UCSD *Energy Biosciences* Institute

University of California, San Diego **Iowa State University** *J. Craig Venter Institute* **Battelle** *Salk Institute* **The Scripps Research Institute**

UCSD PROPOSAL SIGNATURE PAGE

The Regents of the University of California
University of California, San Diego

UCSD# 2007-1503

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Principal Investigator

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Signature — 11/22/06 Date

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This proposal shall remain valid for acceptance for a period of ninety (90) days from the closing date. This proposal is being submitted with the understanding that, for a resulting award, the terms and conditions will be mutually negotiated between the parties.

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1.0 Executive *Summary*

Above *UCSD and environs circa 2005—courtesy of USGS*

UCSD Energy Biosciences Institute[1]

1.0 Executive Summary

UCSD created a collaboration entitled the **Center for BioEnergy Science and Technology (CBEST)** to respond to opportunities in the bioenergy arena. Through a series of visits and retreats at the major participating sites attended by all key participants, we have come to recognize the remarkable synergy among team members, as well as the team's comprehensive expertise to deliver solutions to the relevant challenges. The process of establishing a unified team, we believe, will bring considerable benefit to the establishment of CBEST EBI and facilitate a smooth, rapid transition and implementation of the Institute, as well as enable and sustain truly significant S&T progress.

CBEST collaborators include:

University of California, San Diego (UCSD)

Iowa State University (ISU)

J. Craig Venter Institute (VI)

Battelle Memorial Institute (BMI)/Pacific Northwest National Laboratory (PNNL)

Salk Institute for Biological Studies (SI)

The Scripps Research Institute (TSRI)

This document is the CBEST collaboration's response to BP's vision for establishing an Energy Biosciences Institute (EBI)

UCSD is the home of other mission-driven initiatives of comparable size and scope, including the San Diego Supercomputer Center (SDSC), the California Institute for Telecommunications and Information Technology (Calit2), and Scripps Institution of Oceanography's Fleet of Research Vessels.

UCSD has developed highly-successful mechanisms to link campus activity to San Diego's world-class "biotechnology ecosystem" including **CONNECT, Global CONNECT, BIOCOM, TechTIPS,** and the **William J. von Liebig Center for Entrepreneurism and Technology Advancement.**

The CBEST **Research Program** leverages and integrates members' research strengths and technical capabilities. Documentation on our qualifications to conduct bioenergy research and our track record for commercializing technology is provided on two levels:

- A summary of the experience and expertise of CBEST participating institutions is provided.
- A sampling of selected publications and patents of CBEST researchers is provided.

The CBEST research program is built around a **modular, research-scale, cellulosic ethanol biorefinery**. Researchers from collaborating institutions have formed teams to focus on one or more aspects of the refinery including: **Projects** that develop the biorefinery and its components; **Enabling Technologies** that are necessary for the projects; and **System Level Analysis** that will guide the development and evaluate the impact of the biorefinery. Research will also focus on **enhanced oil recovery, hydrocarbon conversion, and sequestration**.

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[1] *UCSD departments, schools, and divisions participating in UCSD's CBEST (to further be referred to as "CBEST") are presently Jacobs School of Engineering, the Division of Biological Sciences, Bioengineering, Mechanical and Aerospace Engineering, Neuroscience, Chemistry and Biochemistry, Computer Science & Engineering, Psychiatry, California Institute for Telecommunications & Information Technology, Center for Earth Observations & Applications, Economics, Physics, and Scripps Institution of Oceanography.*

UCSD will provide **two new faculty FTE (ten total) for five years** to bolster the research program. We are requesting that BP endow a Chair for each of these faculty positions, which would be assessed as a component of the research funding.

The EBI will be established as a **501(c)3 not-for-profit research organization.** Sample **Articles of Incorporation, Bylaws,** and an **Affiliation Agreement** are provided. We offer a solid plan for **IP management** that meets BP's requirements and provide examples of non-exclusive and exclusive license agreements.

The EBI will be governed by a **Board of Directors.** The Board will comprise equal numbers of BP and UCSD representatives, as well as independent members jointly appointed by BP and UCSD.

A roster of **EBI senior staff positions** has been assembled and a hiring process has been defined in the proposal.

An **EBI Permanent Facility** of 50,000 assignable square feet (ASF) will be developed adjacent to the UCSD campus in the Science Research Park. The Governor of California has committed $40 million as an incentive for establishing the EBI at UCSD. We plan to complete construction of this facility two years after the beginning of negotiations. Preliminary plans for the EBI include laboratory and office space, enabling technologies and equipment, meeting and conference facilities, as well as high-end computing and IT/telecommunications infrastructure.

Arrangements have been made to lease office and laboratory space near the UCSD campus to create an **Interim Facility** while a permanent home for EBI is constructed. These facilities will be in place by the summer of 2007.

We provide a preliminary **Budget,** developed under a set of overarching assumptions, which includes planning and development costs as well as overhead costs.

2.0 *Vision and Overview* of the Proposal

Above *ISU*

2.0 Vision and Overview of the Proposal

2.1 Vision

Responding to BP's Vision for an Energy Biosciences Institute

Reducing the world's dependence on fossil fuels has become increasingly urgent in light of growing economic, environmental, and geopolitical concerns. Biology is a cornerstone of medicine and agriculture, but its potential to revolutionize the energy sector has only recently been recognized. There is a growing awareness that large-scale, multidisciplinary bioenergy initiatives will be required to develop clean, renewable, carbon-neutral alternatives to fossil fuels. Indeed, a commitment to the construction and operation of a commercial cellulosic ethanol biorefinery near ISU has already been announced by Broin Cos., emphasizing the urgency of launching the EBI so that it can contribute inventions to the foundation level of this nascent industry. This document contains our views and suggestions for advancing BP's vision. Our approach hinges on the following key factors:

- Systems Biology research into microbes and plants, especially the structural cellulosic components, will enable us to overcome critical roadblocks to cost-effective production of ethanol and other renewable energy from biomass.
- Engineering sciences will enable technology integration and scale-up. It is our aim to develop lab-scale production facilities and test beds as predecessors to a full-scale plant.
- Best practices from corporate and academic management will be blended to integrate basic and applied research effectively in a University setting.
- An integrated cyberinfrastructure will promote modeling and simulation, data analysis, instrument networking, and collaboration.

The CBEST Collaboration

To meet the challenges of society's growing demand for economically and environmentally sustainable energy solutions, the University of California, San Diego created the Center for BioEnergy Science and Technology (CBEST), which has active collaborations with Iowa State University (ISU), the J. Craig Venter Institute (VI), Battelle Memorial Institute/Pacific Northwest National Laboratory (BMI/PNNL), The Scripps Research Institute (TSRI) and the Salk Institute for Biological Studies (SI). Enabled by state-of-the-art facilities and equipment, the CBEST collaboration comprises world-class scientists, who collectively specialize in agronomy and agriculture, genomics, microbial and plant biology genetics, proteomics, physiology, biochemistry, structural and computational biology, bioinformatics and engineering. Our research strengths, our scientific and technical capabilities, and our state-of-the-art facilities and instrumentation complement one another. UCSD brings basic science in plant and microbial biology, cyberinfrastructure, process controls, and combustion experience and expertise to the table. ISU provides world leadership in molecular breeding, sustainable production, and bioprocessing of energy crops. The Venter Institute is renowned for bacterial metagenomics, microbial and plant bioinformatics, and synthetic biology. Battelle Memorial Institute excels in biomass pre-treatment, bioreactor design, fungal biology and enzymatic research. The Scripps Research Institute and Salk Institute have both focus on identifying and improving key factors affecting biomass yield. Taken together, CBEST collaborators articulate a distinct EBI identity with a history of, and commitment to research excellence in bioenergy applications.

CBEST's Vision for an Energy Biosciences Institute

Emerging as a cornerstone of San Diego's burgeoning biotechnology hub, the uniquely collaborative, internationally renowned Energy Biosciences Institute will revolutionize biology-based energy production by achieving breakthroughs in the production of clean, renewable, carbon-neutral alternatives to fossil fuels.

The EBI will be established as a not-for-profit research institute, which will differentiate itself through a unique juxtaposition of collaborators, enabling technologies, and pioneering bioenergy research programs that will:

- Promote scientific discovery and technology development in the fields of biofuels, enhanced oil recovery, conversion, and carbon sequestration.

- Capitalize on the interdisciplinary CBEST research team to bring world leadership to each focal point of the research program.
- Provide comprehensive technology resources to promote bioenergy discovery, including a lab-scale cellulosic ethanol biorefinery, plant and microbial growth and gene transfer facilities, high-throughput screening systems for cells and enzymes, and cyberinfrastructure to manage genome data and metadata and to promote knowledge discovery.
- Encourage field tests and demonstration projects with an eye to commercialize biotechnology applications in the energy sector.
- Enable BP and other for-profits to develop and access proprietary technology through arrangements extending from licensing agreements.
- Provide graduate and postdoctoral training in energy-related systems and synthetic biology.
- Promote communication, education, and outreach programs at CBEST collaborator institutions.
- Be housed in a permanent 50,000 assignable square foot (ASF) structure specifically designed to meet the needs of pioneering bioenergy researchers.

Integration and Implementation of EBI Research Components

The EBI research program will be built around a modular, research-scale, cellulosic ethanol biorefinery. Each member of the EBI research program will be focused on one or more aspects of the biorefinery including: Projects that develop the biorefinery and its components; Enabling Technologies that are necessary for the Projects; and System Level Analysis that will guide the development and evaluate the impact of the biorefinery.

Projects

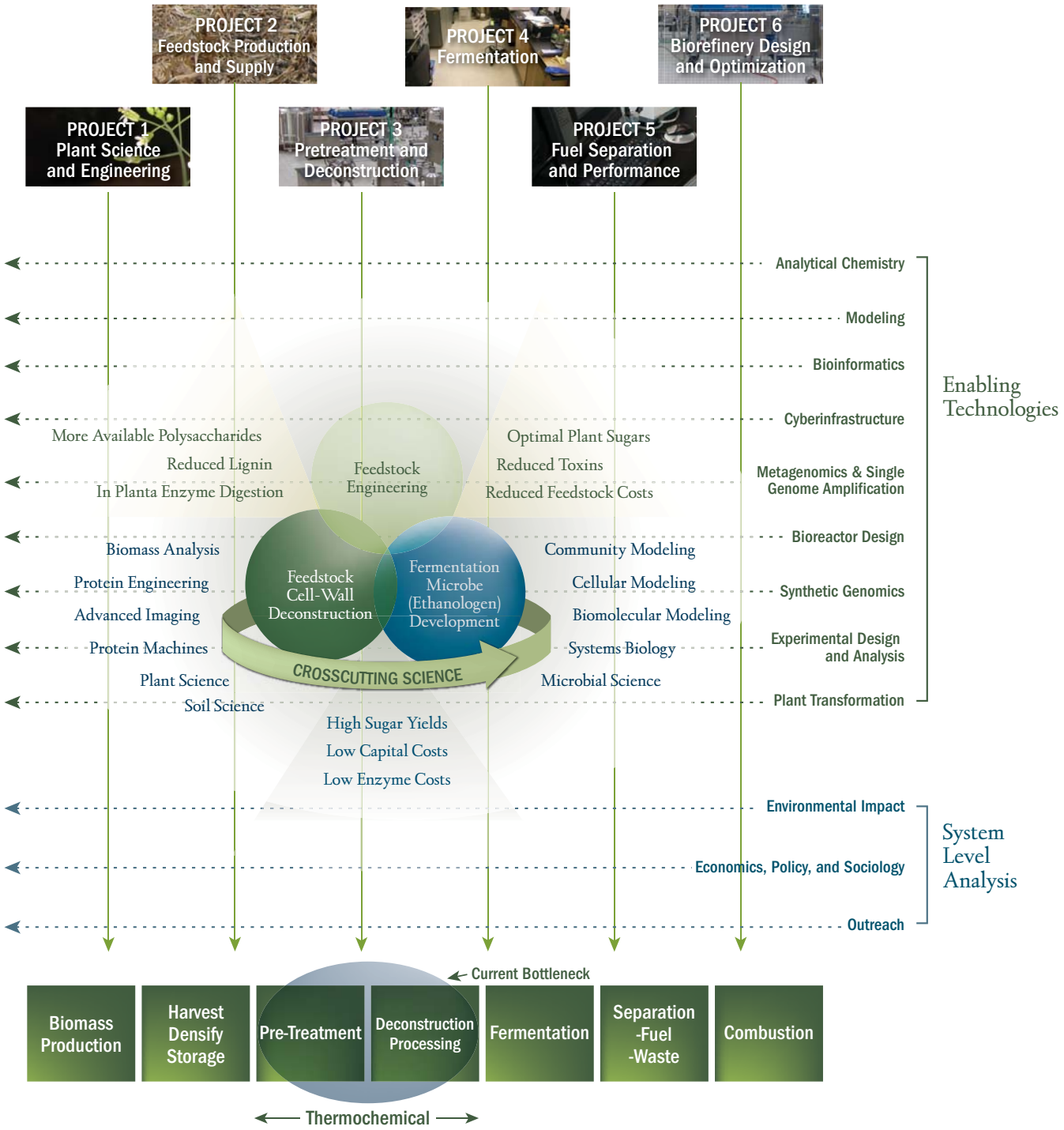
- Biorefinery Design and Optimization
- Plant Science and Engineering
- Feedstock Production and Supply
- Pretreatment and Deconstruction
- Fermentation
- Fuel Separation and Performance

Enabling Technologies

- Analytical Chemistry (transcriptomics, proteomics, metabolomics, DNA sequencing and biomarkers)
- Modeling
- Bioinformatics
- Cyberinfrastructure
- Metagenomics and Single Genome Amplification
- Bioreactor Design
- Synthetic Genomics
- Experimental Design and Analysis

System Level Analysis

- Economics, Sociology and Policy
- Environmental Impact
- Outreach



The researchers from each collaborating institution have been integrated into teams on Projects, Enabling Technologies, and System Level Analysis. Project Leaders at the EBI will take charge of each Project listed above, providing direction for work within the EBI and coordination of work at UCSD and its collaborating institutions. We expect another cohort of Project Leaders to direct and coordinate the Enabling Technologies and System Analysis efforts. CBEST research leaders have been designated to work in an executive fashion with the EBI leadership in each of the Project, Enabling Technology, and System Level Analysis teams. (See **Appendix A,** "Project Area Listing of Project Leads.")

Addressing Gaps in Bioenergy Research Through the EBI

There are many strategic gaps in bioenergy research. First, there is an absence of established benchmarks. Because the academic community has lacked access to a cellulosic ethanol biorefinery, there are no benchmarks of component or system performance against which advances can be measured. Second, genome-wide analytical chemistry capabilities, mathematical models, and metagenomic library screens have never been combined in an integrated, focused effort to solve the problems of bioenergy crop development or consolidated bioprocessing. Third, the full complement of enzyme classes that are required for complete cell wall deconstruction has not been identified. This reflects ignorance of how cell walls are made and, more importantly, ignorance of the catalytic properties required for complete cell wall deconstruction; the former does not necessarily predict the latter. Fourth, a system level analysis of the potential consequences from the myriad choices to be made in deciding on a biorefinery strategy has not been available. The local environment, politics, infrastructure, and economy; feedstock choice; pretreatment method; deconstruction technology; fermentation organism; advantage molecules; and separation technology can each play a determinative role in the successful outcome of a commercial biorefinery, and so must be considered in system level analyses that guide decision-making.

Short, Intermediate, and Long-term Goals

Years 1-2. The following key steps constitute the plan of action for establishing the CBEST EBI:

- Finalize Enabling Agreements with BP and establish EBI's Board of Governors.
- Hire the EBI Director, Associate Director, and Project Leaders for the Project, Enabling Technology, and System Level Analysis teams. The EBI Director should be hired before the start of operations. The Associate Director and Project Leaders should be hired within twelve months of the start of operations.
- Prioritize each component of the research plan so that resources are allocated according to logical importance and sequencing. This will permit immediate implementation of the plan at UCSD and collaborating institutions while EBI is acquiring its staff and facilities. The priorities should be agreed upon within three months of the start of operations.
- Develop key infrastructure for the EBI:
  (a) Phase 1 will involve the establishment of an interim facility. We expect to begin research operations in the interim facility by Summer 2007.
  (b) Phase 2 will culminate in the construction of a new 50,000 assignable square foot (ASF) facility in UCSD's Science Research Park. We recommend that the EBI first build its laboratory biorefinery and enabling technology capabilities, filling out the internal staff after the major equipment purchases have been made. The biorefinery and enabling technologies at EBI will serve a dual purpose; first, they will enable EBI to achieve its research goals; second, they will act as a magnet encouraging researchers to work directly with EBI staff to conduct experiments not otherwise possible. Accordingly, the EBI enabling technologies should complement rather than duplicate resources at UCSD and its collaborating institutions.
- Benchmark the performance of EBI's biorefinery, so that every Project will have quantitative measurements against which improvements can be judged. Thus, each module of the biorefinery must also have a benchmark. These benchmarks should be set within 18 months of the start of operations.
- Establish the culture of EBI. The culture includes the set of values, expectations, and behaviors that are shared by its members. Culture is created through the office of the Director, who leads by example. EBI employees must perceive that they each have equal opportunity to contribute to EBI and to be rewarded. Accordingly, it may be best not to restrict some EBI employees to work exclusively on open research while others work exclusively on applied research. Instead, each employee could be expected to contribute based on their role in the research plan; if success leads to inventions, then the inventions could be protected by intellectual property law. Every EBI employee should be expected to contribute to proprietary research as needed, but after filing patents their research should be published in high profile journals that will build the reputation of the EBI as the "Bell Labs of Bioenergy," In cases where trade secrets are preferred over patents, technicians rather than students or post-docs would be assigned to conduct the research. The culture should be established within 18 months of the start of operations.

- Establish an aggressive intellectual property group that will foster the recognition and protection of EBI and collaborator inventions prior to their public disclosure.
- Create linkages with community relations, education, ethics, and outreach programs at each of the collaborating institutions.

Years 3-6

- Publish landmark discoveries in bioenergy science and technology.
- Complete the development of a consolidated bioprocessing organism and process.
- Provide the design, materials, and methods for the world's most successful commercial biorefinery.
- Deliver engineered organisms with improved tolerance to ethanol and biomass hydrolysate, using metabolic models to inform the research.
- Develop high-speed sensors and control strategies for bioreactors.
- Refine proteomics to improve protein extraction, cell fractionation, coverage of protein modifications, and quantitation of most proteins.
- Develop and apply bioinformatics algorithms and software to empirical genome annotation, mRNA splice site selection, and coding polymorphisms to refine models of cell physiology and regulation.
- Provide genetic markers for additional species (e.g. switchgrass and Miscanthus).
- Couple single-cell genome amplification technologies to high-throughput fluidics and cell-sorting devices to screen several environments for novel microbes with enhanced bioprocessing traits.
- Convene a broad, multi-stakeholder symposium to develop an integrated assessment of the larger economic, environmental, social, and policy concerns surrounding the development of the biofuels industry.
- Provide a life-cycle assessment, including modeling, of all inputs and outputs including environmental, resource, and health impacts of large-scale biofuels production.
- Develop an understanding of how hydrocarbon associated microorganisms convert high molecular weight hydrocarbons into metabolites and other advantage molecules.

Years 7-10

- Renew the long-term commitment of BP to the EBI.
- Transition to new sources of funding as needed.
- Bring into production bioenergy crops that have been optimized to make biofuel.
- Design and enable the next generation biorefinery.
- Incorporate next generation mass spectrometer-based measurement capabilities into EBI biorefinery.
- Use metagenomics tools in a more directed fashion to search for optimized versions of specific catalysts, pathways, and organisms.
- While focusing on a small set of biofuels technologies, provide a forward-looking guide for balancing environmental impact with economic performance.
- Transfer discoveries from metagenomics and functional genome analyses into testable hypotheses and lab-scale experimentation.

2.2 Overview of the Proposal Organization

Section 3.0 details the **EBI Research Program** beginning with an analysis of the Department of Energy's GTL Research Roadmap. The **Introduction** that follows outlines specific overarching goals of our research program. The subsequent **Research Plan** illustrates capabilities and areas of research focus, but it should not be construed as a proposed set of experiments. The Research Plan has three elements: Project Areas, Enabling Technologies, and System Level Analyses. This section closes with a brief description of means whereby the EBI proposes to maximize **Program Flexibility.**

Section 4.0 details our **Qualifications** to host the EBI. We start our discussion with a focus on San Diego, home of the greatest concentration of life sciences companies in the United States. A section on **UCSD's experience and leadership** follows, and includes information on UCSD's academic rankings, research impacts, faculty caliber, management awards, role in regional economic development, and experience hosting other large, mission-driven research initiatives. UCSD has developed highly-successful mechanisms to link campus activity to **San Diego's world-class "biotechnology ecosystem,"** and a section is devoted to describing the programs of CONNECT, Global CONNECT, BIOCOM, TechTIPS, and the von Liebig Center. Finally, documentation of our qualifications to conduct bioenergy research and our track record for commercializing technology is provided on two levels:

- A summary of the experience and expertise of CBEST collaborators is provided.
- A sampling of select publications and patents of CBEST researchers is provided.

Section 5.0 provides information on the proposed **legal and organizational structure** of EBI. We also include a section on **governance**. These sections are bolstered by draft Articles of Incorporation, Bylaws, and an Affiliation Agreement, which can be found in the appendices. This material is followed by a roster of potential **EBI staff positions,** as well as information on suggested **management practices** and **mechanisms to promote integration and linkages** in all EBI relationships.

In Section 6.0, we offer a solid plan for **IP management** consistent with BP requirements, which is augmented by samples on non-exclusive and exclusive license agreements located in the appendices.

Section 7.0 outlines our plans to develop the **EBI Permanent Facility** and provide for an **Interim Facility** for researchers to use until the Permanent Facility is completed.

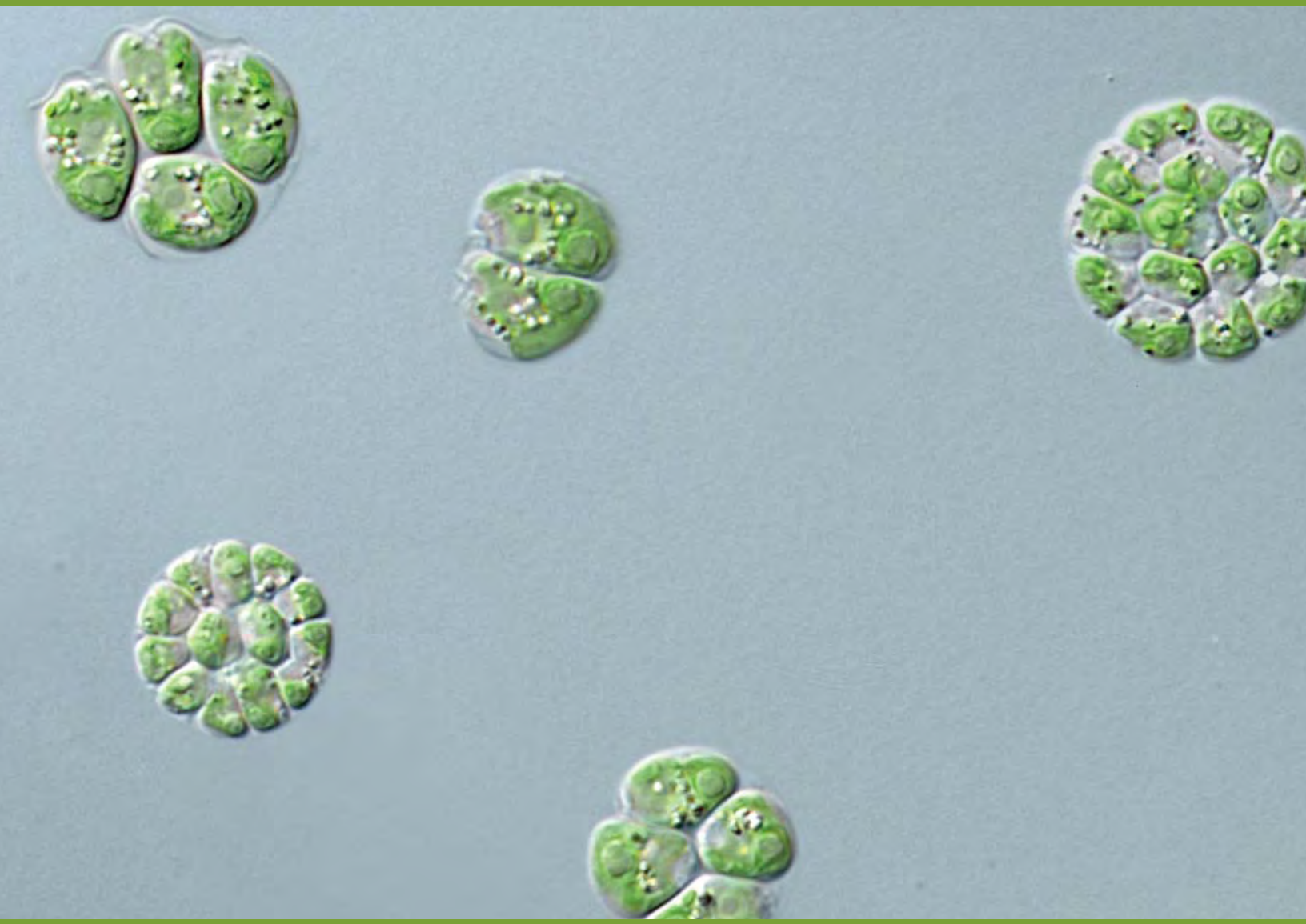
In Section 8.0, we provide a preliminary **Budget,** developed under a set of overarching assumptions, which includes planning and development costs as well a overhead costs.

A description of **incentives** provided by CBEST collaborators is found in Section 9.0.

A range of supporting material is provided in Section 10.0, the **Appendices**.

Immediately following the appendices are Project Leader **Patents,** Curriculum **Vitae, Publications** submitted by CBEST scientists who have expressed interest in pursuing research within the EBI, **Letters of Commitment,** and **Letters of Support.**

3.0 *Research Program* Definition



Above *Postmitotic clusters of the unicellular green alga* Chlamydomonas reinhardtii. *Clusters of 2^n daughter cells are produced when a mother cell undergoes a burst of rapid division cycles, a process that is controlled by the retinoblastoma (RB) tumor suppressor pathway. The clusters with small cells are from a strain that is missing RB, and the clusters with large cells are missing DP, a protein that is repressed by RB. Courtesy of the Salk Institute*

3.0 Research Program Definition

3.1 Evaluation of DOE GTL Research Roadmap

The DOE-GTL workshop report or roadmap represents a useful plan for basic scientific investigations that will enhance the bioenergy field over the long term. This document was, however, prepared over a year ago, and given the level of investment that is being made in the bioenergy field, we consider the timeline outlined in the roadmap to be conservative. For example, several lignocellulosoic ethanol production facilities will soon be operational (the roadmap envisions these not coming on-line until Phase II, i.e., in years nine to sixteen). Access to these early production facilities, which are likely to make use of the maize stover and perennial grasses abundant in the Midwest, will be essential for an integrated biofuel research program.

The report's technical milestones (five, ten, and fifteen years) are not in alignment with BP's goals of building a commercial-scale renewable fuels biorefinery by 2012. Most of DOE's five-year milestones are simply the first steps in a fifteen-year program of fundamental biological science. These near-term milestones do not offer any specific near-term solutions to the barriers of commercial development of cellulosic fuels. To build cellulosic biorefineries by 2012, the early targets should be: increased yield of legacy crops; inexpensive pretreatments; and feedstock-efficient conversion processes that can be built at moderate capital cost.

Given the accelerated timeline desired by BP, greater emphasis should be given to development of biomass traits in legacy crops. Our agricultural production systems are geared toward legacy crops, and it is unrealistic to think that the massive knowledge base and infrastructure that we have built on present day cropping and farm-to-market systems could be readily redirected toward dedicated bioenergy crops. Instead, we propose a bioenergy cropping system that is based on maize (the number one crop in the US and in the world), with transitions to the related C4 grasses or trees such as poplar—the likely dedicated bioenergy crops of the future.

Miscanthus *in TSRI greenhouse*

Maize is both the most important economic crop in the nation and the best understood model crop in the scientific community. Elaborate genetic tools have been developed for maize over the years, and sequencing of the maize genome is scheduled for completion in 2009. The DOE report tends to overlook the power of maize as a model system and points to totally undeveloped systems such as Brachypodium as models for evaluating bioenergy crop traits. We are confident that maize represents the most powerful system for near term output and it is the stepping-stone toward the development of other dedicated bioenergy crops such as switchgrass and *Miscanthus*.

Apart from the timeline, we feel that there are several key areas of investigation that the roadmap neglects. The roadmap should have provided greater emphasis on plant science and plant biotechnology. Over the next decade, it is likely that selection within and among plant species, traditional breeding, and biotechnology will provide substantial enhancements to both total biomass yields and conversion efficiencies of biofuel crops.

The roadmap fails to exploit the opportunities to build into plants their own capacities for cell wall deconstruction. The underlying assumption of the report is that plants will provide biomass and microbes will deconstruct it. Enormous savings in bioprocessing could be realized by exploiting the capabilities of plants to deconstruct, or at least, to contribute to the deconstruction, of their own biomass. Plants have underutilized capacity for deconstructing their own biomass. In two fundamental biological processes, abscission and dehiscence, plants deconstruct their own cell walls—in the first case to drop leaves and petals and in the second to spread pollen or drop seeds. These processes need to be studied at the molecular level in order to unleash them for controlled biomass deconstruction in post-harvest processes.

The roadmap makes brief mention of building into plants the capacity for cell wall deconstruction using transgenic plant tech-

nologies, such as by expressing hydrolytic enzymes. That technology needs to be extensively exploited with the goal of eliminating or substantially reducing biomass pretreatment, an expensive step in bioprocessing. Endowing plants with greater capacity for their own cell wall deconstruction may also benefit densification of biomass during harvest. A huge problem that is not addressed in the report is transport of biomass from agricultural fields to bioprocessing facilities. Biomass is less dense than grain and the clearing of biomass from the field and transport to bioprocessing facilities requires a substantial amount of energy not typically factored into cost equations. Developing transgenic plants with the capacity for limited cell wall deconstruction will aid in the development of equipment for biomass densification and hence, reduce transport costs.

The DOE-GTL roadmap does not provide sufficient emphasis on agronomic practices. In the short run, improved cropping systems will be the most efficient means to increase biomass yields. To ensure long-term stability of biofuel cropping systems additional research is needed on nutrient cycling, soil quality and other environmental parameters.

The harvesting, shipping and storing of sufficient biomass to supply lignocellulosic ethanol production facilities also involve substantial challenges. To meet these challenges, it will be necessary to engage agricultural engineers and others. The report recognizes that lignin represents a significant by-product of cellulosic ethanol, but does not offer a research plan for efficiently utilizing it. Instead, the emphasis on this major plant component is removing it as a barrier to cellulosic hydrolysis. This approach may be reasonable for a workshop focusing on a potential contribution of biology to the development of biofuels. However, to develop commercial lignocellulosic ethanol, BP must address the problem of profitably using lignin, which can represent 25% or more of the energy content of the biomass.

The report does not veer far from the conventional wisdom that biofuels will be produced from a dedicated lignocellulosic biomass crop, mechanically pretreated and enzymatically hydrolyzed to hexose and pentose, which are fermented and subsequently distilled to produce pure ethanol. It mentions briefly the possibility of producing high yield oil crops, but virtually ignores the possibility of other feedstocks, other fuels, other fermentation schemes, and other approaches to fractionating lignocellulose. Betting on one horse has rarely proved to be the best technology development strategy.

The report, with its focus on fundamental science, does not provide a framework for the engineering development and economic and environmental analyses required to translate this science into practice. A complete research plan for the EBI will require something other than this report to inform this effort. Furthermore, industry generally performs techno-economic analyses in advance of its technology development effort, and BP should expect such capability to be part of the Host Institute Research Component.

Finally, the roadmap fails to direct substantial research towards modeling the agricultural, social, environmental, and energy sectors that will be impacted by the biofuel revolution. How will food and energy crops compete for farmland? What federal policies are needed to ensure that adequate and stable supplies of food, feed and energy are available? How will rural communities react to the new initiatives? Addressing these questions and identifying appropriate responses will require investments in predicting agricultural economics, rural sociology, environmental modeling, and federal policy.

3.2 Introduction to the Scientific Research Program

The initial goal of our plan is to build and benchmark a cellulosic ethanol research biorefinery within 18 months. In addition to the expected functions of a biorefinery, the EBI program will include upstream activities to develop a sustainable supply of feedstock and downstream activities to evaluate the costs and benefits of the biorefinery. The biorefinery will be modular, enabling each component to be replaced, improved, or evaluated as a unit. Each module will be the focus of a Project whose purpose is to improve efficiency and enable consolidation with other modules. This will permit each Project to operate as independently as necessary, and it will facilitate the evaluation of module improvements with regard to the performance of other modules and to the performance of the biorefinery as a whole. The design and scale of the research biorefinery will be decided together with BP management to ensure compatibility with BP business interests while taking advantage of BP expertise.

The second goal is to use a systems biology approach to improve specific plant and microbial strains for feedstock and fermen-

tation, respectively. Systems biology uses mathematical models to encode the DNA sequence of an organism into metabolic and regulatory networks. Then, quantitative genome-wide profiles of biochemical function animate the models by measuring the networks actually in operation under given conditions. The animated models provide predictions of organism performance under a much wider range of conditions than those under which measurements were made and are particularly useful for predicting effects of genetic changes. Thus, systems biology can guide the rational genetic improvement of organisms. In addition, models can predict the performance of microbes in response to changing nutrient conditions, making dynamic bioreactor management more effective. Desired improvements in biofuel feedstock could include increased sustainable yield, greater ease of cell wall deconstruction, optimized lignin levels, and decreased levels of microbial inhibitors. Desired improvements in fermentation strains could include deconstruction of plant cell walls, improved utilization of C5/C6 sugar mixtures, decreased sensitivity to inhibitors, and higher yields of ethanol or other advantage molecules. It is hoped that rational methods will provide improved feedstock and fermentation strains in years, rather than in decades as is typical when using conventional breeding or strain improvement methods. We will decide together with BP management what plants and microbes will best fit BP's business interests and then, encode their DNA sequence into models, and adapt genome-wide profiling technologies for them.

The third goal is to identify a collection of plant cell wall degrading enzymes that can be engineered into either the plant or the microbe or both to eliminate the cost of added enzymes. Fungi have been the traditional source of plant cell wall degrading enzymes and we will begin by testing the collection of fungal enzymes from Battelle. We will synthesize genes for cellulases, hemicellulases, and other cell wall degrading enzymes discovered from environmental metagenomic sequencing projects and test their ability to degrade plant cell walls; Venter Institute has already used metagenomics to discover 12,000 new cellulases. We will discover cell wall degrading enzymes from cell-based functional screens of metagenomic libraries made from environments in which cell walls are naturally degraded. Combinations of enzymes that work well *in vitro* will be expressed in plants to evaluate their potential to make plants self-processing. Cell wall degrading enzymes will also be expressed in microbes to determine whether microbes can be endowed with the ability to degrade plant cell walls during the process of fermentation.

The first three goals should be met, at least partially, to produce measurable improvements in biorefinery performance within three years. During this period the Project Leaders in the EBI will have matured their plans with UCSD and collaborators for extending the research program eventually to create a highly consolidated process that utilizes raw biomass but that also takes advantage of selected bioenergy crop improvements such as self-processing.

Each of the project scientists will require several enabling technologies to conduct their research. A set of enabling technologies will be established at the EBI to complement those at UCSD and collaborating institutions and to complete the technical requirements for conducting EBI research. The EBI technologies, if unique in capability and scaled to provide service, will act as a magnets to attract collaborators and students. Successful collaborations are based on mutual need. It will be an advantage for the EBI to develop the requisite expertise and facilities that individual university investigators can't afford. In some cases, the most advanced technology may already exist at UCSD or collaborators, but it will be more practical and desirable to scale it up as a service at the EBI.

The creation of a cellulosic biofuel industry will be constrained by economic, environmental, social, and policy issues. To anticipate these issues, we have included in the Research Plan a modest effort that will provide practical guidance to the researchers in deciding how to focus their efforts.

The Research Plan describes how to set up the EBI and integrate its activities with UCSD and collaborators. The plan is based on our direct experiences in creating and leading similar enterprises. It is expected that BP employees will play an integral role in helping the EBI management shape the research program so that it meets the strategic goals of BP. Therefore, the Research Plan is meant to illustrate capabilities and ideas more than to lay out the proposed experiments that are typical of a grant proposal.

The Research Plan has three elements: Project Areas; Enabling Technologies; and System Level Analyses.

3.3 Project Areas

Biorefinery Design and Optimization

The centerpiece of the EBI will be a small-scale lignocellulose-to-biofuels research biorefinery where laboratory advances can be tested at levels that will be scalable, and proof-of-concept can be demonstrated. The facility will bring in raw biomass and produce products suitable for fuel testing. The scale most useful for these purposes will be capable of processing 100 to 500 lbs of dry fermentation feedstock. All unit operations will be included from pretreatment to product recovery and evaluation.

We envision a building space with a footprint of about 3,500 sq. ft. for the pilot plant. Because the pretreatment method is strategic and optimum processes are not yet identified, precise operations have not been chosen and provisions for multiple approaches will be provided. At the very least, biomass grinders, closed treatment tanks for using noxious and harsh chemicals, and possibly dry reactors such as an extruder. will be needed. Two different types of 500-L fermenters will accommodate different microorganisms and fermentations: one top-drive mixed reactor for ethanol fermentations and one air-lift reactor with draft tube for butanol fermentations. A 500-L working volume can accommodate an estimated 385 lbs (175 kg) of dry solids at a 35% solids loading level. The preferred product recovery systems depend on the biofuels produced. Provisions for distillation, adsorption and reactor scrubbing will be provided. A three-phase horizontal decanter centrifuge, evaporator and solids drying equipment will be provided to produce co-product fractions such as fermentation dried biomass which are suitable for small-scale animal feeding trials. A steam boiler and provisions for handling flammable products will be needed.

Plant Science and Engineering

There are arguments pro and con for launching the cellulosic ethanol industry using a grass such as maize. Maize is the number one crop in the U.S. and throughout the world. The scientific base and the technical tools are more highly developed for maize than for any other crop. Almost all maize planted in the U.S. is hybrid, which encourages farmers to adopt new varieties because they must make annual seed purchases. Few if any crops can exceed the productivity of maize. As an annual crop, maize encourages crop rotation, which is a low-cost yet effective way to control pests and restore nitrogen to the soil.

On the other hand, the largest standing biomass in the USA is forest in the southeast and northwest. Besides availability, trees have the advantage of high biomass density. We expect that trees will eventually play an important role in biofuel production, but it may require several additional years beyond those required to utilize grasses whose cell walls are more easily digested. It is also likely that the cellulosic ethanol business will develop faster in regions with existing starch ethanol business such as the maize growing states of the Midwest. We are working on trees such as poplar for biofuel, but only maize will be discussed in any detail in this document. However, conversion of wood to biofuel should be given some attention by the EBI given its long-term potential.

We have substantial strengths in the field of plant science and engineering with particular emphasis on grasses, including maize. Our team maintains thousands of diverse maize lines that are expected to exhibit substantial genetic variation for cell wall characteristics that can be mined to identify and isolate genes that will improve the conversion of biomass to fuel. These genes will be identified using our experience in gene discovery, bioinformatics, global transcript profiling, genetic marker development, and QTL mapping. Similarly, our plant transformation facility is the leading public facility in the world for the transformation of maize and other grass crops. Discoveries made using maize should be directly transferable to other grass bioenergy crops.

During the first five years, we will focus on improving the efficiency with which maize stover (biomass) can be converted to fuel. For example, genes responsible for the chemical cross-linking of cell wall components and lignin biosynthesis that reduce conversion efficiencies will be identified and modified. Our expertise in laser capture microdissection will be used to identify (and subsequently modify) genes that are up-regulated in specific cell types that express novel cell wall characteristics. We will generate maize plants that pre-digest their own cell walls following harvest. We will explore the utility of alternative biomass crops such as switchgrass, *Miscanthus*, and poplar. Key issues with these alternatives include low-yields, risks of gene flow and seed escape, and a lack of proven technology for improving performance. During the second five years lessons learned during

the first five years will be applied to multiple biomass crops, which can be deployed across multiple agronomic systems (soil types, climate and management intensity). We will modify plant architecture in ways that increase total biomass yield and the proportion of the most desirable types of biomass. For example, we will exploit heterosis to increase biomass yields, and we will down-regulate genes involved in reproductive development to produce more abundant vegetative growth. Novel biofuels (e.g., hydrocarbon advantage molecules) will be produced in plants using genes from microbes or other plant species.

Fresh-water microalgae, such as Botryococcus braunii, can convert up to 75% of their dry mass to hydrocarbons and thus, have the potential to contribute to a biofuel economy. Some consideration should be given to innovative scale-up possibilities.

Feedstock Production & Supply

There are many challenges to producing large quantities of biomass in a sustainable manner. These involve feedstock production and environmental sustainability, soil conservation, soil organic matter, and nutrient management. Success in each of these areas requires management of NO_3 levels in ground and surface water, soil erosion rates, and soil organic matter. Other measures relate to the proportion of land area planted to perennial crops, and the fraction of the growing season used for crop production. The most immediate goal in biomass production and sustainability is to maximize biomass production in legacy crops. The long-term goal is to identify and improve new bioenergy crops, recognizing that it is more efficient to build on strengths than to start from scratch.

Biomass production is about the capture and conversion of solar energy. The conventional maize-soybean rotation utilizes only 60% of the potential growing season in the upper Midwest. Cropping systems will be optimized to identify the most promising combinations of herbaceous and woody species and cultivars for feedstock production. Plant breeders will screen germplasm of existing herbaceous and woody species and evaluate the potential of new species. Breeding programs will be initiated for biomass improvement and maximizing biomass conversion to carbohydrates. The strategic integration of large-scale herbaceous and woody biomass species within maize-based agricultural landscapes will assist in meeting society's energy demands while improving agro-ecosystem health and function.

The development of efficient harvest and densification systems will be necessary to collect, transport, and store large quantities of biomass feedstock. The development of systems capable of pretreatment of the biomass during storage could significantly increase the efficiency of downstream bioprocessing operations. This research will capitalize on our well-developed relationships with agriculture machinery companies.

The development and implementation of new cropping systems will reduce soil erosion from the current rates of 4.6 tons/acre (due to water) and 0.5 tons/acre (due to wind) for maize and soybean production systems. Research will be designed to assess the impact of cropping systems on soil erosion. The development of genetic markers for these species will speed the development of improved varieties. In addition, prairie-derived soils naturally are rich in soil organic matter, giving rise to the incredible production capacity of upper Midwest soils. Soil organic matter is also a primary sink for carbon. Cropping systems and crops will be designed that lead to an increase in soil organic matter, which will maintain soil productivity while serving as a net carbon sink. Remote sensing and GPS will be used to manage landscapes to optimize biomass productivity and to manage inventory of biomass. Landscape and watershed level tools and models will be developed to understand the spatial variability of soil properties and processes as they impact biomass production.

Biofuel systems will need to maximize biomass production while minimizing discharges of nutrients into ground and surface water. Research on the plant rhizosphere, cropping systems, and plant breeding will allow us to improve nutrient uptake efficiencies and minimize synthetic nutrient applications. Current information indicates that residues from biomass processing contain valuable nutrients that could be used in fertilizing biomass crops. Research is needed on the feasibility of recycling these nutrients back to the soil. Plant breeding and genetic technologies will be used to improve the water use efficiency of plants, thus improving the stability of performance and minimizing water use. Similarly, our long history of designing perennial native grass and woody components of agro-ecosystems to maximize biomass production and environmental and ecological services

will allow faculty working with biomass producers to design land-use patterns that optimize ecological, social, and economic values.

Pretreatment & Deconstruction

The recalcitrance of lignocellulose materials remains a central problem in biomass to ethanol production. The disruption of a cellulose chain from its matrix, making it accessible to enzymatic action, represents a key bottleneck. Enzymatic hydrolysis has low specific activity, low conversion rates, and sensitivity to breakdown products from aggressive pretreatments. Product inhibition in the enzyme-catalyzed steps is also a significant issue to be addressed. Enzymatic action may occur through cell-free, enzyme-based systems, microbial systems, or enzyme-augmented microbial systems. Consolidated bioprocessing, where deconstruction and fermentation occur in single processes rather than multiple sequential processes, is a further goal in reducing capital and production costs for biomass-to-fuels processes.

Steam, high pH, low pH (dilute acid), and enzymatic methods have been applied to pretreatment. The hydrolysate produced in the NREL process by hot water and dilute acid can next be processed with commercial or fungal enzymes to fermentable sugars. Because there is little commercial practice of cellulose to ethanol conversion, solid benchmarks do not exist. Nevertheless, it has been estimated that pretreatment is one of the most costly steps in conversion of lignocellulose to fermentable sugars, accounting for 33% of the total processing costs.

Conversion approaches from biomass to ethanol will be informed by an integrated research program that links gene sequence to protein function in cellulose, hemicellulose, and lignin degradation; explores the intersection of genetic and metabolic engineering with hydrolysis and fermentation; and uses real time imaging at the molecular, microbial and substrate level. Systems biology (global genomics, proteomics, and metabolomics integrated through mathematical models) and high throughput methodology will be applied to this problem, including directed discovery of novel molecular machinery and more effective cellulases for deconstruction and conversion of biomass. High throughput protein production techniques will be used to generate, purify, and characterize leads from discovery pipelines. Proteins, protein complexes, and membrane proteins and cellulase/cellulosome interactions will be characterized and modeled *in-silico*. Visualization techniques will include NMR imaging and SEM and TEM microscopy. High-throughput biomass compositional analysis methods will be developed to support this research. Physical and chemical changes occurring in biomass as a result of pretreatment will be determined.

Biocatalytic enzyme systems will be implemented in cell-free, microbial, and enzyme-augmented microbial systems to degrade recalcitrant lignocellulose. Alternative solvent systems that make lignocellulose more accessible to degradation have been discovered. Fractionation of biomass into alternative fermentable compounds has been explored using thermochemical pretreatments. We have demonstrated a simultaneous saccharification and fermentation system where enzyme augmentation significantly improved the yields of ethanol. We have also developed a diverse set of biocatalytic nanobiocomposites that incorporate enzymes in nanostructured materials. These dramatically stabilize enzyme activity, provide a means for biocatalyst recovery from processes, and stabilize enzymes for use in alternative solvent systems that may be inhospitable to microbes.

In the first five years, pretreatment and deconstruction approaches suitable for a first generation commercial cellulosic ethanol biorefinery based on enzymatic hydrolysis will be developed and selection will be made among alternative approaches for pretreatment and deconstruction, such as consolidated bioprocessing and production of alternative fermentable compounds. Within ten years, we will develop approaches that eliminate capital and energy intensive pretreatments, consolidate bioprocessing for second generation ethanol biorefineries, recover greater value from lignin, characterize novel advantage molecule pathways, and identify bioprocessing approaches for next generation commercial biorefineries.

Fermentation

The current efficiency of ethanol production from glucose is 50% conversion to a final concentration of approximately 100g ethanol per liter (10%). In contrast, hydrolysis of cellulose by a mixture of cellulase enzymes produces ethanol at a final yield of less than 60g/liter (6%). Enzyme systems used to hydrolyze cellulosic biomass are not optimal and the overall economics of

the cellulosic ethanol process are unfavorable at this time due in part to the cost of the enzymes. Moreover, the yeast used to convert glucose to ethanol is not capable of efficiently converting the 5-carbon sugars that occur in the hemi-cellulose fraction of biomass; the hemi-cellulose fraction is about 35% of the total biomass. To date, there are only a few examples of engineered yeast capable of converting xylose (the primary sugar in hemicellulose) to ethanol. Furthermore, yeast is not tolerant of crude biomass hydrolysate so that expensive separation is required to obtain higher ethanol yields.

A systems approach will be taken for the development of technology to convert biomass to ethanol efficiently and, therefore, economically. Using model microbial organisms (fungal and bacterial), and results from the other projects in the program (molecular genetics, comparative genomics, proteomics and metabolic modeling), we will establish the target process parameters for consolidated bioprocessing (biomass to ethanol). We will identify molecular targets to improve ethanol tolerance in microbes and identify molecular targets to improve microbial tolerance to crude hydrolysate. Looking beyond ethanol, we will identify advantage molecules with practical utility.

Within 5 years we will deliver engineered organisms with improved ethanol tolerance or improved tolerance to biomass hydrolysate in addition to the metabolic models and associated information that predicted the result and informed the research process. Data on model systems for alternative biofuels will be used to define yield and conversion targets. Process development research for biomass to ethanol at pilot scale will be well underway. Within 10 years engineered organisms and production processes will be in hand to convert biomass to ethanol (more than 60g/liter and 50% conversion of biomass to ethanol in a single unit operation). We will deliver engineered organisms and processes to convert crude biomass hydrolysate to alternative biofuels. Strains with optimized performance specific for a given feedstock will be developed.

Fuel Separation and Performance

Recovery of ethanol from fermentation broths is the most energy intensive step in biofuel production. There are several methods available, including membrane processes such as reverse osmosis and pervaporation, liquid-liquid extraction, vacuum fermentation, selective adsorption, and distillation. These methods differ in their energy requirements and ability to be coupled to the fermenter to achieve continuous alcohol production and separation. We have extensive experience with all of these methods and they are even included as projects in our teaching laboratories. We will select one or more methods in consultation with BP engineers.

For combustion, we will accomplish three major tasks in support of biofuel development. We will develop models and run experiments to enable biofuel reactor scale-up, in conjunction with our extant Resource Center for Alcohol Fuels. We will characterize combustion performance based on fundamental measurements, which will provide an understanding of how biofuels and biofuel blends will perform in combustion devices such as engines and turbines. We will also predict (based on fuel chemistry) and measure pollutant emissions for the biofuels and blends, such that environmentally sound fuels are developed. We will focus on real-time measurement of the output of the bioreactors for closed-loop control of the bioreactor fuel production.

Examples of five-year goals include: (a) working models of the bioreactor / biofuel production designs under consideration; (b) experimentally-supported chemical kinetic mechanisms for the biofuel products; and (c) development of high speed sensors and control strategies applicable for the bioreactors. Ten-year goals include: (a) application of the reactor models to process scale-up; (b) optimization of fuel composition for combustion performance in engines and turbines; and (c) an operational sensor and control system that has been fully implemented for control of a pilot-scale or larger-scale bioreactor.

3.4 Enabling Technologies

Analytical Chemistry

Transcriptomics. Until recently, scientists who were interested in understanding the regulation of gene expression in plants, animals, and microbes had to study one gene or a small number of genes at a time. After the genomes of many species were sequenced, new methods were quickly developed to exploit the information. Among the first and most important of these is

gene expression or mRNA profiling. Regardless of the technical platform used, such methods allow us to examine all of the gene transcripts (mRNAs) that are increased or decreased in response to any given experimental manipulation; this is called transcriptomics. It should be clear that this approach can be used to answer myriad questions, and more than 15,000 papers have been published describing gene expression studies since the first, primitive profiling platform (a small printed microarray) was built in 1995. We will use mRNA profiling to investigate both plants and microbes. In both cases, the data will be used to determine the nature of the genes that drive beneficial and deleterious changes in the species examined; and to direct, follow, and measure improvements in the way they function.

We have extensive experience identifying transcripts from maize, rice and other grasses. These transcripts have been used to develop spotted cDNA and oligo arrays that can assay the expression of thousands of genes in a single experiment. We have experience using laser capture microdissection to conduct global gene expression profiling experiments on specific cell types. In the first five years these technologies will be used to support the research goals of Plant Science and Engineering projects.

Proteomics. Our proteomics infrastructure includes capabilities for high throughput characterization of eukaryotic and prokaryotic proteomes using separations and mass spectrometric instrumentation. We can rapidly identify unmodified proteins as well as phosphorylated proteins and other modification states, in plant and microbial cells. In addition to the high throughput enabled by an Accurate Mass and Time (AMT) tag approach, our capabilities include the ability to make broad high quality quantitative proteome measurements using both stable isotope labeling and label-free approaches, determine cellular localization using subcellular fractionation methodologies, and ultra-high sensitivity to provide high dynamic range measurement and broad proteome coverage.

For example, we have identified more than 5,600 non-redundant proteins and 2,100 non-redundant phosphopeptides from rice; more than 7,600 non-redundant proteins from tomato; and more than 6,500 non-redundant proteins from *Arabidopsis*. Among the many microbial applications, we have surveyed more than 3,200 unmodified proteins from the microbe *Shewanella oneidensis;* determined the primary site of protein localization in *Rhodobacter sphaerodies;* measured the quantitative protein response of *Geobacter sulfurreducens* to soluble and insoluble iron; and determined the temporal protein production patterns of *Rhodobacter* transitioning from an aerobic to a photosynthetic life style.

These proteomic capabilities permit direct rather than inferred (e.g., from mRNA measures) descriptions of plant and microbial cells. Such measures of cell state enable quantitative models of cell physiology and regulation. For the first five years of the EBI we will provide proteomics technology support to the plant and microbial projects and we will further refine the technologies to improve protein extraction and cell fractionation, provide more complete coverage of protein modifications, and provide absolute quantitation for most proteins. We will develop and apply bioinformatic algorithms and software, e.g., to improve genome annotation, and locate mRNA splice sites and coding polymorphisms, to refine our models of cell physiology and regulation. Over the second 5 years we will incorporate next generation mass spectrometer-based measurement capabilities into the EBI biorefinery to optimize control of the refinery process based on real-time protein data, and quantitative models of the cells and the refinery.

Metabolomics. We currently have the capability to monitor 1,500 individual molecular species of lipids and several hundred other metabolites including sugars, amino acids, nucleotides, terpenoids, phenylpropanoids, and alkaloids. Specific assays will be developed that are tailored to the species and pathways under development so that constraint-based models can be used to accurately predict performance. The dominant species of sugars and sugar oligomers remaining after cell wall deconstruction will be identified and used to create high-throughput screens of metagenomic libraries to discover enzymes for complete deconstruction and utilization by fermenting microbes.

DNA Sequencing and Biomarkers. We have the expertise to generate high-throughput genetic markers and develop high-density genetic maps to associate specific genes with bioenergy traits (e.g., genes that control cell wall composition). For example, we have generated almost 1,000 SNP-based genetic markers in maize and have developed a genetic map for this species that contains over 9,000 genetic markers. In the first five years genetic markers will be developed for additional species (e.g., switch-

grass and *Miscanthus*) that have not yet been subjected to significant genomic analyses, but that have potential as bioenergy crops.

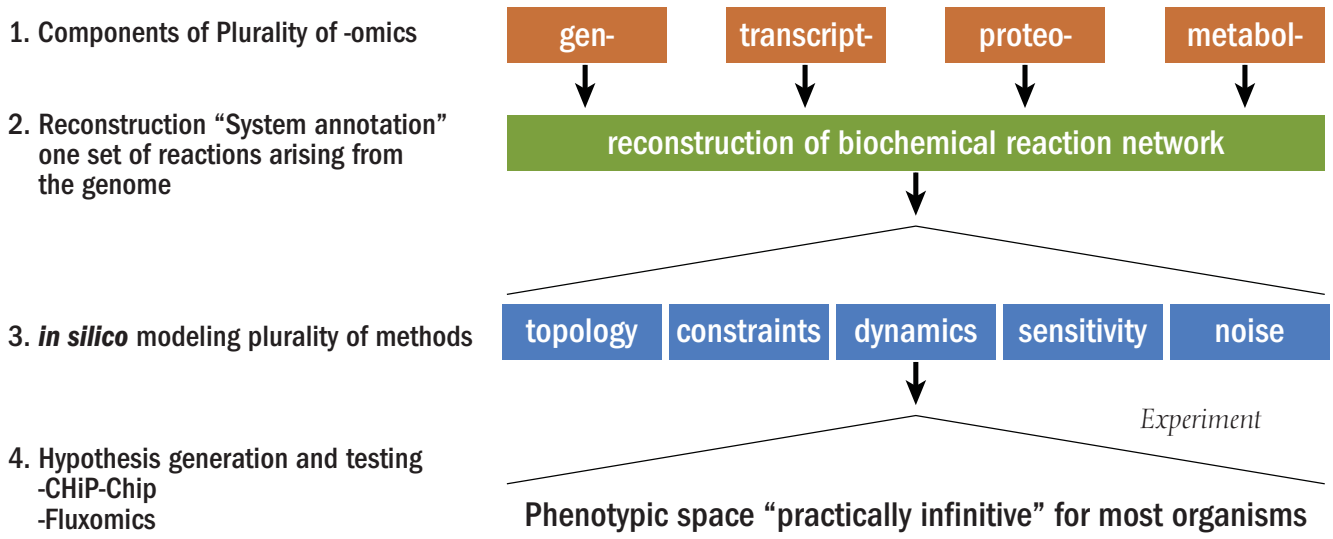
Our Joint Technology Center (JTC) has produced more than 110 million sequence reads containing approximately 75 billion high quality bases from an extraordinarily diverse set of projects. The average sequencing success rate has been 88% and the average read length is approximately 800 base pairs. To date, the JTC has successfully produced approximately 2,000 libraries of different types, including over 1,500 small (‹6 Kb) and medium (6-12 Kb) insert genomic libraries, approximately 200 fosmid libraries and over 100 16s rRNA libraries, and completed more than 250 genomes, including those of phages, plasmids, virus, microbes, fungi, plants, invertebrates and mammals. The JTC has been a leader in the field of metagenomics, generating approximately 8 million sequence reads from more than 50 environmental libraries derived from ocean, soil, and air samples, as well as from within humans. The JTC was also one of the first organizations to acquire and implement two new massively parallel sequencing platforms from 454 Life Sciences Corporation (454).

Modeling

The availability of genome-scale reconstruction of metabolic networks in micro-organisms has grown rapidly in recent years. A reconstruction represents a highly curated set of information, including the genome annotation that can be converted into a mathematical form, which in turn can be used to compute phenotypic properties. Genome-scale reconstructions are thus a key step in quantifying the genotype-phenotype relationship in cells and can "bring genomes to life."

The systems biology process comprises four steps. The need for formal and structured multi-'omic' data integration has become pressing with growth in volume and types of data. The data types fall into three categories: i) component or composition data; ii) component pair-wise interaction data; iii) network state data. These data, along with legacy data (i.e., the 'bibliome') and small-scale detailed experiments, are then used to systematically reconstruct networks of interactions. Ideally, a reconstruction is a biochemically, genetically and genomically structured database that represents the state of knowledge about a cell or an organism. As a result, network reconstruction is a common denominator in the field, and effectively amounts to a 2-D annotation of a genome. Genome-scale reconstruction technologies for metabolic, transcriptional regulation, and signaling networks have been established, and transcriptional/translational network reconstruction methods are currently under development.

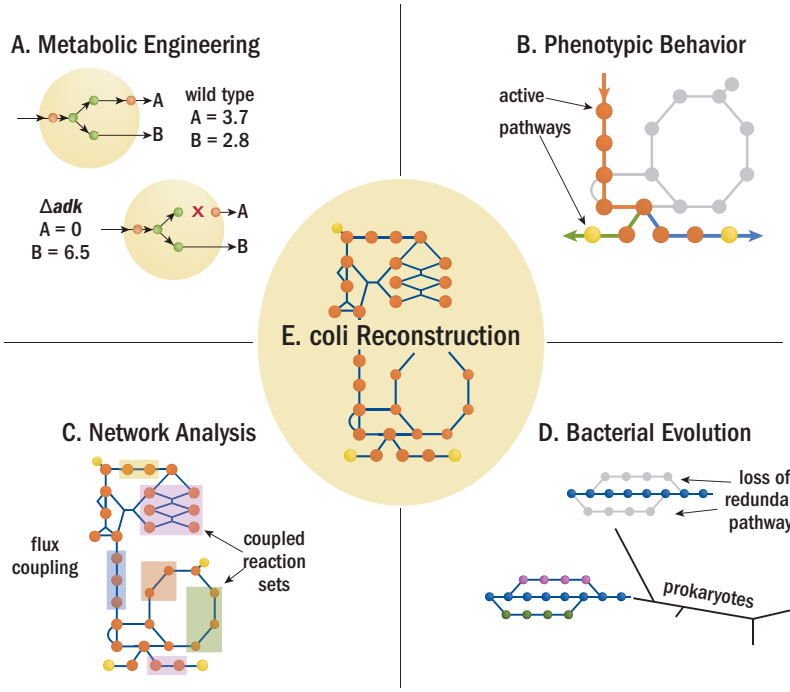
The arrow from step two to step three in the figure involves a subtle, but critical, transition. With the definition of systems boundaries and other details, a network reconstruction can be converted into a mathematical format that can be computationally interrogated and subsequently used for experimental design. The process that this arrow represents is the bridge between the realms of high-throughput data/bioinformatics and systems science. Thus, we have two separate steps with different impli-



Systems biology as a four step process.

cations; the **first** is a network reconstruction that should be accessible to all, and the **second** is the conversion of the network into a computational model. The latter requires computational skills and access to specialized software that may not be open source and often requires significant licensing fees. Many imaginative studies have now been performed using genome-scale reconstructions as detailed below.

The complete genome sequence for *E. coli* K-12 MG1655 was published in 1997 making genome-scale reconstruction possible. Using these data, a series of genome-scale reconstructions of *E. coli* metabolism and transcriptional regulation have appeared. The most recent metabolic reconstruction consists of 2,050 reactions and 1,254 genes and incorporates data from the most recent *E. coli* K-12 MG1655 genome annotation. The *E. coli* reconstruction has led to similar efforts for many microorganisms. The genome-scale reconstruction of *E. coli* represents the best-developed network reconstruction to date.



The in silico analyses conducted by various research groups fall into four general categories: 1) metabolic engineering applications; 2) studies of phenotypic behavior; 3) biological network analysis; and 4) studies of bacterial evolution. Only the most relevant application to a biofuels program is described here.

Metabolic Engineering Applications: Applying computational methods such as linear optimization and mixed integer linear programming (MILP) to the metabolic reconstruction of *E. coli* demonstrated that model-based, directed strain design of *E. coli* could lead to increased metabolite production in vivo. This strategy was used to engineer strains designed to overproduce target metabolites such as lycopene, the end-products hydrogen and vanillin, and various targeted amino acids. This body of work demonstrates the power of using the reconstruction to generate a predictive model that can be directly applied towards engineering applications. In conjunction with several available computational platforms (i.e., Matlab™ Lindo™, GAMS™ and SimPheny™), the reconstruction has provided a mathematical framework to analyze the metabolite production potential of *E. coli*. These applications are beginning to influence other fields of study, such as environmental applications for generating renewable energy sources and also bioremediation efforts. The use of genome-scale reconstructions has allowed researchers to examine and simulate the system as a whole, compared to classical methods of manually assessing interactions, which may fail to detect non-intuitive causal interactions. With an increase in size and coverage, the genome-scale reconstructions will become even more useful in these attempts to manipulate *E. coli* and similar organisms for industrial production.

Bioinformatics

We will focus on the bioinformatic data and tools that are required to support the six project areas, enabling technologies, and system level analyses. In the first year of the project, computational infrastructure and interfaces will be in place that will enable gene discoveries and data analyses required by the six project areas. Throughout the course of the project, the bioinformatics team will annotate the genomes (or portions of the genome) for species (plant and microbes) relevant to biofuel production as requested by the Project Area scientists or as the genome sequence is made available. Within a ten-year time frame, we expect microbial and plant genome sequence data to be abundant with complete genomes numbering in the hundreds and genes of interest sequenced from even more species. The bioinformatics team will provide scientific work flow structures for automated gene structure annotation of novel genome sequences, tentative functional annotation based on similarity measures compar-

ing with model organisms, and link and evaluate relevant gene expression data. In close collaboration with the proteomics team, we will develop models of gene expression as predicted from primary sequence by modeling promoter elements, splicing events, and mRNA stability.

Cyberinfrastructure

UCSD is a dominant player in cyberinfrastructure. Programs at the California Institute for Telecommunications and Information Technology (Calit2), the San Diego Supercomputer Center (SDSC), and in the academic departments have led the way in eliminating bottlenecks to data sharing, remote instrument use, computing, sensor networks and display. Connected both to UCSD and the grid using proven technologies, the EBI will benefit from the continuous, rapid advances in cyberinfrastructure that are being made at UCSD. This technology will play a major enabling role in the joint research between EBI, CBEST collaborators and others.

Leading organizations helping develop CI in an integrated fashion at UCSD include:

- The San Diego Supercomputer Center (SDSC): Founded in 1985, SDSC is funded primarily by the NSF and enables scientific discovery through high performance computing, large scale data storage, and visualization. SDSC has been a center piece of the Nation's efforts in advancing the applications of scientific computing and now provides exceptional storage technology and capacity.
- The National Center for Microscopy and Imaging Research (NCMIR): Founded in 1988, NCMIR, funded primarily by the National Institutes of Health, introduced remote access to specialized, rare instrumentation and more generally, the use of telescience to bring the best science together with the best technology outside of geographical constraints. NCMIR provides experimental analyses and the software tools needed to analyze multiscale, multimodal data in order to understand the dynamic form and function of biosystems.
- The National Biomedical Computation Resource (NBCR; http://nbcr.net): Funded by the National Institute of Health, NBCR was established in 1993 to bring computational tools to the broader biomedical community. NBCR's mission is to conduct and catalyze multiscale biomedical research by harnessing advanced computation, software development and tool implementation, modeling and simulation, and data CI through integrative, multidisciplinary, multi-institutional R&D activities.
- The Center for Wireless Communications (CWC): Founded in 1995, by the Jacobs School of Engineering at UCSD, CWC is funded primarily by the private sector and is focused on achieving the research and education needs of the cellular and wireless communications industries.
- The California Institute for Telecommunications and Information Technology (Calit2): Founded in 2001, Calit2 is funded through a variety of state, federal and private sources and is focused on creating and applying leading edge information and telecommunication technologies to scientific domains critical to the future of California including energy, the environment, civil infrastructure, genomics and genomic medicine, homeland security, and entertainment/community engagement.
- The Biomedical Informatics Research Network (BIRN): Founded in 2001 by the National Institutes of Health, BIRN led by UCSD is developing the key information technologies and applications designed to support biomedical scientists in conducting research. With its very successful platform for advancing and sharing knowledge and organizational integration, BIRN has become the model for cyberinfrastructure for other domains and efforts by other agencies.

Exemplars of current CI efforts on the UCSD campus which speak to our broad experience and proven track record include:

- The Geosciences Network (GEON): An information technology research program led by SDSC and funded by the National Science Foundation, aimed at developing the cyberinfrastructure needed for integrative geosciences research.
- OptIPuter: The largest information technology research award made by the National Science Foundation ($13.5M million over five years), this computer science research project led by Calit2, and initiated in 2003, couples computational hardware, data storage, sensors, and visualization facilities over optical networks, using pilot projects in brain and environmental science. The OptIPuter spun off the extraordinary cybermetagenomics project CAMERA, described below.

- Wireless Information Systems for Medical Response in Disasters (WIISARD): Funded by the National Institutes of Health ($4.1M over three years), WIISARD uses cutting edge wireless technologies to coordinate and enhance care of mass causalities in the case of terrorist attack or natural disaster.
- The Community Cyberinfrastructure for Advanced Marine Microbial Ecology Research and Analysis (CAMERA): Funded by the Gordon and Betty Moore Foundation ($24.5 million over seven years) CAMERA provides cyberinfrastructure tools and resources and bioinformatics expertise to enable the scientific community to use the vast, rapidly growing treasure of marine metagenomic information and allows UCSD EBI to deliver novel biosolutions for health care, energy, and the environment.
- Sensor networks have been pioneered at UCSD. Examples include the NSF Real-time Observatory, Analysis, and Data management Network (ROADNet; http://roadnet.ucsd.edu/index.html), the Laboratory for Ocean Observatory Knowledge Integration Grid (LOOKING; http://lookingtosea.ucsd.edu/), HiSeasNet (http://hiseasnet.ucsd.edu/), the EarthScope Array National Facility (ANF; http://anf.ucsd.edu/) and the California/NOAA—sponsored Southern California Coastal Ocean Observing System (SCCOOS; http://sccoos.org/). CI developed through these programs will soon be applied to the NSF's Ocean Observatories Initiative (OOI) program. To address the ocean observatory's demand for real-time access and response to detected events, the architecture must extend to real time distribution and processing of data and the provision for interaction with the state of the observing system, not just with its resultant data products. To do so, the OOI architecture will model the command processes driven and captured by a distributed collection of information that can be coherently accessed. This knowledge network archives and disseminates not only the data and their resultant products, but also the experience and understanding gained through use of the observatory. The technology is directly applicable to the command and control of a distributed analytical instruments in a distributed, virtual laboratory or notably, a modern biofuels plant.
- The Pacific Rim Application and Grid Middleware Assembly (PRAGMA; http://www.pragma-grid.net): PRAGMA, led by UCSD and including 29 institutions, was established in 2002 to build sustained cyber collaborations among research in the Pacific Rim region and to advance the use of requisite technologies by focusing on applications. PRAGMA (with $3.2M for next five years) consists of 29 institutions from more than ten countries. Connected to this is the Pacific Rim Experiences for Undergraduates (PRIME: http://prime.ucsd.edu), another NSF international project engaging cyber to prepare students for excellence in 21st Century global workforce.

Metagenomics and Single Genome Amplification

Most of the microbes in soil and water are not easily cultured. But new developments in genomics—two of which are now in practice in our labs—provide a way to find new genes, biochemical pathways, and organisms without the bias imposed by selection or culture. The first development is environmental genome shotgun sequencing on DNA extracted from communities of microbes found in the environment. Environmental shotgun sequencing has been used to discover millions of new genes and proteins and thousands of new organisms. The second development involves amplification of genomic DNA directly from single cells via multiple displacement amplification. Amplification of DNA directly from single cells provides sufficient DNA to carry out genomic sequencing without the need to develop culture methods. The combination of these two new technical approaches will provide a fertile source of new organisms, genes, gene products and biochemical pathways that can be systematically screened for activities relevant to bioprocessing ranging from biomass deconstruction through synthesis of biofuels.

We will apply environmental shotgun sequencing and whole genome amplification to natural and enriched populations of microbes to identify novel genes, pathways and organisms that engage in bioprocessing of biomass and its constituents. The initial five-year focus will be primarily on discovery and characterization of new bioprocessing capabilities. Towards the end of the first five years, we expect to have coupled the single cell genome amplification technologies to high-throughput fluidics and cell-sorting devices designed to handle hundreds of thousands of microbial cells. Additional capabilities that need development include efficient labeling technologies for microbial cells to identify features of interest (sequence, metabolites, proteins), and efficient detection devices for imaging single labeled microbial cells. The second five-year focus will be guided by our successes in bioprocessing and use metagenomics tools in a highly directed fashion to search for optimized versions of specific catalysts, pathways and organisms.

