilient outcomes among children at high risk for poor health, scholastic, and social outcomes

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
Child abuse and neglect is an ancient, complex, problem that goes back to at least the dawn of human history. Nearly one million children each year in the USA are documented victims of severe forms of child abuse and neglect with the actual number likely in the 10s if not 100s of millions globally. Children who have been abused or neglected are known to be at high risk for a variety of health and social problems (e.g., premature death, crime, drug abuse, homelessness), which can persist for decades after the abuse and neglect has ended. The costs of child abuse and neglect to federal and state governments in the USA have been estimated at $95 billion annually to cover necessary services such as foster care, child protective services, medical and mental health treatment, court costs, and others.

Despite the large scale nature of this serious problem in human behavior, the scientific study of child abuse and neglect is less than 50 years old. Over the past four decades, preliminary progress has been made in our understanding of child abuse and neglect. We now have general consensus within the developed world on how to define and measure the wide range of forms in which child abuse and neglect occur. Several theories of the causes and consequences have been put forward and have received preliminary study. Animal models of child abuse and neglect also have been developed with primate species. Primarily in the past ten years, investigators have begun to develop an empirical science of which treatments are effective at preventing child abuse and neglect as well as reducing some of the negative consequences associated with its aftermath. This new direction is promising not just to help reduce the suffering of victims, but also because treatment studies require experimental manipulations that provide excellent opportunities to rigorously test scientific theories of the causes and consequences of a problem such as child abuse and neglect.

The biggest obstacle to research on child abuse and neglect in our nation is federal funding. Child abuse and neglect has received less attention from the federal government than any other health or social problem. Within the health sciences, child abuse and neglect is a concern of several professions including psychology, psychiatry, pediatrics, radiology, social work, law, public policy, criminal justice, primatology, and the neurosciences. Each of these professions has their own unique foci, methods, theories, and literatures. While each has made some progress scientifically, I believe that the fractioning of the professional disciplines has created obstacles and gaps in our fuller understanding of child abuse and neglect. I believe the science of understanding and responding to child abuse and neglect can be advanced greatly through the collaboration of the disciplines who have been addressing this important social concern. It is time that the National Institutes of Health establish an institute that is solely focused on the scientific understanding and prevention of child abuse and neglect and its aftermath. We as a nation should utilize science not just to give our rockets the safest launches possible, but our children as well.

Federal research grants:
I am currently collaborating with Dr. Li and colleagues on a study of health and social outcomes among Chinese youth who have lost one or more parents to HIV/AIDS. Our work is funded by the National Institutes of Health.

Michelle L. Cote, Ph.D. Assistant Professor, Department of Internal Medicine and Karmanos Cancer Institute, School of Medicine, Wayne State University

Area of research/field of work:
Lung Cancer

Current work/research and its relevance:
My current research explores regions of the genome that have been associated with both COPD and lung cancer, two of the leading causes of morbidity and mortality in the United States and worldwide. If particular genetic sequences appear to be associated with increased risk of disease or worse prognosis, we may be able to direct therapies towards these targets.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
In my mind, the next decade will bring amazing strides in personalized medicine, including the ability for individuals to have access to their own genome sequence. Thus far, the sequencing of the human genome has brought with it as many questions as it has answers, but I believe we are poised to start benefiting widely from this prior work. While all humans share over 99% of the same genetic code, the 1% of differences can be of great importance when determining what treatments we will respond best to and how susceptible we may be to certain conditions. As Americans, we need to continue to educate ourselves on both the scientific and societal implications of this research. In addition, research in this area needs to be supported not just monetarily, but through participation in things such as clinical trials. My current research explores regions of the genome that have been associated with both COPD and lung cancer, two of the leading causes of morbidity and mortality in the United States and worldwide. If particular genetic sequences appear to be associated with increased risk of disease or worse prognosis, we may be able to direct therapies towards these targets, leading to improved survival.

Federal research grants:
Dr. Cote's research on lung cancer and COPD is supported by a grant from the NIH/NCI.

Norman Cheng, Ph.D., Assistant Professor of Radiology, School of Medicine, Wayne State University

Area of research/field of work:
Magnetic Resonance Imaging (MRI)

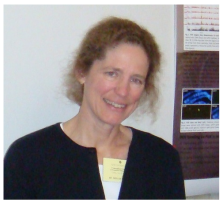
Current work/research and its relevance:
Wayne State University's research in radiology is focused on developing new quantitative imaging tools that will facilitate predictive medicine. Microbleeds or iron accumulation in the brain are more clearly seen in MRI using our new techniques. They arise in chronic diseases such as Alzheimer's and brain-bleeding problems. We have now developed the first-version tools that can let us measure magnetic properties of microbleeds or iron. The progression of disease and normal aging both demonstrate changing magnetic effects. Quantifying these magnetic properties with MRI can determine not only the stage of the disease but also identify and track the disease for each individual. Our next scientific frontier is to further improve our tools such that they can be used clinically for disease prediction at an early stage.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
A new Scientific Frontier will be to facilitate predictive medicine. We wish to predict the progress of a disease, and to prevent the disease or control it at an early stage, and then to prescribe the treatment based on each individual's needs. Imaging has played an important role in the routine annual physical exams that just became standard 40 or 50 years ago, not long before Project Apollo. MRI is now reaching a maturity where it can contribute to fairly general routine examinations and early diagnosis. With fine image resolution but without ionizing radiation, many quantitative methods in MRI have become feasible for the goal in predictive medicine. However, in order to advance techniques, more developments in MRI or imaging in general are still needed.

