

**BIOLOGICAL RESEARCH FOR ENERGY
AND MEDICAL APPLICATIONS AT THE
DEPARTMENT OF ENERGY OFFICE OF SCIENCE**

HEARING
BEFORE THE
SUBCOMMITTEE ON ENERGY AND
ENVIRONMENT
COMMITTEE ON SCIENCE AND
TECHNOLOGY
HOUSE OF REPRESENTATIVES
ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

SEPTEMBER 10, 2009

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**BIOLOGICAL RESEARCH FOR ENERGY AND
MEDICAL APPLICATIONS AT THE DEPART-
MENT OF ENERGY OFFICE OF SCIENCE**

THURSDAY, SEPTEMBER 10, 2009

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 2:02 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Brian Baird [Chairman of the Subcommittee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

RALPH M. HALL, TEXAS
RANKING MEMBER

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Committee on Science and Technology
Subcommittee on Energy and Environment

Hearing on

***Biological Research for Energy and Medical Applications
at the Department of Energy Office of Science***

Thursday, September 10, 2009
2:00 p.m. – 4:00 p.m.
2318 Rayburn House Office Building

Witness List

Dr. Anna Palmisano

*Director
Office of Biological and Environmental Research
U.S. Department of Energy*

Dr. Jay D. Keasling

*Lawrence Berkeley National Laboratory
Joint BioEnergy Institute*

Dr. Allison Campbell

*Director
WR Wiley Environmental Molecular Sciences Laboratory
Pacific Northwest National Laboratory (PNNL)*

Dr. Aristides A. N. Patrinos

*President
Synthetic Genomics, Inc.*

Dr. Jehanne Gillo

*Office of Nuclear Physics
U.S. Department of Energy*

**SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES**

**Biological Research for Energy
and Medical Applications at the
Department of Energy Office of Science**

THURSDAY, SEPTEMBER 10, 2009
2:00 P.M.–4:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On Thursday, September 10, 2009 the House Committee on Science & Technology, Subcommittee on Energy and Environment will hold a hearing entitled "*Biological Research for Energy and Medical Applications at the Department of Energy Office of Science.*"

The Subcommittee's hearing will receive testimony on the biological research activities of the Department of Energy (DOE) Office of Science conducted through the Biological and Environmental Research (BER) and Nuclear Physics (NP) programs. It will also examine how these areas are related to the work of other DOE program offices and other federal agencies.

Witnesses

- **Dr. Anna Palmisano** is Director of BER. Dr. Palmisano will provide an overview of the program and discuss its coordination with other DOE program offices and federal agencies.
- **Dr. Jay Keasling** is CEO of the Joint BioEnergy Institute (JBEI) at Lawrence Berkeley National Laboratory. Dr. Keasling will testify on the status of the three major bioenergy centers and the efficacy of this model for bioenergy research.
- **Dr. Allison Campbell** is Director of the WR Wiley Environmental Molecular Sciences Laboratory (EMSL) at the Pacific Northwest National Laboratory. Dr. Campbell will explain EMSL's role in meeting DOE's mission needs with a particular focus on environmental remediation.
- **Dr. Ari Patrinos** is President of Synthetic Genomics, Inc. Dr. Patrinos will testify on the private sector's perspective of the BER program in bioenergy, as well as his experience as a former Director of BER.
- **Dr. Jehanne Gillo** is Facilities & Project Management Division Director of NP. Dr. Gillo will testify on the status of the isotope development and production program recently transferred from the DOE Office of Nuclear Energy.

Background

The origins of biological research conducted by the Department of Energy date back to 1946. The U.S. had recently developed and deployed the atomic bomb in World War II and was subsequently examining the potential peaceful uses of nuclear energy, which led to major concerns regarding health effects from exposure to radiation. Research in these health effects produced advances in genetics and developments in nuclear medicine, such as radioisotopes for common medical tests and positron emission tomography (PET) scanners that are still used to diagnose millions of patients each year.

Perhaps the most significant event in the last two decades of the DOE Office of Science's Biological and Environmental Research (BER) Program was its initiation of the Human Genome Project in 1990 in collaboration with the National Institutes of Health (NIH). A genome is a complete genetic sequence of the DNA of an organism. Built on the advances in technology development at DOE's national laboratories, the Human Genome Project led to the determination of the complete DNA

sequence of humans by 2003, two years ahead of schedule. Work to support the project was conducted by teams of scientists in the public and private sectors from around the world, and their results have provided new opportunities for discovering and understanding fundamental principles of life.

Biological Systems Science

| | (dollars in thousands) | | |
|--|------------------------|---------|---------|
| | FY 2008 | FY 2009 | FY 2010 |
| Biological Systems Science | | | |
| Genomic Science | 164,085 | 169,858 | 165,626 |
| Radiological Sciences | 46,674 | 50,768 | 46,615 |
| Ethical, Legal, and Societal Issues | 5,000 | 5,000 | 5,000 |
| Medical Applications | 8,191 | 8,226 | 8,226 |
| Biological Systems Facilities and Infrastructure | 80,011 | 80,300 | 84,300 |
| SBIR/STTR | — | 8,663 | 8,709 |
| Total, Biological Systems Science | 303,961 | 322,815 | 318,476 |

Table 1: Budget table for the DOE Office of Science's Biological Systems Science program. FY 2008 and FY 2009 are appropriated levels, and FY 2010 is the Administration's request level. This does not include funding from the American Recovery and Reinvestment Act of 2009, of which the Department currently plans to allocate \$13.5 million in the Genomic Science subprogram for capital equipment at the Bioenergy Research Centers and \$13.1 million in Biological Systems Facilities and Infrastructure for additional support of the Joint Genome Institute.

BER then shifted the focus of this new capability to rapidly sequence an organism's complete genome to the fields of microbial and plant biology with an emphasis on organisms with energy and environmental relevance. The Biological Systems Science program within BER—first authorized in the *Energy Policy Act of 2005*—brought together genomic research in microbial and plant biology with protein science, computational biology, and environmental science to support the energy, national security, and environmental missions of DOE. The ability to study an organism beginning with its DNA sequence has provided new understanding of fundamental biological processes related to biofuels production, carbon sequestration, and environmental clean-up. Details on current and proposed funding for Biological Systems Science can be found in Table 1.

Genomic Science

The Genomic Science subprogram includes three major components:

- **Bioenergy Research Centers**—Bioenergy research is now a primary focus in the BER program. In 2006 BER solicited applications for several Bioenergy Research Centers. The Centers were to be focused on achieving significant breakthroughs in the development of cost-effective technologies to make production of cellulosic (plant-fiber based) biofuels commercially viable on a national scale. Each Center was chosen for its unique set of skills to address three major challenges—the development of next-generation bioenergy crops; the discovery and design of enzymes and microbes with novel biomass-degrading capabilities; and the discovery and design of microbes that create fuels directly from biomass. Three were finally selected in the summer of 2007, and include the:
 - **BioEnergy Science Center (BESC)** led by the Oak Ridge National Laboratory. This center focuses on the resistance of plant fiber to breakdown into sugars and is studying the potential energy crops poplar and switchgrass. Partners of BESC include Georgia Institute of Technology Atlanta; DOE's National Renewable Energy Laboratory, Golden, CO; University of Georgia in Athens; University of Tennessee, Knoxville; Dartmouth College, Hanover, NH; ArborGen, Summerville, SC; Verenum Corporation, Cambridge, MA; Mascoma Corporation, Boston, MA; The Samuel Roberts Nobel Foundation, Ardmore, OK; and Ceres, Inc., Thousand Oaks, CA.
 - **Great Lakes Bioenergy Research Center (GLBRC)** led by the University of Wisconsin, Madison in close partnership with Michigan State University. Other partners include Illinois State University, Normal; Iowa State University, Ames; Lucigen Corporation, Middleton, WI; and

both DOE's Oak Ridge National Laboratory (ORNL) and Pacific Northwest National Laboratory (PNNL). This center is studying a range of plants and, in addition to exploring plant fiber breakdown, aims to increase plant production of starches and oils, which are more easily converted to fuels. GLBRC also has a major focus on sustainability, examining the environmental and socioeconomic implications of moving to a biofuels economy.

- **Joint BioEnergy Institute (JBEI)** led by Lawrence Berkeley National Laboratory and headed by Dr. Jay Keasling. JBEI is using well-characterized genomes and genetic-engineering tools established for rice and *Arabidopsis* (a small flowering plant related to mustard). These two model species are ideal research subjects because they go from seed to mature plant in weeks or months, rather than the year or more required for energy crops such as switchgrass and poplar. Genetic insights from rice (a model for grasses) and *Arabidopsis* (a model for trees) are thus expected to accelerate the development of new energy crops. JBEI is also exploring microbial-based synthesis of fuels beyond ethanol. Partners of JBEI include DOE's Sandia National Laboratories; University of California, Berkeley; University of California, Davis; Carnegie Institution for Science, Palo Alto, CA; and DOE's Lawrence Livermore National Laboratory, Livermore, CA.

The Centers consist of multi-disciplinary teams of scientists from 18 universities, seven DOE national laboratories, two nonprofit organizations, and a range of private companies. They were soon authorized in the *Energy Independence and Security Act of 2007* in which the Secretary was directed to establish at least seven bioenergy research centers to accelerate basic transformational research and development of biofuels.

The funding plan for the Centers is for each to receive up to \$125 million over a period of 5 years starting in 2008: \$25 million in the first year for startup costs and up to \$25 million per year for operations during the subsequent four years. The Administration's FY 2010 budget request continues this plan, recommending \$25 million each or \$75 million in total.

- *Fundamental Genomic Research*—This activity supports fundamental research on microbes and plants, with an emphasis on understanding biological systems across multiple scales of organization, ranging from sub-cellular protein-to-protein interactions to complex microbial community structures. It investigates how cells are able to balance dynamic needs for synthesis and assembly of cellular machinery in response to changing signals from the environment. A broad diversity of biological functions are examined, from microbial respiration and separation of soil minerals to nutrient uptake and cell-to-cell communication. There is a strong focus on understanding the conversion of carbon from simple forms to advanced biomolecules, as well as a focus on development of new strategies and tools to fully exploit the information contained in complete DNA sequences from microbes and plants for bioenergy, carbon sequestration, and bioremediation applications.
- *Computational Biosciences*—Advanced computational models and tools are needed to accurately describe the biochemical capabilities of microbial communities and plants. These new tools must be able to integrate diverse data types and data sets into single functioning models. An important task over the next several years will be the extension of database capabilities beyond data generation and storage to cross-database comparative computational modeling so that better microbes for bioenergy, carbon sequestration, or bioremediation purposes can be more readily engineered. This research is closely coordinated with the Office of Science's Advanced Scientific Computing Research (ASCR) program.

Radiological Sciences

The Radiological Sciences subprogram supports fundamental research in radiochemistry to develop new methodologies for real-time, high-resolution imaging of dynamic biological processes. This includes examination of biological systems with benefits for DOE mission needs as well as techniques and tool development that can be applied to nuclear medicine diagnostic and therapeutic research.

This subprogram also supports research that will help determine health risks from exposures to low levels of radiation, information critical to adequately and appropriately protect radiation workers and the general public. It provides a scientific

basis for decisions regarding remediation of contaminated DOE sites and for determining acceptable levels of human health protection, both for cleanup workers and the public.

Medical Applications

The Medical Applications subprogram utilizes resources and expertise in engineering and materials science primarily available at DOE national laboratories rather than NIH facilities to develop unique neuroprostheses—medical devices that connect directly to the human brain, spinal cord, or nerves. It has focused in particular on the development of an artificial retina to restore sight to the blind. DOE's goal for this project is to create the technology underpinning a device that will allow a blind person to read large print, recognize faces, and move around without difficulty. The DOE-funded phase of the artificial retina project will be completed in FY 2010.

Biological Systems Facilities and Infrastructure

- *Joint Genome Institute*—The Joint Genome Institute (JGI), based in Walnut Creek, CA and operated by the University of California, is the only federally funded large center focusing on genome discovery and analysis in plants and microbes for energy and environmental applications, including bioenergy, carbon cycling and sequestration, and soil remediation. JGI incorporates expertise from five DOE partner laboratories—Lawrence Berkeley (LBL), Lawrence Livermore (LLNL), Los Alamos, Oak Ridge, and Pacific Northwest—along with the HudsonAlpha Institute for Biotechnology. Its workforce draws most heavily from LBL and LLNL. Through the development of genome assembly methods, tools for comparative gene analysis, and integration of data from multiple technology platforms, JGI enables researchers and plant breeders to identify traits and genes for specific bioenergy applications or environmental conditions. The Institute provides these services to the broad scientific user community, including the Bioenergy Research Centers, on a merit-reviewed basis. Synthetic Genomics Inc. (SGI), a privately-held company, is the only other institution with similar capabilities in the world.
- *Structural Biology Infrastructure*—The Structural Biology Infrastructure program develops and supports access to DOE's national user facilities for the Nation's systems biologists. BER coordinates with NIH and the National Science Foundation (NSF) the management and maintenance of 22 experimental stations at several DOE light and neutron sources used to examine biological materials and processes. BER assesses the quality of the instrumentation at its experimental stations and supports upgrades to install the most effective instrumentation for taking full advantage of the facility capabilities as they are improved by DOE. This activity enables a broad user community to conduct the high-resolution study of biological molecules involved in cellular architecture, environmental sensing, and carbon capture.

Isotope Development and Production for Research and Applications

In FY 2009, the Isotope Development and Production for Research and Applications subprogram was transferred to the DOE Office of Science's Nuclear Physics (NP) program from the Office of Nuclear Energy. This subprogram provides facilities and capabilities for the production of isotopes to address national needs. Stable and radioactive isotopes are vital to the mission of many federal agencies and play a crucial role in basic research, medicine, industry, and homeland defense. Isotopes are produced for the National Institutes of Health (NIH) and their grantees, National Institute of Standards and Technology, Environmental Protection Agency, Department of Agriculture, National Nuclear Security Administration (NNSA), Department of Homeland Security (DHS), other DOE Office of Science programs, and other federal agencies. The subprogram also supports research related to the development of advanced isotope production techniques.

Isotopes are used to improve the accuracy and effectiveness of medical diagnoses and therapy, enhance national security through the development of advanced sensors, improve the efficiency of industrial processes, and provide precise measurement and investigative tools for materials, biomedical, environmental, archaeological, and other research. Some examples are: strontium-82 used for heart imaging; arsenic-73 used as a tracer for environmental research, and helium-3 as a component in neutron-detectors that may be used to scan for radioactive weapons.

The consequences of shortages of radioactive and stable isotopes needed for research, medicine, homeland security, and industrial applications can be extremely serious ranging from the inability to treat cancer to the failure of detecting terrorist

threats. To address several of these issues before they become larger problems, NP has established a working group with NIH to act on the recommendations of a 2007 National Academies report, *Advancing Nuclear Medicine through Innovation*, which identified areas in isotope production warranting attention. NP has also facilitated the formation of a federal working group on He-3 supply, involving staff from NP, NNSA, DHS, and the Department of Defense.

Isotopes are made available by using NP's unique facilities, including the Brookhaven Linear Isotope Producer (BLIP) at Brookhaven National Laboratory and the Isotope Production Facility (IPF) at Los Alamos National Laboratory. The sub-program also produces isotopes at the reactors at Oak Ridge and Idaho National Laboratories. It operates under a revolving fund as established by the FY 1990 *Energy and Water Development Appropriations Act*, and maintains its financial viability by utilizing a combination of Congressional appropriations and revenues from the sale of isotopes and services. These resources are used to maintain the staff, facilities, and capabilities at user-ready levels and to support peer-reviewed research and development activities related to the production of isotopes. Commercial isotopes are priced at full cost. Research isotopes are priced to provide reasonable compensation to the government while encouraging research.

Chairman BAIRD. Our hearing will now to come order. I want to welcome everyone to today's hearing on *Biological Research for Energy and Medical Applications at the Department of Energy Office of Science*. Our hearing today will explore the Office of Science's biological research programs and how they fit in with our broader federal research infrastructure for energy, environmental, and medical applications.

The Department of Energy's role in examining biological processes is not always well understood, nor is it appreciated always, but it dates back to 1946. At that time, of course, we needed to learn more about the effects that radiation could have on people from the use of either atomic weapons or nuclear power. This required bringing together the best and brightest researchers from both physical and medical sciences to study the issue.

Over the years DOE developed unique engineering capabilities within its national laboratories that allow the Department to quickly catalog the building blocks of living organisms. These technologies are what enable the Human Genome Project to be considered by scientists at DOE and NIH in the late 1980s and the successfully completed that project on budget and ahead of schedule by 2003.

Today the Office of Science focuses on these capabilities on—focuses these capabilities on developing next-generation biofuels, finding ways, new ways to sequester carbon, and on cleaning up the legacy waste from our nuclear weapons complex.

In addition, DOE's nuclear physics program has recently shouldered the responsibility of providing critical, non-commercial isotopes for cancer treatments as well as other research applications.

I look forward to learning more about the progress DOE is making in working with NIH and other agencies to meet the science and medical communities' needs.

And with that I would like to thank this excellent panel of witnesses for appearing, and I yield to our distinguished Ranking Member, Mr. Inglis.

[The prepared statement of Chairman Baird follows:]

PREPARED STATEMENT OF CHAIRMAN BRIAN BAIRD

Today's hearing will explore the Office of Science's biological research programs, and how they fit in with our broader federal research infrastructure for energy, environmental, and medical applications. The Department of Energy's role in examining biological processes is not always well understood nor is it appreciated, but it dates back to 1946. At that time we needed to learn more about the effects that radiation could have on people from the use of either atomic weapons or nuclear power. This required bringing together the best and brightest researchers from both physical and medical sciences to study the issue. Over the years, DOE developed unique engineering capabilities within its national laboratories that allowed the Department to quickly catalogue the building blocks of living organisms. These technologies are what enabled the Human Genome Project to even be considered by scientists at DOE and NIH in the late '80s, and then successfully completed on budget and ahead of schedule by 2003.

Today, the Office of Science focuses these capabilities on developing next-generation biofuels, finding new ways to sequester carbon, and on cleaning up the legacy waste from our nuclear weapons complex. In addition, DOE's nuclear physics program has recently shouldered the responsibility of providing critical non-commercial isotopes for cancer treatments as well as other research applications. I look forward to learning more about the progress DOE is making in working with NIH and other agencies to meet the scientific and medical communities' needs.

With that I'd like to thank this excellent panel of witnesses for appearing before the Subcommittee this afternoon, and I yield to our distinguished Ranking Member, Mr. Inglis.

Mr. INGLIS. Thank you, Mr. Chairman, and thank you for holding this hearing.

Today we are going to find out about the complexity of the Department of Energy's Office of Science. Biology isn't the first thing that comes to mind when we think of critical research gaps in developing new energy technologies, but the Biological Environmental Research Program at the Office of Science is currently advancing biofuel development, helping us better understand the impacts of climate change in our environment and improving medical technologies.

Research in 1949, about the health impacts of radiation exposure has evolved into dramatic advancements in genetics, radiology, and nuclear medicine. One of the most notable achievements of biological research at DOE is certainly the Human Genome Project. In coordination with NIH, the project resolved the complex human DNA sequence in 13 short years.

With the diversity of efforts at DOE I am looking forward to hearing about other potential breakthroughs from our witnesses, particularly in the area of biofuels.

I should also admit to a parochial interest in the Biological Environmental Research Program. Clemson University in the upstate of South Carolina has a remarkable research program in the college of agriculture, forestry, and life sciences. Researchers there do a considerable amount of work on the genomics and development of biofuel crops and have collaborated with DOE on several such projects previously, as you point out in your testimony, Dr. Keasling.

Again, I am very much looking forward to the testimony of our witnesses, while much of the work in the Biological Environmental Research Program seems only loosely related to the overall mission of DOE, they are working on exciting progress in a variety of energy and medical initiatives.

Thank you, Mr. Chairman, for holding the hearing and look forward to hearing the witnesses.

[The prepared statement of Mr. Inglis follows:]

PREPARED STATEMENT OF REPRESENTATIVE BOB INGLIS

Good afternoon and thank you for holding this hearing, Mr. Chairman.

Today we're going to be reminded of the unique complexity of the Department of Energy's Office of Science. Certainly biology is not the first thing that comes to mind when we think of critical research gaps in developing new energy technologies. The Biological and Environmental Research Program in the Office of Science is currently advancing biofuel development, helping us better understand the impacts of climate change on our environment, and improving medical technologies.