Bioreactor Design

Bioreactors are critical for optimization and scale-up of biofuel production in a biorefinery. We have several complementary technical approaches. Suspended cell and cell aggregate chemostats are used to minimize biochemical and physiological variability to provide more representative and replicable samples for global proteomic, transcriptomic and metabolomic studies of anaerobic bacterial-archael consortia, cyanobacteria, and filamentous fungi. The resulting large data sets are amenable to advanced modeling of carbon and energy flows, novel approaches to pathway and process modification, and improved fundamental understanding of cellular responses to changes in process control parameters. For example, electron acceptor limitation has been shown to led to rapid synthesis of nanowires in multiple bacterial species that have implications for intra- and interspecies electron flow and hydrogen production. In addition to use as research tools, production reactors will need to be designed to accommodate the variety of fermentation substrates envisioned for the biorefinery including syngas and pyrolysis oils from thermochemical processes, chemically pretreated biomass, and enzymatic hydrolysates of cellulose and hemicellulose. Biofilm or attached growth bioreactors can meet this challenge. Biofilms are a natural form of immobilized cells, which are resistant to harsh environments, provide high cell densities, can be developed for pure and mixed culture populations, and operate in repeat batch, fed-batch or continuous mode. We have a patented technology to produce plastic composite supports (PCS) which contain 50% polypropylene to provide a ridged solid matrix and 50% agricultural products blends to provide a porous structure and micronutrient for attachment. PCS has been used to detoxify pyrolysis liquor from plant biomass, produce lignin peroxidases, organic acid, and maize wet milling waste water conversion to fungal biomass.

During the first five years of EBI, the following bioreactor systems are research candidates: (a) Fermentation of syngas to ethanol in a Continuous Stirred Tank Reactor (CSTR), including modeling-enabled modification of strains to enhance ethanol yield; (b) Fungal or mixed fungal/bacterial consolidated bioprocessing systems with PCS, as appropriate; (c) PCS discs packed-bed reactors with production of volatile hydrocarbons from syngas by *Rhodospirillum rubrum* or *Rhodobacter sphaeroides;* (d) PCS tubes attached to the agitator shaft of a CSTR bioreactor train will be developed for the biological detoxification and bioconversion of energy crop biomass pyrolysis liquors into butanol and other advantage molecules; (e) PCS draft tubes in an airlift reactor will be used to immobilize *Clostridium beijerinckii* BA101 for the production of increased yields of butanol from C5 and C6 sugars; (f) Microorganisms will be genetically engineered to produce molecules that are more similar to petroleum than ethanol and butanol (e.g., esters, terpenes, hydrocarbons), and the performance of any these engineered microorganisms will be evaluated in a computer controlled bioreactor. Over the second five years scale up protocols for promising fermentations with desirable production rates and yields will be developed.

Synthetic Genomics

Synthetic genomics provides a powerful new dimension to the engineering of individual genes and multi-gene pathways. This technology will be useful for a number of the plant and microbial projects. Consider the hypothetic example of a biochemical pathway with five genes that leads from feedstock material to an advantage molecule. The genes can be synthesized as a tandem array of genes controlled either by a single regulatory region, or under individual regulation such that the genes could be over-expressed as desired. The genes can be codon-optimized such that translation and folding of the proteins for each gene are maximally efficient. In addition, we can use a combinatorial approach whereby several versions of each gene are synthesized and then, the five genes each with their several versions are assembled in a single reaction into tandem arrays to produce a library of pathways. If each of the five genes has five variants, the library would have $5^5 = 3125$ members. When the assembled library is transformed into the host cell for expression, the best assembly can be selected based on product yield. Some of the gene variants could be consensus sequences built by selecting the most common amino acid for each position of the protein from an alignment of orthologs taken from the genome databases. In some cases that a consensus sequence designed in this way has been shown to have greater activity than any ortholog in the collection. We have developed the capability for both gene synthesis and gene assembly and can routinely assemble, in a single reaction, tandem arrays of up to 8 gene cassettes that overlap by 40 to 80 bp. In the first five years of the program, we will provide synthetic genomics support to the plant and microbial projects and further develop the synthetic technology. In the second five years, the synthetic genomics effort will sustain its contributions to the plant and microbial projects, but focus on optimization of a few selected pathways of industrial importance.

Experimental Design & Analysis

We have been developing novel multivariate data analysis methods applicable to a wide variety of genetics and genomics data including DNA sequence data, amino acid sequence data, polymorphism data, gene expression data, proteomic data, and others. These methods can be used to test very broad or very specific hypotheses (or mine data for patterns) about relationships between massive amounts of data that 'profile' specific sets of individuals or objects (such as protein sequence data from different families of genes; gene expression patterns from different species). We have applied these and related analysis methods to large-scale gene expression data, polymorphism data, and large-scale population genomics data. We also apply these methods to identify genomic regions that harbor certain distinguishing features among different individuals or species that correlate with certain phenotypic endpoints (e.g., methanogenesis potential; disease status). The data analysis tools can also be combined with sophisticated visualization tools to explore features in very large data sets that may otherwise be overlooked with conventional data analysis methods.

Specialized expertise includes design and analysis of experiments in agriculture, Bayesian methods, ecological and environmental studies, computer simulation and industrial process control, and plant genomics. Statistics faculty are prepared to support biofuel research by ensuring that experiments are efficiently designed and that data are appropriately analyzed to maximize the information derived from experimentation.

Plant Transformation

The transformation of maize is now a routine procedure in the our Plant transformation Facility. In the near term, methods will be developed and/or optimized to transform and regenerate specific genotypes of other C4 grasses that are likely to become important bioenergy crops (e.g., switchgrass and *Miscanthus*). In the longer term, these technologies will be enhanced to make them applicable to a wider group of genotypes within each species.

3.5 System Level Analysis

Economics, Sociology, and Policy

An important component of the overall scientific management of EBI will be an integrated assessment team focusing on the larger economic, environmental, social, and policy concerns surrounding the development of a biofuels industry. We will undertake a series of research and outreach activities defined by ever-widening system boundaries. The first of these draws the system boundary around the production facility, looking for opportunities to lower costs, improve energy efficiency, and enhance environmental performance. We have already developed techno-economic models used to help guide DOE's biofuels research program within its Office of Energy Efficiency and Renewable Energy. At the next level, the integrated assessment group will consider the economy-wide and social impacts of an emerging biofuels industry. Potentially 100s of millions of acres of farm- and forestlands might be engaged in this new endeavor. Such changes will of course shift land values, land-use patterns, and if not done carefully, may have adverse environmental consequences. We are developing models that can be used to examine the impact of a cellulose-based biofuels industry on the rest of agriculture and on such environmental attributes as carbon sequestration and water use. Over the first few years, the focus of the research will be on maize stover as a feedstock; gradually focus will shift to other feedstocks (such as switchgrass and wood). Finally, to ensure that the EBI truly understands the multiple criteria that must inform and guide its research, the integrated assessment group will convene a multi-stakeholder symposium, bringing together perspectives from the energy, agriculture, and forestry industries; the environmental and other public interest communities; governments; and researchers from within the EBI collaborators and the broader academic community. We have considerable experience designing this type of multi-stakeholder symposium and combining the several levels of analyses discussed above into an integrated assessment.

Environmental Impact

The long-term viability of large-scale biofuel production depends on its economic and environmental sustainability. The environmental impacts of biofuel production and use arise through complex interactions between the agricultural, energy, trans-

portation and food systems. Our strategy is to quantify the net environmental impacts of biofuel systems based on a life cycle accounting approach. We have the capability and expertise to perform environmental life cycle assessments that consider all inputs and outputs, including environmental, resource, and health impacts. This provides quantitative comparisons of different systems, feedstocks, and technologies based on energy efficiency, or environmental quality parameters such as net greenhouse gas emissions. Our systems analysis and environmental impact assessment capabilities are significantly enhanced by our demonstrated ability to form highly productive interdisciplinary teams that provide in-depth knowledge of the full biofuel life cycle from biomass production and supply through conversion and fuel use. We have developed a large number of integrated life cycle models that have the capability to evaluate local, regional, and global impacts of biofuel systems. We have evaluated hundreds of cellulosic biofuels system scenarios, utilizing dozens of biomass feedstocks, feedstock production systems, conversion technologies, and co-product use scenarios. For the first five years of the EBI we will provide life cycle assessment and scenario modeling. We will evaluate the anticipated mature state to predict technologies and best practices for greater use efficiency and a more positive environmental impact. This prospective analysis will allow us to provide a forward-looking guide to balance environmental impact with economic performance. Over the second five years of EBI, we will focus on a small set of biofuel technologies. Detailed analysis will enable optimization of biofuel system designs based on local environmental impacts. Significant improvements over current maize grain ethanol production should be possible, with the goal being a 50% improvement in the full life-cycle environmental impact (greenhouse gas, volatile organic chemicals and NOx emissions; eutrophication and acidification potentials; soil erosion rates; and human toxicity potential).

We also have exceptional technology to measure atmospheric effects of biofuel use. Our stable isotope technique has been applied throughout the United States, Pacific and Indian Oceans, the Arctic and Antarctic, and Europe. It has also recently been used to make measurements of the Martian atmosphere and regolith and, from terrestrial ice core samples, to study past climates. With increased crop growth for biofuels, there are associated risks with the enhancement of microorganism growth and enhanced addition of nitrogenous species to the environment. In particular, it is well known that such activities accelerate the emission of nitrous oxide. Nitrous oxide is a greenhouse gas with a warming potential 200 times that of carbon dioxide on a per molecule basis. Further, the lifetime of nitrous oxide is nearly 150 years and as such, it is a powerful greenhouse gas with a still inadequately known budget. We have a full isotopic capability to identify sources and transformation mechanisms of atmospheric nitrous oxide. Success with our method has lead to a group of scientists around the world utilizing this technique to better understand the sources of nitrous oxide and to restrain emissions.

A second presently unknown factor is the impact upon the global biogeochemical cycle of nitrogen associated with the scale up of agriculture. The nitrogen cycle is presently one of the more poorly known cycles. Utilizing multi-isotopic techniques, our measurements of nitrogen atmospheric aerosols, soils, rivers, fog, rain, and sub surface waters have lead to enhanced resolution of the nitrogen cycle.

Outreach

EBI research, technology development and product delivery will have profound societal impacts. Moreover, the success of the institute will depend in part on societal factors as diverse as public perception of the benefits, risks, and environmental impacts arising from biofuels and biofuels research, farmers' willingness to change land use practices to produce biofuels feedstock, and the development of a highly skilled workforce to advance biofuels research and technology, to name a few. By proactively addressing such complex issues through a multifaceted communications, outreach and social science research program, EBI will ensure widespread public support for its research. This outreach program will facilitate adoption of EBI technology both on the farm and at the pump, and will promote the long-term sustainability of the biofuels industry. CBEST collaborators are uniquely positioned to tackle this diverse set of societal issues and envision supporting the EBI with a communications, outreach and social sciences research program that will draw upon the extensive resources and expertise of all collaborators.

UCSD is a national leader in outreach programs that raise public awareness and support for science and technology innovation and address the societal challenges that can stem from these innovations. In addition to a top-tier communications office, UCSD hosts an array of high quality programs including a nationally recognized center for ethics in science and technology, a world-

class public science center specializing in bringing research results to the public, a satellite and cable TV network (UC-TV) that provides UCSD science education programs to more than 15 million homes nationwide, extension biosciences and online education programs, and numerous K-12 science outreach projects. UCSD also excels in preparing both graduate and undergraduate students for careers in industry through intensive internship and training programs that emphasize entrepreneurship and working within the high tech corporate culture.

ISU Extension's exemplary outreach and distance education program is directed at helping farmers analyze and adopt technologies to enhance profitability and sustainability. ISU is also home to one of the best extension sociology units in the country. Specializing in social sciences modeling, the sociology program is recognized for its innovative research on the community and economic impacts of rural social change, as well as how research findings can be useful in triggering planned social change. Combining social sciences research with extension education will be especially important as markets develop for energy crops, and farmers need to make decisions about how to transition their operations to produce new crops and/or adopt new cropping systems. Recently, ISU has proposed creation of a New Century Farm—the first integrated, sustainable biofuels feedstock production farm in the U.S.—which will serve to demonstrate the economic, social and environmental viability of bioenergy production to producers, policy makers and the public.

Collectively, CBEST collaborators will be able to directly address both anticipated and unanticipated societal issues inherent in biofuels research, technology development and implementation. The combined capabilities of ISU and UCSD in these areas are described in detail in **Appendix B,** "CBEST Outreach Capabilities."

3.6 Other Research Areas

Enhanced oil recovery and hydrocarbon conversion

Microbial consortia are known to break down complex hydrocarbons into methane, hydrogen and carbon dioxide, and such communities have been documented in oil deposits, production waters, tar sands, oil shales, coal seams, and benthic gas hydrates. These microorganisms engage in numerous activities of interest, including viscosity reduction, heteroatom removal, surfactant oil mobilization, *in-situ* gas production, and the conversion of complex hydrocarbons into lighter fractions. While the existence of subsurface hydrocarbon ecosystems has been known for some time, a number of bottlenecks in microbial cultivation and multi-species analysis have limited their biotechnological application. The EBI is in a unique position to overcome these barriers and fully describe the potential array of microbial tools available in the subsurface. The EBI will apply skills in metagenomic analyses of environmental samples, including high-throughput sequencing and annotation, metabolic profiling and multi species modeling. The near term objective of the EBI is to fully characterize subsurface microbial communities associated with recalcitrant hydrocarbon deposits. This will include describing and annotating known genes and gene functions, cataloging metabolic pathways, and modeling metabolite flux across microbial guilds. The goal at the end of the first five-year period would be to develop an understanding of how hydrocarbon associated microorganisms convert high molecular weight hydrocarbons into metabolites and other advantage molecules.

The ten-year, long-term technology goal will be the transfer of discoveries from metagenomic and functional genome analyses into testable hypotheses and lab-scale experimentation. Numerous cross-cutting EBI tools will be required: high throughput cultivation of target microorganisms, single cell genomic analyses of difficult to grow organisms, RNA profiling and modeling of mixed populations. High-throughput assays will be developed for heteroatom removal, viscosity reduction and metabolite generation. Research objectives would be centered on a) improving hydrocarbon resource utilization and b) reducing the carbon emissions during extraction, upgrading and conversion. Potential small footprint *in-situ* applications will be explored, including *in-situ* gas production, viscosity reduction for oil mobilization, *in-situ* methane and hydrogen generation, and *in-situ* hydrocarbon upgrading. Other biotechnology applications which may emerge from the metagenome analyses include enzymes and whole-cell systems for post-extraction upgrading and conversion. Additional programs of interest to the EBI include the metabolic engineering of methanotrophs for the selective oxidation of methane to methanol, a gas-to-liquid technology with promising fuel cell applications, and stimulating coal bed methane production through microbial augmentation.

Terrestrial and Geologic Carbon Sequestration

Using existing land management practices, sequestration of atmospheric CO_2 in soils via photosynthesis holds the potential to contribute to greenhouse gas mitigation. Over the next three to five decades this will, in essence, "buy some time" for the development and deployment of other advanced technologies as longer term solutions. Near term carbon sequestration research at the EBI will focus on biological, physical and chemical processes which control the rate and allocation of carbon in soil. Specific projects will include belowground biomass production and sequestration, enhancing soil carbon recalcitrance through lignin modification, and understanding mechanisms of soil carbon storage. Our team leads the Consortium for Research on Enhancing Carbon Sequestration in Terrestrial Ecosystems (CSiTE; funded by DOE); beginning in 2007, CSiTE will undertake a new 5-year field campaign on switchgrass ecosystems to address the overarching hypothesis that simultaneous biofuel production and soil C sequestration is sustainable. In the area of long-term research, the EBI will also be able to take advantage of our team's management of FutureGen (a $1B industry-DOE investment), the project to construct (in the coming decade) the world's first zero-emission coal-fired power plant,which will capture and store CO_2 in deep geologic formations. Similar complementary strength is provided by our membership in two regional carbon sequestration partnerships (with DOE funding). Our work builds on a broad capability for fundamental and applied research and integrated assessment of economic, technical, environmental and social implications for carbon capture and storage in deep geologic formations, and can serve as a resource for research on biological methods.

Modified cyanobacteria, among promising biological methods, can be used for treatment of industrial gases rich in CO2, such as those generated by coal-burning power plants. The biomass generated by such a technique can then be used for renewable energy production. Specifically, cyanobacteria can convert CO_2 into organic carbohydrates using free energy generated by oxygenic photosynthesis. Since the genomes of cyanobacteria can easily be manipulated, we plan to genetically modify their metabolic pathways to increase efficiency of CO_2 sequestration and to improve their ability to absorb nitrogen oxide and sulfur dioxide that are hazardous to environment. Improvement of the relevant microbial processes is facilitated by the more than a dozen cyanobacteria genomes already sequenced, including unicellular *Synechocystis* PCC6803 and thermophilic *Thermosynechococcus*.We will also seek novel enzymes and pathways from metagenomics to use them for cyanobacterial modification. Our modified cyanobacteria may be used for treatment of industrial gases rich in CO_2, such as those generated by coal-burning power plants. Moreover, biomass generated may be used for renewable H_2 or ethanol production through fermentation processes.

3.7 Program Flexibility

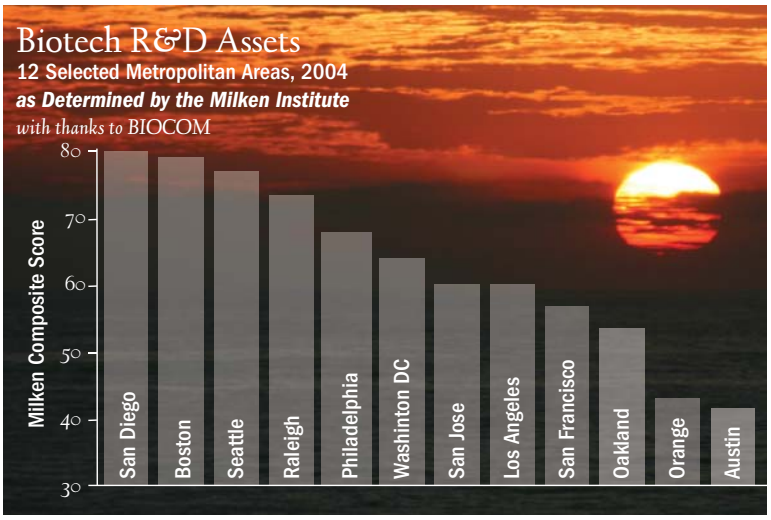
The research program has been designed to maximize flexibility by providing a framework for rapid decision-making and focused efforts. An essential component of an excellent research program is continuity of funding, which argues against flexibility. But another essential component is funding to immediately exploit research breakthroughs and this counter-balances the need for continuity. By making the EBI collaborative research program transparent to its participants, the EBI Director will be able to balance these competing interests. We have found that the academic research community is very good at providing and responding to peer review. Therefore, transparency and peer review, possibly by a Scientific Advisory Board (SAB), will provide flexibility by facilitating the identification of the best research opportunities and maintaining the buy-in of the stakeholders. Transparency can be achieved using one-day retreats every six months in which posters are presented that describe the plans and progress of all funded research. All funded participants and the SAB would be expected to participate, but the meeting would be closed to outsiders. Annual re-allocation of funding by the EBI Director based on the quality of plans, research progress, and alignment with EBI priorities can provide the flexibility needed without destroying continuity. The EBI priorities should be written and shared with participants. Initial allocations should be for two-years with a rolling 12-month adjustment or renewal. By ramping up the program over two years there will be a major opportunity annually to adjust the research priorities. The concept of a balanced portfolio should be agreed at the outset in which a fraction of the budget is dedicated to long-term breakthroughs and the rest to near term execution. A 1:1 ratio may be best.

4.0 Qualifications

Above *Research fields—courtesy of ISU*

4.0 Qualifications

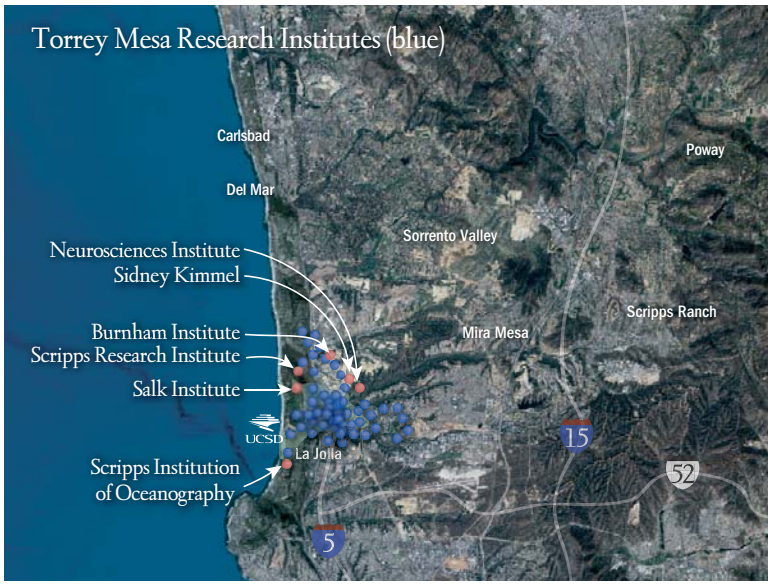
4.1 San Diego: #1 in the Life Sciences Industry



San Diego is increasingly recognized as a major hub for biosciences and biotechnology. San Diego, of course, has long been known for its attractive residential environments, its world-class beaches and year-round recreation opportunities including surfing, sailing, scuba diving, biking, hiking, golf, hang-gliding and tennis. (See also "San Diego Overview" in the Miscellaneous section at the end of this proposal.)

A Milken Institute *2004 Life Science Survey* ranked San Diego Number 1 in R& D assets, NIH Funding to Institutes, Technology Fast 500 companies, and the size and growth of the biotech industry. San Diego was ranked Number 2 in biotech venture capital investment, number of biochemists and biophysicists, and for the number of people employed in the biotechnology sector.

San Diego has the greatest concentration of life science companies in the U.S. and it is also the home of several world-class bioresearch centers that have sprung up on the edges of the UCSD campus. These institutions have impressive tech-transfer track records. As examples, The Scripps Research Institute has spun off 50 companies, and the Salk Institute 27 companies since the late 1980s.



San Diego hosts 29 venture capital firms dedicated to the Life Sciences. Investment in local companies is at record levels, and there is increasing interest in partnering by non-local venture capital firms.

According to the *E&Y Venture One Survey* of the Milken Institute, the San Diego Life Science Cluster received

- $2.8 billion in biotechnology VC money from 2001-2005.
- $716 million in medical device VC money from 2001-2005.
- $1.1 billion from NIH in 2004

4.2 UCSD Experience and Leadership

Founded just over four decades ago, UCSD has rapidly achieved the status as one of the top institutions in the nation for higher education and research. UCSD's deeply ingrained interdisciplinary ethos coupled with an equivalent tradition of innovation and risk-taking underlie its research strength and ability to recruit top scholars and students. To support our bid to become host to the EBI, we offer six 'snap-shots' as justification:

- UCSD scores well in academic rankings.
- UCSD has demonstrable research impacts.
- UCSD has high caliber faculty.
- UCSD has won management awards for implementing innovative business practices.

- UCSD plays a significant role in Southern California's regional economic development.
- UCSD is home to other mission-driven research initiatives of comparable size and scope.

Academic Rankings

- UCSD was named the **"hottest"** institution in the nation for students to study science by *Newsweek* and the 2006 *Kaplan/Newsweek College Guide.*
- UCSD ranks 7th in the nation in National Academy of Sciences membership.
- *U.S. News and World Report* ranks UCSD as **8th best public university in the nation.**
- UCSD was ranked the **6th best university in the nation** by the *Washington Monthly's 2006 College Guide,* based on the positive impact the university has had on the country.
- The National Research Council ranks UCSD **10th in the nation in the quality of its faculty and graduate programs**. The NRC ranks oceanography and neurosciences **1st** *in the nation.*
- Kiplinger's Personal Finance ranks UCSD **8th nationally** for best values in public colleges in the U.S. UCSD outranks UC Berkeley and UCLA in this ranking of the top 50 values in public colleges. The *Princeton Review 2007* edition of America's Best Value Colleges also lists UCSD among 150 "best values."
- The 2006 Academic Rankings of World Universities conducted by Shanghai Jiao Tong University in China ranked UCSD **13th internationally.**

Research Impact

- UCSD's total research funding for 2004-05 was $728 million. The National Science Foundation ranks UCSD **5th in the nation in federal R&D expenditures.** *(The top ten research universities, in rank order, are: Johns Hopkins, Washington, Stanford, Michigan, UCSD, UCLA, Pennsylvania, Wisconsin-Madison, MIT, UCSF.)*
- Thomson Scientific ranks UCSD the **7th most-cited institution in the world,** based on its published research in science and the social sciences from 1995-2005.
- Thomson Scientific also ranks UCSD **2nd in the nation** for the most cited clinical medicine research papers, **3rd in the nation** for the most influential research in pharmacology, and **5th highest impact research institution** in the nation from 1995-2005.
- In the 2007 survey of graduate programs by *U.S. News,* the Jacobs School of Engineering ranked 3rd and the School of Medicine ranked **1st in the nation for research expenditures per faculty member.** Total federal, state and industry research support at the School of Medicine is $273.7 million, and at the Jacobs School, $129 million.
- UCSD, already one of the most important centers for advanced biotechnology, has emerged, in collaboration with other California partners including the Salk Institute for Biological Studies and The Scripps Research Institute, at a new level of potential with the passage of CA Proposition 71 providing $3 billion in State funding for stem cell research. While the stem cell initiative is just beginning, the state's new stem cell agency, the California Institute of Regenerative Medicine, has awarded UCSD $3.6 million to train scientists to use stem cells in research and clinical settings. The UCSD Human Stem Cell Core Facility maintains established human embryonic stem cell lines, trains scientist to work with them, and provides lab space to conduct stem cell research.

High-Caliber Faculty

- 8 Nobel Prizes (2 are participating in this proposal for the BP EBI)
- 4 National Medals of Science
- National Humanities Medal
- 2 Balzan Prizes

- Fields Medal
- Pulitzer Prize
- Kyoto Prize
- Enrico Fermi Award
- 7 MacArthur Foundation Awards
- 66 National Academy of Sciences Memberships
- 12 American Philosophical Society Memberships

Management Awards

- 1999 Rochester Institute/USA TODAY Quality Cup award for its innovative approach to cutting costs, solving problems, and increasing efficiency. Sole winner in the educational category.
- 1999 Top Prize from the National Association of College and University Business Officers

UCSD Plays a Leading Role in Regional Economic Development

UCSD has an impressive track record in delivering mission-oriented research in support of industrial business applications. A 2006 study by the Milken Institute ranked UCSD as one of the top universities in the world for its prowess in developing and translating biotechnology into medical treatments, drugs, and other commercial applications. The study ranked UCSD 6th and 8th, respectively, for publications and patent activity, and the UC system overall was ranked 2nd in transfer commercialization, which included start-ups, the number of new spin-off companies, and patents issued.

UCSD is actively engaged with 416 R&D companies representing all areas of California's R&D economy.

Between 1995 and 2005, UCSD generated

- 466 active U.S. patents
- 435 active license agreements
- 89 start-ups using UCSD technology
- Approximately 220 companies have been spun-off from UCSD (from faculty, staff and alumni) since it's inception in 1960. Over 40% of these have been founded on technology licensed from the campus.

Faculty and industry are key players in bringing new products to the market. UCSD has an active technology transfer program that serves as an important interface to

- Facilitate transfer of UCSD innovations for public benefit,
- Enhance research experience through tech transfer,
- Promote and target economic development with UCSD technologies.

UCSD is Home to other Mission-Driven Research Initiatives of comparable Size and Scope

The San Diego Supercomputer Center (SDSC)

SDSC is a national center whose mission is to empower the research and education community through the innovation and provision of information infrastructure. Over the last 20 years, SDSC has been a leader in high performance computing and data management, stewardship, and preservation for the academic community. Through a wide spectrum of collaborations and partnerships, SDSC staff and resources have enabled new advances and discoveries and provided leadership in computational science and engineering.

Today, SDSC is the global focus for data-oriented infrastructure and technologies, and data provides the overriding theme for a large number of projects involving SDSC professional staff and collaborators. To serve the research and education community, SDSC has assembled a strong and diverse set of resources, including:

- An outstanding team of 400 multi-disciplinary staff who provide deep expertise in a variety of information technologies and community leadership.
- Three nationally allocated high performance computing systems (DataStar, BlueGene Data, TeraGrid cluster) used by 4500 national users.
- A high reliability data center including a 25 petabyte capacity tape archive—the largest academic data center in the world.
- Broad impact resources for facilitating collaboration including the SDSC/Calit2 Synthesis Center, and a portfolio of robust software and data visualization tools.

SDSC's approach is to provide "value added" services to the community, focusing on larger-scale, synergistic efforts that are difficult to organize or sustain even at a departmental level. SDSC and its collaborators are funded by the National Science Foundation, the National Institutes of Health, the Library of Congress, the National Archives, the Department of Defense, the Department of Energy, and other federal agencies, as well as the private sector and the UC system.

Since its inception in 1985, SDSC has generated $833 million in total funding. With the exception of $83M in support from the State of California and the University of California, San Diego, this funding is generated primarily from contracts and grants. More than 1,000 awards totaling $693 million have been awarded to SDSC for peer reviewed federal awards (primarily by the National Science Foundation). Another $57 million in awards have been generated through other non-federal contracts and grant, collaborations with industry partners and gifts.

California Institute for Telecommunications and Information Technology (Calit2)

The California Institutes of Science and Innovation (CISIs) were established in 2000 as a bold experiment to enhance and sustain economic development for the State of California. They were created to tackle demanding societal problems by harnessing technology-rich research that traverses conventional academic boundaries. As the result of a highly competitive and nationally peer-reviewed process, four institutes were selected and inaugurated. In the short time since their creation, the Institutes have substantively engaged with industry, infrastructure stakeholders, and government agencies. The CISIs have attracted attention worldwide for their innovative and effective models for public-private partnerships and are recognized as a credit to California's farsightedness. Calit2, comprising academic researchers at both the UC San Diego and UC Irvine Campus, is widely recognized as the most successful of the Institutes.

The mission of Calit2 is to: (a) develop and deploy communications and information technologies that will establish California's leadership in the global knowledge economy; (b) apply these transformational technologies to high-impact sectors that will improve citizens' quality of life, among them energy, health care, intelligent infrastructure (buildings and roads), ubiquitous communication, environmental monitoring, transportation, homeland security, nanodevices, and entertainment, and; (c) provide an interdisciplinary, world-class research environment that will educate and inspire professional, graduate and undergraduate researchers to apply science and engineering to address societal needs. Calit2 also provides numerous state-of-the-art test beds for both industry and for the services provided by SDSC.

Calit2 has over 300 faculty members from 30 different academic departments who have worked together on a variety of federal, private, and state funded projects. The Institute has been awarded over 145 peer reviewed federal grants in its four-year history amounting to $346 million dollars. In addition, to the work with the public sector Calit2 was partnered with over 150 companies from the private sector. 77 of these companies have contributed gifts or worked on sponsored research with the Institute amounting to $72 million dollars of funding. These dollar amounts supplement the initial $100 million dollar investment from the State of California, leading to a scientific R&D portfolio of nearly half a billion dollars.

Scripps Institution of Oceanography's Fleet of Research Vessels

Scripps has operated research vessels since 1917. Over time the fleet has grown and changed from coastal sailing ships, to converted Navy vessels in the postwar era, to today's set of four modern ships: R/Vs Roger Revelle, Melville, New Horizon and Robert Gordon Sproul. Scripps is a founding member of the nearly 35-year old University-National Oceanographic Laboratory System (UNOLS), the consortium of U.S. ocean science institutions that operate and/or make significant use of research vessels in pursuit of programs of ocean science research and education. The Scripps component of the UNOLS fleet is larger than that of any other UNOLS member institution. Scripps' newest and most capable ship, R/V Revelle, was built and is owned by the US Navy, in common with several of the large UNOLS vessels based at institutions around the country. Scripps won assignment and operating responsibility for Revelle in a national competition in 1991; the ship was completed and delivered to Scripps in 1996. Scripps ships have supported projects in every ocean and have sailed well over 6 million miles globally since voyage records began to be kept in the 1950s.

The purpose of the vessels of the Scripps fleet, and of the larger UNOLS fleet of which it is a part, is to give safe, effective and cost-efficient support to the funded seagoing science projects supported by US science agencies, and also to state-, university- and privately-funded research projects making use of the same vessel capabilities for similar objectives. The UNOLS ships, and all four of the Scripps ships, stand ready to accommodate a wide variety of scientific projects. These could range from detailed geophysical surveys of the seafloor to air-sea interaction studies to collection and analysis of biological samples in a study region, to deployment and management of autonomous vehicles in a focused regional experiment, and more. The overwhelming majority of utilization of the fleet is by federally-funded research projects, chiefly those of the National Science Foundation, with lesser involvement of the Office of Naval Research and the National Oceanic and Atmospheric Administration. Within the last ten years, funding for the Scripps Fleet has approached $212 M.

4.3 Connecting to the "Biotechnology Ecosystem"

UCSD is one of the primary drivers of the San Diego biotechnology ecosystem, and has been since its creation. Ivor Royston was a UCSD professor when he founded San Diego's first biotech company, Hybritech, in 1978 (and he remained at the University until 1990). Many of San Diego's leading biotech companies were founded by Hybritech's original management team. Royston subsequently founded Forward Ventures, a leading life sciences venture firm, in addition to Idec Pharmaceuticals, which was sold to Biogen in 2003 to become Biogen Idec, the third largest biotech company in the world. In 2004, the Milken Institute's Biotech Index listed San Diego's biotech cluster first in the world, based on research and development, and company creation.

Professor Irwin Jacobs is another great example. He was a Professor of Computer Science & Engineering at UCSD from 1966 to 1972. He founded LINKABIT Corporation with Dr. Andrew Viterbi in 1978 to develop satellite encryption methods. IN 1985 he funded Qualcomm to develop CDMA technology commercially. The company is now one of the largest wireless communications companies in the world and is located immediately adjacent to the UCSD campus.

In 1985, in collaboration with the San Diego business community and other civic leaders, UCSD founded CONNECT to accelerate technology-based economic development in San Diego. From the beginning, CONNECT was a resource for the entire San Diego community. CONNECT has always been entirely funded by the private sector, through company sponsorships and event underwriting. Between 1985 and 2005, UCSD operated CONNECT as a public program of UCSD Extension. In 2005, it spun out of UCSD, but it still remains intimately linked to the University. Since its inception in 1993, Springboard, CONNECT's entrepreneur-assistance program, has assisted well over 1,000 start-ups, roughly half of which have been in biotechnology/life science. These Springboard companies have collectively raised over $620M in early-round financing, with over two-thirds surviving more than five years. Today, these companies have a total market capitalization of more than $12B.

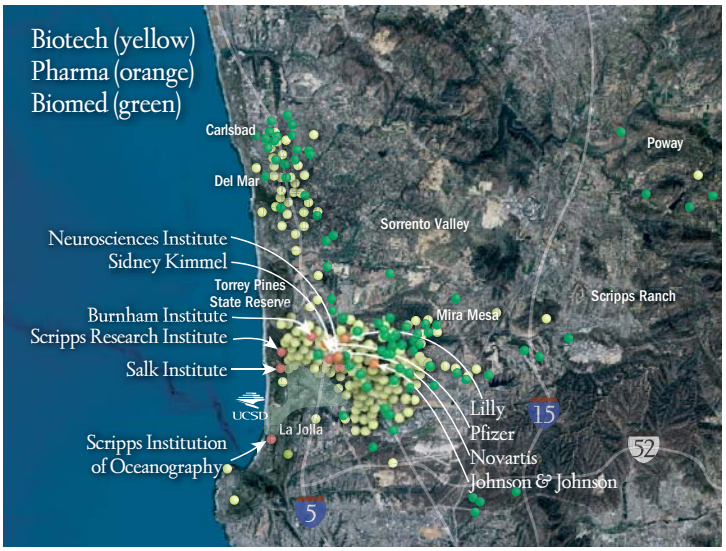
The CONNECT model has inspired the creation of similar business accelerators around the world, in countries such as Australia, Denmark, Estonia, Jordan, Korea, Latvia, New Zealand, Norway, Sweden, Taiwan, and the UK. Global CONNECT was founded in 2003 (and remained at UCSD after CONNECT's spin-out in 2005), to interface with this growing worldwide

network of business accelerators, to bridge high tech/life science enterprise into and out of Southern California, to conduct research and assessment of regional innovation systems, and to provide project-support for international university-industry collaboration.

The current CEO of CONNECT, Duane Roth, is himself a biotechnology entrepreneur, and is a board member and previous chair of BIOCOM, San Diego's life sciences industry trade association and the largest regional life sciences association in the world, representing more than 470 member companies. BIOCOM focuses on initiatives that influence the growth of the life science industry, including capital formation, public policy, workforce development, and scientific discovery and development.

Through CONNECT and Global CONNECT, UCSD's links with the San Diego, California, U.S., and worldwide biotechnology ecosystems extend far beyond the work of UCSD's technology transfer office, although that office (TechTIPS) is the most active campus technology transfer office in the University of California. In fiscal 2005, TechTIPS filed more patents and negotiated more licenses than any other campus in the University of California. TechTIPS works closely with the von Liebig Center at UCSD to accelerate the commercialization of research out of the School of Engineering. The von Liebig Center catalyzes the commercialization of early-stage UCSD technologies via an innovative mix of Center-managed private capital, educational programs, and highly-skilled entrepreneurs-in-residence. Since being founded in 2001, the Center has seeded more than 50 UC San Diego technologies. These technologies have led to 16 licenses, approximately equally spit between startups and larger companies. The Center is active in all technology areas, including information technology, life sciences, clean technologies, materials, and defense applications. The von Liebig Center, with CONNECT operating downstream, actively pulls promising discoveries out of the labs and into the commercialization pipeline.

The absence of a clear separation between the research institutions on Torrey Pines Mesa, the area adjacent to UCSD, and the private sector in San Diego is most apparent from the physical density of the life sciences industry cluster. The vast majority of the biotechnology and pharmaceutical firms in San Diego are located in the immediate neighborhood of UCSD and the other major research institutions. Over 28,000 biomedical professionals work within a four-mile radius of UCSD. The physical proximity of so many colleagues facilitates frequent interaction, and, in turn, an intensely collaborative environment.



In a 2001 US Council on Competitiveness study, Michael Porter noted that "successful regions do not rely on chance, but rather seek to institutionalize the innovative process" and "institutions for collaboration can significantly increase the success rate of start-up companies." This study highlighted how San Diego's life sciences industry has benefited from the culture of collaboration that has been institutionalized through UCSD, CONNECT, BIOCOM and the other regional organizations that comprise key elements in San Diego's biotechnology ecosystem.

In addition to world-class science, entrepreneurs, and skilled talent, San Diego has a substantial share of risk capital. From angel capital to growth private equity, San Diego has a continuous and well linked "capital food chain." The Tech Coast Angels, the largest organized angel network in the U.S., with four chapters, shares administrative support and meeting space for its San Diego chapter with CONNECT. San Diego has a total of 29 venture capital firms, 16 of which are headquartered locally. Since 1995, San Diego entrepreneurs have received more than $10.3B in venture capital in 1,357 separate deals. In addition, San Diego is home to one of the nation's few venture capital firms with a focus on global agricultural biotechnology, Finistere Partners. Their chairman, Jerry Caulder, is often referred to as the "father of AgBio," and his company, Mycogen, San Diego's

second life sciences company, was sold to Dow in 1998 for $1.2B. Finistere Partners have expertise in the plant and agricultural side of life sciences, together with a deep domain knowledge of biology and chemistry.

San Diego's capital and professional services communities interact with researcher-entrepreneurs routinely. The entrepreneur-assistance program at CONNECT, Springboard, is sponsored by the various local professional services firms, and representatives of these firms, as well as members of the capital community, serve regularly on Springboard panels to assess business cases. CONNECT convenes about 50 Springboard panels per year.

The previous director of the Springboard Program at CONNECT now directs the Biosciences Department at UCSD Extension. The instructors of Extension's bioscience courses, both live and online, are practitioners from the local biotechnology sector. An average of 1,200 professionals, mostly from the local life sciences community, take these courses annually. The director plans new course development with the assistance of an advisory board made up of industry professionals.

Through these multiple contact-points, including the many UCSD student-interns and UCSD alumni working in the local life sciences sector, UCSD's relationship with the biotechnology ecosystem extends well beyond education and research, through knowledge transfer and company creation, to lifelong retraining.

4.4 CBEST Experience in Relevant Research Domains

The extensive, diverse qualifications of the CBEST collaborators are difficult to provide a summarize concisely. We have chosen to document our qualifications at two distinct levels:

- Below, CBEST collaborators provide a brief description of their research expertise and experience at an *institutional* level.
- We include a section containing relevant publications after the appendices. This material was forwarded by *researchers* who have expressed interest in pursuing research within the EBI.

University of California, San Diego

Researchers in the **Division of Biological Sciences** have experience and expertise primarily in the area of biomass production. Some of the skills and plans of these faculty are enumerated here.

- Creating whole proteome profiles of cells or organs that identify (by amino acid sequence) and quantify (precise relative quantities) more than 10,000 proteins from cultured cells and tissues. These methods should be very robust with the simple proteomes of microbes.
- Designing and making artificial DNA-binding proteins that target any given 19 bp sequence. These can be used as transcription factors to create artificial regulatory networks or as affinity reagents to purify intact chromatin for characterization by mass spectrometry. This artificial DNA binding technology can be adapted for use as rapidly-engineered disease resistance genes and is working on this technique to control pests in a manner which is economically feasible for large-acreage, low-value crops.
- Laying the foundation for systems biology using *in silico* models to accelerate the development of plant and microbial strains, and developing systems approaches for engineering microbes. Employing constraints-based analysis methods to identify strategies and approaches for optimizing biomass production and conversion to fuel.
- Identifying and characterizing a number of genes that regulate lignification in plant cells. UCSD holds a patent on the use of these genes to control lignification, and plans to expand this work in this area to support biofuel production.
- Identifying a number of regulatory genes that act early in the pathway of grass inflorescence development. Modifying expression of these genes in transgenic *Miscanthus* or switchgrass could prove beneficial to creating plants shuttling more energy into vegetative biomass (leaves and shoots), as opposed to reproductive biomass (inflorescences, pollen and seeds).
- Improving sustainable biomass production by increasing nitrogen use efficiency, identifying nitrate regulatory factors (NRF) that control nitrate assimilation, modifying expression or activity of NRFs and determining effect on N and C metabolism, and then determining the effect of nitrate and nitrate transporters on guard cell movements that control gas exchange and C-fixation.

- Understanding cytoskeleton-dependent mechanisms governing plant cell shape and the orientation of plant cell division, identifying single gene changes that improve the yield of fermentable sugars from walls of bioenergy crops of the grass family, and developing tools for engineering low-silica bioenergy crops.
- Enabling the production of enzymes for industrial scale degradation of plant ligno-celluosic materials, identifying promoters for activating genes at important times and important tissues for biomass production. Bioengineered microbial enzymes that mediate enhanced and/or inducible (e.g. heat-inducible and thermo stable) degradation of lignin and cellulosic materials will be expressed in biomass producing plants at late pre-harvesting stages. The pre-degradation of lignin and cellulose materials in plants via expression of these enzymes directly in transgenic plants, at the right time and in the right tissues will contribute to greatly enhancing the cost effectiveness and competitiveness of biofuel production.
- Pursuing projects defining mechanisms that control drought resistance, CO_2 influx into leaves of plants; microscopic scale and large field scale analyses of water use efficiency in plants; carbon dioxide sensing mechanisms that control CO_2 intake into plants, and methods for characterizing ion and nutrient transport and allocation mechanisms and stress-induced signal transduction mechanisms.

Current genome-scale systems biology research aimed at microbial cells taking place in the **Department of Bioengineering** focuses on: (a) the reconstruction of genome-scale biochemical reaction networks, (b) the development of mathematical analysis procedures for genome-scale models, and (c) the experimental verification of genome-scale models with current emphasis on cellular metabolism and transcriptional regulation in *E. coli* and yeast. Genome-scale reconstructions are a common denominator for the scientific community that is focused on analyzing the systemic aspects of cellular functions. Accordingly, continued development of these reconstructions is needed, and their applications to distal and proximal causation in biology will continue.

The economic viability of fermentation-derived products from fermentable sources can be determined through econometric models. During the energy crisis of the early 1980's, researchers developed an integrated econometric model of the chemical industry and fermentation-derived products. This model showed, at the time, that fermentation products were about eight-times more expensive than petro-chemically derived products. The study must be updated for changes in (a) the economic environment and (b) the changes in technical capabilities that have taken place, such as the genome-scale strain design procedures outlined above.

The Department of Chemistry and Biochemistry at UCSD has the breadth of expertise to contribute to a wide range of questions relevant to a successful biofuel program. Atmospheric chemists are prepared to address the critical questions of the environmental implications of biofuel production and how we deal with production of additional nitrous oxide, a key greenhouse gas. In addition, measurements can be made of the emissions and health effects of new biofuels compared to traditional fuels. A prerequisite for increased energy crop production is a clean and cost-effective method to generate fixed nitrogen. We are seeking understanding of the molecular basis of biological nitrogen fixation, with the goal of improving the efficiency of the industrial process and generating new biocatalysts for ammonia and hydrogen production. This avenue of research is in line with the department's strengths in biological and inorganic chemistry, and is supported by extensive intellectual and instrumental infrastructure including protein crystallography, EPR and laser spectroscopy, and electrochemistry.

We are also developing an understanding of the physical and mechanistic chemistry occurring at solid/solution interfaces, including those interfaces that are at the heart of innovative alcohol-utilizing fuel cells, novel batteries, and an important energy-storage technology known as supercapacitors. The expertise of the researchers in this field exploits optical spectroscopy, NMR spectroscopy, and microscopy. NMR spectroscopy is among the principal approaches to chemical and biological research at UCSD. All of the spectrometers are capable of the full-range of high-resolution solid-state NMR experiments involving multiple-pulse and multiple-resonance methods for stationary and magic angle spinning samples. This instrumentation is essential for the studies of cellulose, hemicellulose, and lignin in plants.

Another relevant focus of inquiry is the chemistry, electrochemistry, and photophysics of nanophase semiconductors, with emphasis on photonic crystals and biomaterials. Current departmental research focuses on applications in medical diagnostics, high-throughput screening, and low-power sensing of toxins, pollutants, and chemical or biological warfare agents.

Scripps Institution of Oceanography (SIO) has extensive experience in small-scale biomass production from non-plant non-terrestrial sources such as phytoplankton, algae, and cyanobacteria. We have isolated novel marine phototrophs such as *Prochlorococcus* and *Synechococcus*, which are now known to be the most abundant phototrophs on the planet. Characterization of microbe photophysiology for measuring or optimizing growth rate of these and similar organisms is also an area of expertise. Genetic manipulation of marine phototrophs that could be used to alter characteristics such as sugar or lipid content have been developed or are being used by SIO scientists. Phytoplankton are considered an important future source of biomass especially for biodiesel and a evaluation of this from a marine/estuarine perspective could be undertaken with SIO expertise.

SIO scientists have been involved in exploring the immense diversity of enzymes and metabolisms found in marine organisms through ecological, physiological, biochemical, molecular, and genomics techniques. While not yet working on cellulases specifically, SIO scientists believe that novel cellulases from marine or estuarine microbes would be a fruitful area of discovery using techniques developed in their labs.

SIO has an active group of researchers, including two Nobel Laureates, interested in atmospheric science and the environmental implication of increased nitrous oxide concentrations associated with biomass production. SIO also has substantial expertise in the study of microbial carbon fixation, especially in the surface ocean, by marine cyanobacteria. Several researches have led or been involved in analyzing the genomes and metabolic pathways of cyanobacteria as part of DOE sponsored projects to understand the mechanisms of microbial carbon fixation. SIO also has expertise in the microbiology of deep-sea environments including those possessing methane hydrates or being proposed for carbon dioxide injection. The general factors regulating microbial cycling of C in the oceans is an active area of research at SIO.

SIO has invested for several years in the establishment of The Scripps Genome Center. This facility has the cyberinfrastructure for multiple types of genomic and metagenomic analyses. The application of this information to understanding carbon fixation by model phototrophs and carbon degradation by heterotrophic microbes has been a focus of the center. SIO also has an analytical facilities center and substantial expertise in the chemical analyses of microbial cell constituents using state of the art analytical techniques including LCMS, GCMS, FTIR, UV and NMR. These could be readily applied to analysis of biomass production.

The computational proteomics group in the **Computer Science and Engineering Department** is developing novel algorithms for analysis of mass spectrometry data. They plan to generate proteogenomic annotation of plant genomes using high-throughput tandem mass-spectrometry datasets. They have developed algorithms to construct and efficiently search spectra against a genomic database, with no prior knowledge of encoded proteins. A recent study by this group involved searching of a corpus of 18.5 million MS/MS spectra. They validated 39,000 exons and 11,000 introns at the level of translation. This included translation-level evidence for novel or extended exons in 16 genes, confirmed translation of 224 hypothetical proteins, and greater than 40 alternative splicing events. Polymorphisms were efficiently encoded in the database, allowing the confirmation of variant alleles for 308 coding SNPs. Correspondingly, they constructed the first comprehensive proteogenomic map of a bacterial genome (*Shewanella oneidensis* MR-1), including a large number of chemical modifications, mutations, signal peptide cleavages, and cleavage of N-terminal methionine residues. They also detected multiple genes that were missed or assigned incorrect start positions by gene prediction programs and suggested corrections to improve the gene annotation. The results show that as many as 20% of genes even in such well-studied genomes as *Shewanella oneidensis* MR-1 may be misannotated. Interestingly, both studies were conducted on 'well annotated' genomes. The use of mass spectrometry towards the annotation of plant genomes, as well as the identification of novel post-translational processing will be a critical part of the proposed cyberinfrastructure.

Faculty members in the **Department of Physics** have experience and expertise in a number of areas that are relevant to research on biofuels. Several faculty members have performed research on various aspects of heterogeneous catalysis related to hydrocarbon fuels such as catalysis of methanation reactions $CO + 3H_2 \rightarrow H_2O + CH_4$ and $CO_2 + 4H_2 \rightarrow 2H_2O + CH_4$ by novel rare earth compounds and environmental control such as catalyzed oscillatory carbon monoxide oxidation reaction $CO + O_2 \rightarrow CO_2$ by Pt, Pd, and Ir. Other faculty members have made important contributions in the biophysics of photosynthesis and electron transport. This experience will be useful in engineering improved molecular apparatus for photosynthesis. We also have expert-

ise in the nonlinear dynamics and fluid mechanical issues involved in oil recovery. More generally, there is deep experience and expertise within the theoretical biophysics group in the computation of molecular interactions, which may be channeled to developing software for purposes such as carbon/nitrogen sequestration and methanation. Researchers also have expertise in statistical physics and optics which are relevant to optimal sunlight redistribution, engine design, and power conversion.

The **Department of Mechanical and Aerospace Engineering** (MAE) at UCSD houses the Chemical Engineering Program, and the faculty also represent a large portion of the Center for Energy Research. The faculty, as a group, have substantial expertise in combustion, reactor engineering and process scaling, sensors, and controls. Experience with bio-reactors and biofuels includes a USDA-sponsored project that investigated production of ethanol in a continuous flow bioreactor, including study of microbial kinetics, immobilization technology, and air-lift and fluidized fermentor design. In conjunction with West Biofuels, a number of MAE faculty are currently pursuing development of a reactor for production of alcohol-based fuels from cellulosic biomass. Plant design and process engineering software, vital for scaling processes from lab to reality, is commonly used and could be applied to bioreactor design.

Fuels produced from bioreactors will need to be practically useful; they will need to have ignition and combustion properties so that they will work in common combustion devices such as gas turbines and engines. MAE researchers conduct cutting-edge research into the influence of fuel properties on combustion performance, including the effect of additives, and the effect of addition of biofuels into traditional (coal) power systems. Laboratory measurements are translated into compact chemical mechanisms that can be used in process performance prediction. Practical measurements are made in engines, gas turbines, and power plants, including a current project emphasizing measurements in gasification systems. Such work has resulted in well over 120 publications by MAE faculty, and has been funded over many years by the NSF, AFOSR, DOE, and the U.S. Army, in particular.

The Controls group in the MAE department is a leader in the development of techniques for real-time optimization, and have been involved in several application areas relevant to energy systems, such as gas turbine engines, automotive engines, chemical process control, and bioreactors. Related to reactor design and resource extraction, faculty in MAE have also had funded projects in surfactant-enhanced porous media flow and its application to enhanced oil recovery, and have numerous publications in modeling heterogeneous flows in porous media using stochastic methods.

Iowa State University

Iowa State University, as a premiere land grant university located in the center of the burgeoning biofuels industry, will bring a combination of expertise in agronomy, plant science, agricultural engineering, economics, and rural sociology to the problem of large-scale biomass production and processing. Iowa State University has a long history of breeding high yielding crops with desirable feedstock properties; developing agronomic practice and harvesting machinery appropriate to large-scale agriculture; processing commodity crops into a variety of food, feed, and fuel products; and analyzing the economic and environmental impacts of agricultural enterprises.

In 1999, Iowa State University established the **Plant Science Institute** to apply genomics, proteomics, metabolomics, and bioinformatics to the improvement of agriculture. The PSI has helped generate knowledge and develop practices for the creation of valuable traits in crops important to Iowa using the power of genomics and bioinformatics. The PSI serves as a catalyst for collaborative education, inter-disciplinary research and technology transfer activities and is devoted to the development of innovative solutions to meet challenges in agriculture for the benefit of society.

More recently in this 150-year history of agricultural and engineering research, education, and outreach, ISU faculty have turned their attention to a variety of problems in bioenergy. In 2002, the university formally organized the **Bioeconomy Initiative** to bring cohesion to these diverse efforts in biorenewable resources and biobased products. The Office of Biorenewables Programs works with 15 research centers and 15 academic departments at ISU to organize faculty in multi-disciplinary teams to apply integrated approaches to large-scale bioenergy systems. This effort has resulted in over $40 million in cumulative funding in the last four years to support bioenergy and biobased products research.

Since its creation in 1905, the **Department of Agricultural and Biosystems Engineering** (ABE), has been a leader in providing engineering solutions to agricultural problems in the United States and the world. In addition to traditional strengths, the department's current research efforts include biosystems engineering through the use of biosensors, image analysis, biological systems modeling, and the design and control of biological systems and processes. The Department was ranked 5th nationally in undergraduate programs and 10th in graduate programs by *U.S. News & World Report*.

The **Agronomy Department's** research programs range from very basic molecular-level projects to applied, field-oriented projects. Between departmental faculty and USDA scientists, the Agronomy Department has a large critical mass of plant breeders and geneticists spanning the spectrum from variety development to gene discovery and mapping. Agronomy Extension provides research-based educational programs in a variety of agronomic areas to support producers and agri-business professionals, with the objective of making crop production more efficient, productive, and economically and environmentally sustainable. Programs within the Department of Agronomy are leveraged by the tremendous expertise of a large group of USDA scientists located at Iowa State.

The USDA-ARS National Soil Tilth Laboratory is a multidisciplinary laboratory that addresses the problems of crop and livestock management and environmental quality. The USDA-ARS Corn Insects and Crop Genetics Research Lab develops strategies for genetic improvement of adapted and exotic maize germplasm and the relationship between these genetic improvements and genome modifications.

The North Central Regional Plant Introduction Station is one of four plant introduction stations in the United States and supports the acquisition, documentation, regeneration, health, characterization, evaluation, distribution and enhancement of the plant genetic resources held in the collections. Nearly 50,000 accessions of germplasm are maintained at the station.

The USDA-ARS/ISU is developing a collaborative bioinformatics and computational genetics facility called the Crop Genomics and Genome Informatics Laboratory (CGGIL). ISU hosts several national and international crop genome databases directed by leaders in the field of plant bioinformatics. The databases include BarleyBase and PLEXdb, Maize GDB, SoyBase, and Plant GDB. CGGIL will consolidate many of these activities into a central facility on campus.

The **Center for Agricultural and Rural Development** (CARD) conducts public policy and economic research on agricultural, environmental, and food issues. Recent CARD research efforts have focused on the impacts of policy alternatives for trade and agricultural policy, resource and environmental policy, food and nutrition policy, agricultural risk management policy, science and technology policy, and biorenewables policy. Communication efforts target state and federal policymakers; the research community; agricultural, food, and environmental groups; individual decision makers; and international audiences.

The new Biorenewables Policy Division in CARD addresses questions surrounding expansion of biorenewables in the United States. Initial research will focus on the outlook for biofuels and crops used for biofuels production, including the effect of biofuels growth on the level and volatility of crop prices. Research will also explore the impact of biofuels growth on the mix and location of livestock, effects of possible policy changes on biofuels production and prices, impacts of increased biofuels production on water quality, and impacts on local bases for maize and soybeans.

Established in 1984 by a grant from the U.S. Congress, the **Food and Agricultural Policy Research Institute** (FAPRI) is a unique, dual-university research program. With research centers at ISU's CARD and the Center for National Food and Agricultural Policy (CNFAP) at the University of Missouri-Columbia, FAPRI uses comprehensive data and computer modeling systems to analyze the complex economic interrelationships of the food and agriculture industry.

J. Craig Venter Institute

The Venter Institute (VI) comprises two research divisions—The Institute for Genomic Research (TIGR) and The Center for Advanced Genomics (TCAG—and the Joint Technology Center (JTC). VI has world-class expertise in the development and application of genomics to a number of basic and applied research areas including biological energy, environmental genomics,

human genomic medicine, synthetic biology, microbiology, and plant biology. High-throughput technologies such as DNA sequencing, DNA amplification, annotation, gene expression and protein identification are the hallmarks of the Institute.

An overarching focus of the Institute is to move frontiers of "discovery science" forward with an eye toward very specific, problem-based goals. Implicit in the focus of our bioenergy program is the recognition that a basic understanding of the various components in biological systems is necessary to make predictions and identify new functions and to be able to engineer new pathways and organisms for developing bioenergy production. The VI Biological Energy group is currently working on cellulosic ethanol, biohydrogen production, and microbial fuel cells to create cost-effective alternative fuels for both transportation and energy needs in other industrial sectors.

The Joint Technology Center (JTC) is a highly efficient, state-of-the-art high-throughput sequencing and research facility. In 2003, the high throughput DNA sequencing, template preparation, genome closure and library construction groups from the Venter Institute's sister organization, TIGR were renamed as the JTC upon moving to a new 27,000 sq. ft. laboratory space. Since inception, the JTC has produced more than 110 million sequence reads containing approximately 75 billion high quality bases from an extraordinarily diverse set of projects. The average sequencing success rate has been 88% and the average read length is approximately 800 base pairs. To date, the JTC has successfully produced approximately 2,000 libraries of different types, and completed more than 250 genomes, including those of phages, plasmids, virus, microbes, fungi, plants, invertebrates and mammals. In addition to whole genome sequencing projects, the JTC has also completed a variety of different types of projects, including approximately 20 EST projects, more than 10 BAC end projects and several metagenomic and PCR-directed sequencing projects. The JTC has been a leader in the field of metagenomics, generating approximately 8 million sequence reads from more than 50 environmental libraries derived from ocean, soil, and air samples, as well as from within humans. The JTC was also one of the first organizations to acquire and implement a new massively parallel sequencing platform from 454 Life Sciences Corporation.

Two capabilities provided by the TIGR component of VI are high-throughput functional genomics and plant genomics. The functional genomics program comprises microarray production, the Gateway® Clone Resource, comparative genomics, and proteomics to provide reagents, training, and bioinformatics support. The microarray production program also provides a platform for high-throughput comparative genomics (gene discovery, comparative genome hybridization, and diagnostics). The Gateway® Clone Resource at TIGR uses Invitrogen recombination cloning technology to provide sequence-validated entry clones as the initial reagent for recombinant protein expression and protein arrays. TIGR currently has the ability to generate 25,000 clones per year. Because the process uses microtiter plate technology and is an entirely robotic, LIMS driven process, clone production levels are scalable to several times that capacity if required.

The plant genomics program at TIGR is a major endeavor with more than a dozen major research projects underway involving a wide range of plant species, including rice, *Arabidopsis*, potato, maize, Medicago, soybean, tomato, barley, pine, onion, banana, and several microbial pathogens that afflict important crops. In a groundbreaking international project, TIGR played a leading role in an international consortium that deciphered the first complete plant genome: *Arabidopsis thaliana* (thale cress), which is widely used as a model plant for global research. Since that landmark publication in Nature in 2000, TIGR plant researchers have tackled other major plant genomics initiatives, including the international rice genome initiative and a new project to identify and decipher genes in maize. Taking steps well beyond the basic sequencing of plant DNA, researchers at TIGR are also using cutting-edge technologies to examine the functions of plant genes, to compare them to the genes of related species, and to track the complex metabolic pathways through which plants convert energy to sustain life. TIGR's plant genomic research is focused mainly on discovering genes and their functions, comparing the genomes of various plant species, and exploring the interactions between plants and the pathogens that infect them. With its ability to collect the necessary data in linked databases, TIGR is an ideal center for comparing the genomes of related plants. Given the tremendous diversity of crop species, comparative genomics is playing an increasingly important role in leveraging the complete sequences of model species—such as *Arabidopsis* and rice—to a variety of crop relatives.

The Synthetic Biology and Biological Energy groups at the Venter Institute, led by Nobel Laureate, Dr. Hamilton Smith, are working on new methodologies to synthesize large segments of DNA to eventually enable the construction of whole artificial

chromosomes that can be used in a variety of ways related to bioenergy production. These teams are interested in engineering new pathways that could lead to new methods for fuel production and perhaps carbon sequestration. In 2003, the Synthetic Biology team made significant advances toward the goal of a synthetic genome. Using new methods the group improved the speed and accuracy of genomic synthesis by assembling the 5,386 base pair bacteriophage ÊX174 (phi X) in just 14 days. The Biological Energy team is currently working on reengineering cellulose and photosynthetic pathways in certain bacteria to produce ethanol and biological hydrogen.

The Gordon and Betty Moore Foundation has awarded $24.5 million over seven years to UCSD, Calit2, the Center for Earth Observations and Applications, and the Venter Institute to create the Community Cyberinfrastructure for Advanced Marine Microbial Ecology Research and Analysis (CAMERA)—a state-of-the-art computational resource tool that will be used to decipher the genetic code of communities of microbial life in the world's oceans. Scientists will use CAMERA for metagenomics research—analyzing microbial genomic sequence data in the context of other microbial species, as well as, in comparison to a variety of other "metadata" such as the chemical and physical conditions in which microbes are sampled. The CAMERA project builds on pioneering efforts in metagenomics to sequence the genomes of entire microbial communities, often comprising thousands of species. The largest such effort is Venter Institute's Sorcerer II Expedition, which is developing the first large-scale genomic survey of microbial life in the world's oceans to produce the largest gene catalogue ever assembled. The data from the Expedition will more than double the number of protein sequences currently available in the National Institutes of Health's GenBank. The metagenomics database will include new sequences, genes and gene families, together with their annotations and associated environmental metadata. The expedition has uncovered approximately 12,000 new cellulases and other enzymes related to bioenergy production.

Over the past two years, the VI Policy Center has been committed to fully exploring and educating the public and policymakers about the risks and benefits of synthetic biology, through a series of multidisciplinary workshops and in-house research. VI Policy Center researchers have had extensive experience with policy and integrated assessments of air and water pollution, climate change, and biotechnology.

Battelle Memorial Institute/Pacific Northwest National Laboratory

As contractor o the federal government for managing Pacific Northwest National Laboratory, BMI has full access to all government-owned facilities and equipment to perform private research as Battelle under the terms of a Use Permit unique within the national laboratory system.

BMI/PNNL possesses several technologies and capabilities to support bioenergy research and development. Fungal biotechnology expertise focuses identification of glycosyl hydrolases, cellulases, hemicellulases, and ligninases in fungal genomes, and in strain improvement for increased ethanol tolerance that the ability to co-ferment C5 and C6 sugars. Enzyme activity and stability is often improved by the use of nanoporous materials: enzymes immobilized to these materials can show increased specific activities, and activity in extreme conditions. Catalysis research focuses on the use of combinatorial libraries to identify new catalysts followed by verification and scale-up.

Systems biology at BMI/PNNL combines several high-throughput technologies. Global proteomics relies on the use of an array of mass spectrometers coupled to a high performance liquid chromatography front end. The two-part process first identifies peptides, much like other traditional proteomic methodologies. The second part uses the FTICR mass spectrometer for high capacity validation and quantitation. The use of an NMR bioreactor allows for in situ measurement of metabolites in single or mixed community cultures of microbes. BMI/PNNL has the capacity to currently produce 384 proteins per day using an in vitro wheat germ translation system. This technology allows the use of PCR to generate templates for transcription and is ideally suited to express proteins identified in community sequencing projects or the Global Ocean Survey sequencing project. Microbial community dynamics capabilities allow the cultivation of microbes under highly controlled conditions that promote a variety of growth conditions (aerobic, anaerobic, fermentative, or photosynthetic) of single or mixed organism (community) cultures. This capability allows for extensive research into metal reducing cycles, carbon fixation and sequestration, hydrogen

production, and syntrophy conditions.

BMI/PNNL is also home to DOE's Environmental Molecular Sciences Laboratory, or EMSL, user facility. This facility houses instrumentation and scientific expertise for several capabilities for environmental, biological, and energy research. These capabilities include:

- Fundamental research on the chemistry and physics of complex systems determines molecular information about processes occurring at the surface and interface of liquids, solids, and gases.
- Minerals and microbe surfaces are examined using environmental spectroscopy and biogeochemistry analysis and modeling.
- Structural biology, solid-state materials and catalysis, and imaging studies are the focus of EMSL's high-field magnetic resonance resources, which include spectrometers ranging from 300 to 900 MHz.
- Proteomics research by high-throughput techniques is carried out using high-performance mass spectrometers.
- The interfacial and nanoscale science of materials are determined by material synthesis, characterization, and microanalytical separations and sensing.
- Computational studies of physical, chemical, and biological processes are performed using molecular science computing hardware, software, and visualization resources.

These capabilities are driven by over 130 instruments comprising several spectroscopic, imaging, and computational platforms. In addition, BMI/PNNL has partnered with Washington State University to build the Bioproducts Science and Engineering Laboratory (or BSEL). This facility, now under construction in Richland, WA, will house scientists from both institutes who aim to develop new processes to harness microbes and fungi to make chemicals and bioproducts on an industrial scale.

The Salk Institute of Biological Studies

The Plant Biology Laboratory at The Salk Institute is committed to pursuing questions that are fundamental to understanding the basic biology of plants. A major goal of the lab is to understand how plants grow and to translate these results to improvements in crop yield, biomass, and alternative energy production. These studies have led to a better understanding of the contributions of ethylene, auxin, brassinosteroids and light quality on plant architecture, yield, and biomass, resulting in more than a dozen issued patents. In addition, research in the Plant Biology Laboratory has led to an improved understanding of chloroplast signaling. Although most of the published studies have used the reference plant, *Arabidopsis thaliana*, the lab technologies are currently being applied to a number of grasses of relevance to this application.

The Salk Institute is also home to "SIGNAL" (Salk Institute Genome Analysis Laboratory) which houses one of the most widely accessed functional genomics databases for plants. Adjacent to the Plant Biology Laboratory is the Chemistry and Proteomics Laboratory, where researchers have studied and manipulated a number of biosynthetic pathways that make natural products in plants. Of relevance to this application, the Chemistry group proposes to employ atomic resolution enzyme structures to guide the design and selection of modular biosynthetic pathways for the production of (a) fatty acid derived acyl resorcinols/acyl phloroglucinols, (b) fatty acid methyl esters, and (c) fatty acid derived acyl methylketones in the chloroplast.

The Scripps Research Institute

Researchers within The Scripps Research Institute's Plant Biology Division of Biochemistry have extensive experience studying the transition from vegetative to reproductive growth in plants, programmed transcriptional control of cell wall elongation and biosynthesis as well as the genetic improvement of grasses to increase yield. TSRI researchers have produced many peer reviewed scientific reports relating to plant biomass.

Novel research at TSRI explores the construction and evolution of complex regulatory networks that regulate a wide range of cellular processes. A key discovery was the tremendous depth at which the circadian clock regulates plant physiology, more specifically, cell wall elongation and biosynthesis. Research focusing on identifying and improving key factors affecting biomass

yield and conversion efficiency has successfully revealed mechanisms by which plants sense the changes in day length and incorporate the environmental information to modulate their growth and developmental programs. Breeding to improve yield of various small grain crops including barley, durum, and wheat has enabled researchers to characterize genotype, environment, and genotype-by-environment interaction effects on wheat kernel quality attributes and survey the population structure of cultivated wheat. Previous research has focused on the functional genomics of hemicellulose biosynthesis in rice and maize and current research explores the molecular mechanisms of biomass yield potential.

4.5 Application of Science & Technology to Energy and Other Industries

We have chosen to document the tech-transfer activities of the CBEST collaborators at two distinct levels:

- Below, CBEST collaborators have provided a brief institutional-level account of their track record for commercializing technology.
- We have included a section with the patents of Project Leaders after the appendices.

University of California, San Diego

Through the **Jacobs School's Center for Energy Research**, UCSD enjoys extensive collaboration with the energy industry. For example, several faculty members are involved in research in gas turbine fuel flexibility in conjunction with Solar Turbines, Inc. This research aims to both predict and limit the occurrence of combustion instabilities associated with lean combustion and with changing fuel blends. Collaborative work with engine manufacturers such as Caterpillar, Pratt and Whitney, and the United Technologies Research Center has explored optimum controls, and is initiating research on the subject of biodiesel combustion. The Jacobs School has just recently signed a Memorandum of Understanding with Sempra Energy to explore ways that faculty and researchers from UCSD could assist in matters ranging from energy strategy to technology implementation. Finally, the Center for Energy Research and the Jacobs School have a long-standing relationship with General Atomics on the subject of fusion energy research; General Atomics and UCSD conduct several million dollars annually in collaborative research on fusion.

Leveraging research investments made by the federal government and not for profits, California **Institute for Telecommunications and Information Technology** (Calit2) has recently initiated a major research thrust focused on energy. Calit2 efforts cover three areas:

- BioFuels-The CAMERA metagenomics data complex gives the Institute a unique opportunity to partner with leading edge energy companies looking for new genes for biomass conversion.
- Green Facilities-Calit2 researchers are looking at how active sensing environments and alternative energies can be used to create physical facilities that decrease energy consumption.
- Fuel Cells-Calit2 is in preliminary conversations with the National Fuel Cell Research Center at UCI to discuss how these technologies can be bought into the Institute's living labs and ways in which cyberinfrastructure can empower their research.