The U.S. has the technology to develop many new techniques in 3 to 5 years, or let them "evolve" over the next decade. However, those developments will require more medical research and funding in the next decade. With today's economic status and high national debt, many medical researches cannot obtain funding. A possible solution is to support most research projects with a much smaller scale of money for each project, which may lead to more rapid implementation of advances in clinical researches.

Federal research grants:
Current research is supported by the "Susceptibility Weighted Imaging" grant (co-investigator) from NIH

Victoria Meller, Associate Professor of Biological Sciences, College of Liberal Arts and Sciences, Wayne State University



Area of research/field of work:
Gene regulation

Current work/research and its relevance:
My laboratory studies how male fruit flies modulate expression of X-linked genes to make up for the fact that males have a single X chromosome but females have two X chromosomes.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
The moon launch comparison is interesting because in my field, biological sciences, most research is conceived and carried out independently in small laboratories. An exception is the genome sequencing efforts of the last ten years. Genomes were sequenced by consortiums of labs, most guided by federal agencies and scientific societies. A genome sequence is pretty dull reading. But the push to get sequencing done, and the need to manage the massive amount of data produced, drove the development of technologies that changed the fundamental nature of experimentation. We can now ask questions about the regulation and evolution of genomes that would have been previously unthinkable. My research group uses information from the *Drosophila* (fruit fly) sequencing project to ask questions about how large groups of genes are coordinately regulated. This type of research is crucial to understand how genomes function normally – and how genome-wide misregulation leads to diseases like birth defects and cancer. Our studies, like those of most geneticists, rely on the tools and resources that flowed from the massive effort of genome sequencing. This is similar to the power of the moon launch, which stimulated the development of technologies that changed research far beyond lunar exploration.

Federal research grants:
My research has been funded by National Institutes of Health and the National Science Foundation.

Dr. Earl Scime, Robert C. Byrd Professor of Physics, Chair, Department of Physics, Eberly College of Arts and Sciences, West Virginia University

Area of research/field of work:
In addition to space-related research, Scime explores plasma-based techniques to gasify coal for creation of transportation fuels, and develops new diagnostics for thermonuclear fusion experiments.

Scime's research program in experimental physics is one of the few in the world that incorporates both laboratory and space plasma physics and has been widely recognized in the plasma physics community.

Scime and his research group – which includes postdoctoral students, graduate students and undergraduate students – create space-like conditions in the lab to study natural phenomena in space. His group also collaborates on a variety of space missions, including the mission to provide stereo imaging of Earth's magnetosphere.

As chair of the Department of Physics, Scime has supported the development of interdisciplinary research programs, including nano research and a new multidisciplinary astrophysics/radio astronomy research program involving WVU and the National Radio Astronomy Observatory in Green Bank. Additionally, he has mentored six Goldwater Scholars, recipients of the nation's premier award for undergraduates pursuing careers in math, science or engineering.

He served as a U.S. Department of Energy Distinguished Postdoctoral Fellow at Los Alamos National Laboratory before joining the WVU faculty.

Current work/research and its relevance:
I currently contribute to the development of fusion diagnostics and to the training of the next generation of plasma scientists.

In your view, what are the next great scientific frontiers – what is today's equivalent to putting a Man on the Moon? If America decided to accept the challenge, what could we accomplish through science, research and discovery within the next decade? What do we need to do as a nation to accomplish this?
The greatest scientific challenges facing our world involve the production and distribution of energy. With vast supplies of energy, water can be desalinated, homes and industries powered, toxic chemicals destroyed, and new materials synthesized. Renewable energy sources are an important component of distributed energy production, but base load energy systems are still needed. Fission power makes a significant contribution, but issues of

nonproliferation make worldwide fission power problematic. Nuclear fusion, having already demonstrated impressive progress over the past 50 years, is poised to make the next step towards energy production with the international ITER project - which will demonstrate controlled nuclear fusion. As a nation, we need to increase our involvement in ITER to the level of a major contributor and foster the innovation needed to design fusion systems that will be more economically viable and less complicated than ITER. It would take a "moon race" or "Manhattan level" project to move fusion energy from a scientific challenge to an implementation challenge. With vast supplies of fusion fuel, an energy based economy is feasible.