Research in 1949 about the health impacts of radiation exposure has evolved into dramatic advancements in genetics, radiology, and nuclear medicine. One of the most notable achievements of biological research at DOE is certainly the Human Genome Project. In coordination with NIH, the Human Genome Project resolved the complete human DNA sequence in 13 short years. With the diversity of efforts at DOE, I'm looking forward to hearing about other potential breakthroughs from our witnesses, particularly in the area of biofuels.

I also should admit a parochial interest in the Biological and Environmental Research Program. Clemson University in the Upstate has a remarkable research program in the College of Agriculture, Forestry, and Life Sciences. Researchers there do a considerable amount of work on the genomics and development of biofuel crops,

and have collaborated with DOE on several such projects previously, as you point out in your testimony, Dr. Keasling.

Again, I'm very much looking forward to the testimony of our witnesses. While much of the work in the Biological and Environmental Research Program seems only loosely related to the overall mission of DOE, they are working on exciting progress in a variety of energy and medical initiatives.

Thank you again for bringing us back from the August recess with this hearing, Mr. Chairman.

Chairman BAIRD. Thank you, Mr. Inglis.
[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good afternoon. Thank you, Mr. Chairman, for holding today's hearing to receive testimony on the medical and energy applications of biological research conducted by the Biological and Environmental Research (BER) Program at the Department of Energy (DOE) Office of Science.

BER demonstrated its capacity for cutting-edge research in 2003, when its scientists completed the Human Genome Project and produced the first map of the entire human DNA sequence. Since that accomplishment, BER has continued to use its ability to map an organism's genome to make major advances in energy and medical research.

The energy applications of BER research are particularly important to Illinois. I am proud that the Normal, IL, campus of Illinois State University is partnered with the Great Lakes Bioenergy Research Center to engage in cutting-edge research on the production of biofuels. These research efforts will enhance the work being done at Southern Illinois University—Edwardsville's National Corn to Ethanol Research Center and make renewable fuels easier to produce and more sustainable to use. In addition, the Fundamental Genomic Research conducted by BER is in the process of developing innovative ways to sequester carbon in the soil, making clean coal facilities more efficient and helping new clean coal facilities come online in the future. As a major supporter of the FutureGen project in Mattoon, IL, I applaud BER's efforts to support clean coal technology.

The collaborative efforts between national laboratories, universities, non-profit organizations, and the private sector have allowed BER to develop new medical and energy applications for biological research. I would be interested to hear from our witnesses how Congress can continue to support this collaboration. In particular, I look forward to hearing how can Congress support efforts to move these important projects towards demonstration and, eventually, commercial viability on a national scale.

I welcome our panel of witnesses, and I look forward to their testimony. Thank you again, Mr. Chairman.

Chairman BAIRD. It is my pleasure to introduce our distinguished witnesses at this time. Dr. Anna Palmisano is the Director of the Office of Biological and Environmental Research at DOE. Dr. Jay Keasling is the Acting Deputy Director of Lawrence Berkeley National Laboratory and Chief Executive Officer of the Joint Bio-Energy Institute at DOE. Dr. Allison Campbell, we are proud to say, is the Director of the WR Wiley Environmental Molecular Sciences Laboratory at Pacific Northwest National Laboratory (PNNL), near and dear to my heart. Dr. Ari Patrinos is the President of Synthetic Genomics, Incorporated. Dr. Jehanne Gillo is the Director of the—did I say that right?

Dr. GILLO. Gillo.

Chairman BAIRD. That would be Gillo. Are you sure you are right? Okay. We will go with Gillo if you say so. And after all, you are the Director of Facilities and Project Management Division in the Office of Nuclear Physics at DOE.

As our witnesses should know, you will have five minutes for your spoken testimony. Your written testimony will be included in the record. When you have completed your spoken testimony, we

will begin with questions. Each Member will have five minutes to question.

Again, I just want to apologize. We normally have a pretty packed house on this panel, but with early dismissal today folks are racing home to their districts. Some have said they will try to make it. They also have, believe it or not, many other hearings conflicting with this, but we have an incredibly distinguished panel. We look forward very much to learning your input, and please, we will ask Dr. Palmisano to begin, please.

**STATEMENT OF DR. ANNA PALMISANO, ASSOCIATE DIRECTOR
FOR BIOLOGICAL AND ENVIRONMENTAL RESEARCH, OF-
FICE OF SCIENCE, U.S. DEPARTMENT OF ENERGY**

Dr. PALMISANO. Mr. Chairman, Ranking Member Inglis, and Members of the Committee, I appreciate the opportunity to appear before you today to discuss the Biological and Environmental Research Program in the Department of Energy's Office of Science. I am the program director.

Biological and Environmental Research, known as BER, supports innovative and transformational science to provide a fundamental understanding of biological, climate, and environmental systems. Through our research programs and our scientific facilities we support a wide range of disciplines to engage a broad scientific community, using peer review to ensure scientific excellence.

The BER Program addresses three major scientific challenges. The first challenge is to explore the frontiers of genome-enabled biology. BER supports research that uncovers nature's secrets to harness the catalytic power and biomass of microbes and plants for bioenergy, the carbon cycle, and bioremediation. Starting with an organism's DNA, BER-funded scientists seek to understand whole biological systems as they interact with their environments.

The second challenge is to discover the physical, chemical, and biological drivers of climate change. BER plays a vital role in the U.S. Global Climate Change Research Program by improving predictive climate models and by addressing some of the key uncertainties such as clouds and aerosols in the carbon cycle.

The third challenge is to seek the scientific basis for environmental sustainability and stewardship. The Earth's subsurface is a new frontier for discovering novel microbes and understanding geochemical and hydrological processes that affect the fate and transport of environmental contaminants.

BER supports three world-leading scientific facilities that benefit a broad community of scientists. The Joint Genome Institute provides state-of-the-art genome sequencing and bioinformatic analysis for microbes and plants of energy and environmental significance. To date the Joint Genome Institute has sequenced over 500 microbes and microbial communities, as well as 25 plants.

The Environmental Molecular Sciences Laboratory provides novel experimental and computational tools for molecular-level studies of the environment.

The Atmospheric Radiation Measurement Climate Research Facility provides unmatched level of observations and measurements of climate—of clouds and aerosols for climate researchers.

BER-supported biological research has a long history of major contributions to the DOE mission and national needs through discovery, science and innovation. Today BER supports genome-enabled research to understand biological systems, ranging from single microbes to microbial communities to plants. Our ultimate goal is to predict, manage, and control biological systems to support mission needs in bioenergy production, climate change, and environmental stewardship and sustainability.

In September 2007, three DOE bioenergy research centers were launched to provide transformational science to overcome the most difficult scientific and technological barriers to the production of biofuels. Scientists are using systems biology to discover and optimize enzymes, microbes, and plants that will lead to new approaches to cellulosic biofuels.

BER is deeply committed to coordination with the DOE's technology offices to facilitate a smooth transition of knowledge to application. Successful mechanisms for coordination include participation in joint reviews, site visits, science team meetings, and strategic planning. BER-supported research provides the fundamental knowledge of microbes and plants needed by the DOE's Office of Energy Efficiency and Renewable Energy for the successful development and deployment of new bioenergy crops for sustainable biofuel production.

BER research on the fate and transport of contaminants and the subsurface environment provides knowledge for DOE's Office of Environmental Management to develop new strategies for stewardship and remediation of contaminants and for DOE's Office of Legacy Management to develop tools to monitor contaminants at clean-up sites.

Looking to the future, BER will strive to continue to advance the Nation's biologic, climate and environmental science through leading-edge programs that meet DOE needs.

Thank you, Mr. Chairman, for providing this opportunity to discuss Biological and Environmental Research Program at the DOE's Office of Science. This concludes my testimony, and I would be pleased to answer any questions you may have.

[The prepared statement of Dr. Palmisano follows:]

PREPARED STATEMENT OF ANNA PALMISANO

Thank you Mr. Chairman, Ranking Member Inglis, and Members of the Committee. I appreciate the opportunity to appear before you today to discuss the Biological and Environmental Research (BER) Program in the Department of Energy's (DOE's) Office of Science (SC). I am the Program Director.

Overview of the Biological and Environmental Research Program

The BER program supports fundamental research and scientific user facilities designed to advance our understanding of complex biological, climate, and environmental systems. A hallmark of BER-supported research is the strong coupling of theory, observations, experiments, models, and simulations, with an emphasis on interdisciplinary research. The nature of biological, climate, and environmental research necessitates involvement of a wide range of scientific disciplines including microbiology, plant sciences, computational sciences, ecology, geochemistry, atmospheric sciences, and hydrology, to name just a few.

Using peer review to ensure scientific excellence, the BER program engages scientists from national laboratories, universities, and the private sector to generate cutting edge science. In FY 2009, BER supported more than 1,800 Ph.D. scientists and nearly 500 students. In addition, BER user facilities hosted more than 2,500 biological, climate, and environmental scientists. In FY 2009, the BER program

funded research at more than 85 academic and private institutions in 39 states and at nine DOE laboratories in eight states.

The BER program is organized into two subprograms—Biological Systems Science and Climate and Environmental Sciences—that provide the fundamental knowledge for:

Exploring the frontiers of genome-enabled biology. BER Biological Systems Science subprogram supports research that uncovers nature's secrets to harness the catalytic power and biomass of microbes and plants for DOE mission priorities in bioenergy, carbon cycle, and bioremediation. Starting with an organism's DNA, BER-funded scientists seek to understand whole biological systems as they interact with their environments. BER scientists investigate a range of systems from individual proteins and other molecules, to groups of molecules that comprise molecular machines, to interconnected biological networks comprising whole cells, communities, and entire ecosystems. BER also supports the development of new tools and technologies to explore the interface of the biological and physical sciences.

Discovering the physical, chemical, and biological drivers of climate change. The BER Climate and Environmental Sciences subprogram plays a vital role in the U.S. Global Change Research Program by supporting research to improve predictive climate models by addressing key uncertainties such as clouds and aerosols and the carbon cycle. BER scientists study atmospheric processes, climate change modeling, interactions between ecosystems and greenhouse gases, and the impacts of climate change on energy production and use.

Seeking the geochemical, hydrological, and biological determinants of environmental sustainability and stewardship. The Earth's subsurface is a new frontier for discovering novel microorganisms and understanding important geochemical and hydrological processes that affect the fate and transport of environmental contaminants. The BER Climate and Environmental Sciences subprogram supports laboratory studies and field scale hypothesis-testing at BER's Integrated Field Research Centers to provide the foundational knowledge needed for cost-effective strategies for environmental stewardship and remediation.

BER supports three world-leading scientific facilities. The Biological Systems Science program supports the Joint Genome Institute (JGI) which provides state-of-the-art genome sequencing and bioinformatic analysis for microbes and plants of energy and environmental significance. The JGI has sequenced 500 microbes and microbial communities, as well as 25 plants using state-of-the-art sequencing and genomic analysis. The JGI is an innovator in genomic sequence and analysis of complex microbial communities that degrade cellulose, sequester carbon dioxide, and remediate environmental contaminants. Recent scientific accomplishments include the genome sequencing of key plants of bioenergy and agricultural importance (soybean, sorghum) and microbes of importance to the carbon cycle (single celled algae) and development of advanced data analysis tools for metagenomes.

The Climate and Environmental Sciences program supports the Atmospheric Radiation Measurement Climate Research Facility (ACRF) and the Environmental Molecular Sciences Laboratory (EMSL). ACRF consists of three stationary facilities that provide an unmatched level of observations and measurements of clouds and aerosols, as well as two mobile facilities that are strategically deployed by the scientific community. In the past year, a mobile facility was deployed to China to measure aerosols and to the Azores to collect measurements on the marine boundary layer near the Equator. In 2009, the ACRF hosted more than 800 users, resulting in over 185 publications in the scientific literature. The Environmental Molecular Sciences Laboratory (EMSL) supports scientific discovery at the frontier of molecular systems science and serves 600–700 scientists annually. EMSL develops and applies one-of-a-kind experimental and computational tools to novel molecular-level studies of complex environmental systems.

BER is using FY 2009 *American Recovery and Reinvestment Act* (Recovery Act) funds to update, improve, and optimize the capabilities of its three user facilities and the three Bioenergy Research Centers and to initiate planning and development for a Systems Biology Knowledgebase to manage and integrate large systems biology data sets.

Biological Systems Science

BER supported biological research has a long history of major contributions to DOE mission and national needs through science, discovery, and innovation. BER's origins date to 1946, the atomic bomb, concerns for health effects from exposure to radiation, and the promise of benefits from peaceful uses of nuclear energy. Health effects research gave us breakthroughs in genetics and developments in nuclear

medicine. Interest in the effects of radiation exposure led to understanding the most fundamental level of biology, DNA, and prompted DOE to initiate the Human Genome Project, spearheading today's biotechnology revolution.

Today, BER supports discovery science to understand complex biological systems. Our ultimate goal is to predict, manage, and control biological systems to support mission needs in bioenergy production, climate change, and environmental stewardship and sustainability. To this end, BER supports work to address some of the toughest

grand challenge science questions facing biologists: to understand the functions and emergent properties of biological systems at multiple levels. These systems can range in complexity from single microbes to multicellular frameworks of plants, microbial communities, and plant-microbe associations; yet all are specified by underlying information encoded in the organism's genome. The subprogram supports systems biology approaches that translate the genomic blueprint into subcellular proteins, metabolites, and cellular architecture that govern biological function and the interactions between an organism and its environment. Systems biology approaches include genome sequencing, proteomics, metabolomics, structural biology, high-resolution imaging and characterization, and integration of the resulting information into predictive computational models of biological systems that can be tested and validated.

BER's foundational science in biological systems addresses critical national needs in energy production and understanding the consequences of energy use. Scientific innovation and discovery that drive new solutions is essential for meeting the challenges posed by the energy demands of a growing population and the impacts of energy use on climate and the environment. The ongoing revolution in biological sciences, driven by genomics, provides new ideas and paradigms for the synthesis of novel biofuels as well as new approaches for understanding the carbon cycle and harnessing the catalytic power of microbes for bioremediation.

Input from the Scientific Community

The BER biological sciences subprogram engages the scientific community through focused scientific workshops and program reviews and through the Biological and Environmental Research Advisory Committee (BERAC). Hundreds of scientists provide input to BER programs every year.

For example, in May 2008, BER hosted a workshop on "Systems Biology Knowledgebase for a New Era in Biology" in coordination with the Office of Science's Office of Advanced Scientific Computing Research. A knowledgebase is comprised of a data repository and a suite of tools for data analysis, comparison, visualization, and integration. It also provides a framework for creating, testing, and improving predictive models of biological systems. The workshop participants described the need to facilitate the integration of diverse types of biological data as well as environmental data describing the organism's habitat.

Another example is a November 2008 community-based workshop, "New Frontiers of Science in Radiochemistry and Instrumentation for Radionuclide Imaging." BER supports research in radiochemistry and radiotracer development with the goal of developing new methodologies for real-time, high-resolution imaging of dynamic in plants and microbes, with the potential for broader application to areas of human health. Participants included leading scientists from DOE laboratories, universities, and federal agencies such as the National Institutes of Health (NIH). The workshop participants identified knowledge gaps and future opportunities for development of new radiochemical tracers and new imaging modalities.

Details of the Biological Systems Science Subprogram

This subprogram explores the fundamental principles that drive the function and structure of living systems of importance to energy and the environment.

Genomic sciences use the genome as a blueprint for the foundational biological understanding of microbes, microbial communities, and plants. The research addresses: What information is contained in the genome sequence of microbes and plants? How is that information translated to proteins and metabolic networks? And, how can we predict and control biological responses to environmental changes?

Three DOE *Bioenergy Research Centers* (BRCs)—led by Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, and the University of Wisconsin at Madison in partnership with Michigan State University—support multi-disciplinary teams of leading scientists to accelerate transformational breakthroughs needed to convert cellulose to biofuels. A more detailed description of the BRCs is provided later in the testimony.

The *Joint Genome Institute* (JGI) is a high-throughput DNA sequencing facility providing the basis for the systems biology of environmental and energy-related microbes and plants. Current sequencing capacity at the JGI is over 124 billion base pairs per year and is growing rapidly. JGI provides the scientific community with the latest technologies for genomic sequencing, genetic analysis, and genomic comparison.

Structural biology supports access to DOE's world-class synchrotron and neutron sources for scientists to understand the proteins encoded by DNA. *Radiochemistry and imaging instrumentation* focuses on development of new methods for real-time, high-resolution imaging of energy- and environmentally-relevant biological systems. This fundamental research and tool development may have broader applications to nuclear medicine. *Radiobiology* supports research on the biological effects of exposure to low dose radiation.

DOE Bioenergy Research Centers

In September 2007, three DOE Bioenergy Research Centers (BRCs) were launched to provide transformational science to overcome the most difficult scientific and technological barriers to the production of biofuels from microbes and plants. The Centers are marshalling the full arsenal of modern genomics-based methods to overcome plant cell wall recalcitrance. Scientists are using systems biology to model, predict, and engineer optimized enzymes, microbes, and plants for the discovery and development of new, innovative approaches to efficient cellulosic biofuels production. Expertise at the BRCs spans the physical and biological sciences, including genomics, microbial and plant biology, analytical chemistry, computational biology and bioinformatics, and engineering. The BRCs engage DOE National Laboratories, universities, and the private sector in interdisciplinary partnerships to ensure the best possible science and rapid transition to application. The BRCs serve to galvanize the top researchers in the field to accelerate the scientific breakthroughs needed by the emerging biofuel industry.

Although the Bioenergy Research Centers have only been fully operational for two years, some early successes include:

1. New High-Throughput Pipeline to Identify Improved Bioenergy Feedstocks

The BioEnergy Science Center (BESC) developed a screen to rapidly identify the chemical, structural, and genetic features of biomass that provide better access to the sugars within plant biomass. This pipeline can screen more than 10,000 samples per week which is over 100-fold more biomass samples per day than conventional methods. BESC researchers tested 1,100 poplar trees from the Pacific Northwest. Digestibility or sugar release ranged from 0.2 to 0.7 grams of sugar per gram of biomass—the highest numbers will bring us close to desired commercial biofuels production levels. This screening is accelerating the discovery and optimization of plants most easily converted into biofuels.

2. Innovations in Biomass Pretreatment and Deconstruction

Researchers at the Joint BioEnergy Institute (JBEI) have developed an advanced biomass pretreatment process using room temperature ionic liquids that completely remove virtually all the lignin from the plant cell walls of switchgrass, corn stover, and eucalyptus. This approach has reduced by a factor of five the time required for enzymatic breakdown of biomass. Researchers have also developed a new cellulase enzyme that is more stable and active in ionic liquid solutions at elevated temperatures and low pH. Patents have been filed on both these innovations.

3. Improved Screening for the Discovery of Biomass-degrading Enzymes

Microorganisms in natural environments have evolved enzymes for degrading biomass; however, conventional methods for identifying these enzymes are inefficient and time consuming. Scientists at the Great Lakes Bioenergy Research Center (GLBRC) are coupling a novel genetic expression approach with a newly developed enzymatic screening process to dramatically improve the discovery of new cellulose-degrading enzymes. They found that the rate and efficiency of enzyme discovery was ~100 times higher with the new expression and screening tools than conventional methods. The novel cellulose-degrading microbes or enzymes that are being discovered are providing hundreds of candidate hydrolytic enzymes for use in biomass-degradation studies.

R&D Coordination in the Biological Sciences

BER is deeply committed to coordinating with DOE's technology offices to better integrate the basic and applied research supported by the Department. We have developed and maintained good working relationships with DOE technology offices and other key stakeholders. BER works closely with DOE's Office of the Biomass Program (OBP) in the Office of Energy Efficiency and Renewable Energy (EERE). Strong partnerships have been forged and maintained to facilitate the transition of scientific knowledge to applications that address DOE mission needs.

BER has a long history of coordination with OBP that began over a decade ago, when we worked with OBP and the scientific community to identify key microbes of importance for the breakdown of cellulosic biomass. Those microbes were subsequently sequenced by the JGI, and bioenergy researchers worldwide have greatly benefited from that new knowledge. From the earliest stages of planning BER bioenergy research, we have worked closely with OBP—beginning with the jointly funded 2006 workshop "Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda." The workshop report provided a roadmap for addressing the toughest research questions to support biofuel production. BER-supported research on the biochemical pathways and genetic mechanisms of microbes and plants provides knowledge needed by OBP (and the U.S. Department of Agriculture) to make decisions about the development and deployment of new bioenergy crops and cost effective and sustainable approaches to bioenergy production.