Researchers in the **Department of Bioengineering** co-founded a biotechnology company, AASTROM BIOSCIENCES (NASDAQ: ASTM) in 1988. This company still trades on NASDAQ after an IPO in 1997. Among other products, this company has developed bioreactor technology for cell therapies and retroviral delivery devices. ONCOSIS, founded in 1998, focused on the purging of occult tumor cells in autologous bone marrow transplants. Renamed as CYNTELLECT in 2001, it began to focus on instrumentation for high-throughput screening and *in situ* cell sorting and processing. First commercial product was produced in early 2006 and a second is to be introduced in mid-2007. GENOMATICA, a UCSD spin-off company that is focused on genome-scale reconstruction of metabolic networks in microbial cells, started operations in mid 2000. The primary applications of genome-scale metabolic models are for designing microbial strains for fermentation of bio-feed stocks to chemicals and biofuels, and for antibiotic development in pathogenic strains. Human metabolic models can be used for a variety of clinical and health care applications. These commercialization efforts have lead to over 25 U.S. patents, many of which are in the area of hematopoietic stem cell transplantation, cell culture technology, bioreactor design, gene transfer, cell separations, high-throughput single cell manipulation, network reconstruction, *in silico* model building and metabolic engineering.

Researchers in the **Department of Physics** have applied science and technology to the energy industry and other industries. One application involves superconducting materials that have applications in energy technology in the production, storage, transmission, and efficient use of electrical energy through the development of more efficient motors and generators, superconducting solenoids for storage of electrical energy, and electrical transmission lines. Other technological applications include microwave filters for wireless communication, superconducting quantum interference devices for magnetic sensors, and superconducting electromagnets for magnetic levitation of high-speed trains, magnetic resonance imaging, and mineral separation. Another area involves research on novel materials such as clathrates and filled skutterudites for thermoelectric applications such as refrigeration and electric power generation. Substantial research effort is being conducted in plasma physics towards the ITER project, whose goal is controlled nuclear fusion for electric power conversion. Another area is associated with nanostructures that can be applied to the development of novel catalysts, magnets, and electronics.

Current or former members of the **Division of Biological Sciences'** faculty have founded several companies, including Agouron Pharmaceuticals, Aurora Bioscience, and Senomyx. Many faculty provide consulting services to biotechnology, agricultural, and pharmaceutical companies. Researchers in the Division hold over 50 patents; 37 of these are currently licensed to 11 companies, 6 in agriculture and 5 in biotechnology. The researchers involved in this proposal are among the most productive and the most engaged with industry, largely in food production, but also in health-related pest control and other agricultural applications. The Center for Molecular Agriculture, an Organized Research Unit within the Division of Biological Sciences of which these EBI collaborators are members, has an extensive and very successful track record of bringing together industry and academia for collaboration in annual symposia and other programs and events. Many of these researchers have worked with food and agricultural giants such as Dupont, Novartis and Monsanto, providing both contract research, licensing and consulting.

Researchers in the **Department of Mechanical & Aerospace Engineering** (MAE) are working with West Biofuels on advanced dual-fluidized bed gasification of waste stream processing: forest waste, urban green waste, and agricultural waste. Current work with Solar Turbines (Caterpillar subsidiary) includes measurement, prediction, and mitigation of combustion instabilities, and the impact of fuel variability, in gas turbines. The Controls group has worked with a broad range of industry, notably Pratt and Whitney and United Technologies, to implement control systems for engines based on input from both models and measurements. They currently have a project involving rapid, real-time control of an advanced homogenous charge compression-ignition (HCCI) engine. MAE researchers have also developed models of the operation of catalytic emission control reactors; in particular, these models have been used by Toyota in their Lexus automobile emission control systems. In general, MAE researchers work with a broad variety of industrial partners in both energy and life sciences.

Climate scientists at **Scripps Institution of Oceanography** (SIO) have interacted with the energy industry in predictions of global climate change as a function of growing atmospheric greenhouse gas levels. In particular, regional observations of snow pack, time of melting, and annual precipitation have been used to couple energy needs regionally with secular changes in the climate. SIO scientists have been working closely with the pharmaceutical industry to discover new marine natural products and bring them to clinical trials. Recent efforts from SIO biologists funded by the Air Force have been directed at designing novel nanodevices using parts constructed from (diatom) phytoplankton, e.g., silica frustules and ceramics derived from them.

The BP Institute at Scripps is currently three years old. The past three years have been devoted to research and development in deep ocean technology used to detect submarine ground movement and instabilities. The research is increasingly important as oil recovery proceeds to greater and greater depths. During the coming three years, the research program will concentrate on understanding the climate in the Gulf of Mexico and particularly its impact on loop currents and hurricanes. Discussions are underway with the BP Institute in Cambridge to develop a joint program in understanding the relationship between extensive seismic data from the Valhall field in the North Sea and cracking, porosity, and transport in the reservoir. ChevronTexaco, as head of a Joint Industry Program sponsored in part by DOE, supports a research program at Scripps on instabilities associated with methane hydrates in the Gulf of Mexico. The seafloor geodesy group works closely with Statoil in monitoring CO2 sequestration in the Norwegian Sleipner field.

Iowa State University

Business and Industrial Applications of Research

- ExSeed Genetics was created in one of ISU's Industry Incubator Facility in 1992 with three employees. They employed more than 60 people when acquired by BASF in 2004.
- In 1991, AMPC, Inc. started using ISU's Incubator Facility to develop a suite of new products from animal blood protein. The Iowa-based (re-named as Proliant in 2000) manufactures high-purity plasma fractions for the diagnostic, life science research, biopharmaceuticals, veterinary vaccine, and human health industries.
- ISU faculty assisted West Central Cooperative in Iowa, in designing their biodiesel manufacturing process in their first biodiesel plant in 1996. This plant is expected to produce 640 million gallons of biodiesel annually by 2010. In 2004, West Central and ISU faculty commercialized adhesives made from soy protein and developed new heterogeneous catalyst for making biodiesel more cost effectively. ISU faculty have helped establish an infrastructure to provide modified soy proteins for industrial use, using a new technology developed at Iowa State that recently was disclosed in a U.S. patent application.
- In collaboration with Genencor, ISU faculty have developed a competitive method of extraction using state-of-the-art enzymes to enhance oil and protein recoveries and separation. In 2004, Genencor expanded its project with ISU by participating in the development of new enzymatic methods for producing soy adhesives.
- ISU faculty have assisted SafeSoy Technologies, Iowa, and Crown Iron Works, Minnesota, to develop a process to mechanically extract oil from soybeans without using hazardous solvents and denaturing the protein in the meal. These products may improve human health by reducing the incidence of heart disease and certain cancers as well as provide new functional properties for food, biobased products and pharmaceutical manufacturing.
- ISU faculty have worked with Grain Processors Corporation, Iowa, since 1992 in developing starch-based technologies using ISU's pilot plant extrusion equipment.
- ISU faculty have assisted MicroSoy (formerly Mycal Corporation), in developing a new process to manufacture soymilk and tofu.
- ISU's Biocomposite Research Team has been working with companies to develop soybean-based adhesives that can compete in traditional adhesives markets.
- Emphasis on leaner pigs has produced pork with lower scores for juiciness and flavor. ISU faculty have worked with Biotronics Inc., to show how ultrasound could be used to improve the quality of pork.
- Sirrah, LLC is a startup biotech company that originated out of research laboratories at Iowa State. The company develops vaccines for swine diseases, specifically Porcine Reproductive Respiratory Syndrome (PRRS) and swine influenza.
- ISU faculty are investigating biorenewable, biodegradable plastics made from proteins found in Iowa crops in collaboration with two Iowa companies, Vermeer Manufacturing Co. and Vibroacoustics Solutions Inc.
- In collaboration with John Deere Co. faculty at ISU are working in the area of biomass harvesting technologies related to renewable energy, as well as in automated guidance and control systems for agricultural equipment.
- Researchers at ISU developed "Impellicone," a patented technology that can significantly reduce the amount of anhydrous ammonia typically used on crops by more accurately controlling its application. The Impellicone is licensed to CDS-John Blue Company, an agricultural equipment manufacturer.
- ISU agricultural engineers are collaborating with the University of Kentucky in first-in-the-nation collection of air emissions data from commercial broiler houses. This is the first data collected anywhere in the country under a new national air-quality monitoring program.
- Smithfield Foods Inc. has provided $100,000 a year for 10 years to support ISU's extension educational programs that focus on best production practices that emphasize environmental stewardship.
- Four All Seasons, L.L.C. is a startup company that develops natural fertilizers for the turfgrass industry made from co-prod-

ucts of the ethanol manufacturing process. The company has been working with an ISU faculty member, who received a patent in 1991 for his discovery that maize gluten meal can be used as a natural "weed and feed" product on lawns.

- Commercially tested soybean oil made from Iowa State varieties may help food companies address potentially unhealthy trans fats problems in their products. The soybean varieties were developed by ISU researchers in the Department of Agronomy and the Department of Food Science and Human Nutrition.
- The Grain Quality Laboratory at ISU provided instrument design and calibration services to six manufacturers of grain-testing equipment. The lab's ability to work with multiple manufacturers and multiple technologies has created new opportunities, such as rapid testing for low-linolenic oil soybeans that do not produce unhealthy trans fats.
- From 1999 to 2005, the NASA Food Technology Commercial Space Center in the College of Agriculture partnered with many Iowa companies to get foods on American astronauts' menus.
- ISU's Food Science and Human Nutrition scientists helped develop the product SoyPlus, a resin derived from soybeans to make new plastics that are biodegradable, yet durable and functional, to produce a variety of products. The ISU researchers are involved in technology transfer of soy-based biodegradable plastics with an industrial partner, Soyworks, which is commercializing products such as pet toys and golf tees.
- ISU faculty have provided assistance to a wide variety of food companies and associations (General Mills, Anheuser-Busch, Frito-Lay, Inc, Warrens' Frozen Foods, Valley Foods). Iowa State's meat science program is recognized as the number-one program in the nation, has developed several targeted courses for meat processing companies in the United States and abroad.
- Seed Science Center researchers developed a computer-based technology to continuously and non-invasively measure the flow of seeds during seed and grain conditioning operations. Currently, the device has been licensed to an Iowa company.
- Software developed by a bioinformatics research group has been licensed to companies that need help managing and analyzing genetic data from genome projects. One program, the GeneSeqer, which helps predicts gene structure, has been licensed to several plant biotechnology companies during the last four years. This year, NewLink Genetics Corporation, based in the ISU Research Park, acquired the exclusive commercial distribution rights to GeneSeqer and a companion program, MyGV, and has begun marketing the software.

Examples of Partnerships with Industries

ISU and Pioneer Hi-Bred International (a subsidiary of DuPont). A unique and strategically important relationship between Iowa State University and Pioneer Hi-Bred International dates back to the late 19th century. Throughout the 20th century and into the 21st century, ISU and Pioneer have continued a close working relationship, collaborating on key research, developing new technology, disseminating knowledge and educating the future work force. (More than 500 ISU alumni currently are employed by Pioneer.) DuPont/Pioneer is one of the largest corporate sponsors of contract research at ISU, having funded nearly 80 projects in the last six years. The company's support includes four key faculty chairs and a professorship.

ISU and Monsanto. Iowa State University and Monsanto are longtime partners in improving agriculture and preparing students for successful careers. Monsanto has provided significant grant and gift support to many ISU research programs, particularly in agronomy (i.e., plant breeding, weed science, soil fertility) entomology and economics. Monsanto also has supported starch research in Food Science & Human Nutrition. Monsanto has provided state-of-the-art lab equipment for the Plant Sciences Institute -more than $1 million in gift-in-kind support. Monsanto is committed to the next generation of scientists, and demonstrated that commitment recently by supporting doctoral fellowships in plant breeding, seed science and genetics, and by endowing the Monsanto Graduate Fellowship in Seed Policy and Regulation in the Seed Science Center.

ISU and Iowa's Agricultural Organizations

Iowa's agricultural organizations provide substantial research support for Iowa State university faculty members. In 2004-2005, their support—for research involving soybeans, poultry, eggs, pork and other commodities—totaled more than $3 million.

Technology Transfer and Development

ISU has maintained its position as one of the nation's leading universities in technology transfer accomplishments. In the latest survey conducted by the Association of University Technology Managers (FY04), in which 164 U.S. universities participated, ISU ranked 3rd in the number of licenses and options executed and 1st in this category for those universities without medical schools. ISU also ranked 4th for licenses and options yielding income and 2nd in this category for universities without medical schools.

Examples of recent accomplishments in this area:

- ISU inventors disclosed 120 new technologies to the Office of Intellectual Property and Technology Transfer and 19 patents were issued on ISU inventions.
- ISURF executed 140 new licenses and options for ISU technology, including 95 for plant germplasm. Forty new technology licenses were executed with companies, four of which are located in Iowa. Of the five new option agreements executed in FY06, two of them are with Iowa companies.
- Technologies licensed to Iowa companies (not including plant germplasm) resulted in over $38 million in sales by those companies in calendar year 2005.
- Eighty new Iowa companies were formed over the past two decades due to ISU technologies and/or technical expertise.
- 151 new companies and affiliates have joined the ISU Research Park since its inception. These companies employ nearly 2,100 people throughout the world.
- The Institute for Physical Research and Technology (IPRT) leads the State in matching Iowa businesses and entrepreneurs with university resources in cost-shared research and development projects. In FY06 IPRT cost-sharing funds of $364,931 were leveraged to $1,097,912 in 30 product development and process improvement projects with Iowa companies.
- The inventiveness of ISU's faculty has been recognized by receipt of 28 R&D Awards since 1984. These range from a technology to protect the security of internal computer networks to a multiplexed capillary electrophoresis systems using absorption detection (making it possible to rapidly separate samples of complex chemical or biochemical mixtures) to development of a maize gluten herbicide. (add to prominent examples).
- During FY06, as a result of CIRAS (Center for Industrial Research and Service) activities, 267 companies in Iowa reported $27 million in new investments, $9 million in costs saved or avoided, and $63 million in sales gained or retained.

J. Craig Venter Institute

VI's accomplishments with regard to tech transfer include:

- Developing and commercializing GPCR methods with Applied Cell Sciences.
- Developing malaria vaccines with Sanaria.
- TIGR and Novartis Vaccines (former Chiron Vaccines) have been collaborating for almost a decade on a process called reverse vaccinology which makes use of genomics to identify novel vaccine candidates against bacterial human pathogens, including Neisseria and Streptococci. Candidates from the Neisseria work are now in clinical trials while antigens against group B Streptococcus are being tested in the animal model.
- Collaborations with Ibis (San Diego) to develop bioinformatics tools for building a database to house disease information linked to genomic data.
- A joint venture with Canon life sciences (Rockville) and BioHelix (Boston) to design signatures and assays for detecting infectious disease agents.

Battelle Memorial Institute/Pacific Northwest National Laboratory

In 2000, the internally funded PNNL Biobased Products Initiative began a new research program to develop enabling biotechnology for the conversion of Biomass to products. This Initiative was successful in the development of new internal capabilities for work on filamentous fungi. In 2004, BMI/PNNL won support from DOE EERE Office of Biomass Programs to continue this research thrust. This support by the Office of Biomass Programs has continued to date and centers on research projects that include industry partners (e.g., ADM, Cargill). The support requires the participation of industrial partners. This has been accomplished through a Partners Review Board composed of representatives of industry. The Board members are from the enzyme industry, the chemical industry, the ethanol industry and small business. The research program is reviewed annually by the Board.

Successful deployment of BMI/PNNL biotechnology has included a project funded by the USDA/DOE Joint Biomass Solicitation. The project was entitled Value Added Products form Hemicellulose, and was led by a consortium of maize growers with industrial enzyme companies participating as 40% cost share partners. The research involved filamentous fungal fermentation process development research as well as discovery and application of biomass degrading enzymes derived from fungal species. BMI/PNNL and a commercial partner are pursuing patent protection.

The Fungal Biotechnology Team has partnered with industry in several projects to sequence valuable industrial fungi. For example, the *Aspergillus niger* sequencing project at the Joint Genome Institute was led by BMI/PNNL with enthusiastic support by industry representatives. BMI/PNNL leads the project at JGI to sequence a large number of fungi representing the entire diversity within the Fungal Kingdom to insure we can access all genome information relevant to bioenergy.

Salk Institute for Biological Studies

Research at the Salk Institute has led to a better understanding of the contributions of ethylene, auxin, brassinosteroids and light quality on plant architecture, yield, and biomass, resulting in more than a dozen issued patents. Salk Institute scientists are also making great strides in elucidating the pathways that emanate from the chloroplast to regulate nuclear gene expression in response to abiotic stress. The Salk Institute has spun off 27 companies since the late 1980s.

The Scripps Research Institute

Researchers within The Scripps Research Institute's Plant Biology Division of Biochemistry have made several discoveries relevant to the plant biotechnology industry as well as the BioPharma sector. These include:

- Identification of transcriptional regulatory factors that allow manipulation of key metabolic pathways in plants
- Identification of regulatory modules critical for the manipulation of flowering time in crop species
- Identification of several potential drug targets for sleep disorders

The Scripps Research Institute has spun off 50 companies since the late 1980s. Researchers have long established relationships with large Pharma companies including Novartis. They also have extensive experience working with both Monsanto and Syngenta in advising on basic science programs relevant to crop improvement and protection.

4.6 CBEST Resources

The strength of the CBEST collaboration is reflected in its lengthy list of facilities, technical capabilities and instrumentation (See **Appendix C**). This compilation will also be a valuable tool for

- developing and launching the initial EBI Science Program (before the EBI facility is constructed),
- avoiding facility duplication as we design and develop a plan for the EBI,
- enhancing CBEST collaborators' utilization of existing resources, and
- promoting research interaction and collaboration.

5.0 EBI *Organization, Governance, Staffing and Management*

Above *Calit2 clean rooms—courtesy of UCSD*

5.0 EBI Organization, Governance, Management, and Staffing

5.1 Legal Structure

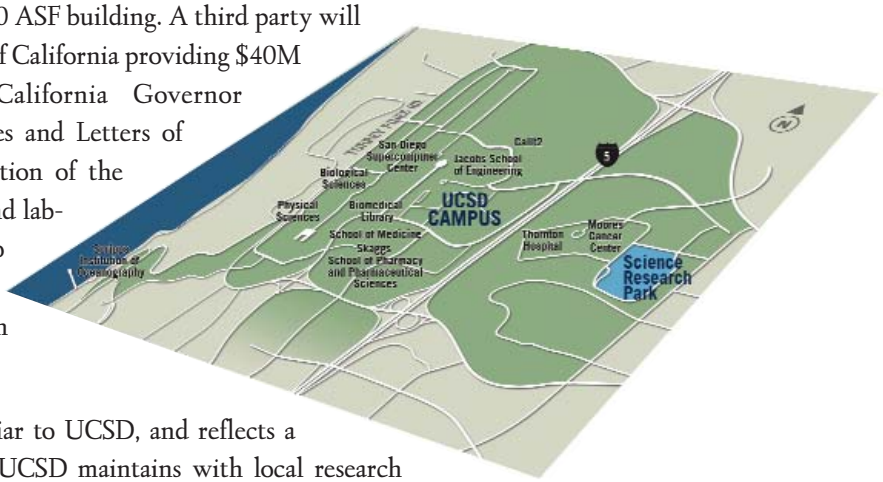
UCSD and BP will jointly create a not-for profit 501(c)3 corporation, to be called the Energy Biosciences Institute (EBI), the purpose of which is to conduct research on bioenergy science and technology related to modern biofuels. BP and The Regents of the University of California will be the founding principals of the EBI and will elect the directors of the entity in accordance with the Bylaws described below. The EBI will be a legal entity distinct from UCSD.

The Articles of Incorporation will meet the requirements for qualifying for tax-exempt status within the Internal Revenue Service (see Appendix D). UCSD has selected this proposed legal structure as the most suitable for the EBI for the following reasons:

- UCSD will benefit because it acquires a facility at the end of the project's lifetime, because we intend to leverage the ongoing operation of the research facility through continued funding to extend its life, and because it provides a center of excellence for undergraduate, graduate and post-doc educational opportunities.
- EBI will benefit from having a flexible affiliation with UCSD and because this model is not difficult to implement.
- BP will benefit from this arrangement by having a majority of its resources fully allocated to research activity and not to overhead.

UCSD has selected the not-for-profit status of the corporation which requires there be no monetary gain or profit, directly or incidentally. None of the earnings can be used to benefit the Directors or officers of EBI, or be distributed to them, although the 501(c)3 can pay reasonable compensation for services rendered. We plan to consider corporate "Excess Benefits" in applying for not-for-profit status with the IRS, including "disqualified persons" on the EBI Board, EBI Directors, and members of the EBI Steering Committee (see below). We expect to avoid potential tax pitfalls by appealing to "Safe Harbor" practices at the IRS.

EBI will become a tenant in the UCSD Science Research Park on UCSD East Campus under the terms of a long-term ground lease calling for the construction of a 50,000 ASF building. A third party will construct the new building with the State of California providing $40M as an incentive (see letter from California Governor Schwarzenegger under Tab for "Incentives and Letters of Support"). During planning and construction of the new EBI facility, the EBI will lease office and laboratory space in the La Jolla area adjacent to the UCSD campus, where there are numerous research institutes and biotech companies in operation.



The proposed corporate structure is familiar to UCSD, and reflects a combination of several relationships that UCSD maintains with local research institutes. For example, since 1989, the Howard Hughes Medical Institute has been located on the campus of UCSD and has engaged in medical research in collaboration with UCSD faculty. More recently, UCSD ground leased land in the UCSD Science Research Park to the La Jolla Institute for Allergy and Immunology. Currently, UCSD is negotiating with the newly formed San Diego Consortium for Regenerative Medicine, comprising local research institutes, for a long-term ground lease on UCSD land where cutting-edge stem cell research will occur. All of these institutes are independent, not-for-profit corporations funded by third parties (i.e., a foundation, Kirin Brewing Co., Ltd., and the State of California, respectively). Researchers employed at the institutes are eligible for academic appointments to UCSD, and they engage in collaborative research with UCSD faculty and staff. Except for the San Diego Consortium for Regenerative Medicine, which will not employ research personnel separate from those of its participant institutions, the research programs at these institutes are planned, supervised, conducted and evaluated by the management of the institute itself, in consultation with UCSD.

BP funding will flow directly to the EBI as a 501(c)3 organizational entity, and a portion of the BP funding will support research activities. EBI will offer grants to UCSD faculty for research performed in UCSD facilities or to other collaborators for research performed in Third Party facilities through CBEST resource allocations. EBI will disburse these funds to CBEST based on its annual research plan. Such research will be conducted according to pre-agreed standard terms and policies, including management of IP. Each participating institution in EBI, including UCSD, will charge overhead on research conducted at that institution. Research conducted at the EBI by UCSD personnel will be subject to an off-campus overhead (currently 26%).

Because EBI researchers and staff will be primarily employees of the EBI, intellectual property resulting from their research will belong to the EBI, rather than to the University. To the extent that research undertaken by the EBI is conducted with the participation of either UCSD or BP employees, the resulting intellectual property will be the subject of an Affiliation Agreement between UCSD, BP and the EBI. Revenue sharing arrangements for joint research between UCSD, the EBI and BP will be the subject of negotiated terms in accordance with common practices in effect at the University for collaborative research activity (see Section 6.2 of the proposal).

The EBI will establish its own operating policies and procedures for the conduct of research, employment and other matters. EBI employees with academic appointments will be subject to University policies but will otherwise be governed by EBI business practices. UCSD anticipates that it will furnish the EBI with research support services such as review of human and animal subject research, Environment Health & Safety compliance, assistance in immigration matters and other resources as negotiated (See **Appendix E,** "Sample EBI Affiliation Agreement").

UCSD's participation in a 501(c)3 will require approval by the University's Office of the President and the Board of Regents, but the advice and concurrence of each will be sought at the earliest appropriate time to assure that the approval will be forthcoming. All long term lease transactions entered into by the University of California also require approval of the Board of Regents. That approval will also include approval of the construction of the proposed building on University property in the Science Research Park.

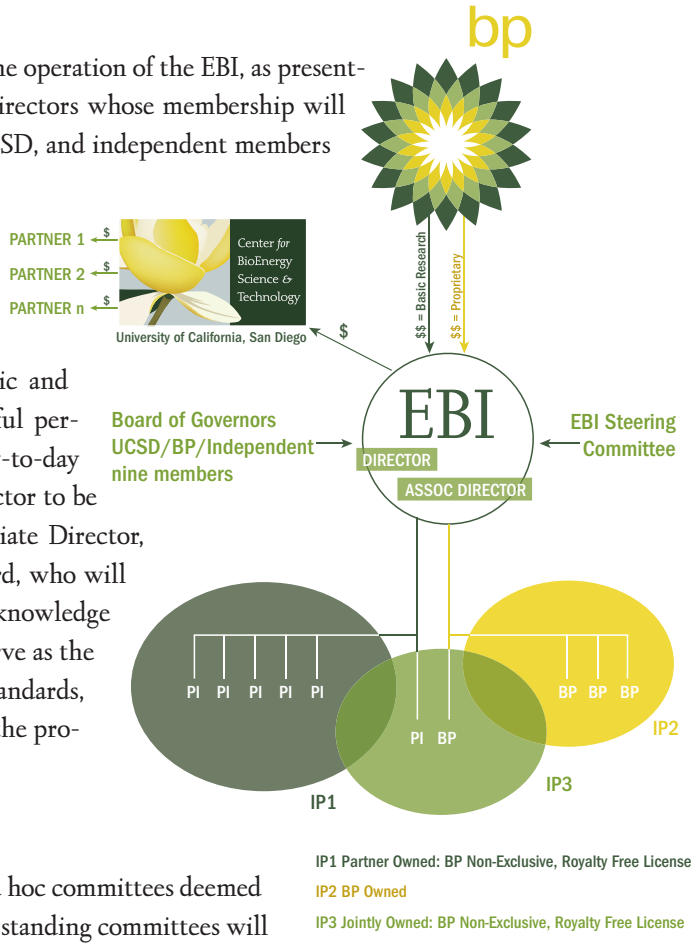
While UCSD prefers the 501(c)3 legal vehicle, there are closely-related options that can be explored, if necessary, later. The EBI could also be structured as a nonprofit mutual *benefit* corporation and forego applying for federal tax exemption under section 501(c)3 of the Internal Revenue Code. This would provide additional operational flexibility. This form, rather than initial creation of a public benefit, 501(c)3 entity, may better facilitate the development of the proprietary component of the research of the new institute since it would not have the limitations applicable to a public benefit corporation regarding private inurement issues and non-exempt activities. Moreover, because all the assets of the EBI would not necessarily be dedicated to charitable purposes, the EBI would not be subject to examination by the Attorney General of the State of California as a charitable trust (California Corporations Code section 7240).

In any event, UCSD proposes to structure the EBI with the expectation and capability of long-term growth. This will enable the continuation of the EBI at the end of the BP partnership with UCSD by creating alternative sources of funding including, government grants, company contracts, philanthropy, and intellectual property rights (IPR) licensing. This strategic planning approach will help satisfy corporation independence legal requirements, and the extended lifetime will help attract high-quality scientific, technical, and administrative staff that will have to be recruited throughout the duration of the decadal BP program. A long-term EBI also justifies hiring a dedicated Director and senior staff, allocating major resources including university land, securing associated faculty with EBI endowed chairs, and significant financial commitments by the State of California.

Upon completion of the 5th year of the BP EBI activities, BP and UCSD will review progress and plans, which will potentially serve to extend the contract beyond the 10th year. This review will be conducted annually after this 5th year review. The EBI will nominate senior research employees of EBI for rolling five-year EBI contracts.

5.2 Organizational Structure

UCSD proposes the following organizational structure for the operation of the EBI, as presented in the figure here. The Institute will have a Board of Directors whose membership will comprise equal numbers of representatives from BP and UCSD, and independent members mutually selected by UCSD and BP, to establish an effective EBI collaboration relationship.



The Board of Directors

The Board will direct the overall strategic, tactical, and operational functions of EBI's research program (both basic and applied). The Director will be responsible for the successful performance of the Institute's entire research program and day-to-day operations. The EBI Board of Directors will select the Director to be employed by EBI, working in conjunction with the Associate Director, hired by the Director in consultation with BP and the Board, who will oversee applied research at EBI while providing an intimate knowledge of BP's long-term goals to guide research. The Board will serve as the highest level of governance, determining the policies, standards, scope and priorities of the EBI research program. Details of the proposed Board are presented in Appendix F, "Sample Bylaws."

Committees Reporting to the Board

The Board will be supported by a number of standing and ad hoc committees deemed to provide added oversight and consulting value to EBI. The standing committees will include Audit, Finance, Facility, Governance, and an external Scientific Advisory Board. The EBI may create ad hoc committees that will be charged as needed to review and dispose of specific short-term issues. Non-Board committees will comprise EBI employee representatives as well as UCSD and collaborating scientists and engineers actively involved in EBI research.

Flow of BP Funds

Initially, BP will provide all funding for the EBI to develop a proposed research plan for review and approval. These funds will be allocated to support the Institute's operations and basic and proprietary research, with the former being substantially larger than the latter in order to meet the constraints of incorporation as a 501(c)3. Funding in support of basic research will be distributed to UCSD's CBEST. CBEST will in turn distribute funds to its research collaborators—by subcontract—that is, to UCSD departments, schools, or divisions, Venter, ISU, TSRI, Salk, BMI, and other third-party collaborators, if any. UCSD will charge off-campus overhead (26% of qualified costs; e.g. none on hardware, full on personnel and supplies) on its research costs for work at EBI and full overhead otherwise, while our collaborators will charge their normal overhead appropriate for research grants and contracts. The University charges overhead on the first $25K for each subcontract. Costs above the $25K are overhead exempt. EBI will retain funds for applied (proprietary) research, with internal EBI policies governing indirect costs for all funds received.

5.3 Governance

UCSD proposes a governance framework that integrates the policies, standards, oversight processes, enabling IT tools, and organizational structures needed to ensure EBI organizational success. Within the context of the EBI Program, UCSD envisions the governance function as the aligning mechanism between BP strategic goals and EBI operational effectiveness. The EBI governance function will include strategic planning, policy and standards definition, and enterprise-level risk assessment and issue resolution.

Governance Goals and Objectives

UCSD's governance goal is to implement a robust approach for EBI that integrates organizational, business process, and cultural dimensions to ensure effective and consistent guidance and oversight. Our objectives in implementing a governance function are to:

- Ensure that EBI maintains its business alignment with that of BP and UCSD and meets or exceeds BP's performance expectations
- Monitor program operations to maintain compliance with UCSD and BP policies, procedures, and applicable regulations
- Resolve issues and mitigate risk through disposition at the appropriate organizational level
- Facilitate any cultural change required to effectively advance EBI's progress and performance

Order of Precedence

UCSD will implement Articles of Incorporation, Bylaws, an Affiliation Agreement, and a Ground Lease (see **Appendices D-G** for samples of these documents) to govern effectively the operations of EBI, as follows:

- Articles of Incorporation—define the legal status of EBI.
- Bylaws—define the relationships of participants, and the composition, responsibilities, activities, and procedures of the Board of Directors.
- Affiliation Agreement—outline negotiated terms of the inter-institutional collaboration.
- Ground Lease—defines land use terms.
- EBI business standards and conduct guidelines—these items, to be developed, will detail an operating standard to govern EBI business practices involving staff, collaborators, contracts and health, safety and security procedures.

UCSD's order of precedence begins with the articles of incorporation serving as the overriding corporate documentation, taking priority over the Bylaws, which in turn, have precedence over corporate resolutions. UCSD anticipates that, once approved, the articles of incorporation and ground lease would not be revised. However, UCSD anticipates that the Board of Directors may amend Bylaws and Affiliation Agreements if they determine that changes are necessary for operational purposes.

Organizational Structure for EBI Governance

We propose a hierarchical governance structure that is headed by the Board of Directors where ultimate responsibility for governance resides. Governance will be performed in a top-down fashion to the program and project levels as presented in our governance model.

The Governance structure will be comprised of the following:

- EBI Board of Directors—full governance authority.
- EBI Director Steering Committee—program-wide governance support as requested by the Board.
- CBEST—governance support as requested for project level governance and interrelationships between CBEST collaborators (see **Appendix H** for "CBEST Committee Membership").

This structure provides for ongoing governance dialogue between the Board, the Director and program/project managers. The Board of Directors will set oversight and control policies, while the Steering Committee will perform project reviews to ensure policies are being adhered to during all phases of the research life cycle, as presented below.

Governance Role	BP	EBI/Collaborators	UCSD
Board of Directors: Governance Responsibility	**Co-Lead**	Participation when requested	**Co-Lead**
Director's Steering Committee: Program-Level Governance Support; Annual Program Plan and Budget	Participation	**Lead**	Support
CBEST: Project-Level Governance Support	Support	Participation	**Lead**

Whether governance for a given issue is performed by the Board or delegated to a lower level, we propose that EBI governance be accountable for nurturing a collaborative but rigorous function to deliver effective communications and explicit decision-making for the following:

- Ensuring that each governance issue or opportunity is appropriately framed and that recommendations are respectively defined and aligned.
- Providing guidance and sanction before the issue or initiative is given final approval.
- Evaluating the status of EBI programs and projects against planned milestones throughout their duration.
- Monitoring program and project level efforts to ensure that BP and EBI business objectives are being satisfied.
- Ensuring that performance indicators (measures of success) are clearly defined and that the information used for making oversight and guidance decisions are consistent with EBI's mission and strategies.
- Determining whether the current and future resources, both planned and actual, are justified and appropriately allocated.
- Reviewing organizational communications to determine if they are effective in supporting project success and program integration.

Governance by the Board of Directors

The EBI Board of Directors will govern EBI, with each member having a standard term of service of six years, although the initial terms will be staggered to avoid complete turnover in the sixth year. Minimally, the Board will comprise equal representation of BP (three members), UCSD (three members), and independent members appointed by the Board (three members). The Board will elect its Chairperson. The Board will meet as dictated by its Bylaws, but will meet at least twice a year. The Board will conduct an Annual Meeting that coincides with the review and approval of the annual plan and audit, while the second meeting of the year will concentrate on evaluations of the research program, the performance of the chief executive, and the effectiveness of the Board itself.

The Board is responsible for defining the mission of the EBI as well as its goals. The Board's commitment to the EBI will include a commitment to public accountability. The Board will continually assess EBI's activities to ensure the Institute remains true to its stated mission and goals. The Board has a fundamental responsibility for allocating sufficient resources to the EBI and for ensuring that the Board itself and the EBI adhere to legal standards and ethical practices. In California, a 501(c)3 must also adhere to 2004's S.B. 1262, the first not-for-profit "mini"-Sarbannes-Oxley law in the U.S.

The University of California's mission for teaching, research and public service requires a shared commitment to the core values of the University as well as a commitment to the ethical conduct of all University activities. In that spirit, the UC *Standards of Ethical Conduct* are a statement of our belief in ethical, legal and professional behavior in all of our dealings inside and outside the University.

The Board will select the EBI Director and approve the research program with an associated Institute budget. The Board will ensure an annual audit is performed in accordance with generally accepted accounting practices. The Board's Audit and Finance Committees will be separate, in accordance with S.B. 1262. In addition, the annual financial statements must be made public, generally in an annual report and on the Web.

If the EBI does lobby within the restrictions imposed by the IRS, the Board must ensure that management maintains the necessary detailed records of these expenditures. In the US, qualified lobbyists will have to be registered with the federal government. The Board will participate in EBI's strategic planning to provide vision, contribute strategies for attaining objectives, and propose performance measures by which EBI will be evaluated on a quarterly basis.

The Board Charter will provide for the scope of Board oversight, to ensure strategic guidance without interfering in the day-to-day management decisions, which are within the purview of the EBI Director. Individual Board members will be required to be free of vested interests in order to consider issues and render judgments of the EBI as a whole, since they will not be representing either UCSD or BP, but the welfare of the Institute. The Board will develop an EBI Conflict of Interest policy and verify, by filing an annual statement, that members comply with the policy. The Chair of the Board and the EBI Director will identify a single EBI spokesperson having the authority to speak on behalf of the corporation and serve as an advocate for the EBI. Normally, when fully functional, this will be the EBI Director.

The Board policies will be designed to facilitate selection of successors to the Board itself over its lifetime. The Board will periodically evaluate its own effectiveness in order to inform the Board's Governance Committee. Subject to the approval of the full Board, the Committee will oversee the definition of Board needs, cultivate future members, ensure Board evaluation, check nominee credentials, and recruit nominees.

The Board will be responsible, as noted, for approving the annual program plan and budget. The Board is also responsible for major reviews of the program during the course of the ten-year contract with BP. These reviews, which will almost certainly involved referees selected from outside the body of basic and applied research scientists and engineers associated with the EBI, should be conducted in years 3, 5, and 8. The first of these reviews will be conducted after the EBI has moved into its permanent home. The second review, conducted in mid-term, will examine the case for continuing the EBI beyond the initial 10-year contract with BP. Much of the near-term work will have been completed in accordance with the milestones; the prospects of the next five years' work is important as well as a longer, strategic view 10 and 15 years into the future. The review in year 8 will provide an excellent opportunity for a retrospective view of contributions made, problems encountered, and research failures and challenges. Again, the EBI will look to the future and contributions to be made over the next decade.

5.4 EBI Staffing

The EBI staff will include a Director, Associate Director, Project Leaders, technical and administrative staff, and management personnel.

EBI Director

The Director of the UCSD EBI will be a world-class biologist or biotechnologist with the leadership characteristics needed to guide an Institute of this scale and importance. BP has consulted with potential search firms and we understand that the search process has begun. If UCSD is successful, we will work with BP in integrating the search into UCSD academic processes for appointing an adjunct faculty member. It is our intention that the Director have a joint appointment with UCSD as a faculty member as well as being the leading employee of the Energy Biosciences Institute.

The EBI Board will be responsible for hiring the Director and will judge the Director's performance and set salary and bonuses based on the following duties:

- Developing, with the Board, a clear vision and mission for the EBI. The Director must understand BP's business strategy sufficiently well to allow informed judgments about potential technical developments and business alternatives. The Director must enter into the appropriate agreements with BP to permit the incorporation of BP's longer-term strategic plans into the EBI's research program.
- Translating the vision and mission into realistic goals including the integration of new discoveries and breakthroughs into BP's business.

- Developing an annual plan and budget consistent with the vision, mission, goals and available resources.
- Selecting and cultivating qualified senior staff.
- Ensuring there are effective systems in place to facilitate day-to-day operations including:
  - Approval of all financial disbursements or the development of the necessary controls needed including monitoring of all financial and accounting activities of the organization;
  - Development and delivery of research programs;
  - Education and Outreach;
  - Policy Development;
  - Administration and operations;
  - Fund raising and resource development;
  - Maintenance of organizational records, files, documents, and archives.
- Creating partnerships with not-for-profit and for-profit organizations and other external entities needed to meet the EBI's mission.
- Guiding revenue-generating activities to provide adequate income to the EBI.
- Maintaining confidentiality where warranted, as well as care of sensitive information.
- Ensuring that the EBI has:
  - A sound risk management policy including insurance coverage;
  - Appropriate personnel policies for staff;
  - Complied with all legal and regulatory requirements.

Associate Director

The EBI Associate Director will assist the EBI Director in managing the day-to-day operation of the Institute. While the Director will be a renowned scientist, the Associate Director will have extensive education, training and experience in operating a program the size and scope of the EBI. In addition, the EBI Associate Director is responsible for

- Administering the applied research side of the Institute.
- Working with the Director to incorporate applicable BP strategy, business plans. technologies, capital, management and decision-making processes into EBI activities.
- Ensuring that EBI discoveries and breakthroughs are deployed within BP.

Other EBI employees

EBI employees will include EBI Principal Investigators (PIs), post-doctoral trainees, technicians and senior and support staff directly compensated by the Institute. EBI researchers include EBI employees, UCSD Principal Investigators and their technical staff who are performing UCSD research using EBI facilities, or other visiting researchers who are conducting research in the EBI facility. UCSD faculty may engage in non-compensated collaborations with EBI investigators or may be employed as consultants to the EBI within the time frames normally allowed by University policy. UCSD faculty may also be directly employed by the EBI if on an unpaid leave of absence from the University. To the extent they are qualified, UCSD will extend adjunct appointments to EBI investigators in academic departments as appropriate. EBI investigators with UCSD appointments may participate fully in the activities of the University allowed by their academic title, including supervision of graduate students and post doctoral scholars. The EBI may offer joint PI appointments to scientists from Third Parties including academic, for-profit, or governmental institutions as deemed appropriate.

Senior Staff

The duties of the **Facilities Manager** will include:

- Participating in the planning, designing, constructing and maintaining facilities to ensure compliance with applicable federal, state, and city laws, regulations, rules, standards and guidelines.
- Maintaining accurate records with regard to annual inspection of equipment and general preventative maintenance.
- Developing appropriate safety and/or service plans to alleviate risk and provide protection.
- Selecting internal and external providers to obtain the best level of service for the EBI.
- Taking charge of all emergencies and ensuring responsible back-up is available in order to take corrective action.

The duties of the **Health Safety Security & Environment (HSSE)** Manager will include:

- Developing and maintaining HSSE regulatory compliance documentation and filings, including policies for health & safety and tracking on all regulatory inspections and filings.
- For the EBI Board, generating a bi-annual report that documents HSSE incidents, audit results, improvement plans, risk self-assessments, and training measures.
- Training EBI employees as well as those working at the EBI in health and safety procedures.
- Enforcing HSSE rules and regulations in the EBI workplace.

The duties of the **IT Manager** will include:

- Evaluating user needs and system functionality.
- Planning, developing and implementing the ICT budget, obtaining competitive prices from suppliers, where appropriate, to ensure cost effectiveness.
- Scheduling upgrades and security backups of hardware and software systems.
- Researching and installing new systems.
- Ensuring the smooth operation of all ICT systems, including anti-virus software, print services and email provision.
- Ensuring that software licensing laws are followed.
- Providing secure access to the network for remote users.
- Ensuring the security of data from internal and external attack.
- Providing users with appropriate support and advice.
- Managing crisis situations, which may involve complex technical hardware or software problems.
- Mentoring and training new ICT support staff.
- Keeping up to date with the latest technologies.

The duties of the **HR Manager** will include:

- Recruiting and staffing.
- Developing performance management and improvement systems.
- Complying with regulatory regimes including policies for equal opportunity employment.
- Organizing employee orientation, development, and training.
- Managing employee relations.
- Developing compensation and benefits administration.
- Ensuring employee safety, welfare, wellness and health.
- Monitoring EBI compliance with all HR policies.

The duties of the **Finance/Procurement Manager** will include:

- Developing and overseeing the maintenance of budget monitoring systems.
- Developing financial reports for forecasting, trends, and results analysis.
- Providing oversight for the expenditure of funds, ensuring that funds are expended according to BP/UCSD stipulations.
- Conferring with appropriate internal and external administrative offices to ensure that required procedures are followed.
- Maintaining individual attendance records and payroll processing.
- Establishing and implementing a policy of making purchases from vendors.
- Ensuring the appropriate liability insurance coverage is obtained.
- Providing the required annual reporting required by California S.B. 1262, the first Sarbannes-Oxley rules for 501(c)3's in the U.S.

The duties of the **Contracts and Grants Manager** will include:

- Defining and implementing EBI grants and contracts policies and procedure.
- Administering all contracts, grants, and cooperative agreements, including compliance, contract change orders, contract audits, and reporting.

The duties of the **Education, Ethics, Outreach and Communications Manager** will include:

- Managing a broad range of EBI communication and outreach activities including community and K-12 programs.
- Developing external collaborations that serve to expand the reach of the EBI and position it as an attractive collaborative resource.
- Writing and developing promotional brochures and establishing an Internet presence.
- Identifying, authoring, and oversight of grants related to continuing education or professional development programming.
- Monitoring external threats to EBI research including GM and environmental activists.

The duties of the **Policy and Governmental Relations Manager** will include:

- Managing external interfaces with community and governmental entities, national and international visitors.
- Coordinating Governance Board Meetings.
- Monitoring rules, laws and regulations that may impact EBI operations and research.

The **Legal Counsel** will provide legal advice in connection with EBI's activities. The Legal counsel will attend all meetings of the Governing Board and will assist in the preparation of all EBI agreements and contracts. The Legal Counsel must be a member of the State Bar of California and must maintain membership as a condition of continued employment.

The **Patent Counsel's** duties will include:

- Managing the EBI patent portfolio.
- Identifying, validating and protecting technology arising in the EBI.
- Structuring and negotiating patent licensing agreements with BP, UCSD, Collaborating Institutions and other corporations.
- Analyzing business, market and technical data to assist in the patent cross-licensing valuation and negotiation strategies.
- Negotiating and closing patent cross-license deals and related agreements.

In addition, the Patent Counsel's duties will include tracking and reporting

- The number and value of patents obtained by EBI for inventions conceived or reduced to practice using EBI facilities or employees, in whole or in part.
- The number and value of licensing agreements executed by EBI involving technology developed, in whole or in part at EBI.
- The extent to which research conducted by EBI results in commercial applications.
- The number of collaborative agreements reached and maintained with different partners (academic, for-profit, governmental, non-profit).
- The number and value of spin-off businesses created as a result of commercialization of the research at EBI.
- The number and value of businesses recruited to the region as a result of EBI.

Additional Technical and Administrative Support Staff

EBI will require technical personnel to support research, lab and system operations and maintenance as well as shipping and receiving. Administrative personnel will be required for reception, web and graphics development, publications management and office administration.

Staff Recruitment

EBI will develop a staffing plan showing personnel levels required over the ten-year period, stratified by job category. We are confident that EBI will achieve its scientific staffing goals. The EBI Human Resources Manager, in accordance with EBI policies and guidelines will develop the recruitment strategies driving the staffing plan. For Principal Investigators, our recruitment strategy includes seminar presentations, visits with and assessment by EBI employees, letters of recommendation, and a written summary of proposed research activities. EBI will leverage BP contract staffing relationships with third parties to recruit Laboratory technical support staff where a competitive global rate structure has already been established with BP.

EBI will recruit its staff in compliance with relevant employment regulations and standards. EBI will post all positions in a variety of media at selected locations, including detailed project descriptions that map to specific rate structures. We will establish and standardize support staff skill levels for different skill domains within EBI. We will map rate structures between pre-existing BP contractor support staff levels and the following EBI staff job definitions, including but not limited to:

- Project management (I, II, III)
- Laboratory technician (I, II, III)
- Health & Safety Officer (I, II, III)
- Facilities Engineer (I, II, III)
- Systems Engineer (I, II, III)
- Software Engineer (I, II, III)

Our recruitment process will be based on detailed job definitions, which will include the requisite level of training and certification required to meet the relevant BP operating standards (i.e. project management PMP certification, ISO quality, ITIL operational certification, etc).

EBI will evaluate all potential candidates against criteria reflecting the posted job requirements. Once candidates have been screened to determine that they meet required skills, educational background, and experience, EBI will conduct in-house and remote interviews using a designated staff selection team for that position. The selection team will use formatted interview evaluation forms to gather information and document their evaluation of the candidates. These forms will be submitted to the hiring manager for review and final selection, based on the recommendations of the hiring team.

Staff Training and Development

EBI will ensure upon hiring that all staff have the requisite technical domain expertise and skills to perform their job duties. To supplement these baseline skills, EBI will provide training on EBI policies, health and safety, operational practices and procedures, and IT systems. This training will be part of the EBI initiation process for each new hire, and then will be conducted annually for all staff. This is to ensure that all personnel are made aware of EBI business standards and conduct guidelines, constituting an operating standard, to encompass business practices involving staff, collaborators, contracts and health, safety and security procedures.

EBI anticipates the need for flexible staffing over time as EBI requirements evolve significantly over the first three years as the organization proceeds from a startup phase, though its development phase, into a steady-state operational phase. Partner contractor resources will be used under competitive rates to ensure flexibility in staffing levels (i.e. to minimize recruiting and redirection costs and risks) as the requirements for support staff change.

5.5 EBI Management Practices

Performance Measurement and Reporting

The Board will collaborate with the Director in defining EBI performance measures on both the overall programmatic level addressing the Institute enterprise, as well as the project level for specific research initiatives. EBI will establish performance measures such as:

- Level of BP satisfaction with EBI Program and Project-level performance (qualitative)
- Number of scientific projects in various phases of research and development (quantitative)
- Staff Retention (quantitative)
- Staff Effectiveness (qualitative)
- Project level Schedule Performance Index
- Project level Cost Performance Index
- Number of research results delivered to BP for development (quantitative)
- Revenue potential of research results delivered to BP for development (qualitative)
- Number of patents filed (quantitative)
- Number and quality of scientific publications (quantitative)
- Press coverage of EBI activities (quantitative)

Project Management

UCSD proposes that EBI implement an integrated set of program/project management practices to effectively plan, monitor, execute, assess, and measure performance of each approved EBI research project. UCSD will leverage its project management expertise and experience in planning and delivering hundreds of research projects since its inception. UCSD has experience with Earned Value Management (EVM), which is required by the National Science Foundation for all large projects such as the major Research Equipment & Facilities Construction programs. The Project Management Institute (PMI) provides a forum for professional communication and education. While BP has developed its own approaches, including the Capital Value Process (CVP), risk management, and Project Executive Planning (PEP), UCSD will work with BP, if selected, to develop a program management scheme appropriate for the effective operation of the EBI, recognizing the importance of the research environment as balanced with the need to develop useful biofuel solutions in time frames of 2-5 and 5-10 years.

5.6 Mechanisms to Promote Integration and Linkages

EBI will pursue strategies to promote integration and linkages in the following key components of its enterprise architecture:

Organizational Architecture: identifying and implementing interdependency and relationship requirements and constraints between EBI, BP, UCSD and its institutional collaborators, as well as interfaces within the EBI organizational structure. These issues will be considered in detail during the negotiation phase of the BP grant.

Business Process Architecture: identifying and implementing interfaces among EBI's internal management practices, as well as interfaces to BP, UCSD, its institutional collaborators and public/private enterprises. It will be critical to standardize, to the extent possible, best business practices among the EBI participants. It will be critical to iron out and make explicit specific contractual arrangements between parties.

BP has asked if government research laboratories will be contractual parties to UCSD. We have developed a collaboration with Battelle Memorial Institute. Battelle, the manager of Pacific Northwest National Laboratory for the U. S. Department of Energy (DOE), has a contractual arrangement, called a "Use Permit," with DOE, which allows Battelle to use PNNL facilities and equipment to perform research and development for the sole account of Battelle. Battelle's participation in this proposal is advanced under this Use Permit. This is an instrument unique to Battelle and not characteristic of other lab management arrangements. The control provisions of the Host Institution, including IP, budgeting, procurement etc., will remain in effect. Battelle also has extensive experience in all aspects of contracting with the government under contracts, cooperative agreements, grants, and Cooperative Research and Development (CRADA) agreements, and has the professional staff and infrastructure to support such efforts.

Although CBEST does not, at present, include any for-profit collaborators, we will continue to investigate the potential for these kinds of relationships in order to access technologies and expertise unavailable among CBEST collaborators. Potential examples include SAIC, Diversa, General Atomics, and Solar Turbines Incorporated. For example, Solar Turbines Incorporated has testing facilities and analytical tools for evaluating the operability limits, durability, performance and emissions of combustion systems. Additionally, General Atomics, located in San Diego, has an active microalga biofuels research program, and they have expressed an interest in collaborating with UCSD on biofuels research.

Research Program Architecture: identifying and implementing interdependency and relationships through the integrated research program described in this document. Integration and linkages can be furthered via joint seminar series, workshops and symposia. EBI employees who have joint appointments with UCSD would have the same rights as UCSD employees, including library privileges, parking, etc. All others can be appointed as Research Associates to provide library, bookstore, seminar and building access. All UCSD employees must pay for parking.

Information Architecture: identifying and implementing interfaces among EBI's internal information systems, as well as other EBI information assets, their owners and users, and business rules for information creation, sharing, storing, and archiving. An excellent example of the opportunities that exist includes the BORNEAS-Net (Broadband Optical Research, Education and Science Network) that will provide ISU with the capability of connecting to national and international research networks such as NLR (National Lambda Rail), Internet2, and NewNet thereby facilitating direct end-to-end 10 gigabit circuits with the University of California San Diego (UCSD) and the J Craig Venter Institute, making possible real time interactive collaborations with terabyte-sized data sets. The network is constructed largely from dark fiber optics owned by major telecommunications companies under twenty-year exclusive right to use agreements. The optical electronics (optronics), owned and operated by BOREAS-Net, employ Dense Wavelength Division Multiplexing (DWDM) that initially will be configured to support forty 10 gigabit light wavelengths or lambdas. BOREAS-Net is one of approximately twenty regional optical networks interconnecting the major research facilities in the world. Iowa State University through BOREAS-Net and the national research infrastructure is strategically positioned to connect with UCSD and the Venter Institute using similar technologies and capabilities as UCSD used to connect with University of Illinois at Chicago in the OptiPuter project.

6.0 IP *Management*

Above *UCSD Science Research Park*

6.0 IP Management

6.1 Definitions

"Invention" shall mean any invention or discovery, whether or not patented or patentable, conceived and reduced to practice using funds from the EBI together with all intellectual property rights therein.

"BP Affiliated Business" shall mean any business that controls BP, is controlled by BP, or is contractually obligated to act for the benefit of BP.

"Host Institute" shall mean the University of California San Diego.

"BP" shall mean [BP should fill this in to precisely reflect its legal entity status]

"EBI" shall mean the Energy Biosciences Institute.

"Participating Institute" shall mean any institute that is invited by the Host Institute to collaborate in EBI funded projects under subcontract and is anticipated to include the Iowa State University, Battelle, and/or the Venter Institute.

"NERF License" shall mean a non-exclusive, royalty-free license with the rights to grant sublicenses to BP and BP Affiliated Businesses.

6.2 Inventorship, Ownership, and Licenses

Inventorship shall be determined in accordance with the United States Patent Laws (35 United States Code). Ownership of Inventions shall be determined in accordance with the common laws applicable to genuine employer-employee relationship and subject to the California Labor Code. In general, Inventions solely invented by one or more EBI employees shall be solely owned by EBI (EBI Invention). Inventions solely invented by one or more Host Institute (i.e. UCSD) employees shall be solely owned by the Host Institute (Host Institute Invention). Inventions solely invented by one or more employees of a Participating Institute (e.g. Venter Institute, ISU, or BMI) shall be solely owned by the Participating Institute (Participating Institute Invention). Inventions solely invented by one or more BP employees shall be solely owned by BP (BP Invention). Inventions invented jointly by one of more employees of EBI and one or more employees of the Host Institute and/or the Participating Institute shall be jointly owned by EBI and the Host Institute and/or the Participating Institute (Joint Invention).

EBI shall have a time-limited right to obtain a NERF License to all Host Institute Inventions and Participating Institute Inventions. The rights shall commence when EBI is notified of each Invention in writing by the Host Institute or the Participating Institute and shall expire sixty (60) days thereafter (Option Period) for said Invention. EBI shall notify Host Institute or the Participating Institute in writing of its intent to secure the NERF License during the Option Period for each Invention and EBI shall then (a) be responsible for all past and future patent costs for each patent or patent application in each country EBI elects to have the NERF License to the Invention, (b) pay the Host Institute or the Participating Institute which is the owner of the licensed Invention an annual license fee of Ten Thousand US Dollars (US$10,000), and (c) enter into a license (the NERF License) with the Host Institute and/or the Participating Institute that is substantially similar in form to the example illustrated in Appendix J, "Sample Non-Exclusive License Agreement." If EBI does not inform the Host Institute or the Participating Institute during the Option Period its intent to secure a NERF License, the Host Institute or the Participating Institute shall then have no further obligation to EBI respecting the reported Invention.

EBI shall have a time-limited first right to obtain an exclusive license to all Host Institute Inventions, Participating Institute Inventions, and the Host Institute's rights and/or Participating Institute's rights in Joint Inventions. The rights shall commence when EBI is notified of each Invention in writing by the Host Institute or the Participating Institute and shall expire sixty (60) days thereafter (Option Period) for said Invention. EBI shall notify Host Institute or the Participating Institute in writing of its intent to secure the exclusive license during the Option Period for each Invention and EBI shall then (a) be responsible for all past and future patent costs for each patent or patent application in each country EBI elects to have the exclusive license to the

Invention, (b) pay the Host Institute and/or the Participating Institute which has rights to the Invention the following consideration:

(i) a negotiated upfront, non-refundable license issue fee which shall not exceed twenty-five percent (25%) of the amount of funding EBI provided to support the work from which the subject Invention arises;

(ii) a negotiated annual license maintenance fee which shall not exceed ten percent (10%) of the amount of funding EBI provided to support the work from which the subject Invention arises. The annual license maintenance fee is payable on each anniversary of the license for the years the licensed Invention is not in commercial use;

(iii) a negotiated annual royalty which shall not exceed fifty percent (50%) of the amount of funding EBI provided to support the work from which the subject Invention arises. The annual royalty is payable on each anniversary of the license for the years the licensed Invention is in commercial use.

Notwithstanding the foregoing, the cumulative fees and royalty to be paid by EBI for the exclusive license of each Invention under (i) to (iii) above shall not exceed (a) twenty times (20x) the amount of funding EBI provided to support the work from which the subject Invention arises if the Invention is a Host Institute Invention or a Participating Institute Invention; or (b) ten times (10x) the amount of funding EBI provided to support the work from which the subject Invention arises if the Invention is a Joint Invention, and (c) enter into a license (the exclusive license) with the Host Institute and/or the Participating Institute that is substantially similar in form to the example illustrated in **Appendix I**, "Sample Exclusive License Agreement."

If EBI does not inform the Host Institute or the Participating Institute during the Option Period its intent to secure an exclusive license, the Host Institute or the Participating Institute shall then have no further obligation to EBI respecting the reported Invention.

Notwithstanding the foregoing, if EBI elects not to be responsible for the patent costs of any patent or patent application in any country in 2 or 3 above, then the license granted therein shall not include said patent or patent application in said country.

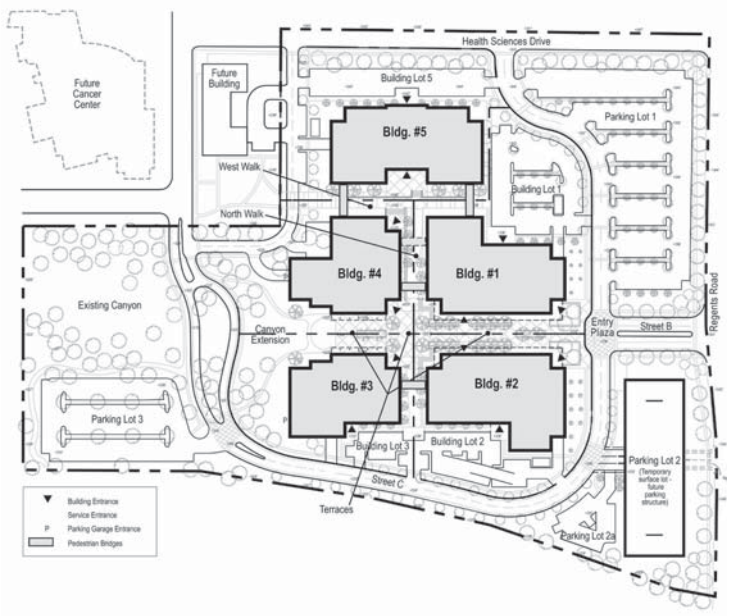
7.0 EBI *Building and Lab* Facilities

Above *Atkinson Hall—courtesy of UCSD*

7.0 Buildings and Laboratory Facilities

7.1 Permanent EBI Site Location

UCSD's Science Research Park (SRP) is a prized gateway to the talent and resources of UCSD. The SRP is strategically located on thirty discrete acres within UCSD's East Campus. Designed to promote interaction between outstanding industrial and academic research teams, the site is ideal for companies, institutes, and agencies that would benefit from significant linkages with UCSD researchers. The SRP offers sites for UCSD's research collaborators to develop research facilities on campus land. For example, the 130,000 gsf research facility on Site 1 developed by Kirin is home to Kirin's for-profit subsidiary, Gemini Science, Inc., and its non-profit research institute, La Jolla Institute for Allergy and Immunology.



UCSD proposes that BP develop the EBI Permanent Facility in the UCSD SRP. There are two parcels (Sites 3 and 4) in the SRP with building development capacity of approximately 50,000 assignable square feet (ASF) or approximately 70,000-75,000 ground square feet (GSF) (please refer to Appendix K, "Permanent Facility Site Plan"). The SRP land would be made available to BP or its development partner for development of the EBI facility under an unsubordinated 52-year ground lease.

A number of property owners in the Torrey Pines Mesa, such as Alexandria Real Estate Equities, Biomed Realty Trust, Slough Estates, etc., could offer opportunities for Interim Leased Space, as well as development and ownership of the Permanent EBI Facility. UCSD's Real Estate Office is available to assist BP to coordinate both locations. UCSD understands that BP would have the Permanent Facility developed and owned by a third party, and that EBI would occupy the facility under an operating lease for its funded term, at this point proposed to be 10 years. UCSD would retain rights of first refusal to occupy space in the building should EBI not occupy all the space, and would retain rights of first offer and first refusal were the facility to be sold.

The SRP is dedicated to UCSD research collaborations, so certain eligible party occupancy requirements would be included in the terms of the ground lease. Sample ground lease terms are included in Appendix G, "Sample Ground Lease Terms." Estimated Ground Rent for the Permanent Facility and SRP common area maintenance charges are included in Appendix L, "Sample Permanent Facility Ground Rent". Since BP has significant experience with its leased corporate facilities, BP may want to use its own building occupancy cost estimates from its sale/leased back corporate facilities for its building occupancy costs in the UCSD SRP.

7.2 Space

The design of the EBI building should be directed at three primary objectives. First and foremost, it should be designed in order for science to flourish on campus and throughout the EBI collaboration. It should encourage, indeed create, collaboration. Finally, it should assure the inclusion of EBI investigators in the intellectual life of the campus.

Staffing targets

Total staffing for EBI at maturity should be about 100 employees. Of these, approximately 60 will be research scientists and staff, approximately 30 will be directors and technical support staff for the core facilities, and approximately 10 will provide general administrative support to the Institute in addition to the Director and Associate Director. An additional 150-180 researchers will be associated with EBI through funding to collaborating institutions.

Space Design, Allocation, Development

Space should be allocated for six to ten EBI Principal Investigators with laboratory capacity sufficient for six to eight lab members for each. Each lab module should include at least six to eight linear feet of bench space for each member, plus one fume hood, and sink per lab. Each station should include a knee space, drawer space, and access to data and power. Each lab should be provided with at least three vacuum, gas, and air outlets. Each module should have an associated procedure room which can be closed off from the general lab environment. There should be at least two constant temperature rooms and tissue culture rooms available for researchers, and at least 300 square feet of common equipment space available per lab for incubators, small plant growth chambers, centrifuges, freezers and other equipment. Each research oriented floor of the EBI building should include an autoclave, dishwasher, Millipore filter system, and still for distilled water. Each PI should have an office of at least 125 square feet, and two additional similarly sized offices for lab personnel. Each module, including offices, common space and lab should occupy 2000-2500 square feet of assignable space, so the total allocation to PI's should be 20,000-25,000 ASF.

An additional 15,000 ASF should be allocated to core facilities which will support EBI researchers and draw collaborators from EBI collaborators and the biotech community to the EBI facility. These should include state-of-the-art high-throughput screening systems for cells and enzymes; an analytical facility including mass spectrometry, microarray analysis, and 2-D NMR for chemical analysis of complex mixtures such as plant extracts and fermentation broths; and a facility for gene synthesis. Additional core support facilities for bioinformatics and cyberinfrastructure will be critical for information sharing and long distance collaborations, including visualization facilities and real-time conferencing capabilities. Facilities required to support EBI researchers include a fermentation core, plant growth facilities, and a gene transfer lab. EBI should also have a pilot-scale cellulosic ethanol refinery, so that researchers can test experimental results from plant growth to fuel refining. All of these facilities will require special utilities, such as heating, cooling, lighting and electrical service, as well as appropriate separation of space for different needs and functionality. UCSD greenhouse facilities will be available for larger-scale plant growth needs, but will require upgrading to be appropriate to the EBI needs.

A suite of offices for corporate officers and administrative staff will also be required. In addition, the EBI facility should have a suite of eight to ten offices for policy analysis, outreach, and educational personnel. A suite of six to eight offices will also be reserved for visiting researchers who come to use the core facilities, or to perform analytical work on downstream discoveries.

To encourage both intellectual inclusion and public outreach, the EBI building should include a small auditorium, seating 200-300 participants, and a large meeting room that can seat up to 40. Small meeting rooms for scholarly activity among EBI scientific staff, seating approximately 12 should be placed on each floor of the building as well.

EBI will feature a high-end computer machine room and IT and telecommunications infrastructure. Key pieces of the IT infrastructure will include information management and security systems.

Enabling Technologies

EBI will be equipped with all state-of-the-art equipment required to address its scientific objectives. This will require the purchase, installation, and maintenance of several high-ticket items that have been included in the capital equipment budget.

Preventing duplication of facilities

The core facilities at EBI will be unique for several reasons. First, they will be state of the art, and monies will be allocated each year to keep up with the latest advances in technology. Second, they will be staffed and directed by EBI employees. Third, along with all the research which is envisioned in the EBI facility, they will be available for proprietary EBI research, and disclosure will be subject to the overall EBI agreement. This will provide clarity on the issues of disclosure and IP which might otherwise be clouded if partner institution facilities were used.

EBI Enabling Technologies Capital Equipment Budget

Year 01	$M
Pilot scale lignocellulosic bioprocessing facility	5
HT Bioanalytical core/metabolomics, including ABI 4000Q triple quad LC-MS, HPLCs, GC	2.5
Proteomics core, including two Finnegan-Thermo Orbitraps	2
Database servers and clusters	1
Robotics workstations for DNA clone preparations, novel enzyme production, arraying, seqprep	1.5
Gene synthesizer	1
General shared laboratory equipment, growth facilities	2
	Total: 15M
Year 02	**$M**
Experimental large scale fermentation	2
Automated HT protein production robotics	1
Expanded database and cluster infrastructure	1
Spectroscopy/Microscopy Core, including Multiphoton imaging and EPR spectroscopy	1.5
Plant growth environments/transgenic facility	1.5
Core laboratory support	1
	Total: 8M
Year 03	**$M**
Organic chemistry analytical support	1.5
Bioprocessor Facility expansion	1.5
Experimental feedstock incubators	1
Core laboratory support	1
Years 04-10	
Turnover and replacement of initial equipment	

Creating a collaborative environment

The design of the EBI facility, its labs, gathering spaces, and core facilities, will be carried out with the express intention of fostering collaboration and communication among researchers. We will seek out and study the design of a number of recently constructed buildings at a variety of locations across the country, selecting the best ideas and most effective devices to enhance collaboration.

Ensuring confidentiality of proprietary work

It is anticipated that 90% of the research performed will be basic research and 10% will be applied research. Access to the facility will be via an entrance screened by either reception or security personnel as appropriate dependent upon the nature of the research. Name badges will be required of all personnel while at the facility.

Planning for growth of the Institute

EBI will be structured with the expectation of long-term growth, surviving the end of the BP collaboration with UCSD by creating alternative sources of funding including government grants, company contracts, philanthropy, and licensing revenues. This will helps satisfy the legal requirements for independence, it will enable high quality staff to be recruited and retained throughout the duration of the 10-year program, and it will help justify the allocation of major university resources, including land.

We expect to lease property for the first two years for EBI research and administrative offices, so that research can begin immediately in July 2007, while the EBI building is constructed in the UCSD Science Park. During this time, equipment for the core facilities will be purchased, and as the number of employees ramps up, the budget for equipment will be decreased, with salaries replacing equipment purchases. We do not anticipate that the EBI staff will reach the steady state capacity described above until year four or five of the ten year agreement.

7.3 EBI Facility Construction and Maintenance

EBI Facility Construction Assistance

UCSD's Facilities Design & Construction (FD&C) comprises functional support units that include project management, contract administration, fiscal management, construction services, health care design and construction, and administrative services. Although the EBI facility will be built by a third party, FD&C may potentially assist with aspects of the construction process, and it will have some oversight responsibility because the University of California Regents must approve the design.

Site, Community Liaison, and Environmental Documentation

UCSD Physical Planning administers the campus site selection process. This includes defining site capacity, site development opportunities and constraints, and design guidelines. Physical Planning is also responsible for determining the environmental documentation requirements pursuant to the California Environmental Quality Act (CEQA), and then carrying out the compliance activities in accordance with state law. It is anticipated that key UCSD administrators and community-relations advisers would develop a strategy for responding to community inquiries and disseminating site and environmental information to the general public and media. UCSD Community Planning staff is also responsible for consulting with external agencies as needed; e.g., City of San Diego, community planning groups, etc.

Schedule Information—Planning Component

Physical Planning activities associated with site approval are triggered by confirmation of the building program. At that point, Physical Planning staff will undertake a site analysis for the project that takes approximately two months to prepare. The site analysis is then taken before the Campus/Community Planning Committee (C/CPC) twice: once for information and comment and then a second time for site approval. This process takes a minimum of two months. Once site approval is granted, design can commence. Project schematics are developed and reviewed by the campus' Design Review Board (DRB). The DRB generally meets three times over a four to six month period. Environmental documentation pursuant to CEQA is initiated when schematic design reaches approximately 50% level, and document preparation takes approximately six months to complete. Once complete, the CEQA environmental document is forwarded to the Regents of the University of California who will certify the findings of the document and at the same time will approve the ground lease and design of the project. The University of California is its own lead agency, and is not subject to local land use jurisdiction.

Laboratory equipment provisioning and maintenance

Because of the variety of specialized equipment anticipated in the core facilities, it is unlikely that it will be cost effective to have in-house maintenance personnel. Therefore budgetary provision will be made for maintenance agreements with the vendors of most of the equipment.

Laboratory physical asset management and inventory tracking

A physical asset management system will be installed as part of the general accounting system, to enable EBI to seek and manage grants in compliance with federal regulations.

Health, Safety, Security and Environmental Administration

EBI will create administrative systems which conform to the most stringent of the requirements held by either the federal government, UCSD or BP. Like BP, UCSD considers Health, Safety, Security, and Environmental (HSSE) elements of critical importance, warranting specific consideration. UCSD is committed to providing a safe and healthful environment for faculty, staff, students, and visitors while at the same time practicing good environmental stewardship. Historically, UCSD has maintained substantial compliance with all environmental health and safety regulations. At present, UCSD does not anticipate the need for any additional health, safety or environmental permits to complete the research being proposed to BP. Additional information about UCSD policies and performance on HSSE issues, please refer to **Appendix M**.

7.4 Interim Space

Our goal is to begin research operations in interim facilities by Summer 2007.

Office Space

The nature of BP's initial staffing of the EBI will determine the nature of the required Interim Space. UCSD will make available by lease to BP, 10,226 rentable square feet (rsf) of office space and conference rooms and 36 garage parking spaces at Torrey Pines Center South, its office building located at 10280 North Torrey Pines Road, La Jolla , beginning July 1, 2007. Interim Space office rent, for a full-service, gross lease net of electricity, until a permanent facility is completed, is included in **Appendix N**, "Sample Interim Laboratory and Office Leased Space Rent."

Laboratory and Office Space

If the EBI Interim Space requirement is for combined laboratory and office space, the UCSD Real Estate Office will assist BP or the EBI to lease laboratory and office space in a facility on the Torrey Pines Mesa. The UCSD Real Estate Office has identified a number of leased space location alternatives currently available on the Torrey Pines Mesa for the requirement. UCSD is investigating greenhouse space both on-campus and off-campus. Identification of the best alternatives would be based upon information from BP on the ramp-up schedule for EBI. A summary of alternative sites is presented in **Appendix O,** "Torrey Pines Availability." In general, a three-year minimum lease commitment would be required. Estimated rent, based upon a triple net lease and tenant improvement costs for the EBI Interim Lab and Office Space, based upon an occupancy range of 12,000 rsf (8,400 asf) to 78,571 rsf (55,000 asf), until a permanent facility is completed, is included in **Appendix P**, "Sample Interim Office Leased Space Rent, North Torrey Pines Road."

8.0 *Budget* and Costs

Above *The Joint Technology Center (JTC) high-throughput sequencer laboratory—courtesy of the Venter Institute*

8.0 Budget and Costs

8.1 UCSD Host Institution Planning, Transition and Development Budget

(January 1, 2007 - June 30, 2007)

Includes salaries and related costs for administrative staff and faculty members who are committed to participate in EBI design, program development and operating provisions. Staffing includes one and a half months total shared by Professors Orcutt, Briggs and Wooley, who will provide scientific content and serve as points-of-contact on all issues during the planning stage. C. Keen is the Project Manager (three months) and will coordinate the process of developing the EBI. P. Jordan (two months) will assist with costing and budgets during the planning stage. J. Matthews, Graphics Designer, will spend approximately one month in providing design layout and web content as required. M. Stark will provide three months as Dr. Briggs' Administrative Assistant, and will help make arrangements for meetings and travel accommodations. A. Withey will provide two months as a Senior Writer and will help write content for planning documents. L. Cravens-Wertz is a Project Assistant and will provide three months assisting Dr. Orcutt and others in preparing documents and making meeting and travel arrangements. At no cost to BP, other administrative staff including A. Briggs-Addo (Assistant Vice-Chancellor Administration), A. Parode (UC Legal) and J.J. Ford (Contracting Officer) will provide assistance as needed to complete the requirements as part of their normal duties.

Charges are included for reporting materials, meetings including a retreat for BP, host and collaborating participants to meet and confer off site. These costs include meeting arrangements such as facility rental, meals and refreshments. Travel (six round trips) is included for collaborators to participate in planning. Communications and computer consortium connect charges are also included. These total $234,571.

8.2 Overhead Costs

The overhead rate at UCSD is currently 54.5% and is based on Modified Total Direct Costs (MTDC). This rate is in accordance with the University's Federally negotiated DHHS agreement dated May 28, 2004. MTDC base comprises of the following direct costs:

> Salaries and Wages, Fringe Benefits, Materials and Supplies, Services, Travel, and first $25,000 of each subgrant/subcontract issued by UCSD to an outside entity/organization.

Categories of costs that are not assessed Indirect Costs include:

> Equipment and capital expenditures tuition and fees for University Students, rental costs for off-site facilities, scholarships and fellowships, and portion of each subgrant/subcontract in excess of $25,000 issued by UCSD to an outside entity/organization.We have included for informational purposes an estimate of the indirect cost based on UCSD policy. Indirect costs will be more accurately reflected when detailed budgets are calculated and submitted for future research.

8.3 Budget Assumptions

The budget reflects the establishment of the EBI Director's Office in the amount of $36.4M over the ten years. Included in these costs are fully burdened salaries for management and administrative support staff to provide project management and business functions for a model university division.

EBI research staff has been estimated to ramp up from 20 persons to 100 persons in Year 5. Beginning with Year 1, we estimated 20 persons each year would be hired and added to the EBI staff. We assumed a standard university research group of six persons, including a Senior Scientist, a Postdoc, a Project Scientist, two Staff Research Associates and a Lab Technician. We estimated three groups beginning Year 1 plus two additional Senior Scientists or 20 persons. The number of Senior Scientists each year would total three. At Year 5, the full staff of 100 would be hired. These fully burdened salary costs are estimated at $119.5M over ten years.

Capital building expense has been estimated with the assumption that EBI would lease a UCSD owned and available building

comprising of offices (7158 ASF) plus an office and lab building in North Torrey Pines area adjacent to the University (8400 ASF) for years 1-2. Years 3-10 include permanent facility ground rent located in the UCSD Science Research Park, which would house the 50,000 ASF building with funding of $40M provided by the State of California. This is estimated at $6.3M over the ten years.

New research equipment and replacement equipment have been estimated for outfitting the EBI building with state of the art laboratory instruments and facilities. The cost is estimated at $68.6M over the ten years.

We have included start up funds for the newly hired Research Scientists. We have included these costs based on the practice that the University normally expects that full Professors will need $1M/each in start up funding and this category is estimated at $16.3M. We have only included 15 FTEs since some Scientist will join existing groups and not require these start-up funds.

The final category of funding we have estimated is for research funding for UCSD and collaborators in this proposed effort. These costs are estimated at $252.7M over the ten years, and include UCSD's 54.5% indirect cost rate.

We anticipated that 90% of the research performed will be as basic research in open space (Host Institution or EBI facility) and 10% will be proposed for any potentially proprietary research (EBI facility).

See **Appendix Q**, "Estimated Budget Overview."

9.0 *Incentive* Elements

Above *Plant Transformation Facility—courtesy of ISU*

9.0 Incentives and Letters of Support

UCSD intends to add two new faculty FTE (ten total) for five years in fields related to the multidisciplinary research being supported by the EBI (e.g., plant biology, genomics, marine metagenomics, bioengineering, chemistry and biochemistry, chemical engineering, energy technology, bioinformatics, cyberinfrastructure, climate and public policy). We are requesting that BP endow a Chair for each of these faculty positions, which would be assessed as a component of the research funding.

It will be a great challenge to build the 50,000 ASF laboratory facility for the EBI within two years of the start of negotiations. The cost of this facility, and the required state-of-the-art equipment that will be housed in the facility, cannot be determined prior to detailed discussions with BP. To help leverage our efforts to bring this outstanding opportunity to UCSD, the Governor of California has committed $40 million towards the construction of the facility.

ISU is working with Iowa's State Legislature and Governor to obtain additional resources to support expanded opportunities in bioenergy, including a new building to house some of the research, new infrastructure for a field laboratory at its Agronomy Farm, and additional faculty positions in plant science, microbial science, and production and bioprocessing to expand ISU capabilities in energy biosciences. The State Legislative session does not convene until January, but preliminary discussions with legislators of both parties have indicated significant interest in working with ISU to determine and obtain the level of state support needed for ISU's participation in a successful EBI collaboration.

Battelle Memorial Institute/PNNL is partnering with Washington State University to construct and operate the Bioproducts Sciences and Engineering Laboratory (BSEL) on the campus of WSU Tri-Cities. The BSEL will be a multipurpose facility including operating space for all activities required in the research and development of the science and engineering of processes for bio-based product manufacture. A key feature of the BSEL is the Biorefinery, which is a 2500 square foot high-bay facility for integration and scale-up of the various processing steps in bioproducts manufacture. In addition to the Biorefinery, plans for the BSEL include high-pressure catalytic reactor rooms (for hydrogenation and other chemical processing); bioprocessing labs for development and engineering of fungal fermentations; and supporting wet chemical labs for synthesis and preparation of catalysts and feedstocks; the Combinatorial Catalysis research laboratory, analytical chemistry including chromatography and spectroscopy; and process engineering research and development. Ten new joint Battelle/PNNL-WSU faculty appointments are expected to soon be approved by the state legislature. DOE through Battelle will support 50% of each position. Scientific expertise associated with these position descriptions is yet to be determined but could include input from BP through EBI and CBEST.

A variety of individuals and institutions provided Letters of Support for the CBEST EBI. These letters can be found behind the appendices and the sources are summarized in the table above. Letters of Commitment from CBEST collaborating institutions are also found behind the appendices and summarized in the table.

Letters of Commitment from Collaborating Institutions

Gregory L. Geoffroy, *President, University of Iowa*

J. Craig Venter, *President and Chairman, J. Craig Ventor Institute*

Douglas Ray, *Vice President, Pacific Northwest Division, Battelle Memorial Institute*

Kim E. Witmer, *Vice President and Chief Financial Officer, Salk Institute for Biological Studies*

Douglas A. Bingham, *Executive Vice President and Chief Operating Officer, The Scripps Research Institute*

Incentives and Letters of Support

Arnold Schwarzenegger, *Governor, State of California*

Marye Anne Fox, *Chancellor, University of California, San Diego*

Diane Feinstein, *United States Senate*

Susan Davis, Ken Calvert, Brian Bilbray, Duncan Hunter, Darrell Issa, Bob Filner, *Congress of the United States*

Denise Ducheny, *California State Senator, 40th District, Chair, Budget Committee*

Members of the California State Assembly

Jerry Sanders, *Mayor, City of San Diego*

Scott Kessler, *Deputy Director, Economic Development Division, City of San Diego*

Iowa Congressional Delegation Members

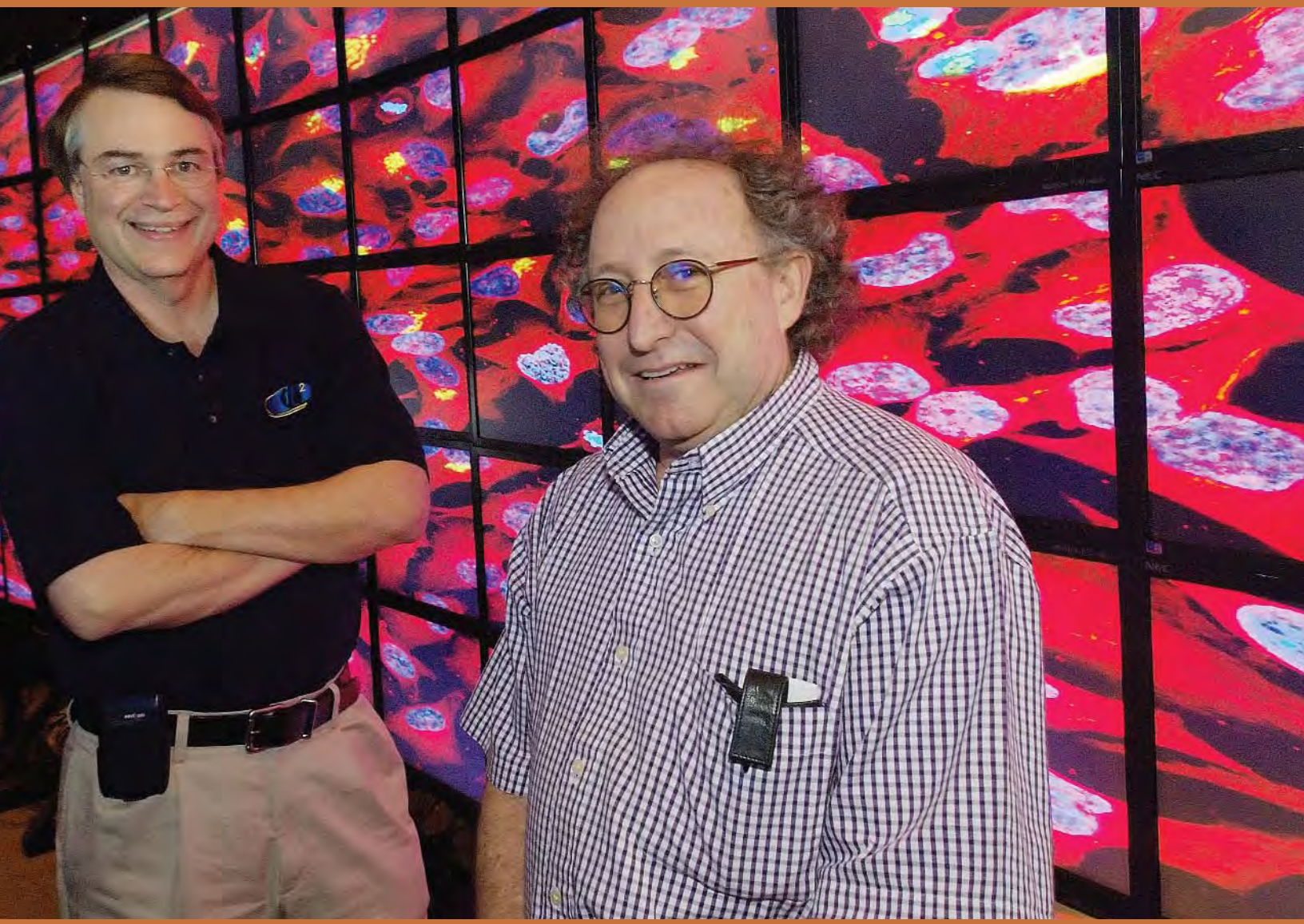
Leaders of the Iowa General Assembly

Martha Willits, *President and CEO, The Greater Des Moines Partnership*

Eve A. Doi, *Associate Director of Chamber Relations, Ames Chamber of Commerce*

Joe Panetta, *President and CEO, BIOCOM*

10.0 Appendices



Above (left to right) *Larry Smarr and Mark Ellisman—courtesy of UCSD*

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Appendices

A. Project Area Listing of Project Leads

Above *Torrey Pines Mesa sea dahlias*

UCSD Energy Biosciences Institute

Project Area Listing of Project Leads

PROJECT AREAS

Biorefinery Design and Optimization	Faculty and BP Engineers	EBI/BP
Plant Science and Engineering	Pat Schnable Steve Kay	ISU Scripps Research Institute
Feedstock Production & Supply	Kendall Lamkey Matt Liebman	ISU ISU
Pretreatment & Deconstruction	Z. Conrad Zhang Robert Brown	Battelle ISU
Fermentation	Linda Lasure Bernhard Palsson	Battelle UCSD
Fuel Separation and Performance	Steve Buckley Robert Cattolica	UCSD UCSD

UCSD Energy Biosciences Institute

Project Area Listing of Project Leads

ENABLING TECHNOLOGIES

Analytical Chemistry			
	Proteins	Dick Smith Steve Briggs	Battelle UCSD
	Metabolomics	Basil Nikolau Ed Dennis	ISU UCSD
	mRNA Profiling	Mike Brownstein Willem Rensink	Venter Institute Venter Institute
	NA Sequencing/Biomarker Discovery	Pat Schnable Yu-Hui Rogers	ISU Venter Institute
Modeling		Jackie Shanks Bernhard Palsson	ISU UCSD
Bioinformatics		Volker Brendel Robin Buell	ISU Venter Institute
Cyberinfrastructure		Mark Ellisman John Orcutt Larry Smarr John Wooley	UCSD UCSD UCSD UCSD
Metagenomics and Single Genome Amplification		Roger Lasken Claire Fraser-Liggett	Venter Institute Venter Institute
Bioreactor Design		Fred Brockman Tony Pometto	Battelle ISU
Synthetic Genomics		Clyde Hutchison Hamilton Smith	Venter Institute Venter Institute
Experimental Design & Analysis		Dan Nettleton Nicholas Schork	ISU UCSD
Plant Transformation		Kan Wang	ISU

UCSD Energy Biosciences Institute

Project Area Listing of Project Leads

SYSTEM LEVEL ANALYSIS

Economics, Sociology and Policy	Todd Werpy	Battelle
	Bruce Babcock	ISU
	Dermot Hayes	ISU
	Robert Friedman	Venter Institute
Environmental Impact	Rob Anex	ISU
	Paul Crutzen	UCSD
	Mario Molina	UCSD
	Kim Prather	UCSD
	Richard Somerville	UCSD
Outreach	Jack Payne	ISU
	Cheryl Peach	UCSD

B. EBI *Outreach Capabilities*

Above *Farrokh Najmabadi, Director of UCSD's Center for Energy Research works with a student—courtesy of UCSD*

UCSD and ISU Outreach And Social Sciences Research Capabilities

Full realization of the EBI potential will require broad public support for all phases of the project, from research to implementation. Recognizing that not addressing societal issues could impede EBI progress, UCSD and ISU envision a public outreach, education and social sciences research program that will draw upon the extensive resources and expertise of both institutions. Collectively, EBI, ISU and UCSD communications and outreach staff will be able to directly address both anticipated and unanticipated societal issues inherent in biofuels research, technology development and implementation. Below is a synopsis of capabilities that each institution can bring to bear on the EBI project.

University of California San Diego

Communications: Conveying the relevance of research through the media

UCSD's University Communications Office oversees and coordinates the activities of more than 20 public relations professionals across the campus with specific expertise in translating and promoting developments in a broad array of academic disciplines, including the environmental sciences, bioengineering, plant genomics, computation and science policy. It is responsible for informing the public and the news media nationally and internationally about UCSD's research developments and other activities. Its website (www.ucsdnews.ucsd.edu) features an online press room, press releases, university news, an event calendar, a faculty expert's database and a variety of university reference resources. The Communications Office also designs and produces many of UCSD's print and online publications, manages campus-wide special events for the Chancellor and oversees state and local governmental relations.

Research Ethics: Promoting science in the public interest

The Center for Ethics in Science and Technology (*ethicscenter.net*) is a community endeavor launched in 2003 and with primary leadership from UCSD in collaboration with the University of San Diego. The Center provides resources and services to increase awareness, understanding, and discussion of the ethical implications of new developments in science and technology. It serves the San Diego region in particular, but in a way that produces materials and models of national relevance. In so doing, it promotes science in the public interest through more informed policy development and decision-making on the part of individuals, corporations, and institutions. The Center's primary focus has been on stem cell research, resulting in national prominence (publications relevant to national policy discussion in Nature Biotechnology and Stem Cell Reviews) and convening multiple public events in San Diego. The Center is an outgrowth of the UCSD Research Ethics Program (ethics.ucsd.edu). Founded in 1997, the program has an institutional responsibility for a variety of aspects of research ethics, but particularly for training of researchers in the responsible conduct of research (RCR).

Above *Students view 3-D graphics in the SIO VizCenter*

Multimedia: Reaching millions through television, the internet and visualization technology

Science Television at UCSD UCSD is the hub of two television endeavors: UCSD-TV and UCTV. Award-winning UCSD-TV and UCTV produce and deliver documentaries, faculty lectures and cutting-edge research symposiums to over 15 million homes nationally via DBS satellite and cable systems. Calit2 also has the capability to produce original programs that air on three 24-hour networks (UC- and UCSD-TV and the ResearchChannel) reaching approximately 40 million U.S. households—more than any other U.S. research institution producing original science programming.

Streaming Video on the Web Both UCSD-TV and Calit2 have extensive collections of archived scientific presentations and programs available for download from their web sites, constituting one of the largest video archives of any U.S. university. UCSD-TV recently joined with Google Video to extend the reach of their programming to millions of users world-wide. Since 2001, Calit2 at UCSD has made all of the seminars and conferences it sponsors or co-sponsors available in real time as live webcasts and is currently in the process of developing a new Multimedia Portal that will offer unparalleled ease of use to search for content and launch videos from a hub.

HD Production Facility at Calit2 Calit2 is constructing a High-Definition (HD) Production Facility in its San Diego headquarters to accommodate the growing demand for producing content for a variety of venues. The facility will also enable satellite media tours and video news releases (VNRs), in addition to allowing Calit2 to produce a regular stream of research programs for distribution over the Internet in streaming formats, and on television. Calit2's public relations director, Doug Ramsey, is a former television anchor and producer, providing the expertise to capitalize fully on this enabling technology.

Visualization Technology at UCSD Calit2 and Scripps Institution of Oceanography have endeavored to make visualization a cornerstone of UCSD's research agenda because it is a foundational technology that can support scientists working on a very wide range of applications. State of the art facilities and leadership in visualization technology innovations have positioned UCSD at the forefront of academia in the use of visualization in both research and outreach. This focus on visualization technologies puts UCSD in a unique position to support scientific collaboration—even among researchers thousands of miles apart—and that same capability allows UCSD to deliver powerful messaging and imagery to audiences in San Diego and around the world.

Science exhibits: Creating public portals into the research and technology

UCSD's Birch Aquarium at Scripps The Birch Aquarium at Scripps (BAS) is the interpretive center for Scripps Institution of Oceanography (SIO). Host to more than 350,000 visitors a year, BAS provides a window into the world-class research conducted at UCSD/SIO. Keeping abreast of current research is a specialty of the exhibit designers at BAS. Lead by a PhD scientist, the exhibit team excels at translating complex science into innovative, interactive exhibits that both intrigue and inform visitors. *Sea of Genes,* an exhibition based on SIO marine genomics research, makes complex concepts in genetics, molecular biology and marine ecology accessible to a broad pubic audience. An upcoming exhibit on climate (May 2007), *Climate Change: Feeling the Heat,* will illustrate evidence for global warming, how climate scientists know what they know and steps that can be taken to mitigate the problem. BAS is poised to create an exhibit based on the research conducted through the Energy Biosciences Institute that could be transported and/or replicated for use in science centers across the country, as well as in the lobby or other public space of the new EBI facility.

Workforce development: Building the foundation for a biofuels industry

Integrative Graduate Education and Research Traineeship The National Science Foundation recently awarded a five-year graduate student training grant to biological sciences faculty members Julian Schroeder and Steve Briggs. This program will train Ph.D. graduate students in the newly emerging interdisciplinary field of Plant Systems Biology. Faculty from multiple UCSD divisions and departments, as well as from the Salk Institute for Biological Studies and the Scripps Research Institute, will participate in the training and research of graduate students. UCSD entities include the UCSD Division of Biological Sciences, the Bioengineering Department, the Department of Computer Sciences and Engineering, San Diego Super Computer Center, the Division of Physical Sciences, and the School of Medicine. IGERT students in this highly interdisciplinary program are likely to be excellent recruiting targets for EBI and BP.

Internships at the Jacobs School of Engineering The Jacobs School's Bioengineering Department consistently ranks among the top three biomedical programs in the nation. The multidisci-

plinary bioinformatics and biotechnology programs were created, in part, to respond to the needs of the biotech and pharmaceutical industries. This responsiveness to the needs of employers has made UCSD and the Jacobs School a prime source for highly trained biotechnology personnel. The Jacobs School also maintains strong internship programs within the biomedical industry. The Jacobs School has pioneered a team internship concept, which is especially relevant for biotechnology companies. Students learn how the knowledge and theory garnered in class is applied in the real world. At the same time, industry has access to talented students with fresh ideas—and benefit from an early look at the talent pool. Similar internship programs can be developed in collaboration with EBI.

In addition to engineering training, the Jacobs School helps prepare students to become leaders in innovative companies through a course series offered by its' von Liebig Center for Entrepreneurism & Technology Advancement. Students gain an insider's look at life sciences business from CEOs, venture capitalists and other professionals, and through readings, case studies and projects, they learn how entrepreneurial companies work. Most importantly, they gain insights into how to contribute to business discussions and decision-making.

UCSD Extension Biosciences Department UCSD Extension offers a broad array of courses and certificate programs to meet the continuing education needs of the life sciences community, support high-level skills development for industry professionals and career transition for those interested in entering the biotechnology field (extension.ucsd.edu/studyarea/index.cfm). Through UCSD Extension's burgeoning online education program many courses in biotech related fields are available online, providing access to users around the world.

K-12 Outreach: Creating pathways to careers in science

The Divisions of Physical and Biological Sciences, the Jacobs School of Engineering and the Birch Aquarium at Scripps Institution of Oceanography have emerged as leaders in K-12 outreach activities at UCSD. Educational outreach within these UCSD divisions has focused on two main goals: 1) portraying the relevance and importance of scientific research to students, teachers and the general public; and 2) demystifying the process of scientific discovery for these audiences. Helping people understand the nature and importance of science reduces fear and skepticism and expands the base of support for scientific research. In addition, enhancing K-12 students' interest in science is critical to increasing the pipeline of talented young people into science and technology careers and creating a skilled workforce.

UCSD faculty, staff, graduate students and undergraduates help infuse cutting-edge science into local and regional classrooms by participating in enrichment programs that bring K-12 students and teachers to campus. Programs include science workshops for teachers, K-12 student programs, lab tours and summer programs for college bound high school students. In order to reach K-12 teacher and student audiences who live outside of the San Diego area, the Division of Physical and Biological sciences outreach staff partner with researchers and teachers to develop multimedia curriculum materials that are made available via the internet. These materials are based on state and national science curriculum standards and provide a rich source of up-to-date teaching and learning materials based on UCSD science. These resources are archived at (www.ucsd.tv/researchexplorations).

Iowa State University

Social sciences research and outreach: Transforming from the rural economy to the bioeconomy

Iowa State University Extension Sociology Department has been recognized by the last three external reviews conducted by the Cooperative State Research, Education, and Extension Service-USDA as having "one of the best, if not the best Extension Sociology units in the country". This recognition is the result of a tightly integrated research, teaching and extension program that draws upon the faculty in both the College of Agriculture (rural sociology) and the College of Liberal Arts and Sciences (sociology). With a faculty of 32 PhDs and approximately 60 graduate students, the department is recognized for its innovative research that addresses community and economic impacts of change. Research in this arena explores the human dimensions of acceptance and rejection of change as well as social action models to facilitate change. Sociology faculty are engaged in wide variety of interdisciplinary efforts across the campus, and frequently are team members in addressing the social, psychological and economic factors that prevent communities or households from recognizing opportunities or accepting change.

One of the identified strengths of the Department is its commitment to understanding the dynamics of rural social change through the application of social science research models. Known as a leader in survey research methods, the

faculty continually monitor changes in the social fabric of the state through community surveys, statewide polls, and collection of secondary data available through a variety of state and federal agencies. The transformation of the rural economy to the bioeconomy will require local and state leadership, an understanding of community dynamics, and how effective networks and cooperation can be built. The Department of Sociology stands ready to assist EBI in realizing the new opportunities of the bioeconomy.

Iowa State University Extension Outreach

University Extension, the institution's outreach arm, is the primary means of fulfilling Iowa State's land-grant mission of engagement and service. Extension builds partnerships and delivers research-based learning opportunities to enhance community economic development and quality of life. In cooperation with the federal government (through the USDA), Extension delivers educational programs through offices located in all 99 Iowa counties. Important aspects of this work include: community and business planning and infrastructure development; assistance to existing companies through educational and business assistance; and business development support, including that driven by technology transfer and newly generated intellectual property.

Iowa State Extension has a century of experience in using the University's knowledge and resources to meet the challenges and opportunities facing Iowa and its diverse cultures and communities. Extension brings with it a number of strengths:

- Effective systems that link those who create, disseminate, and apply knowledge
- Proactive communication with constituents and stakeholders
- Established connections to policy and decision makers
- Recognized capacity to build and maintain thriving partnerships among citizens, agencies, and organizations
- Entrepreneurial spirit and a reputation for successful innovation
- Efficient use of information and technology
- Highly successful efforts in community development
- Multiple efforts to promote economic development throughout the state

Iowa State is involved in many areas of engagement and service that enhance its ability, as a public university, to educate Iowans. These varied programs and activities meet key tests of responsiveness, partnership, academic neutrality, and integration of varied disciplines and units.

ISU's proposed New Century Farm

Establishment of the proposed New Century Farm at Iowa State University would be the first integrated, sustainable biofuel feedstock production farm in the United States. The New Century Farm will be a model for American bioenergy production and demonstrate the transformation of agriculture to feedstock-readiness. The vision for sustainable biofuel production at the New Century Farm will include:

Research Bring together scientific expertise to address biomass cropping systems, biofuel processing, logistics of biomass supply and recycling nutrients back to the land.

Teaching Serve as a laboratory and extension resource for training future scientists, producers and extension experts.

Extension Demonstrate economic, social and environmental viability of bioenergy production to producers, policy-makers and the public.

The New Century Farm will:

Integrate agronomy, ecology, industrial technologies, economics and community needs. Producing biofuel feedstocks while maintaining environmental quality requires a new scientific and managerial approach that combines the principles and technologies of agronomy, ecology, chemistry, engineering and economics.

Analyze technological systems. Successful bioenergy production must integrate biomass production, efficient harvest methods, feedstock handling and storage, feedstock pretreatment and transport and bioenergy processing.

Analyze economics and ecological services of systems. Large-scale, long-term studies will address the performance, cost-effectiveness and profitability of biomass production systems. Dynamic interactions between feedstock production and the ecosystem will be assessed, particularly in

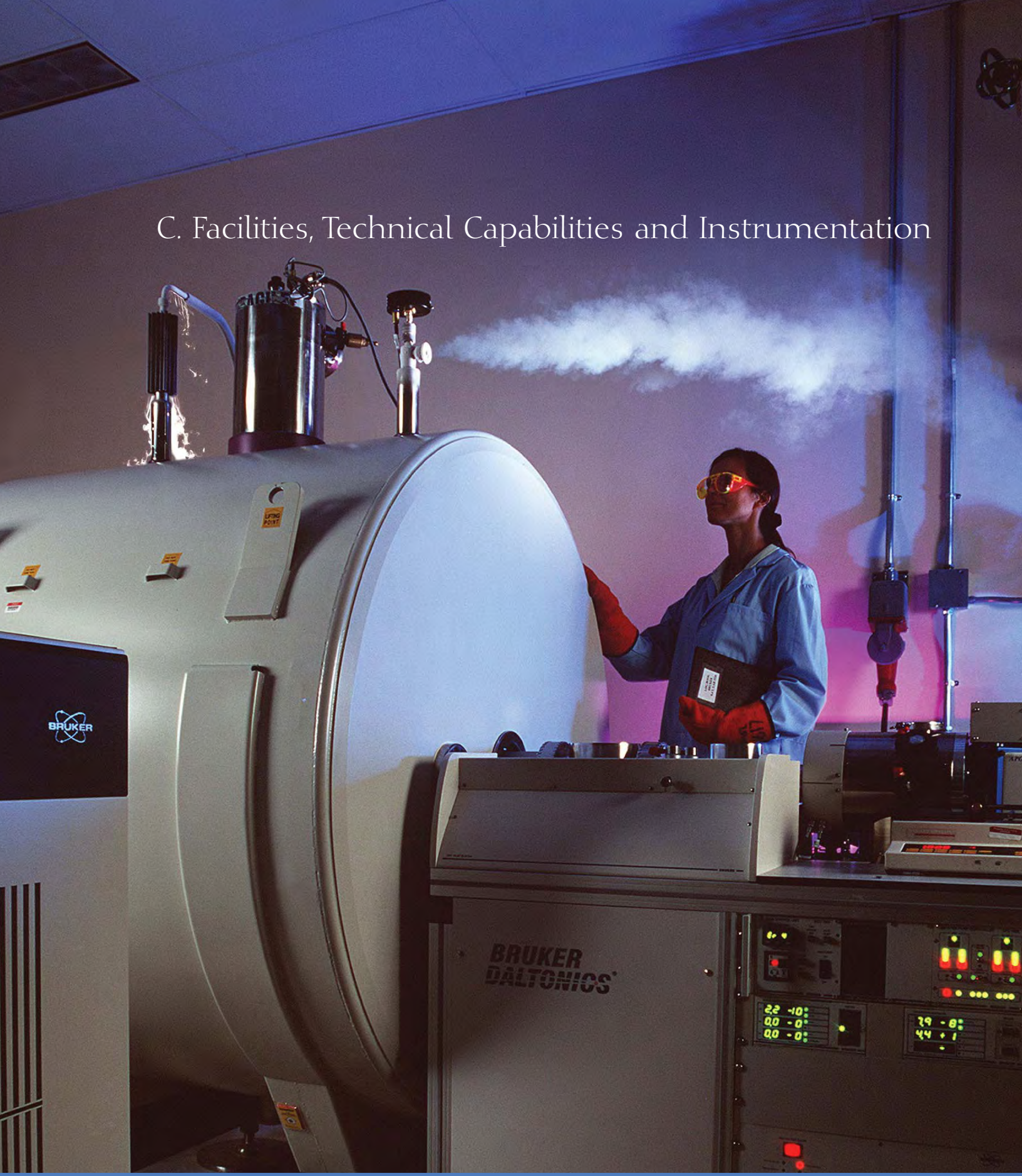
terms of soil, water and air quality.

Build partnerships. Engaging producers, community members and industry representatives will ensure that relevant, practical issues and opportunities are addressed. The New Century Farm will be a model for how Iowa State University fulfills its land-grant mission through service and engagement.

Build on Iowa State's strengths. With nearly 150 years of research, teaching and extension accomplishments, Iowa State is at the geographical, research and educational epicenter of the expanding bioeconomy. The university's research and expertise in biorenewables dates back to the 1970s. The university's internationally recognized Office of Biorenewables Programs offers the only graduate degree program in biorenewables in the nation. Iowa State also has close collaborative relations with major agricultural and chemical industries, most of whom have major facilities in central Iowa. Iowa State has excellent statewide extension and outreach programs serving agriculture and business and industry.

ISU Extension Communications and Information Technology ISU Extension employs 38 professional staff offering comprehensive communications and technology services supporting the university's outreach and distance education activities. Services include digital media production (video, radio, web); publishing (print and electronic); marketing, graphic design, development, web/videoconferencing, and distance education delivery technologies. ISU Extension's Communications Office is staffed by professionals with a wide range of experiences including working for national news networks. Plans are underway to hire a communications specialist who will focus exclusively on bioeconomy topics.

C. Facilities, Technical Capabilities and Instrumentation



Above *Tesla FTICS Mass Spectrometer—courtesy of Battelle*

University of California, San Diego

Division of Biological Sciences

The Division of Biolgical Sciences at UCSD is assigned a total of 252,350 sq. ft. of space in 18 buildings in two primary locations: the Revelle Campus on the southwest side of the UCSD general campus and the Biology Field Station, located on the northeast edge of campus, adjacent to I-5. Nearly 200,000 sq. ft. of this space are dedicated to research laboratories, offices and facilities, including 8,300 sq. ft. of greenhouses and almost 16,000 sq. ft. in three vivaria. An additional 28,000 sq. ft. are dedicated to instructional activities, and the balance of the assigned space is used for administrative offices and support activities.

The five primary research buildings are the Natural Sciences Building (shared with Physical Sciences), Pacific Hall (shared with Physical Sciences), Bonner Hall, the Muir Biology Building, and the Center for Molecular Genetics (shared with the School of Medicine). Instructional space is primarily located in York Hall, with a group of teaching labs also on the first floor of Bonner Hall.

In addition to the greenhouses located at the Biology Field Station, there are several small plant growth facilities located in the Muir Biology Building, the adjacent Applied Physics and Mathematics Building, and in the Natural Sciences Building. Other research support facilities include several shared confocal microscopes, a fly kitchen to support research using drosophila, a cryo-electron microscope facility, a mass spectrometry core facility, a NMR core facility, and electronics, machine, and developmental shops to support equipment maintenance and construction.

Research space is assigned to Principle Investigators in the division based on a formula primarily driven by laboratory populations. Assigned labs range in size from less than 1,000 sq. ft. to more than 3,000 sq. ft.. The average lab population is eight individuals, including the PI, graduate students, postdoctoral fellows, professional research scientists, and staff technicians. Many labs also include undergraduate students who are engaged in independent research projects.

Division of Physical Sciences

The Department of Chemistry and Biochemistry has outstanding facilities for support of the Energy Biosciences Institute in the area of the structure and composition of a wide range of molecules and materials. The structure and dynamics of proteins and small molecules can be examined with a number of NMR spectrometers ranging in size from 900 MHz to 400 MHz. Both large molecule (protein) and small molecule X-ray facilities are available for accurate high-resolution structure determination of crystalline samples. Mass spectrometers allow characterization of the structure and composition of systems ranging in complexity from proteins to small molecules. A state-of-the-art cryo-electron microscopy laboratory has recently been completed, allowing structure characterization of biological assemblies, including viruses and large protein complexes. The department also has world-class expertise in Raman spectroscopy and aerosol and stable isotope mass spectrometry for environmental applications.

The Departments of Chemistry and Physics also maintain a

Above *Geisel Library—courtesy of UCSD*

nanofabrication facility that may be used in the design and construction of nanosensing devices.

Center for NMR Spectroscopy and Imaging of Proteins

Solid-state NMR Spectometers

The principal instrumentation of the resource currently consists of five NMR spectrometers (900, 750, 700, 500, 500 MHz) dedicated to high-resolution solid-state NMR experiments. Since major goals of the resource include the development and implementation of new instrumentation for solid-state NMR spectroscopy, the capabilities of the spectrometers are constantly evolving. In particular, the design, construction, and modification of probes is a significant part of core research activities.

Electronics Shop

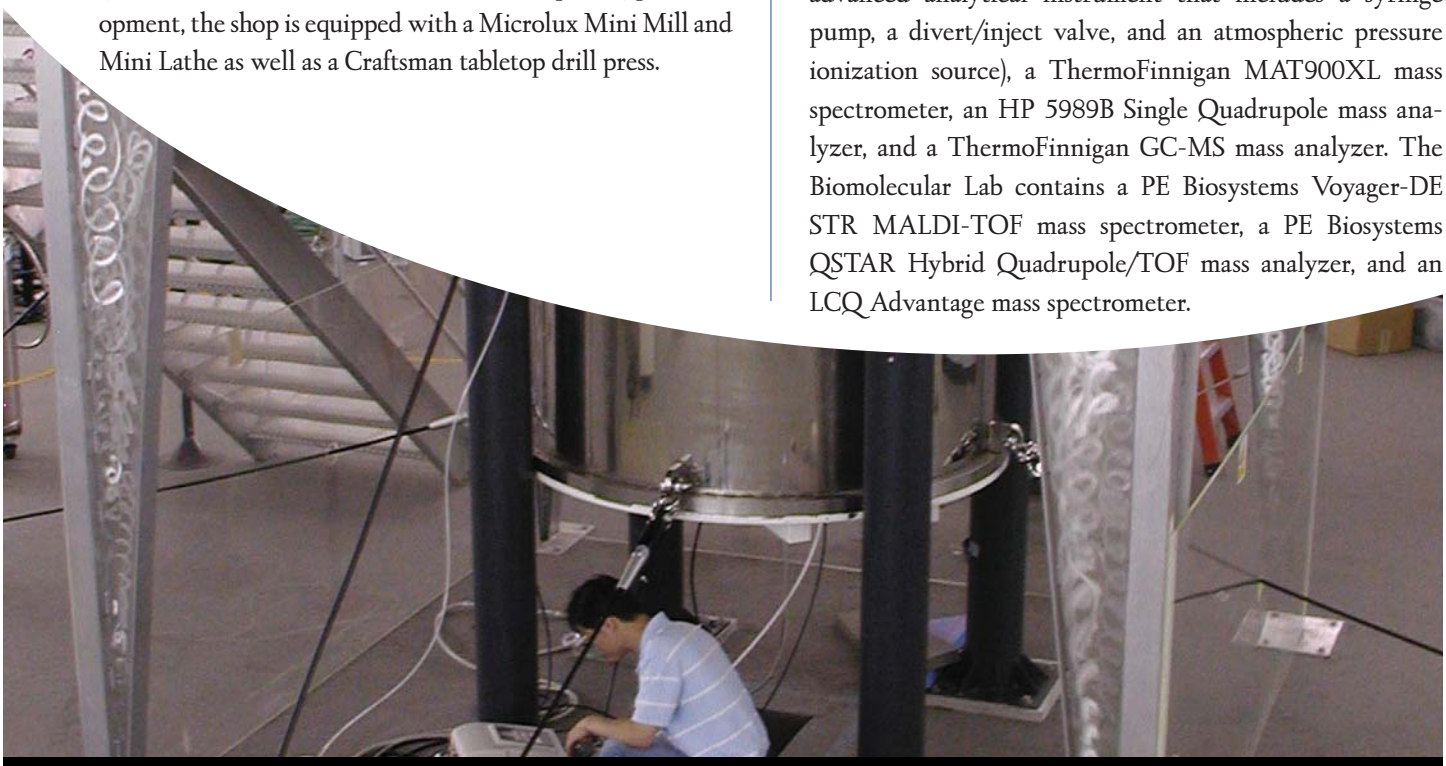
The resource includes an electronics shop dedicated to construction and maintenance of NMR probes and electronics. This work area is equipped with several test instruments, including a Hewlett Packard 8752A 300 kHz-1.3 GHz Network Analyzer and a Hewlett Packard 4815A 0.5-108 MHz Vector Impedance Meter. The electronics shop shares one of four oscilloscopes with the spectrometers, including Tektronics models TDS 5104 (1 GHz), TDS 782A (1 GHz), TDS 3052B (500 MHz) and one Agilent scope model H-P54835A. A Tektronics 2712 9 kHz-1.8 GHz spectrum analyzer is also available. For construction and prototype development, the shop is equipped with a Microlux Mini Mill and Mini Lathe as well as a Craftsman tabletop drill press.

Computer Resources

The resource is equipped with a variety of computers for data analysis. Several Apple computers for general use are available, including an iMac and a G4 all running OSX. Three PC computers are also available, two Dell Dimension XPS T500 desktop computers, and one Dell Dimension XPS m200s desktop computer. These computers are all equipped with Microsoft Office software and assorted other software for data manipulation and visualization including NMRpipe (Delaglio, et al. 1995). Probe circuit design is analyzed using the Aplac software package, and mechanical designs are produced using Vector Works. An SGI Indigo computer is available for data analysis using the Felix software package.

Chemistry and Biochemistry Mass Spectrometry Facility

The mass spectrometry facility in the Department of Chemistry and Biochemistry provides collaborative interaction with mass spectrometry experts so that the highest quality analysis can be obtained. The best method for sample preparation and analysis will be determined after consultation with the mass spectrometry facility director. The facility provides technical and educational resources so that researchers can obtain high-quality analyses with a full understanding of their implications. The Small Molecule Lab instrumentation contains a Finnegan LCQDECA (an advanced analytical instrument that includes a syringe pump, a divert/inject valve, and an atmospheric pressure ionization source), a ThermoFinnigan MAT900XL mass spectrometer, an HP 5989B Single Quadrupole mass analyzer, and a ThermoFinnigan GC-MS mass analyzer. The Biomolecular Lab contains a PE Biosystems Voyager-DE STR MALDI-TOF mass spectrometer, a PE Biosystems QSTAR Hybrid Quadrupole/TOF mass analyzer, and an LCQ Advantage mass spectrometer.



Above *The 900 MHz spectrometer utilizes a Magnex 52mm bore superconducting magnet.*

Chemistry and Biomolecular NMR facilities

These facilities provide UCSD researchers and external users with access to NMR services and state-of-the-art NMR equipment. The facility is subdivided into two centers: the Chemistry NMR facility, located in Pacific Hall, and the Biomolecular NMR facility, located in the basement of the Natural Science Building. The Biomolecular facility features an 800, 600 and 500 MHz Bruker NMR, and the Chemistry facility features one 500, two 400, and one 300 MHz Varian spectrometers.

Jacobs School of Engineering

Instrumentation Core

The earliest component of the Instrumentation Core is the Quantitative Imaging and Confocal Microscopy Resource sponsored by the NSF and the Whitaker Awards. This core has a Bio-Rad MRC-1024UV confocal microscope, a research prototype high-speed confocal microscope and four high-throughput microscopes (HTMs), which were developed at UCSD and added to the resource through a $1.1 million NSF Major Research Instrumentation grant. The confocal microscopes, which can be used to obtain high-resolution 3-D images of cells and tissues, provide an important microscopy-imaging tool for a broad range of researchers, as well as local biotechnology companies. The HTM system, with the equivalent of tens of thousands of confocal microscopes operating in parallel, has allowed high-speed in vivo confocal imaging for direct measurement of blood flow in the microcirculation. High-throughput 3-D cytometry instrumentation is being developed to allow direct cell measurement over large volumes of tissue at high resolution for brain mapping, study of in vivo and in vitro organ development, and more realistic models of biocompatibility. The new PFBH building has allowed the housing of the Instrumentation Core Facility in the basement to have, in addition to the Confocal Microscopy and Imaging Facility, several new equipment items purchased with the funds made available through the Whitaker Foundation Leadership Award, including an Atomic Force Microscope, Florescence Resonance Energy Transfer system (FRET), and Flow Cytometer. This Core is under the direction of Drs. Jeff Price and Shunichi Usami.

Information Technology Core

The Information Technology Core has had a major enhancement and renovation after moving into the new facilities on the first floor of PFBH, with the installation of electronic security. The 16-seat Graduate Computing Lab is equipped with four Sony Pentium workstations (gift of Sony Corp.), four Pentium workstations, eight HP Itanium workstations (educational grant from Hewlett Packard). Adjacent to the graduate computing lab is office space for two full-time departmental system administrators. The 52-seat Multimedia Computing Lab is designed for formal classroom instruction, distance learning and undergraduate computing projects. It is currently equipped with 25 Windows/Linux dual boot workstations, a printer and video projection (supplied by UCSD Instructional Computing Services), video conferencing cameras and plasma display (gift of Sony Corp.), and a Smartboard "sympodium" that allows instructors to annotate digital displays interactively. This special lab has been used successfully for undergraduate- and graduate-level education. Courses that have been taught in this space include the following: BENG 87 Freshmen Seminar, BENG 103B Bioengineering Mass Transfer, BENG 122 Biosystems and Control, BENG 125 Modeling and Computation in Bioengineering, BENG 202/CSE 257A Bioinformatics/Sequence and Structure Analysis, BENG 212 and 213 Systems Biology and Bioengineering, BENG 238 Molecular Biology of the Cardiovascular System, and BENG 258 Biomedical Transport Phenomena.

Biotechnology Core

The Biotechnology Core, which was established with the support from the Whitaker Foundation Development Award, is directed by Dr. Jeff Hasty. It was previously called the Molecular Biology Common Facility, and physically set up on the sixth floor of the Engineering Building I (EBU1). For more than six years, this core has provided the Bioengineering graduate students and researchers the facilities to apply recombinant DNA technology and cell biology to solve bioengineering problems in a cost-effective way. This core has moved to rooms 341-347 of the new PFBH, and is functioning very well. The new building allows personnel in the cold room (which did not exist in EBU1) to perform temperature-sensitive procedures. A tissue culture room (which also did not exist previously) for culturing pri-

mary cells and cell lines. The new building also has allowed for a better design to handle radioactive materials, in two graded areas, which eliminates potential contamination. Furthermore, the new building has a darkroom in close proximity for imaging needs related to the core, and an autoclave room that houses a new autoclave with a larger capacity for sterilization. This core facility is used by faculty and students in Bioengineering and occasionally by other departments in JSOE. Each user is trained by designated trainers for each piece of the equipment he or she intends to use, and agrees to follow the rules and regulations of the core, before being authorized and given an individualized lock code to enter and use the facility.

Instructional Core

This complex on the first floor provides dedicated space tailored to the educational needs of bioengineering laboratory classes. It features a 944 sq. ft. main lab, adjoining tissue culture (193 sq. ft.) and electronics test and assembly (193 sq. ft.) rooms, and specialized labware and supplies rooms. Also part of this complex is the core machine shop, housing mechanical supplies for design courses and lab instruments, and the department's Senior Development Engineer (302 sq. ft.), who maintains the core facilities. The workstations in the main lab are custom-designed to support the combined needs of a facility that does both instrumentation experiments with specialized electronics, as well as more traditional biological tasks. The department is now teaching the undergraduate Biotechnology lab (BENG 162), Biomechanics lab (BENG 172) and the recently created Molecular Biology labs (undergraduate BENG 160 and graduate BENG 208). By spring quarter of 2007, the new Tissue Engineering course will be sharing the space, and a design course will be added soon after.

Richard C. Atkinson Hall

Floors or Levels:	7
Number of Rooms:	418
Assignable Area:	150,891 sq. ft.
Outside Gross Area:	245,173 sq. ft.

General Spaces

Atkinson Hall is a physical manifestation of Calit2's multidisciplinary agenda. A defining feature of the UCSD Division facility is the shared facilities, including clean rooms for nanofabrication, digital theaters for new media arts and scientific visualization, test and measurement labs for circuit design, smart spaces for experiments in augmented reality, transmission and networking testbeds for wireless and optical communications, and labs for designing systems on a chip. In addition to such highly specialized research facilities, floors 1-6 of Atkinson Hall include reconfigurable open research spaces to accommodate hundreds of personnel, standard offices, sixteen conference rooms, and public spaces for events, as well as informal collaboration and impromptu gatherings.

Specialized Facilities

First Floor

Digital Cinema This 200-seat theater/concert hall includes ultra-high resolution digital video/cinema projection (4K, 10,000 lumen and dual 1600x1200 computer/HDV projection, 7,000 lumen each) and 21 Terabytes of ultrafast disk playback and real-time computer graphics capability at 4K or HDTV. It is networked via 1 Gigabit and 10 Gigabit Ethernet to Calit2/SDSC servers and the CineGrid network, and has 22-channel 8.2 stereo sound. Capabilities also include high-definition video, H.323 teleconferencing, and webcasting.

Immersive Visualization Lab A multi-screen, multi-user virtual reality environment has been created with 1980x2160 resolution in stereo, 60 Terabytes of data/visualization servers, and 30-unit dual-Opteron cluster w/120 Gigabytes of RAM. Networked via two 10 Gigabit Ethernet connections to Calit2/SDSC servers and the CAVEwave network, it includes a 100-Megapixel panel display with HDTV input and HDTV uncompressed video conference equipment.

Multipurpose Room Designed for experiments exploring the audience's relationship to the media and the physical environment, the MPR has four 3,500 lumen 1600x1200 projectors, stereo video on 16'x12' screen, seating for up to 100, and bundles of single-mode and multi-mode optical fiber to the Calit2/SDSC server rooms for networking.

HD Production Studio This studio will be an advanced, high-definition video studio for production, as well as experimental research. The facility will produce programming on the arts, sciences and other fields; create content for display on devices ranging from iPods to Calit2's 4K Super-HD system; originate faculty presentations to international conferences in high-definition through Calit2's CalViz system; and feature a Calit2-developed OptiPortal, which permits interactive discussion and high-resolution visualization for collaborators across campus, or across the world.

Audio/Video editing suites The suites are optimized to sup-

Below *Atkinson Hall—courtesy of UCSD*

port high-definition video post-production of content for science programming, as well as production of Super-HD content and scientific visualizations to be displayed throughout the Calit2 building. Equipment includes an "encoder farm" to facilitate the export of edited videos into a variety of online, tape, and hard copy (DVD, CD) formats to support research projects and "tell" the Calit2 story to its constituencies and audiences.

Art Gallery This 800 sq. ft. networked exhibition space showcases world-class experimental art and prototype technology.

Audio Spatialization Lab The Audio Spatialization Lab includes a reconfigurable, multi-channel audio system, which allows for the production of audio content in a variety of standard, as well as custom multi-channel audio formats. A base setup of 16 audio channels provides for content production occurring alongside the development of software tools, which facilitate multi-channel composition in addition to the development of imaging algorithms. The lab is configured to allow for synchronization and staging of complex audio along with multi-media content.

Performative Computing Lab This computer vision/motion capture lab supports research into new techniques for integrating image-based data into computer environments. Hybrid approaches are provided to allow for specialized developments, as well as for the integration of previously disparate approaches for the capturing of complex spatial and motion data.

3-D Fabrication Lab Manipulating physical material with the same facility expected from manipulation of virtual material will be supported by the 3-D fabrication lab. CNC machines such as a mill, router, and lathe provide for subtractive fabrication, while rapid prototyping devices are an additive platform. A range of activities is supported from the development of new machine control methodologies, to the development of new sculptural forms and the ability to design and implement designs for new types of devices such as antennas, encasement's and robotic parts.

Server Room Atkinson Hall initially had 1,000 sq. ft. of server space on the first floor, with room for approximately 32 racks (19x84x30) of equipment. The space provides 558,000 BTU (48 ton) of cooling capacity and 4 3 phase 225 Amp power panels. The server room is currently being expanded to add 1,000 sq. ft. of additional server space.

Nanofabrication Facility An approximately 10,000 asf Materials and Devices laboratory supports nanoengineering, nanoscience, and nanomedicine research with a clean room (approximately 7,000 asf of clean space, class 100 and class 1,000), a growth and processing facility, analysis facilities, and a nanomedicine laboratory. This state-of-the-art research and demonstration facility's capabilities will support research in photonics, electronic devices, semiconductor materials engineering, heterogeneous integration/packaging, and biomedical electronics. The process bays house photo and electron beam lithography, nanofabrication, thermal processing, wet processing, metrology, and metallization/thin film deposition. The analysis facilities provide laboratories for the characterization of materials and devices developed in clean room facilities.

Wet Etch Lab This lab includes capabilities for fabricating RF circuit boards using chemical etching techniques and photograph development. Additional capabilities include tin plating and gold plating.

Fourth Floor

High-Definition Studio A dedicated broadcasting studio, the HD studio is capable of producing and transmitting high-definition quality audio and video over optical fiber to distant locations around the world, giving Calit2 "tele-presence" at international conferences, and providing a venue for Calit2 and UCSD experts to be interviewed by national and international media.

Fifth Floor

Smart Room Lab Instrumented with displays, cameras, microphone arrays, and other sensors to experiment with the concepts of augmented reality, telepresence and collaboration, this lab will develop a prototype of "Super-Studio", where the resident of this futuristic space will be able to experience virtual reality through a Smart-Window.

Circuit Assembly and Sub-System Integration Lab This lab supports pre-production assembly and testing of prototype circuits for large-scale demonstrations of wireless networks for telecommunications, telematics, sensors, safety and disasters. Production capabilities are available for building dozens of modules of various types required for the system. The lab also enables electrical schematic capture and Printed Circuit Board (PCB) layout tools.

MicroWave and High Power Circuits Lab The lab focuses on high- and low-power microwave amplifier experiments for high-efficiency and high-linearity for wireless communication. The lab also includes capabilities for digital signal pro-

cessing experiments with power amplifiers and low-noise amplifiers to mitigate impairments and improve quality of wireless services. DC/DC "super" converter experiments and wireless protocol-aware battery management experiments can be performed.

Millimeter Wave and MicroProbe Circuits Lab Research capabilities of this facility include state-of-the-art research on Radio Frequency (RF) transistors and RFICs. On-wafer probing of devices and circuits up to 110GHz for full S-Parameter Characterization, IV Curves, Noise Figure, Phase Noise is possible. The lab also includes a mmWave antenna range for testing intelligent multiple-antenna systems (MIMO) and high gain antennae.

Sixth Floor

Wireless Platforms Lab and System Integration Current platforms under development and test include portable software-defined radio, bench-top software-defined radio, wireless pulse oximeter, wireless paperless patient tag, ground-based wireless mesh network nodes, wireless smart-door control, wireless patient drug dosage monitor, and mushroom networks. These sub systems are also integrated in the lab.

Photonics Lab This facility houses a high capacity optical network testbed and associated physical layer research. The high-capacity testbed includes up to 200 independent channels and advanced modulation facilities for 10Gb/s (OC-192) and 40Gb/s (OC-768) rates, complemented with real-time RS forward error correction (FEC) system. The testbed is equipped with a complement of fiber and EDFA/Raman amplifier plants for up to 1,500 km in-line transmission and the recirculating loop for ultralong-haul (>5,000 km) experiments. An optical parametric facility provides ultrawide-band fiber amplification, band mapping and 320Gb/s signal processing, and, combined with the conventional high-capacity capability, remains unmatched by present industrial or academic laboratories. A commercial 40Gb/s terrestrial system provides interoperability with in-ground and experimental networks, both on campus and nationwide. High-capacity fiber research is complemented by high-speed free-space optical capability for next-generation access networks.

Systems-on-Chip Lab Calit2's SoC Lab is dedicated to the design and development of applications, architectures, and system software for state-of-the-art microelectronic integrated systems. Capabilities will support new applications, system-chip architectures, system-chip (microelectronic and microfluidic) platforms and packaging, semiconductor intellectual property, and embedded software: mobile code, middleware and infrastructure software, and cross-cutting thrusts on energy, bandwidth, usability, availability, mobility, security and standards. It does so utilizing four core capabilities: (1) to architect, prototype and build hardware and software platforms that provide capabilities for a variety of sensor, embedded computing and wireless networking functions under domain-specific physical and performance constraints; (2) to build models of the target platforms and associated software development environments; (3) to test board- and chip-level parts operating up to 500 MHz; and (4) to design up to RTL implementations using IP blocks.

Undergraduate Research Laboratory This lab supports undergraduate research as part of senior-level, project-based courses as well as the Calit2 Scholars summer research program.

Roof

Antenna Garden Lab The roof of Atkinson Hall provides 13 antenna pedestals with AC power, GigiBit Ethernet, and RF cables for experimental wireless communication systems. Additional locations are available for cameras associated with wide-area surveillance systems for experiments in artificial intelligence detection and estimation of security-related events.

Radio Base Station (RBS) Lab An Ericsson experimental CDMA base station allows experimentation with live, on the air CDMA systems. Researchers can use the base station for experiments at the physical, MAC, and network layers.

San Diego Supercomputer Center

The resources available through the San Diego Supercomputer Center include supercomputers, archival storage systems, data-handling platforms, high-bandwidth networking, and advanced visualization systems. The capabilities of the center are being upgraded continually to include higher-capability systems that provide a robust environment for cyberinfrastructure research, development and deployment.

Among the hardware resources at SDSC, the foremost is DataStar, an IBM system with a peak performance of 15.6 teraflops. DataStar has 2,518 Power4+ processors in 283 nodes connected to the same high-speed Federation switch and parallel file system, giving DataStar communication and I/O performance far in excess of conventional clusters. SDSC also hosts an IBM/Intel cluster associated with the

TeraGrid containing 512 compute processors with a peak performance of 3.1 teraflops. Most recently, SDSC has deployed the first IBM Blue Gene/L system at an academic institution. This unique architecture boasts 2,048 compute processors plus 128 nodes for the maximum I/O performance possible.

Data-handling resources include a storage-area network (SAN) of 1.4 petabytes (1,400 terabytes) of disk and a 25-petabyte tape-storage archive. Managed by a powerful Sun Fire 15K server, with 72 processors and 288 GB of shared memory, SDSC's data-handling environment provides support for databases, data management, and data mining. Associated data-intensive computing software includes the Storage Resource Broker, a distributed data management system developed at SDSC, digital library technology acquired through collaborations with MIT and Cornell, parallel object-relational database technology acquired in collaboration with IBM, and the High-Performance Storage System (HPSS) archival storage software that is being developed and tested in conjunction with IBM and LLNL. SDSC also has available and continues to work with Sun on the SAM-QFS online/archival storage environment. SDSC has integrated these systems to provide support for massive data collections. The archival storage systems at SDSC has 32 tape drives, and sustains up to 10 terabytes of data movement per day per tape drive.

SDSC's core program supports scientific data collections for disciplines including oceanography, seismology, neuroscience, molecular science, Earth systems science, and astronomy. Access to these data collections is provided through the SDSC Storage Resource Broker. The combination of information management technology, scientific data collections, and the data-handling platforms that support rapid access to the data provides an excellent testbed for evaluating new infrastructure for managing scientific data and scientific algorithms.

The SDSC Synthesis Center supports collaborative viewing of scientific data and advanced scientific visualization capabilities. A complete video and audio production suite is used to produce publication quality animations. The video lab is network accessible and can be used to render scientific images.

School of Medicine

The GeneChip Microarray Core

The GeneChip Microarray Core provides access to high-density oligonucleotide microarray technology based on the Affymetrix GeneChip, NimbleGen, Invitrogen, Exiqon and Ambion microarray platforms. We also provide an integrated environment for data analysis, dissemination, and archiving. These versatile platforms allows researchers to perform RNA expression profiling in multiple prokaryotic and eukaryotic species, as well as DNA genetic analyses such as single-nucleotide polymorphism (SNP) assays, resequencing, loss-of-heterozygosity, comparative genomic hybridization, whole genome transcription factor localization, ChIP-on-chip, mitochondrial mutation detection, and miRNA profiling.

Core equipment comprises an Affymetrix GeneChip System, a Maui 12-chamber hybridization station, a Molecular Dynamics/Axon Genepix 4000B scanner, an Aglient BioAnalyzer, a NanoDrop spectrophotometer, and a BioRad Chromo4 Q-PCR machine for Q-PCR validation. The Affymetrix GeneChip system contains three components: a hybridization oven, a fluidics station, and a high-resolution scanner. The core possesses one Hybridization Oven 640 that holds up to eight rotating probe array cartridge carriers (each with eight cartridge slots) allowing for controlled hybridization of up to 64 probe arrays. This unit delivers precise temperature control for consistent performance across all probe array applications. The core possesses two GeneChip 450 Fluidics Stations incorporating automated wash and staining routines. These fluidic stations minimize user intervention improving chip-to-chip consistency and efficiency. The Core has a GeneChip Scanner 3000 which accepts all the current GeneChip arrays with 5 µm feature size and 0.5 µm pixel resolution. Low inter-scan variation and increased speed dramatically improves throughput and consistency giving more accurate grid alignment, more consistent scanner-to-scanner biological performance, and improved data integrity. The Agilent 2100 Bioanalyzer is a microfluidics-based platform for the analysis of DNA, RNA, proteins, and cells. This analytical instrument uses lab-on-a-chip technology as an alternative to labor-intensive gel electrophoresis, and delivers fast, high quality digital images for quality control of submitted samples and labeled probes. The NanoDrop ND-1000 UV-Vis Spectrophotometer enables highly accurate analysis of extremely small samples with remarkable reproducibility using a patented microliter sample retention system. The BioRad Chromo 4 real time PCR system is a 96-well, four-channel real-time QPCR system which features a four-color detector allowing multiplexing with up to four probes. All 96 wells are independently excited and detected for each color to minimize crosstalk.

Genomics Core Laboratory

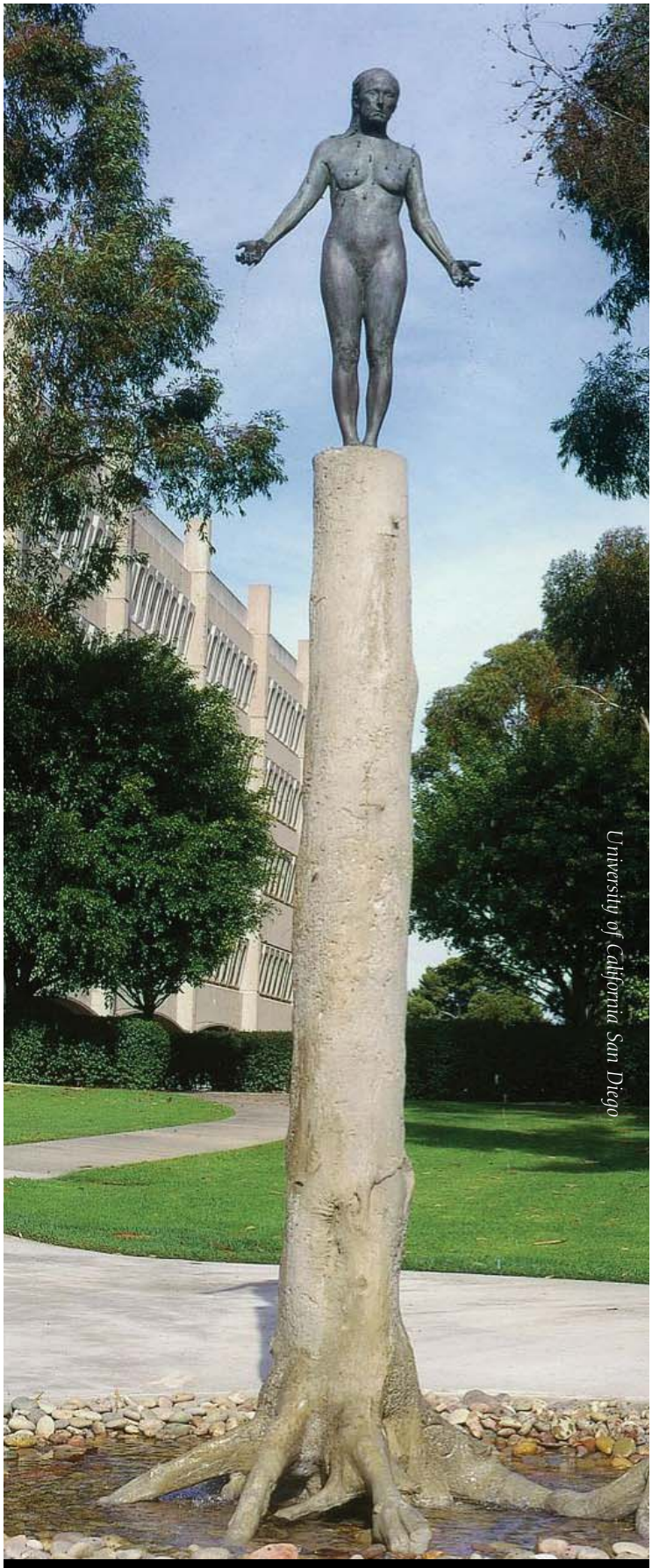
The lab provides expertise in the arena of genomics and sequence analysis, and develops new services in these fields at the request of core users. Recent advances in genome sequencing and high-throughput technology to analyze gene expression has placed biology at the forefront of modern science. The Genomics Core is able to provide services, reagents and expertise to perform a number of assays ranging from small-scale to large-scale analysis of gene expression. Primarily, the core focuses on the validation of gene expression data using real-time quantitative RT-PCR technology (Taqman, Amplifluor and SYBRGreen). The core is equiped with two ABIPrism 7700 Sequence Detection Systems and a Bio-Rad iCycler for qRT-PCR analysis, and a Sun Microsystems Sunfire 880 dual processor (UltraSPARC) machine for bioniformatic analyses. The core staff are highly trained and skilled in areas of RNA isolation, purification and quantification, primer design, gene expression, and phylogenetic analysis. The Genomics Core is sponsored by the UCSD Center for AIDS Research and the Veterans Medical Research Foundation.

DNA Sequencing Shared Resource

Established in 1998, the Rebecca and John Moores UCSD Cancer Center DNA sequencing facility is a shared resource for Cancer Center members, as well as general public investigators. The shared resouce generates high quality sequences with speed and flexibility to meet the growing demands of scientific researchers. Sample data turnaround time is within 24 to 48 hours with all systems running.

Flow Cytometry Shared Resourc

1. *Analytical Flow Cytometry:* Utilizes a Becton Dickinson FACSCalibur, a four-color, dual-laser benchtop flow cytometer. Included is the CellQuest software for list-mode data recording and analysis. Data recording and analysis can be performed with the FACS Aria, a triple-laser, multiparameter flow cytometer using up to 11-color fluorescence signals, along with forward and side-angle light scatter.
2. *Cell Sorting:* In addition to analytical experiments, the FACSAria can perform aseptic sorting of living cell subpopulations utilizing various criteria, such as intrinsic cell properties, e.g. DNA content, Green Fluorescent Protein (GFP), or extrinsic properties, such as molecular markers identified by fluorescently labeled monoclonal antibodies.
3. *Automated Magnetic Cell Sorting (autoMACS):* Used for convenient isolation of rare cell subpopulations or large



Above "*Standing", a fountain by Kiki Smith, is installed between the basic Science and Medical Teaching buildings*

Above *Scripps Crossing, Scripps Institution of Oceanography (designed by Frieder Seible)—courtesy of UCSD*

numbers cells, up to 4 x 109. Its use of magnetic particles for cell separation is both useful and efficient, and the cells can then go straight to FACS analysis or further sorting.

4. *Consultation:* In addition to education about the functionality and capabilities of the shared resource, technical support personnel also advise in the design of experiments and assist investigators in the initiation of pilot projects, provide limited amounts of specific reagents, and contribute detailed consultation in analysis of data.

Digital Imaging Shared Resource

The IVISR provides optical, CT, ultrasound, Hi Res planar gamma imaging, and PET of mice and rats, as well as high-resolution digital autoradiography and fluorescent imaging of thin whole body rodent sections. Support and expertise includes imaging physics, biological applications, animal support, image computation, optical hardware and software, diagnostic agent chemistry, preparation of F18 and C-11 labeled radiotracers, and kinetic modeling.

Biomedical Genomics Microarray Laboratory

The Biomedical Genomics Microarray (BIOGEM) Laboratory is a genomics facility located in the Department of Medicine at UCSD. BIOGEM was established in 2000 to provide spotted cDNA microarray technology to the UCSD research community. Since then the scope has been expanded to include a variety of related services and resources, including several commercial microarray platforms. Currently BIOGEM provides RNA sample analysis and quantification services. Additionally BIOGEM processes commercial array platforms including Illumina, Applied Biosystems, Amersham CodeLink and Agilent. BIOGEM also offers custom-spotted array fabrication, image scanning, and data analysis services. A major research-driven activity within the facility is genome-wide location analysis (GWLA or "ChIP-on-Chip").

Microarray fabrication, probe preparation, array hybridization, data acquisition and data analysis require expensive instrumentation and reagents and a highly skilled team of individuals who are experts in specific components of the overall procedure. Microarray technology therefore lies beyond the scope of most individual laboratories and can only be made accessible to academic and early stage biotech investigators through specialized centers and core facilities. In addition to providing conventional microarray services, such core facilities provide essential platforms for advancing new technologies. BIOGEM currently offers a range of microarray and data analysis services to the local and international academic and biotech communities.

Scripps Institutions of Oceanography

Nimitz Marine Facility

The Nimitz Marine Facility, which is the support and management center for the Scripps fleet of research vessels and platforms, is one of the largest and most completely outfitted operating bases at any oceanographic institution. Located on 5.7 acres of land on Point Loma, the 110-meter finger pier and 85-meter quay wall can accommodate five ships and the platform FLIP, and as many as seven ships doubled up. The piers afford a complete suite of utilities connections for vessels. The marine facility serves as homeport for the NOAA ship David Starr Jordan, and it hosts visiting research vessels from U.S. and foreign institutions as time and space permit. The facility houses R/Vs Melville, Revelle, New Horizon, Sproul and FLIP.

Buildings adjacent to the pier and quay wall house shops, the control room of marine radio station WWD, scientific staging and storage areas, administrative offices, and shipboard technical support spaces and offices.

The marine facility is capable of carrying out a variety of ship maintenance, repair, and modification work in-house. Scientific equipment of every description can be loaded and unloaded, or prepared and sent to ports around the world for scientists from Scripps and from many other institutions.

Shipboard Technical Support (STS) provides specialized expertise, personnel, instrumentation and support services to science groups that use oceanographic research vessels.