BER takes advantage of numerous mechanisms to encourage knowledge transfer from BER science discoveries to applied programs within the Department of Energy, including: 1) Regularly-scheduled program briefings between SC-BER and EERE-OBP program staff; 2) briefings by BRC directors to OBP program managers; 3) participation and attendance at program reviews and investigator meetings for SC-BER and EERE-OBP; and 4) joint participation in interagency working groups by SC-BER and EERE-OBP program staff, such as the Biomass Research and Development Board and the Metabolic Engineering Working Group. Moreover, EERE is planning to use Recovery Act funds to build a pilot biorefinery that can be used as a testbed for products from the three BRCs. Such an approach will help to facilitate a smooth transition of knowledge from the BRCs to applications by EERE.

Coordination and Partnering with other Federal Agencies in Biological Sciences

A hallmark of the BER program is the coordination of research across federal agencies and scientific disciplines. BER values partnering and cooperation with many research agencies, including the National Science Foundation (NSF), the U.S. Department of Agriculture USDA, the NIH, the National Aeronautics and Space Administration (NASA), and others. Several examples of interagency activities in the biological sciences include the following:

- BER and the USDA have partnered on a competitive grants program entitled Plant Feedstock Genomics for Bioenergy. Now in its fourth year, the program develops and applies the latest approaches in plant genomics to marker-assisted plant breeding and crop production for potential bioenergy crops, including fast growing trees, shrubs, and grasses.
- BER coordinates with seven other agencies in the Metabolic Engineering Interagency Program. The program, now in its 11th year, supports innovative research in the fields of targeted metabolic pathway design and construction.
- BER supports the Protein Data Bank with NIH and NSF. This community resource provides an archive of experimentally determined, three-dimensional structures of biological macromolecules.
- BER is an active participant and partner with NSF and USDA in the National Plant Genome Initiative. Current focus of this initiative is the sequencing and analysis of the maize (corn) genome.
- BER actively coordinates with NIH on areas of common interest such as tools and technologies for data management, genome annotation, structural biology, proteomics, and radiochemistry. For example, BER and the Office of Science's Office of Nuclear Physics co-chair a working group with NIH on radioisotope production and use.

In addition, BER actively participates in numerous working groups to enhance dialogue and coordination. Interagency activities such as these ensure that the BER portfolio is well-coordinated with other agencies and that opportunities for interagency partnering are vigorously pursued.

Climate and Environmental Sciences Subprogram

The Climate and Environmental Sciences subprogram addresses national needs and DOE priorities in energy, environment, and security. Although this hearing is focused on BER's biology programs, I would like to share a few highlights from our climate and environmental programs which represent almost half (47 percent) of BER's budget. The subprogram supports an integrated portfolio of research ranging from molecular to field scale studies with emphasis on the use of advanced computer models, interdisciplinary experimentation, and observations. BER supports fundamental research activities as well as two national scientific user facilities for climate and environmental science.

DOE plays a vital role in advancing fundamental climate and environmental research as part of the U.S. Global Climate Change Research Program. BER supports a unique set of resources and capabilities to address the major questions of global climate change with a goal of providing more accurate simulations of the Earth's climate. Climate simulations provide the foundations for future climate projections and guide potential mitigation or adaptation strategies, thereby informing the Nation's energy policies, and contribute to assessments by the Intergovernmental Panel on Climate Change. BER climate research addresses the areas of greatest uncertainty in climate change: clouds and aerosols and carbon cycling. BER also develops world-class coupled climate models that take advantage of DOE's leadership computing capabilities. Reducing uncertainty in climate prediction will help us to identify potential vulnerabilities and to develop new approaches for mitigation and adaptation to climate change. The BER Atmospheric Radiation Measurement Climate Research Facility (ACRF) provides key observational data to the climate research community on the radiative properties of the atmosphere, especially clouds. The facility includes highly instrumented ground stations (including radars, lidars, and a range of meteorological instrumentation), a mobile facility, and an aerial vehicles program.

BER's subsurface biogeochemistry program is the only one of its kind in the Federal Government that focuses on basic research in the fate and transport of radionuclides and metals in subsurface environments. BER seeks to understand the role that subsurface biogeochemical processes play in determining the fate and transport of contaminants at DOE sites. Laboratory studies are coupled with field scale hypothesis testing that is carried out through three Integrated Field Research Challenges located at sites at Hanford in Washington, Oak Ridge in Tennessee, and Rifle, Colorado. Improved understanding and predictive modeling of subsurface environments will lead to novel approaches and strategies for remediation and stewardship of DOE sites that are needed to address the staggering costs of cleanup of contaminants. BER coordinates its environmental research with other federal agencies through working groups under the aegis of the White House National Science and Technology Council. BER also plays an active role in the Strategic Environmental Research and Development Program (SERDP) in partnership with DOD and EPA. BER supports the Environmental Molecular Sciences Laboratory (EMSL) to accelerate scientific discovery at the frontier of environmental systems science. EMSL houses an unparalleled suite of state-of-the-art capabilities, including a supercomputer and over 60 major instruments. EMSL instrumentation, with capabilities in nuclear magnetic resonance, mass spectroscopy, and a range of imaging modalities, supports major science themes of biogeochemistry, biological interactions and dynamics, and catalysis.

R&D Coordination in Climate and Environmental Sciences

The knowledge and tools developed by BER research to understand Earth's climate system and to predict future climate and climate change is used by DOE's Office of Policy and International Affairs as it develops strategies for our nation's future energy needs and control of greenhouse gas emissions. BER also works with the U.S. Global Change Research Program in numerous stakeholder engagement activities.

BER research on the behavior and interactions of contaminants in the subsurface environment provides knowledge needed by DOE's Office of Environmental Management (EM) to develop new strategies for stewardship and remediation of weapons-related contaminants at DOE sites and by DOE's Office of Legacy Management to develop tools to monitor the long-term status of contaminants at cleanup sites. Mechanisms to foster R&D integration with EM include joint participation by BER and EM in planning activities, site visits and reviews, and involvement of EM site managers in BER Integrated Field Research Challenge projects. Knowledge of the subsurface environment as a complete system will also be useful to DOE's Office of Fossil Energy in their efforts to predict the long-term behavior of carbon dioxide in-

jected underground for long-term storage. As a direct result of BER supported basic research in modeling the fate and transport of contaminants, EM will initiate an effort in FY 2010 to develop the next generation simulation software needed to address the prediction, risk reduction, and decision support challenges faced by DOE sites.

Looking to the Future

BER continues to leverage its scientific strengths and novel community resources for understanding complex biological, climate, and environmental systems as it looks to the future. Biology has entered a systems-science era with the goal to establish a predictive understanding of the mechanisms of cellular function and the interactions of biological systems with their environment and with each other. Vast amounts of data on the composition, physiology, and function of complex biological systems and their natural environments are emerging from new analytical technologies. Effectively exploiting these data requires developing a new generation of capabilities for analyzing, mining, and managing the information.

To manage and effectively use this rapidly growing volume and diversity of data, BER is developing a systems biology knowledgebase that will facilitate a new level of scientific inquiry by serving as a central component for the integration of modeling, simulation, experimentation, and bioinformatic approaches. A systems biology knowledgebase will be a primary resource for data sharing and information exchange among scientists. It will not only enable scientists to expand, compute, and integrate data and information program wide, but it also will drive two classes of work: experimental design and modeling and simulation. Integrating data derived from computational predictions and modeling will increase data completeness, fidelity, and accuracy. These advancements in turn will greatly improve modeling and simulation, leading to new experimentation, analyses, and mechanistic insight.

BER will continue to leverage its unique combination of user facilities and DOE computational resources to improve our ability to predict future climate with greater accuracy. BER will develop high resolution regional climate simulations for use in assessing regional and national implications of climate change on human systems and infrastructure, especially energy demand, production, and supply, such as biofuel feedstock production. This effort will also support interagency activities of the U.S. Global Change Research Program.

Concluding Remarks

Thank you, Mr. Chairman, for providing this opportunity to discuss the Biological and Environmental Research program. This concludes my testimony, and I would be pleased to answer any questions to you may have.

BIOGRAPHY FOR ANNA PALMISANO

Dr. Anna Palmisano is the Associate Director of Science for Biological and Environmental Research at the U.S. Department of Energy (DOE). With an annual budget of about \$600 million, the Office of Biological and Environmental Research supports complex systems science to meet DOE mission needs in bioenergy, climate and the environment. She joined the Office of Science on March, 2008 from the U.S. Department of Agriculture's Cooperative State Research, Education, and Extension Service where she served as the Deputy Administrator for Competitive Programs. From 1998 to 2004, she was a Program Manager in the Office of Biological and Environmental Research, where she developed and managed a wide range of basic research programs including bioremediation, carbon cycling and sequestration, and genomics. Dr. Palmisano has also served as a Program Manager and acting Division Director for Biomolecular and Biosystems Sciences and Technology in the Office of Naval Research, and she worked as a staff microbiologist in the Environmental Safety Division of the Procter and Gamble Company. Dr. Palmisano received a B.S. degree in Microbiology from the University of Maryland and the M.S. and Ph.D. degrees in Biology from the University of Southern California. She was an Allan Hancock Fellow at the University of Southern California and a National Research Council Fellow in planetary biology at NASA-Ames Research Center. Her research interests have included sea ice microbial communities, stream ecology, microbial mats, bioremediation of organic pollutants, and landfill microbiology. She has led five research expeditions to Antarctica and published numerous papers in the field of microbial ecology.

Chairman BAIRD. Thank you.
Dr. Keasling.

STATEMENT OF DR. JAY D. KEASLING, ACTING DEPUTY DIRECTOR, LAWRENCE BERKELEY NATIONAL LABORATORY; CEO, JOINT BIOENERGY INSTITUTE

Dr. KEASLING. Mr. Chairman, Ranking Member Inglis, and distinguished Members of the Committee, thank you for the opportunity to testify today and for your strong support for science. My name is Jay Keasling. I am the CEO of the Joint BioEnergy Institute (JBEI), Acting Deputy Director of the Lawrence Berkeley National Laboratory, and a Professor of Biochemical Engineering at the University of California Berkeley.

I am honored to testify before you today about the Bioenergy Research Centers (BRCs), which are advancing the science and technological development of cellulosic-based biofuels. From biofuels to cost-efficient remediation of toxic environments to changing the way we understand and predict global impacts of climate change, BER serves an irreplaceable role in the federal research enterprise.

At the core of BER's strengths are its unique facilities and world-leading scientists. Since spearheading the Human Genome Project in the 1980s, BER has led advancements in modern systems biology that today enable the cutting edge research into sustainable energy alternatives.

Upon this foundation BER established three centers to research and develop cellulosic-based biofuels. These are Bioenergy Research Centers, which today are up and running and making great progress. JBEI's sisters are the DOE Great Lakes Bioenergy Research Center (GLBRC) at the University of Wisconsin, led by Tim Donohue, and the DOE Bioenergy Center at DOE's Oak Ridge National Laboratory (ORNL), led by Martin Keller.

JBEI is led by Lawrence Berkeley National Laboratory in partnership with Sandia Labs, UC-Berkeley, UC-Davis, Lawrence Livermore National Lab, and Carnegie Institution for Science. The mission of the BRC is maybe simply stated, to advance the development of cellulosic biofuels. However, the challenge is grand. Unlocking the energy potential in the sugars of cellulose requires a lot of basic research and technology development.

The BRCs are ideally suited to make rapid progress toward this goal. Although unique in many ways, each of the BRCs has pulled together the best of the national laboratories, academics, and the private sector to build a new model for interdisciplinary research. Working collaboratively, the three BRCs have the potential to provide a better investment for the federal dollar than a single large center and may serve as a good model for similar energy research challenges.

Let me take a moment to describe JBEI in more detail. JBEI is dynamically organized with scientific teams working together in a single location, under one roof, to enable researchers to share ideas and address problems at a systems-wide level. Researchers don't have to wait for the weekly conference call or the annual retreat to connect. It happens all the time.

Organized like a start-up, JBEI is designed to be nimble and flexible, able to focus and refocus resources quickly, not the typical research model. Unproductive research avenues are quickly redirected. Ideas that show the most promise are invested in aggressively. JBEI researchers are focusing on developing next-generation

biofuels that are compatible with existing infrastructure and utilize feedstocks more efficiently. Taking a whole-systems approach to this objective ensures that our research is applicable on large scales.

Four independent areas are investigated: developing new bio-energy crops, enhancing biomass deconstruction, producing new biofuels through synthetic biology, and creating technologies that advance biofuel research. The magic of this approach is that advancements in any of the four areas can be shared with and employed by other areas, by other BRCs, and by industry.

The exciting research includes searching for new ways, including novel and better enzymes, to break down lignocellulose, the tough matrix of fibers that hold plant material together. An answer may be found in microbial communities, in Puerto Rican rainforest soils that boast some of the planet's highest rates of biomass degradation. JBEI researchers are analyzing these organisms to find potential solutions.

On the fuel production side, using synthetic biology JBEI researchers have re-engineered the microbes of *E. Coli* and yeast to produce advanced "drop-in" fuels that perform better than ethanol. Basically, these tiny microbes can become biofuel refineries.

My personal area of research is in synthetic biology. In addition to biofuels, this exciting field offers great promise for bio-based chemical and medical products. One of the most important applications of synthetic biology has been re-engineering organisms to produce the anti-malarial drug, artemisinin. There are currently 300 to 500 million cases of malaria at any one time with one to three million people dying of the disease each year and 90 percent are children under the age of five. And while quinine-based drugs are no longer effective, plant-derived artemisinin combination therapies are highly effective but cost prohibitive for the world.

To decrease its cost we engineered a microbe to produce a precursor to the drug by transferring the genes from plants to the microorganism. The process has been licensed by Sanofi-Aventis, which will scale the process and produce the drug within the next two years, providing it "at cost" to the developing world.

Luckily the precursor to the chemical artemisinin is a hydrocarbon, a fundamental building block of fuel. We are now re-engineering those same microbes to produce drop-in biofuels. The artemisinin project required \$25 million in funding and 150 person-years to complete in part because the engineering of biology is so incredibly time consuming. Through synthetic biology we hope to make the engineering of biology more predictable and easier, thereby reducing its cost to develop biofuels and other useful products, from chemicals to medicine to consumer and commercial products.

Limiting BER research to just fuels would be a mistake and a lost opportunity. Indeed, BER can take an important and leading role in the development of this transformative field of synthetic biology.

Thank you again for holding this important hearing and for inviting me to participate, and I would be happy to answer any questions.

[The prepared statement of Dr. Keasling follows:]

Introduction

Mr. Chairman, Ranking Member Inglis and distinguished Members of the Committee, thank you for the opportunity to testify at this important hearing. And, thank you for your strong and consistent support for science and the innovation process. My name is Jay Keasling and I am the CEO of the Joint BioEnergy Institute and the Acting Deputy Director of the Lawrence Berkeley National Laboratory (Berkeley Lab), a Department of Energy (DOE) Office of Science laboratory operated by the University of California. I am also a professor at the University of California, Berkeley, in chemical and biological engineering.

The Joint BioEnergy Institute (JBEI) is a scientific partnership led by Berkeley Lab and including the Sandia National Laboratories, the University of California campuses of Berkeley and Davis, the Carnegie Institution for Science and the Lawrence Livermore National Laboratory. JBEI's primary scientific mission is to advance the development of the next generation of biofuels—liquid fuels derived from the solar energy stored in plant biomass. JBEI is one of three DOE Bioenergy Research Centers (BRCs) funded by the Office of Biological and Environmental Research (BER).

Lawrence Berkeley National Laboratory is a world-leading multi-disciplinary science laboratory founded in 1931 by Nobel Laureate Ernest Orlando Lawrence. Eleven scientists associated with Berkeley Lab have won the Nobel Prize and 55 Nobel Laureates either trained at the Lab or had significant collaborations with the Lab. It has a very distinguished history in several fields of science including physics, chemistry, biology, computing, energy efficiency and Earth sciences, among others.

Today, Berkeley Lab is mobilizing its strong bench of scientific and engineering talent to lead the scientific advancement and technological development of solutions to the energy and environmental challenges facing our planet. Much of this good work is funded by the Office of Biological and Environmental Research within the DOE's Office of Science. I am delighted to be here with you today to share information about this productive and good use of federal research dollars, and to share a few thoughts about BER, the BioEnergy Research Centers and more generally on biology-based opportunities in energy and other fields.

Overview of Testimony

The energy and environmental demands facing our nation and the world are daunting and require a broad and balanced mix of solutions—from advancements in science and technology to bold changes in policy and human behavior. BER is aggressively advancing the scientific knowledge and the technological know-how needed to address these grand challenges with its unique cadre of experts and facilities. From the development of biofuels, to cost-efficient remediation of toxic environments, to changing the way we understand and predict the global impacts of climate change, BER serves a crucial and irreplaceable role in the federal research enterprise.

Today I want to draw your attention to four key areas:

1. BER's arsenal of research resources, such as the BRCs and the Joint Genome Institute, are unparalleled in the Nation's science and technology complex and are hotbeds of potentially game-changing energy and environmental research.
2. The BRCs' development of cellulosic biofuels, especially next generation, environmentally benign, drop-in biofuels, will contribute significantly to new technological approaches to transportation fuels.
3. Synthetic Biology, a transformational approach to biological energy and medical challenges, holds great promise for the design and development of sustainable, safe, bio-based products.
4. In order to make rapid and meaningful progress, DOE's basic and applied energy research and development activities must collaborate closely and strategically. The BRCs are an excellent model for building stronger alliances between these two areas.

BER's Arsenal of Resources

Championing large scale and team-centric biology-based approaches to big problems have propelled BER to a world-leadership position in the biological sciences and in the development of biology-based technologies. Since spearheading the Human Genome Project in 1986, BER has led the development of modern genomics-

based systems biology that today is enabling cutting-edge research into sustainable energy alternatives and global climate change solutions.

At the core of BER's strength are its unique facilities and world leading scientists. From the three BRCs to the Joint Genome Institute, BER is providing American research institutions and companies the intellectual horsepower and the specialized tools and equipment needed to make progress quickly. Also, BER is careful to ensure that it and its facilities utilize and leverage one another as well as other DOE assets to support its mission.

A case in point: each of the BRCs has access to the tremendous genomic research capabilities of the Joint Genome Institute (JGI). JGI was created in 1997 to unite the expertise and resources in DNA sequencing, informatics, and technology development pioneered at the DOE genome centers at Berkeley Lab, Lawrence Livermore National Laboratory, and Los Alamos National Laboratory. By combining these efforts, the significant economies of scale achieved enabled the JGI to be the first to publish the sequence analysis of the target chromosomes 5, 16, and 19, in the journal *Nature*. Following this accomplishment, the DOE JGI went on to advance basic science by sequencing scores of microbial species as well as several model organisms and provided this information freely to public databases.

Building on its success, in 2004 the BER established JGI as a national user facility. The vast majority of JGI sequencing is conducted under the auspices of the Community Sequencing Program, surveying the biosphere to characterize organisms relevant to the DOE science mission areas of bioenergy, global carbon cycling, and biogeochemistry. Today, JGI's largest customers are the BRCs, which utilize the JGI's skills and tools to sequence the genomes of prospective biofuel feedstocks, such as the poplar tree and the grass arabidopsis, or of potentially highly effective organisms for cellulosic deconstruction, such as those in the hindgut of termites or on the rainforest floor.

Additionally, JGI works with institutions and companies from around the country, including from the Chairman's and Ranking Member's home states. These projects include:

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|--|-------------------------------------|--|
| Scott Baker, PNNL, Richland, WA | fungus <i>Trichoderma reesei</i> | Developing strains with boosted production of biomass-degrading enzymes for industrial use in making biofuels |
| Toby Bradshaw, University of Washington | poplar tree | First tree genome sequenced laid groundwork for developing trees as potential feedstocks for cellulosic ethanol production |
| Maud Hinchee, ArborGen, Summerville, SC | eucalyptus tree | Fast-growing woody plant is one of the DOE's candidate biomass energy crops for cellulosic ethanol production |
| Jeff Tomkins, Clemson University | plant <i>Aquilegia Formosa</i> | Used as a model system to study how plants adapt to changes in the environment, especially as a result of climate change |

BER's leadership role in biological sciences and technology development continued with its request for proposals in the summer of 2006 to establish three centers to research and develop cellulosic derived ethanol. Inspired by a joint BER-EERE workshop, the report, "*Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda*," provided direction for a program that would more directly effect large-scale solutions to our energy and environmental challenges. The workshop, in which I participated along with my UC-Berkeley colleague Chris Somerville (Executive Director of the \$500 million, BP funded, Energy Biosciences Institute), provided a cohesive research strategy that could best be realized through the creation of dedicated, collaborative scientific research centers.