SIO Oceanographic Collections

The Oceanographic Collections of SIO/UCSD are world-renowned resources supporting basic research, educating current and future generations of scientists, providing factual information to governmental agencies and public policy makers, stimulating curiosity and scientific understanding in the citizens of the state of California, and providing a repository for samples collected by SIO researchers. The SIO Collections house over 2 million marine vertebrate specimens, over 110,000 whole zooplankton samples, over 40,000 lots of sorted specimens, over 15,000 core sections, more than 2,000 hauls of dredged rocks, and geophysical data collected underway on Scripps expeditions.

Above *A California Moray eel in a rocky reef environment—courtesy of SIO Collections*

Scripps Genome Center

The Scripps Genome Center provides the computational resources and expert analysis required to interpret each microbial genome in its environmental, ecological, and evolutionary context. The Center creates partnerships between computational and experimental biologists, and provides guidance, including training and documentation, resources and access to cutting-edge bioinformatics tools, as well as individualized, one-on-one training to researchers to help them choose, learn to use and interpret data from the software packages best suited to their needs. The Center also trains the next generation of marine biologists and ecologists in computational techniques. The Center maintains local copies of the most commonly used bioinformatics databases, as well as a selection of complete genomes. The databases include BLAST, BLOCKS, Pfam, PRINTS, PROSITE and Swiss-Prot. The complete genomes include Amphioxus, Ciona intestinalis, Flavobacterium BBFL7, Microscilla marina and Ostreococcus.

Maintaining local copies of the databases allows the Scripps Genome Center to provide its users with private data. The databases, some of which contain draft genomes, can be used by researchers for many months before the public data is released. The security and privacy of the data allow the researchers to conduct experiments without exposing their proprietary information. Additionally, researchers can perform BLAST searches against draft sequence contigs, traces, ESTs and annotated predicted proteins.

The Center has a cluster system containing nine Sun servers and five Apple servers, for a total of 58 processors and over 200 gigabytes of RAM. RAID disk arrays provide an additional 17 terabytes of storage. Backups of the data are performed regularly and stored in a tape library. Two TimeLogic DeCypher Engines, combined with TimeLogic's Tera-BLAST software, perform BLAST searches with run times comparable to those of clusters containing hundreds of CPUs. All hardware is interconnected by gigabit Ethernet, via a dedicated CISCO switch, with router boards connected to the University of California, San Diego's Internet backbone and also directly to external links via a T1 line to provide redundancy.

Marine Biology Research Division DNA Sequencing Facility

MegaBACE™ 500 DNA Analysis System (Amersham Biosciences/GE Healthcare): This is a medium-throughput, fluorescence-based DNA analysis system utilizing capillary electrophoresis with 48 capillaries operating in parallel. The MegaBACE 500 at SIO is capable of both sequencing and genotyping applications. As a sequencer, it can produce 48 sequences of ~700 bp in approximately 2.5 hours, with a potential daily throughput of well-over 100,000 nucleotides. The MegaBACE is operated on a recharge basis. Investigators perform their own sequencing reactions and clean-up. Data are available on-line immediately following the run.

Birch Aquarium at Scripps

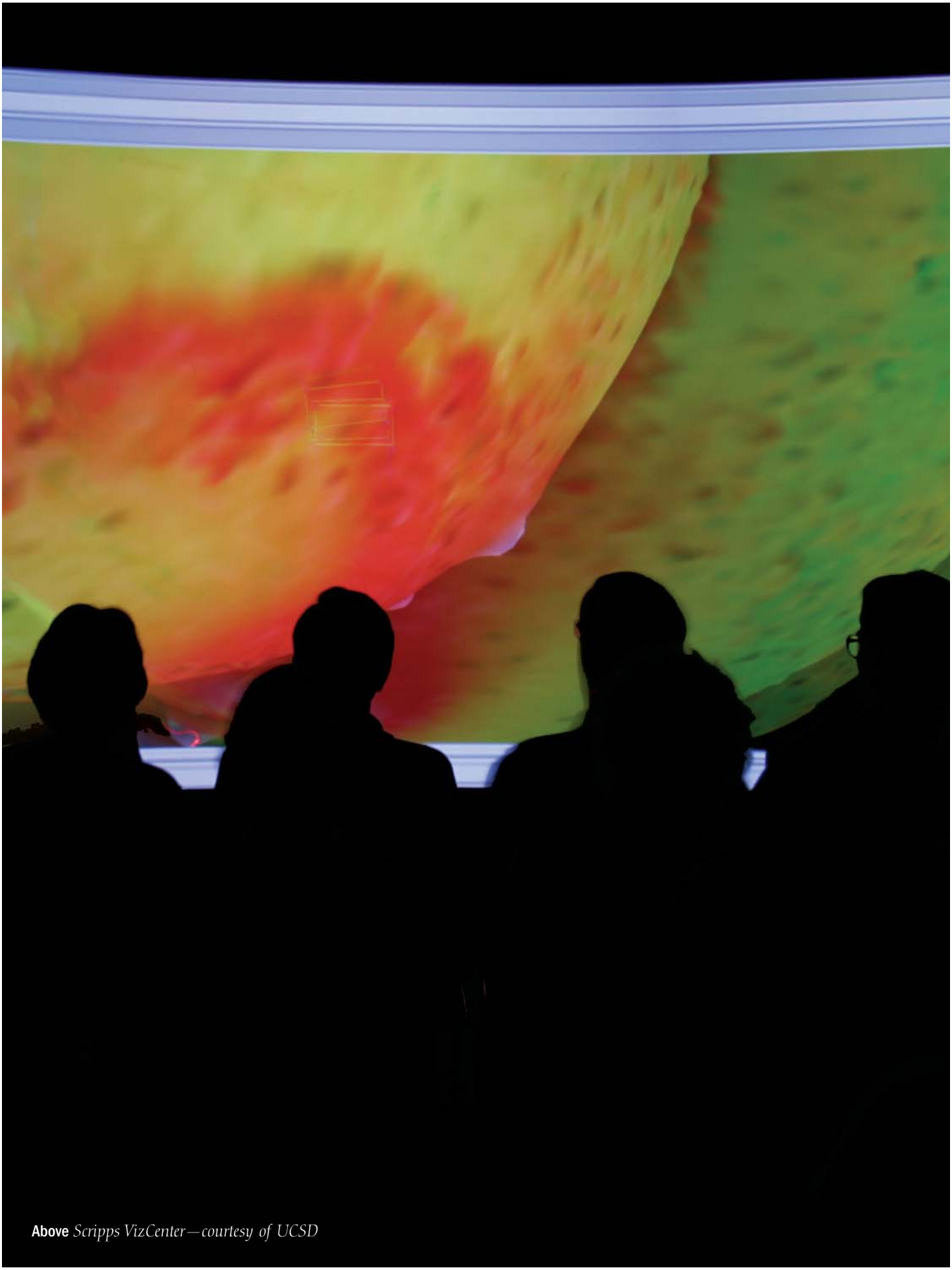
A public aquarium was established as part of Scripps Institution of Oceanography in 1903, and one has been operated by the institution ever since. In 1992, the newest facility, the Birch Aquarium at Scripps (BAS) opened on the bluff above the Scripps campus. As the public interpretive center of Scripps Institution of Oceanography, the mission of the Birch Aquarium at Scripps is to

- *Provide Earth and ocean science education* through creative exhibits, programs and activities designed to help people use critical thinking, and to make science relevant to their daily lives.
- *Interpret Scripps research,* emphasizing the interdisciplinary nature of the science used to study Earth, and inspiring public support of scientific endeavors.
- *Promote conservation* through education and research in the belief that, with increased understanding of the ocean, people will respect and protect the marine environments.

More than 350,000 people visit annually, including more than 75,000 school children. The aquarium features 46 tanks representing natural habitats throughout the Pacific, including a 70,000-gallon tank supporting a kelp-forest community. The Scripps Explorers Gallery showcases the cutting-edge research conducted at Scripps in an ever changing series of exhibitions. Recent and future exhibit themes include climate change, marine genomics, seismic sciences, marine biodiversity and the global ocean. Exhibits draw on the scientific expertise of Scripps researchers as well as the considerable talents of the BAS exhibit design staff. Lead by a Ph.D. scientist, the exhibit team excels at translating complex science into innovative, interactive exhibits that both intrigue and inform visitors. BAS also hosts monthly public lectures by UCSD/SIO scientists, delivers a wide-range of K-12 student programs and a variety of hands-on public science activities.

Marine Facility Shop

The Marine Facility Shop (MarFac) building is 265 feet long and 70 feet deep on the main floor. Its 18,500 sq. ft. are divid-



Above *Scripps VizCenter—courtesy of UCSD*

ed into a carpenter shop, welding shop, mechanical shop, machine shop, electric shop, and the office of the shop superintendent and his assistant. The second floor contains office space, store rooms, and a lounge, shower, and wash room. There is a second building that houses the electronics repair shop and our radio station, WWD, and has a small, indoor storage space for shop overflow. An outdoor storage area is available for large objects such as containers and winches.

The shop has four employees trained in pipefitting, general steel and aluminum fabrication, woodworking, hydraulic and mechanical repair, and the operation of material handling equipment. When the need arises, a pool of retired employees and ship's personnel on leave is available and can be called on.

The shop material handling equipment consists of five forklifts ranging in capacity from 15,000 pounds to 500 pounds. Two mobile cranes, one 10 ton and one 12 ton, are equipped with all the slings and bridles needed to lift anything in their capacity. The shop also has four cable spooling devices, one of them truck-mounted and powered.

The portable winch pool has four winches that can be deck-mounted to the standard bolt pattern. Three of them need only an electrical hookup. The fourth, which can carry 1/2" dredge or .680 cable, needs a hydraulic hook up. The shop also maintains eight portable marine cranes with either a 1,000 or 2,000 pound capacity. Six plug in electrically and two need a hydraulic hookup. The MarFac shop is also the west coast depository for new UNOLS wire. A large supply of used, standard-sized oceanographic wire is maintained at the facility. A small supply of stock and hardware is kept in the shop, but a vast network of suppliers is just a phone call away.

SIO Visualization Facility

The Visualization Center at the Cecil and Ida Green Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, University of California, San Diego is a state-of-the-art laboratory for the display, integration, analysis and exploration of various geophysical datasets supporting interdisciplinary research. It provides a diverse array of research tools supporting data sharing among distributed locations, live field reports, real-time data acquisition and presentation, real-time video teleconferencing and lectures. Its resources are also being applied to wider community needs, such as education and outreach, and providing heightened response to natural disasters like earthquakes,

The center comprises high-resolution projection and tiled display systems supporting geosciences visualization that are driven by multiprocessor SGI machines and Linux and MacOS X clusters. It is a node on the OptIPuter grid.

Experimental Aquarium Facilities

Facilities for in vivo studies include two large experimental aquarium rooms. Hubbs Hall experimental aquarium facility is 2,751 sq. ft. with 12 trays and 30 tanks (most insulated) of volumes ranging from 1020 l to 7560 l, utilizing an "open seawater system" that can deliver chilled (8˚C), ambient (12˚C-21˚C), and warm (28˚C) seawater . Chilled and warm seawater temperatures are very reliable, usually fluctuating no more than +/- 1˚C deg. Four additional aquarium wet labs exist throughout Hubbs Hall, including a chilled "closed system" in a controlled-temperature room.

The Ritter Hall Experimental Aquarium facility is 2,150 sq. ft., with 18 trays and 19 tanks with volumes ranging from 300 l to 21,000 l, a two-chambered, controlled light room, and three each 3 m square cubicle rooms. Chilled (10˚C) and ambient (12˚C-21˚C) seawater is also available via an "open system".

Approximately 4,000,000 liters of seawater are supplied daily to various SIO facilities. Seawater is pumped from inlets at the end of the SIO Pier (330 m long) and then flows by gravity through a prestrainer into a large settling tank. It is filtered through several large-capacity sand filters and further pumped up to a series of 227,000 l holding tanks. The filtered seawater is then gravity fed to labs and aquaria at SIO, the Birch Aquarium, and Southwest Fisheries Science Center.

Iowa State University

Instrumentation and Service Facilities (for Bioscience Research)

Cell Facility *(www.biotech.iastate.edu/facilities/cell)*

The Cell Facility of the Office of Biotechnology offers flow cytometric analysis and cell sorting for a wide range of research applications. Facility personnel are trained to assist researchers in flow cytometry experimental design, sample preparation techniques and data analysis. Training sessions to provide general instruction in these areas is also offered by the facility. All Cell Facility services are open to Iowa State University clients, as well as to off-campus institutions and individuals.

Flow cytometry has been used to analyze bacteria, various mammalian cell types, fungi, yeast, Drosophila cells, soybean cyst nematode eggs, Euglena, Tetrahymena, dinoflagellates, plant cells, nuclei, organelles and chromosomes. Immunofluorescence measurements are often used to provide information on lymphocyte subsets and cell surface receptor densities. DNA/RNA-specific stains supply information on genome size, chromatin structure, and cell cycle kinetics. Fluorochromes are available for quantitating intracellular pH or cytoplasmic-free calcium. Phagocytosis of fluorescently labeled particles (beads, yeast or bacteria) can be quantitated. Cell viability can be measured for mammalian cells, as well as bacteria. Fluorescent lipophilic dyes are available that have been utilized as a means of tracking cell life and tissue localization in vivo. Levels of enzyme marker gene expression, such as -galactosidase, can be correlated with the fluorescence intensity of cleaved substrate by flow cytometry. Intracellular protein products can be measured by immunofluorescent labeling of fixed cells. Fluorescence in situ hybridization (FISH) techniques provide information on the mRNA expression level of a specific gene and can be used in conjunction with flow cytometry to provide quantitative gene expression information on a cell-by-cell basis. Necrotic- versus apoptotic-mediated cell death can be distinguished using flow cytometry. It is also possible to sort individual cell populations via flow cytometry, enabling researchers to separate and further characterize subpopulations of cells.

Flow Cytometry Data Acquisition and Cell Sorting

The Cell Facility maintains four flow cytometers: a Becton-Dickinson FACSCanto, Beckman-Coulter EPICS ALTRA, Becton-Dickinson FACScan and Guava Technologies Personal Cell Analyzer (PCA). The Facility also maintains several computer workstations with software packages for performing off-line analysis of flow cytometry data.

BD FACSCanto

The FACSCanto flow cytometer combines a patented optical design and manufacturer upgrades for simultaneous data acquisition of eight fluorescent signals (FITC, PE, PE-TxRed, PerCP-Cy5.5, PE-Cy7, APC, Alexa 700 and APC-Cy7) and two scatter parameters (FSC and SSC), digital electronics for processing up to 10,000 events per second, and a novel sample injection system supporting carryover of less than 0.1%. High-speed data processing, industry-leading sensitivity (‹50 MESF for PE and ‹100 MESF for FITC) and minimal sample-to-sample carryover make this instrument uniquely suited for rare event analysis. The FACSCanto has

Above *ISU*

the capacity for ten-parameter detection on particle sizes from 0.5 to 50 mm in diameter. Reading more parameters per individual test decreases the total sample volume necessary for a specific project and the wide range of size detection enables projects with leukocytes, cell lines, platelets, bacteria, multiplexed bead technologies and beyond.

The FACSCanto is built with blue (488 nm, 20 mW solid state) and red (633 nm, 17 mW HeNe) excitation sources. Patented detector arrays use serial reflections to guide fluorescent emission signals to their target detectors, which results in highly efficient light collection and maximum signal retention at the detector level. This design collects the dimmest emission signals first, starting with the longest wavelengths (typically PE-Cy7), and finishing with the shortest (FITC), further enhancing sensitivity.

Digital electronics improve performance by eliminating dead time and the need for inter-beam time-delay calibration—this means the system can handle faster sample flow rates (up to 120 mL/min) and faster acquisition rates (up 10,000 events per sec). Digital electronics also facilitate compensation, with no limits to inter- and intra-beam compensation, allowing post-acquisition compensation. Data files are stored raw and compensated as part of the FCS files, allowing flexibility for off-line compensation when viewing data.

Beckman-Coulter EPICS ALTRA

The EPICS ALTRA flow cytometer is a sorting cytometer. It includes two lasers (blue 488 nm and red 633 nm) for dual excitation wavelengths and utilizes an optical bench that can accommodate a variety of fluorescent dye combinations, simultaneously acquiring data on relative cell size and up to five fluorescence signals. The cell sorting capacity of the EPICS ALTRA routinely produces sort purity >95%, with an event analysis rate of up to 10,000 events per second. When even greater sorting precision is required, the autoclone sorting attachment to the ALTRA can deposit single cells into individual wells for cloning hybridoma or mammalian cell cultures.

The FACSCanto and EPICS ALTRA instruments are located in the Molecular Biology Building (MBB) main facility and are operated by facility personnel only. Data acquired on the FACSCanto and EPICS ALTRA are loaded onto a network server which allows customers to retrieve data files from their office/lab via an Ethernet connection. The Cell Facility also maintains a backup of user data.

Iowa State University

BD FACScan

The FACScan flow cytometer is located in the Veterinary Medicine Complex satellite facility. It is equipped with a 488 nm laser and three fluorescent signal detectors. The FACScan is user-operated. Required training is available through facility personnel. An online calendar allows users to reserve instrument time through any web browser (www.biotech.iastate.edu/cgi-bin/calweb/calweb.cgi). Archiving FACScan-generated data files is the responsibility of individual users.

Guava Technologies PCA

The Guava PCA is also a user-operated cytometer. This instrument, located in the MBB main facility, is equipped with a 532 nm diode laser and signal detectors for measuring relative cell size and two separate fluorescent signals at 580 and 675 nm wavelengths. Equipped with 100 mm- and 250 mm-diameter flow cells, the Guava PCA is capable of analyzing a wide range of cell types and particles. The system can analyze thousands of cells in seconds using 20 ml or less of an original sample. Analysis procedures require as few as 2,000 total cells, which allows for multiple experiments with a single small cell sample.

The Guava PCA is capable of performing a number of cytometry-based assays. Guava Technologies, Inc., offers kits designed to make critical cellular assays accessible to life science researchers everywhere. Based on widely accepted protocols, kits are available to assess markers of early-, mid- and late-stage apoptosis; cell cycle phase distribution; and cell surface/ intracellular protein expression.

Results of experiments are created in flow cytometry standard (FCS) format and can be exported to a spreadsheet or examined in various FCS data analysis programs, a number of which are currently maintained by the Cell Facility.

This unique instrument offers several features heretofore unavailable on campus. User training is minimal and assistance is available within the facility.

Cell Counting Device

The Guava Personal Cell Analyzer System (see above) is an automated cytometer that is able to quantitate cell counts and viability using the widely accepted propidium iodide (PI) protocol. Unlike most cytometers, the Guava PCA uses a motorized microsyringe to aspirate a defined sample volume. This feature allows the instrument to calculate precise cell concentrations. And unlike simple particle-counting instruments, the laser and fluorescence-based systems of the

Guava PCA have the ability to detect and analyze individual viable cells, differentiate between live and dead cells and distinguish cells from debris.

Large-Scale Cell Separation

The facility maintains an AutoMACS (Miltenyi Biotec) magnetic cell separation instrument within the Veterinary Medicine Complex satellite office. The AutoMACS is a fully automated bench-top sorter that can be used to perform sterile or non-sterile bulk sorts. Designed for ultra high-speed positive selection as well as depletion, the AutoMACS can isolate virtually any cell type and is compatible with almost any direct or indirect MACS reagent (Miltenyi Biotec). Users need only label cells to be sorted and choose an AutoMACS separation program. The separation is done automatically. Several separation programs can be selected from a touch-screen menu. By using the positive selection program, the AutoMACS is capable of isolating up to 2x108 pure target cells within minutes. Cells as rare as 1 in 106 can be enriched to high purity through the use of double positive selection programs. "Untouched" cells may be obtained just as easily by depleting unwanted cells with the AutoMACS depletion programs. The AutoMACS and associated reagents are completely compatible with flow cytometry. Fluorescent and magnetic labeling of cells can be performed simultaneously. After AutoMACS sorting, cells are immediately ready for flow cytometric analysis. The AutoMACS is user-operated. Potential users must complete a mandatory training session, which is provided upon request by facility personnel.

Additional Laboratory Equipment

Refrigerated table-top centrifuge, CO2 incubators, biohazard hood, temperature-controlled water baths, analytical balances, pH meter, refrigerators, freezers, and a cryostorage system are available.

Chemical Instrumentation Facility

(www.cif.iastate.edu)

The Chemical Instrumentation Facility has more than $5 million worth of analytical instrumentation available to faculty, graduate students, industry and other educational institutions. The staff of five highly qualified professionals supports university research by keeping the analytical equipment available and operable and by providing application support and user training. Services available to the research community include the following:

Magnetic Resonance

Eight NMR spectrometers of varying frequencies from 60 to 600 MHz are available. Magnetic resonance spectroscopy allows the use of atomic nuclei as magnetic probes within a molecule. Chemical analysis and spatial orientation are determined by using this technique. A fully equipped EPR system also is available. Equipment located in the facility includes a Bruker Avance 600 (solids) NMR, aBruker DRX-400 NMR, a Varian VXR-300 NMR, a Varian VXR-400 NMR, a Bruker AC-200 NMR, two Varian EM-360 NMRs and a Bruker ER-200 EPR. A Bruker Avance 700 MHz NMR is available in the Molecular Biology Building.

Mass Spectrometry

The mass spectrometry lab is equipped to provide both low- and high-resolution GC-MS on mixtures and high-resolution measurements for determining the elemental composition of pure samples. In addition, electrospray and APCI are used for the ionization of higher molecular weight compounds, particularly those of biological origin. Two dedicated LC-MS are now available for special projects. MS-MS (parent-daughter relationship) experiments are routine. A fully equipped MALDI-TOF for the analysis of biopolymers also is available. Equipment located in the facility includes a Finnigan TSQ-700 GC-LC-MS, a Kratos MS-50 MS, a Finnigan Magnum ITD GC-MS, a Micromass GCT-MS, a Shimadzu LCMS2010, a Finnegan LCQ LCMS and a Bruker PROFLEX-DE MALDI-TOF.

X-Ray Diffraction

A completely equipped X-ray diffraction laboratory provides instrumentation for the study of the molecular structures of small molecules and powders. The equipment includes a Bruker SMART 1000 CCD single-crystal diffractometer equipped with low-temperature devices and a Scintag SDS-2000 powder diffractometer available for general use.

Spectrophotometry

A variety of spectrophotometers are available for routine use. These instruments provide "fingerprint" spectra for characterizing and identifying compounds. These instruments currently include a Bruker IFS 66V FT-IR, a Hewlett-Packard HP-8452 Diode Array UV-Vis and a Jasco J-710 circular dichroism spectrophotometer.

Elemental Analysis

A Perkin-Elmer Model 2400 Series II CHN/S elemental analyzer is available for sample submission or for investiga-

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tor use. Normally, the instrument is configured for carbon, hydrogen and nitrogen, but sulfur also can be analyzed upon special request.

Computation

In addition to computer systems associated with the instrumentation, numerous PCs and workstations are available for network-based data processing and modeling. All data acquired in the facility are automatically backed up to tape or CD.

Confocal Microscopy Facility

The Confocal Microscopy Facility of the Office of Biotechnology and the Institute for Combinatorial Discovery has two confocal microscopes available for use by on- and off-campus researchers. The microscopes are located in the Veterinary Medicine Complex and the Molecular Biology Building. Researchers can choose which microscope best fits their research needs.

Veterinary Medicine Complex

The confocal microscope in the Veterinary Medicine Complex allows for real-time optical sectioning of fixed and living specimens, providing significant improvements in optical contrast and resolution over traditional light and fluorescence microscopy. The facility is equipped with a Leica TCS NT confocal microscope system featuring both an upright and an inverted microscope front end, high-resolution imaging (0.18 microns in X and Y, 0.35 microns in Z), as well as fast physiologic imaging and a hardware zoom capability that yields a true increase in resolution of up to six times that of the objective being used. Excitation wavelengths of 340—365, 458, 488, 568 and 633 nm are available from the UV, Argon, Krypton and HeNe lasers and offer maximum flexibility in detector configurations for all experimental requirements. Transmitted light is also available. The system is user-friendly and requires no alignment. An Acousto-Optic Tunable Filter lets users select/combine multiple wavelengths and individually and variably adjust their intensities. The system also features an electronically driven Z-stage control. All user-selectable functions are computer-controlled and motorized, i.e., all filters and dichroic beam splitters selection, detection pinhole setting, photomultipliers' voltage and offset (contrast) setting, channels selection, scanning galvanometer speed setting and focusing mode selection. These are stored in a file and restored by users at any time. Images collected on the confocal microscope system can be transferred via the Ethernet, Zip® disks or CD.

Molecular Biology Building

A second confocal microscope is housed in the Roy J. Carver Laboratory for Ultrahigh Resolution Biological Microscopy. A Prairie Technologies scanning confocal microscope is part of an optical workstation attached to an inverted Nikon Eclipse 200 microscope. Excitation wavelengths of 488, 568 and 633 nm are provided by an Argon, Argon/Krypton and HeNe lasers. The instrument is completely computer controlled, including choice of dichroic mirrors, filters, pinhole size, scan size, integration time, photomultiplier voltage and z-focus. Images are stored on a hard drive and are available for export via Internet and CD. Image software is available that allows 3D reconstruction of confocal images generated with the confocal microscope.

Crop Products Pilot Plant

(www.ag.iastate.edu/centers/ccur)

The Crop Products Pilot Plants of the Center for Crops Utilization Research (CCUR) is a resource to assist ISU researchers and off-campus businesses in developing new value-added processes, products and markets for Midwest crops, especially corn and soybeans. CCUR strives to add value to grain and other crop-derived materials by conducting grant and contract research; offering short courses, workshops, seminars and training experiences; providing analytical, pilot-plant processing, and consumer evaluation services; providing technical consulting services and information retrieval; and operating small-business incubator services. The center has grain, food and material processing equipment in state-of-the-art laboratory and pilot-plant facilities.

The pilot-plant facilities include a 5,000 square-foot wet-processing pilot plant (soy protein isolation, corn wet milling, brewing, etc.); a 2,600-square-foot dry-processing pilot plant (dry corn milling, drying, grinding, sieving, etc.); a 900-square-foot hazardous solvents extraction facility (vegetable oil extraction grain, plant material extractions); 3,000-square-foot product development laboratory (plastic extrusion, molding, and film blowing; building material processing; etc.); and various process development and analysis laboratories (chromatography, grain analysis, vegetable oil refining, baking, laboratory-scale process development, etc.). A small theater and conference facilities are available for technology transfer activities.

CCUR partly administers and works closely with the *ISU Fermentation Facility*, the Iowa Grain Quality Initiative and *the Grain Quality Laboratory*.

DNA Facility *(www.dna.iastate.edu)*

The DNA Facility of the Office of Biotechnology performs DNA synthesis, DNA sequencing, high-throughput DNA sequencing, plant genomic and plasmid DNA extraction, automated fluorescent genotyping, quantitative, real-time PCR and automated microarray slide hybridization.

DNA Sequencing

The facility has one Applied Biosystems 3730 DNA Analyzer, two Applied Biosystems 3100 Genetic Analyzers, eight Perkin-Elmer thermal cyclers, and a Packard MultiProbe II liquid handling robot. Both standard read length (500-700 bases) and long read length (700-900 bases) sequencing are available. DNA can be sequenced as plasmid, lambda, cosmid or BAC DNA, or as PCR products (direct sequencing). Custom primers can be used with all types of templates. Clients submit sequencing orders using the OnCore software. Use of this software allows clients to track the progress of their orders and will automatically notify them when their data are ready to download. A four-color printout of the data is provided. When no problems are encountered with a template, the results are generally returned within 24-72 hours after receipt of the samples. The facility also provides a primer walking service (www.dna.iastate.edu/framepwalk.html).

High-Throughput DNA Sequencing

For clients who have high-throughput sequencing projects, samples can be submitted in 96-well format. The Applied Biosystems 3730 is capable of processing 12 sets of 96 samples in a 24-hour period. Please contact the facility before submitting samples for high-throughput projects to obtain information regarding sample submission, etc.

DNA Template Preparation

The facility performs plant genomic DNA preparation using the AutoGen 740 instrument. Plasmid template preparation in small-scale and in 96-well format also is available. In addition, the facility offers a seed grinding service using our Spex Certiprep GenoGrinder.

Automated Genotyping

The facility processes primarily microsatellite and AFLP markers using Applied Biosystems 3100 Genetic Analyzers to electrophorese samples and collect the gel image. Each sample can have as many markers as the client can identify. The data are analyzed by ABI Prism GeneScan analysis software. Automated allele calling of microsatellites can be performed by the ABI Genotyper software. Electronic files are provided on optical disk or via the facility server.

DNA Synthesis

The DNA Synthesis Service synthesizes DNA oligomers in two scales, 50-nmol and 200-nmol, and can make modified oligomers such as the fluorescent primers used in genotyping applications as the client desires. In addition, primer design for primer walking sequencing projects is available for those who desire this service. Oligos are synthesized using a BioAutomation MerMade-192 DNA synthesizer.

Quantitative Real-Time PCR

The DNA Facility has available two quantitative, real-time PCR instruments—the Stratagene Mx4000 and the Stratagene Mx3005—and will accept jobs on a ready-to-run basis. Applications include gene expression studies, validation of microarray data, allelic discrimination, SNP analysis, and screening for GMOs. DNA staff are also available to advise or assist clients at any point in the experimental process from initial project design through chemistry and material selection and data analysis.

Microarray Slide Services

Slide Hybridization—An Amersham Lucidea SlidePro hybridization unit is available for use by on-campus users. This instrument can perform hybridization and washing of up to six microarray slides in a uniform and highly reproducible manner.

Slide Scanning—Microarray slides are scanned using Applied Precision's array WoRxe® Biochip Reader. It is a high-resolution, white light, CCD-based system that provides high-quality images with accurate and reproducible results. Slides can be analyzed using API's SoftWoRx Tracker.

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Environmental Engineering Research Laboratory

The laboratory, a service of the Department of Civil, Construction, and Environmental Engineering, provides ideas, chemical analysis and related training, and consultation services in support of university-sponsored research. Documented quality assurance receives top priority and is made available to researchers wishing to verify the quality of results.

Facility staff can function as consultants to assist the Iowa State University research community by preparing quality assurance plans for research proposals, configuring computer systems for data acquisition and manipulation, training departmental personnel in analytical instrumentation and methodology, implementing chemical hygiene plans, and preparing specifications for instrument purchases. Most of

the laboratory's major instrumental systems are available for use by researchers who wish to do their own analytical work. The laboratory provides training and supervision for those researchers.

Atomic Absorption Spectrophotometry

Flame, graphite furnace, hydride, and cold vapor atomization are available. A 150-position autosampler and a TJA Smith-Hieftje 12 AA/AE spectrophotometer can be used to determine metals in large numbers of samples.

Automated Analysis

A four-channel Technicon AutoAnalyzer II Industrial System is used to automate nearly any colorimetric test. A BD-40 block digester is available for simultaneous, semi-automated Kjeldahl nitrogen and total phosphorus determinations. Data collection, computation, and reporting are conducted with a microcomputer data station. The facility custom-builds Auto Analyzer manifolds for specialized research applications.

Gas Chromatography

Three gas chromatographs served by a Maxima 820 Chromatography Workstation provide a wide range of options for organic analysis. FID, ECD, TCD, ELCD, PID, and NPD detectors are available. Autosamplers are available for liquid injection as well as purge-and-trap sampling. Chromatographs are equipped for operation with packed, capillary, or Megabore columns. Sample preparation techniques include continuous or discrete liquid-liquid extraction for water samples and sonication or Soxhlet extraction for soil, tissue, and other solid samples.

Carbon Analysis

A Dohrman DC 180 TOC Analyzer is available to analyze carbon in water samples by the UV-promoted persulfate oxidation method. A boat-sampling accessory is available for determining carbon in solid samples by the combustion-infrared method.

Other

The laboratory is also equipped for most types of wet chemical analysis, including related spectrophotometric and potentiometric methods. Membrane filter techniques are used for bacterial testing.

Fermentation Facility

The Fermentation Facility of the Office of Biotechnology, Center for Crops Utilization Research and chemical engineering and food sciences departments offers services including the production of microbial cells and their metabolites. The facility is rated for BL1 containment.

Pilot-scale equipment housed in the Food Sciences Building includes two B. Braun fermentors with working volumes of 100 and 50 liters, one NBS 4500 fermentor with a working volume of 22 liters and one Bioengineering fermentor with a working volume of 15 liters. Benchtop fermentors located in the Food Sciences Building include two NBS Microferm fermentors (6 or 12 liter working volumes), two NBS Bioflo 3000 fermentors (1.2 or 5 liter working volumes) and three B. Braun Biostat M fermentors (2 liter working volumes). Benchtop fermentors located in Sweeney Hall include two NBS Bioflo 110 units with 1- and 5-liter working volumes. Downstream processing equipment includes an Amicon DC10-L ultrafiltration system, CEPA Z-41 continuous centrifuge, SLM "French" pressure cell press and a VirTis Ultra 35, eight-shelf freeze dryer with stoppering capability.

Gene Chip Facility

(www.biotech.iastate.edu/facilities/genechip/Genechip.htm)

The GeneChip® Facility of the Office of Biotechnology, Plant Sciences Institute and Agriculture Experiment Station provides services for analysis of Affymetrix GeneChip® microarrays that can be used for the study of global patterns of gene expression.

Affymetrix GeneChip® instrumentation system

The following two levels of service are available to users:

Full GeneChip® analysis is available for analysis of gene expression in eukaryotic samples. RNA samples are submitted to the facility for labeling, hybridization and scanning. GeneChip® microarrays can be purchased through the facility or provided by the users.

Hybridization and scanning is available for analysis of gene expression in both eukaryotic and prokaryotic samples. Labeled samples are submitted to the facility for hybridization and scanning. GeneChip® microarrays can be purchased through the facility or provided by the users. Because the facility does not label prokaryotic RNA samples, users wishing to assay gene expression in prokaryotes must provide labeled samples for hybridization and scanning.

After scanning, the facility will perform initial data analysis to ensure data quality and then provide users with raw and/or normalized data.

Agilent Bioanalyzer 2100 lab-on-a-chip instrument

This instrument is used for analysis and quantification of DNA, RNA and protein. Each chip can be used to assay from one to 12 samples. Users will receive training in its operation and be responsible for running their own samples as scheduled by the facility manager. Users running protein samples must supply their own chips.

Hybridoma Facility

(www.biotech.iastate.edu/facilities/hybridoma/)

The Hybridoma Facility of the Office of Biotechnology provides valuable resources for scientists who need monoclonal or polyclonal antibodies, but do not have the appropriate equipment, or who are not experienced in antibody production techniques. A wide array of procedures can be customized to meet the researcher's individual requirements. These techniques are provided on an individual charge basis and include animal immunization; cell fusion and hybridoma culture maintenance; cell culture and maintenance of other cell lines used in biotechnology and virology labs; large-scale mammalian cell culture (bioreactor); blood sera collection; antibody purification and isotyping; cryopreservation and cryostorage of cell lines (-140 degrees centigrade); and ELISA tests. The hybridoma projects are usually screened and selected by the client; however, the facility can do the screening and/or training of lab personnel when needed. A hybridoma project usually requires three to five months for completion. The following timetable is used for general planning of a hybridoma project:

- Mouse immunization: 4-6 weeks
- Selection of primary hybridomas after cell fusion: 2 weeks
- Expansion and freezing of primary hybridomas: 2 weeks
- Cloning and screening of clones: 2 weeks
- Expansion and freezing of clones: 2 weeks
- Bioreactor/ascites fluid production: 4 weeks

Polyclonal antibody production in rabbits is available for on-campus clients only. Polyclonal services include the purchase and care of rabbits through the Laboratory Animal Resource group on campus, blood collection and processing of sera, adjuvant addition, and injection of antigen and administration of procedures according to an approved protocol and timetable.

All hybridoma services are open to Iowa State University clients and off-campus individuals or companies. Current price information for each procedure offered may be obtained by calling 515-294-9837 during regular business hours or by sending an e-mail message to pakapke@iastate edu.

Image Analysis Facility

The Image Analysis Facility of the Office of Biotechnology provides 2D and 3D imaging resources for researchers interested in sample measurement or visualization. Services include: 2D image analysis (morphometry, particle analysis, densitometry, etc.), 3D image analysis (volumetric sample measurement) and reconstruction, image editing instruction and photomicroscopy. Images of samples are acquired via digital and video cameras, a flatbed scanner or a slide scanner. Analysis is performed with Zeiss KS400, IPLab, Openlab, or Metamorph software. In addition to the numeric results of the analysis, photographic quality prints can be provided for use in publications or poster presentations.

Equipment in the facility includes PC and Macintosh computers, software for 2D and 3D image analysis and visualization, a variety of digital and video cameras, a flatbed scanner, CD/DVD writers, a laservideodisc recording system, VCRs, a time base corrector, a Zeiss photomicroscope and a Zeiss inverted microscope.

A laser capture microdissection system also is available for use. This instrument is used to identify and retrieve individual cells from tissue sections. The retrieved cells can be used for assessment/analysis of RNA, DNA, protein and other biochemical properties. Those not wanting to prepare their own slides may wish to make use of the services offered by the Histology Laboratory in the Veterinary Pathology Department (515-294-0956).

Isothermal Titration Microcalorimetry Facility

Isothermal Titration Calorimetry (ITC) is a thermodynamic technique for monitoring any chemical reaction initiated by the addition of a binding component. It is often used to characterize biomolecular interactions. The ITC Facility is not a fee-for-service facility, but provides access to a MicroCal VP-ITC to foster collaborative research efforts. Users may operate the instrument after going through appropriate training.

W. M. Keck Metabolomics Research Laboratory

(www.designercrops.iastate.edu/metabolomics)

Part of the Center for Designer Crops within the Plant Sciences Institute, the W.M. Keck Metabolomics Research Laboratory provides six different analytical instruments to

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pursue metabolomics studies. The instruments available are two Agilent Technologies gas chromatography systems coupled to mass-spectrometer detectors that use different ionization methods, an Applied Biosystems QSTAR® LC/MS/MS system, Agilent LC/MS-Ion Trap instrument with three different ionization capabilities, a Beckman Coulter capillary electrophoresis instrument coupled to a laser-induced fluorescence detector, and a Beckman HPLC system with four different detectors. In the process of understanding the metabolome of a biological sample, the use of all or a combination of any of these analytical instruments provides access to assay a large variety of small molecules known as metabolites.

Users of the laboratory have the option of being trained in the use of these instruments, following which they can use the instruments themselves, or having the on-site researcher analyze the samples for them for a fee.

MicroArray Facility

(www.plantgenomics.iastate.edu/microarray)

Part of the Center for Plant Genomics of the Plant Sciences Institute, the Microarray Facility provides access to instruments to produce and scan microarrays.

The facility's instruments can be used to determine the expression patterns of thousands of genes in parallel. Users provide their own gene targets for spotting on microarray chips. Researchers interested in assistance with preparing DNA samples for spotting should contact the DNA Facility, which provides service for such projects.

Personnel of the Microarray Facility prepare chips on a fee-for-service basis. High-throughput users may operate the instrument after being trained by personnel of the facility.

Scanning is performed by users trained to operate the instrument.

Microfabrication Facility

The W. M. Keck Laboratory for the Fabrication of Microminiaturized Analytical Instrumentation (Keck Lab) of the Institute for Combinatorial Discovery provides the ISU and industrial communities with access to state-of-the-art microfabrication technologies. With its approximately 1,000 sq. ft. of class 10/100 clean rooms, the Keck Laboratory supports all phases of microfabrication and its use in fields ranging from analytical chemistry to cell biology. Drawing from affiliates across campus and its resident support staff, expertise in micromechanics, microfluidics, microchip arrays, biology, chemistry, physics and microelectronics can be integrated in translating research ideas into experimental reality.

Research capabilities in the laboratory include developing microanalysis systems, chip-scale chromatography, microelectrode assemblies, biochips and cell culture platforms. The laboratory also houses equipment for optical lithography, wet and dry chemical etching and thin film deposition. Analysis and testing equipment, computer workstations and drying and vacuum annealing ovens also are available.

Microscopy and Nano-Imaging Facility

(www.biotech.iastate.edu/facilities/BMF)

The Microscopy and Nano-Imaging Facility (MNIF), formerly known as the Bessey Microscopy Facility, of the Office of Biotechnology provides a variety of instrumentation, technical assistance, consultation and training to individuals and groups of life sciences and biotechnology researchers who want to use photomacrography, light microscopy, scanning and transmission electron microscopy, cryopreservation, cytochemistry, autoradiography, X-ray microanalysis and image analysis. In addition to the around-the-clock open hours, the BMF carries out service work for both on- and off-campus researchers. The director and assistant scientist of the BMF are available for consultation and individual help.

Electron Microscopy

Electron microscopy instrumentation includes a JEOL 1200EX scanning/transmission electron microscope (STEM) with elemental analysis and image analysis systems, and a JEOL 5800LV scanning electron microscope (SEM) with elemental analysis and image analysis systems.

The JEOL 1200EX, with 1.4Å resolution, consists of the basic STEM, a light element energy dispersive X-ray spectrometer (EDS) and computer. The digital microscope and analytical system allow elemental analysis of the composition and structure of specimens with a nanometer resolution. Special features include a backscattered electron detector, Megaview III digital camera for image recording, and analySIS Pro image analysis system that provides for image capture, as well as quantitative analysis of size, distribution and density of specimens.

Ancillary equipment available for preparation of specimens for electron microscopy include an Edward's 502A Vacuum Evaporator, Denton critical point apparatus, Denton Desk II sputter coater, a microwave processing unit, two Reichert

Ultracut S ultramicrotomes (one with FCS cryo-sectioning system) and a LKB glass knife maker.

The digital JEOL 5800LV scanning electron microscope (SEM), with 35Å resolution, operates at either high (30-15) or low (10-0.3) kVs and at either high or low pressures to allow for the observation of both fixed and fresh specimens. Cryopreservation, X-ray microanalysis and image analysis are available for special specimens. Images can be photographed directly on film or captured using the analySIS ADDA II digital system with SIS Pro software.

Light Microscopy

Light microscopy instrumentation includes a Zeiss Axioplan II compound microscope equipped with AxioCam HRC digital imaging system, stereo and dissecting microscopes; a microspectrophotometer/fluorometer, and an Apotome, micromanipulator and microforge; a TV and image analysis system; and a photomicroscope equipped with bright-field, phase-contrast, polarizing, darkfield, fluorescence and Nomarski (DIC) optics, automatic color and B/W camera and color TV monitor. An Olympus SZH10 stereomicroscope and AxioCam digital camera are available for macro specimens. Image analysis capabilities are available with the light microscope.

Specialized Rooms

The 24-room BMF also has two specimen preparation labs, a fully-equipped print darkroom; a copy room housing a Bencher photo duplication system and macro photography equipment; a computer suite; an autoradiography/in situ hybridization and developing room containing an isotope incorporation hood, balance, cryostat, tissue culture shaker, refrigerator, oven and processing sinks; a prep room with dishwasher, distilled water system and autoclave; a small conference room with a library; and a four-room complex for teaching.

Instruction

A limited amount of individual instruction, approved by the director, is provided and charged on a per-technical-hour basis. The normal route for instruction of graduate students (as well as staff and faculty) is through the three graduate-level courses that are taught on a rotating basis, each with a limit of ten students: Light Microscopy (GDCB 679, Fall 2006), five credits; Scanning Electron Microscopy (GDCB 680, Fall 2005), five credits; Transmission Electron Microscopy/X-ray Microanalysis (GDCB 681, Spring 2006), five credits. For more information about the courses, visit the ISU web site catalog.

Nuclear Magnetic Resonance Facility

(www.public.iastate.edu/~bfulton/nmr_home.html)

The Nuclear Magnetic Resonance (NMR) Facility is supported by the Office of Biotechnology and the department of biochemistry, biophysics and molecular biology. The facility currently operates Bruker Avance 700 and 500 spectrometers, both capable of performing a broad range of modern multi-nuclear, multi-dimensional NMR experiments on biomolecules. The 700 is equipped with an H/C/N cryoprobe, an H/C/BB conventional probe and an H/BBX/BBY-MAS solids probe. The 500 is equipped with H/C/N and BB/H probes.

The facility has computational resources for processing and analyzing NMR data and obtaining molecular structures. The facility provides consultation on the application of NMR to solve research problems. NMR data can be acquired and interpreted as an analytical service. Projects larger in scope can be pursued on a collaborative basis. In the latter case, the facility will provide training and guidance for researchers to operate instruments and interpret data.

Plant Transformation Facility

The ISU Plant Transformation Facility is supported by the agronomy department, Office of Biotechnology and the Plant Sciences Institute. It offers research partnerships for the genetic transformation of crops. The target crops are corn, rice and soybeans. The facility uses the Bio-Rad Biolistic Apparatus and Agrobacterium tumefaciens as the gene delivery systems for transformation of corn immature zygotic embryos and callus. The Agrobacterium-mediated transformation method is used in the rice and soybean system.

The facility provides expertise in corn, rice and soybean transformation for on- and off-campus researchers. It includes complete transformation (transgenic seeds or plantlets), stable transformation (transformed callus) and transient transformation (bombarded cultures). The facility also provides a variety of instrumentation, technical assistance, consultation and training to individuals and groups of plant sciences and biotechnology researchers who want to conduct plant transformation. A graduate workshop entitled "Plant Transformation and Transgenic Plant Analysis" (Zoo 542D) is given by the facility every spring semester.

Equipment in the facility includes a Bio-Rad Biolistic PDS-1000/He Apparatus, dissecting microscopes, Percival biological incubators, laminar flow hoods, a refrigerated shaker

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incubator and an SZH10 Olympus fluorescent microscope with digital camera for GFP detection.

Protein Facility *(www.protein.iastate.edu)*

The Protein Facility is supported by the Office of Biotechnology and Biochemistry, Biophysics and Molecular Biology Department, and provides protein and peptide analytical services for both on- and off-campus researchers. The following instruments are available in the facility:

- Applied Biosystems Model 420A PTC amino acid analyzer
- Applied Biosystems Model 494 Procise protein/peptide sequencer
- Applied Biosystems Model 432A Synergy peptide synthesizer
- Advanced ChemTech Model 396 multiple peptide synthesizer
- Thermo BioAnalysis Dynamo MALDI mass analyzer
- Applied Biosystems DE-Pro MALDI mass analyzer
- Three Beckman System Gold high-performance liquid chromatographs
- Amersham-Pharmacia IPGPhor IEF unit
- Amersham Pharmacia DALT 2D electrophoresis system
- Molecular Dynamics Typhoon 8600
- Amersham Pharmacia Image Scanner
- Genomics Solutions ProGest
- Biorad minigel and blotting apparatus

Software for the analysis of 1D and 2D gels is also available. The Protein Facility also oversees the use of the Beckman Optima XL-A analytical ultracentrifuge and a Jasco-710 spectropolarimeter. The following services are offered:

Amino Acid Analysis

The facility provides amino acid analysis to determine the quantities of the normal 16 amino acids (no cysteine and tryptophan) in a protein.

Analytical Ultracentrifugation

The facility provides analytical ultracentrifugation as a means for determining molecular weight and the hydrodynamic and thermodynamic properties of a protein or macromolecule. Molecular weight determination in the native state, analysis of self-associating systems and determination of sedimentation coefficients can all be determined using this instrument. The analytical ultracentrifugation equipment also is available as a user-operated instrument after a required training session.

Circular Dichroism

The facility provides circular dichroism (CD) spectroscopy as an optical technique to allow the detection and quantitation of the chirality of molecular structures. The CD equipment also is available as a user-operated instrument after a required training session.

High Performance Liquid Chromatography (HPLC)

The facility offers microanalytical, analytical and preparative HPLC purification of proteins and peptides. The HPLCs also are available as user-operated instruments after a mandatory training session conducted by facility personnel.

MALDI-TOF Mass Spectrometry

The facility provides mass spectrometry services for proteins, peptides, glycoproteins, oligosaccharides, oligonucleotides and other polymers using a matrix-assisted laser

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desorption/ionization time-of-flight (MALDI-TOF) mass spectrometer. The mass spectrometer also is available as a user-operated instrument after a required training session.

Peptide Synthesis

The facility can do both large- and small-scale peptide synthesis, including the synthesis of phosphopeptides, peptides containing unusual amino acids and multiple antigen peptide systems (MAPS) for vaccine production or monoclonal antibody production. The facility also has the capability to synthesize combinatorial peptide libraries.

Protein/Peptide Sequencing

The facility provides N-terminal protein/peptide sequence analysis of samples in solution or of samples electro-blotted onto polyvinylidene difluoride (PVDF) membranes. The facility personnel also perform chemical and enzymatic digestion of proteins in solution or proteins blotted onto PVDF to provide internal sequence information.

SDS-PAGE/Electroblotting

The facility provides SDS-PAGE analysis of proteins for purity and molecular weight estimation and western blotting to nitrocellulose or to PVDF for immuno-detection or amino acid analysis and protein/peptide sequencing, respectively. Stained gels (Sypro Ruby®, Coomassie Brilliant Blue, silver, etc.) can be scanned and analyzed in the facility. The SDS-PAGE equipment also is available as a user-operated service after a required training session.

2D Gel Electrophoresis

The facility provides two-dimensional electrophoresis by separating proteins in the first dimension according to charge (isoelectric focusing [IEF]), followed by separating the focused proteins in the second dimension according to molecular weight by sodium dodecyl polyacrylamide gel electrophoresis (SDS-PAGE). The proteins may be visualized by staining with Coomassie Brilliant Blue R250, silver stain or fluorescent dyes. These spots can be excised for further analysis or the 2D array can be analyzed for differences in protein quantity or in proteins present in the gel. Two-dimensional gels also can be electroblotted to PVDF or nitrocellulose membranes for further analysis. The 2D electrophoresis equipment also is available as a user-operated service after a required training session.

Isoelectric Focusing (IEF)

The facility provides IEF as a method for separating proteins based on isoelectric point prior to SDS-PAGE. The IEF equipment also is available as a user-operated instrument after a required training session, allowing the researcher to perform the second dimension in their own lab.

In-gel Digestion/Peptide Mass Fingerprinting

The facility provides automated in-gel digestion of protein samples from 1D or 2D gels. Gel spots can be digested with a variety of enzymes including trypsin, Arg-C and Glu-C. The resulting peptides from the digestion can then be analyzed by MALDI-TOF using the Applied Biosystems Voyager DE-Pro. From the spectrum obtained, peptide mass fingerprinting can be performed to identify the original protein using databases available on the web. The peptides from the digested proteins can also be separated by HPLC for further analysis by N-terminal sequencing or MALDI-TOF.

Proteomics Facility *(www.proteomics.iastate.edu)*

The Proteomics Facility of the Plant Science Institute's Center for Plant Genomics offers instrumentation to resolve complex proteomes and to identify and characterize the component proteins.

Image Scanning and Analysis

A Typhoon 9410 Variable Mode Imager is available for scanning of 1D and 2D gels and for phosphor imaging. A screen eraser is available for erasing phosphor imaging screens. The scanner is equipped with three lasers and can scan gels staining with Cy dyes (2D-DIGE gels), Sypro, ProQ and Deep Purple fluorescent gel stains, as well as the common visible stains like silver and Coomassie Blue. Gel analysis software is available for analyzing 1D and 2D gels, and Amersham's Decyder Program is available for analysis of DIGE gels.

Sample Preparation

The Amersham Ettan Spot Handling Workstation in the facility uses sophisticated robotics to provide high-throughput processing of gels and automatically picks individual proteins in preparation for mass spectrometric analysis. Automated tryptic digestion and extraction and MALDI plate spotting are also performed by the system. A UV lightbox and spot picking tools are available for manual gel processing.

Mass Spectrometry

An ABI Q-Star XL quadrapole-TOF tandem mass spectrometer provides a wide range of protein analysis. This instrument is equipped with ESI, nanospray and oMALDI sources providing a wide range of sensitivity and multiple types of ionization sources. An LC-Packings UltiMate capillary high pressure liquid chromatography (HPLC) system

is also available for LC-MS, LC-MS/MS and LC/LC-MS/MS applications for analysis of complex protein mixtures and ICAT analysis. For both gel-based and chromatographic separations, proteins will be identified, when possible, by searching databases with both MS and MS/MS data using Mascot software. For organisms which do not have complete protein databases, de novo sequences from trypsin fragments can be obtained from MS/MS data. Digestion with other proteases will also be available to increase coverage when required. MS-based methods will be made available for the identification and mapping of post-translational modification of proteins.

Facility Operation

The Proteomics Facility will provide as much hands-on accessibility as practical, while still maintaining efficient use of the instrumentation. All sample preparation will be done by individual researchers in their labs or in the Protein Facility (located in the Molecular Biology Building) with advice and training by the Protein Facility for 2D gel electrophoresis and by the Proteomics Facility for other techniques. Some equipment will be made available for researchers to use after receiving suitable training. Training classes will be provided by the Proteomics Facility on these instruments as needed. Data analysis will be conducted by individual investigators with assistance and training from the Proteomics Facility. The Typhoon laser scanner will be available for individuals to use for gel scanning. A data analysis workstation will be available in the Proteomics Facility containing the programs required for 2D-gel analysis, interpretation of mass spectra and database searching.

Molecular Interactions

A Biacore T100 Surface Plasmon Resonance Instrument is available for measuring affinity and kinetics of molecular interactions.

Iowa State University

Ultrahigh Resolution Biological Microscopy Laboratory

The Roy J. Carver Laboratory for Ultrahigh Resolution Biological Microscopy, located in the Molecular Biology Building, provides an atmosphere for the development of interdisciplinary research between the life and physical sciences. Researchers can use the instrumentation housed in the laboratory to perform optical and scanning force imaging of their samples. Housing is available for students working on projects in the laboratory. In addition, the Carver Lab has a fully equipped cell culture facility and a data processing center where experiments can be analyzed and the results copied onto CDs for use in researchers' home laboratories.

Optical Workstation

The workstation consists of an inverted Nikon Eclipse 200 microscope with bright-field and differential interference contrast optics, fluorescence, wavelength separation to two digital cameras, iris and pinhole localization and confocal microscopy. Software controlling the optical workstation is designed to automate image acquisition and integrate with electrophysiological experimentation. The fluorescent system on the workstation has filter sets for DAPI, FITC, CY3/TRITC, CY5, GFP, CFY and YFP while the Prairie Technologies scanning confocal microscope is equipped with laser excitation for 488nm, 568nm and 633nm wavelengths. The confocal microscope is completely computer controlled, including choice of dichroic mirrors, filters, pinhole size, scan size, integration time, photomultiplier voltage, and z-focus. Images are stored on a hard drive and are available for export via the Internet and CD. Image software is available that allows 3D reconstruction of confocal microscope images. The Nikon Eclipse is equipped with high numerical aperture objectives from 2X to 100X.

Hyperspectral Workstation

The latest addition to the laboratory is an Optical Insights hyperspectral microscope. Designed specifically to eliminate problems inherent in fluorescence microscopy, this system allows spectral separation of defined objects in the data set of imaged specimens. This workstation consists of the Optical Insights instrument attached to an inverted Nikon Eclipse 2000 equipped with a Photometrics Cascade 512B digital camera. The system has a wide range of customized fluorescent filter cubes and microscope objectives. This system has software specific for hyperspectral data acquisition and analysis, in addition to the latest MetaMorph (7.0) imaging software which allows 4D viewing and 3D measurements

Additional hyperspectral and MetaMorph analysis software is installed on computers in the laboratory's data processing room

Atomic Force Microscopy

Three atomic force microscopes are available for use in the Roy J. Carver Laboratory for Ultrahigh Resolution Biological Microscopy of the Institute for Combinatorial Discovery.

Digital Instruments Dimension™ 3000 Scanning Probe Microscope

The Dimension 3000 scanning probe microscope (SPM) brings together all SPM techniques in a single platform and handles a wide range of sample sizes and types. A rigid, low vibration construction of the Dimension 3000 SPM ensures the highest quality images and measurements.

Samples up to eight inches in diameter can be scanned in ambient air or fluids using the Dimension 3000 SPM. The Dimension 3000 SPM requires little or no sample preparation, and the simple vacuum mounting system allows easy and convenient setup. Superior linearity and resolution in all three dimensions is obtained, even for large samples. Integrated top-view video optics with motorized zoom and 1.5 µm optical resolution help identify areas of interest for detailed scanning quickly and easily. Changing scanning techniques, for example from AFM to STM, requires no tools. The NanoScope IIIa system controller is a main part of the SPM system providing the software and electronics that drive the microscope. Digital tracking and feedback control insure accuracy and speed at all scan sizes and positions on the sample.

Digital Instruments MultiMode with a Nanoscope IIIa controller

The MultiMode system features multiple scanners that permit the user to tailor the system for individual research. Scanners with large scan ranges up to 120 microns on the X—Y axes, and a Z range up to six microns, as well as high-resolution scanners with 0.5 microns X—Y axes and sub-micron Z range are available. The vertical-engage "JV" and "EV" scanners allow the tip to be positioned at any point on the surface, without adjusting for lateral movement during approach. The MultiMode is controlled with a NanoScope IIIa controller. This controller provides 16-bit resolution on all three axes, with three independent 16-bit digital-to-analog converters (DACs) in X and Y for control of the scan pattern, scaling and offset. This configuration provides 16-bit resolution of the lateral scanning motion at any scan size.

Digital Instruments Dimension™ 3100 Scanning Probe Microscope

The Dimension 3100 is controlled with a Nanoscope IV controller. The NanoScope IV features up to ten-times-faster scanning, as well as increased functionality, bandwidth, flexibility and expandability.

Field Laboratory Facilities (Research and Demonstration Farm System)

Strong agriculture production, cropping systems, plant breeding, quantitative genetics, plant physiology, soil science, water quality, and agricultural engineering research programs require state-of-the-art field laboratory research facilities. These facilities need the research and management flexibility to accommodate many different types and scales of research. Field research can vary from the hill plots used by small grains breeders, to 100 sq. ft. plots used by maize breeders, to the 0.25- to one-acre plots used in cropping systems research. Many agricultural engineering equipment experiments can require five to ten acres of land to properly conduct an experiment. The other factor that complicates the management of field research plots is time. For most of the major crops it takes at least six months to collect the data needed due to the annual nature of the crop. Some perennials require two or more years before the first reliable data can be collected. Some soil science experiments require the application of either excessively high or low amounts of nutrients thus rendering this land unusable for normal production research for some years. Coupled with the need to establish rotations, the management of an active field research laboratory needs dedicated and qualified personnel who have the ability to work with many different projects simultaneously.

Through its statewide Research and Demonstration Farms system, Iowa State University's College of Agriculture has established an extensive field research laboratory system in conjunction with stakeholders in the state. The system employees about 40 individuals who work closely with sci-

Iowa State University

ISU Research and Demonstration Farms

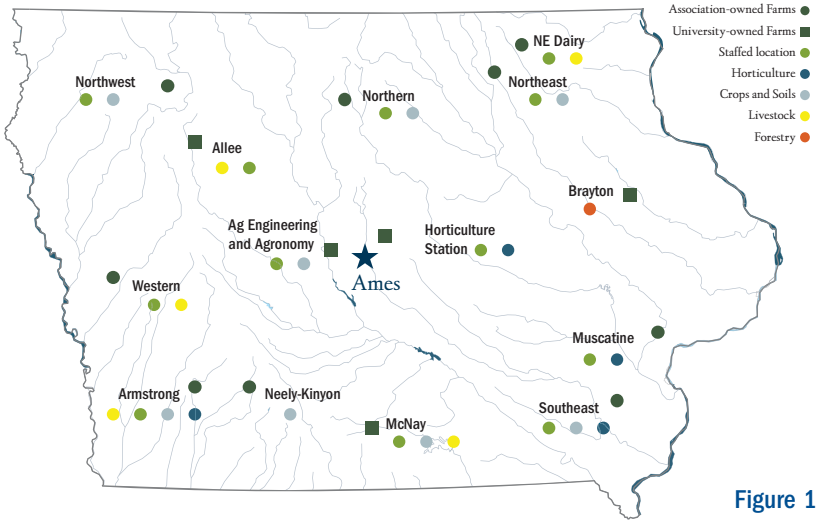


Figure 1

entists to enable the collection of high quality data for research projects. There are 12 primary program farms in the state with full time staff. Eight of the program farms are owned by affiliate associations. Affiliate associations are local organizations of farmers and agribusinesses that own the land and have a long-term agreement with ISU to conduct research and demonstration projects in their region of the state. The association provides input to ISU on research topics and ISU operates the farms and provides field days and progress reports. This is a proven linkage that builds relationships between ISU faculty and staff and local stakeholders. ISU has a total of 9,409 acres in program farms and an additional 6,646 acres in production farms that are not used for research (but could be if needed) around the state of Iowa. The location and types of farms are shown in Figure 1.

The Research and Demonstration Farms system gives the ISU College of Agriculture remarkable capabilities to conduct multidisciplinary research with plants, animals and soil, water and other environmental subjects (including biodiversity, wildlife habitat, etc). Nine academic departments actively use the field research laboratories. This adds up to 120 project leaders composed of 90 faculty, 20 area extension specialists, and ten staff. More than 400 agricultural experiments or projects are conducted at these field research laboratories annually. This gives scientists and stakeholders in Iowa an opportunity to interact with each other and to share information.

This kind of field research laboratory system can be thought of as the equivalent of a chemistry, physics, or engineering laboratories. The differences are the scale of investigation and research and the variables that can be controlled. Research in chemistry, physics, and engineering laboratories can be controlled to the extent desired. Many aspects of field research can also be controlled through the use of experimental design, knowledge of soil types and formations, applications of synthetic fertilizers, applications of herbicides and insecticides, etc. One aspect that cannot be generally controlled, however, is weather. This necessitates the replication of experiments in both space and time. Quality data on the performance of new varieties, fertilizer treatments, cropping systems, can only be obtained by replicating the experiments in both space (by planting the experiment at two or more locations) and time (repeating the experiment in a second or even third year). Some experiments that relate to soil quality characteristics may need to be replicated over five to ten years to obtain quality data. These kinds of experiments require the same attention to experimental protocols as any experiment that would be conducted in a chemistry, physics, or engineering laboratory.

ISU's field research laboratory system is centrally managed by Dr. Mark Honeyman in the College of Agriculture. Centralized management gives the system the management and flexibility to respond quickly to changing research needs. Iowa State University and its network of land-owning affiliates have the capability and land capacity to quickly respond to changing research needs.

The ISU Research and Demonstration Farms serve researchers with on-site resources of land, specialized agricultural machinery, trained research staff, and facilities (dryers, coolers, storage, and work areas). Researchers bring ideas and carefully designed projects for implementation at the field research laboratories. The research farm staff aids the researcher in setting up and conducting the experiment, collecting data, and providing on-site expertise and management.

The ISU Research and Demonstration Farms also serve a critical role as a public interface. About 15,000 visitors come to more than 65 demonstration and training days each year. Automated weather stations daily upload data to the Internet. The ISU Research and Demonstration Farms serve a "public farm" role where school children learn about where food comes from, young people explore agricultural careers, and farmers see the latest ideas related to crops, soils, machinery, and livestock. The farms are places where many reconnect with land and the science of agriculture.

Iowa State University

US Department of Agriculture's North Central Regional Plant Introduction Station

Located on the ISU campus, this facility is responsible for maintaining diverse genetic resources for a number of crops and crop relatives, including 17,000 accessions of corn. These unique genetic resources represent an important resource for identifying useful variants of genes involved in cell wall architecture and composition.

PROPOSED *New Century Farm: Renewing Research, Education, and Extension to Lead Iowa and the Nation into a Sustainable Future*

The emerging bioeconomy presents Iowa with an opportunity to develop new industries and to diversify its agriculture. Key to Iowa's success in attracting biorefineries will be the ability of producers to grow the kinds and quantities of feedstocks needed by the industry. It is widely recognized that the bioeconomy cannot be supported by corn grain alone, and that a variety of annual and perennial cellulosic crops likely will be grown alone or in rotation with corn and soybeans. If carefully designed and deployed, the transformation of agriculture to serve the bioeconomy can preserve the soil, water, and other natural resources that make Iowa productive; while also strengthening rural communities and improving the quality of life for those who produce and supply the biomass materials. Achieving this vision of sustainable bioenergy production will require new crops and new cropping systems, integrating academic disciplines into multidisciplinary platforms, and involving producers, industry representatives, and policy makers in all stages of the research and development process. The New Century Farm—the first integrated, sustainable, and ecologically sound biofuel feedstock production system of its kind—will be important in fulfilling this vision. It will serve as a "living laboratory" for testing systems and for training future scientists, producers, and extension educators; and it will help Iowa retain its status as a national leader in the bioeconomy through research agendas and new models of extension communication that will allow the land grant university to better serve and engage its constituency.

The university currently has adequate land in its inventory to devote to this purpose. Plans include construction of a planting and harvesting machinery development workshop, a pilot plant and laboratory for on-site biochemical and thermochemical pre-treatment and conversion of biomass, and storage buildings for feedstocks and production and harvesting equipment.

The vision for sustainable biofuel production at the New Century Farm will include the following:

Research—Bring together scientific expertise to address biomass cropping systems, biofuel processing, logistics of biomass supply, and recycling nutrients back to the land.

Teaching—Serve as a laboratory and extension resource for training future scientists, producers, and extension experts.

Extension—Demonstrate economic, social and environmental viability of bioenergy production to producers, policy-makers, and the public.

More specifically, the New Century Farm will allow researchers to:

- Integrate agronomy, ecology, industrial technologies, economics and community needs. Producing biofuel feedstocks while maintaining environmental quality requires a new scientific and managerial approach that combines the principles and technologies of agronomy, ecology, chemistry, engineering, and economics.
- Analyze technological systems. Successful bioenergy production must integrate biomass production, efficient harvest methods, feedstock handling and storage, feedstock pretreatment and transport, and bioenergy processing.
- Analyze economics and ecological services of systems.

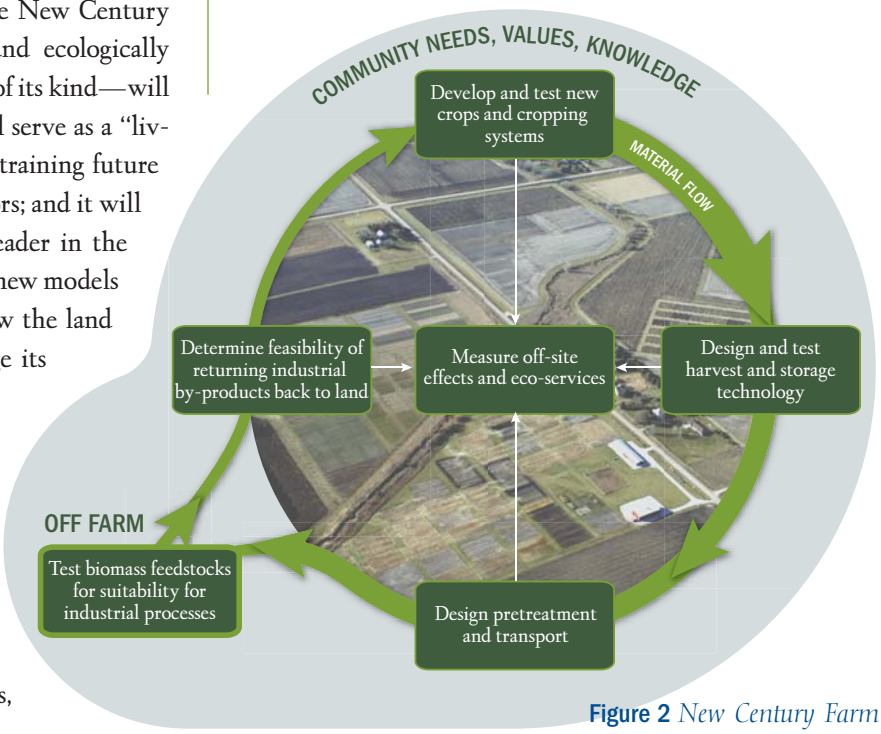


Figure 2 *New Century Farm*

Large-scale, long-term studies will address the performance, cost-effectiveness, and profitability of biomass production systems. Dynamic interactions between feedstock production and the ecosystem will be assessed, particularly in terms of soil, water, and air quality.

- Build partnerships. Engaging producers, community members, and industry representatives will ensure that relevant, practical issues and opportunities are addressed. The New Century Farm will be a model for how Iowa State University fulfills its land-grant mission through service and engagement.
- Build on Iowa State's strengths. With nearly 150 years of research, teaching and extension accomplishments, Iowa State is at the geographical, research and educational epicenter of the expanding bioeconomy. The university's research and expertise in biorenewables dates back to the 1970s. The university's internationally recognized Office of Biorenewables Programs offers the only graduate degree program in biorenewables in the nation. Iowa State also has close collaborative relations with major agricultural and chemicalindustries, most of whom have major facilities in central Iowa. Iowa State has excellent statewide extension and outreach programs serving agriculture and business and industry.

Integrating Agronomy, Ecology, Industrial Technologies, Economics, and Community Needs

Producing biofuel feedstocks (biomass) while maintaining environmental quality requires a new scientific and managerial approach that combines the principles of agronomy and ecology with industrial technologies of chemistry, engineering, and economics. These new systems must be developed in partnership with producers and community members whose values, needs, and labor contribute to the viability of bioenergy production systems. Whereas agronomy traditionally manipulates the environment to maximize crop production, ecology teaches us to understand the complex interactions of dynamic systems. Properly managed, biomass production and fuel processing systems can also provide additional benefits such as clean water, carbon sequestration, more diverse wildlife, rural amenities, enhanced public health, and social well-being. The NCF provides a unique study area for detailed analysis of biomass production and fuel processing systems.

Analyzing the Technological Systems

Successful bioenergy production must integrate biomass production, efficient harvest methods, feedstock handling and storage, feedstock pretreatment and transport, and bioenergy processing into a system that is economically, environmentally, and socially viable. Each element of the system has effects on the other elements. Research, instruction and outreach activities planned for the New Century Farm will connect all these crucial elements so that the inter-relationship between all the parts of the system can be improved. More importantly, a farm-scale facility will allow us to close the loops between biomass production and processing. Harvesting biomass from fields removes nutrients and potential soil matter. Some of the lost nutrients can be replaced by recycling by-products from bioprocessing plants and returning them to the soil. This practice simultaneously reduces waste streams from the processing plants. The research planned at the New Century Farm will allow us to determine how much biomass can be removed from the landscape while maintaining plant productivity, and soil and water quality.

Analyzing the Economics and Ecological Services of the Systems

Large-scale and long-term research and demonstration is crucial for proper understanding of the performance of the biomass production and fuel processing systems. Farm-scale research also allows us to understand systems design and the impact of agricultural practices on bottom line — profitability and on the environment. On New Century Farm we can study 1) cost-effectiveness and profitability of the biomass production systems, and 2) the dynamic interactions between feedstock production and the ecosystem by measuring biophysical changes on the farm, at its boundaries, and at off-site locations, particularly in terms of soil, water quality, and air quality. Only long-term research allows researchers to monitor the way systems develop and perform in economic and ecological terms with enough detail and duration to validate these as viable.

Building Partnerships

Engaging producers, community members, and industry representatives in partnerships with the research, instruction, and outreach at the New Century Farm will ensure inclusion of practical issues and opportunities with respect to the biomass production and biofuel processing systems. New Century Farm will be a resource for scientists, producers and community members, but also a training ground for professionals from the EPA, NRCS, DNR and ISU Extension. Through partnerships and ongoing outreach functions, the New Century Farm will be a model for how our land grant university can serve and engage producers, agribusinesses, and communities.

The J. Craig Venter Institute

The J. Craig Venter Institute (JCVI) is comprised of the Joint Technology Center (JTC) and two research divisions: The Institute for Genomic Research (TIGR) and The Center for Advanced Genomics (TCAG). With a campus of six buildings and more than 250,000 sq. ft. of lab space for combined assets of more than $200 million, the JCVI is one of the largest independent research institutes in the United States. Total number of employees is more than 500, 392 of whom are dedicated to research and 124 of those having doctoral degrees. The new organization also boasts one Nobel Laureate and three members of the National Academy of Sciences.

Joint Technology Center

Designed to be one of the world's leading DNA sequencing organizations, the Joint Technology Center (JTC) supports ongoing and new genomic research projects at the JCVI. The 60,000 sq. ft. facility in Rockville, Maryland is a highly efficient state-of-the-art high throughput sequencing and research facility. In 2003 the high throughput DNA sequencing, template preparation, genome closure and library construction groups from The Venter Institution's sister organization, TIGR were renamed as the JTC upon moving to a new ~27,000 sq. ft. laboratory space. Since inception, the JTC has produced more than 110 million sequence reads containing approximately 75 billion high quality bases from an extraordinarily diverse set of projects. The average sequencing success rate has been 88% and the average read length is approximately 800 base pairs. To date, the JTC has successfully produced approximately 2,000 libraries of different types, including over 1,500 small (‹6 Kb) and medium (6-12 Kb) insert genomic libraries, approximately 200 fosmid libraries and over 100 16s rRNA libraries, and completed more than 250 genomes, including those of phages, plasmids, virus, microbes, fungi, plants, invertebrates and mammals. In addition to the WGS projects, the JTC has also completed a variety of different types of projects, including approximately 20 EST projects, more than 10 BAC end projects and several metagenomic and PCR-directed sequencing projects. The JTC has been a leader in the field of metagenomics, generating approximately 8 million sequence reads from more than 50 environmental libraries derived from ocean, soil, and air samples, as well as from within humans. The JTC was also one of the first organizations to acquire and implement a new massively parallel sequencing platform from 454 Life Sciences Corporation (454).

JTC labs include:

1) A 2,600 sq. ft. dedicated library construction laboratory equipped with the equipment required for DNA purification, manipulation and the construction of the highest quality libraries,

2) A 4,500 sq. ft. plasmid template preparation laboratory equipped with four Genesis Qbot and Qpix colony picking robots and two fully automated and integrated plasmid template purification stations,

3) A 2,000 sq. ft. sequencing reaction laboratory equipped with versatile and highly accurate Biomek FX pipetting

Above *Sequencer laboratory with ABI 3730xl sequencers—courtesy of the Venter Institute*

robots, as well as over one hundred ABI 9700 384-well dual head thermal cyclers,

4) A 10,000 sq. ft. sequencer room that can accommodate up to 400 automated sequencers,

5) A 1,663 sq. ft. PCR laboratory designed, with anteroom, pass-through windows, independent air handling system and other features, specifically for handling highly sensitive PCR reaction set up process.

6) A 1,000 sq. ft. QC/QA laboratory where reagent QC and daily process testing is performed,

7) A 1,600 sq. ft. New Technology Development laboratory for developing, testing and validating the most advanced and novel DNA sequencing technologies. Recently, we have acquired a new massively parallel sequencing platform developed by 454 Life Sciences.

8) Approximately 3,000 sq. ft. of freezer and storage space for storage of clones and bulk reagent and supplies and

9) A data center, occupying 2,500 sq. ft., to accommodate the advanced and powerful computing equipment required to process the large data sets generated by the sequencing production team.

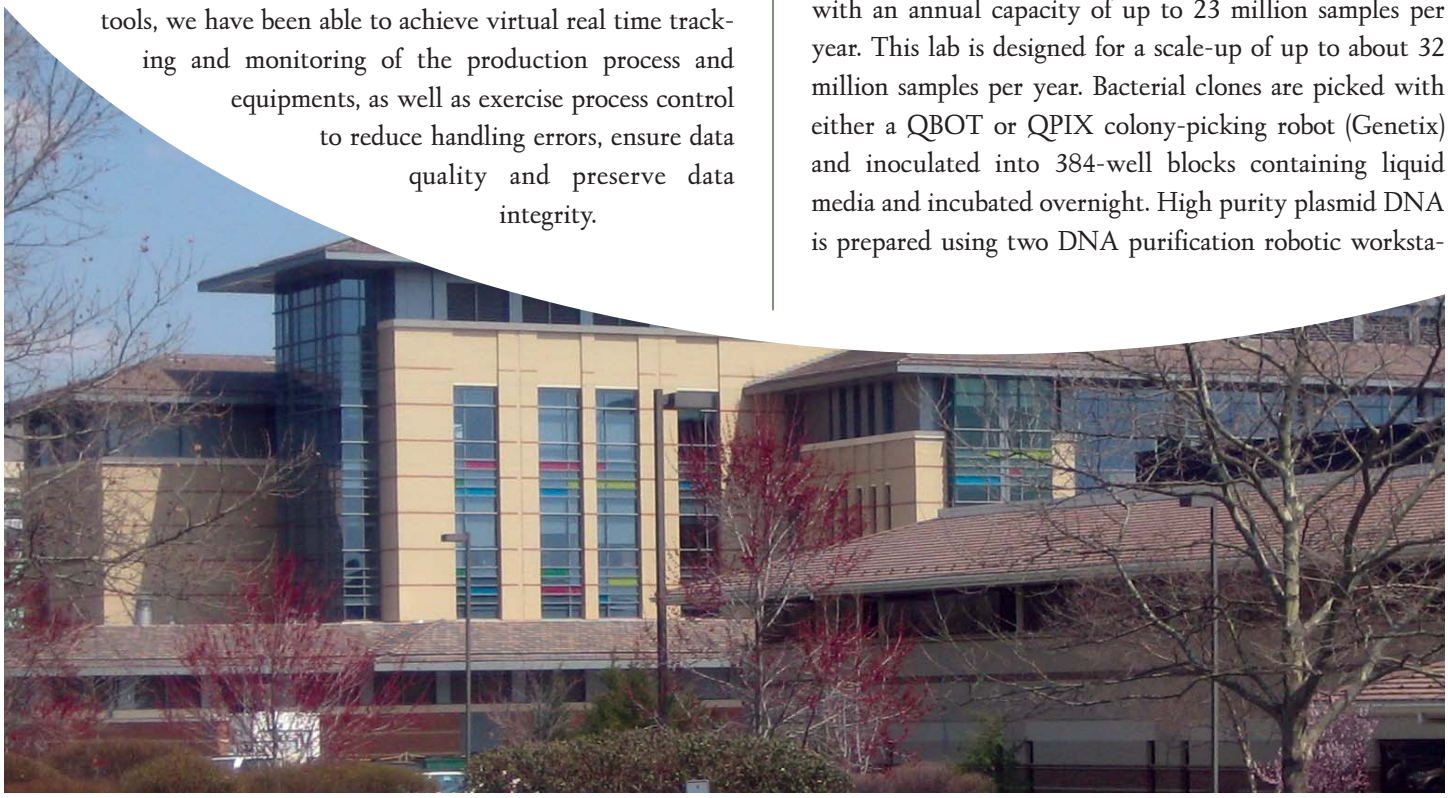
We have also put into place a comprehensive laboratory information tracking system (LIMS) specifically designed to accurately handle and track the large numbers of projects, samples and reagents through the sequencing production pipeline. By combining the most cutting edge computer/electronic hardware and sophisticated software tools, we have been able to achieve virtual real time tracking and monitoring of the production process and equipments, as well as exercise process control to reduce handling errors, ensure data quality and preserve data integrity.

Detailed Summary of JTC Laboratories

27,000 sq. ft.	Production laboratories (library construction, template preparation laboratory, sequencing reaction set-up laboratory, PCR laboratory, sequence determination, QA/QC laboratory, inventory)
5,000 sq. ft.	Closure laboratories
1,600 sq. ft.	New technology development laboratory
3,100 sq. ft.	Molecular biology laboratory
2,500 sq. ft.	Data center
900 sq. ft.	Freezer space
18,000 sq. ft.	Office space, storage, general use space, lab support (autoclaves, shipping/receiving, etc.)

Library Construction: The 2,600 sq. ft. laboratory is equipped and staffed to produce more than 60 libraries per month. It also has a 140 sq. ft. darkroom. Available equipment includes centrifuges, incubators, water baths, pipetting devises, gel electrophoresis equipment, UV and blue box transilluminators, and Gel Doc 2000 gel imaging and documentation system.

Template Preparation: The 4,535 sq. ft. area for template preparation and plating of bacterial clones is equipped to produce approximately 73,000 DNA template preps/day with an annual capacity of up to 23 million samples per year. This lab is designed for a scale-up of up to about 32 million samples per year. Bacterial clones are picked with either a QBOT or QPIX colony-picking robot (Genetix) and inoculated into 384-well blocks containing liquid media and incubated overnight. High purity plasmid DNA is prepared using two DNA purification robotic worksta-



J. Craig Venter Institute

tions custom built by CRS. Plasmid isolation is based on a modified alkaline lysis method with a potential throughput of 90,000 templates per 24-hour period.

Sequencing Reaction Set-up: The 1,840 sq. ft. reaction set-up laboratory is equipped to produce about 45 million sequence reactions per year (about 150,000 reactions/day), immediately scalable to at least 60 million reactions in production. We expect greater room for scale-up to become available with new technology development that primarily focuses on volume reduction and process integration, which may eliminate centrifugation steps. Two sequencing reactions are set up from each template or PCR product using Big Dye terminator chemistry (Applied Biosystems) and standard forward and reverse primers. Reactions are be prepared using the Beckman Biomek FX automated pipetting workstations. Linear amplification steps are performed on AB 9700 dual PCR systems and MJ Research Tetrads PTC-225. Reactions are cleaned by isopropanol precipitation and centrifugation.

PCR Laboratory: The 1,663 sq. ft. PCR laboratory is a Clean Lab, and therefore has an anteroom. It has two rooms that are connected by a pass-through window. The second lab connects to the sequencing reaction lab by a pass-through window, allowing only for sample flow. DNA extraction, DNA haplotype extraction, DNA dilutions, reagent preps and QC work requiring a Clean Laboratory, are performed in the pre-PCR lab. Primer dilutions and PCR reactions are set up on Biomek FX automated pipetting workstations and other liquid handling stations. Cycle sequencing reactions are performed in AB 9700 dual PCR systems. This lab is compliant to biosafety level 2 standards, including 2 laminar flow hoods, a separate air handling system, and seamless flooring for work with hazardous material.

Sequence Determination; This 10,130 sq. ft. laboratory is equipped with 100 ABI 3730xls sequencers with a minimum annual capacity of about 40,500,000 lanes per year. The room is sufficiently air conditioned, and equipped to remove excess heat. Expansion to an annual capacity of 60,000,000 sequence reads can be immediately accommodated in this space.

Quality Assurance/Quality Control: QA/QC work is performed in 1,050 sq. ft. standard laboratory space. QA and QC include raw material and in-process testing of template preparations, PCR and sequencing reactions, equipment maintenance and repair, validation, and optimization of procedures. In addition, one group is responsible for the creation of standard operating procedures, policies and batch records.

New Technology Development: This 1,600 sq. ft. laboratory is being utilized to test and validate the most advanced and novel DNA sequencing technologies. Recently, we have acquired a new massively parallel sequencing platform developed by 454 Life Sciences. This platform has the potential of providing several fold improvement in sequencing through-put as well as sequencing production cost.

Freezer room: This 915 sq. ft. room can hold 40 freezers, and serves as a depository for biological reagents. It has seamless flooring for easy clean-up of potentially hazardous material. All freezers are equipped with an automated temperature monitoring system that runs on a 24-hour schedule. Personnel are automatically notified in the event of a freezer malfunction. All freezers are backed-up by generator power in case of power failure.

JTC Data Center Description

Data Center is co-resident with the sequencing facility and is approximately 2500 sq. ft. usable designed to support over 10 teraflops of compute power and in excess of 1 Petabyte of storage, both near-line and on-line. The floor is raised 15" to provide a plenum for optimal cooling performance. All power and data cables are run overhead in cable trays for maximum configuration flexibility and security. Internet access is provided by 4 T1 lines and direct access to both VI and TIGR is through two dedicated Gigabit fiber connections. All external data communications is protected by state-of-the-art firewalls monitored and managed by a information security team. The data center's primary role is to support the sequencing and assembly operations of the JTC.

High Availability Facility Infrastructures

The data center is conditioned by four individual 20 ton Liebert computer room air handling units (CRAHU) with re-heat and humidification. The microprocessor based controls are programmed to maintain a space temperature of 72 F and 50% RH within the computing environment. These high efficiency units pressurize the sub-floor plenum of the data center floor to provide optimal cooling conditions and heat movement within the room. The chilled water supply plant feeding these units consists of two Trane 340 ton chillers that have been arranged in a redundant configuration. Additional capacity can be readily added to system via pre-installed connections for additional CRAHU's inside the datacenter and an additional outdoor chiller. This system is designed to allow double the cooling capacity to be added to the data center if and/or when the load requires.

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The JTC has three 500 kVA uninterruptible power systems (UPS) systems in isolated redundant (N+1) configuration supplying clean power to our data center, sequencing lab, and other critical lab equipment loads. In terms of density, the JTC UPS system was architected to provide 100+ Watts/sq. ft. to keep pace with the increasing power demands of modern technologies. A 2000 KW generator provides emergency back-up power to both the UPS system as well as other critical facility loads such as HVAC equipment and sample freezers. A 6000 gallon above ground diesel tank and a 660 gallon belly tank house sufficient fuel to generate power for the facility for a full 72 hours at peak electrical load before refueling is required. In the event of commercial power loss, the JTC's programmable 3000A Automatic Transfer Switch (ATS) ensures a smooth transition to the emergency generator power supply.

Additional redundancies are built in at the rack level through the use of an overhead ladder rack system which provides alternate paths for both power and data connections to any given piece of equipment. Likewise, external carrier fiber circuits enter the building from opposite sides and follow diverse paths back to local exchanges providing redundant internet connectivity.

Every element of the JTC's emergency power and HVAC systems are tested annually and logged with the Facility Manager. Other critical elements such as the generator are inspected and tested on a weekly basis. The system was field-tested during 2003's Hurricane Isabel and performed flawlessly.

J. Craig Venter Institute

JTC Network

The Joint Technology Center (JTC) network is designed to provide a cost effective, scalable, reliable, and intelligent network. The network is designed to provide a switching and routing architecture that lends itself to ease of maintenance, rapid reconfiguration, and longevity. The design supports integrated security, wireless technology, and the convergence of voice, video, and data traffic. The network is designed to primarily support the high-throughput sequencing operations of the JTC.

The network architecture for the JTC is a modular design where the Core, Access and Network Edge can scale to a higher density of ports and higher levels of redundancy by adding modules to the existing components. The modular design is easier to grow and troubleshoot. The multi-layer design provides the flexibility to accommodate immediate and future requirements.

The network is designed to provide the JTC with a highly available, scalable and cost effective solution. Network availability is a function of redundancy. Redundancy is achieved through three main components, redundant device (external redundancy), internal redundancy (redundant internal sub-systems like power supply, Supervisor engine) and redundant cable paths. Redundancy and fast convergence are provided by features such as UplinkFast and HSRP. Bandwidth scales from Fast Ethernet to Fast EtherChannel to Gigabit Ethernet without changing addressing or policy configuration.

The MDF core and the server farm is designed into 2 redundant Cisco 6513s utilizing a 256GB backplane to provide scalability and growth capabilities. This design assures a non-blocking architecture and wire speed switching. Each switch is Gigabit uplinked to the MDFs and gigabit ether channel linked to each other. Async terminal server services are provided by a Cisco 3662 which provides 128 connections and can scale by adding additional async modules.

Each of the IDF user switches is designed with a Cisco 6509, with redundant power, Supervisor engines, and gigabit uplinks to the core. The Cisco 6509 is highly available and has a 256 GB backplane to provide scalability and growth capabilities. This design assures a non-blocking architecture and wire speed switching. Each IDF supports only a part of the building users and provides redundancy by distributing users across separate wiring closets and separate equipment. Each IDF switch has a primary and a redundant path to the core switches.

Security is provided at the perimeter with an integrated Firewall and Intrusion Detection System. Host based intrusion prevention is provided for critical resources.

The infrastructure also provides for growth scalability and other advanced services such as additional wireless IP communications and IP video conferencing. The modular architecture of the network allows new technology to be easily deployed when required.

Major Computer Equipment

Assembly Servers: There are two Hewlett Packard servers with four processors and 32 Gb of RAM. One is an HP AlphaServer ES40 with 4 x 834 Mhz. The other is a HP Proliant DL585 WITH 4 X 2.2 Ghz (AMD Opteron) They have a minimum of internal disk to hold the operating system. Additional storage requirements are provided via a fiber-based storage area network (SAN). These servers are dedicated to the computing associated with the genomic

assembly jobs only. These systems will be scheduled for assembly processing via the Sun Grid Engine (SGE).

Database/Datastore Servers: There are three Hewlett Packard DL580 servers with four 2.8 Ghz Zeon processors and 4 Gb of RAM. They have a minimum of internal disk to hold the operating system. Additional storage requirements are provided via a fiber-based storage area network (SAN).

Application Web Servers: There are two Hewlett Packard RX56780 servers with four 1 GHz Itanium 2 processors and 8 Gb of RAM. They have a minimum of internal disk to hold the operating system. Additional storage requirements is provided via a fiber-based storage area network (SAN).

Sequence Processing Servers (Compute Farm): There are 188 Hewlett Packard DL140 servers (1U), 3.0 Ghz dual processor systems with 2GB RAM, configured in a high-density configuration with a 40 GB local disk for local scratch data. Additional storage is accessed over the network through dedicated fileservers connected to storage via a fiber-based storage area network (SAN). The sequence processing servers are dedicated to the computing associated with the genomic assembly and sequence processing and will be scheduled through the Sun Grid Engine.

Application Servers: There are 32 Hewlett Packard BL20 (Blade) servers, 3.0 Ghz dual processor systems with 2GB RAM, configured in a high-density configuration with a 40 GB local disk for local scratch data. Additional storage is accessed over the network through dedicated fileservers connected to storage via a fiber-based storage area network (SAN). These servers are dedicated to processing the Jtrace pipeline using the JBoss application services.

Disk Storage: There are three Hewlett Packard's Enterprise Virtual Array (EVA) 2C12D each partially populated with 10Tb of physical disk. The EVA is in a highly available (HA) cluster failover configuration and are used to store the data required for the genomic assembly as well as the auto-annotation portion of the project and all the associated results. The EVAs are attached to the fiber-based SAN network providing maximum throughput and performance for the Alpha/Opteron based assembly servers and Pentium based sequencing systems.

Database Disk Space: Database storage is provided by a Hewlett Packard Enterprise Virtual Array 2C6D (EVA) with 3 Tb of physical disk. The EVA is in a highly available (HA) cluster failover configuration to provide high performance, highly available storage for computationally intensive tasks. The EVA is attached to the fiber-based SAN network providing maximum throughput and performance for the Proliant (DL580) based database servers.

Disk Storage (EMC): In addition to the HP-EVA Storage, there are NFS Services being provided by an EMC Celerra Network Attached Storage frontend Data Movers (3 + hot spare). These data movers present the data from an EMC Clariion CX700 that holds, currently 20 TB of usable data. The current plan is to migrate as much as possible, the current EVA attached file system to the EMC NAS devices.

DiskXtender File Archiver: A Disk-based file archiver has been provided to allow users to archive files that can be kept indefinitely. There is a Linux (HP DL380) that provides a frontend NFS mounted file system. With DiskXtender software (File System Manager), the data is migrated over to an EMC file archiver (Centera) that currently has the capacity to store up to 50 TB of storage space. When users have the need to access data that has been migrated, DiskXtender works with the Centera to retrieve (stage) data back to the frontend file system.

Backup Storage Library: Backup and archiving is provided by a Hewlett Packard MSL5052S2 Fibre Channel tape library, with 8 SDLT2 Drives, and 16Tb of total storage capacity. The tape libraries are attached to the fiber-based SAN network providing maximum throughput and performance for the Alpha/Intel/Opteron based database and file servers. Thirty Five Tb of disk storage on an existing Hewlett Packard's Enterprise Virtual Array 2C12D (3), 2C6D(1) (EVA) provides disk cache to improve backup and archiving performance.

Test and Development: To ensure the opportunity to thoroughly test new software releases a test and development environment is be provided that is a subset of the production environment. This environment consists of some of the BL20 (Blade) servers (mentioned above) as well as several 1U Penguin Computing servers.

JTC Physical Security

The JTC incorporates a 24x7 Physical Security Plan designed to protect employees, guests/visitors, and contractors and to secure all organizational assets and employee property. Uniformed security officers employed by either the Venter Institute or Montgomery Security Services patrol the JTC facility 24 hours daily, 365 days a year. Patrols consist of exterior and interior building patrols,

An electronic access control system, using employee prox-

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imity cards, are utilized to control exterior building entrances, loading dock, interior lobby, data center, and selected sensitive labs, electrical, and mechanical rooms. A multi-lock key system is used to secure individual offices and selected rooms. Glass break detectors are installed to monitor all exterior windows.

Surveillance cameras are placed in strategic locations inside and outside the JTC to augment the electronic access control system and security patrols. Security officers monitor the cameras from the security office.

Selected lab freezers and temperature-critical equipment at JTC are equipped with an Ademco or similar alarm monitor system to protect inventory. When an alarm is activated, a signal will be sent from the FMS internal facility paging system which electronically pages on-duty security officer and the Facilities Manager. The security officer will respond and investigate alarm activations and contact the Facilities Manager or call person(s) whose contact information is attached to front of freezer/equipment for additional instructions.

The Institute for Genomic Research

The Institute for Genomic Research, founded in July 1992, is an independent, not-for-profit research organization with approximately 350 employees. TIGR researchers are organized into five academic departments: Mammalian Genomics, Plant Genomics, Microbial Genomics, Parasite Genomics, and Bioinformatics. Computational, Chemistry, and Sequencing Core Facilities provide support services to the departments. In addition, TIGR's Department of Conferences, Education and Training organizes three annual international conferences in genomics, microbial genomics, and computational genomics; an ongoing series of internal and external courses in DNA sequencing; and internal training courses in safety, radiation safety, genome closure and annotation, and basic bioinformatics.

TIGR's spacious campus in the Shady Grove Life Sciences Center in Rockville, MD, encompasses four buildings and was recently expanded to add a new four-story building (Building 5), a122,000-sq.-ft. facility that has doubled TIGR's total office and laboratory space and includes a large, state-of-the-art computer center. The entire facility has round-the-clock security coverage seven days a week. TIGR's first two buildings, designed and built for the institute, opened in 1995. Of the total 48,000 sq. ft., approximately 27,000 sq. ft. is designated laboratory space, comprising a general molecular biology laboratory and a Microarray Facility (4,000 sq. ft.), the DNA Sequencing Facility (13,500 sq. ft.), with the remainder dedicated to common areas and laboratory support facilities. The rest of the space is designated as administrative, general use (including conference rooms and a library), with computational and scientist office areas. In 1999, TIGR expanded to include the 47,000 sq. ft. Building 3, which features: 13,000 sq. ft. of general laboratory space for functional genomics research and general support facilities (including a tissue culture facility, a plant biology laboratory, radioactive room, dark room, training laboratory, etc.); a 1,000 sq. ft. state-of-the-art central computer facility; office space for faculty, bioinformatics personnel, and computer programmers; a large training classroom; and two small conference rooms. The building also houses a 230-seat auditorium that is used for public meetings, conferences and lecture series, as well as internal meetings. Building 4 is a pavilion with a kitchen that is used as a lunchroom and for meetings. TIGR has all the necessary facilities to conduct the most advanced molecular biology and biochemistry research, including tissue culture, bacteriology, plant biology, glass-wash/autoclave, radioactive waste handling, film processing, and water purification. TIGR's laboratories operate under Biosafety Level 1 or 2 procedures, as appropriate. Through the institute's formal affiliation with the George Washington University and its Institute for Biomedical Sciences, TIGR faculty have access to a new, state-of-the-art 6 unit Biosafety Level-3 facility located in Ross Hall on the GWU campus in Washington, DC, for work with microorganisms classified as BL-3 pathogens.

Laboratory: TIGR's DNA Sequencing capacity is now part of an off-campus Core Facility managed by the Venter Institute, a sister organization under the same Foundation. The laboratories have been specifically designed to support high through-put production pipelines for shotgun and BAC end sequencing projects, as well as for PCR-based sequencing and SNP detection. In addition, approximately 5,000 square ft of the laboratory space is dedicated to finishing and closure work. The high through-put sequencing operation, which occupies approximately 25,000 sq. ft. of laboratory space, consists of 1) a 2,600 sq. ft. dedicated library construction laboratory equipped with the equipment required for DNA purification, manipulation and the construction of the highest quality libraries, 2) a 4,500 sq. ft. plasmid template preparation laboratory equipped with four Genesis Qbot and Qpix colony picking robots and two fully automated and integrated plasmid template purification stations, 3) a 2,000 sq. ft. sequencing reaction laboratory equipped with versatile and highly accurate Biomek FX

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pipetting robots, as well as over one hundred ABI 9700 384-well dual head thermal cyclers, 4) a 10,000 sq. ft. sequencer room that can accommodate up to 400 automated sequencers, 5) a 1,000 sq. ft.QC/QA laboratory where reagent QC and daily process may be performed, 6) a 1,600 sq. ft. new technology development and instrumentation laboratory for testing the newest and most advanced sequencing technologies and instrumentation, 7) approximately 3,000 sq. ft. of freezer and storage space for storage of clones and bulk reagent and supplies and 8) a data center, occupying 2,500 sq. ft., to accommodate the advanced and powerful computing equipment required to process the large data sets generated by the sequencing production team.

TIGR has all the necessary facilities for conducting state-of-the-art molecular biology and biochemistry research including tissue culture, bacteriology, glass-wash/autoclave, radioactive waste handling, film processing, and water purification. All of the lab, computer and office equipment listed below was purchased new between 1992 and 2005. All laboratory areas are available for use by all faculty members.

TIGR's Microarray Expression Analysis Facility is housed in a 1024 sq. ft. clean room containing two Intelligent Automation High Density Micorarrayers capable of spotting up to 60,000 elements per standard microarray slide. There is a small anteroom prior to entry into the main arraying clean room. Clean room specifications are similar to a standard computer clean room and include air-flow to generate positive pressure and to accommodate 16 room air changes per hour at 95% filtration efficiency. The Facility is equipped with compressed air lines, piping to the RO/DI system and data lines for network connectivity. Humidity is controlled by a dedicated humidifying unit. The resident arrayers are wired through one of two resident 100 kVa UPS systems to ensure uninterrupted power source during the intermittent power outages and anomalies that are frequent to this area. The Facility also houses five non-confocal laser scanners (Axon GenePix 4000) for quantitation of fluorescent hybridization to glass slide microarrays and a Beckman Multimek TM 96 Automated 26-Channel Pipettor for re-arraying 96 well plates into 384 well plates, diluting/resuspending microarray print plates and other high-thoughput pipetting needs. In addition, the facility has a NanoDrop Spectrophotometer and Agilent BioAnalyzer for RNA quantification and quality control, and an ABI 7700 DNA Sequence Detection System for real time RTPCR validation of microarray results. TIGR also houses an Affymetrix GeneChips FS400 Fluidics Station and GeneArray Scanner as an alternative platform for gene expression experiments.

Computers: In February of 2004, TIGR migrated its computing facilities to a newly-constructed computer center on the first floor of a new building (Building 5) on our five-building campus. This new data center encompasses approximately 3000 sq. ft. of usable space with an 18-inch raised floor to provide a plenum for optimal cooling as well as power and data cabling. Except for desktop and notebook computers, all of the hardware supporting the research efforts of the Institute is housed in the new data center.

TIGR's campus is interconnected by gigabit Ethernet, a high-performance switched network powered by Cisco equipment. All buildings are connected to the LAN backbone and core switches via fiber cabling. As part of the Building 5 construction and campus redesign, we have introduced physical and topological redundancy where every floor of every building will not only have a dual uplink to the LAN backbone, but the links will take separate physical paths to the core switches in the new computer center. This provides maximum redundancy and uptime in cases of technical problems, equipment failures, or physical damage to the cabling.

TIGR's computing infrastructure consists of high-end Compaq Alpha and AMD Opteron-based computers which provide genome assembly services, with Sun UltraSparc and Dell Linux servers providing most database services. Over 250 Intel CPUs in rack-mounted multi-processor PCs are available for parallel grid computing, providing capabilities for large-scale sequence alignments and database searches (using BLAST, HMMer, and other bioinformatics systems). Added to these are approximately 300 Intel-based PCs spread across the TIGR's campus, all available as part of the same grid computing infrastructure, controlled by custom software written using the Condor parallel computing system. High-speed disk storage is provided by NetApp network-attached storage (NAS) systems and EMC fiber-channel storage area network (SAN), providing almost 40 Terabytes of highly-available storage. TIGR backs up all critical data nightly through incremental backups and weekly through complete backups, and tapes are stored offsite. IT support includes systems, network, web, and database services, and is provided by a staff of 18 engineers.

TIGR maintains a 45 megabit per second (Mbps) connection to Internet2, the high-speed network designed to facilitate collaboration and communication among research institu-

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tions, as well as the aggregated bandwidth of 20 Mbps to the regular Internet network.

Major Equipment: TIGR has an impressive equipment inventory that is more than ample to support large-scale DNA sequencing, DNA microarraying, technology development, general molecular biology activities, tissue culture, plant growth, and follow-up characterization of specific gene and protein families. All of the laboratory, computer and office equipment listed below was purchased new between 1992 and 2002. All laboratory areas are available for use by all faculty members. Temperature-critical equipment in all laboratories (freezers, cold boxes, cold rooms, cell freezers, incubators, etc.) is equipped with a set of "dry contacts" and a temperature probe (sensor) that is tied back to the Ademco monitoring system. When a probe detects a programmed "out of range temperature" rise, a signal is immediately sent to a call out modem that dials our monitoring company. They in turn call the pager that is carried 24/7 by TIGR's Facilities personnel.

To protect TIGR's operations from loss of electrical power, a 300 KW generator on campus powers the eight air handling units that supply air and return air, as well as exhaust fans, freezers, fire alarm systems, telephone, security, lighting, pumps, (hot water and cold, ejector, sump), computer equipment room and the 100 KVA UPS, back-up A/C and cold rooms in Buildings 1, 2 and 4. A second 600KW generator covers all the above services in Building 3, and a Siemens Building Automation System monitors and controls all TIGR buildings.

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Biobased Research and Capabilities

(www.pnl.gov/biobased)

The Pacific Northwest National Laboratory (PNNL) has been involved in bio-products research since the mid-1970s, developing and applying novel thermal, chemical, and biological processes to convert biomass to industrial and consumer products, fuels, and energy. The hallmark of PNNL's research has been novel catalytic processes that convert sugars and organic acids to much-higher-value commodity and specialty chemicals. As contractor to the federal government for managing Pacific Northwest National Laboratory, Battelle Memorial Institute has full access to all government owned facilities and equipment to perform private research as Battelle under the terms of a Use Permit unique within the national laboratory system.

Novel Catalyst Research and Chemical Transformations

PNNL is developing new catalyst formulations and demonstrating their utility in new chemical transformations for production of bio-based chemicals. Novel high-activity catalysts for hydrogenation and oxidation in condensed phase conditions use noble metals and stabilized base metals for catalysis. Also under development at PNNL are stable catalyst support materials including metal oxides and carbons for aqueous phase processing. Other chemical transformations utilize the structures derived from biomass feedstocks to produce new chemical products.

Eukaryotic Organisms in Fermentation and Enzyme Discovery

PNNL has a group dedicated to fully exploiting the capabilities of filamentous fungi, the group of microorganisms largely responsible for recycling lignocellulose biomass in nature and the source of beta lactam antibiotics, the miracle drugs of the mid-twentieth century. These eukaryotic organisms have been relatively ignored for development of new fermentation systems and enzyme discovery, and only a few of the hundreds of thousands of known fungal species are used to make useful products via large-scale culture. As these organisms are less well studied and generally less exploited than other groups of microbes, PNNL has established the capacity to study and manipulate them by building a culture collection for discovery, characterization, and product screening; establishing a fermentation laboratory; and developing novel molecular biology tools for genetic manipulation of the fungi as part of developing optimal production systems.

Applications of this new capability include

- Development of novel fermentation systems to produce new chemical feedstocks
- Discovery of new enzymes useful in processing biomass and derived products
- Improvement of existing enzyme or acid production strains.

Above *30 liter chemostat—courtesy of Battelle*

Biomass to Clean Fuels

PNNL has a long history in biofuels process development. Most of the work has focused on thermochemical conversion processes. Initial work in biomass liquefaction began in 1975 with an assessment of a wood to oil process demonstration plant. Subsequent work led to process optimization of biomass liquefaction and upgrading of bio-oils to transportation fuels. Catalytic and non-catalytic steam gasification of biomass was studied at several levels from laboratory tests to a small fluidized-bed pilot plant. These studies led to the development of an entirely new catalytic gasification concept using high-pressure liquid water as a low-temperature gasification environment.

Separations and Other Supporting Process Technology

PNNL designs, develops, and deploys integrated processing suites to produce high-value chemicals and fuel components from agricultural biomass and other low-valued feedstocks. These systems often require new processing concepts and systems development, and PNNL addresses all of the steps in the complete processing scheme, from feedstock pretreatment to purified product recovery. Included in PNNL process research are basic science and engineering capabilities, applied to biomass pretreatment to ensure effective recovery of optimal value from biomass, carbohydrate polymer systems to maximize energy efficiencies, and advanced micro-technology systems for separation and conversion processes.

Process Engineering, Integration, and Optimization

PNNL expertise in bio-based products is based on chemical and biological processing of renewable feedstocks for the production of chemical products. As shown here, the transformation of low-value byproducts or waste into value-added products can follow a number of pathways. Our broad knowledge allows us to develop optimized systems of processing to produce value-added products from individual examples of biomass feedstock materials and processing situations.

Biobased Projects

Examples of biobased projects under way and completed at PNNL can be viewed at www.pnl.gov/biobased/projects.stm.

Bioproducts Sciences and Engineering Laboratory (www.pnl.gov/biobased/bsel.stm)

Scheduled for occupancy in 2007, the Bioproducts Sciences and Engineering Laboratory (BSEL) is a $24 million research center in which researchers will develop technology to convert biomass, including low-value agricultural residues, into value-added fuels and chemicals such as plastics, solvents, and fibers. The 57,000-square-foot facility will house state-of-the art analytical, chemical, and biological research instrumentation, and integrated, advanced conversion and processing technologies for process development. It will also provide much-needed classrooms and laboratories for science education and additional research. The BSEL is a joint effort between Washington State University (WSU) and PNNL and is located on the WSU Tri-Cities campus near PNNL in Richland, Washington.

Chemical and Biological Processes Development

PNNL's chemical and biological processes development group develops process technologies tailored to solving energy, security, and environmental problems. The group operates key facilities and laboratories at PNNL that are available to collaborators and clients.

Physical Sciences Laboratory (chembioprocess.pnl.gov/ad_capabs.asp)

The Physical Sciences Laboratory contains facilities, equipment, and systems for work in areas such as catalysis and reaction engineering, chemical analysis, and biochemical process and bio-based product development. These include applied biotechnology facilities for applied biotechnology such as a multi-well plate reader, an environmentally controlled shaker and an ambient shaker, two computer-controlled fermentation stations with 1.25- or 2.5-liter capacities, and a 30-liter fermentor. All of this equipment allows process development in bioprocessing systems from initial organism characterization to continuous fermentation process development, optimization, and scale-up.

Process Development Laboratory (environment.pnl.gov/resources/resource_description.asp?id=52&type=labs)

The Process Development Laboratory (PDL) is a high-bay facility that includes seven walk-in hoods with utilities and gas lines for many types of small-scale, chemical, physical, or catalyst process systems. Workbench islands can easily be set up to accommodate the activities within the hoods. There is floor space for pilot plant systems and 480 volt, a large supply of compressed air, and steam capabilities for large systems. Past pilot plants in the PDL have included ones for biomass processing, supercritical fluid processing, fluidized-bed and high-pressure, high-temperature, chemical processing systems. Biomass processing methods for extraction or

hydrolysis have been developed in this laboratory and then scaled up for engineering assessment.

A laboratory area is available for bench-top studies or analytical work, with its own ventilation hood, glassware, chemicals, and sinks. There is a separate shop area, with power tools and supplies, for assembling experimental projects in the building.

Chemical Engineering Laboratory (www.pnl.gov/biobased/cel.stm)

The CEL is a reinforced concrete block building with two laboratory areas containing high-pressure reactor systems for chemical process development. The outer laboratory area has three small stirred batch reactors placed in fume hoods for use in preliminary testing of chemical processes or catalyst formulations. These reactors have internal volumes of 100 or 300 milliliters, can be operated at up to 300˚C and 2,500 psig, and are equipped with a liquid-phase sample removal system that can be operated at high-temperature and high-pressure processing conditions.

The inner high-pressure reactor room contains three continuous flow reactor systems used in fixed bed catalytic processing, two units with 40-mL internal volume lab-scale tubular reactors and one unit with a 1-liter reactor volume. All three reactor systems are heated with individual circulating oil heating baths and are operable at up to 3,000 psig and 300˚C. Process flow is controlled by individual high-pressure metering syringe pumps. Each unit has a dual piston pump that maintains online continuous flow by automatic changeover and refill of the 500-mL syringe cylinders. These reactors typically involve catalytic processing and hydrogen reactions. The CEL has a stand-alone hydrogen compressor that feeds the building's hydrogen supply system. Hydrogen at up to 3,000 psig can be fed into any or all of the reactors simultaneously. The CEL also contains a chromatographic gas analysis system with both thermal conductivity and flame ionization detector capability.

Environmental and Molecular Sciences Laboratory (EMSL) *(www.emsl.pnl.gov)*

The William R. Wiley Environmental Molecular Science Laboratory (EMSL), a national scientific user facility at PNNL, provides integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences to support the needs of the U.S. Department of Energy (DOE) and the nation. Since its inception in 1997, the 200,000 sq. ft. facility has played host to more than 7,500 visiting scientists, professors, and other individuals who requested use of the facility's resources through a peer-review proposal process. These users come to EMSL from academia, other research and development laboratories, and industry.

EMSL offers—at one location—a comprehensive array of cutting-edge resources that are available to its users. Some of the key resources are described here; more information is available at www.emsl.pnl.gov/capabs.

Biological Resources at EMSL

The EMSL includes a full range of facilities for cell culture, sample preparation, separations (CE, CIEF, SEC, etc.), storage, chemical synthesis, and derivatization. The 900 sq. ft. Sample Processing Laboratory is equipped with two certified BL2 cabinets that house equipment and instrumentation for complete sample processing of all biological samples. The required BL2 precautions are already in place for this facility. Advanced biological separation capabilities within the EMSL are available for producing unique and sophisticated biological separations systems for the following pressure régimes: high-pressure liquid chromatography (HPLC; ≤5.000 psi); very high-pressure LC (VHPLC; >~10,000 psi); and ultra-high-pressure LC (HPLC; >~20,000 psi). Additional capabilities are available for packing custom LC columns in a wide range of lengths (10 to 2.000 mm), internal diameters (10 µm to 1 mm), and for a wide range of chemistries and separations modes (reversed-phase, ion-exchange, size-exclusion, etc.). Twenty-five LC systems for 1D and 2D proteomics separations, on-line sample cleanup, on-line concentration, and ultra-low-level LC/MS analyses of proteolytic digests have been developed along with unique systems automation and integration capabilities. The EMSL laboratories also include capabilities for sample preparation and storage, chemical synthesis and derivatization, 1D and 2D polyacrylamide gel electrophoresis, CE and ESI-MS, and related instrumentation development and experimentation, purifications, synthesis, and biological research activities. Four CE systems are available, including three Crystal systems that are optimal for MS interfacing.

Mass Spectrometry

EMSL houses the world's highest magnetic field (based around 12- and 11.4-tesla superconducting magnets) high-performance FTICR (with one system optimized for intact protein detection and the other for peptide detection from tryptic digests of proteins) as well as as one 7-tesla FTICR for special projects, one tandem 7-tesla FTICR from Thermo Electron, and one Bruker 9-tesla FTICR instrument. The Bruker and Thermo Electron systems are config-

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ured for high-throughput proteomic measurements.

Other mass spectrometers available include five Thermo Electron LCQ ion traps, four Thermo Electron linear ion traps, and a Micro Mass Q-tof Ultima. They are interfaced with automated high-pressure (10,000 psi) capillary LC systems for high-efficiency separations of biological mixtures ,and have been integrated into a high throughput protein characterization environment and data management system. Also available is an Orbitrap™ mass spectrometer from Thermo Electron that is the first new type of mass spectrometer in the last 20 years and offers performance comparable to the FTICR spectrometers. Added features of each instrument include the PNNL-developed electrodynamic ion funnel, unique devices for external ion accumulation with the FTICR instruments, and ultra-high sensitivity ESI sources developed at PNNL and installed on all instruments.

The laboratory space devoted to these and their ancillary capabilities amounts to >5,000 sq. ft. and includes a 1,500 sq. ft. FTICR lab, a 1,200 sq. ft. prototype high-throughput laboratory, a 1500 sq. ft. lab for other mass spectrometers, and two 600 sq. ft. labs for the development of microscale separations and sample clean-up, ion source and vacuum system hardware development, peptide and protein separations, capillary LC, CE, cell growth, and wet chemistry. All spectrometers are on a common computer network with direct high-speed access to the EMSL data storage and archive facility, a multi-terabyte storage system that allows large numbers of data files to be archived indefinitely.

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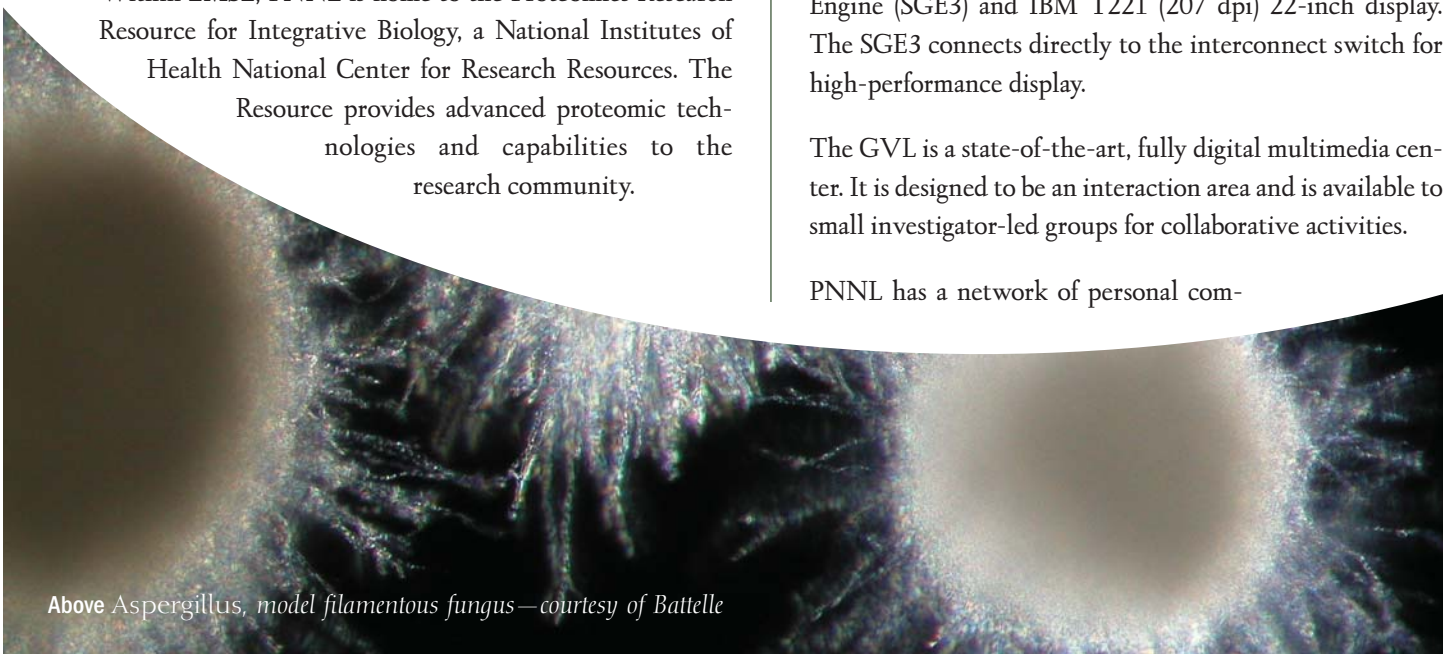
Proteomics Resource (NCRR) (ncrr.pnl.gov)

Within EMSL, PNNL is home to the Proteomics Research Resource for Integrative Biology, a National Institutes of Health National Center for Research Resources. The Resource provides advanced proteomic technologies and capabilities to the research community.



Above Aspergillus, *model filamentous fungus—courtesy of Battelle*

Molecular Science Computing Facility (MSCF)

(mscf.emsl.pnl.gov)

As part of the EMSL, the MSCF provides an integrated production computing environment accessible onsite or remotely, with links to external facilities within the DOE, collaborating universities, and industry. EMSL and MSCF provide scientific resources to attain a molecular-level understanding of the physical, chemical and biological processes needed to solve critical environmental problems and advance molecular science in support of the long-term environmental missions of DOE and the nation. Both computational and experimental resources are available to users at no cost.

MSCF incorporates high-performance hardware, scalable software, as well as technical consulting support resources. The MSCF has installed an 11+ Tflops (peak) Linux-based supercomputer from Hewlett Packard. The system has a total of 980 dual Itanium-2 (Madison) processors with 6.8 terabytes of system memory and an Elan interconnect from Quadrix. There are 450+ terabytes of I/O storage including a single 50+ terabyte high-performance Lustre filesystem. A 300+ terabyte data storage system is available for online use and archival storage of computational experimental data. This data storage system will be directly connected to the large, massively parallel computing system using the Lustre software.

The MSCF also provides a graphics and visualization laboratory (GVL) with high-end graphics computers, an SGI, eight R12K processors with 8 gigabytes of memory, and two Infinity Reality3 graphics heads. In addition there is an 8-processor Linux-based cluster with IBM's Scalable Graphics Engine (SGE3) and IBM T221 (207 dpi) 22-inch display. The SGE3 connects directly to the interconnect switch for high-performance display.

The GVL is a state-of-the-art, fully digital multimedia center. It is designed to be an interaction area and is available to small investigator-led groups for collaborative activities.

PNNL has a network of personal com-

puters and servers attached to the PNNL Intranet. The network is used primarily for printer, file sharing, backups, and electronic mail. It is also connected to the Internet and the laboratory-wide information network, databases and computer resources. All laboratories and offices have full-time and direct access to dedicated computer resources. Additional resources are available as required.

PNNL has developed the Molecular Science Software Suite, a trio of integrated, comprehensive, and unique software packages that allow EMSL users to easily couple advanced computational chemistry techniques with existing and rapidly evolving high-performance, massively parallel computing systems. The software suite includes the following:

- *Extensible Computational Chemistry Environment*this provides a sophisticated graphical user interface, scientific visualization tools, and the underlying data management framework that enable scientists to efficiently set up calculations and store, retrieve, and analyze the rapidly growing volumes of data produced by computational chemistry studies.
- *NWChem* provides the ability to compute the properties of molecular and periodic systems using standard quantum mechanical descriptions of the electronic wave function or density. NWChem also performs classical molecular dynamics and free-energy simulations. These approaches may be combined to perform mixed quantum-mechanics and molecular-mechanics simulations.
- *ParSoft* provide the high-performance, efficient, and portable computing libraries and tools that enable NWChem to operate on a wide variety of parallel computing systems with leading-edge performance and scalability.

PNNL's Systems Biology Program *(www.sysbio.org)*

PNNL is home to one of the world's forefront systems biology programs. Systems biology seeks to understand how the molecular processes of cells are linked to higher biological functions. The relationships between the processes and functions must be specified to the point where one can predict how a change to a part gives rise to a change in the whole.

PNNL's systems biology program focuses on understanding cellular networks—gene and protein networks involved in individual cell signaling, communication between cells in communities, and cellular metabolic pathways. PNNL has created a strong environment for systems biology by investing in essential capabilities and technologies.

Life Sciences Laboratory-2

PNNL has a centralized facility providing instrumentation for high-throughput biological experiments in its Life Sciences Laboratory-2. This facility includes a Flow Cytometry Lab (300 sq. ft.); a Sample Preparation and Robotics Facility (600 sq. ft.) that contains automated microfluidics, robotics, and sample preparation capabilities; a Fermentation and Culture Facility (600 sq. ft.); a Cell Culture Facility (400 sq. ft.) that includes eukaryotic cell culture, incubators, optical microscopes, and media storage facilities; a Proteomics R&D Lab (400 sq. ft.); a Protein Biochemistry and Biophysics Lab (400 sq. ft.) with protein derivatization, physical characterization, immunoprecipitation, and UV-visible spectroscopy capabilities; a Protein Production and Protein Purification Lab (400 sq. ft.) that includes in vitro protein expression, HPLC-based protein purification systems, high-throughput robotics, and cold-box facilities; and a Molecular Biology and Affinity Reagents Lab (800 sq. ft.).

Life Sciences Laboratory-1 (331 Building)

PNNL's 331 Building has more than 5,000 sq. ft. of newly remodeled laboratory space devoted to cellular and molecular biology studies available for the proposed Center. This space houses common-use equipment, including a 522-sq. ft. Cell Culture Facility equipped with five biosafety level 2 (BSL2) hoods and 12 CO_2 water jacketed incubators, coulter counters, low-speed centrifuges, several inverted microscopes, and separate cold rooms for sample preparation, medium preparation, and storage. Ancillary cell culture facilities are also available in many of the investigators' laboratories. Adjacent to the culture facility is a Microscopy Laboratory (185 sq. ft.) devoted to live-cell fluorescent imaging, including three inverted Nikon microscopes equipped with cooled CCD cameras (Quantix, Photometrics), Bioptechs temperature control units, computer workstations, and image acquisition and analysis software, including Metamorph™, Metafluor™ and Velocity™. A Fluorolog spectrofluorimeter is also housed in this lab for fluorescent spectral studies in live cells and cell extracts.

Additional lab space includes a 500-sq. ft. shared instrumentation room and a 500-sq. ft. separations lab. Complete facilities for molecular biology, media preparation, large-scale cell culture, binding kinetics, and electrophoresis are on the same floor. Also in the 331 Building is a low-pressure liquid chromatographic unit (Äkta, Amersham Bioscience). This equipment is designed for size-exclusion, ion-exchange, and affinity chromatography for special applications.

Battelle

Microarrays

PNNL's microarray laboratory provides rapid, accurate, and state-of-the-art microarray capabilities by expert technical personnel. Ongoing work involving DNA and protein microarrays is focused on elucidation of gene and regulatory networks in both prokaryotic and eukaryotic organisms, development of novel detection methods for phylogenetic identification of pathogens as well as screening, and identification and clinical validation of disease biomarkers.

The 619-sq. ft. microarray laboratory is equipped with two robotic microarray pin spotters from Apogent (MicroGrid II) and Cartesian Technologies (model PixSys 5500); ScanArray Express HT imager system (Perkin-Elmer), equipped with 20-slide autoloader and three internal lasers capable of detecting most commercially available fluorescent dyes; ArrayWorx CCD imager (Applied Precision); Luminex and Becton Dickinson bead-based microarray systems); a 96-well microtiter plate fluorometer from Perkin Elmer (HTS7000 Bioassay Reader) for large-scale DNA quantitation; two NanoDrop spectrophotometers from DuPont, and Qiagen BioRobot 8000 and Quagen BioRobot 9600 Laboratory Automated Workstations for highly multiplexed experiments and other high-throughput needs. A variety of computer software (e.g., Vector NTI, Sequencer, Kodak 1-D, GeneSpring, ArrayVision, ArrayStat, and QuantArray) for gel pattern analysis, DNA sequence analysis, and microarray image analysis is available.

Additional molecular biology resources include two MJ Research DNA Tetrad Peltier thermal cyclers, Perkin Elmer 9700 and 9600 thermal cyclers, TaqMan PCR, and a Light Cycler, as well as pulsed field, horizontal and vertical gel electrophoresis systems. To complement the current suite of microarray capabilities available at PNNL, the facility has recently purchased an Affymetrix GS3000 Micoarray Analysis System. This state-of-the-art workstation is capable of performing automated microarray hybridization experiments, imaging, and preliminary gene analysis using commercially available software. In addition to whole-genome expression studies, the Affymetrix system can be used for high-resolution SNP detection, genotyping work, and resequencing projects. The system is composed of the following components: the Affymetrix® GeneChip® Scanner 3000, Fluidics Station 450, 640 Hybridization Oven, AutoLoader option, and GeneChip® Operating.

Microbial Cell Dynamics Laboratory

The Microbial Cell Dynamics Laboratory uses culturing technologies to tightly control the extracellular environment and provide a molecular-based understanding of how individual organisms behave in their natural surroundings. Scientists can study simultaneously gene expression, protein expression and metabolism in microorganisms. Our long-term mission is to develop a molecular-based understanding of complex microbial assemblages such as biofilms. Capabilities include

- Dedicated collocated laboratories and analytical stations, including mobile culturing equipment and analytical instruments
- Small reactor-scale (1-50 liter) culturing of prokaryotic cells under equilibrium conditions for generating small cell populations
- Systems for growth and analysis of planktonic cells and cells associated with surfaces or residing in biofilms
- Establishment of gradients in physical and/or chemical conditions during cell culturing
- Systems for controlling cell-cell interaction distance and rates of substrate diffusion to probe cell-signaling events
- Rapid harvesting of cultures and processing and delivery of cells and components to multiple analytical instruments with minimal composition alteration
- Real-time analysis of in situ biological, chemical, and physical processes and parameters
- Analysis of gene expression and signaling in individual cells and bulk populations.

Advanced Cell and Molecular Imaging

Advanced cell and molecular imaging at PNNL includes an extensive collection of instruments and imaging tools to visualize biological processes at many scales, from macroscopic features to individual molecules. At PNNL, we merge our imaging technologies to observe more than one sample characteristic at one time. In this way, we can learn about the structure and function of cellular components, regulatory pathways, and cells' responses to environmental stimuli. Tools available at PNNL include

- Combined CARS and Two-Photon Confocal Microscope
- Combined Confocal and Magnetic Resonance Microscope
- Combined Atomic Force and Optical Microscope
- High-Speed Multispectral Confocal Microscope
- FRET for Single-Molecule Imaging
- TIRF for Single-Molecule Imaging
- Scanning Acoustic Microscope

- Electron Microscope Suite

Nuclear Magnetic Resonance and Electron Paramagnetic Resonance

Nuclear magnetic resonance (NMR) and electron paramagnetic resonance (EPR) facilities (www.sysbio.org/capabilities/nmr/index.stm) house research to determine the molecular structures of compounds that could affect environmental remediation and biological health. These instruments have been used at PNNL for a variety of biological studies, including structural and functional genomics. They include

- 900-, 800-, 750-MHz NMRs
- 600-MHz Varian Inova NMR
- 600-MHz Varian Unity NMR
- 500-MHz Bruker Avance WB NMR
- 500-MHz Varian Unity WB NMR
- 500-MHz CMX NB NMR
- 500-MHz Varian Unity NB NMR
- 400- and 300-MHz WB NMRs
- 300 CMX MHz WB NMR
- EPR Spectrometer with ENDOR (Electron-Nuclear Double Resonance)/ELDOR (Electron Double Resonance) capability
- Combined optical and magnetic resonance microscope
- Low-temperature probes for metalloprotein chemistry and structure
- Virtual NMR capability enables use and collaboration with EMSL scientists for remote users via secure shell over the Internet.

Computational Biology and Bioinformatics focuses on creating sophisticated mathematical and computer-based models and simulations to understand cell behavior. PNNL is developing the databases and software necessary to capture, store and provide access to the high-throughput data required to test these models. PNNL recently made available for free download the Bioinfomatics Resource Manager (BRM), which seamlessly connects researchers; data sources, including data in private, publicly available, and custom in-house formats; and commercial and private bioinformatic tools. BRM allows biologists to use efficiently analytic techniques that are otherwise costly, time-consuming, require expertise in bioinformatics and statistics, and require knowledge of data sources (see www.sysbio.org/research/bsi/bioanalytics/Bioinformatics.stm).

Catalysis Activities and Capabilities

(www.pnl.gov/cmsd/research/transformations.stm)

Catalysis is a particularly strong research area at PNNL, taking advantage of the historical emphasis on chemistry and chemical engineering at the lab. Catalysis programs at PNNL range from fundamental science to process development with significant activities in the following areas:

- fundamental catalysis science
- catalytic vehicle emission measurement and control
- solid acid catalysis
- heterogeneous catalysis of bio-based feedstocks
- catalyst and process development using microchannel reactors
- catalyst materials for solid-oxide fuel cells.

PNNL has patented catalytic processes that convert sugars, acids, and fermentation-derived carbohydrates to high-value commodity and specialty chemicals.

Joint Global Change Research Institute

(www.globalchange.umd.edu)

Pacific Northwest National Laboratory and the University of Maryland created the Joint Global Change Research Institute (JGCRI) in 2001. It was designed to bring together a critical mass of interdisciplinary experts to address global change challenges. The strong global ties and network of the JGCRI connect its efforts in climate change to national and international policy communities. It is also developing educational opportunities to train university students in these areas. The JGCRI operates programs in the following areas of research:

- Integrated Assessment Modeling
- Technology Strategies to Address Climate Change
- Natural Resource Modeling and Assessment
- Vulnerability and Adaptation Studies
- Local and Global Environmental Mitigation Measures—Policy Development and Testing.

Battelle

Below *Joe Ecker examines seeds of T-DNA mutants in the Arabidopsis seed library at the Salk Institute—courtesy of the Salk Institute*

Salk Institute for Biological Studies

Structural Biology Laboratory

The Structural Biology Laboratory (SBL) comprises two large temperature- and humidity-controlled rooms, which house two dissecting microscopes for crystal mounting and viewing, two temperature-controlled freezer/incubators for crystallization setups, a rotating anode x-ray generator (SFR-18-HF, MacScience), and a dual imaging plate detector (DIP-2000, MacScience). A second rotating anode is equipped with a striped anode (Cr, Cu, and Au) for wavelength variation. The detector is also a MacScience DIP system. In addition to routine data collection applications, this particular instrument is used to maximize the anomalous signal from suitably derivatized crystals. Routine microprocessor control of the DIP-2000 systems and data processing are accomplished on a SGI XL graphical workstation and a dual-Pentium PC running Linux. The total data storage capacity of the structural biology laboratory is approximately 1,000 GB. Flash freezing is operational and is maintained by two Oxford Cryosystems (Stoe Diffraction). SBL's core computing needs are filled by a number of Linux systems for graphics and computation. The Salk Institute is linked to the UCSD Supercomputer Center by a fiber optics cable affording greater storage capacity and greater computational resources if needed. Through a competitive proposal submission procedure, we have been successful in obtaining time at the Stanford Synchrotron Radiation Facility in Palo Alto, California, and the European Synchrotron Radiation Facility in Grenoble, France. Currently, we make approximately six trips a year to these facilities, staying an average of three to five days. We have also purchased a state-of-the-art robotics platform to greatly accelerate the pace with which we can screen protein samples for crystallization. Moreover, as part of HHMI, we have ready access to a very high-energy and intense source of x-rays at the Advanced Light Source (ALS) in Berkeley, California. We can, with very short notice, typically no more then a few days, obtain a sufficient amount of data collection time to obtain upwards of 60 data sets on two-beam lines funded by HHMI. In several cases, we have found that this quick turnaround time allowed us to effectively "screen" newly obtained crystals at ALS rather than in the laboratory. In at least three cases thus far, we have collected data to beyond 2.5 Å resolution when no diffraction was visible using a laboratory source. A state-of-the-art Bruker 700 MHz DRX NMR spectrometer equipped with a triple-resonance probe, with an actively shielded z-gradient coil and an inverse probe, has been installed and is operational. This machine is further equipped with a cryo-probe, resulting in an additional sensitivity gain by a factor of three, exceeding the sensitivity of the highest-field NMR spectrometer currently available.

Biochemistry and Chemistry

The biochemical lab of approximately 1,500 sq. ft. is part of the 7,500 sq. ft., newly opened Jack H. Skirball Center for Chemical Biology and Proteomics at the Salk Institute. This area is well-equipped to handle general molecular biological procedures and houses general supplies of chemicals, enzymes, electrophoresis equipment and reagents (agarose, polyacrylamide protein/DNA sequencing), and two lami-

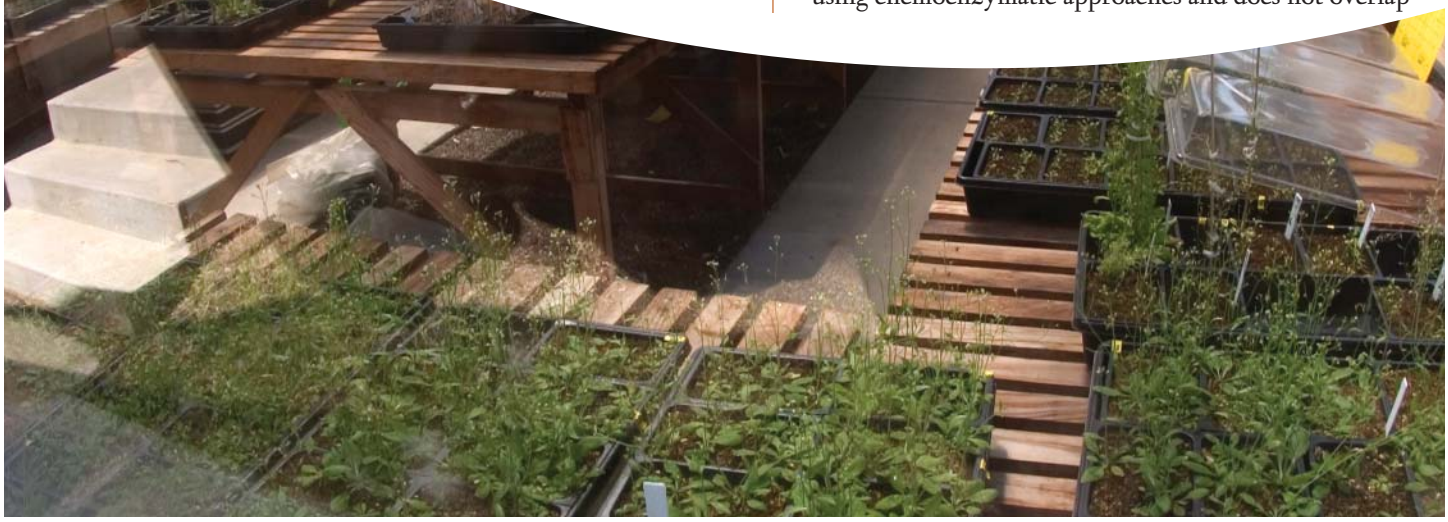
Above *Western view of the Salk Institute for Biological Studies*

nar-filtered cell culture benches in separate rooms. Major pieces of laboratory equipment are housed down a central instrumentation core and include low-speed and supraspeed Sorvall centrifuges, a UVICON dual beam UV-VIS spectrophotometer, dynamic and static light scatterers for characterization and screening of macromolecular oligomeric states, and two PCR machines. Microbial growth and cell culture are conducted in four Innova shakers (4C-60C) from New Brunswick and a 5.0 liter, fully automated and microprocessor-controlled BioFlow 3000 fermentor (New Brunswick). Chromatographic procedures are handled by three available AKTA purifiers (Amersham Biosciences). A cold room with bench space adjoins the wet lab. The Salk Institute Instrumentation facility houses a BIAcore surface plasmon resonance instrument, an isothermal titration calorimeter (Microcal), an analytical ultracentrifuge (Beckman), quenched and stop-flow devices, and three fluorimeters equipped for routine fluorescence measurements, as well as polarization studies under both equilibrium and pre-steady state conditions. GC-MS analysis is conducted in-house on a HP 6890 Series Gas Chromatograph with a PTV inlet and detection on a HP 5973 Mass Selective Detector operated at 70 eV for ionization.

The chemical biology lab encompasses approximately 800 sq. ft. This area is well-equipped to handle general synthetic organic and bio-organic chemistry procedures and houses general supplies of chemicals, reagents, solvents, catalysts, enzymes, polymer supports and scavengers, fluorous-based reagents, glassware and synthesis apparatus (microscale to kg scale), chromatographic apparatus, media and supplies (Flash & HPFC, TLC, SPE, HPLC), and six 6 ft. chemical fume hoods and associate benches, and one 8 ft. explosion-proof walk-in fume hood. Major pieces of laboratory equipment housed within the lab and in a central instrument corridor (~1,700 sq. ft.) include Buchi rotary evaporators and programmable vacuum sources (2), Julabo Chiller/heater circulators (2), Dataplate Programmable Heater/Stirrers (3), assorted magnetic stirrers and reaction controllers, Biotage Initiator 60 Microwave Reactor with 60-position autosampler, Parr Instruments series 5100 Low/Medium Pressure Reactor System, Ace Glass Photochemical Reactor System, Mettler-Toledo Autochem (Bohdan) and Charybdis Technologies Parallel Synthesis Reaction Block Systems (12-, 24-, 48- and 96-well versions), Eppendorf automated pipettes and delivery devices, high-vacuum systems, Genevac EZ2 Plus Parallel Evaporation System, Ace Glass Modular Flash Chromatography System, Biotage SP4 Automated High-Performance Flash Chromatography System, Argonaut Technologies SPE Workstation, and a shared Agilent 1100 HPLC with ion trap MS (LC-MS/MS capable). Additional shared equipment includes a centralized 10-Solvent Purification System (Glass Contour) and associated solvent storage area (maximum capacity ~480 gal. Class 1A, 1B, 1C combined). Analytical instrumentation includes a Varian NMR System 500 MHz NMR Spectrophotometer with three channels, autotuning dual broadband and triple resonance probes, full automation (100 samples), VT and gradients (housed in CBPL). Laboratory automation includes a Tecan Freedom EVO 200 with integrated sample automation, Safire 2 full spectrum plate reader for protein/cell-based assays, combinatorial chemistry modules, and crystallography workstation, designed to carry out high throughput molecular biological manipulations, protein purification, crystallization screening, and chemistry.

Infrastructure Support Through Howard Hughes Medical Institute

Part of the HHMI budget provides much needed infrastructure support to create natural product small molecules using chemoenzymatic approaches and does not overlap



with the specific aims of this grant. Moreover, the expenditures support staffing and high maintenance costs that indirectly facilitate access to equipment and training that was previously unavailable. This level of infrastructure support greatly reduces the rapidly rising costs associated with the expanded efforts to create effective mechanism-based probes of type III PKS systems. Specifically, the money for departmental operations is used to maintain a number of high-cost instruments used at the Salk Institute. These pieces of equipment include 1) a Tecan Freedom EVO 200 robotic system with integrated sample management automation, Safire 2 full spectrum plate reader for protein/cell based-assays featuring top/bottom UV-Vis and Fluoresence reading, as well as Fluorescence Polarization detection, an integrated high-speed carousel, and dedicated automation modules for protein preparation, purification, combinatorial chemistry synthesis, reaction work-up, analytical sample preparation, and crystallography, 2) a Varian NMR Systems 500 MHz Spectrophotometer with three channels, autotuning dual broad band and triple resonance probes, full automation (100 samples), VT, and gradients, 3) a Biotage Initiator 60 Microwave Reactor with 60-position autosampler, 4) a Biotage SP4 Automated High-Performance Flash Chromatography System, 5) a shared Agilent 1100 HPLC with LCT ion trap MS (LC-MSn capable), and 6) a HP 6890 Series Gas Chromatograph with a PTV inlet and detection on a HP 5973 Mass Selective Detector, operated at 70 eV for ionization.

Plant Biology Laboratory

The Plant Biology Laboratory has 8,000 sq. ft. of contiguous laboratory space that includes a cold room, media preparation room, tissue culture room, autoclave and dishwashing, microscopy, computer and conference rooms, as well as low and ultralow freezers, liquid nitrogen storage, PCR machines, sterile tissue culture hoods, and plant tissue culture incubators with precise temperature control. Additionally, the Ecker Salk Institute Genome Analysis Laboratory occupies 5,000 sq. ft. of space in the Genome Annex Building, with an additional 1,300 sq. ft. of plant growth space in an adjacent building. The Plant Biology Lab also includes the following:

Algal culture and growth space: A 1,200 sq. ft. shared facility with four sterile hoods and multiple incubators is devoted exclusively to cell/tissue culture and transgenic procedures. Two separate rooms are devoted to algal culture. One 100 sq. ft. room is fitted with custom, enclosed water baths that will allow control over light, temperature and air/CO2 in liquid cultures, and is suitable for synchronous culturing of Chlamydomonas and Volvox. A second 100 sq. ft. semi-sterile room is fitted with an air filtration system and contains two racks of light shelves that can accommodate cultures in liquid or agar plates. Bench space for dissecting microscopes and for culture work is also in this room.

Plant tissue culture and plant growth space: A 1,200 sq. ft. facility is devoted exclusively to plant tissue and cell culture, protoplast preparation, transgenic plant procedures, plant regeneration and propagation. In addition, there are three plant growth rooms with 700 sq. ft. of shelf space and approximately 2,300 sq. ft. of greenhouse space. The growth rooms have independent climate and light controls, and can be used for genetic screens under different light conditions. There are four LED growth chambers, a high-light growth chamber, and a temperature-controlled chamber for the proposed studies.