This committee and the Congress also played a critical role in the establishment of the BRCs. From the biofuel provisions in the *Energy Policy Act of 2005*, research agencies' budget authorizations in the *America COMPETES Act*, and the appropriations that made the Centers possible, you and your colleagues have demonstrated

your leadership and your understanding that new approaches are needed to attack these big problems.

All of the BRCs are up and running and are making great progress. As an addendum to this testimony I have attached the recently updated "Bioenergy Research Centers Overview" (07/09) which includes information about the three centers, our progress and successes. JBEI's sister centers are profiled below.

The **DOE Great Lakes Bioenergy Research Center** is led by the University of Wisconsin in Madison, Wisconsin, in close collaboration with Michigan State University in East Lansing, Michigan. The Center Director is Timothy Donohue, and other collaborators include: DOE's Pacific Northwest National Laboratory in Richland, Washington; Lucigen Corporation in Middleton, Wisconsin; University of Florida in Gainesville, Florida; DOE's Oak Ridge National Laboratory in Oak Ridge, Tennessee; Illinois State University in Normal, Illinois; and Iowa State University in Ames, Iowa.

The **DOE BioEnergy Science Center** is led by the DOE's Oak Ridge National Laboratory in Oak Ridge, Tennessee. The Center Director is Martin Keller, and collaborators include: Georgia Institute of Technology in Atlanta, Georgia; DOE's National Renewable Energy Laboratory in Golden, Colorado; University of Georgia in Athens, Georgia; Dartmouth College in Hanover, New Hampshire; and the University of Tennessee, in Knoxville, Tennessee.

Each of the BRCs has pulled together the best of the national laboratories, academics, and the private sector to build a new model for interdisciplinary research. Working collaboratively, the three BRCs have the potential to provide a better investment for the federal dollar than a single large center. As has been pointed out by many, the days of Bell Labs and Xerox Labs are behind us. Therefore, it is critical that the Federal Government continue to invest in high payoff research that will bring transformative technology to the marketplace, maintain the leadership position of the United States in technology development and support the creation of new economic sectors. As example, let me describe JBEI to you in more detail.

As noted earlier, the Joint BioEnergy Institute (JBEI) is a six-institution partnership led by Berkeley Lab and based in the San Francisco Bay Area in a new research facility in Emeryville, California, within commuting distance of its partner institutions. JBEI is designed to be an engine of ingenuity, dynamically organized with all the scientific teams working together in a single location, under one roof, to enable researchers to share ideas and address cellulosic biomass problems at a systems-wide level. Within 60 miles of JBEI are some of the world's foremost expertise and facilities for energy, plant biology, systems and synthetic biology, imaging, nanoscience, and computation, plus the highest concentration of national laboratories and world-class research universities in the Nation.

Organized like a start-up company (for example, my title is CEO), JBEI is designed to be nimble and flexible, able to focus and refocus resources quickly, efficiently and effectively—not the typical mode for basic scientific research. This organizational structure is critical to JBEI's success. For example, research avenues that are unproductive as related to meeting biofuels development targets may be quickly redirected. Ideas that show the most promise are invested in aggressively and resources are allocated to ensure rapid progress.

Biofuels: The Next Generation

Although biofuels have been in use, and in some stage of development for decades, the Federal Government and industry have not invested adequately in the basic science and technology development needed to advance more useful and sustainable forms. Ethanol derived from corn starch and other starch based biomass is a good place to start and have demonstrated the viability of bio-based fuels as useful and effective alternatives to fossil fuel. However, ethanol, especially when derived from starches, presents problems that must be overcome.

From the limitations of using existing transportation infrastructure, such as our inventory of automobiles and fuel distribution networks, to the inefficient utilization of the feedstock, starch derived ethanol is ultimately not the best way to address our energy security or global climate change challenges. New ways must be developed, and BER's investment in the BRCs is one critical path that holds great promise.

At JBEI, we are focusing on developing "next generation" biofuels that are compatible with existing infrastructure and utilize feedstock more efficiently. To do this we are taking a whole-systems approach to ensure that our research is applicable on large scales. The research revolves around four interdependent efforts that focus on (1) developing new bioenergy crops, (2) enhancing biomass deconstruction, (3)

producing new biofuels through synthetic biology, and (4) creating technologies that advance biofuel research. The magic of this approach, as well as similar approaches at the other BRCs, is that advancements and discoveries in any of the four areas can be shared with and employed by each other, and by industry. In other words, commercially applicable developments made at the BRCs can speed improvement in various components of biofuels production before game changing discoveries are made and perfected.

JBEI researchers are engineering microbes and enzymes to process the complex sugars of lignocellulosic biomass into biofuels that can directly replace gasoline. However, the process and the research begin much earlier than the conversion of sugars into fuels. First, we must develop better biomass and better technologies for deconstructing the tough cellulosic bonds. Below are three examples of work through which JBEI researchers will improve the fermentable content of biomass and transform lignin into a source of valuable new and sustainable fuels.

The conversion of cellulosic biomass to biofuels begins with pretreatment—the use of chemical or physical treatments to loosen the tight linkages among cell-wall components, making the biomass easier to degrade. A new development in pretreatment research is the use of ionic liquids—salts that are liquid rather than crystalline near room temperature. Ionic liquids can dissolve both lignin and cellulose; their use, however, has required large amounts of anti-solvent to recover the dissolved cellulose. JBEI researchers have studied solvent extraction technology based on the chemical affinity of boronates to complex sugars and determined optimal pH and temperature conditions for recovering sugars from the ionic liquid-biomass liquor.

To find other ways, including new and better enzymes, to break down lignocellulose, JBEI researchers have analyzed microbial communities in Puerto Rican rainforest soils that boast some of the planet's highest rates of biomass degradation. Scientists used the Phylochip, a credit card-sized microarray developed at Berkeley Lab that can quickly detect the presence of up to 9,000 microbial species in samples. Using bags of switchgrass as “microbe traps,” the researchers conducted a census of these soil microbes to identify the most efficient biomass-degrading bacteria and fungi.

Through re-engineering microbes, JBEI researchers have used synthetic biology and metabolic engineering techniques in *Escherichia coli* and *Saccharomyces cerevisiae* (yeast) to produce advanced, “drop-in,” fuels that perform better than ethanol. The scientists redirected central metabolic, fatty acid, and cholesterol biosynthetic pathways to produce candidate gasoline, diesel, and jet fuel molecules. JBEI also has developed a new metabolic pathway that potentially could produce both advanced fuels and other molecules (e.g., polymer monomers) that might otherwise be produced from petroleum, paving the way to replace a significant portion of petroleum-based products with sugar-based products. I will discuss this in more depth later in the testimony.

Close collaborations with industry is critical to the whole systems approach and to the process of getting discoveries and technological improvements to the market. At JBEI, we collaborate with companies in a number of ways to achieve this goal. We have an Industry Advisory Committee, comprised of leading companies in a number of sectors that relate to biofuels: agriculture, biotechnology, chemicals, oil and gas, automobile and aerospace. Currently this committee is comprised of representatives from the following companies: Arborgen, Boeing, BP America, Chevron, DuPont, GM, Mendel Biotechnology, Plum Creek, and StatoilHydro. These companies meet annually for a review of JBEI's research and provide feedback from an industry perspective. They are able to identify challenges and opportunities that are difficult to perceive from the lab bench, but critical to address in the marketplace.

We also have an Industry Partnership Program through which companies can collaborate with JBEI in a variety of ways to best meet their needs. JBEI partners with companies to expand the scope of its biofuels research and take JBEI's fundamental discoveries the next step in development by focusing on an applied research problem in tandem with a company. In one example, JBEI is planning to work with a company on testing the compatibility and efficacy of our inventions with their processes. In another, JBEI has leveraged industry funding from Boeing and StatoilHydro to develop an economic model of a cellulosic biorefinery that will identify those aspects of the process that would most benefit from cost reduction.

JBEI ensures that its discoveries offer value to industry by patenting those inventions that we expect to be commercially valuable. Thus far, JBEI has produced 30 inventions and copyrighted or filed a patent application on 21 of them. JBEI actively promotes these inventions to the public and the target markets, not only to ensure that Fairness of Opportunity is met, but to find the most qualified licensee in each case.

Although we are making significant progress, I do not want to leave here today having given you unrealistic expectations. I estimate that whole-system, cellulosic to drop-in biofuels production on a mass scale is still at least a decade away. However, as stated before, we and our colleagues at the other BRCs are rapidly developing solutions for various aspects of the biofuels enterprise that may come to market much quicker. Synthetic biology offers more immediate opportunities.

The Promise of Synthetic Biology

As an example, I would like to describe my personal research in synthetic biology and how this exciting field offers great promise, not just for the development of game-changing biofuels, but for other bio-based chemical, consumer and medical products.

I started my career at Berkeley in the early nineties when it was very difficult to engineer biology. I began with the idea that one could engineer microorganisms to be chemical factories to produce nearly any important chemical from sugar. Unfortunately, there were very few tools to engineer microorganisms to produce chemicals. So, we began by developing tools to control the expression of genes that had been transferred to cells so that we could accurately control the production of the chemical of interest. There was really no name for what we were doing, but now it is referred to as synthetic biology.

At the time, I was somewhat ostracized by my colleagues for focusing on the development of tools for engineering biology—even though the development of tools is at the heart of every engineering field. As an example, Gordon Moore famously recommended that Intel spend at least 10 percent of its budget on the development of tools. Obviously, tools help to move science forward.

One of our most important and well-known applications of these tools has been engineering microorganisms to produce the anti-malarial drug artemisinin. There are 300–500 million cases of malaria at any one time, with one to three million people dying from the disease each year, 90 percent are children under the age of five. While the quinine-based drugs that have been so widely used to treat malaria are no longer effective, artemisinin combination therapies are highly effective in treating malaria.

Because the drug is extracted from a plant that naturally produces it in rather low yield, artemisinin combination therapies are too expensive for most people in the developing world to afford. To increase the availability of the drug and decrease its cost, we engineered a microorganism to produce a precursor to the drug by transferring the genes responsible for making the drug from the plant to the microorganism. Through generous funding from the Bill & Melinda Gates Foundation, we were able to complete the science in three years. That science was greatly enabled by our previous work on developing biological tools. The engineered microorganism was further optimized and a production process developed by Amyris Biotechnologies. The microbial production process has been licensed by Sanofi-Aventis, which will scale the process and produce the drug within the next two years.

Artemisinin is just a start. Just as synthetic biology is being applied to develop new fuels, I believe that similar processes and techniques can also be applied to the production of many other products—from chemicals and medicine to consumer and commercial products. Today, companies like Amyris and DuPont are leading the way in the development of more sustainable, bio-based products that traditionally have utilized fossil fuels. Investing in cleaner, non-petroleum based manufacturing methods for non-fuel products should also be a significant focus of our energy and global climate change federal research agenda. Limiting this research to just fuels would be a mistake and a lost opportunity.

Collaborating for Success

I wanted to bring to the Committee's attention an important issue that, if addressed effectively, could greatly improve the Department's ability to develop solutions to great problems and help to move them to the marketplace. Energy research and the development of energy and environmental technologies at DOE demonstrate an unfortunate disconnect between the basic sciences and applied technology development at DOE.

Instead of dwelling on the problem, however, I prefer to concentrate on the huge upside presented by closer collaboration. If the Office of Science and DOE's applied research and development programs were more strategically and organizationally aligned, the progress that could be made would be astounding. Just as JBEI and the other BRCs are taking a whole-systems approach, so must the Office of Science and the DOE technology offices work together to establish objectives, to coordinate

activities and to jointly invest in programs and projects. The BRCs provide a great opportunity for this type of collaboration.

There are signals that this is occurring. A recent instance is the announcement by Secretary Chu that EERE's Office of Biomass will fund a biofuels pilot plant for use by the Office of Science/BER-funded BRCs and other users across the Nation. The pilot plant would translate the technologies created by the Joint BioEnergy Institute (JBEI) and its sister BRCs beyond laboratory scale to facilitate their commercialization. The facility will have capabilities for pilot scale pretreatment of biomass, production of enzymes for biomass deconstruction (cellulases, hemicellulases, and lignases), and fermentation capacity for advanced biofuels production and purification in quantities sufficient for engine testing at partner institutions.

Finally, I would like to share one last example of a potentially dynamic and productive collaborative effort. More foundational research is needed to develop the underpinning technologies in synthetic biology (SB), and to apply synthetic biology to test beds like microbial production of transportation fuels and specialty chemicals (EERE). An example of this foundational research is that conducted at the National Science Foundation-funded Synthetic Biology Engineering Research Center (SynBERC), a collaboration of the University of California campuses at Berkeley and San Francisco, Stanford University, Harvard University, and the Massachusetts Institute of Technology. BER could play large role in this foundational research, which would complement its work at the Joint Genome Institute, and advance its mission-focused research in many fields. Specifically, the funding of a biological fabrication facility dedicated to the construction and characterization of biological components would increase the speed and reduce the costs of the development of microorganisms that produce biofuels, commodity and specialty chemicals, and pharmaceuticals.

Conclusion

I hope that my testimony has illustrated for you the remarkable role that BER has and will continue to play in our nation's research and innovation enterprise. Your actions and the support of the Congress, however, will determine whether these efforts described today are ultimately successful. This is a marathon, not a sprint, and requires consistent and continuous nourishing and care. Additionally, the Department has a huge burden to shepherd their programs in a coordinated, strategic and efficient manner. To meet the monumental tasks before us, just in the area of advanced biofuels, will require more than what BER can do alone—all of DOE's resources, in coordination and collaboration with industry and other federal agencies, must be brought to bear.

Finally, thank you, again, for holding this important hearing and for inviting me to participate. Please let me know if I may ever be of any assistance.

BIOGRAPHY FOR JAY D. KEASLING

Jay Keasling was named as Berkeley Lab's Acting Deputy Director in March, 2009. While serving in this interim position he continues his duties as the Chief Executive Officer of the U.S. Department of Energy's Joint BioEnergy Institute and as a professor of chemical and bioengineering at the University of California-Berkeley. From April 2005 to June 2009, he served as Director of Berkeley Lab's Physical Biosciences Division. He joined that division in 1992 and in 2002 became the first head of its Synthetic Biology Department. In addition, he directs UC-Berkeley's Synthetic Biology Engineering Research Center and is also a founder of Amyris Biotechnologies, a leading firm in the development of renewable fuels and chemicals.

Keasling is one of the foremost authorities in the field of synthetic biology research. His work has focused on engineering microorganisms for the environmentally friendly synthesis of small molecules or degradation of environmental contaminants. He led the breakthrough research in which bacteria and yeast were engineered to perform most of the chemistry needed to make artemisinin, the most powerful anti-malaria drug in use today. In 2004, the Bill and Melinda Gates Foundation awarded a \$42.6 million grant to further develop the technology which is now nearing commercialization. For this research, Keasling received the 2009 Biotech Humanitarian Award from the Biotechnology Industry Organization. Keasling is now applying his synthetic biology techniques towards the production of advanced carbon-neutral biofuels that can replace gasoline on a gallon-for-gallon basis.

Keasling grew up on his family's corn and soybean farm in Harvard, Nebraska, then earned his Bachelor's degree from the University of Nebraska, and his graduate degrees in chemical engineering from the University of Michigan. He is the recipient of the American Institute of Chemical Engineers Professional Progress

Award (2007) and Scientist of the Year, Discovery Magazine (2006). He is a Fellow of the American Academy for Microbiology (2007) and the American Institute of Medical and Biological Engineering (2000). In 2006, he was also cited by *Newsweek* as one of the country's 10 most esteemed biologists.

Chairman BAIRD. Dr. Campbell.

**STATEMENT OF DR. ALLISON A. CAMPBELL, DIRECTOR, WR
WILEY ENVIRONMENTAL MOLECULAR SCIENCES LABORA-
TORY, PACIFIC NORTHWEST NATIONAL LABORATORY**

Dr. CAMPBELL. Thank you, Chairman Baird, Ranking Member Inglis, and Members of the Committee for the opportunity to appear before you today. I am the Director of Wiley Environmental Molecular Sciences Laboratory, a BER-funded national scientific user facility.

EMSL's mission is to provide researchers worldwide with integrated computational and experimental capabilities to advance scientific discovery and provide technological innovation in the environmental molecular sciences in support of DOE and the Nation's needs.

It is unique in that it offers users under one roof a problem-solving environment that integrates these capabilities with staff expertise that enable the highest impact science possible. Capabilities include high-performance computing tools, ultrahigh resolution microscopes, and world-leading magnetic resonance spectrometers. Think of it as an MRI for molecules. And mass spectrometers.

Within the Office of Science BER supports, sponsors, and advances world-leading biological and environmental research programs and operates scientific user facilities that drive fundamental scientific discoveries to meet its mission priorities. In addition to DOE's Office of Science, the National Science Foundation and the National Institutes of Health also fund programs in biology and medical research.

Many scientists from—funded by these three agencies perform their research at DOE-sponsored National Scientific User Facilities such as EMSL. A few examples of highlights in the biological arena include researchers from Washington University at St. Louis, who recently discovered a novel cluster of genes that include proteins essential for photosynthesis. This is the process by which plants convert light into energy. Understanding this process and how nature converts light into energy is a reaction important in the development of new clean fuels.

Another example is researchers from Oregon State University and the University of California, as well as at PNNL, for the first time measured protein complements of microbial communities in the Sargasso Sea. Insights afforded by this research is important because bacteria such as these heavily influenced biogeochemical cycles affecting the concentrations of elements such as carbon and therefore, the greenhouse gas carbon dioxide in the Earth's air, water, and soil.

Finally, an international team from the Erasmus Research Center at Rotterdam have identified 55 different proteins that vary in amounts between patients who were responsive to a certain breast cancer therapy and those who were not. This discovery can poten-

tially lead to new biomarkers for the efficacy of new therapies and drugs.

BER continues to make significant investments in EMSL to keep the user facility unique and state-of-the-art, such as the recent investment of \$60 million of Recovery Act funds to enable our planned investments and recapitalization.

We are also collaborating with the National High-Field Magnet Laboratory at Florida State University, as well as an institute in the Netherlands to develop the world's highest-field mass spectrometer. This high-field magnet would make what today is impossible, possible, through increases in dynamic range, sensitivity, and resolution. New knowledge garnered from this instrument could enable biofuel development and foster better-informed technology and policy decisions affecting bioremediation, waste processing, energy production, and associated health impacts.

Of course, EMSL would not exist without our user base. During our 12 years of operation we have hosted more than 10,000 scientists from all 50 states, including all the states represented by this committee, and over 60 countries. Nearly half of our users come from university systems, 40 percent come from other national labs and other government labs, and a small portion come from the industrial sector.

Nearly 45 percent of EMSL users are funded by DOE, with one-third of those being funded by the Office of Biological and Environmental Research, and another 25 percent are funded by NIH and NSF, the remaining balance being funded by various associated agencies across the government sector. User productivity has been excellent. Over the last two years EMSL-based research and discoveries have been the subject of more than 1,000 peer review papers and journals and featured on more than 30 journal covers.

To summarize, in partnership with BER, EMSL will continue to provide these world-class scientific resources and scientific expertise to the scientific community worldwide, with integrated capabilities to achieve the highest impact science possible in support of the needs of the DOE and the Nation.

Thank you, Mr. Chairman, for the opportunity to discuss EMSL and DOE's biological programs with you. As we both call Washington our home, I would like to invite you at your convenience out to the Laboratory to take a look yourself, and I would be pleased to answer any questions the Committee might have.

[The prepared statement of Dr. Campbell follows:]

PREPARED STATEMENT OF ALLISON A. CAMPBELL

Thank you, Chairman Baird, Ranking Member Inglis, and Members of the Committee for the opportunity to appear before you to provide testimony on *"Biological Research for Energy and Medical Applications at the Department of Energy Office of Science."* In 1990, I became affiliated with the Department of Energy's (DOE's) national laboratory system as a post-doctoral chemist at the Pacific Northwest National Laboratory (PNNL) in Richland, Washington. Since that time, I have spent nearly 20 years at PNNL as a senior research scientist, a technical group leader and, as of 2000, the Associate Director of EMSL—the Environmental Molecular Sciences Laboratory. In May 2005, I was named EMSL Director.

Today, my testimony will focus on three objectives: (1) introducing you to EMSL, its mission, its users, and the science it enables; (2) articulating the role of EMSL in supporting the biological research efforts of DOE's Office of Biological and Environmental Research (BER) and other agencies; and (3) describing future opportunities that will accelerate scientific discovery at EMSL.

History of EMSL

Located at PNNL, EMSL is a BER-funded national scientific user facility. The concept of EMSL began in 1986, when then-PNNL Director Dr. William R. Wiley and his senior managers met to discuss how PNNL could respond to the scientific challenges that faced DOE. Dr. Wiley and his senior leadership team, knowing of the tremendous advances made in the ability of the research community to characterize, manipulate, and create molecules, believed that molecular-level research would be instrumental to solving significant challenges in the environment, energy, and health arenas. The resulting concept was a center for molecular science research that would bring together experimentalists from the physical and life sciences and theoreticians with expertise in computer modeling of molecular processes.

Dr. Wiley's vision was realized in July 1994 when construction began on the William R. Wiley Environmental Molecular Sciences Laboratory, as it came to be called, and the building was dedicated in October 1996, shortly after he passed away unexpectedly. The doors of EMSL opened to the user community on October 1, 1997.

The Uniqueness of EMSL

Today, Dr. Wiley's vision continues to be embodied in EMSL's mission to provide researchers worldwide with integrated experimental and computational resources for scientific discovery and technological innovation in the environmental molecular sciences to support the needs of DOE and the Nation. EMSL is unique in that it offers users a problem-solving environment that integrates scientific expertise with transformational capabilities to enable the highest-impact scientific results possible. These capabilities include, under one roof, high-performance computing tools that advance molecular science in areas such as aerosol formation, bioremediation, catalysis, climate change, and subsurface science; high-resolution microscopes that enable scientists to visualize molecules and molecular processes; and world-leading nuclear magnetic resonance (NMR) and mass spectrometry capabilities that allow researchers to characterize complex systems such as microbial communities.

Many of these capabilities are built in house, another feature that sets EMSL apart from other facilities. For example, the EMSL-developed NWChem, DOE's premier computational chemistry software, runs on systems such as EMSL's high-performance, third-generation supercomputer, Chinook—an HP system that can reach 163 teraflops in peak performance. Researchers apply NWChem to run highly scalable, parallel computations to gain understanding of large, challenging scientific problems such as the biological activity of reactive sites in proteins, providing insight into how they carry out critical functions such as DNA repair. Another example is EMSL's STORM—an optical microscope that allows users to observe biological systems in natural environments at electron microscopy resolution, without altering the material from its natural state as required by electron microscopy.

However, world-class instruments are only one component of a world-class facility. The most important aspect of EMSL is the cadre of leading scientific and technical experts. EMSL scientists have been recognized with the Presidential Early Career Award for Scientist and Engineers, and they have been elected as Fellows in a variety of professional societies such as the American Chemical Society and the American Association for the Advancement of Science. They serve as editors on scientific journals, have patented several new technologies, and publish their work in leading scientific journals. Our researchers have dedicated their careers to building new and innovative technologies, pushing the limits of scientific discovery and advancing the science of our users.

These capabilities and scientific expertise are focused to support DOE's missions in energy and environment and address complex challenges within EMSL's three science theme areas: (1) Biological Interactions and Dynamics, (2) Geochemistry/Bio-geochemistry and Subsurface Science, and (3) Science of Interfacial Phenomena.

Biology Research within BER and other Federal Agencies

DOE's Office of Science is the single largest supporter of basic research in the physical sciences in the United States, providing more than 40 percent of total funding for this vital area of national importance. Within the Office of Science, BER sponsors, supports, and advances world-class biological and environmental research programs and scientific user facilities to drive fundamental science discoveries and to meet its mission priorities to:

- Develop biofuels as a major secure national energy resource
- Understand relationships between climate change and the Earth's ecosystems, and assess options for carbon sequestration

- Predict fate and transport of subsurface contaminants
- Develop new tools to explore the interface of biological and physical sciences.

In addition to DOE's Office of Science, the National Science Foundation (NSF) and National Institutes of Health (NIH) fund research programs in the biological and health sciences. Scientists funded by these programs advance their research with the help of DOE's national scientific user facilities, such as EMSL. EMSL is particularly well positioned to foster discovery in the biological sciences for these researchers because of its strong focus on providing transformational capabilities. Such capabilities at EMSL offer researchers new approaches to view chemical and biological systems—from **single molecules or organisms to complex structures or communities**, from **static to dynamic** processes, and from *ex-situ* systems to *in-situ* **observation**. These capabilities and EMSL's world-leading scientists are helping researchers unravel complex biological problems such as the following.

- **Understanding the light path to bioenergy.** Using EMSL's world-leading high-throughput proteomics resources, a team led by researchers from **Washington University in St. Louis** discovered a novel cluster of genes that encode proteins essential for photosynthesis. This discovery is providing insight into how nature converts light into energy, a reaction of interest because future clean energy sources will rely heavily on this conversion.
- **Understanding how oceanic microbial communities are optimized for nutrient uptake.** EMSL's world-leading proteomics resources were critical to pioneering research in which EMSL users from **Oregon State University, the University of California and PNNL**, for the first time, measured protein expression in microbial communities from the Sargasso Sea. The insight afforded by this research into oceanic microbial communities is important because such bacteria heavily influence biogeochemical cycles, affecting the concentrations of elements such as carbon—and therefore the greenhouse gas, carbon dioxide—in the Earth's air, water, and soil.
- **Fundamental studies give insight into ocular function.** The eyes house the elegant machinery that responds to light and triggers the neural impulses that allow us to visualize our surroundings. Researchers from the **University of Washington** have used EMSL's NMR spectrometers and sophisticated probe technologies to gain new knowledge about the complex visual system at the molecular level. The team is the first to determine a high-resolution structure of a photoreceptor domain that affects how quickly the eye can see. Studies such as this one are the first steps toward a fundamental understanding of the how the visual system works and how to fix it when it goes awry.
- **Identifying newly found proteins that may indicate if breast cancer cells will resist treatment.** Researchers from **Erasmus Medical Center Rotterdam** combined EMSL's mass spectrometry capabilities with EMSL expertise in proteomics to identify 55 proteins that vary in abundance between patients responsive to the breast cancer treatment tamoxifen and those who are not, indicating that a biomarker for resistance to this drug might exist.
- **Developing new tools to aid in understanding the physiology of live cells.** A research team from **PNNL, The J. Craig Venter Institute, and Merck Co., Inc.**, used EMSL resources to develop a first-of-its-kind MRI bio-chamber that provides accurate metabolic information for live cells maintained in a controlled growth environment. This new capability is helping researchers understand the processes employed by microorganisms under different conditions, an important step in using these microbes to manufacture biofuels and other valuable chemicals from waste.
- **Investigating how bacterium immobilizes subsurface contaminants.** An international team used EMSL's surface science and imaging capabilities to determine the location, with nanoscale resolution, of two proteins on the surface of the bacteria, *Shewanella oneidensis*. These proteins help *Shewanella* exchange electrons with minerals in the subsurface, which can affect the migration of environmental contaminants. Understanding the role of these proteins in electron exchange may lead to enhanced bioremediation methods. The team was comprised of participants from **The Ohio State University; PNNL; Corning Incorporated, Johannes Kepler University of Linz, Austria; Ecole Polytechnique Fédérale de Lausanne, Switzerland; and Umeå University, Sweden.**

Future Opportunities

BER continues to make significant investments in EMSL to keep the user facility unique and state of the art. Perhaps the greatest vote of confidence in EMSL and our ability to serve the user community is BER's recent investment of \$60 million in *American Recovery and Reinvestment Act* funds, which will accelerate planned recapitalization activities and condense the effort from more than five years to 18 months. This investment represents a "game changer" for EMSL in that it allows us to push forward critical, cutting-edge capabilities for *in situ* chemical and biological imaging, ultra-high resolution microscopy, near-real-time integration of theory and experiment, and characterization of molecular dynamic processes. These new high-end capabilities will bolster and refresh our user program and our users' research and allow EMSL to attract and retain vital scientific leadership. Our efforts are under way, and the instruments will be in our facility by December 31, 2010.

We are also collaborating with the National High-Field Magnetic Laboratory at Florida State University and the Atomic and Molecular Physics Institute in the Netherlands to develop the world's highest-field Fourier Transform-Ion Cyclotron Resonance mass spectrometer. This high-field magnet would make the scientifically impossible possible through increased analytical performance—sensitivity, dynamic range, accuracy, resolution, and speed/throughput. Such a system has the potential to revolutionize our biomolecular understanding of how organisms function and how microbial systems cooperate as communities by allowing our users to qualitatively identify and measure intact proteins, the machinery of life. The magnet would also allow our users to better investigate complex environmental samples such as fossil fuels and atmospheric aerosols. New knowledge garnered from this instrument would have applications to energy and environment problems of national significance. For example, it would help enable biofuel development and foster better-informed technical and policy decisions affecting environmental remediation, waste processing, energy production, and associated health impacts.

In concert with the unique instrumentation at EMSL, BER has provided the user facility with much needed critical infrastructure support. They are making investments for the development a radiochemistry capability that will serve a broad and growing base of users who require instrumentation in a radiological environment to further their studies of chemistry and biogeochemistry of actinides, fission products, and the use of radiotracers for biological research. In addition, EMSL will build a new space that will house ultra-high-resolution instruments for providing physical and chemical information at unprecedented spatial or energy resolution. Called the Quiet Wing, it will house new microscopy capabilities that require extremely low electromagnetic field and vibrational interference as well as high-temperature stability.

EMSL Users

Of course, EMSL would not exist without its user base. Users can access EMSL to perform either non-proprietary or proprietary research. There is no charge for access to EMSL if the research is considered non-proprietary, meaning that researchers will publish the results in the open literature and acknowledge EMSL's contribution. However, if the research is proprietary—the results are to be confidential—the user will pay full-cost recovery of the facilities used, which includes, but is not limited to, labor, equipment use, consumables, materials, and EMSL staff travel.

During our 12 years of operation, we have hosted more than 10,000 scientists from all 50 states and more than 60 countries, including many countries from Asia, most European countries, and Australia. Many of these users—nearly half—come from the university system.

Another large user set of EMSL capabilities is scientists from the government sector, including the DOE national laboratory system, NASA, the Department of Defense, and the Department of Agriculture. Finally, members of industry comprise a much smaller sector of EMSL's user base due mostly to the proprietary nature of their research. These entities include, for example, Bayer Polymers, 3M, Ford Motor Company, and Dow Chemical Company.

In terms of agencies that fund the projects of EMSL users, most—nearly 45 percent—are funded by DOE; and one third of these DOE projects are funded by BER. The NIH and NSF fund approximately 25 percent of projects at EMSL, and the balance is funded from a variety of sources, such as the Department of Defense, Department of Agriculture, and private industry.

EMSL users range from undergraduate and graduate students to post-doctoral fellows and research scientists and engineers. EMSL strives to bring in the best and brightest users to conduct the highest-impact science possible. We have counted

among our users 160 distinguished scientists—including 11 National Academy members, 32 endowed chairs, two Nobel laureates, and 131 authors who are considered top publishers over a 10-year span.

We have had many users from the states that the Members of this committee represent; for example, during the history of EMSL, we count among our users more than 20 researchers representing the University of South Carolina and Westinghouse Savannah River. Nearly 120 of our users call Texas their home and represent institutions such as University of Texas at Austin, Texas A&M, and Baylor College of Medicine. From Illinois, 90 researchers from institutions such as Argonne National Laboratory, the University of Illinois, and the University of Chicago have benefited from use of EMSL's capabilities and expertise. And in our home State of Washington, EMSL has been an excellent scientific resource for more than 2,300 researchers not only from PNNL, but also institutions such as the University of Washington, Washington State University, and the Fred Hutchinson Cancer Research Center.

We continue to conduct outreach activities to grow our user base. This is done through colleague-to-colleague interaction, contact at professional society meetings, and development of programs such as the Wiley Visiting Scientist Fellowship and EMSL Distinguished User Seminar Series, among others.

Scientific and Technological Output

Since Fiscal Year 2007 alone, EMSL-based research and discoveries have been the subject of nearly 1,000 papers in peer-reviewed journals, with 57 percent of them in top-10 journals and 13 of them in top-tier journals such as *Science*, *Nature*, and *Proceedings of the National Academy of Sciences*. Since that time, research at EMSL by our users and staff has been featured on more than 30 journal covers, including *Science*, *Physical Chemistry Chemical Physics (PCCP)*, *ACS Nano*, *Nanotechnology*, and *Proteomics*. These statistics help illustrate the broad scientific impact enabled by EMSL.

Concluding Remarks

To summarize, with continued support and investment from BER in the user program, EMSL will continue to bring Dr. Wiley's vision to fruition by providing the scientific community worldwide with the unique ability to integrate capabilities and staff expertise for achieving the highest-impact science.

Thank you, Mr. Chairman, for providing this opportunity to discuss EMSL and DOE's biological research programs. This concludes my testimony, and I would be pleased to answer any questions you might have.

BIOGRAPHY FOR ALLISON A. CAMPBELL

Dr. Allison A. Campbell is the Director of EMSL—the Environmental Molecular Sciences Laboratory. Her primary responsibility is to lead EMSL in achieving its vision of being a premier scientific user facility for the Department of Energy by ensuring that EMSL develops and provides transformational computational and experimental resources to the scientific user community and conducts research that is focused on critical scientific issues. Dr. Campbell began her career with Pacific Northwest National Laboratory in 1990 as a post-doctoral fellow, when she joined the Materials Synthesis and Modification Technical Group. In 1992, she was hired into that group as a research scientist involved in developing new methods for synthesizing ceramic coatings from aqueous processes. She went on to manage the Advanced Materials Product Line and the Materials Synthesis and Modification Technical Group at PNNL before joining the EMSL management team in 2001. She was named the EMSL Director in May, 2005.

Dr. Campbell is nationally recognized for her contributions towards materials development through her research in the field of biomaterials. Dr. Campbell is credited with co-inventing a bio-inspired process to "grow" a bioactive calcium phosphate layer, from the molecular level, onto the surfaces of artificial joint implants (total hip and knee) to extend implant life and reduce rejection. She is also recognized for her work in understanding the role of proteins in biomineralization process such as tooth formation and decay. She has authored numerous peer reviewed technical papers, been an invited speaker at national and international meetings, and has several patents based upon her research. Additionally, Dr. Campbell is an avid promoter of science education, sharing her enthusiasm for science with young students through a number of hands-on education programs.

Dr. Campbell is a member of the American Association for the Advancement of Science, the International Association for Dental Research, and the American Chemical Society.

Awards and Honors:

- 2006 R&D100 Award
- 2006 Federal Laboratory Consortium Award
- 2005 American Chemical Society Regional Industrial Innovation Award
- 2003 George W. Thorn Award, SUNY/Buffalo
- 2002 American Chemical Society—Outstanding Women in Chemistry
- 2001 Energy 100 Award for Biomimetic Coating for Orthopedic Implants, DOE
- 2000 Young Alumni Achievement Award for Career Development, Gettysburg College
- 1997 Fitzner-Eberhardt Award for Outstanding Contributions to Science & Engineering Education, PNNL
- 1997 Woman of Achievement Award, PNNL
- 1995 DOE Basic Energy Sciences Award in Materials Science
- 1994 Director's Award for Scientific and Engineering Excellence, PNNL
- 1987 Excellence in Teaching Award; SUNY/Buffalo
- 1985 Undergraduate Research Award; Gettysburg College

Chairman BAIRD. Dr. Patrinos.

**STATEMENT OF DR. ARISTIDES A.N. PATRINOS, PRESIDENT,
SYNTHETIC GENOMICS, INC.**

Dr. PATRINOS. Thank you, Mr. Chairman, Ranking Member Inglis, and Mr. Ehlers. I am honored to be asked to speak about BER and about my company, Synthetic Genomics, Incorporated. I am also pleased to see that my colleagues at the table also still recognize me and remember me.

The common theme between BER and my company, Synthetic Genomics Incorporated, is, in fact, genomics, which you have heard so much about already. SGI was created by a genomics pioneer, Craig Venter, in the summer of 2005, to drive commercial solutions using genomics, starting with energy but eventually we expect to move into things such as vaccines, clean water, and many other applications. We are currently partnering with industry giants like BP to enhance hydrocarbon recovery, subsurface hydrocarbon recovery; with a Malaysian company, Genting ACGT, to sequence the genomes of *Jatropha* and oil palm, and of the microbial communities residing in the rhizosphere to include things such as yields, and very recently we also announced an alliance with Exxon to exploit algae-produced biofuels.

The genomics revolution as you correctly have stated started really with the Human Genome Project that was launched by the BER Program back in 1986, by one of my predecessors, Charles DeLisi. Through the genomics program, through the Human Genome Project, we have developed many high-throughput technologies for sequencing, assembly, and informatics, and many of those technologies were actually developed by Craig Venter himself.

Over the years there have been very many successful partnerships between BER and Craig Venter, and in fact, one of them continues today.

As you have heard already, synthetic biology, synthetic genomics, genome engineering are all new fields that have been, essentially

have been launched by genomics and promise disruptive technologies with myriad applications beyond energy: in medicine and in other industrial processes.

I am very proud of my many-year association with the BER Program and for the contributions the program has made since its inception. I will always remember the age of the program because it is the same age that I am, 62 years, and the contributions it has made in radiation biology, in nuclear medicine, climate change, bioremediation, genomics, structural biology, the list goes on.

BER has always invested in high-risk and high-payoff research and leveraged the physical and the computational sciences that reside within the Office of Science, that unique position that BER enjoys. BER, therefore, should not be like NIH or NSF. It should retain its own DNA so to speak, because diversity is really the strength of the American scientific enterprise, and I mean diversity of performers, diversity of scientific approaches, and yes, diversity of funding sources. A good idea that gets shut out by an agency that dominates a field needs another chance to be shopped around. If it wasn't for the BER Program, the Human Genome Program would probably be much delayed and probably we would still be sequencing it.

When I was in DOE, I suffered in the last few years by many—much questioning about why DOE should be doing biology. Questions came from the Secretary's office, from the OMB, and also from your sister committee on Energy and Commerce. There was also an attempt to raid BER to provide funding for the newly-founded Department of Homeland Security.

I am hopeful that these dark days are over, and my successor will not have to suffer what I suffered back in those days. BER is extremely important for the DOE missions, especially those involving clean energy as you have heard. Carbon capture and sequestration will not be possible without a biological solution and also bioremediation of the legacy of the cold war.

Also, BER has important scientific user facilities like you have heard: the Environmental Molecular Sciences Laboratory, the Joint Genome Institute, and the facilities and stations it nurtures, the light sources and the neutron sources of the National Labs.

My suggestions for continuing the successful tradition of BER is to push the high-risk, high-payoff envelope. Too much is at stake, especially for climate, not to do that. Continue to exploit the physical and computational sciences that reside in the Office of Science. There are still many new tools and methodologies that BER can steal shamelessly in order to serve biology.

Also, nurture public-private partnerships. I particularly appreciate that now being in the private sector. There are obstacles like intellectual property, but these obstacles should not stand in the way of making them successful. And build the scientific infrastructure for synthetic biology, including looking at the ethical, legal, and social implications of this new disruptive technology.

Finally, I must say that the BER stewardship role for genomic science, Mr. Chairman, Mr. Inglis, Mr. Ehlers, needs to be affirmed, needs to be strengthened and generously funded if we are to successfully confront the great challenges of our times.

Thank you very much for the opportunity to testify, and I would be delighted to answer any questions you may have.
[The prepared statement of Dr. Patrinos follows:]

PREPARED STATEMENT OF ARISTIDES A.N. PATRINOS

Mr. Chairman and Members of the Subcommittee:

Thank you for the opportunity to testify before the Energy and Environmental Subcommittee. I am honored to be asked to speak about the DOE Biological and Environmental Research (BER) program and about Synthetic Genomics, Inc. (SGI). I led the BER program between 1993 and 2006 and since February of 2006 I have been the President of SGI.