Major Equipment: The Plant Biology Laboratory contains the following major equipment: Bio-Rad 2D gel system with imaging system and software, scanning spectrophotometer, spectrophotometer for phytochrome work, fluorometer, luminometer, ABI310 automated sequencer, DHPLC for SNP analysis, gel scanner, two FPLC systems, scintillation counter, Leica confocal microscope, one dissecting microscope with integrated camera system, three regular dissecting microscopes, five thermal cyclers, two CHEF gel apparatuses, Biolistic gun for transformation, and a Leica DM 500B fluorescence microscope with a SPOT RT SE6 Slider digital camera. It also has two Leica S8Apo dissecting scopes, two Leica S6E dissecting scopes, and a Leica F5 FL fluorescent dissecting scope. For histology, it also has a Leica RM2615 microtome.

Equipment within the facility also includes QIAGEN BioRobot 9604 liquid handler system, DNA plasmid purification, and PCR product purification. A microarray Generation III Spotter from Molecular Dynamics, and a Generation III Array Scanner from Molecular Dynamics. Data acquisition and communication with the database is performed using Array Vision software. Other equipment are one Solexa 1G DNA Sequencer and Cluster Station (awaiting delivery), one Affymetrix GeneChip 3000 System, four ABI 3700 sequencers, two Biomek 2000 robotic workstations, one Tecan Genesis liquid handling workstation, one Rev-prep Plasmid Preparation Robot (GeneMachines), one Mantis automated plate-filler/colony Picker robot (GeneMachines), two Hygro high-density biological growth unit (GeneMachines), one Hydra 96-channel pipettor (Robbins), 14 (2x384) MJ Research PTC-200

Thermocyclers, six (2x384) PE 9600 Thermocyclers, one Polyplex 96 channel oligonucleotide synthesizer (GeneMachines), one Wave Technologies denaturation HPLC unit, seven CHEF pulsed-field gel apparatus, assorted gel electrophoresis apparatus, electroporation devices, power supplies and numerous other small equipment items, two Beckman J2-21 centrifuges, three Jouan refrigerated centrifuges, two Beckman tabletop and refrigerated tabletop centrifuges, seven Forma 85C freezers, six 20C freezers, four refrigerator/freezers, two New Brunswick G-25 incubator/shakers, two G-75 shaking water baths, three G10 shakers, six Hot-Pack incubators, lyophilizer, three Baker flow hoods, a dark room with x-ray film developer, two-video gel doc system, a scanning spectrophotometer, a Molecular Devices fluorometer with ELISA plate reader, and a liquid scintillation counter, a TEM, a confocal microscope, and a PhosphorImager. FACS sorting and Arturus laser-capture microdissection facilities are available at The Salk Institute.

The following major items are shared within the Plant Biology Laboratory: Biorad PDS 1000/HE Particle gun for transformations, two ultracentrifuges, three high-speed centrifuges, five -70 ˚C freezers, lyophilizer, four sterile transfer hoods, dark room with x-ray film developer and Polaroid documentation system, Bio-Rad 2D gel system with imaging system and software, scanning spectrophotometer, gel scanner, 2 FPLC systems, scintillation counter, a large working cold room, five thermal cyclers, two CHEF gel apparatuses. Three plant growth rooms with 700 sq. ft. of shelf space and approximately 2,300 sq. ft. of greenhouse space.

Computers: Our computers include four Sun Sparc workstations w/1GB RAM for sequence editing, one Sun Ultra 10 w/768MB RAM for Coding, Web and database services, one Sun Ultra 80 w/2GB RAM for Web Hosting, Database driver and gateway, one Dell PowerEdge Linux w/2G RAM for T-DNA Express database and graphic server, Transcriptome database and graphic backup, one Com Logic Linux w/2GB RAM for Transcriptome database server and SFP database,one Supermicro Linux w/4GB RAM for Blast and GCAT alignment server, RiceGE database, one Frontier Sys Linux w/12GB RAM for Methylome database server, one Supermicro Linux w/4GB RAM for System backup server and T-DNA genotyping project, one Mac G3 to run Polyplex oligosynthesizer, one Dell Pentium 2 to run Biomek1 robot, one Dell Pentium 3 to run Biomek2 robot, one Dell Pentium 3 to run Hydra robot, one Dell Pentium 3 to run Tecan robot, one Dell Pentium 2 to run ABI 3700 DNA sequencer, one Dell Celeron for gel image capture, two Dell Pentium 3s for general lab use and word processing, one Dell Pentium 4 for label printing and TDNA gel analysis, and two Mac G4s for general lab use and word processing. Our network has a total of 1.5TB of storage with storage redundancies built-in. A variety of Apple iMacs, G4s and Powerbooks are available. There are three Dell computers running Linux for bioinformatics analyses. Computers are connected via Ethernet to a central server and to the UCSD Supercomputer Center.

The Scripps Research Institute

The Scripps Research Institute (TSRI), one of the country's largest, private, non-profit research organizations, is currently housed in 14 laboratory buildings with more than 1,000,000 sq. ft. of space overlooking the Pacific. The Institute's staff includes more than 270 professors, 800 postdoctoral fellows, 1,500 laboratory technicians, administrative and support personnel, and 126 Ph.D. students. The design of each facility, with a central galleria area ringed by laboratories and offices around its perimeter, is a tangible reflection of the value placed on multidisciplinary collaboration in traditional and emerging areas of science.

Rather than isolating faculty members and laboratories into separate and distinct disciplines, the cooperative, collaborative spirit is encouraged and embraced. Technicians, postdoctoral fellows and administrative support staff all are considered part of the team and are given the latitude and responsibility to accomplish their tasks so as to serve the best interests of science. The pursuit of scientific excellence is paramount and all efforts are directed toward that end.

Research Facilities

TSRI's facilities are located on approximately 35 acres of land of which 14.7 are owned by TSRI. The campus is within close proximity to the University of California, San Diego, in La Jolla, California. This location provides access to San Diego's scientific community, which includes The Salk Institute and the Burnham Institute, as well as a concentration of some 300 biotechnology companies. The campus includes leased and owned space. TSRI owns facilities, including approximately 410,500 sq. ft. of laboratory space. Additionally the Institute leases some 573,500 sq. ft. of laboratory space in 12 buildings and approximately 60,800 sq. ft. of administrative space in three buildings.

Technical Support Capabilities

The research activities of TSRI's scientists require significant technical support, including research computing, NMR spectroscopy, particle beam spectroscopy, mass spectroscopy, optical spectroscopy, a fluorescence activated cell sorting facility, x-ray crystallography laboratories, electron microscopy, bioinformatics, and DNA array and protein chip technology. NMR spectrometers are housed in the Aline W. and L.S. Skaggs NMR Building and the Buddy Taub Center for Molecular Structure and Design.

Computer and Network Facilities

The Institute maintains central computing resources which include a large SGI Linux machine and Linux cluster computers for serial and parallel computation. The SGI Linux machine is a 128 CPU 1.3 Ghz Itanium-2 SGI 3700 server, with 128 GBytes of memory and one Terabyte of local disk space. The Linux cluster contains 512 2.4 GHZ Intel XEON processors used for computations and additional Intel XEON processors are used for system functions. Between local and shared disks these systems have ten Terabytes of disk space available for computational data. Both systems schedule jobs using the PBS batch queueing system to ensure maximum system throughput and fair access.

Above *Geisel Library—courtesy of UCSD*

An extensive data communications network connects 14 buildings on campus. The major compute and data servers are connected via fast Ethernet switches and numerous high-speed routers with selective use of gigabit ethernet. The majority of workstations, personal computers, and smaller compute servers are connected by 10 and 100 Megabit switched and routed Ethernets. This network links together approximately 4,900 computers. Approximately 600 of these are high-end Unix-based graphics workstations, largely represented by Linux/Intel, Silicon Graphics and Sun Microsystems. Other Unix workstations include Compaq and Hewlett-Packard. The other computers are equally divided between Windows and Macintosh desktop computers.

The Institute operates a central data archival facility which uses a Silicon Graphics Origin 2100 server, a ten Terabyte disk cache, and a large high-speed StorageTek tape library. Current capacity is approximately 1,000 Terabytes.

Off-campus resources, such as massively parallel computers at various Supercomputer Centers, are accessible via a full duplex 100 Megabit fast Ethernet Internet connections.

The Scripps Research Institute

D. EBI Articles of Incorporation, *Sample*

Above *La Jolla Shores at sunset—courtesy of John Wooley*

SAMPLE ARTICLES OF INCORPORATION OF ENERGY BIOSCIENCES INSTITUTE (EBI)

I.

The name of the corporation is: Energy Biosciences Institute.

II.

A. The corporation is a nonprofit public benefit corporation and is not organized for the private gain of any person. It is organized under the California Nonprofit Public Benefit Corporation Law for public purposes. The specific purposes of the corporation are (1) to create and operate a nonprofit scientific research institute to provide a mechanism and facilities (the "Facility") whereby certain institutions currently involved in scientific research and education (the "Institutions") may more effectively coordinate their resources, personnel, and programs for scientific research and education in the field of bioenergy science and technology; (2) to plan for and oversee the procurement and operations of the Facility; and increase the opportunities for research by leading investigators of the Institutions, both individually and collaboratively, in the area of bioenergy science and technology, utilizing the respective expertise of the Institutions in XXX; and (3) to make distributions to organizations that qualify as exempt organizations under Section 501(c)(3) of the Internal Revenue Code of 1986, as amended (the "Code").

B. The corporation is organized and operated exclusively for scientific and educational purposes within the meaning of Section 501(c)(3) of the Code.

C. In furtherance of its purposes, the corporation shall have all the general powers enumerated in Sections 5140 and 5141 of the California Nonprofit Public Benefit Corporation Law, as now in effect or as may hereafter be amended, together with the power to solicit grants and contributions for such purposes. The corporation may engage in any activities that are reasonably related to or in furtherance of its stated charitable and public purposes, or in any other charitable activities.

III.

The name in California of the corporation's initial agent for service of process is:

xyz
which will do business in California
As CSC-Lawyers Incorporating Service

IV.

The Corporation shall have two members: The Regents of the University of California, San Diego Campus ("UCSD") and BP, Plc ("BP").

V.

A. No substantial part of the activities of the corporation shall consist of carrying on propaganda, or otherwise attempting to influence legislation (except as otherwise permitted by Section 501(h) of the Code and in any corresponding laws of the State of California), and the corporation shall not participate in or intervene in any political campaign (including the publishing or distribution of statements) on behalf of, or in opposition to, any candidate for public office.

B. During such period, or periods, of time, if any, as the corporation is treated as a "private foundation" pursuant to Section 509 of the Code, the directors must distribute the corporation's income at such time and in such manner so as not to subject the corporation to tax under Section 4942 of the Code, and the corporation is prohibited from engaging in any act of self-dealing (as defined in Section 4941(d) of the Code), from retaining any excess business holdings (as defined in Section 4943(c) of the Code) which would subject the corporation to tax under Section 4943 of the Code, from investing any amount in such a manner so as to subject the corporation to tax under Section 4944 of the Code, from not removing from jeopardy within the taxable period any investment upon which an initial tax is imposed under Section 4944 of the Code, and from making any taxable expenditures (as defined in Section 4945(d) of the Code).

C. Notwithstanding any other provision of these Articles of Incorporation shall not directly or indirectly carry on any activity which would prevent it from obtaining exemption from Federal income taxation as a corporation described in Section 501(c)(3) of the Code, or cause it to lose such exempt status, or carry on any activity not permitted to be carried on by a corporation, contributions to which are deductible under Section 170(c)(2) of the Code.

VI.

The property of the corporation is irrevocably dedicated to scientific or educational purposes meeting the requirements for exemption provided by Section 214 of the California Revenue and Taxation Code, and no part of the net income or assets of the corporation shall ever inure to the benefit of any director, officer, or member thereof or to the benefit of any payment, or provision for payment, of all debts and liabilities of the corporation shall be distributed to a nonprofit fund, foundation, or corporation which is organized and operated exclusively for scientific purposes meeting the requirements for exemption provided by Section 214 of the California Revenue and Taxation Code and which has established its tax exempt status under Section 501(c)(3) of the Code.

Dated: ___, 2007

_____

Name, Incorporator

E. EBI Affiliation Agreement, *Sample*

Above *Great Egret at La Jolla Ecological Reserve tidepools*

SAMPLE AFFILIATION AGREEMENT BETWEEN THE ENERGY BIOSCIENCES INSTITUTE AND THE REGENTS OF THE UNIVERSITY OF CALIFORNIA (SAN DIEGO)

This Agreement is made and entered into as of the _____ day of _____, 200___, by and between the ENERGY BIOSCIENCES INSTITUTE, a California public benefit corporation, qualified to do business in California, and qualified as an organization described in section 501(c)(3) of the Internal Revenue Code, as amended, ("EBI") and THE REGENTS OF THE UNIVERSITY OF CALIFORNIA, a California corporation and instrumentality of the State of California, qualified as an organization described in section 501(c)(3) of the Internal Revenue Code, as amended, ("UNIVERSITY") acting for and on behalf of its campus at the University of California, San Diego ("UCSD").

RECITALS

WHEREAS, the UNIVERSITY is an educational, research and public service public trust, no part of the net earnings of which inures to the benefit of any private shareholder or individual (except as reasonable compensation for services rendered or as a benefit of its educational purposes); no substantial part of the activities of which is carrying on propaganda or otherwise attempting to influence legislation; which does not participate in or intervene in (including the publishing or distributing of statements) any political campaign on behalf of any candidate for public office; and

WHEREAS, EBI is a not-for-profit corporation dedicated to the advancement of science in support of the energy industry, with an initial emphasis on biofuels, enhanced oil recovery techniques, conversion and carbon sequestration; the members of EBI are the UNIVERSITY and BP Corporation North America, Inc., which have jointly established EBI to be sited at UCSD as its "host institution" for the conduct and support of energy research by EBI; and

WHEREAS, the UNIVERSITY and EBI desire to collaborate on research between their respective faculties in areas of mutual interest, with the expectancy that participation by the UNIVERSITY will operate across departmental and other institutional lines including collaborations with the Scripps Institution of Oceanography, the California Institute for Telecommunications and Information Technology (Cal-(IT)2, the San Diego Supercomputer Center and other distinguished departments, organized research units and institutes at UCSD; and

WHEREAS, EBI desires to conduct its research in conjunction with the UNIVERSITY and to cooperate closely in the active conduct of energy-related research by having EBI conduct research in facilities leased from the UNIVERSITY on a temporary basis pending construction of permanent facilities, by having the

UNIVERSITY make certain of its facilities available to EBI and by permitting personnel of the UNIVERSITY and EBI to participate jointly in such research; and

WHEREAS, it is also contemplated that EBI will initiate a research funding program pursuant to which UNIVERSITY faculty and researchers will receive contract and grant funding for purposes of performing energy research at the UNIVERSITY independently and in cooperation with investigators and employees of EBI; and

WHEREAS, EBI has entered into an agreement ("Ground Lease") with the UNIVERSITY to construct and occupy research and administrative facilities for a term of ten (10) years (the "Premises") located in the research park located adjacent to UCSD; and

WHEREAS, EBI and the UNIVERSITY mutually desire to memorialize through an affiliation agreement ("this Agreement") their collaboration in the active conduct of energy research;

NOW, THEREFORE, the parties hereto agree as follows:

ARTICLE 1: PROGRAM, LOCATION AND COLLABORATION

The purpose of this Agreement is to provide for the continuous active conduct of energy research by EBI in cooperation with the UNIVERSITY by integrating the research of EBI with energy and other relevant research conducted by the UNIVERSITY.

1.1 EBI Research Program

1.1.1 During the term of this Agreement, EBI will, in conjunction with the UNIVERSITY, conduct energy research in its Premises adjacent to the UCSD campus.

1.1.2 All energy research at the Premises will be under the general supervision of the Board of Directors of EBI.

1.1.3 EBI shall appoint an Executive Director who shall be or become an employee of EBI and who shall report to the Board of Directors of EBI. The Executive Director shall direct all research conducted by EBI under this Agreement, which may include coordinating and supporting the work of a scientific committee overseeing the program and as provided in section 1.3.

1.2 Location

1.2.1 The energy research to be conducted hereunder shall be conducted at the Premises and in such appropriate other locations as the parties hereto may hereafter agree upon.

1.2.2 EBI is at liberty to conduct research at places other than the Premises, within or without California, and with organizations other than the UNIVERSITY.

1.2.3 The UNIVERSITY may conduct or support research, including energy research for its own account or with organizations other than EBI.

1.3 Collaboration. As further amplified by the provisions of Article 2, EBI and the UNIVERSITY shall cooperate continuously and closely with each other in the active conduct of energy research at the Premises and at the UNIVERSITY.

1.3.1 The research program at the Premises will be planned, supervised, conducted and evaluated by EBI, in consultation with the UNIVERSITY, in accordance with EBI's overall objectives and standards for energy research, as established pursuant to procedures promulgated from time to time by EBI, subject to the principles of intellectual freedom in research referred to in paragraph 1.3.3 below.

1.3.2 The research program at the Premises will be under the immediate direction and control of professional scientists employed by EBI and assigned by EBI to the research program, and will be conducted by EBI's employees, either alone or in conjunction with employees of the UNIVERSITY, in accordance with the objectives of EBI. EBI will establish and comply with its own policies, procedures, rules and regulations governing research and experimental policies and procedures, including review and approval of its committees having cognizance in such areas; and shall comply with all applicable federal, state and local statutes and regulations.

1.3.3 EBI and the UNIVERSITY both subscribe to principles of intellectual freedom in research, and this contractual, collaborative relationship between the parties will be guided by their common allegiance to these principles.

1.3.4 EBI will bear the costs directly related to conducting the research program at the Premises, including equipment costs and compensation of its employees. EBI may negotiate for services supplied by the UNIVERSITY to its own research programs, such as the cost of veterinary and animal services (including any specialized equipment necessary for the research program), hazardous waste disposal, environmental health and safety

monitoring, and similar mutually agreed upon research support services. Those services would be charged on a usage basis at the UNIVERSITY's established, internal recharge rates at the UCSD Campus, which rates are generally comparable to actual, direct costs or, in the absence of such rates, at the UNIVERSITY's actual, direct costs incurred in providing such services, plus the UNIVERSITY's then current off-campus indirect cost rate. The terms of these services will be the subject of separate agreements negotiated between the parties.

ARTICLE 2: EBI'S RESEARCH PERSONNEL

2.1 EBI's Responsibility for its Employees. EBI will select, employ, supervise and assign its employees to the research program at the Premises, including the appropriate administrative personnel, in accordance with EBI procedures. EBI will be solely responsible for any and all personnel matters concerning EBI employees other than with regard to their UNIVERSITY academic appointments and the application to them of UNIVERSITY academic policies. Such personnel matters (for which EBI has sole responsibility) will include, but not be limited to, compliance by EBI and its employees with all applicable federal, state and local statutes and regulations concerning nondiscrimination in employment on the basis of race, age, sex, handicap or ethnic or national origin, and with all applicable UNIVERSITY regulations.

2.2 Grant of Academic Recognition to EBI Employees. Upon proper application on behalf of persons not holding tenured appointments from the UNIVERSITY, the UNIVERSITY shall grant appropriate academic recognition to such persons during their employment at EBI at the UCSD Campus by conferment of appropriate University titles commensurate with their demonstrated qualifications. Such appointments shall be without any commitment from the UNIVERSITY for compensation or employment by the UNIVERSITY during the employment of such persons by EBI at the Premises or elsewhere. In submitting applications for UNIVERSITY titles on behalf of such persons, it will be the obligation of EBI and the individuals in question, in compliance and in accordance with all applicable UNIVERSITY practices and procedures, to establish to the full satisfaction of UNIVERSITY that such persons are qualified and that the qualifications conform in all respects to the criteria established from time to time by UNIVERSITY for the titles sought and to demonstrate to UNIVERSITY that such persons can be expected to make an important contribution to UNIVERSITY activities. All titles so conferred by UNIVERSITY under this paragraph 2.2 shall, except as otherwise specifically agreed, be revocable for cause or upon termination of this Agreement (unless this Agreement shall have been extended or renewed for a subsequent term by an agreement of substantially similar tenor, in which case, upon the termination of such extension or renewal agreement).

2.3 University Policies. EBI warrants, represents and covenants that all persons receiving titles from the UNIVERSITY pursuant to this Article 2 shall, at all times,

(i) conform to the requirements of the UNIVERSITY insofar as the use of UNIVERSITY facilities are concerned, and

(ii) comply with all UNIVERSITY policies and procedures applicable to persons holding the academic recognition or title in question.

The foregoing notwithstanding, EBI employees who receive such recognition and/or title, shall not, unless the parties have reached agreement in writing to the contrary, at any time or in any manner during the term of this Agreement be deemed to be employees or agents of the UNIVERSITY as a result of such titles or requirements.

2.4 Grant Applications. Each party shall administer its own research program and funding sources in accordance with its own policies and procedures, including possible subcontracts from one to the other in appropriate cases of shared or joint research.

ARTICLE 3: PATENTS, COPYRIGHTS AND OTHER INTELLECTUAL PROPERTY

3.1 All rights, title to and interests in intellectual property that is conceived by the faculty and staff of each party in the course of conducting research at its own facilities shall remain the intellectual property of such party, such that the party owning the intellectual property shall be responsible for any commercialization of the research and the research shall be governed by the policies and procedures applicable to research conducted at such institution. Any rights to research to be conducted at either EBI or the UNIVERSITY cooperatively by investigators from both institutions shall be governed by any existing policies and practices relating to cooperative research adopted by the parties.

ARTICLE 4: INSURANCE & INDEMNIFICATION

4.1 EBI's Insurance. EBI, at its sole cost and expense, shall insure its activities in connection with this Agreement and obtain, keep in force and maintain insurance as follows:

4.1.1 Comprehensive or Commercial Form General Liability Insurance (contractual liability included) with minimum limits as follows:

(i)	Each Occurrence	$1,000,000.
(ii)	Products/Completed Operations Aggregate	$1,000,000.
(iii)	Personal and Advertising Injury	$1,000,000.
(iv)	General Aggregate*	$5,000,000.

*applicable to commercial form only

However, if such insurance is written on a claims-made form following termination of this Agreement, coverage shall survive for a period of not less than three years. Coverage shall provide for a retroactive date of placement coinciding with the commencement date of this Agreement.

4.1.2 Business Automobile Liability Insurance for owned, scheduled, non-owned, or hired automobiles with a combined single limit no less than One Million Dollars ($1,000,000.) per occurrence.

4.1.3 Worker's compensation and employer's liability insurance in a form and amount covering EBI's full liability under the Worker's Compensation Insurance and Safety Act of the State of California, as amended from time to time.

4.1.4 Business income (business interruption insurance) and extra expense coverage, with coverage amounts that shall reimburse EBI for all direct or indirect loss of income and charges and costs incurred arising out of perils commonly insured against including prevention of, or denial of use of or access to the Premises as a result of those perils. The business income and extra expense coverage shall provide coverage for no less than twelve (12) months of the loss of income, charges and costs contemplated under this Agreement and shall be carried in amounts necessary to avoid any co-insurance penalty that could apply.

4.1.5 Property insurance, fire and extended coverage form in an amount sufficient to reimburse EBI for all of its Equipment and personal property located on or in the Premises including improvements hereinafter constructed or installed.

4.1.6 Such other insurance in such amount which from time to time may be reasonably required by the mutual consent of UNIVERSITY and EBI against other insurable risks relating to performance.

The insurance and the coverage referred to under 4.1.1 and 4.1.2 of this Section shall be endorsed to include the The Regents of the University of California as an additional insured. Such a provision, however, shall apply only in proportion to and to the extent of the negligent acts or omissions of EBI, its officers, agents, partners, employees; or any person or persons under EBI's direct supervision and control. EBI, prior to the execution of this Agreement, shall furnish the University with Certificates of Insurance evidencing compliance with the requirements of this Section.

The coverage required herein shall not in any way limit the liability of EBI, its officers, agents, partners, or employees.

4.2 UNIVERSITY's Insurance. UNIVERSITY, at its sole cost and expense, shall insure its activities in connection with this Agreement and obtain, keep in force and maintain insurance, or a funded program of self-insurance, as follows:

4.2.1 Comprehensive or Commercial Form General Liability Insurance (contractual liability included) with minimum limits as follows:

(i)	Each Occurrence	$1,000,000.
(ii)	Products/Completed Operations Aggregate	$1,000,000.
(iii)	Personal and Advertising Injury	$1,000,000.
(iv)	General Aggregate*	$5,000,000.

*applicable to commercial form only

However, if such insurance is written on a claims-made form following termination of this Agreement, coverage shall survive for a period of not less than three years. Coverage shall provide for a retroactive date of placement coinciding with the commencement date of this Agreement.

4.2.2 Business Automobile Liability Insurance for owned, scheduled, non-owned, or hired automobiles with a combined single limit no less than One Million Dollars ($1,000,000.) per occurrence.

4.2.3 Worker's compensation and employer's liability insurance in a form and amount covering UNIVERSITY's full liability under the Worker's Compensation Insurance and Safety Act of the State of California, as amended from time to time.

4.2.4 Fire and extended self-insurance program with coverage in an amount equal to the full replacement value (100%) of the Building (excluding land and the footings, foundations and installations below the basement level) and the costs of demolition and debris removal.

The insurance, self-insurance, and the coverage referred to under 4.2.1 and 4.2.2 of this Section shall be endorsed to include EBI as an additional insured. Such a provision, however, shall apply only in proportion to and to the extent of the negligent acts or omissions of UNIVERSITY, its officers, agents, employees; or any person or persons under UNIVERSITY's direct supervision and control.

The coverage required herein shall not in any way limit the liability of UNIVERSITY, its officers, agents, or employees.

4.3 Waiver of Subrogation. UNIVERSITY and EBI each hereby waive any right of recovery against the other due to loss of or damage to the property of either UNIVERSITY or EBI when such loss of or damage to property arises out of the acts of God or any of the property perils included in the classification of fire, extended perils ("all risk") as such term is used in the insurance industry) whether or not such perils have been insured, self-insured or non-insured.

4.4 Indemnification.

4.4.1 EBI's Indemnification. EBI shall indemnify, defend and hold harmless, UNIVERSITY, its officers, agents, and employees from and against any claims, damages, costs, expenses (including an amount equal to reasonable attorneys' fees) proceedings, or liabilities arising out of or in any way connected with the performance of, or failure to perform, EBI's obligations under this Agreement including, without limitation, claims, damages, expenses, or liabilities for loss or damage to any property, or for death or injury to any person or persons in proportion to and to the extent that such claims, damages, expenses, or liabilities arise from the negligence or willful acts or omissions of, or breach of this Agreement by EBI, its officers, agents, partners, or employees.

4.4.2 UNIVERSITY's Indemnification. UNIVERSITY shall indemnify, defend and hold harmless, EBI, its officers, agents, partners and employees from and against any claims, damages, costs, expenses (including an amount equal to reasonable attorneys' fees) proceedings, or liabilities arising out of or in any way connected with the performance of, or failure to perform, UNIVERSITY's obligations under this Agreement including, without limitation, claims, damages, expenses, or liabilities for loss or damage to any property, or for death or injury to any person or persons in proportion to and to the extent that such claims, damages, expenses, or liabilities arise from the negligence or willful acts or omissions of, or breach of this Agreement by UNIVERSITY, its officers, agents, or employees.

ARTICLE 5: CONFIDENTIALITY

5.1 Both EBI and the UNIVERSITY mutually acknowledge and recognize the valuable and proprietary nature of the other's confidential information and agree that the confidential information of the other party shall remain the property of such other party throughout the term of this Agreement, subject to the terms hereof. In this regard, the parties agree to receive and maintain all confidential information of the other party in confidence and to refrain from any use thereof, in whole or in part, except as expressly provided by this Agreement.

5.2 In recognition of the proprietary nature and value of the confidential information, the parties agree that the obligations of this paragraph shall remain in full force and effect regardless of termination of this Agreement for any reason.

5.3 A party may disclose the confidential information of the other party as is necessary or appropriate in order to have qualified students, employees and representatives act hereunder. However, no disclosure shall be made without taking suitable measures to assure that any such student, employee or representative is bound under confidentiality requirements at least equal in scope to those it uses for its own confidential information. All reasonable steps shall be taken to assure that the disclosure of the confidential information of the other party to any employee will be limited to those having a need to know to fulfill the terms and conditions of this Agreement. Further, the receiving party shall take all reasonable steps to assure that its students, employees and representatives will maintain the confidential nature of the other's confidential information.

5.4 Neither party shall be obligated or required to maintain in confidence any information, even though deemed by the disclosing party to be its confidential information, for which it can be demonstrated by competent documentary evidence that it was:

5.4.1 In the public knowledge prior to the disclosure made between the parties at any time, whether after or before the date of this Agreement; or

5.4.2 In the possession of the receiving party without binder of confidentiality prior to the earliest disclosure made between the parties at any time, whether after or before the date of this Agreement; or

5.4.3 While originally confidential information, subsequently is received without binder of confidentiality from a third party who is free to disclose the information, as of the date of such third-party disclosure; or

5.4.4 While originally confidential information, and subsequently becomes part of the public knowledge through no fault of the non-disclosing party; or

5.4.5 Independently developed by the receiving party's employees or agents provided that those employees or agents had no access to any corresponding confidential information of the closing party received hereunder.

5.5 Unless otherwise mutually agreed by the parties in writing, any result, idea, refinement, invention or improvement developed or acquired in the course of any collaboration between the parties shall be owned solely by the party initiating the original research project relating to the collaboration.

ARTICLE 6: ARBITRATION

Any dispute arising from this Agreement, including any of its terms, their interpretation or their property application, which cannot be otherwise resolved, shall be submitted for

resolution by discussions between UNIVERSITY's San Diego Campus Vice Chancellor for Research and EBI's Chief of Research. If these two individuals are unable to resolve the dispute, then, on request by either of them, the dispute shall be submitted for resolution by the UNIVERSITY's Chancellor at UCSD and EBI's Executive Director. If these individuals are also unable to resolve the dispute, then either of them may, upon notice to the other, request that the dispute be submitted to a disinterested third party arbitrator to be jointly selected by mutual agreement or by the American Arbitration Association. In this latter case, the selected individual shall conduct the arbitration pursuant to the rules of the American Arbitration Association then obtaining. The arbitrator shall be bound by the provisions of this Agreement. The fees and expenses of the arbitrator shall be shared equally, and each party shall bear its own costs and attorneys' fees in any arbitration proceeding. The award of the arbitrator shall be final and may be enforced in any court having jurisdiction thereof.

ARTICLE 7: EFFECTIVENESS AND DURATION

7.1 Term. Subject to other provisions of this paragraph, this Agreement shall be for a term commencing _____, 200___, and continuing, unless sooner terminated, until the expiration or earlier termination of the Ground Lease.

7.2 Additional Extensions. In the event the Original Term of the Ground Lease is extended, the parties agree to negotiate in good faith further extensions of this Agreement and (i) the Ground Lease or (ii) for the lease of suitable alternative space on UCSD campus. Such negotiations shall commence not later than eighteen (18) months prior to the expiration of the Ground Lease.

7.3 Effect of Lease Termination. This Agreement shall terminate on the termination of the Ground Lease for the Premises.

7.4 Termination Without Cause. Either party may terminate this Agreement without cause, at any time upon providing the other party with ninety (90) days advance written notice.

ARTICLE 8: COMPLETE AGREEMENT; AMENDMENT

Except for the Lease, which, along with any amendments thereto, are expressly incorporated herein, this Agreement constitutes the entire agreement between the parties hereto with respect to the subject matter hereof and supersedes all prior agreements, representations, warranties, statements, promises and understandings, whether oral or written with respect to such subject matter. Neither party hereto shall be bound by, nor charged with, any oral or written agreements, representations, warranties, statements, promises or understandings not specifically set forth in this Agreement. This Agreement may not be amended, altered or modified except by a writing signed by both parties hereto.

ARTICLE 9: INDEPENDENCE OF PARTIES

While the parties intend this Agreement to reflect their collaboration in the pursuit of energy research of common interest, nothing contained in this Agreement shall constitute either party to this Agreement an agent of the other party, it being the intent of the parties hereto not to create an agency, partnership or joint venture. Each party to this Agreement will act independently and will not be an agent for the other. Neither party will use the name of the other in any activity, or take any other action that could imply an institutional endorsement of a particular policy, product or solicitation of any kind without the other party's prior written consent.

ARTICLE 10: BINDING ON SUCCESSORS AND ASSIGNMENT

This Agreement shall be binding upon the parties hereto and their respective successors. This Agreement may not be assigned without the written consent of the other party.

ARTICLE 11: NOTICES

All notices under this Agreement shall be in writing and shall be delivered by personal service, by certified or registered mail, postage prepaid, return receipt requested (or by common carrier providing overnight delivery and confirmation of receipt), to the parties at the addresses hereinafter set forth. The addresses for such notices are as follows:

To the UNIVERSITY: _____
_____
_____
_____

With a copy to: Campus Counsel
University of California, San Diego
9500 Gilman Drive, Mail Code 0097
La Jolla, CA 92093-0097

To EBI: _____
_____
_____
_____

Either party may, by notice to the other, designate a different address for such notices to such party.

ARTICLE 12: GOVERNING LAW

This Agreement shall be construed in accordance with and governed by California law.

ARTICLE 13: MISCELLANEOUS

13.1 Use of Name. The UNIVERSITY and EBI agree that neither party may use the name of the other party in describing its activities under this Agreement, without the express written consent of said other party.

13.2 Publicity. The UNIVERSITY and EBI agree to coordinate public announcements, including press releases, related to activities contemplated under this Agreement, and to give public recognition to each party under terms, and in circumstances, on which they may in the future agree.

IN WITNESS WHEREOF, this Agreement has been signed by the duly authorized representatives of the parties hereto as of the day and year first above written.

ENERGY BIOSCIENCES INSTITUTE

By: _____
Title: _____

By: _____
Title: _____

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

By: _____
Title: _____

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F. EBI Bylaws, *Sample*

Above *Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, UCSD*

SAMPLE BYLAWS
OF
ENERGY BIOSCIENCES INSTITUTE

A CALIFORNIA NONPROFIT PUBLIC BENEFIT CORPORATION

ARTICLE I.
Name, Offices and Purposes

Section 1.01 Name. The name of the corporation is Energy Biosciences Institute (EBI).

Section 1.02 Principal Office. The Board of Directors of the EBI ("Board of Directors") shall determine where to locate the principal office of the EBI. By resolution, the Board of Directors may change the principal office from one location to another and may establish additional offices.

Section 1.03 General Purposes of EBI. The EBI is a nonprofit public benefit corporation as described in the California Nonprofit Public Benefit Corporation Law (the "Law"). The property of the EBI is irrevocably dedicated to scientific and educational purposes in a manner which meets the requirements of Section 501(c)(3) of the Internal Revenue Code of 1986, as amended ("Internal Revenue Code"), and Sections 23701d and 214 of the California Revenue and Taxation Code. The specific purposes of the EBI are (a) to create and operate a nonprofit scientific research institute to provide a mechanism and facilities (the "Facility") whereby certain institutions currently involved in scientific research and education (the "Institutions") may more effectively coordinate their resources, personnel, and programs for scientific research and education in the field of bioenergy science and technology; (b) to increase the opportunities for research by leading investigators of the Institutions, both individually and collaboratively, in the area of bioenergy science and technology, utilizing the respective

expertise of the Institutions in XXX; and (c) to make distributions to organizations that qualify as exempt organizations under Section 501(c)(3) of the Internal Revenue Code of 1986, as amended (the "Code").

The Institutions are THE REGENTS OF THE UNIVERSITY OF CALIFORNIA, a California corporation, represented by its San Diego campus, the UNIVERSITY OF CALIFORNIA, SAN DIEGO ("UCSD"), J. CRAIG VENTER INSTITUTE FOR CANCER RESEARCH, a Maryland charitable corporation, qualified to do business in California, and qualified as an organization described in section 501(c)(3) of the Internal Revenue Code of 1986, as amended, IOWA STATE UNIVERSITY, a non profit Iowa corporation, and BP Corporation North America, Inc.

Section 1.04 Specific Objectives of EBI. The specific objectives of the EBI are to:

(a) obtain nonprofit tax exempt status for the EBI in order to receive public or private financial support for the activities of the EBI;

(b) develop and manage the Institute effectively and efficiently to enable leading investigators from the Institutions to work together synergistically in the area of bioenergy science and technology to realize the full potential from the respective expertise of the Institutions in the areas of XXX;

(c) facilitate research and educational collaborations among the researchers of the Institutions in the field of bioenergy science and technology; and

(d) encourage the translation of basic bioenergy science and technology research conducted by the Institutions into commercial development.

ARTICLE II.
Membership

Within the meaning of Section 5056 of the Law, members of EBI shall include UCSD and BP.

ARTICLE III.
Board of Directors

Section 3.01 Duties and Powers of the Board of Directors. Subject to any limitations in the EBI's Articles of Incorporation (the "Articles") or these Bylaws, the Board of Directors shall manage the activities of the EBI and shall exercise or oversee the exercise of all corporate powers. The Board of Directors may delegate its duties and powers as it sees fit to the extent permitted by law, *provided however,* that the activities and affairs of the EBI shall be managed and all corporate powers shall be exercised under the ultimate direction of the Board of Directors. The Board of Directors shall have all powers permitted to or conferred on a board of directors of a nonprofit public benefit corporation by Law, except as limited by the Articles or these Bylaws.

Section 3.02 Number of Directors and Election. The initial Board of Directors shall have nine (9) directors. The directors of the Board of Directors shall be elected by the Members of EBI. The Board of Directors shall be comprised of an equal number of UCSD and BP directors, and additional external, independent directors mutually selected by UCSD and BP. An independent director is a person with substantial ties to San Diego County and is not an employee of any of the Members. Directors of the Board of Directors shall be appointed, removed and replaced by the Members.

Section 3.03 Term of Office. Each director of the Board of Directors shall sit for an initial term which shall be the "start-up phase" of the EBI. The Board of Directors shall determine the length of the start-up phase, which shall not exceed two (2) years.

Section 3.04 Board of Directors – Election of Successor Directors. The Board of Directors shall create a nominating committee process by which persons shall be nominated as independent directors of the Board of Directors (as set forth in Section 3.02 above), subject to election by the Board of Directors, by majority vote. Each Member shall appoint its nominee to

the Board of Directors without a vote of the Board of Directors. The Board of Directors may, by majority vote, increase its size and nominate and elect additional directors as community members or as nominees of institutions or organizations other than the Members.

Section 3.05 Interested Persons. No more than forty-nine percent (49%) of the directors serving at any one time may be "interested persons." For purposes of this Section 3.07, an "interested person" is:

(a) Any person currently being compensated by the EBI for services rendered to it within the previous twelve (12) months, whether as a full-time or part-time employee, independent contractor, or otherwise, excluding any reasonable compensation paid to a director as a director; or

(b) Any brother, sister, ancestor, descendant, spouse, brother-in-law, sister-in-law, son-in-law, daughter-in-law, mother-in-law, or father-in-law of any person listed in Section 3.07(a) above.

Any violation of the provisions of this Section 3.07 shall not affect the validity or enforceability of any transaction entered into by the EBI.

Section 3.06 Officers of Board of Directors. The Board of Directors shall elect one or more persons as Chairman of the Board ("Chair") and as a Secretary of the Board, each to serve for a term of one (1) year. The offices of Chair and Secretary of the Board can be filled by one person. In the event the Board of Directors shall elect more than one person to act as Chairman of the Board, such persons shall be referred to as Co-Chairman and, acting by majority vote, shall perform the duties and responsibilities of the Chair set forth herein. A person other than a director of the Board of Directors may act as Secretary of the Board.

Section 3.07 Resignation, Removal, and Vacancies.

(a) A director may resign effective upon giving written notice to the Chair, the President, the Secretary of the Board, the Secretary of the EBI or the Board of Directors, unless the notice specifies that the resignation shall be effective at a later time; *provided, however,* that a director may not resign without permission of the Attorney

General in a case where the EBI would be left without a duly elected director in charge of its affairs.

(b) The Board of Directors may remove a director who fails to fulfill his or her duties, including failing to attend meetings of the Board of Directors or failing to fulfill tasks designated by the Board of Directors; *provided, however,* that such removal must be authorized by an affirmative vote of a majority of directors then in office.

(c) Vacancies on the Board of Directors shall be filled as provided in Section 3.06 above. A director elected to fill a vacancy shall hold office until the expiration of the term of the replaced director or until his or her successor has been elected and qualified.

(d) A vacancy in the Board shall be deemed to exist upon the occurrence of the death, resignation, or removal of any director, or if the authorized number of directors is increased.

(e) The Board of Directors may declare vacant the office of a director who has been declared of unsound mind by a final order of court, or is convicted of a felony, or has been found by a final order or judgment of any court to have breached a duty to the EBI.

Section 3.08 Place of Meetings. The Board of Directors may meet at any place designated in the notice of the meeting or, if not stated in the notice or if there is no notice, as designated by the Chair or the Board of Directors.

Section 3.09 Annual Meetings. The Board of Directors shall hold an annual meeting to elect directors and officers then up for election, and to conduct all other business as may properly come before the Board of Directors. The annual meeting shall take place at such time and place as determined by resolution of the Board of Directors.

Section 3.10 Regular Meetings. Regular meetings of the Board of Directors shall be held at the discretion of the Board of Directors at such time and place as may be fixed by the Board of Directors.

Section 3.11 Special Meetings. Special meetings of the Board of Directors for any purpose may be called at any time by the Chair, the President, the Secretary of the Board, or any two (2) directors.

Section 3.12 Notice. Annual, regular and special meetings of the Board of Directors shall be held upon notice of at least one (1) week by first-class mail or forty-eight (48) hours' notice given personally or by telephone, electronic mail, facsimile, or other equivalent means of communication. Such notice shall contain the date, time, and place of meeting and the agenda of business to be discussed at such meeting.

Any such notice shall be addressed or delivered to each director at his or her address or contact number as it is shown upon the records of the EBI, or, if such address or number is not shown on such records or is not readily ascertainable, at the principal place of business of the EBI.

Notice by mail shall be deemed to have been given at the time that the notice is deposited in the United States mails, postage prepaid. Any other written notice shall be deemed to have been given at the time it is personally delivered to the recipient or to a common carrier for transmission. Notice by electronic mail shall be deemed to have been given when it is actually transmitted by the person sending the notice by electronic means to the recipient. Oral notice shall be deemed to have been given at the time it is communicated, in person or by telephone, to the recipient or to a person at the office of the recipient who, the person giving the notice has reason to believe, will promptly communicate it to the recipient.

Section 3.13 Quorum and Action of the Board of Directors.

(a) A majority of directors currently in office constitutes a quorum of the Board of Directors for the transaction of business, except for purposes of adjournment as provided in Section 3.18 of these Bylaws. Unless a greater number is expressly required by law, the Articles or these Bylaws, every action taken or decision made by a

majority of the directors present at a meeting duly held at which a quorum is present is the act of the Board of Directors; *provided, however,* that a meeting at which a quorum is initially present may continue to transact business notwithstanding the withdrawal of directors, if any action taken is approved by at least a majority of the required quorum for such meeting.

(b) The following actions shall require a vote by a majority of *all* directors then in office in order to be effective:

(i) the amendment of the Articles or these Bylaws (except as provided in Section 6.07);

(ii) creation or dissolution of a committee of the Board of Directors (as provided in Section 3.20) or an advisory committee (as provided in Section 3.22);

(iii) the election of new directors or a vote to change the number of directors (as provided in Section 3.06); and

(iv) the dissolution of the EBI and winding up of business.

(c) Unless otherwise required by law, voting on any matter requiring a vote of the Board membership shall be by mail, including electronic mail, to the extent permitted by law, and a majority of the votes cast shall determine the outcome.

Section 3.14 Participation in Meetings by Conference Telephone. Directors may participate in meetings of the Board of Directors through the use of conference telephone or equivalent communications equipment, so long as directors participating in the meeting can hear one another. Participation in a meeting pursuant to this Section 3.16 constitutes presence in person at the meeting.

Section 3.15 Waiver of Notice. Notice of a meeting need not be given to any director who signed a waiver of notice or a written consent to holding the meeting or an approval of the minutes thereof, whether before or after the meeting, or who attends the meeting without protesting, before or at its commencement, the lack of notice to such director. All such waivers, consents and approvals shall be filed with the corporate records or made a part of the minutes of the meetings.

Section 3.16 Adjournment. A majority of the directors present, whether or not a quorum is present, may adjourn any meeting to another time and place. If the meeting is adjourned for more than twenty-four (24) hours, notice of any adjournment to another time or place shall be given prior to the time of the adjourned meeting to the directors who were not present at the time of the adjournment.

Section 3.17 Action Without Meeting.

(a) Any action required or permitted to be taken by the Board of Directors may be taken without a meeting, if all directors consent in writing to such action. Such written consents shall be filed with the minutes of the proceedings of the Board of Directors and shall have the same force and effect as the unanimous vote of such directors taken at a meeting.

(b) Directors may consent, vote, or otherwise take action under this Section 3.19 by a signed document transmitted by mail, messenger, courier, facsimile, or any other reasonable method satisfactory to the Chair (if any) or the President.

Section 3.18 Committees of the Board of Directors. The Board may, by resolution adopted by a majority of the number of directors then in office, create one or more committees of the Board of Directors ("Board Committee"), each consisting of at least two directors, to serve at the pleasure of the Board of Directors. Board Committees may be standing (no set term) or special (set term). Appointments of directors to Board Committees shall be made by the Board of Directors. Any such Board Committee, to the extent provided in a resolution of the Board, may be given the authority of the Board except with respect to:

(a) The approval of any action for which the Law requires approval of the Board or of a majority of the Board;

(b) The filling of vacancies on the Board of Directors or in any Board Committee;

(c) The amendment or repeal of its Bylaws or the adoption of new Bylaws;

(d) The amendment or repeal of any resolution of the Board of Directors which by its express terms is not so amendable or repealable;

(e) The appointment of Board Committees or the members thereof;

(f) The expenditure of corporate funds to support a nominee for director after there are more people nominated for director than can be elected; or

(g) The approval of any self-dealing transaction, as defined in § 5233(a) of the Law or any successor provision thereto.

Section 3.19 Meetings and Actions of Board Committees. Regular and special meetings and actions of Board Committees shall be governed by the provisions of this Article III applicable to meetings and actions of the Board of Directors; *provided, however,* that the Board may adopt rules for the conduct of the business of any Board Committee consistent with these Bylaws, or in the absence of rules adopted by the Board, the Board Committee may adopt such rules.

Section 3.20 Advisory Committees. The Board may, by resolution adopted by a majority of the number of directors then in office, create one or more advisory committees to serve at the pleasure of the Board of Directors. Each advisory committee shall have at least one (1) director as a member at all times. Other appointments to such advisory committees need not, but may, be directors. The Board of Directors shall appoint and discharge advisory committee members. All actions and recommendations of an advisory committee shall require ratification by the Board before being given effect.

Section 3.21 Fees, Compensation and Liability. The EBI shall not pay any compensation to directors for services rendered to the EBI as directors, except that directors may be reimbursed for expenses incurred in the performance of their duties to the EBI, in reasonable amounts as approved by the Board of Directors.

Section 3.22 Facility Committee. A committee of the Board of Directors (the "Facility Committee") shall, with the assistance of the Members and such outside consultants as may be authorized by the Board of Directors, prepare a detailed plan and budget for the construction and

financing of the Facility. The Facility Committee shall present such plan and budget to the Board of Directors, which shall approve or modify such plan and budget. In addition, the Facility Committee shall have such duties and responsibilities as are set forth in a committee charter of the Facility Committee approved by the Board of Directors.

Section 3.23 Finance Committee. A committee of the Board of Directors (the "Finance Committee") shall prepare a plan and budget relative to the day-to-day operations of the EBI. The Finance Committee shall present such plan and budget to the Board of Directors, which shall approve or modify such plan and budget. In addition, the Finance Committee shall have such duties and responsibilities as are set forth in a committee charter of the Finance Committee approved by the Board of Directors.

Section 3.24 Audit Committee. A committee of the Board of Directors (the "Audit Committee") shall have the responsibility on behalf of the EBI for the safeguarding of its assets, for the oversight of the quality and integrity of the accounting, financing reporting and internal control practices of the EBI, as well as other duties and responsibilities set forth in a committee charter approved by the Board of Directors. The Audit Committee shall consist of at least three directors, at least half of which are not members of the Finance Committee, as approved by the Board of Directors. No executive officer of the EBI shall be a member of the Audit Committee.

Section 3.25 Scientific Advisory Board. The EBI shall establish a group of qualified persons, each of whom distinguished himself or herself in a scientific field related to the purposes of the EBI, which group shall be known as the Scientific Advisory Board. The members of the Scientific Advisory Board shall be selected by the Board of Directors and shall serve for a term of two years, with no limits on the number of times a member may be re-appointed. The EBI shall endeavor to have represented on the Scientific Advisory Board

outstanding scientists from the United States and other nations. The Scientific Advisory Board shall serve in an advisory capacity to the President and the Board of Directors, making recommendations and suggestions to further the purposes of the EBI.

ARTICLE IV.
Corporate Officers of the EBI

Section 4.01 Officers. The officers of the EBI shall be a President, a Secretary, and a Chief Financial Officer. The Board of Directors shall have the power to designate additional corporate officers of the EBI, who need not be directors, with such duties, powers, titles, and privileges as the Board of Directors may fix. Any number of offices may be held by the same person except that neither the Secretary of the EBI nor the Chief Financial Officer may serve concurrently as President or Chair.

Section 4.02 Election. The officers of the EBI (except such officers as may be elected or appointed in accordance with the provisions of Section 4.03 or Section 4.05 of this Article IV) shall be chosen annually by, and shall serve at the pleasure of, the Board of Directors, and shall hold their respective offices until their resignation, removal, or other disqualification from service, or until their respective successors are elected and qualified.

Section 4.03 Chair's Power to Appoint Officers. The Board of Directors may empower the Chair, or if none, the President, to appoint or remove such other officers as the business of the EBI may require, each of whom shall hold office for such period, having such authority, and perform such duties as are provided in these Bylaws or as the Board of Directors from time to time may determine.

Section 4.04 Removal and Resignation.

(a) Any officer may be removed with or without cause by the Board of Directors at any time or by any officer upon whom such power of removal may be conferred by the Board of Directors.

(b) Any officer may resign at any time by giving written notice to the EBI without prejudice to the rights, if any, of the EBI under any contract to which the officer is a party. Any such resignation shall take effect at the date of the receipt of such notice or at any later time specified therein.

Section 4.05 Vacancies. A vacancy in any office because of death, resignation, removal, disqualification, or any other cause shall be filled in the manner prescribed in these Bylaws for regular election or appointment to such office, *provided, however,* that such vacancies may be filled as they occur and not necessarily at the annual meeting.

Section 4.06 Chair. The Chair, if any, shall preside at, or, if unavailable, shall designate another member of the Board of Directors to preside at, all meetings of the Board of Directors. The Chair shall exercise and perform such other powers and duties as may be assigned from time to time by the Board of Directors.

Section 4.07 President. Subject to such powers as may be given by the Board of Directors to the Chair, the President is the general manager and chief executive officer of the EBI and, subject to the control of the Board of Directors, shall have general supervision, direction, and control of the business and officers of the EBI. In the absence of the Chair, or if there is none, the President shall preside at all meetings of the Board of Directors. The President has the general powers and duties of management usually vested in the office of president and general manager of a corporation and such other powers and duties as may be prescribed by the Board of Directors.

Section 4.08 Specific Duties of President. Each year, in accordance with written policies approved by the Board of Directors or a Committee of the Board of Directors, the President (in conjunction with such other officers or employees of the EBI as the President shall determine) shall:

(a) prepare for the Board of Directors's approval a budget and plan of operation for the EBI, which shall include an estimate of operating expenses and costs;

(b) enter into such agreements as are necessary to build, operate, lease and maintain the Facility, including, without limitation, enter into a lease arrangement relating thereto with each of the Institutions;

(c) be responsible for the day-to-day operation of the Institute, including, without limitation, through the promulgation of Facility use rules intended to ensure compliance with applicable state and Federal regulations and through the hiring of staff or a third party to operate and maintain the Facility; and

(d) undertake such other activities as are consistent with the goals and purposes of the EBI.

Section 4.09 Vice-Presidents. In the absence or disability of the President, the Vice-Presidents, if any, are appointed in order of their rank as fixed by the Board of Directors or, if not ranked, a Vice-President designated by the Board of Directors, shall perform all the duties of the President and, when so acting, shall have all the powers of, and be subject to all the restrictions upon, the President. Vice-Presidents shall have such other powers and perform such other duties as from time to time may be prescribed for them by the Board of Directors.

Section 4.10 Secretary of the EBI.

(a) The Secretary of the EBI shall keep or cause to be kept, at the principal office of the EBI or such other place as the Board of Directors may order, a book of minutes of all meetings of the Board of Directors and any Board of Directors Committees. The minutes shall include the time and place of meetings, whether annual, regular, or special, and if special, how authorized, the notice thereof given, the names of those present at meetings of the Board of Directors and of the Board Committees, and the proceedings thereof. The Secretary of the EBI shall keep, or cause to be kept, at the principal office of the EBI, the original or a copy of the EBI's Articles and Bylaws, as amended.

(b) The Secretary of the EBI shall give, or cause to be given, notice of all meetings of the Board of Directors and its committees of the Board of Directors required by law or by these Bylaws to be given, shall keep the seal of the EBI, if any, in safe custody, and shall have such other powers and perform such other duties as may be prescribed by the Board of Directors.

Section 4.11 Chief Financial Officer.

(a) The Chief Financial Officer shall keep and maintain, or cause to be kept and maintained, adequate and correct books and accounts of the properties and business transactions of the EBI. The books of account shall be open at all reasonable times to inspection by a director.

(b) The Chief Financial Officer shall deposit, or cause to be deposited, all money and other valuables in the name and to the credit of the EBI with such depositories as may be designated by the Board of Directors. The Chief Financial Officer shall disburse the funds of the EBI as may be ordered by the Board of Directors, shall render to the President and the directors, whenever requested, an account of all transactions as Chief Financial Officer and of the financial condition of the EBI, and shall have such other powers and perform such other duties as may be prescribed by the Board of Directors.

Section 4.12 Compensation. The Board of Directors shall decide all matters relating to the compensation of any officer. No salaried officer serving on the Board of Directors shall be permitted to vote on his or her own compensation as an officer.

ARTICLE V.
Indemnification and Insurance

Section 5.01 Indemnification. The EBI shall, to the maximum extent permitted by the Law, indemnify each of its directors, officers, employees, and agents against expenses, judgments, fines, settlements, and other amounts actually and reasonably incurred in connection with any proceeding arising by reason of the fact that any such person is or was a director, officer, or agent of the EBI, and shall advance to such person expenses incurred in defending any such proceeding to the maximum extent permitted by the Law. For purposes of this Section 5.01 a "director," "officer," "employee," or "agent" of the EBI includes any person who is or was a director or officer of the EBI, or is or was serving at the request of the EBI as a director or officer of a EBI which was a predecessor EBI of the EBI or of another enterprise at the request of such predecessor EBI. The Board of Directors may, in its discretion, provide by resolution for indemnification of, or advance of expenses to, other agents of the EBI, and likewise may refuse

to provide for such indemnification or advance of expenses except to the extent such indemnification is mandatory under the Law.

Section 5.02 Insurance. The EBI shall have the power to purchase and maintain insurance on behalf of any director, officer, employee, or agent of the EBI against any liability asserted against or incurred by such person in such capacity or arising out of the person's status as such, whether or not the EBI would have the power to indemnify the person against such liability under the provisions of this Article V, *provided, however,* that the EBI shall have no power to purchase and maintain such insurance to indemnify any person in respect of a violation of Section 5233 of the Law (relating to self-dealing) or any successor provision.

ARTICLE VI.
Miscellaneous

Section 6.01 Fiscal Year. The fiscal year of the EBI shall be the calendar year unless otherwise fixed by the Board of Directors.

Section 6.02 Corporate Seal. The corporate seal, if any, shall be in such form as may be approved from time to time by the Board of Directors.

Section 6.03 Checks, Notes, and Contracts. The Board of Directors shall determine which persons shall be authorized from time to time on the EBI's behalf to sign checks, drafts, or other orders for payment of money; to sign acceptance notes, or other evidences of indebtedness; to enter into contracts; or to execute and deliver other documents and instruments.

Section 6.04 Endorsements of Documents; Contracts. Subject to the provisions of applicable law, any note, mortgage, evidence of indebtedness, contract, conveyance or other instrument in writing and any assignment or endorsement thereof executed or entered into between the EBI and any other person, when signed by both the Chair, the President or any Vice-President, and the Secretary of the EBI, any Assistant Secretary of the EBI, the Chief Financial

Officer or any Assistant Chief Financial Officer, shall be valid and binding on the EBI in the absence of actual knowledge on the part of the other person that the signing officers had no authority to execute the same. Any such instruments may be signed by any other person or persons and in such manner as from time to time shall be determined by the Board of Directors, and, unless so authorized by the Board of Directors, no officer, agent, or employee shall have any power or authority to bind the EBI by any contract or engagement or to pledge its credit or to render it liable for any purpose or amount.

Section 6.05 Representation of Shares of Other Corporations. The Chair, or any other officer or officers authorized by the Board of Directors or the Chair, are each authorized to vote, represent, and exercise on behalf of the EBI all rights incident to any and all shares of any other corporation or corporations standing in the name of the EBI. The authority herein granted may be exercised either by such officer in person or by any other person authorized to do so by proxy or power of attorney duly executed by said officer.

Section 6.06 Construction and Definitions. Unless the context otherwise requires, the general provisions, rules of construction, and definitions contained in the Law shall govern the construction of these Bylaws.

Section 6.07 Amendment of Articles and Bylaws. The Articles and Bylaws may be adopted, amended, or repealed in whole or in part by majority vote of all directors then in office.

Section 6.08 Maintenance of Certain Records. The accounting books, records, and minutes of proceedings of the Board of Directors and of the executive committee, if any, of the Board of Directors shall be kept at such place or places designated by the Board of Directors, or, in the absence of such designation, at the principal business office of the EBI. The minutes shall be kept in written or typed form, and the accounting books and records shall be kept either in

written or typed form, or in any other form capable of being converted into written, typed, or printed form.

Section 6.09 Annual Report. No later than one hundred twenty (120) days after the close of the EBI's fiscal year, the EBI shall make available to each director an annual report in accordance with Section 6321 of the Law, which shall be accompanied by any report of independent accountants or, if there is no such accountant's report, the certificate of an authorized officer of the EBI that such statements were prepared without audit from the books and records of the EBI.

Section 6.10 Annual Statement of Certain Transactions and Indemnifications. The EBI shall make available to its directors an annual statement affixed to the annual report described in Section 6.09 of these Bylaws which briefly describes (a) any transaction(s) during the previous fiscal year involving both (i) the EBI and either a director or officer of the EBI (or its parent or subsidiary) or any holder of more than ten percent (10%) of the voting power of the EBI (or its parent or its subsidiary) and (ii) more than $50,000; or (b) any indemnifications or advances aggregating more than $10,000 paid during the fiscal year to any officer or director of the EBI.

Section 6.11 Loans to Directors and Officers. The EBI shall not make any loan of money or property to or guarantee the obligation of any director or officer, unless approved by the Attorney General; *provided, however,* that the EBI may advance money to a director or officer of the EBI or of its parent or any subsidiary for expenses reasonably anticipated to be incurred in the performance of the duties of such director or officer, provided that in the absence of such advance, such director or officer would be entitled to be reimbursed for such expenses by the EBI, its parent, or any subsidiary. The provisions of this Section 6.11 do not apply to (a) the payment of premiums in whole or in part by the EBI on a life insurance policy of a director or

officer so long as repayment to the EBI of the amount paid by it is secured by the proceeds of the policy and its cash surrender value; or (b) a loan of money to or for the benefit of an officer in circumstances where it is necessary, in the judgment of the Board of Directors, to provide financing for the purchase of the principal residence of the officer in order to secure the services or continued services of the officer and the loan is secured by real property located in the state of California.

[*signature page follows*]

THIS IS TO CERTIFY:

That I am the duly elected, qualified, and acting Secretary of EBI and that the foregoing Bylaws were adopted as the Bylaws of the EBI as of _____ by the Board of Directors of the EBI.

Dated: ___, 2007

_____
Name: _____
Title: Secretary of the EBI

G. Ground Lease Terms, *Sample*

Above *View from Torrey Pines State Reserve*

Sample Ground Lease Terms

1. ***GROUND LESSEE:*** BP or its designee, subject to approval of The Regents of the University of California.

2. ***GROUND LESSOR:*** The Regents of the University of California, on behalf of the San Diego Campus ("UCSD").

3. ***LOCATION:*** Parcel _ in the UCSD Science Research Park (SRP)

4. ***AS-IS:*** Parcel would be leased "as-is" in its present condition and subject to all existing conditions of title and applicable governmental regulations, except as otherwise provided herein.

5. ***PROJECT DEVELOPMENT:*** BP would have exclusive use of the leased parcel and would have constructed a Building of approximately _____ square feet of gross Building square footage (the development rights for Parcel _). BP would obtain its own construction funding and provide evidence of such to UCSD. BP would obtain payment and performance bonds for completion of the project. UCSD understands that BP would retain the services of a third party to develop, own, and manage the Building, and that BP would occupy the Building as the site for the Energy Biosciences Institute (EBI) under an operating lease.

6. ***GENERAL BUILDING DESCRIPTION:*** The size and general exterior configuration of the Building would be consistent with the UCSD SRP Development Concept. A more detailed definition of the Building shell would be incorporated into the Ground Lease.

7. ***DESIGN AND CONTRACTOR TEAM:*** UCSD would have the right to approve the architect and general contractor selected by BP for construction of the Building shell and tenant improvements.

8. ***DESIGN PROCESS, APPROVALS AND FEATURES:*** UCSD's Design Review Board and Board of Regents approvals would be required for the conceptual and schematic plans for the project. BP's project and completed building would comply with the UCSD Building Design Standards.

   In general, UCSD is the permitting and inspection agency for development of buildings in the UCSD SRP. Development of the Building would require BP to pay Plan Review fees and Building Permit fees to UCSD. In addition, BP would be responsible for securing and paying for approvals from 1) the State's Architect's Office for ADA compliance prior to beginning of construction, 2) the State Fire Marshal through the UCSD Fire Marshal for plan review and construction inspection, and 3) UCSD's Environmental Health and Safety Department ("EH & S"). BP would also coordinate with UCSD Facilities Design and Construction to secure an independent seismic review.

9. ***USE****:* The Permitted Use of the property is for scientific research purposes, provided that significant linkages between research programs conducted in the Building and current or future proposed research and/or instruction at UCSD, are clearly demonstrated and that research programs do not include research designated by the Federal Government as classified. Such significant linkages would be memorialized in a separate agreement, the EBI Agreement, between

BP and UCSD. Provided that the preceding conditions are met, "Permitted Uses" for the premises would be limited to any one or more of the following:

a. Research, product development, prototype testing, along with the offices, laboratories or other facilities that support these activities;

b. Production or assembly of prototypes and pilot facilities that are related to on-site research and development activities or the testing of production processes located elsewhere;

c. Provision of research-related services that support and enhance UCSD's academic programs.

10. ***GROUND LEASE TERM:*** The term of the Ground Lease would commence upon execution of the Ground Lease by the parties ("Ground Lease Commencement Date"). The Ground Lease would be for a term of fifty-two (52) years from the Ground Lease Commencement Date.

11. ***GROUND LEASE RENT:*** BP would pay UCSD ground lease rent as follows:

Pre-construction Ground Rent would be $_____ annually, payable one-twelfth monthly. The first Pre-construction Ground Rent payment would be due on the Ground Lease Commencement Date and such payments would continue up until the first Post-construction Ground Rent payment is due. Prior to the date Post-Construction Ground Rent is first due, BP's obligations under the Ground Lease would include the payment of the monthly Pre-construction Ground Rent, the payment of property taxes and/or possessory use taxes, and the payment of any utilities costs and other site costs.

Post-construction Ground Rent would commence ("Post-construction Rent Commencement Date") on the day that any Certificate of Occupancy is issued for any portion of the site or the Building and would be payable monthly thereafter. Post-construction Ground Rent would be based on a 10% annual rate of return ("Year 1 Land Return") on the mutually accepted appraisal of the land that takes into consideration the development rights of _____ gross building square feet as defined in Paragraph 13 ("Appraised Land Value"). Appraised Land Value shall be determined as provided for in Paragraph 31 below.

12. ***GROUND LEASE RENT ADJUSTMENTS:*** Commencing on the fifth (5^{th}) anniversary of the Post-construction Rent Commencement Date, and every five (5) years thereafter (excluding Re-Appraisal Dates, as defined below), Post-construction Ground Rent would be adjusted upward for the next five-year period by the actual cumulative increase in the CPI (All Urban Consumers/LA-Riverside-Orange County index) during the prior five-year period, by a factor of no less than 15% and no greater than 50%.

Every fifteen (15) years, commencing on the fifteenth (15^{th}) anniversary of the Post-construction Rent Commencement Date ("Re-Appraisal Dates"), the land would be re-appraised taking into consideration the development rights of _____ gross building square feet as defined in Paragraph 5 ("Re-appraised Land Value"). The parties would agree upon a mutually acceptable re-appraisal process, as outlined in Paragraph 22 which would be incorporated into the Ground Lease.

On each Re-Appraisal Date, BP's annual Post-construction Ground Rent would be adjusted to an amount that yields 10% (the Year 1 Land Return rate) on the Re-appraised Land Value. In no event would the re-appraisal adjustment result in a decrease in the Post-construction Ground

Rent. Post-construction Ground Rent following re-appraisal would be adjusted by the CPI every five years as provided for in paragraph one of this Paragraph 12.

13. ***COMMON AREA OPERATING EXPENSES:*** The common area and the formula for calculation of proportionate share of its operating expenses would be contained in the Ground Lease. BP would have the right to review and audit the common area operating expenses and the allocation of costs to BP on an annual basis.

14. ***PARKING:*** BP would provide ____ parking spaces on Parcel _. BP would have exclusive rights to parking spaces located on its leased parcel, the use of which BP shall regulate. Other parking for BP would be in the shared common area SRP parking lots for a parking ratio of 3.5/1,000 rsf.

15. ***BUILDING FINANCING:*** BP or its development partner would obtain construction funding for the Building. UCSD would have approval of any mortgages or deeds of trust that would encumber BP's leasehold interest or the Building. The Ground Lease would provide that for BP's permanent financing or for any purchaser of the Building, such Building financing shall not exceed a seventy-five percent (75%) loan-to-value ratio, and a no less than 1.25 debt coverage ratio shall be maintained, determined at the time the loan is made. UCSD's interest in the land and the Ground Lease would not be subordinated to any Building financing arrangements, nor shall any encumbrance of BP's interest in the project be permitted to extend beyond the term of the ground lease. Upon refinancings, including initial permanent financing, UCSD would receive 1% of net proceeds (after repayment of the then-existing debt and subtraction from gross proceeds of all reasonable costs of refinancing).

16. ***TRANSFER OF BUILDING TITLE:*** Upon termination of the Ground Lease, title to the Building and other improvements (but not including trade fixtures, furniture, equipment and personal property) would pass unencumbered to The Regents of the University of California.

17. ***UCSD'S RIGHT TO PURCHASE BUILDING:*** If BP or its designee elects to sell the Building and leasehold interest in the Ground Lease to anyone other than to any entity which controls, is controlled by or is under common control with BP or its designee (collectively, "Exempt Party"), BP would first notify UCSD and UCSD would have both a right of first offer and right of first refusal to purchase the Building and leasehold interest. If UCSD makes an offer to purchase which BP rejects, then BP may sell to another; provided, however, that if BP enters into a sale agreement under substantially more favorable terms to the buyer, or if the purchase price is not at least 95% of that offered by UCSD, then BP would provide UCSD the opportunity to purchase the building under the more favorable price and terms. UCSD's right of first offer would not apply to any sale or transfer of the Building to an Exempt Party. If BP has not provided to UCSD a right to exercise its right of first offer, and an offer to buy the Building and leasehold interest which BP desires to accept is received by BP from a non-Exempt Party, then BP shall provide UCSD with written notice thereof and UCSD shall be given the right to match the offer on the same terms and conditions. The Ground Lease would include appropriate time frames for UCSD's response periods. The purchase rights granted to UCSD under this Paragraph 17 shall survive any sale of the Building and apply to subsequent transactions.

    If UCSD does not exercise its right to purchase the building and leasehold interest, then BP would have the right to sell the building and leasehold interest to a Non-Exempt Party meeting the following criteria and conditions: (i) the Non-Exempt Party would be subject to the Use requirements outlined in Paragraph 9; (ii) the Non-Exempt Party would have a minimum net worth of $100 million; (iii) BP, UCSD or another entity with a substantial relationship to UCSD, subject to UCSD's approval, or any combination of the foregoing, must continue to lease greater

than one-half of the Building space upon the sale of the Building; (iv) for the initial sale of the Building and leasehold interest, following completion of construction, BP would pay an assignment fee to UCSD. If the Non-Exempt Party Buyer qualifies as an "Eligible Party" as provided below:

a. A person or entity with which UCSD has or may be entering into technology licenses, research grants, contracts, research affiliation agreements, donations, or gift agreements related to research or instructional support, unless subject to a dispute between UCSD and licensee, contractor, affiliate, or donor, subject to UCSD's sole approval.

then, except in the event of the initial sale of the Building and leasehold interest following completion of construction, Building Seller would pay UCSD a reduced assignment fee.

18. ***RIGHT TO LEASE:*** If BP elects to lease any Building space to an entity other than BP or EBI or another Exempt Party, BP would first notify UCSD and UCSD would have a first right of offer to lease the space. UCSD shall be offered a minimum lease term of 5 years at 90 % of fair market rental rate. If BP makes an offer to lease Building space to UCSD that UCSD rejects, then BP would have the right to lease such space to another Non-Exempt Party subtenant meeting the following criteria and conditions: (i) subtenants would be subject to the Use requirements outlined in Paragraph 9; (ii) BP, UCSD or another entity with a substantial relationship to UCSD, or any combination of the foregoing, must continue to lease greater than one-half of the Building space upon the execution of the sublease; and (iii) the Non-Exempt Party must qualify as an "Eligible Party" as provided above.

19. ***ASSIGNMENT:*** BP would have the right, following completion of the Building, to assign the Building and/or the Ground Lease to an Exempt Party (collectively, "Exempt Assignee"). BP would not be released from further liability under the Ground Lease for any transfer of the Ground Lease to an Exempt Assignee. BP would be released from further liability under the Ground Lease following any transfer of the Building and Ground Lease to UCSD, except in the event of default. Any other assignments of the Building and/or ground lease would be subject to approval by UCSD.