Genomics is the field of science that exploits new technologies and tools to allow scientists to routinely and accurately sequence the DNA of thousands of species. SGI was founded in 2005 by genomics pioneer J. Craig Venter to create genomics-driven commercial solutions that will revolutionize many industries, starting with energy. SGI is working with BP to study the microbial communities in coal beds in order to enhance the production of natural gas. Through a joint venture with the Malaysian company ACGT, a subsidiary of Genting Corporation, SGI has sequenced the genomes of Oil Palm and *Jatropha* to enhance yields, reduce the use of petroleum based fertilizers, and improve disease resistance of these oil seed crops.

Recently SGI announced an agreement with ExxonMobil to harness the potential of algae to produce renewable fuels. Beyond the energy field we envision a future when synthetic genomics will be used to generate a variety of products, from new and improved vaccines to prevent human disease, to efficient and cost effective ways to provide clean drinking water. The world is dependent on science and SGI is leading the way in turning novel science into "game-changing" solutions.

During the last twenty-five years the field of genomics has undergone a rapid transformation with scientific discoveries coming at a dazzling pace. The spark for this scientific revolution was the BER initiative to sequence the human genome launched by Charles DeLisi in 1986 that led to the Human Genome Project (HGP).

The research momentum created by the HGP enabled the development of technologies such as high-throughput DNA sequencing, genome assembly, and bioinformatics. These advances, many of which are directly attributable to Dr. Venter and his teams, have enabled researchers around the world to readily sequence and analyze the genetic codes of thousands of species. In fact, it was BER that went against the prevailing scientific opinion of the time and funded Dr. Venter in 1995 to sequence the genome of *Mycoplasma genitalium* using the "shotgun" sequencing method.

Over the years the scientific partnership of BER with Dr. Venter's teams has been one of the most successful fuels of the genomics revolution. This partnership led to many accomplishments including the Sorcerer II Global Ocean Sampling Expedition—conducted by the non-profit J. Craig Venter Institute with funding from BER—which more than quadrupled the number of genes in the public data bases. I believe that BER, through support of scientists like Dr. Venter, can be credited with giving birth to the new field of synthetic genomics.

The new fields of synthetic biology, synthetic genomics, and genome engineering have the potential to spawn disruptive technologies and dramatically improve our future. These fields enable us to use living systems to tackle stubborn challenges we face in medicine, energy, and the environment. The eminent scientist Freeman Dyson used genomics as an example when he discusses the difference between a concept-driven scientific revolution and a tool-driven scientific revolution.

In his book "Imagined Worlds" Dyson wrote that in the concept-driven science we are forced to explain old things in new ways whereas in tool-driven science we discover new things that need to be explained, a far more rewarding undertaking. Genomics is the tool that has transformed biology from a strict hypothesis-driven and data-poor discipline into a discovery-driven and data-rich enterprise. BER has been on the front line of this transformation.

I am proud of my association with BER and of its many contributions over the sixty years of its existence. Formed at the dawn of the atomic era to address the impacts of ionizing radiation on human biology, it has been a trailblazer of many scientific activities. They include the fields of radiation biology, nuclear medicine, global climate change, environmental remediation, genomics, structural biology, computational biology, and bioinformatics. In most cases, BER has not had an exclusive role and never had the greatest portion of funding among the U.S. agencies sharing that role. Nevertheless, BER has made unique contributions because it has

invested in high risk but high payoff research. BER has also capitalized on its proximity and association with the physical science and high performance computing programs within the Department of Energy. BER has used its unique resources to cross-fertilize biology, physical sciences and computational power to create new opportunities for discovery. As a relative newcomer to the business world I now also recognize the value of the creative ways by which BER has engaged research partners in the private sector.

BER has never been and should never be like the National Institutes of Health (NIH) and the National Science Foundation (NSF) nor should it mimic all the functions of the other programs within the DOE Office of Science. The U.S. scientific enterprise is the best in the world because of "diversity": diversity in its scientific performers, diversity in its scientific approaches, and diversity in its funding sources. A research idea that may prove too risky or too controversial to a more mainstream funding agency should have a chance to be picked up and funded by a less risk-averse agency with very impactful results. Such is the heritage of BER and I hope this Subcommittee will appreciate this heritage and act to preserve it in the future. Every new political leadership has been tempted to "tidy up" the research activities across the government and periodically even propose a Department of Science. Thankfully, reason eventually prevails and the powers-at-be come to appreciate the value of diverse funding systems.

One of the many challenges I faced during my tenure as Director of BER was the questioning of a DOE role in biology and more specifically in genomics. The questioning came from DOE leadership, from the Office of Management and Budget (OMB) and from Capitol Hill, specifically from the House Committee on Commerce and Energy. At times the questioning was in the context of why DOE should support biological research when it is mostly the primary funder of many elements of the physical sciences. At other times, there was a perceived redundancy with research activities at the NIH that is so generously funded. When the Department of Homeland Security (DHS) was formed there was an attempt to hijack the BER biology funding to support DHS R&D efforts.

I am hopeful that these dark days are over and that it is now universally recognized and accepted that BER is an important member of the U.S. scientific enterprise and that it rightfully belongs within the DOE Office of Science. The existential challenges to BER led to an in-depth examination of the contributions and potential of the BER biology programs to serve the DOE missions. BER genomics science is leading the way in the production of biological energy, including biofuels, which are considered one of the best hopes of improving our energy independence, and tackling the problem of global climate change. The BER Bioenergy Centers are the world's foremost performers in basic research of renewable fuels from biomass. BER science is central to the biological part of carbon capture and sequestration that is considered an imperative of carbon management. BER programs are also essential in environmental bioremediation that holds the greatest promise of containing DOE's cold war legacy of mixed radioactive waste.

BER plays a unique role in serving the needs of biologists from around the world who seek to access and use the scientific user facilities across the DOE National Laboratory complex and that were originally designed for the physical sciences. These include the synchrotron radiation and neutron sources, the Environmental Molecular Sciences Laboratory, and the supercomputer centers. These resources are enabling research in the fields of structural biology, structural genomics, proteomics, and computational biology. BER serves as the valuable intermediary between the biological research world and the research infrastructure of the National Laboratories that host the user facilities. A lead DOE scientific user facility is the BER Joint Genome Institute (JGI), which successfully completed the DOE contribution to the HGP. Today, the JGI is among the world's most productive sequencing centers focusing on organisms that are relevant to the DOE missions in energy and the environment.

My suggestions for continuing the tradition of successful contributions of BER in genomics sciences are:

- First and foremost, push the envelope of high risk and high payoff research. Our energy challenges are huge and even though incremental advances are important we will not be able to meet those challenges without the game-changing approaches that BER has nurtured. In many ways, BER has accomplished the biological piece of what the newly created ARPA-E seeks to accomplish across the entire energy technologies spectrum.
- Continue to capitalize on the inherent strengths of the BER program by virtue of its existence in the bosom of the physical and computational sciences.

There are still many instruments and methodologies in those sciences that BER can exploit to further propel genomics science forward.

- Enable more creative public-private partnerships in genomics involving the DOE National Laboratories and private companies. There are barriers to such partnerships such as issues of intellectual property but no barrier should be insurmountable if the tremendous value of such partnerships is recognized.
- Exploit the full potential of synthetic biology, synthetic genomics, and genome engineering by building the scientific infrastructure that will serve the diverse performers in these fields such as those from academia and the private sector. Take the lead in studying the ethical, legal, and social issues dealing with these fields.

Finally, I would like to address the stewardship role of BER for genomic science. I endorse the stewardship role of NIH in genomic science as it relates to human health and medicine. However, when it comes to genomic science that encompasses the broader living world there is no better and there will be no better steward than BER. That stewardship role of BER needs to be affirmed, strengthened, and generously funded if we are to successfully confront the great challenges of our times in energy and the environment.

I would be happy to answer questions.

BIOGRAPHY FOR ARISTIDES A.N. PATRINOS

Aristides A.N. Patrinos, Ph.D., is President of Synthetic Genomics, Inc. (SGI), a privately held company founded in 2005 applying genomic-driven commercial solutions that address global energy and environmental challenges.

Prior to joining SGI, Dr. Patrinos was instrumental in advancing the scientific and policy framework underpinning key governmental energy and environmental initiatives while serving as associate director of the Office of Biological and Environmental Research in the U.S. Department of Energy's Office of Science. He oversaw the Department's research activities in human and microbial genome research, structural biology, nuclear medicine and climate change. Dr. Patrinos played a historic role in the Human Genome Project, the founding of the DOE Joint Genome Institute and the design and launch of the DOE's Genomes to Life Program, a research program dedicated to developing technologies to use microbes for innovative solutions to energy and environmental challenges.

Dr. Patrinos currently serves on two National Academy of Science committees: America's Energy Future; and Strategic Advice to the U.S. Climate Change Science Program. He is a fellow of the American Association for the Advancement of Science and of the American Meteorological Society, and a member of the American Geophysical Union, the American Society of Mechanical Engineers and the Greek Technical Society. Dr. Patrinos is the recipient of numerous awards and honorary degrees, including three Presidential Rank Awards and two Secretary of Energy Gold Medals, and an honorary doctorate from the National Technical University of Athens. A native of Greece, he received an undergraduate degree from the National Technical University of Athens, and a Ph.D. from Northwestern University.

Chairman BAIRD. Dr. Gillo.

STATEMENT OF DR. JEHANNE GILLO, DIRECTOR FOR FACILITIES AND PROJECT MANAGEMENT DIVISION, OFFICE OF NUCLEAR PHYSICS, OFFICE OF SCIENCE, U.S. DEPARTMENT OF ENERGY

Dr. GILLO. Thank you, Mr. Chairman, Ranking Member Inglis, and Members of the Committee for the opportunity to appear before you to provide testimony on the DOE Office of Science's Isotope Development and Production for Research and Applications Program within the Office of Nuclear Physics.

The Isotope Program was transferred from the Office of Nuclear Energy to the Office of Nuclear Physics in March 2009, and specifically to the Nuclear Physics Facilities and Project Management Division. I served as the Director of the Division since 2004, and I am pleased to share with you my perspectives on the DOE Isotope Program.

The Office of Science recognizes that isotopes are high-priority commodities of strategic importance for the Nation and essential for energy, medicine, national security, and scientific research, and a goal of the program is to make critical isotopes more readily available to meet domestic needs. The expertise of the nuclear science community in operating accelerator facilities and developing instrumentation and accelerator technology for a broad suite of applications complement the expertise of the isotope production community. And the synergies between the two communities will lead to an overall improvement in the productivity of the Isotope Program.

The Isotope Program produces isotopes only where there is no U.S. private sector capability or other production capacities are insufficient to meet U.S. needs. Isotope production for commercial distribution and application is done on a full cost recovery basis. Isotopes are needed for a broad range of basic research, biomedical, homeland security, and industrial applications that benefit society every day. For example, americium-241 for smoke detectors, helium-3 for neutron detectors, nickel-63 for explosive detections, strontium-82 for heart imaging, and californium-252 for oil exploration. Isotopes have had a profound impact on daily life, including reduced health care costs, improved ability of physicians to diagnose illnesses, and advances in agriculture, basic physics research and the security of the Nation.

The Isotope Program supports both production capabilities at a suite of facilities as well as the research and development efforts associated with improving and developing isotope production and processing techniques.

As a service, the Isotope Program also sells and distributes other isotope products that it does not directly produce. Examples are helium-3 and lithium-6 that are produced by the DOE National Nuclear Security Administration or NNSA. The Isotope Program does not produce special nuclear material or sell highly-enriched uranium. The Isotope Program is not responsible for the production of molybdenum-99, a medical isotope which currently is in short supply. The DOE National Nuclear Security Administration (NNSA) is responsible in the long-term for establishing a diverse domestic supply of molybdenum-99 without using highly-enriched uranium.

The Office of Nuclear Physics has taken several actions to improve communication amongst isotope stakeholders. A workshop was organized last summer to bring together university, laboratory, federal and commercial isotope producers and users to discuss issues related to isotope production and identify isotopes in short supply. The Office of Nuclear Physics has specifically engaged federal agencies in discussions regarding agency needs and concerns on isotope production, including the National Institutes of Health, the Department of Homeland Security, and NNSA.

The program is in the process of increasing the suite of production facilities with consideration given to the capabilities at universities, commercial entities, and other government facilities. The research component of the Isotope Program is being strengthened within Nuclear Physics. Research and development efforts associated with improving the effectiveness of or creating altogether new approaches to isotope production are being pursued.

Research isotopes will be produced more reliably and at more affordable prices. In 2008, the Nuclear Science Advisory Committee on Federally Chartered Advisory Committee was charged by the Office of Nuclear Physics to develop a prioritized list of research topics across a wide range of scientific disciplines that used isotopes. The committee was also asked to develop a long-range strategic plan for future production of stable and radioactive isotopes.

The Office of Nuclear Physics is committed to increasing availability of isotopes in short supply, providing isotopes reliably and more—at more affordable prices to researchers and supporting research activities that develop more cost-effective and novel isotope production techniques. NP is using merit peer review and priority-setting mechanisms to optimize the productivity of the Isotope Program within available resources.

Thank you, Mr. Chairman and Members of the Committee, for providing the opportunity to discuss the Isotope Program, and I am happy to answer any questions that you may have.

[The prepared statement of Dr. Gillo follows:]

PREPARED STATEMENT OF JEHANNE GILLO

Thank you Mr. Chairman, Ranking Member Inglis, and Members of the Committee. I appreciate the opportunity to appear before you to provide testimony on the DOE Office of Science's Isotope Development and Production for Research and Applications program within the Office of Nuclear Physics. The Isotope Program was transferred from the Office of Nuclear Energy to the Office of Nuclear Physics within the Office of Science in March 2009, and, specifically, to the Nuclear Physics Facilities and Project Management Division. I have served as the Director of the Division since 2004, and I am pleased to share with you my perspectives on the DOE Isotope Program.

Overview of the Program

For over 50 years, this program and its predecessors have been at the forefront of the development and production of stable and radioactive isotope products and related services that are used worldwide. The Office of Science recognizes that isotopes are high-priority commodities of strategic importance for the Nation and essential for energy, medicine, commerce, national security, and scientific research. A goal of the program is to make critical isotopes more readily available to meet domestic needs. The program produces isotopes only where there is no U.S. private sector capability or when other production capacity is insufficient to meet U.S. needs. Isotope production for commercial distribution and application is done on a full-cost recovery basis.

The Isotope Program has unique expertise and capabilities to address technology issues associated with the production, processing, handling, and distribution of isotopes. The expertise of the nuclear science community in operating accelerator facilities and developing instrumentation and accelerator technology for a broad suite of applications complements the expertise of the isotope production community, and we expect the synergies between the communities to lead to an overall improvement in the productivity of the Isotope Program.

Isotopes are needed for a broad range of basic research, biomedical, homeland security, and industrial applications that benefit society every day. For example, americium-241 for smoke detectors; helium-3 for neutron detectors and lung imaging; nickel-63 for explosive detection; strontium-82 is used in heart imaging, tungsten-188 and rhenium-188 for cancer research; californium-252 for oil exploration; and arsenic-73 as a tracer for arsenic studies. With Federal support over the last several decades, isotopes have had a profound impact on daily life, scientific discovery and innovation, and the Nation's economy, including reduced health care costs, improved medical diagnoses, and advances in agriculture and basic physics research and in national security. The Isotope Program supports both production capabilities at a suite of facilities and research and development efforts associated with improving and developing isotope production and processing techniques.

The facilities used by the Isotope Program to produce radioisotopes include particle accelerators, hot cells, and reactors. Radioisotopes provided through the Pro-

gram are produced in reactors by neutron absorption followed by radioactive decay or are produced in accelerators by bombarding materials with charged atomic particles followed by radioactive decay. Some isotopes provided by the Program are obtained by extraction from the waste byproducts of the Department's weapons programs and research activities. The Isotope Program is the steward of the Isotope Production Facility (IPF) at Los Alamos National Laboratory (LANL), the Brookhaven Linear Isotope Producer (BLIP) facility at Brookhaven National Laboratory (BNL), and isotope processing facilities at Oak Ridge National Laboratory (ORNL), BNL, and LANL. The IPF is completely dependent on the operations of the Los Alamos Neutron Science Center (LANSCE) facility.

The Isotope Program also produces isotopes at facilities where it is not the steward—in this case, the program pays for space and services at those facilities. The Isotope Program purchases irradiation services at the High Flux Isotope Reactor at ORNL, a research reactor with a neutron scattering mission operated by the Office of Science Basic Energy Sciences program, to produce selected isotopes such as Cf-252. In addition, the Isotope Program seeks cooperative isotope supply agreements with other government, private sector, and university isotope producers.

The Isotope Program is also the steward of the National Isotope Data Center (NIDC) at ORNL. The NIDC coordinates isotope production across many facilities and manages business operations for the sale and distribution of isotopes. The NIDC also supports over 50 staff members at LANL, BNL, and ORNL who provide the technical expertise for research, production, processing, and transportation of isotopes, which are then processed, sold, and distributed from ORNL.

While the research activities supported by the Isotope Program are modest, they provide important results. R&D includes target fabrication, enhanced processing techniques, radiochemistry, material conversions, and other related activities. It should be emphasized that the research activities supported by the Isotope Program are focused on isotope production and processing techniques to assure their availability for research and applications, not on their actual end-use applications, which is the mission of other programs and Federal Agencies.

Further, the Isotope Program does not produce special nuclear material or deal in highly-enriched uranium, areas which serve as sources in the production of several important isotopes. So, while the Isotope Program is not responsible for producing such isotopes, it does work cooperatively with the responsible Department offices to provide services, technical advice, or R&D on potential alternative production techniques. For example, as a service, the Isotope Program sells and distributes isotope products like helium-3 (He-3) and lithium-6, which are produced by the DOE/National Nuclear Security Administration (NNSA). But, the challenge associated with producing He-3 is that it is a byproduct of tritium decay; and the availability of tritium is determined by NNSA mission needs, not by a commercial demand for He-3.

Similarly, the DOE Office of Environmental Management is responsible for disposition of excess uranium-233 stockpiles. Though uranium-233's decay products, alpha-emitting radioisotopes are in demand by the research community. Uranium-233's proliferation and national security concerns support continued disposition, thus limiting its availability. To address this dilemma, the Isotope Program is pursuing R&D on alternative isotope production techniques for these alpha-emitters as a high priority, with the goal of decreasing dependence on uranium-233 sources.

Other needed isotopes under various DOE Program Offices include the production of Plutonium-238, for which DOE's Office of Nuclear Energy has mission responsibility to support activities such as the fabrication of radioisotope thermoelectric generators for NASA's deep space program, and the production of Molybdenum-99 (Mo-99), a mission responsibility of NNSA. Mo-99, a commercial isotope used extensively in medical diagnosis, is currently in short supply. NNSA is responsible for establishing a diverse domestic supply of Mo-99 as part of their mission to minimize the use of Highly-Enriched-Uranium to avoid proliferation concerns. Today, the Isotope Program and the Department are actively engaged in interagency and international discussions on how to address the current shortage.

Recent Activities

Operations of the current isotope production facilities are being assessed to ensure that resources are being utilized optimally. The Isotope Program is in the process of increasing the suite of production facilities that will provide isotopes, with consideration given to the capabilities of universities, commercial facilities, and other government facilities. The research component of the Isotope Program will be strengthened, and research and development efforts associated with improving the effectiveness of or creating new approaches to isotope production will be pursued. Research isotope production will be prioritized, based on community input; the overall goal

will be to produce research isotopes more reliably and at more affordable prices. Additional cooperative agreements with the commercial sector will be pursued to leverage resources. Sound planning processes and merit-based peer review will guide the Program's production decisions and strategic planning.

In August 2008, the Nuclear Science Advisory Committee (NSAC), a Federally-chartered advisory committee to the DOE and the National Science Foundation, was charged to develop a prioritized list of research topics across a wide range of scientific disciplines, including the medical field. NSAC was also asked to develop a long-range strategic plan for future production of stable and radioactive isotopes. The Isotope Program also issued a call to universities, national laboratories, and commercial facilities for proposals to produce high-priority research isotopes.

The Office of Nuclear Physics is engaged in discussions with other Federal Agencies concerning isotope needs and production. A working group with the National Institutes of Health (NIH) was established to address the recommendations of the recent National Academies report *Advancing Nuclear Medicine Through Innovation*, which identified areas of isotope production warranting attention. A strategic plan was generated that identifies the isotopes and quantities needed by the medical community for the next five years, in the context of the Isotope Program capabilities. The Office of Nuclear Physics also is represented on several interagency working groups considering the production of Mo-99 in order to enhance communication within the Department and with other federal agencies and to provide technical support in development of short-term and long-term solutions. The Office also facilitated the formation of a federal working group on the He-3 supply issue involving staff from the Office of Nuclear Physics, NNSA, the Department of Homeland Security, and the Department of Defense. This working group will help ensure that the limited supply of He-3 will be distributed to the highest-priority applications and basic research.

Recovery Act Support

Funds from the Recovery Act are supporting an R&D initiative on alternative and innovative approaches for the development and production of critical isotopes and for the improved utilization of isotope production facilities. This includes additional operations for the production of isotopes, one-time investments to improve the efficiency of or provide new capabilities for the production of isotopes at existing production facilities, and opportunities to establish production capabilities at new production sites based on peer review of the proposals received from the open call mentioned above.

Concluding Remarks

The Office of Nuclear Physics (NP) is committed to increasing availability of isotopes in short supply, providing isotopes reliably and at more affordable prices to researchers, and supporting research activities that develop more cost-effective and novel isotope production techniques. NP will utilize merit peer review and priority setting mechanisms to optimize the productivity of the Isotope Program within available resources.

Thank you, Mr. Chairman and Members of the Committee, for providing this opportunity to discuss the Isotope Development and Production for Research and Applications program. I'm happy to answer any questions you may have.

BIOGRAPHY FOR JEHANNE GILLO

Dr. Jehanne Gillo has been the Director of the Facilities and Project Management Division in the Office of Nuclear Physics at the U.S. Department of Energy (DOE) since 2004. In this position, she aids in establishing the vision, strategic plans, goals, budgets and objectives for the scientific and technical activities supported by the Division, and Office of Nuclear Physics in general. She is responsible for planning, constructing, upgrading and operating the Nuclear Physics program's user facilities and for overseeing the fabrication of major instrumentation used at these facilities and elsewhere. During this time she also served as the Acting Associate Director of Science for Nuclear Physics from September 2007 to October 2008.

Dr. Gillo joined the Office of Science's Division of Nuclear Physics at DOE as Program Manager for Facilities and Instrumentation in February 2000. Prior to coming to DOE, Dr. Gillo, was a guest scientist at Los Alamos National Laboratory (LANL) from 1988-1989, and then a staff scientist from 1990-2000. During this time period she performed nuclear physics experiments at Brookhaven National Laboratory, Los Alamos National Laboratory, and the CERN Laboratory in Geneva, Switzerland. Dr. Gillo obtained her Bachelor of Science Degree from Juniata College in 1985, and her

Ph.D. in nuclear chemistry with an emphasis in relativistic heavy ion physics research from Texas A&M University in 1990.

DISCUSSION

Chairman BAIRD. I thank the panel for most informative testimony. You are doing great work.

I will recognize myself for five minutes and then we will proceed with my colleagues.

INTERAGENCY COORDINATION

Help me understand—Dr. Patrinos, it is good to see you again. We were here previously on some of those prior hearings. I remember them. Walk us through, though, a little bit about the interface between, you know, between let us say NSF, DOE, now ARPA-E, and how research is, you know, how do you make sure that we are not all doing the same thing or we are not neglecting the “gee whiz” discovery that is going to solve the problems? How do you sort that out? How do you coordinate with those other agencies, and how do you differ in some ways?

Dr. PALMISANO. Thank you for your question, Chairman Baird. All of our program managers are actively engaged in interagency working groups under the aegis of the National Science and Technology Council and the Office of Science and Technology Policy, the President. And through these relationships we build joint programs, we ensure that our programs are synergistic and complementary, and then we minimize the amount of overlap that exists. And I would be happy to give examples if you would like.

Chairman BAIRD. So if NSF is focusing its funding, related funding in some area, you would say, okay. You have got that covered. We are going to look at a different way?

Dr. PALMISANO. Yes, sir. That is exactly correct, and you know, I can give examples of where, for example, we have partnered with other agencies, such as the U.S. Department of Agriculture in bioenergy, where we realized that we had, both had interests in biofuels but we have complementary expertise. So we launched a program on plant genomics for bioenergy feedstocks, and that took advantage of the USDA's expertise in traditional plant breeding and cultivation of bioenergy crops and DOE's expertise in genomics.

So there are many similar examples of that with the National Science Foundation, NIH and other agencies.

Chairman BAIRD. That is very helpful. The argument, of course, a while back was, well, you know, to what extent is this duplicative, do we have multiple bureaucracies trying to do the same thing, can we not save money, et cetera. And I think there are—there is a great deal of merit to the cross disciplinary synergies that you describe, and unexpected—when a layman looks at DOE to see your operation, it is unexpected—the proof is in the pudding to some extent, and you have done some remarkable things, and I think that is commendable.

Dr. Keasling, you sort of raised an intriguing question that I want to follow up on a little bit.

CONCERNS ABOUT LIMITING RESEARCH

Two things. One, you spoke about limiting research to just fuels would be a mistake and a lost opportunity. Are you feeling like it is limited, or are you concerned about the potential that it would be limited?

Dr. KEASLING. I am more concerned about the potential that it would be limited. I think now that BER has gone down this path of biofuels from biomass, which is a great thing for it to be doing, we could potentially source all of our petroleum-based—all the chemicals that we now source from petroleum, from biomass or from sugar, and so there is huge potential there. And the research would be directly complementary to what is already being done in BER, so it is a potential growth area.

Chairman BAIRD. I am not sure I understand. You are saying because it is a growth area that would rule out some of the other research or—

Dr. KEASLING. No. I am saying that it is an additional area of research that could be done by BER.

Chairman BAIRD. Okay. Related and actually the next area in your testimony you had talked about—and you worded it artfully, so I don't want to try to get you in trouble if this would do so, but it was an important issue that if addressed effectively could improve the Department's ability to develop solutions, and the issue there seemed to be that the energy research seemed somewhat disconnected from the basic sciences.

Can you elaborate on that?

Dr. KEASLING. In fact, we are using a lot of the basic science research that BER has developed over the years, so a lot of the basic research that is going on in their Genomics: GTL Programs, in the Joint Genome Institute, all this is extremely important to the work that we are doing on converting biomass to biofuel.

So, in fact, that core basic research is so important, and the work we are doing, while it has an important goal of breaking down these barriers of biomass to biofuels, it is still fundamental research.

Chairman BAIRD. Okay. Are there artificial constraints, and this is for anybody, where you feel that you have the expertise and knowledge to make major contributions in an area that is consistent with your mission but that we have somehow statutorily or historically constrained? Anyone here feel you have the leeway to do what you need to do?

Dr. KEASLING. For my own perspective the research we are doing is something that I would want to do anyway.

Chairman BAIRD. Yes.

Dr. KEASLING. It is important, though, for us to make a connection to energy, we feel, as we are proposing this research. So—

Chairman BAIRD. The connection is great, but at the same time, you know, you gave a point about artemisinin, and that is a big deal, and if you have the—if you find that thread, you ought to be able to pursue it.

Dr. KEASLING. That is right. That is right, and artemisinin is a unique case because it is a hydrocarbon, so it is not too far a stretch from biodiesel.

Chairman BAIRD. Great.
Proud to recognize Mr. Inglis for five minutes.

FLEXIBILITY AND PROPERLY DIRECTING FUNDING

Mr. INGLIS. Thanks, Mr. Chairman.

So Dr. Keasling said something interesting that I would like to compare with what Dr. Patrinos said about funding.

Dr. Keasling, you said that it is important to figure out which research paths are dead ends and cut them off quickly, which makes a lot of sense to me, and then it is also true Dr. Patrinos said he wants diversity of funding sources, and I guess that is in order to develop the kind of paths that maybe aren't too clear.

So how do you work that out? I think it is an impossible question actually but—

Dr. KEASLING. That is an excellent question, and I was speaking more about how JBEI manages its research portfolio, and one of the things that we wanted to do when we designed JBEI is be able to go down a path that looked like it was going to be productive as quickly as possible and see if it is going to be a productive angle of research, and if not, then we redirect those research funds to another area that—an alternative area that looks like it is going to be productive so that researchers don't spend all of their time going down a particular path that will eventually be non-productive, but they are doing so because they don't have any flexibility.

So we have built in this flexibility at JBEI from the top that allows us to really focus on an important aspect, and if it doesn't work, go to the next aspect of the problem.

Mr. INGLIS. Which is a difficult thing to do, right, because people say they have got their Ph.D. in a particular area. That means that their sort of meal ticket is punched by that area, and so if you find out that that is not productive, they just lost their meal ticket. Right? And so it is—maybe there is a way that you do that. It is a tough management challenge I take it.

Dr. KEASLING. It is a tough management challenge, but because there are so many important problems. If we take, say, the plant area, for instance, we have researchers in JBEI who specialize in plant genetic engineering and understanding how cellulose is made in plants so they could be looking at one particular aspect of how cellulose is made and maybe that won't work or it doesn't look like we can increase the cellulose level. So they will turn their attention to a different way in those same plants or still using plants to increase the cellulose level.

So it is a little more subtle than completely cutting off an entire research area, and we do to the extent we can try to preserve people's meal tickets.

Mr. INGLIS. Right. Well, Dr. Patrinos, anything to add about that, about how you balance that?

Dr. PATRINOS. Well, I would like to say that basic research is fundamentally a messy housewife, and the tendency is always by especially newcomers in political positions to tidy up research, to look for redundancies and remove those because, you know, that way we save money and so on. It turns out that the more you try to tidy up, the more you restrain the research.

There has to be redundancy, because there has to be competition, and there has to be diversity in approaches. I mean, I, when I was—if I was still in DOE, I would have said the same thing my colleague, Anna Palmisano, said that we did a lot of collaborations when I was in DOE across agencies, and I think my record speaks for itself in terms of the partnership with NIH, with NSF, and other agencies and so on.

But I don't hide the fact that there was also competition. We had different attitudes, different approaches, and we presented different cultures, and even though there wERE occasional arguments, sometimes pretty violent ones I would say, the net result was always very, very positive. You know, it was the give and take of competition, the give and take of having different points of view that were brought to the table, and the ultimate result in the conduct and execution and management of research is so far better than anywhere else in the world because of that perceived untidiness.

Mr. INGLIS. Yes. Dr. Palmisano, do you want to add anything to that or how your approach may differ or be consistent?

Dr. PALMISANO. Yes, Congressman Inglis. I agree with everything that Dr. Patrinos said, and I think I would describe it as we challenge one another in a very positive way to provide the best we can for the American public, and I think that there is a very good balance and dynamic among the different agencies pursuing science for that reason.

Mr. INGLIS. Thank you, Mr. Chairman.

Chairman BAIRD. Thank you.

Dr. Inglis—Dr. Ehlers.

Mr. EHLERS. Thank you, and just a quick side note. I agree. Dr. Patrinos said basic research is messy, at least the way I did it it was. I am puzzled why you blamed the housewife instead of the house husband. I find house husbands are much messier than housewives. It is okay. Don't take me seriously.

ISOTOPE PROGRAM

Dr. Gillo, I must admit I am suffering from some sleep deprivation, but I don't quite see how the isotope production relates to what we are doing and what—first of all, what isotopes are you talking about producing, and how does that relate to the energy generation issue? Could you run through that again, please.

Dr. GILLO. So the Isotope Program that was just transferred to the Office of Nuclear Physics has two components: to produce isotopes for basic research and also for a broad suite of applications. And so we operate accelerator facilities and also make use of other facilities domestically—reactors and accelerators—to produce these isotopes and to distribute them as a service to the Nation.

Mr. EHLERS. Okay.

Dr. GILLO. They are used for energy reasons. They are used by the BER Program and—

Mr. EHLERS. Okay. That part I understand, but how does it relate to the cellulosic issue and energy production issue? Are these used as tracers in some of the experiments?

Dr. GILLO. They can be used as tracers, and yes, they are used.

Mr. EHLERS. Are these by and large radioactive isotopes?

Dr. GILLO. There are radioactive isotopes, and there are stable isotopes. For the stable isotopes, we have an inventory that we distribute, and the radioactive isotopes we produce. And so the BER Program scientists are users. The NP Program, we are the producers of the isotopes, and yes, they are used as radiological tracers in plant studies and other life sciences.

Mr. EHLERS. Okay. Now, the non-radioactive ones you trace them with mass spectrometry and so forth?

Dr. GILLO. Yes. They are used—one of the ways that they are used is for nutritional studies since they are non-radioactive, and so that is one of the most popular. Bone studies, calcium retention and bone growth, osteoporosis studies.

Mr. EHLERS. Okay. Thank you.

CELLULOSIC ETHANOL AND ALGAE BIOFUELS

I wonder if somebody could give me the broad perspective here. You know, everyone got excited about ethanol here a few years ago, and we passed some legislation which I thought was probably unnecessary and perhaps damaging, and I would attribute that mostly to the farm lobby rather than the scientific community. And I think my impression has borne, has been borne out, that it is not the best way to go.

But in just picking up what you said, it seems to me you are still talking a lot about ethanol, but producing it with cellulosic material. Are you looking at other fuels, and what other fuels are you looking at?

Dr. PATRINOS. Well, I can start, Mr. Ehlers.

We believe, at Synthetic Genomics, that corn-based ethanol especially is a big mistake.

Mr. EHLERS. Yeah.

Dr. PATRINOS. In some way, of course, we benefited because through that process we cut our teeth in the biofuels business, so at least there is some, some credit is due. But we need to move away from corn-based ethanol as far and as fast as possible.

Any fuel that competes with food should really not be pursued. We should not pursue it.

I also think that ethanol is not a very good fuel by itself, you know, it hasn't—it doesn't mix with water, it is very corrosive. So it may have been a good start, but I think we need to be moving away from ethanol as well.

So there are better quality fuels that we could pursue, even using cellulosic material, but also as I mentioned in my introductory remarks, the use of algae to produce a variety of biofuels is perhaps the one that we think has the greatest promise.

Mr. EHLERS. And what type of biofuels would they produce?

Dr. PATRINOS. Jet fuels is the fuel that we particularly are focusing on at this stage, but it doesn't necessarily have to be a fuel. The process can actually generate crude that mimics in every way the crude that we remove from the ground so we can insert it into the existing infrastructure for the production of a whole variety of fuels that we currently use. So that would be the ultimate holy grail of this enterprise.

Mr. EHLERS. I see, and what sort of chemicals do you pull out of this?

Dr. PATRINOS. They are essentially different molecules of carbon. Let us say starting from C12 all the way up to C20.

Mr. EHLERS. Oh, really? And you will get that large variety from the cellulosic material?

Dr. PATRINOS. No. The one that I am describing is using algae, carbon dioxide, and sunlight.

Mr. EHLERS. Yeah. Okay, and you regard that as a very promising field at the moment?

Dr. PATRINOS. We do indeed.

Mr. EHLERS. Yeah. Are there other promising fields that you are looking at?

Dr. PATRINOS. This is not a renewable field per se, but we are looking to enhance the production of natural gas in existing coal beds, and thus avoid the need to extract the carbon and to burn it. So from a point of view of CO₂ climate change impacts, it is a significant savings because burning methane is a lot cleaner than burning coal.

Mr. EHLERS. That is certainly true, but you still generate a lot of CO₂ from—

Dr. PATRINOS. We generate CO₂ but I go back to my first statement about using algae.

Mr. EHLERS. You are also using carbon there.

Dr. PATRINOS. The CO₂ generated from the methane can then be recycled using the algae and sunlight.

Mr. EHLERS. Okay. I think my time has expired, so I better yield.

Chairman BAIRD. The great thing about Dr. Ehlers is he knows what he is talking about, so he can go on for awhile, and we just watch and learn.

Mr. EHLERS. I am just very good at pretending.

PUBLIC-PRIVATE PARTNERSHIPS

Chairman BAIRD. Give us some discussion of—Dr. Patrinos raised the issue of public-private partnerships, and one of the questions the public rightfully asks is, okay, so what is in it for them. Give us some examples, if you can—Dr. Campbell, for example, take just for example your work at EMSL—what are some examples of things that you think might have commercial applications? Or if I am talking to John Q. Public about why do we do this research, what does the average guy get out of his or her investment in this endeavor? Give us some examples of that. Talk about how you would partner with a private company and what the vocations are, et cetera, for that.

Dr. CAMPBELL. Sure. At EMSL, of course, since it is a national user facility, many of our users or some of our users come from industry, and they can either work with us in one of two ways. They can work in a proprietary manner where they pay the fee to operate and utilize the facility, in which case they would retain any intellectual property or knowledge that would result from that research.

A more common way for industry even is to work in the open environment where they agree to publish. And many times they come with us on—in a lot of cases on the technology development side. So they may be interested in pushing the technology or instrument forward.

An example of that would be in our mass spectrometry area, where we are developing capabilities that would enable us to increase the sensitivity of certain commercially available mass spectrometers or the throughput of those mass spectrometers. We develop that, and then that would be commercially available and licensed out to these companies, for instance.

Then the greater benefit of that is, of course, the resulting science that these advancements have for the scientific community broadly. So if you can do things at higher resolution, at higher throughput, you can perhaps start to do clinical essays or clinical studies or more system-wide-type studies that get published. It goes out to the broader scientific community in that regard.

So you can have a direct line, or you can have a more indirect line where the knowledge base is created through these advancements.

Chairman BAIRD. So on the one hand you have facilities that other people—maybe I am a bright person but I don't have the capital to build the kind of equipment you have, maybe nobody has that capital except government.

Dr. CAMPBELL. Yes.

Chairman BAIRD. And so the government is able to say we will make these resources available, and then people from private sector can contract with you to do that. Right?

Dr. CAMPBELL. That is correct.

Chairman BAIRD. And at the same time then you help refine the instrumentation that could be used by the private sector.

Dr. CAMPBELL. In partnership oftentimes with the private sector. So we have, for instance, a partnership with a company that builds probes that goes into these magnetic resonance spectrometers. They are interested in it because it can go into their product pipeline. We are interested in it because it can open up a whole new area of biological research that will allow you to look at proteins inside intact membranes.

And so our users are now getting a new capability through this partnership with this company, and they are getting a new product pipeline. So it is a win, win in my opinion.

Chairman BAIRD. Do they pay—if I develop a product based on your work, is there a “buy” kind of function? Do I pay back into the system, or how does that work?

Dr. CAMPBELL. Yeah. There are intellectual property rules that we follow, and it depends upon, of course, the type of the agreement or the relationship where the government may take some ownership in the intellectual property and then it comes, it can come back into the laboratory, or it might be an exclusive. It just really depends on the type of relationship.

THE GOVERNMENT'S ROLE AND NEXT STEPS

Chairman BAIRD. Dr. Patrinos, now that you have made the jump to the dark side—I am just teasing with that, but you have made this big move from director of a government program to the private sector—what insights have you gained about that? How do you, you know, in terms of how we can do things better on the government side, or how private sector can interact better? What are you insights from that?

Dr. PATRINOS. First of all, it may sound a little self-serving when I encourage you to foster more and more productive public-private partnerships, but I must say that even when I was in the Department of Energy and specifically with the Human Genome Project, I advocated a very strong presence and involvement of the private sector. In fact, I helped bring Synthetic Genomics to the table, and we successfully completed the program and avoided, you know, serious embarrassment at the time. But we also created many partnerships that survive to the day and are extremely productive. So it isn't just self-serving.

But nevertheless, my move to the private sector has very much reinforced my conviction that it really is the private sector that can translate successfully the wonderful discoveries that the programs like BER nurtures and translates them into real products and services. This is something that I have grown to appreciate a lot more than perhaps I theoretically or, you know, intellectually could accept in the past.

It has already been mentioned what kind of things that needed to be done. One of the areas that I feel needs to be strengthened further is creation of these scientific user facilities across a broader spectrum of the scientific disciplines. I think biology is tremendously benefited by the light sources and the neutron sources and nuclear magnetic resonance facilities like EMSL, for example, but we need to do more for biology, because biology is the science of this century. And we need to provide the resources for all our scientists in both the public and the private domain. And they need these facilities whether they are super-computers for computational biology or dedicated facilities for the production of proteins, for example, or doing the proteomics of looking at the entire protein components of an individual cell.

These are capabilities that are in great demand, and if successfully put in place will enable biology to very quickly deliver on the promises that it has made, very rightfully so, of changing our lives, changing our industries, and solving many of our problems.

Chairman BAIRD. Dr. Palmisano, please share your insights on that as the current director.

Dr. PALMISANO. I think the future lies in our solving the problem of the vast amounts of data that are being generated through systems biology. Our ability to manage those data, to mine them, to integrate them, to provide them and make sure they are accessible to a broad community of sciences, to assure their quality and standardization. And I think that is a major challenge that probably all of us at this table face.

And we are through the new sequencing, types of sequencing, technologies, regenerating a huge amount of genome sequencing, proteomic data, metabolomic data, it goes on and on. Information about genetic networks, trying to combine that with computational models of biology and, you know, I see that as really a need for the future.

Chairman BAIRD. I don't really think the general public has a full appreciation, probably not this body itself, of this kind of model, of the basic science role. Not just the basic science in terms of the, okay, so the publication comes out and the data gets out, but the basic science in terms of the hardware, the physical infra-

structure, the super-computers, the light sources, the Nuclear Magnetic Resonance spectroscopy, et cetera, the average guy just doesn't have access to, but really brilliant people can access it through your resources and then get, you get a tremendous multiplier. We see it with nanotech as well in some of the nanotech initiatives, and I think there is a whole host of—whether it is accelerators that we really need to sort of highlight that. And this comes in the context of the sort of vitriolic debate now of, does government do anything well?

Government does best what people can't necessarily do themselves, and this is something government does well. I don't think the average business is going to create, you know, light sources or accelerators or isotopes in some cases. Some do obviously. They make a business model out of it, but in some cases we just have resource to allow us to do that, and DOE is an example of that.

Mr. Inglis.

Mr. INGLIS. Thank you, Mr. Chairman.

CARBON RECYCLING

Following up on that, it is also true that private industry is the one that is going to implement the technology. So if, for example, Dr. Patrinos was talking about the use of carbon dioxide to grow algae, is that—we need to do more of this research I take it in order to prepare for that, but there is a point at which you want it to tip over to have somebody actually building these things and using the CO₂. Right?

How far away is that before we are really making use of the CO₂ rather than wasting it?

Dr. PATRINOS. It is going to be several years before we can have large-scale recycling of CO₂ through the method that I described using algae and sunlight. But nevertheless, the urgency is huge because of the problem of global climate change and the need to do something about carbon.

Mr. INGLIS. Right.

Dr. PATRINOS. And therefore, if properly funded, both by the public and the private sectors, I think we can see some of these advances happening faster perhaps than other—than we may have assumed originally. This is the promise of biology. This is the promise of genomics.

I make the parallel of currently the advances are on the surface. It used to be that you had to dig real deep to get a nugget of gold in the high-energy physics field. In biology all you need to do is stoop down, and you pick it up from the ground. That is the analogy that I have.

Genomics has given us this power, has given us this tool, and all we need to do at this stage is make sure the right resources are put in place so that we can fully capitalize on this capability.

Mr. INGLIS. So with limited resources would you put your money on using the CO₂ to grow algae, or would you put it on sequestration?

Dr. PATRINOS. I would do both. I strongly believe that dealing with the climate change problem we have a case of silver buckshot as opposed to a silver bullet.

Mr. INGLIS. Okay.

Dr. PATRINOS. We need to look at all forms of sequestration, just like we need to look at all forms of energy, renewable energy.

Mr. INGLIS. Is it because it is not possible to use the great volume of CO₂ so basically you got to figure out some way to sequester it? Is that right? I mean—or can you see a future where there is—the use of CO₂ is scalable to the point that you really could use, say, all that is coming out of a coal-fired electrical plant, for example, to create this biofuel?

Dr. PATRINOS. Perhaps not all of it, but if we were successful in sequestering or recycling 50 percent of that, it is a long ways towards stabilizing the atmospheric concentration of CO₂, if we combine that with aggressive use of renewable energy.

Mr. INGLIS. Interesting. Anybody else want to add to that?

Dr. KEASLING. When plants grow, they are scrubbing CO₂ out of the atmosphere to make the biomass, and this is another way we can reduce carbon dioxide being put into the atmosphere by producing our fuels from that cellulosic biomass.

And so just as algae do it and scavenge it to build more algae, so do plants, and this is a great way to go for carbon-neutral biofuels.

Mr. INGLIS. Yes.

Dr. PALMISANO. At this point in time there is so much we need to learn about the carbon cycle; it is one of the greatest uncertainties in our climate models and very fundamental information. And now we are starting to bring the tools of modern molecular biology and genomics to bear on the carbon cycle. And in doing so we want to cast a wide net and use a number of different models, plant, microbial models, microbial communities.

Mr. INGLIS. Great. Thank you, Mr. Chairman.

Chairman BAIRD. Dr. Ehlers.

MORE ON CELLULOSIC BIOFUELS

Mr. EHLERS. Is it fair to say that what you are doing with cellulosic materials, algae, and so forth is developing very, very sophisticated ways of using solar energy? Or is it more to it than that?

Dr. KEASLING. Well, nature has been doing this for a long time.

Mr. EHLERS. I know.

Dr. KEASLING. So we are repurposing this source of biomass or algae as it is to produce biofuel. So it is a sophisticated form of capturing sunlight and carbon dioxide.

Mr. EHLERS. Yeah. Because that is really your energy source.

Dr. KEASLING. That is correct.

Mr. EHLERS. And it is really the only perpetual, relatively perpetual energy source we have.

Dr. KEASLING. That is right. The key, though, is to get them to produce the right fuels.

Mr. EHLERS. Yeah.

I—last round I had most of my questions for the end of the alphabet but not quite the alphabet but usually we go left to right, so I started the other way, but want to give the three of you on that side a chance to respond to the questions I asked earlier.

If you don't wish to, that is fine, but I just wanted to give you the opportunity.

RADIOISOTOPES

Dr. PALMISANO. Well, thank you, Congressman Ehlers, for that opportunity. One thing I would like to comment on that you asked Dr. Gillo about was this—the use of radioisotopes. We work very closely with Dr. Gillo and with our colleagues at NIH on to develop new types of radio-chemistries that can be used as metabolic tracers for lots of different models. Not just for humans but for microbes and for plants so we can start to understand, for example, carbon allocation in plants and microbes, so we have been able to take advantage of those opportunities that have been provided through our colleagues who are producing these radioisotopes.

Mr. EHLERS. Well, it is true. Radioisotopes are extremely convenient, because they let their presence be known wherever they go and with very specific signatures so you can really track them very easily. Mass spectrometers work for those that aren't radioactive, but that is much more cumbersome.

Dr. Patrinos said something like the next century is a century of biology, and I have to demur just a little bit on that, because I remember, even though I wasn't alive then but I read the books: In 1906, there were predictions that physics was essentially over. We had found everything that was to be discovered via physics, and the century turned out to be the century of physics.

So I appreciate your comment. It made me think about it, but it tells me that some of our other branches of science better get busy, too, if they want to avoid the catastrophe of this being known as the century of biology. Now, of course, for biologists it is a great thing if it happens.

I really appreciate the insights you have brought here. I mean, I have had lots of questions on this topic and just have not had the time to sit down and try and catch up on it, and you have done a very concise and very good job of bringing me up to date. Thank you very much.

I yield back.

Chairman BAIRD. Mr. Inglis had to race to catch a flight. I have just two quick more questions unless—if any of you have to catch a flight, tell me. That occasionally happens for witnesses. We make them miss, and they have to spend another day in this town.

JURISDICTION OVER NUCLEAR MEDICINE ISSUES

One of the questions, the Senate Energy and Water Appropriations Subcommittee has been looking at shifting nuclear medicine and medical applications in its jurisdiction to nuclear physics. Where do you think, Dr. Gillo, is an appropriate residence of this, if I am not asking you to speak out of school? If I am, tell me you would rather not comment, but what is your expertise and insight into this?

Dr. GILLO. I think the program is most optimized within BER. Within the Nuclear Physics Program the focus really is on the production of isotopes, not on the use of isotopes, and so it would be far more productive within the BER Program.

Chairman BAIRD. Okay. It is not there now, though, right?

Dr. GILLO. Yes, it is.

Chairman BAIRD. Okay, I am sorry. Sorry. You were saying earlier it was within the Nuclear Physics Program.

Dr. GILLO. The Isotope Program is within Nuclear Physics. It is best to keep the Medical Applications Program—

Chairman BAIRD. Got you.

Dr. GILLO.—within BER.

Chairman BAIRD. Got you. Thank you. That is helpful.

BIOREMEDIATION AND ISOTOPE RESEARCH

Dr. Campbell, talk to us a little bit about bioremediation if you would. You know, we have got the Hanford Nuclear Site up river. Some of those isotopes make their way down river. Talk to us a little bit about what is done there.

Dr. CAMPBELL. There is a lot of potential in bioremediation in that if you think about the isotopes that are of interest that have the potential to migrate out, for instance, to the Columbia River. It is possible to transform those from mobile species, ones that migrate, to immobilized species, ones that don't migrate. That is often facilitated through microbial interactions, and that is a strong area of research out of the BER Program. It is a strong area of research out of EMSL, where we are trying to understand how these microbes basically transfer electrons to these species, thereby immobilizing them in the subsurface environment. If you immobilize them, you know where they are. They are easier to accommodate and handle in terms of remediation from that point. So—

Chairman BAIRD. Let me make sure I understand. You have got microorganisms that take radioactive material and demobilize it.

Dr. CAMPBELL. Yeah. It is basically a redox reaction, where they transfer an electron to the species, and therefore, changes oxidation state, and what happens is it goes from a soluble species, one that is soluble in water and therefore migrates to an insoluble. It is precipitated into little nodules on the surface of these microbes. And, therefore, they don't migrate through the subsurface.

So it is a really nice example of how biology is actually helping to remediate, a natural example. The challenge is to understand that process so that you can perhaps engineer other processes to do similar types of things.

That is one example. Then there is another way in which you can use computational tools to actually stimulate contaminants and their migration and transfer through the vadose zone out into the subsurface environment and start to mimic their reactions along the way as they go. And so it brings together both experimental and computational resources.

ALGAE AND HARMFUL ALGAL BLOOMS

Chairman BAIRD. Okay. We—next week we will have a hearing in this committee on harmful algal blooms, which is a growing problem. We have a great interest in ocean health issues, and any insights into that? I am intrigued by—I know, Dr. Campbell, your lab is working on some things related to that.

Dr. Patrinos, in a different direction, using algae, any insights into that, which in the Pacific Northwest and around the country is a bipartisan, multi-regional partner, and some of the work on

this is from Connie Mack, a Republican from Florida, and so you have got both corners of the country dealing with this. Any insights gained from your work or potential that you see?

Just while I have got you here. We are going to have another panel next week, but I know you are doing some work on this.

Dr. PATRINOS. Well, algae are among the most ubiquitous of species. I mean, they exist everywhere, in the marine world especially, and we are, over the last few years through the power of genomics, understanding them more and more. Many of them, their genomes have been sequenced specifically by the Joint Genome Institute.

So inside synthetic biology, the biology of algae can also give us the opportunity and the tools to fight them where they are not helping us, where they are hurting the environment primarily because of the insults that we cause, for example, through many of the fertilizers that end up in the Gulf of Mexico and cause the hypoxia, which generates the algal blooms.

Chairman BAIRD. So you feel like you are—some of the insights you are gaining by just working on the genomics of algae could help us understand that?

Dr. PATRINOS. Absolutely.

Chairman BAIRD. Dr. Campbell or Dr. Keasling. Either one.

Dr. KEASLING. I might just mention that a lot of these algal blooms are due to pollution, as Dr. Patrinos said, that it goes into the ocean, and the way these are often cleaned up in municipal wastewater treatment plants is through microbiology.

Chairman BAIRD. Uh-huh.

Dr. KEASLING. Actually, microbes accumulate the phosphates and other nutrients that would have otherwise ended up in the ocean. Using some of the tools that BER has developed, the Joint Genome Institute is trying to understand those microbial communities. So they sequenced the communities from these wastewater treatment reactors, and they now understand the microbes that are responsible for accumulating phosphates, for instance, and then this can help us design new wastewater treatment plants that are much more effective and lower cost at cleaning up these harmful chemicals.

Chairman BAIRD. That is a great example. Thanks.

Dr. Ehlers, do you have any further questions or comments?

Mr. EHLERS. Just a comment. I appreciate this last interchange because I was the one that wrote the legislation about the algal blooms, and it is becoming a problem even in the Great Lakes, much to everyone's surprise. So it is becoming more of a universal problem. Anything you can do to help solve that problem is helpful.

CLOSING

But I also want to conclude just by thanking you. It is a terrible experience, frankly, to be a scientist in the Congress, because you tend to starve. You know what the intellectual community is like, the research community, and how you are constantly interacting with people, generating ideas and so forth. And there are very few scientists to talk to here, and so you have really innervated me again, and I just want to thank you for that.

Chairman BAIRD. Dr. Ehlers, thank you. I was negligent when I mentioned my work with Connie Mack. Dr. Ehlers really has been

the lead on harmful algal blooms for many, many years, and I have been privileged to work with him on that. He really has in many, many cases been seeing things that other folks aren't looking at, and so Dr. Ehlers, thank you for raising that issue. You have been the champion on this issue for many years.

Starving intellectually in the Congress is an interesting observation. We will just leave it at that.

Any other final comments?

VOICE. Not on this committee.

Chairman BAIRD. No, no. This committee is sort of the brain—

Mr. EHLERS. Especially this subcommittee. This is very intellectually stimulating.

Chairman BAIRD. And today was no exception. Fascinating element of research that I think many of us had not been fully apprised of before. I am grateful for your service to the country and your research, which is very, very exciting, and we look forward to working with you. And with that I thank you for your time here and all our witnesses and the staff who put this meeting together, and the hearing stands adjourned. Thank you very much.

[Whereupon, at 3:15 p.m., the Subcommittee was adjourned.]

Appendix:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Anna Palmisano, Associate Director for Biological and Environmental Research, Office of Science, U.S. Department of Energy

Questions submitted by Representative Ben R. Luján**BER clearly sponsors some important work in climate science**

Q1a. While climate modeling work attempts to understand the global climate system, how does your monitoring work feed useful data into these models? Would you say that you need more experimental data in climate monitoring to understand how carbon and other greenhouse gases are captured and released in the Earth's oceans, atmosphere, and forests?

A1a. BER supports a diversity of scientific research ranging from molecular to field scale experiments as well as observational studies designed to increase our understanding of specific climate and Earth systems processes. That understanding is encapsulated into climate and Earth systems models that capture our current and best understanding of how these complex and interrelated systems work.

BER does not directly support environmental monitoring. However, data and knowledge derived from our process research, in conjunction with monitoring data from agencies such as the National Oceanic and Atmospheric Administration and the National Aeronautics and Space Administration, support the development and validation of climate models. Our climate change research activities carefully balance investments in model development, validation, and testing with investments in experiments and observations to understand the fundamental processes associated with key areas of scientific uncertainty.

Increased scientific understanding is continuously being incorporated into state of the art models; and the results from model simulations are regularly evaluated in order to inform subsequent decisions on needed experimental and observational research. This closely coupled, iterative process ensures that our models reflect the current state of the science and that our experimental and observational science is best directed to improve the models.

Q1b. How can we help ensure that the scientific work you are doing is connected to the science that we need in Congress to understand the economic impacts of climate change and the policy impacts of climate legislation?

A1b. We appreciate the continued support of Congress for our research activities in climate change science; and we are actively engaged in research to improve the tools used to help inform policy-makers on issues of climate change. DOE's Office of Science supports fundamental research to provide improved scientific data and models about the potential response of the Earth's climate and terrestrial biosphere to changing climate. A key aspect of this research program is the specialized area of modeling commonly referred to as Integrated Assessment (IA). IA research seeks to understand the complex interactions of human and natural systems and to develop and continuously improve the integrated models and tools that can be used to underpin future national and regional decision-making. IA models are often adopted and adapted by various decision-making entities to project future scenarios and to evaluate potential impacts, adaptations, and vulnerabilities.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Jehanne Gillo, Director for Facilities and Project Management Division, Office of Nuclear Physics, Office of Science, U.S. Department of Energy

Questions submitted by Representative W. Todd Akin

Q1. What are the current efforts by the Department for biomedical research?

A1. Research supported by Office of Science programs, in particular radiochemistry and isotope development and production, as well as Office of Science scientific user facilities, benefit the biomedical research community. For example, research supported by the Office of Science's Biological and Environmental Research (BER) program in radiochemistry and imaging instrumentation focuses on development of new methods for real-time, high-resolution imaging of energy- and environmental-relevant biological systems; some of these methods could also be used in biomedical research to study biological systems of interest to that research community. The Isotope Development and Production for Research and Applications program within the Office of Science's Nuclear Physics program supports the production of isotopes for a broad range of applications, including biomedical applications. Likewise, the scientific user facilities supported by the Office of Science, such as the synchrotron light sources and neutron sources at the DOE national laboratories are used by a broad spectrum of the scientific community, including biomedical researchers.

In addition, the BER Medical Applications activity supports work to develop a prototype of an artificial retina; work at DOE laboratories is supported in engineering, materials sciences, computational sciences, microfabrication, and micro-engineering, in partnership with other federal agencies and the private sector.

Q2. What are the current efforts to address the international shortage of Mo-99/Tc-99m?

A2. The Administration has established an Interagency Working Group to coordinate international and domestic efforts to address the shortage of molybdenum-99 (Mo-99) and the National Nuclear Security Administration (NNSA) is responsible for coordination within DOE. In response to the shutdown of the National Research Universal (NRU) reactor in Canada earlier this year, the Interagency Working Group, together with their counterparts in the Canadian Government, investigated options for creating an interim backup supply of Mo-99 in North America to mitigate expected production shortages in 2010 if the NRU does not resume operation. The group then submitted its options to the Office of Science and Technology Policy (OSTP) in the White House, where they are currently under review.

To further support international efforts, the U.S. Departments of Energy and Health and Human Services represent the U.S. Government in the Organization for Economic Cooperation and Development (OECD)—Nuclear Energy Agency's (NEA) High Level Group on the Security of Supply of Medical Radioisotopes (HLG-MR). The NEA is a specialized agency within the OECD, an intergovernmental organization of industrialized countries, based in Paris, France. The HLG-MR focuses on global supply coordination and contingencies for short-term production by fostering information sharing on reactor operating schedules and production quantities among Mo-99 producers.

Q3. How has the current shortage of Mo-99 impacted health care in the U.S.?

A3. While the Department of Energy does not have the expertise to calculate the impacts to health care in the U.S. attributable to the shortage of Mo-99, we observe that in August 2009, the Society of Nuclear Medicine (SNM) surveyed members to estimate the impact and the response of the medical community to the limited supply of Mo-99 during a period when both the NRU in Canada and the High Flux Reactor in the Netherlands were not in operation.

While the SNM survey data include sampling errors due to self-selection, the data do provide insight on how medical practitioners are managing the current Mo-99 shortage. Roughly 20 percent of respondents indicated that they are operating at less than 50 percent of their normal capacity. The data suggest that medical practitioners appear to be managing the limited supply through the deferral of procedures and the use of alternative isotopes and procedures.

Q4. How is DOE supporting the development of domestic supply of Mo-99?

A4. DOE's National Nuclear Security Administration (NNSA) has worked with both existing and potential Mo-99 producers for years by making technical expertise available, on a non-proprietary basis, to assist in converting and developing Mo-99

production processes in accordance with the U.S. HEU minimization policy. Through these efforts, NNSA has established long-standing relationships with current and potential Mo-99 producers.

NNSA is currently working on several cooperative agreements with potential commercial Mo-99 producers whose projects are in the most advanced stages of development. The objective of the cooperative agreements is to accelerate establishment of domestic sources of Mo-99 without the use of HEU in quantities sufficient to meet U.S. demand by the end of 2013. NNSA anticipates that a group of domestic commercial producers will be able to meet more than 100 percent of U.S. needs for Mo-99 by the end of 2013, thus providing a continuous, sufficient supply during periods of facility maintenance or shutdown. Each potential commercial producer under NNSA's cooperative agreements uses a different non-HEU technology. This strategy aims to ensure that no single points of failure exist within the supply network.

Q5. Will other diagnostic imaging modalities currently in use or envisioned replace the need for Mo-99/Tc-99m?

A5. While the Department of Energy does not have the expertise to provide a comprehensive answer to this question, to the best of our knowledge, the medical community has not identified any other alternative procedure that is preferable or comparable to the Mo-99/Tc-99m procedures.

Q6. What do you think the cost of the current shortage is to health care, to the U.S. Government through Medicare reimbursable?

A6. The Department of Energy does not have the ability to determine the anticipated costs of Mo-99 shortages to health care.

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