20. ***HAZARDOUS MATERIALS AND ENVIRONMENTAL REVIEW:*** Prior to commencement of construction, BP would secure, at its cost, a Phase I report. The Regents of the University of California serves as the lead agency for compliance with the California Environmental Quality Act (CEQA). BP would retain a consultant, at its cost, to conduct the environmental work for project compliance with CEQA. UCSD would provide direction and oversight of the work to ensure that the work products are in conformance with State law and University requirements regarding CEQA, and are consistent with the work typically prepared by UCSD for University projects. BP would comply with all laws and regulations in its use of hazardous materials in the Building. BP would provide annually to UCSD a list of the chemicals and materials it intends to use in the Building, and UCSD shall have the right to inspect the premises annually if UCSD is the regulatory body. If the City or County of San Diego is to fulfill this role, then BP would be subject to the City or County of San Diego's inspections and inventory regulations in lieu of UCSD oversight.

21. ***IN LIEU OF TAXES:*** BP would be responsible for all payments, fees and taxes imposed in lieu of property taxes or possessory use or interest taxes, and other taxes otherwise payable by BP on BP's interests or other assets under the Ground Lease.

22. ***APPRAISAL:*** Post-construction Rent would be based upon a mutually acceptable appraisal of the land that takes into consideration of the development rights as defined in Paragraph 5, the Appraised Land Value. It would be the intention of the parties to reach agreement on a single MAI appraiser to determine the Appraised Land Value. If the parties are unable to reach agreement on a single appraiser, then each party would appoint an MAI appraiser with at least 10 years experience in appraising land for development of scientific research facilities in the Torrey Pines area of San Diego, and would deliver notice of such selection to the other party. If the two appraisers are so selected, then they shall each independently determine the Appraised Land Value. If the two appraisals are within 10% of each other, they would be averaged, and the average shall be the Appraised Land Value. If the two appraisals disagree by an amount greater than 10% (using the higher appraisal as the reference), the two appraisers would appoint a third appraiser. The third appraiser would then independently determine the Appraised Land Value. Thereupon, the Appraised Land Value would be the average of the two appraisals that are closest in value, and the third appraisal would be disregarded. Each party would pay the cost of the appraiser it selects, and the cost of either the single appraiser, if used, or the third appraiser, would be shared equally by the parties.

23. ***OTHER TERMS:*** The Ground Lease would include such other mutually agreeable terms and conditions as are customarily included in ground leases of this type.

This term sheet is contingent upon the following:

a. Receipt of all necessary approvals by Senior Management and the Board of BP

b. BP"s and UCSD's mutual approval of all terms, conditions and final ground lease documentation.

c. Receipts of all necessary approvals by UCSD.

It is strictly understood that the terms and conditions referenced above shall not be binding upon BP or UCSD, until such time as the Ground Lease and related documents have been approved by both BP and UCSD and further provided, that such ground lease and related documents have been fully executed by BP and UCSD.

H. CBEST *Committees*

Above *Beardshear building—courtesy of ISU*

UCSD CBEST Committees

Executive Committee

John Orcutt, *Assoc. VC Research; Director, Center for Earth Observations and Applications, UCSD; Chair*
Steve Briggs, *Professor of Biology, UCSD*
Ed Frieman, *Director Emeritus, SIO, UCSD*
Tony Haymet, *Director, SIO, UCSD*
Pat Schnable, *Director, Center for Plant Genomics, ISU*
Frieder Seible, *Dean, Jacobs School of Engineering, UCSD*
Suresh Subramani, *Interim Dean, Biological Sciences, UCSD*
Larry Smarr, *Director, Calit2, UCSD*
Mark Thiemans, *Dean, Physical Sciences, UCSD*
John Wooley, *Assoc. VC Research, UCSD*

Budgets

Pat Jordan, *Center for Earth Observations and Applications, UCSD; Chair*
Ann Briggs-Addo, *Asst. VC Administration, UCSD*
Linda Dale, *Director, UCSD Contracts and Grants, UCSD*
Pam Daener, *Asst. Dean, Biological Sciences, UCSD*
Marianne Generales, *Asst. VC, Research, UCSD*
Carolyn Keen, *Center for Earth Observations and Applications, UCSD*
Steve Ross, *Asst. Dean, Jacobs School of Engineering, UCSD*
Nancy Wilson, *Director, SIO Contracts and Grants, UCSD*

Education, Outreach, Ethics and Communications (EOEC)

Cheryl Peach, *SIO, UCSD; Chair*
Lynn Burnstan, *UCSD-TV*
Mike Kalichman, *Director, Research Ethics Program, UCSD*
Kim McDonald, *UCSD Communications, Physical and Biological Sciences, UCSD*
Sherry Seethaler, *Director for Education and Outreach, Physical and Biological Sciences, UCSD*
Stacie Spector, *UCSD Communications*
Peter Thomas, *UCSD Global Connect*
Rich Wargo, *UCSD-TV*

Collaborations

John Wooley, *Assoc. VC Research, UCSD, Chair*
Steve Briggs, *Professor of Biology, UCSD*
Charles Cantor, *Sequenom*
Ed Frieman, *Director Emeritus, SIO, UCSD*
Eduardo Macagno, *Professor, Biological Sciences, UCSD*

Management Models and IPR

Art Ellis, *VC Research, UCSD; Chair*
Julie Adelson, *Venter Institute Counsel*
Jordan Becker, *Sr. VP, CTO, SAIC*
Bill Decker, *UCSD Tech Transfer*
Robert Friedman, *Vice President, Environmental Energy and Policy, Venter Institute*
Ed Frieman, *Director Emeritus, SIO, UCSD*
Steve Kay, *Chairman, Department of Biochemistry, TSRI*
John Orcutt, *Assoc. VC Research; Director, Center for Earth Observations and Applications, UCSD*
Alan Paau, *UCSD Tech Transfer*
Duane Roth, *UCSD CONNECT*
Robert Sullivan, *Dean, Rady School of Management, UCSD*

Science and Technology

Steve Briggs, *Professor of Biology, UCSD; Chair*
Robert Brown, *Director, Center for Sustainable Environmental Technologies; Director, Office of Biorenewables Programs, ISU*
Marv Frazier, *Vice President of Research, Venter Institute*
Robert Friedman, *Vice President, Environmental Energy and Policy, Venter Institute*
David Galas, *Vice President and Chief Scientific Officer for Biological and Life Sciences, Battelle National Institute*
Bernhard Palsson, *Professor of Bio-Engineering, UCSD*
Kim Prather, *Professor of Chemistry, UCSD*
Doug Ray, *Chief Research Officer, PNNL*
Richard Somerville, *Professor of Meteorology, SIO, UCSD*
John Wooley, *Assoc. VC Research, UCSD*

Space and Buildings

John Orcutt, *Assoc. VC Research; Director, Center for Earth Observations and Applications, UCSD; Chair*
Nancy Kossan, *UCSD Real Estate*
Jeff Steindorf, *UCSD Capital Planning*

I. Exclusive License Agreement, *Sample*

Above *Tijuana River National Estuarine Research Reserve*

SAMPLE EXCLUSIVE LICENSE AGREEMENT

BETWEEN

THE ENERGY BIOSCIENCE INSTITUTE OF SAN DIEGO

AND

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

FOR

INVENTION DISCLOSURE NO. SD__-___

[Note: text in "red" or is "boxed" is for use only when applicable]

TABLE OF CONTENTS

LICENSE AGREEMENT

This agreement ("Agreement") is made by and between the Energy Biosciences Institute of San Diego, a <STATE> corporation having an address at <ADDRESS> ("LICENSEE") and The Regents of the University of California, a California corporation having its statewide administrative offices at 1111 Franklin Street, Oakland, California 94607-5200 ("UNIVERSITY"), and represented by its San Diego campus having an address at the University of California San Diego, Technology Transfer & Intellectual Property Services, Mail Code 0910, 9500 Gilman Drive, La Jolla, California 92093-0910 ("UCSD").

This Agreement is effective on _____ ("Effective Date").

RECITALS

WHEREAS, the inventions disclosed in UCSD Disclosure No. SD__-___ and titled "DISCLOSURE TITLE - MUST BE ACCURATE" ("Invention"), were made in the course of research at UCSD by Dr. _____ and his/her associates (hereinafter and collectively, the "Inventors") and are covered by Patent Rights as defined below;

WHEREAS, the research was sponsored by LICENSEE and therefore LICENSEE has the right to obtain this license;

WHEREAS, the research was also sponsored in part by the Government of the United States of America and as a consequence this license is subject to overriding obligations to the Federal Government under 35 U.S.C. §§ 200-212 and applicable regulations;

WHEREAS, the Inventors are employees of UCSD, and they are obligated to assign all of their right, title and interest in the Invention to UNIVERSITY and have done so;

WHEREAS, LICENSEE entered into a secrecy agreement (UC Control No. xx-xx-xxxx) with UNIVERSITY, effective _____, for the purpose of evaluating the Invention for the purpose of license determination;

WHEREAS, LICENSEE entered into a Letter of Intent (UC Control No. xx-xx-xxxx) with UNIVERSITY, effective _____, for the purpose of negotiating this Agreement;

WHEREAS, UNIVERSITY is desirous that the Invention be developed and utilized to the fullest possible extent so that its benefits can be enjoyed by the general public; and

WHEREAS, LICENSEE is desirous of obtaining certain non-exclusive rights from

UNIVERSITY for commercial development, use, and sale of the Invention, and the UNIVERSITY is willing to grant such rights.

NOW, THEREFORE, the parties agree:

ARTICLE 1. DEFINITIONS

The terms, as defined herein, shall have the same meanings in both their singular and plural forms.

1.1 "BP" means _____[BP shall give its best legal description of its business] _____and "BP Affiliated Business" means any business that controls BP, is controlled by BP, or is contractually obligated to act for the benefit of BP.

1.2 "Sublicense" means an agreement into which LICENSEE enters with BP or BP Affiliated Businesses for the purpose of granting certain rights that UNIVERSITY granted to LICENSEE under this Agreement. "Sublicensee" means a third party with whom LICENSEE enters into a Sublicense.

1.3 "Field" means all uses related to the production and commercialization of energy.

1.4 "Territory" means world-wide where Patent Rights exist and subject to Paragraph 5.1(c).

1.5 "Term" means the period of time beginning on the Effective Date and ending on the expiration date of the longest-lived Patent Rights for Invention.

1.6 "Licensed Method" means any method that is covered by Patent Rights, the use of which would constitute, but for the license granted to LICENSEE under this Agreement, an infringement, an inducement to infringe or contributory infringement, of any pending or issued claim within Patent Rights had LICENSEE not had rights in any patent or patent application claiming Invention.

1.7 "Licensed Product" means any service, composition or product that is covered by the claims of Patent Rights, or that is produced by the Licensed Method, or the manufacture, use, sale, offer for sale, or importation of which would constitute, but for the license granted to LICENSEE under this Agreement, an infringement, an inducement to infringe or contributory infringement, of any pending or issued claim within the Patent Rights had LICENSEE not had rights in any patent or patent application claiming Invention.

1.8 “Patent Costs” means all out-of-pocket expenses for the preparation, filing, prosecution, and maintenance of all United States and foreign patents included in

Patent Rights. Patent Costs shall also include reasonable out-of-pocket expenses for patentability opinions, inventorship determination, preparation and prosecution of patent application, re-examination, re-issue, interference, opposition activities related to patents or applications in Patent Rights and a 15% patent service fee.

1.9 "Patent Rights" means UNIVERSITY's right in any of the following: the US patent application (serial number _____, titled "_____") disclosing and claiming the Invention, filed by Inventors and assigned to UNIVERSITY; and continuing applications thereof including divisions, substitutions, and continuations-in-part (but only to extent the claims thereof are enabled by disclosure of the parent application); any patents issuing on said applications including reissues, reexaminations and extensions; and any corresponding foreign applications or patents

1.10 "Government Rights" means all the applicable provisions of any license to the United States Government executed by UNIVERSITY and the overriding obligations to the Federal Government under 35 U.S.C. §§ 200-212 and applicable governmental implementing regulations.

ARTICLE 2. GRANTS

2.1 **License.** Subject to the limitations set forth in this Agreement and Government's Rights, UNIVERSITY hereby grants to LICENSEE, and LICENSEE hereby accepts, a license under Patent Rights to make and have made, to use and have used, to sell and have sold, to offer for sale, and to import and have imported Licensed Products and to practice Licensed Methods in the Field within the Territory and during the Term.

The license granted herein is exclusive for Patent Rights.

2.2 **Sublicense.** The license granted in Paragraph 2.1 includes the right of LICENSEE to grant Sublicense to BP Affiliated Businesses. Any Sublicense granted by LICENSEE shall terminate upon the expiration or termination of this Agreement for any reason.

2.3 **Reservation of Rights.** UNIVERSITY reserves the right to:

(a) use the Invention, and Patent Rights for educational and research purposes;

(b) publish or otherwise disseminate any information about the Invention at any time; and

(c) allow other nonprofit institutions to use Invention, and Patent Rights for

educational and research.

ARTICLE 3. CONSIDERATION

3.1 **Fees and Royalties.** The parties hereto understand that the fees and royalties payable by LICENSEE to UNIVERSITY under this Agreement are partial consideration for the license granted herein to LICENSEE under Patent Rights. LICENSEE shall pay UNIVERSITY:

(a) a **license issue fee** of ___ dollars (US$_____), within thirty (30) days after the Effective Date;

(b) an annual **license maintenance fees** of ___ dollars (US$_____) per year and payable on the first anniversary of the Effective Date and annually thereafter on each anniversary; provided however, that LICENSEE's obligation to pay this fee shall end in the year when LICENSEE or its Sublicensee is using the licensed Patent Rights in commerce;

(c) an **annual royalty** of ___ dollars (US$_____) per year and payable on the each anniversary of the Effective Date for the years when LICENSEE or its Sublicensee is using the licensed Patent Rights in commerce.

All fees and royalty payments specified in Paragraphs 3.1(a) through 3.1(c) above shall be paid by LICENSEE pursuant to Paragraph 4.3 and shall be delivered by LICENSEE to UNIVERSITY as noted in Paragraph 10.1.

3.2 **Patent Costs.** LICENSEE shall reimburse UNIVERSITY all past (prior to the Effective Date) and future (on or after the Effective Date) Patent Costs incurred in the Territory within thirty (30) days following the date an itemized invoice is sent from UNIVERSITY to LICENSEE.

3.3 **Due Diligence.**

(a) LICENSEE shall either directly or through its Sublicensee(s):

(i) diligently proceed with the use of the licensed Patent Rights in commerce,

(ii) annually spend not less than _____ dollars (US$_____) for the effort in (i) above. LICENSEE may, at its sole option, fund the research of any one of the Inventors at UCSD and credit the amount of such funding actually paid to UCSD against its obligation under this paragraph;

(iii) reasonably fill the market demand for Licensed Products following commencement of marketing at any time during the term of this Agreement; and

(iv) obtain all necessary governmental approvals for the manufacture, use and sale of Licensed Products.

(b) If LICENSEE fails to perform any of its obligations specified in Paragraphs 3.3(a)(i)-(vi), then UNIVERSITY shall have the right and option to either terminate this Agreement or change LICENSEE's exclusive license to a nonexclusive license. This right, if exercised by UNIVERSITY, supersedes the rights granted in Article 2.

ARTICLE 4. REPORTS, RECORDS AND PAYMENTS

4.1 **Reports.**

(a) **Progress Reports**.

(i) Beginning on the first anniversary of Effecttive Date and ending on the date of first use of the licensed Patent Rights in commerce anywhere in the Territory, LICENSEE shall report to UNIVERSITY progress covering LICENSEE's (and Sublicensee's) activities for the preceding twelve months to develop the commercial use of licensed Patent Rights. Such annual reports shall be due within sixty days of the reporting period and include a summary of work completed, summary of work in progress, current schedule of anticipated events or milestones, plans for commercial use of Patent Rights, and summary of resources (dollar value) spent in the reporting period.

(ii) LICENSEE shall also report to UNIVERSITY, in its immediately subsequent progress report, the date of first commercial use of the licensed Patent Rights.

(b) **Royalty Reports.** After the first commercial use of Patent Rights anywhere in the world, LICENSEE shall submit to UNIVERSITY an annual summary of the countries within the Territory where commercial use of the licensed Patent Rights occurred in the prior twelve months.

4.2 **Records & Audits.**

(a) LICENSEE shall keep, and shall require its Sublicensees to keep, accurate and correct records of all commercial use of the licensed Patent Rights for at least five (5) years following a given reporting period.

(b) All records shall be available during normal business hours for inspection at

the expense of UNIVERSITY by UNIVERSITY's Internal Audit Department or by a Certified Public Accountant selected by UNIVERSITY and in compliance with the other terms of this Agreement for the sole purpose of verifying reports and payments or other compliance issues. Such inspector shall not disclose to UNIVERSITY any information other than information relating to the accuracy of reports and payments made under this Agreement or other compliance issues. In the event that any such inspection shows an under reporting and underpayment in excess of five percent (5%) for any twelve-month (12-month) period, then LICENSEE shall pay the cost of the audit as well as any additional sum that would have been payable to UNIVERSITY had the LICENSEE reported correctly, plus an interest charge at a rate of ten percent (10%) per year. Such interest shall be calculated from the date the correct payment was due to UNIVERSITY up to the date when such payment is actually made by LICENSEE. For underpayment not in excess of five percent (5%) for any twelve-month (12-month) period, LICENSEE shall pay the difference within thirty (30) days without interest charge or inspection cost.

4.3 **Payments**.

(a) All fees, patent costs reimbursement and annual royalties due UNIVERSITY shall be paid in United States dollars and all checks shall be made payable to "The Regents of the University of California", referencing UNIVERSITY's taxpayer identification number, 95-6006144, and send to UCSD according to Paragraph 10.1 (Correspondence).

(b) Late Payments. In the event annual royalty, patent costs reimbursement and/or fee payments are not received by UNIVERSITY when due, LICENSEE shall pay to UNIVERSITY interest charges at a rate of ten percent (10%) per year. Such interest shall be calculated from the date payment was due until actually received by UNIVERSITY.

ARTICLE 5. PATENT MATTERS

5.1 **Patent Prosecution and Maintenance**.

(a) Provided that LICENSEE has reimbursed UNIVERSITY for Patent Costs pursuant to Paragraph 3.2, UNIVERSITY shall diligently prosecute and maintain the United States and, if available, foreign patents, and applications in Patent Rights using counsel of its choice. UNIVERSITY shall provide LICENSEE with copies of all relevant documentation relating to such prosecution and LICENSEE shall keep this documentation confidential. The counsel shall take instructions only from UNIVERSITY.

(b) UNIVERSITY shall consider amending any patent application in Patent Rights to include claims reasonably requested by LICENSEE to protect the products

contemplated to be sold by LICENSEE under this Agreement.

(c) LICENSEE may elect to terminate its reimbursement obligations with respect to any patent application or patent in Patent Rights upon three (3) months' written notice to UNIVERSITY. UNIVERSITY shall use reasonable efforts to curtail further Patent Costs for such application or patent when such notice of termination is received from LICENSEE. UNIVERSITY, in its sole discretion and at its sole expense, may continue prosecution and maintenance of said application or patent, and LICENSEE shall then have no further license with respect thereto. Non-payment of any portion of Patent Costs with respect to any application or patent may be deemed by UNIVERSITY as an election by LICENSEE to terminate its reimbursement obligations with respect to such application or patent. The University is not obligated to file, prosecute, or maintain Patent Rights outside of the territory at any time or to file, prosecute, or maintain Patent Rights to which Licensee has terminated its License hereunder.

5.2 **Patent Infringement.**

(a) If LICENSEE learns of any substantial infringement of Patent Rights, LICENSEE shall so inform UNIVERSITY and provide UNIVERSITY with reasonable evidence of the infringement. Neither party shall notify a third party of the infringement of Patent Rights without the consent of the other party. Both parties shall use reasonable efforts and cooperation to terminate infringement without litigation.

(b) LICENSEE may request UNIVERSITY to take legal action against such third party for the infringement of Patent Rights. Such request shall be made in writing and shall include reasonable evidence of such infringement and damages to LICENSEE. If the infringing activity has not abated ninety (90) days following LICENSEE's request, UNIVERSITY shall elect to or not to commence suit on its own account. UNIVERSITY shall give notice of its election in writing to LICENSEE by the end of the one-hundredth (100th) day after receiving notice of such request from LICENSEE. LICENSEE may thereafter bring suit for patent infringement at its own expense, if and only if UNIVERSITY elects not to commence suit and the infringement occurred in a jurisdiction where LICENSEE has an exclusive license under this Agreement for the infringing activity. If LICENSEE elects to bring suit, UNIVERSITY may join that suit at its own expense. If UNIVERSITY is involuntarily joined the suit by action of LICENSEE, LICENSEE shall be responsible for the costs associated therewith.

(c) Each party shall cooperate with the other in litigation proceedings at the expense of the party bringing suit. Litigation shall be controlled by the party bringing the suit, except that UNIVERSITY may be represented by counsel of its choice in any suit brought by LICENSEE and at LICENSEE's expense.

5.3 **Patent Marking.** LICENSEE shall mark all Licensed Products made, used or sold

under the terms of this Agreement, or their containers, in accordance with the applicable patent marking laws.

ARTICLE 6. GOVERNMENTAL MATTERS

6.1 **Governmental Approval or Registration.** If this Agreement or any associated transaction is required by the law of any nation to be either approved or registered with any governmental agency, LICENSEE shall assume all legal obligations to do so. LICENSEE shall notify UNIVERSITY if it becomes aware that this Agreement is subject to a United States or foreign government reporting or approval requirement. LICENSEE shall make all necessary filings and pay all costs including fees, penalties, and all other out-of-pocket costs associated with such reporting or approval process.

6.2 **Export Control Laws.** LICENSEE shall observe all applicable United States and foreign laws with respect to the transfer of Licensed Products and related technical data to foreign countries, including, without limitation, the International Traffic in Arms Regulations and the Export Administration Regulations.

6.3 **Preference for United States Industry.** If LICENSEE sells a Licensed Product or Combination Product in the US, LICENSEE shall manufacture said product substantially in the US.

ARTICLE 7. TERMINATION OF THE AGREEMENT

7.1 **Termination by UNIVERSITY.** If LICENSEE fails to perform or violates any term of this Agreement, then UNIVERSITY may give written notice of default ("Notice of Default") to LICENSEE. If LICENSEE fails to cure the default within sixty (60) days of the Notice of Default, UNIVERSITY may terminate this Agreement and the license granted herein by a second written notice ("Notice of Termination") to LICENSEE. If a Notice of Termination is sent to LICENSEE, this Agreement shall automatically terminate on the effective date of that notice. Termination shall not relieve LICENSEE of its obligation to pay any fees owed at the time of termination and shall not impair any accrued right of UNIVERSITY.

7.2 **Termination by LICENSEE.**

(a) LICENSEE shall have the right at any time and for any reason to terminate this Agreement upon a ninety (90)-day written notice to UNIVERSITY. Said notice shall state LICENSEE's reason for terminating this Agreement.

(b) Any termination under Paragraph 7.2(a) shall not relieve LICENSEE of any

obligation or liability accrued under this Agreement prior to termination or rescind any payment made to UNIVERSITY or action by LICENSEE prior to the time termination becomes effective. Termination shall not affect in any manner any rights of UNIVERSITY arising under this Agreement prior to termination.

7.3 **Survival on Termination.** The following Paragraphs and Articles shall survive the termination of this Agreement:

(a) Article 4 (REPORTS, RECORDS AND PAYMENTS);

(b) Paragraph 7.4 (Disposition of Licensed Products on Hand);

(c) Paragraph 8.2 (Indemnification);

(d) Article 9 (USE OF NAMES AND TRADEMARKS);

(e) Paragraph 10.2 hereof (Secrecy); and

(f) Paragraph 10.5 (Failure to Perform).

7.4 **Disposition of Licensed Products on Hand.** Upon termination of this Agreement, LICENSEE may dispose of all previously made or partially made Licensed Product within a period of one hundred and twenty (120) days of the effective date of such termination provided that the sale of such Licensed Product by LICENSEE and its Sublicensees,shall be subject to the terms of this Agreement, including but not limited to the rendering of reports and payment of royalties required under this Agreement.

ARTICLE 8. LIMITED WARRANTY AND INDEMNIFICATION

8.1 **Limited Warranty.**

(a) UNIVERSITY warrants that it has the lawful right to grant this license.

(b) The license granted herein is provided "AS IS" and without WARRANTY OF MERCHANTABILITY or WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE or any other warranty, express or implied. UNIVERSITY makes no representation or warranty that the Licensed Product, Licensed Method or the use of Patent Rights will not infringe any other patent or other proprietary rights.

(c) In no event shall UNIVERSITY be liable for any incidental, special or consequential damages resulting from exercise of the license granted herein or the use of the Invention, Licensed Product, Licensed Method.

(d) Nothing in this Agreement shall be construed as:

(i) a warranty or representation by UNIVERSITY as to the validity or scope of any Patent Rights;

(ii) a warranty or representation that anything made, used, sold or otherwise disposed of under any license granted in this Agreement is or shall be free from infringement of patents of third parties;

(iii) an obligation to bring or prosecute actions or suits against third parties for patent infringement except as provided in Paragraph 5.2 hereof;

(iv) conferring by implication, estoppel or otherwise any license or rights under any patents of UNIVERSITY other than Patent Rights as defined in this Agreement, regardless of whether those patents are dominant or subordinate to Patent Rights; or

(v) an obligation to furnish any know-how not provided in Patent Rights .

8.2 **Indemnification.**

(a) LICENSEE shall indemnify, hold harmless and defend UNIVERSITY, its officers, employees, and agents; the sponsors of the research that led to the Invention; and the Inventors of the patents and patent applications in Patent Rights and their employers against any and all claims, suits, losses, damage, costs, fees, and expenses resulting from or arising out of exercise of this license or any Sublicense. This indemnification shall include, but not be limited to, any product liability.

(b) LICENSEE, at its sole cost and expense, shall insure its activities in connection with the work under this Agreement and obtain, keep in force and maintain insurance or an equivalent program of self insurance as follows:

(i) comprehensive or commercial general liability insurance (contractual liability included) with limits of at least: (A) each occurrence, one million dollars (US$1,000,000); (B) products/completed operations aggregate, five million dollars (US$5,000,000); (C) personal and advertising injury,one million dollars (US$1,000,000); and (D) general aggregate (commercial form only), five million dollars (US$5,000,000); and

(ii) the coverage and limits referred to above shall not in any way limit the liability of LICENSEE.

(c) LICENSEE shall furnish UNIVERSITY with certificates of insurance or other written assurance showing compliance with all requirements

(d) UNIVERSITY shall notify LICENSEE in writing of any claim or suit brought against UNIVERSITY in respect of which UNIVERSITY intends to invoke the provisions of this Article. LICENSEE shall keep UNIVERSITY informed on a current basis of its defense of any claims under this Article.

ARTICLE 9. USE OF NAMES AND TRADEMARKS

9.1 Nothing contained in this Agreement confers any right to use in advertising, publicity, or other promotional activities any name, trade name, trademark, or other designation of either party hereto (including contraction, abbreviation or simulation of any of the foregoing). Unless required by law, the use by LICENSEE of the name, "The Regents of the University of California" or the name of any campus of the University Of California is prohibited, without the express written consent of UNIVERSITY.

9.2 UNIVERSITY may disclose to the Inventors the terms and conditions of this Agreement upon their request. If such disclosure is made, UNIVERSITY shall request the Inventors not disclose such terms and conditions to others.

9.3 UNIVERSITY may acknowledge the existence of this Agreement and the extent of the grant in Article 2 to third parties, but UNIVERSITY shall not disclose the financial terms of this Agreement to third parties, except where UNIVERSITY is required by law to do so, such as under the California Public Records Act.

ARTICLE 10. MISCELLANEOUS PROVISIONS

10.1 **Correspondence.** Any notice or payment required to be given to either party under this Agreement shall be deemed to have been properly given and effective:

(a) on the date of delivery if delivered in person, or

(b) five (5) days after mailing if mailed by first-class or certified mail, postage paid, to the respective addresses given below, or to such other address as is designated by written notice given to the other party.

If sent to LICENSEE:

[Name and address of licensee]

Attention: _____

Phone:
Fax:

If sent to UNIVERSITY by mail:
University of California, San Diego
Technology Transfer & Intellectual Property Services
9500 Gilman Drive
Mail Code 0910
La Jolla, CA 92093-0910
Attention: Assistant Vice Chancellor

If sent to UNIVERSITY by courier:
University of California, San Diego
Technology Transfer & Intellectual Property Services
10300 North Torrey Pines Road
Torrey Pines Center North, First Floor
La Jolla, CA 92037

For wire payments to UNIVERSITY:

All payments due UNIVERSITY and made by wire transfers shall include an additional wire transfer fee of twenty-five dollar (US$25) to the amount due. Wire transfers shall be made using the following information:

UCSD receiving bank name:	Bank of America
UCSD bank account no.:	1233-0-18188
UCSD bank routing (ABA) no.:	121000358
UCSD bank account name:	Regents of UC
UCSD bank ACH format code:	CTX
UCSD bank address:	Bank of America PO Box 37025 San Francisco, CA 94137 U.S.A.
UCSD addendum information:	Reference UCSD-TechTIPS Case No.: xxxxx-yyy Department contact: Financial Manager

A fax copy of the transaction receipt should be sent to Financial Manager at: (858) 534-7345. LICENSEE is responsible for all bank charges of wire transfer funds. The bank charges should not be deducted from total amount due to the

Regents of the University of California

10.2 **Secrecy.**

(a) "Confidential Information" shall mean information, relating to the Invention and disclosed by UNIVERSITY to LICENSEE during the term of this Agreement, which if disclosed in writing shall be marked "Confidential", or if first disclosed otherwise, shall within thirty (30) days of such disclosure be reduced to writing by UNIVERSITY and sent to LICENSEE:

(b) Licensee shall:

(i) use the Confidential Information for the sole purpose of performing under the terms of this Agreement;

(ii) safeguard Confidential Information against disclosure to others with the same degree of care as it exercises with its own data of a similar nature;

(iii) not disclose Confidential Information to others (except to its employees, agents or consultants who are bound to LICENSEE by a like obligation of confidentiality) without the express written permission of UNIVERSITY, except that LICENSEE shall not be prevented from using or disclosing any of the Confidential Information that:

(A) LICENSEE can demonstrate by written records was previously known to it;

(B) is now, or becomes in the future, public knowledge other than through acts or omissions of LICENSEE;

(C) is lawfully obtained by LICENSEE from sources independent of UNIVERSITY; or

(D) is required to be disclosed by law or a court of competent jurisdiction; and

(c) The secrecy obligations of LICENSEE with respect to Confidential Information shall continue for a period ending five (5) years from the termination date of this Agreement.

10.3 **Assignability.** This Agreement may be assigned by UNIVERSITY, but is personal to LICENSEE and assignable by LICENSEE only with the written consent of UNIVERSITY except to its wholly-owned subsidiary.

10.4 **No Waiver.** No waiver by either party of any breach or default of any covenant or agreement set forth in this Agreement shall be deemed a waiver as to any subsequent and/or similar breach or default.

10.5 **Failure to Perform.** In the event of a failure of performance due under this Agreement and if it becomes necessary for either party to undertake legal action against the other on account thereof, then the prevailing party shall be entitled to reasonable attorney's fees in addition to costs and necessary disbursements.

10.6 **Governing Laws.** THIS AGREEMENT SHALL BE INTERPRETED AND CONSTRUED IN ACCORDANCE WITH THE LAWS OF THE STATE OF CALIFORNIA, but the scope and validity of any patent or patent application shall be governed by the applicable laws of the country of the patent or patent application.

10.7 **Force Majeure.** A party to this Agreement may be excused from any performance required herein if such performance is rendered impossible or unfeasible due to any catastrophe or other major event beyond its reasonable control, including, without limitation, war, riot, and insurrection; laws, proclamations, edicts, ordinances, or regulations; strikes, lockouts, or other serious labor disputes; and floods, fires, explosions, or other natural disasters. When such events have abated, the non-performing party's obligations herein shall resume.

10.8 **Headings.** The headings of the several sections are inserted for convenience of reference only and are not intended to be a part of or to affect the meaning or interpretation of this Agreement.

10.9 **Entire Agreement.** This Agreement embodies the entire understanding of the parties and supersedes all previous communications, representations or understandings, either oral or written, between the parties relating to the subject matter hereof.

10.10 **Amendments.** No amendment or modification of this Agreement shall be valid or binding on the parties unless made in writing and signed on behalf of each party.

10.11 **Severability.** In the event that any of the provisions contained in this Agreement is held to be invalid, illegal, or unenforceable in any respect, such invalidity, illegality or unenforceability shall not affect any other provisions of this Agreement, and this Agreement shall be construed as if the invalid, illegal, or unenforceable provisions had never been contained in it.

IN WITNESS WHEREOF, both UNIVERSITY and LICENSEE have executed this Agreement, in duplicate originals, by their respective and duly authorized officers on the day and year written.

[COMPANY NAME]:

By:_____
(Signature)

Name:_____

Title:_____

Date:_____

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA:

By:_____
(Signature)

Alan S. Paau, M.B.A, Ph.D.

Assistant Vice Chancellor,
Technology Transfer &
Intellectual Property Services

Date:_____

ATTEST:

By:_____
(Signature)

Name:_____

Date:_____

ATTEST:

By:_____
(Signature)

Name:_____

Date:_____

J. Non-Exclusive License Agreement, *Sample*

Above *Looking south to La Jolla from Torrey Pines State Reserve*

SAMPLE NON-EXCLUSIVE LICENSE AGREEMENT

BETWEEN

THE ENERGY BIOSCIENCE INSTITUTE OF SAN DIEGO

AND

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

FOR

INVENTION DISCLOSURE NO. SD__-___

[Note: text in "red" or is "boxed" is for use only when applicable]

TABLE OF CONTENTS

LICENSE AGREEMENT

This agreement ("Agreement") is made by and between the Energy Biosciences Institute of San Diego, a <STATE> corporation having an address at <ADDRESS> ("LICENSEE") and The Regents of the University of California, a California corporation having its statewide administrative offices at 1111 Franklin Street, Oakland, California 94607-5200 ("UNIVERSITY"), and represented by its San Diego campus having an address at the University of California San Diego, Technology Transfer & Intellectual Property Services, Mail Code 0910, 9500 Gilman Drive, La Jolla, California 92093-0910 ("UCSD").

This Agreement is effective on _____ ("Effective Date").

RECITALS

WHEREAS, the inventions disclosed in UCSD Disclosure No. SD__-___ and titled "DISCLOSURE TITLE - MUST BE ACCURATE" ("Invention"), were made in the course of research at UCSD by Dr. _____ and his/her associates (hereinafter and collectively, the "Inventors") and are covered by Patent Rights as defined below;

WHEREAS, the research was sponsored by LICENSEE and therefore LICENSEE has the right to obtain this license;

WHEREAS, the research was also sponsored in part by the Government of the United States of America and as a consequence this license is subject to overriding obligations to the Federal Government under 35 U.S.C. §§ 200-212 and applicable regulations;

WHEREAS, the Inventors are employees of UCSD, and they are obligated to assign all of their right, title and interest in the Invention to UNIVERSITY and have done so;

WHEREAS, LICENSEE entered into a secrecy agreement (UC Control No. xx-xx-xxxx) with UNIVERSITY, effective _____, for the purpose of evaluating the Invention for the purpose of license determination;

WHEREAS, LICENSEE entered into a Letter of Intent (UC Control No. xx-xx-xxxx) with UNIVERSITY, effective _____, for the purpose of negotiating this Agreement;

WHEREAS, UNIVERSITY is desirous that the Invention be developed and utilized to the fullest possible extent so that its benefits can be enjoyed by the general public; and

WHEREAS, LICENSEE is desirous of obtaining certain non-exclusive rights from UNIVERSITY for commercial development, use, and sale of the Invention, and the UNIVERSITY is willing to grant such rights.

NOW, THEREFORE, the parties agree:

ARTICLE 1. DEFINITIONS

The terms, as defined herein, shall have the same meanings in both their singular and plural forms.

1.1 "BP" means _____[BP shall give its best legal description of its business]_____and "BP Affiliated Business" means any business that controls BP, is controlled by BP, or is contractually obligated to act for the benefit of BP.

1.2 "Sublicense" means an agreement into which LICENSEE enters with BP or BP Affiliated Businesses for the purpose of granting certain rights that UNIVERSITY granted to LICENSEE under this Agreement. "Sublicensee" means a third party with whom LICENSEE enters into a Sublicense.

1.3 "Field" means all uses related to the production and commercialization of energy.

1.4 "Territory" means world-wide where Patent Rights exist and subject to Paragraph 5.1(c).

1.5 "Term" means the period of time beginning on the Effective Date and ending on the expiration date of the longest-lived Patent Rights for Invention.

1.6 "Licensed Method" means any method that is covered by Patent Rights, the use of which would constitute, but for the license granted to LICENSEE under this Agreement, an infringement, an inducement to infringe or contributory infringement, of any pending or issued claim within Patent Rights had LICENSEE not had rights in any patent or patent application claiming Invention.

1.7 "Licensed Product" means any service, composition or product that is covered by the claims of Patent Rights, or that is produced by the Licensed Method, or the manufacture, use, sale, offer for sale, or importation of which would constitute, but for the license granted to LICENSEE under this Agreement, an infringement, an inducement to infringe or contributory infringement, of any pending or issued claim within the Patent Rights had LICENSEE not had rights in any patent or patent application claiming Invention.

1.8 “Patent Costs” means all out-of-pocket expenses for the preparation, filing,

prosecution, and maintenance of all United States and foreign patents included in Patent Rights. Patent Costs shall also include reasonable out-of-pocket expenses for patentability opinions, inventorship determination, preparation and prosecution of patent application, re-examination, re-issue, interference, opposition activities related to patents or applications in Patent Rights and a 15% patent service fee.

1.9 "Patent Rights" means UNIVERSITY's right in any of the following: the US patent application (serial number _____, titled "_____") disclosing and claiming the Invention, filed by Inventors and assigned to UNIVERSITY; and continuing applications thereof including divisions, substitutions, and continuations-in-part (but only to extent the claims thereof are enabled by disclosure of the parent application); any patents issuing on said applications including reissues, reexaminations and extensions; and any corresponding foreign applications or patents

1.10 "Government Rights" means all the applicable provisions of any license to the United States Government executed by UNIVERSITY and the overriding obligations to the Federal Government under 35 U.S.C. §§ 200-212 and applicable governmental implementing regulations.

ARTICLE 2. GRANTS

2.1 **License.** Subject to the limitations set forth in this Agreement and Government's Rights, UNIVERSITY hereby grants to LICENSEE, and LICENSEE hereby accepts, a license under Patent Rights to make and have made, to use and have used, to sell and have sold, to offer for sale, and to import and have imported Licensed Products and to practice Licensed Methods in the Field within the Territory and during the Term.

The license granted herein is non-exclusive for Patent Rights and UNIVERSITY may grant further licenses to third parties under Patent Rights in the Field and within the Territory.

2.2 **Sublicense.** The license granted in Paragraph 2.1 includes the right of LICENSEE to grant Sublicense to BP Affiliated Businesses. Any Sublicense granted by LICENSEE shall terminate upon the expiration or termination of this Agreement for any reason.

2.3 **Reservation of Rights.** UNIVERSITY reserves the right to:

(a) use the Invention, and Patent Rights for educational and research purposes;

(b) publish or otherwise disseminate any information about the Invention at any

time; and

(c) allow other nonprofit institutions to use Invention, and Patent Rights for educational and research.

ARTICLE 3. CONSIDERATION

3.1 **Fees and Royalties.** The parties hereto understand that the fees and royalties payable by LICENSEE to UNIVERSITY under this Agreement are partial consideration for the license granted herein to LICENSEE under Patent Rights. LICENSEE shall pay UNIVERSITY an annual **license fee** of Ten Thousand US Dollars (US$10,000), within thirty (30) days after the Effective Date and each anniversary thereafter.

3.2 **Patent Costs.** LICENSEE shall reimburse UNIVERSITY all past (prior to the Effective Date) and future (on or after the Effective Date) Patent Costs incurred in the Territory within thirty (30) days following the date an itemized invoice is sent from UNIVERSITY to LICENSEE.

All fees and annual license payments specified in Paragraphs 3.1and 3.2 above shall be paid by LICENSEE pursuant to Paragraph 4.2 and shall be delivered by LICENSEE to UNIVERSITY as noted in Paragraph 10.1.

3.3 **Due Diligence.**

(a) LICENSEE shall either directly or through its Sublicensee(s):

(i) diligently proceed with the use of the licensed Patent Rights in commerce,

(ii) obtain all necessary governmental approvals for the manufacture, use and sale of Licensed Products.

(b) If LICENSEE fails to perform any of its obligation specified in Paragraphs 3.3(a)(ii), then UNIVERSITY shall have the right and option to terminate this Agreement. This right, if exercised by UNIVERSITY, supersedes the rights granted in Article 2.

ARTICLE 4. REPORTS AND PAYMENTS

4.1 **Reports.** LICENSEE shall also report to UNIVERSITY the date of first commercial

use of the licensed Patent Rights in each country within the Territory within sixty (60) days of such use.

4.2 **Payments**.

(a) All fees and patent costs reimbursement due UNIVERSITY shall be paid in United States dollars and all checks shall be made payable to "The Regents of the University of California", referencing UNIVERSITY's taxpayer identification number, 95-6006144, and send to UCSD according to Paragraph 10.1 (Correspondence).

(b) Late Payments. In the event annual royalty, patent costs reimbursement and/or fee payments are not received by UNIVERSITY when due, LICENSEE shall pay to UNIVERSITY interest charges at a rate of ten percent (10%) per year. Such interest shall be calculated from the date payment was due until actually received by UNIVERSITY.

ARTICLE 5. PATENT MATTERS

5.1 **Patent Prosecution and Maintenance**.

(a) Provided that LICENSEE has reimbursed UNIVERSITY for Patent Costs pursuant to Paragraph 3.2, UNIVERSITY shall diligently prosecute and maintain the United States and, if available, foreign patents, and applications in Patent Rights using counsel of its choice. UNIVERSITY shall provide LICENSEE with copies of all relevant documentation relating to such prosecution and LICENSEE shall keep this documentation confidential. The counsel shall take instructions only from UNIVERSITY.

(b) UNIVERSITY shall consider amending any patent application in Patent Rights to include claims reasonably requested by LICENSEE to protect the products contemplated to be sold by LICENSEE under this Agreement.

(c) LICENSEE may elect to terminate its reimbursement obligations with respect to any patent application or patent in Patent Rights upon three (3) months' written notice to UNIVERSITY. UNIVERSITY shall use reasonable efforts to curtail further Patent Costs for such application or patent when such notice of termination is received from LICENSEE. UNIVERSITY, in its sole discretion and at its sole expense, may continue prosecution and maintenance of said application or patent, and LICENSEE shall then have no further license with respect thereto. Non-payment of any portion of Patent Costs with respect to any application or patent may be deemed by UNIVERSITY as an election by LICENSEE to terminate its reimbursement obligations with respect to such application or patent. The University is not obligated to file, prosecute, or maintain

Patent Rights outside of the territory at any time or to file, prosecute, or maintain Patent Rights to which Licensee has terminated its License hereunder.

5.2 **Patent Infringement.**

If LICENSEE learns of any substantial infringement of Patent Rights, LICENSEE shall so inform UNIVERSITY and provide UNIVERSITY with reasonable evidence of the infringement. LICENSEE shall not notify a third party of the infringement of Patent Rights without the consent of UNIVERSITY. UNIVERSITY shall use reasonable efforts to terminate the infringement without litigation.

5.3 **Patent Marking.** LICENSEE shall mark all Licensed Products made, used or sold under the terms of this Agreement, or their containers, in accordance with the applicable patent marking laws.

ARTICLE 6. GOVERNMENTAL MATTERS

6.1 **Governmental Approval or Registration.** If this Agreement or any associated transaction is required by the law of any nation to be either approved or registered with any governmental agency, LICENSEE shall assume all legal obligations to do so. LICENSEE shall notify UNIVERSITY if it becomes aware that this Agreement is subject to a United States or foreign government reporting or approval requirement. LICENSEE shall make all necessary filings and pay all costs including fees, penalties, and all other out-of-pocket costs associated with such reporting or approval process.

6.2 **Export Control Laws.** LICENSEE shall observe all applicable United States and foreign laws with respect to the transfer of Licensed Products and related technical data to foreign countries, including, without limitation, the International Traffic in Arms Regulations and the Export Administration Regulations.

6.3 **Preference for United States Industry.** If LICENSEE sells a Licensed Product or Combination Product in the US, LICENSEE shall manufacture said product substantially in the US.

ARTICLE 7. TERMINATION OF THE AGREEMENT

7.1 **Termination by UNIVERSITY.** If LICENSEE fails to perform or violates any term of this Agreement, then UNIVERSITY may give written notice of default ("Notice of Default") to LICENSEE. If LICENSEE fails to cure the default within sixty (60) days of the Notice of Default, UNIVERSITY may terminate this Agreement and the license granted herein by a second written notice ("Notice of Termination") to LICENSEE. If a

Notice of Termination is sent to LICENSEE, this Agreement shall automatically terminate on the effective date of that notice. Termination shall not relieve LICENSEE of its obligation to pay any fees owed at the time of termination and shall not impair any accrued right of UNIVERSITY.

7.2 **Termination by LICENSEE.**

(a) LICENSEE shall have the right at any time and for any reason to terminate this Agreement upon a ninety (90)-day written notice to UNIVERSITY. Said notice shall state LICENSEE's reason for terminating this Agreement.

(b) Any termination under Paragraph 7.2(a) shall not relieve LICENSEE of any obligation or liability accrued under this Agreement prior to termination or rescind any payment made to UNIVERSITY or action by LICENSEE prior to the time termination becomes effective. Termination shall not affect in any manner any rights of UNIVERSITY arising under this Agreement prior to termination.

7.3 **Survival on Termination.** The following Paragraphs and Articles shall survive the termination of this Agreement:

(a) Article 4 (REPORTS AND PAYMENTS);

(b) Paragraph 7.4 (Disposition of Licensed Products on Hand);

(c) Paragraph 8.2 (Indemnification);

(d) Article 9 (USE OF NAMES AND TRADEMARKS);

(e) Paragraph 10.2 hereof (Secrecy); and

(f) Paragraph 10.5 (Failure to Perform).

7.4 **Disposition of Licensed Products on Hand.** Upon termination of this Agreement, LICENSEE may dispose of all previously made or partially made Licensed Product within a period of one hundred and twenty (120) days of the effective date of such termination provided that the sale of such Licensed Product by LICENSEE and its Sublicensees,shall be subject to the terms of this Agreement, including but not limited to the rendering of reports and payment of royalties required under this Agreement.

ARTICLE 8. LIMITED WARRANTY AND INDEMNIFICATION

8.1 **Limited Warranty.**

(a) UNIVERSITY warrants that it has the lawful right to grant this license.

(b) The license granted herein is provided "AS IS" and without WARRANTY OF MERCHANTABILITY or WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE or any other warranty, express or implied. UNIVERSITY makes no representation or warranty that the Licensed Product, Licensed Method or the use of Patent Rights will not infringe any other patent or other proprietary rights.

(c) In no event shall UNIVERSITY be liable for any incidental, special or consequential damages resulting from exercise of the license granted herein or the use of the Invention, Licensed Product, Licensed Method.

(d) Nothing in this Agreement shall be construed as:

(i) a warranty or representation by UNIVERSITY as to the validity or scope of any Patent Rights;

(ii) a warranty or representation that anything made, used, sold or otherwise disposed of under any license granted in this Agreement is or shall be free from infringement of patents of third parties;

(iii) an obligation to bring or prosecute actions or suits against third parties for patent infringement except as provided in Paragraph 5.2 hereof;

(iv) conferring by implication, estoppel or otherwise any license or rights under any patents of UNIVERSITY other than Patent Rights as defined in this Agreement, regardless of whether those patents are dominant or subordinate to Patent Rights; or

(v) an obligation to furnish any know-how not provided in Patent Rights .

8.2 **Indemnification.**

(a) LICENSEE shall indemnify, hold harmless and defend UNIVERSITY, its officers, employees, and agents; the sponsors of the research that led to the Invention; and the Inventors of the patents and patent applications in Patent Rights and their employers against any and all claims, suits, losses, damage, costs, fees, and expenses resulting from or arising out of exercise of this license or any Sublicense. This indemnification shall include, but not be limited to, any product liability.

(b) LICENSEE, at its sole cost and expense, shall insure its activities in

connection with the work under this Agreement and obtain, keep in force and maintain insurance or an equivalent program of self insurance as follows:

(i) comprehensive or commercial general liability insurance (contractual liability included) with limits of at least: (A) each occurrence, one million dollars (US$1,000,000); (B) products/completed operations aggregate, five million dollars (US$5,000,000); (C) personal and advertising injury,one million dollars (US$1,000,000); and (D) general aggregate (commercial form only), five million dollars (US$5,000,000); and

(ii) the coverage and limits referred to above shall not in any way limit the liability of LICENSEE.

(c) LICENSEE shall furnish UNIVERSITY with certificates of insurance or other written assurance showing compliance with all requirements

(d) UNIVERSITY shall notify LICENSEE in writing of any claim or suit brought against UNIVERSITY in respect of which UNIVERSITY intends to invoke the provisions of this Article. LICENSEE shall keep UNIVERSITY informed on a current basis of its defense of any claims under this Article.

ARTICLE 9. USE OF NAMES AND TRADEMARKS

9.1 Nothing contained in this Agreement confers any right to use in advertising, publicity, or other promotional activities any name, trade name, trademark, or other designation of either party hereto (including contraction, abbreviation or simulation of any of the foregoing). Unless required by law, the use by LICENSEE of the name, "The Regents of the University of California" or the name of any campus of the University Of California is prohibited, without the express written consent of UNIVERSITY.

9.2 UNIVERSITY may disclose to the Inventors the terms and conditions of this Agreement upon their request. If such disclosure is made, UNIVERSITY shall request the Inventors not disclose such terms and conditions to others.

9.3 UNIVERSITY may acknowledge the existence of this Agreement and the extent of the grant in Article 2 to third parties, but UNIVERSITY shall not disclose the financial terms of this Agreement to third parties, except where UNIVERSITY is required by law to do so, such as under the California Public Records Act.

ARTICLE 10. MISCELLANEOUS PROVISIONS

10.1 **Correspondence.** Any notice or payment required to be given to either party under this Agreement shall be deemed to have been properly given and effective:

(a) on the date of delivery if delivered in person, or

(b) five (5) days after mailing if mailed by first-class or certified mail, postage paid, to the respective addresses given below, or to such other address as is designated by written notice given to the other party.

If sent to LICENSEE:
[Name and address of licensee]
Attention: _____
Phone:
Fax:

If sent to UNIVERSITY by mail:
University of California, San Diego
Technology Transfer & Intellectual Property Services
9500 Gilman Drive
Mail Code 0910
La Jolla, CA 92093-0910
Attention: Assistant Vice Chancellor

If sent to UNIVERSITY by courier:
University of California, San Diego
Technology Transfer & Intellectual Property Services
10300 North Torrey Pines Road
Torrey Pines Center North, First Floor
La Jolla, CA 92037

For wire payments to UNIVERSITY:
All payments due UNIVERSITY and made by wire transfers shall include an additional wire transfer fee of twenty-five dollar (US$25) to the amount due. Wire transfers shall be made using the following information:

UCSD receiving bank name:	Bank of America
UCSD bank account no.:	1233-0-18188
UCSD bank routing (ABA) no.:	121000358
UCSD bank account name:	Regents of UC
UCSD bank ACH format code:	CTX
UCSD bank address:	Bank of America PO Box 37025

San Francisco, CA 94137
U.S.A.

UCSD addendum information: Reference UCSD-TechTIPS Case No.: xxxxx-yyy
Department contact: Financial Manager

A fax copy of the transaction receipt should be sent to Financial Manager at: (858) 534-7345. LICENSEE is responsible for all bank charges of wire transfer funds. The bank charges should not be deducted from total amount due to the Regents of the University of California

10.2 **Secrecy.**

(a) "Confidential Information" shall mean information, relating to the Invention and disclosed by UNIVERSITY to LICENSEE during the term of this Agreement, which if disclosed in writing shall be marked "Confidential", or if first disclosed otherwise, shall within thirty (30) days of such disclosure be reduced to writing by UNIVERSITY and sent to LICENSEE:

(b) Licensee shall:

(i) use the Confidential Information for the sole purpose of performing under the terms of this Agreement;

(ii) safeguard Confidential Information against disclosure to others with the same degree of care as it exercises with its own data of a similar nature;

(iii) not disclose Confidential Information to others (except to its employees, agents or consultants who are bound to LICENSEE by a like obligation of confidentiality) without the express written permission of UNIVERSITY, except that LICENSEE shall not be prevented from using or disclosing any of the Confidential Information that:

(A) LICENSEE can demonstrate by written records was previously known to it;

(B) is now, or becomes in the future, public knowledge other than through acts or omissions of LICENSEE;

(C) is lawfully obtained by LICENSEE from sources independent of UNIVERSITY; or

(D) is required to be disclosed by law or a court of competent jurisdiction; and

(c) The secrecy obligations of LICENSEE with respect to Confidential Information shall continue for a period ending five (5) years from the termination date of this Agreement.

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IN WITNESS WHEREOF, both UNIVERSITY and LICENSEE have executed this Agreement, in duplicate originals, by their respective and duly authorized officers on the day and year written.

[COMPANY NAME]:

By:_____
(Signature)

Name:_____

Title:_____

Date:_____

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA:

By:_____
(Signature)

Alan S. Paau, M.B.A, Ph.D.

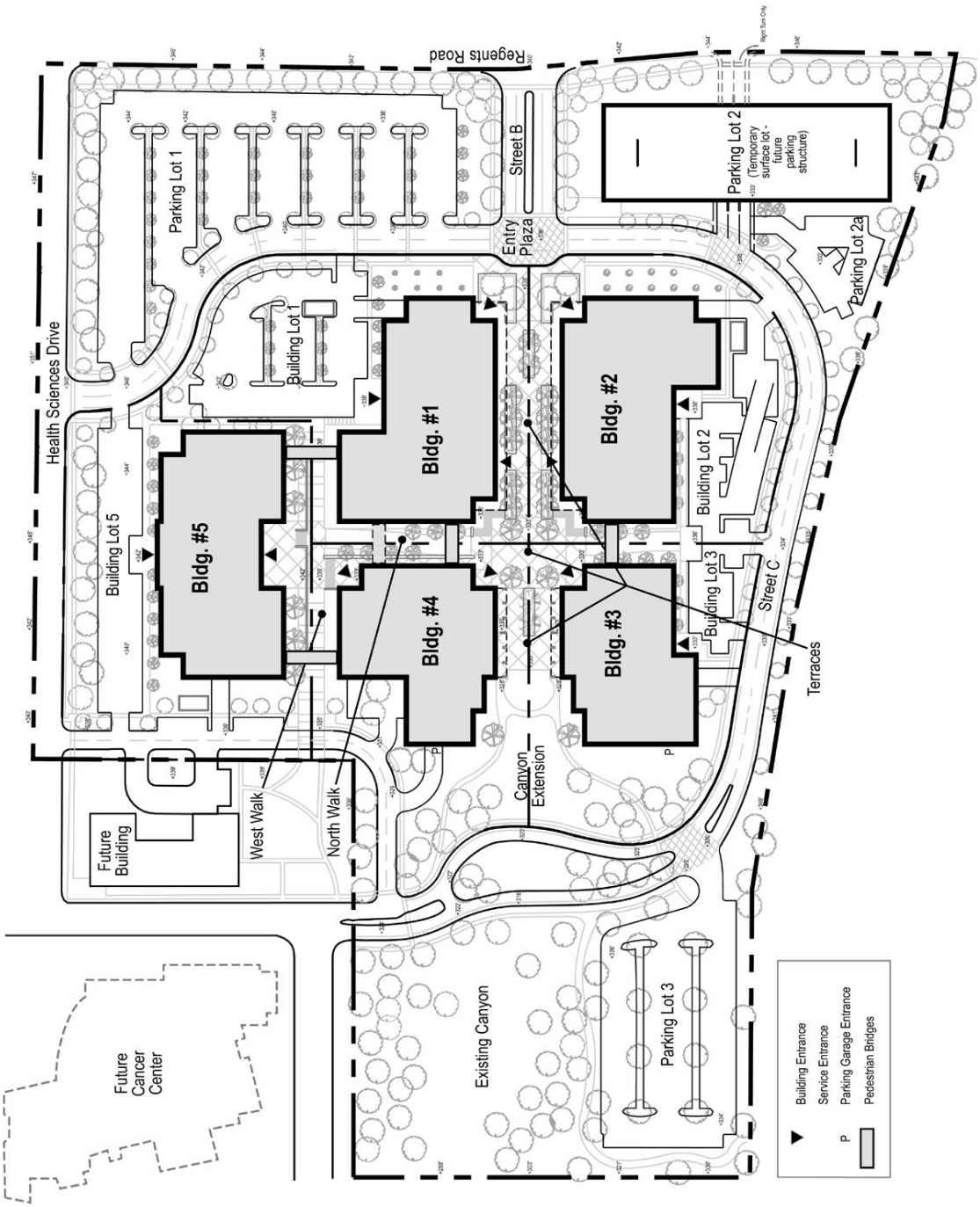
Assistant Vice Chancellor,
Technology Transfer &
Intellectual Property Services

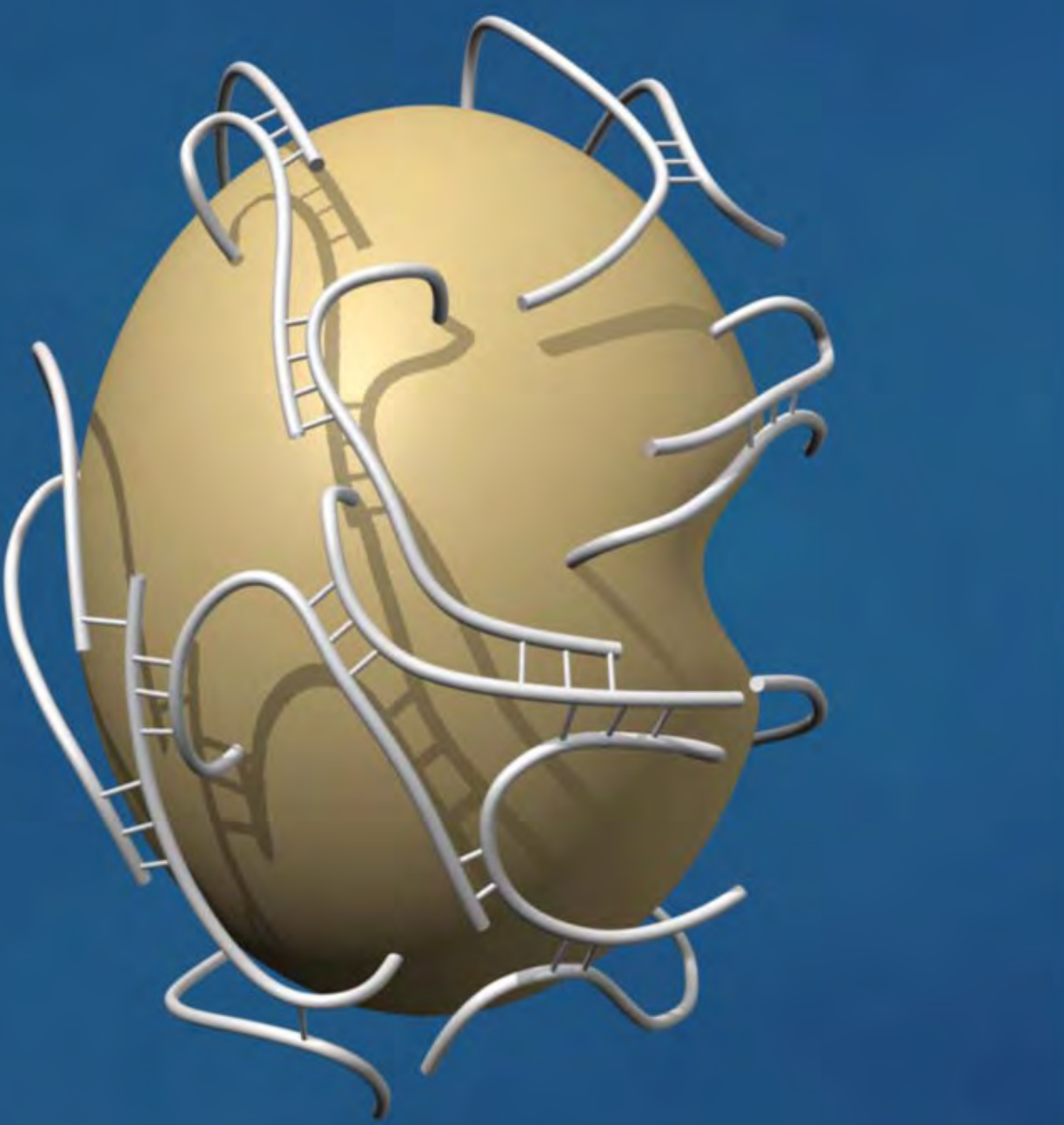
Date:_____

ATTEST:	ATTEST:
By:_____ (Signature)	By:_____ (Signature)
Name:_____	Name:_____
Date:_____	Date:_____

K. Permanent Facility Site Plan

Above *Scripps—courtesy of John Wooley*


Regents Road
Right Turn Only
Parking Lot 1
Street B
Parking Lot 2
(Temporary surface lot - future parking structure)
Entry Plaza
Parking Lot 2a
Health Sciences Drive
Building Lot 1
Bldg. #1
Bldg. #2
Building Lot 5
Bldg. #5
Building Lot 2
Bldg. #4
Bldg. #3
Building Lot 3
Street C
Terraces
Canyon Extension
West Walk
North Walk
Future Building
Future Cancer Center
Existing Canyon
Parking Lot 3
Building Entrance
Service Entrance
Parking Garage Entrance
Pedestrian Bridges



L. Permanent Facility Ground Rent, *Sample*

Above *Single enzyme nanoparticles—courtesy of Battelle*

Sample Permanent Facility Ground Rent

Rent Assumptions:			CAM Assumptions:		
GSF		75,188			
RSF		71,429			
ASF		50,000			
Rent/GSF/Yr	$	6.00	CAM/GSF/Yr	$	0.187
Rent/RSF/Yr	$	6.32			
Rent/ASF/Yr	$	9.02			
CPI Increase		4%	CPI Increase		3%

		Rent		**CAM**		**Total**
Year 1	$	451,128	$	14,075	$	465,203
Year 2	$	451,128	$	14,497	$	465,625
Year 3	$	451,128	$	14,932	$	466,060
Year 4	$	451,128	$	15,380	$	466,508
Year 5	$	451,128	$	15,842	$	466,970
Year 6	$	541,353	$	16,317	$	557,670
Year 7	$	541,353	$	16,807	$	558,160
Year 8	$	541,353	$	17,311	$	558,664
Year 9	$	541,353	$	17,830	$	559,183
Year 10	$	541,353	$	18,365	$	559,718
TOTAL	$	4,962,406	$	161,356	$	5,123,762

M. Environment, Health and Safety, and Data Security Programs at UCSD

Above *UCSD Science Research Park fire hydrant*

Environment, Health and Safety, and Data Security Programs at the University of California, San Diego

An Overview Prepared for the UCSD Energy Biosciences Institute Proposal November 2006

The University of California, San Diego (UCSD) is committed to providing a safe and healthful environment for faculty, staff, students and visitors, while at the same time practicing good environmental stewardship.

Health and Safety

The UCSD Environment, Health and Safety department (EH&S) maintains a comprehensive health and safety program, developed around a philosophy of Integrated Safety and Environmental Management (ISEM). The ISEM approach to health and safety is a decentralized model that places the primary responsibility for loss prevention in the hands of employees and their supervisors. EH&S provides safety and health programs, as well as tools that enable each individual to build safety directly into their work, and practice safety with minimal dependence on others. The ISEM approach helps make safety everyone's job at UCSD.

The formal UCSD health and safety policy below provides a framework used to implement ISEM.

The University of California, San Diego is committed to achieving excellence in providing a healthy and safe working environment, and to supporting environmentally sound practices in the conduct of University activities. It is UCSD policy to comply with all applicable health, safety, and environmental protection laws, regulations, and requirements.

To meet this standard of excellence, UCSD implements management initiatives and best practices to systematically integrate health, safety, and environmental considerations and sustainable use of natural resources into all activities. All UCSD activities are to be conducted in a manner that ensures the protection of students, faculty, staff, visitors, the public, property, and the environment.

The University's goal is to prevent all workplace injuries and illnesses, environmental incidents, and property losses or damage. Achieving this goal is the responsibility of every member of the UCSD community. Supervisors have particular responsibility for the activities of those people who report to them.

EH&S uses the internet to give the UCSD community direct access to health and safety information and tools. For more information please visit: http://blink.ucsd.edu/ehs.

Environmental Compliance and Stewardship

UCSD maintains comprehensive environmental compliance and stewardship programs. EH&S manages an environmental compliance program that consistently meets, and in many cases

exceeds, environmental laws and regulations. The environmental compliance program includes, but is not limited to: air and water discharge, underground and above ground storage tanks, storm water discharge, sea water discharge, contaminated sites, and hazardous materials/waste.

Environmental stewardship at UCSD is overseen by the faculty-led Sustainability Advisory Committee. The mission of this committee is to: 1) Share information about education, research, and outreach activities of UCSD in the context of environmental stewardship and sustainability and prepare periodic reports to the chancellor and University community, 2) Recommend and support efforts to improve environmental stewardship and sustainability in UCSD facility planning and operations, and 3) Make sustainability part of ongoing UCSD education, research, operation, and outreach programs.

On a University of California (UC) system-wide basis, the Regents of the University of California adopted the Policy on Green Building Design and Clean Energy Standards to promote sustainable building practices at all UC campuses. At UCSD, departments collaborate to design, renovate, and construct buildings that meet or exceed these standards by earning points on Green Building Baseline Scorecards. UCSD takes a comprehensive approach that includes planning, design and construction, and operations and maintenance of facilities. The Regents' policy is based on the Leadership in Energy and Environmental Design (LEED) Rating System developed by the U.S. Green Building Council.

UCSD uses the internet to help communicate environmental compliance and stewardship information to members of the UCSD community. For more information see: http://blink.ucsd.edu/Blink/External/Topics/Policy/0,1162,19605,00.html

Data Access and Security

UCSD maintains a stringent data security program to comply with federal, state, and UC system-wide requirements. UCSD strictly adheres to the UC Information Security Policy to reduce risks of electronic information resources through implementation of controls designed to detect and prevent such resources. The UCSD Network Security Policy details specific responsibilities at multiple levels of the organization to ensure that data access is secure and information is not compromised. For more information, please visit: http://adminrecords.ucsd.edu/PPM/docs/135-3.pdf

Permits

At present, UCSD does not anticipate the need for any additional health, safety or environmental permits to complete the research being proposed to BP. If, during the course of the proposed research, the need arises to obtain a specific permit or other environmental or occupational health regulatory approval, EH&S will be responsible for obtaining such approval and ensuring compliance with all terms imposed.

Health, Safety and Environmental Stewardship Performance

Historically, UCSD has maintained substantial compliance with all environmental, health, and safety regulations. When infractions or items of non-compliance have been found, EH&S has

worked to quickly and completely implement corrective action to remedy the situation. Such instances are used as lessons learned by the EH&S Management Team in the development of strategies and/or programs to ensure continued long-term compliance in the area found to be deficient.

UCSD currently has no major citations for non-compliance with environmental or occupational health and safety regulations.

UCSD has historically performed very well in providing for worker health and safety as compared to other large research universities. Reportable injury/illness frequency and severity at UCSD has consistently been in the lowest (best) one-third of our comparison cohort over the past 10-year period. Over the past three years, UCSD has improved even further in these two metrics through implementation of several targeted loss prevention initiatives aimed at reducing workers' compensation cost.

N. Interim Laboratory and Office Leased Space Rent, *Sample*

Above *Cancer Center—courtesy of UCSD*

SAMPLE INTERIM LABORATORY AND OFFICE LEASED SPACE RENT
TORREY PINES MESA
ASF TO RSF CONVERSION FACTOR: ASF/.70

Location	Year	RSF	Lease Type	Est. Monthly Base Rent per RSF w/4% annual increases	Estimated Monthly Base Rent	Estimated Annual Base Rent	Est. Monthly NNN Expenses per RSF w/5% Annual Inc. ($.50 utilities, $.15 janitorial, & $.85 CAM)	Estimated Monthly Expenses	Estimated Annual Expenses	Estimated Monthly Base Rent & Expenses for the Lease Term	Est. Monthly Base Rent & Expenses per RSF	Est. Monthly Base Rent & Expenses per ASF	Estimated Annual Base Rent & Expenses
Torrey Pines Mesa Example 1 - 8,400 ASF (12,000 RSF)													
Laboratory/Office Building													
	Year 1	12,000	NNN	$2.80	$33,600	$403,200	$1.50	$18,000	$216,000	$51,600	$4.30	$6.14	$619,200
	Year 2	12,000	same	$2.91	$34,944	$419,328	$1.58	$18,900	$226,800	$53,844	$4.49	$6.41	$646,128
	Year 3	12,000	same	$3.03	$36,342	$436,101	$1.65	$19,845	$238,140	$56,187	$4.68	$6.69	$674,241
										Estimated Monthly Tenant Imp. Cost	**Est. Monthly Tenant Imp. Cost per RSF**	**Est. Monthly Tenant Imp. Cost per ASF**	**Estimated Annual Tenant Imp. Costs**
Tenant Imp. Cost Estimate: $100/RSF - $1,200,000	Year 1									33,334	$2.78	$3.97	$400,008
	Year 2									33,333	$2.78	$3.97	$399,996
	Year 3									33,333	$2.78	$3.97	$399,996
Torrey Pines Mesa Example 2 - 55,000 ASF (78,751 RSF)													
Laboratory/Office Building													
	Year 1	78,751	NNN	$2.80	$220,503	$2,646,034	$1.50	$118,127	$1,417,518	$338,629	$4.30	$6.16	$4,063,552
	Year 2	78,751	same	$2.91	$229,323	$2,751,875	$1.58	$124,033	$1,488,394	$353,356	$4.49	$6.42	$4,240,269
	Year 3	78,751	same	$3.03	$238,496	$2,861,950	$1.65	$130,234	$1,562,814	$368,730	$4.68	$6.70	$4,424,764
										Estimated Monthly Tenant Imp. Cost	**Est. Monthly Tenant Imp. Cost per RSF**	**Est. Monthly Tenant Imp. Cost per ASF**	**Estimated Annual Tenant Imp. Costs**
Tenant Imp. Cost Estimate: $100/RSF - $7,875,100	Year 1									218,753	$2.78	$3.98	$2,625,036
	Year 2									218,753	$2.78	$3.98	$2,625,036
	Year 3									218,753	$2.78	$3.98	$2,625,036

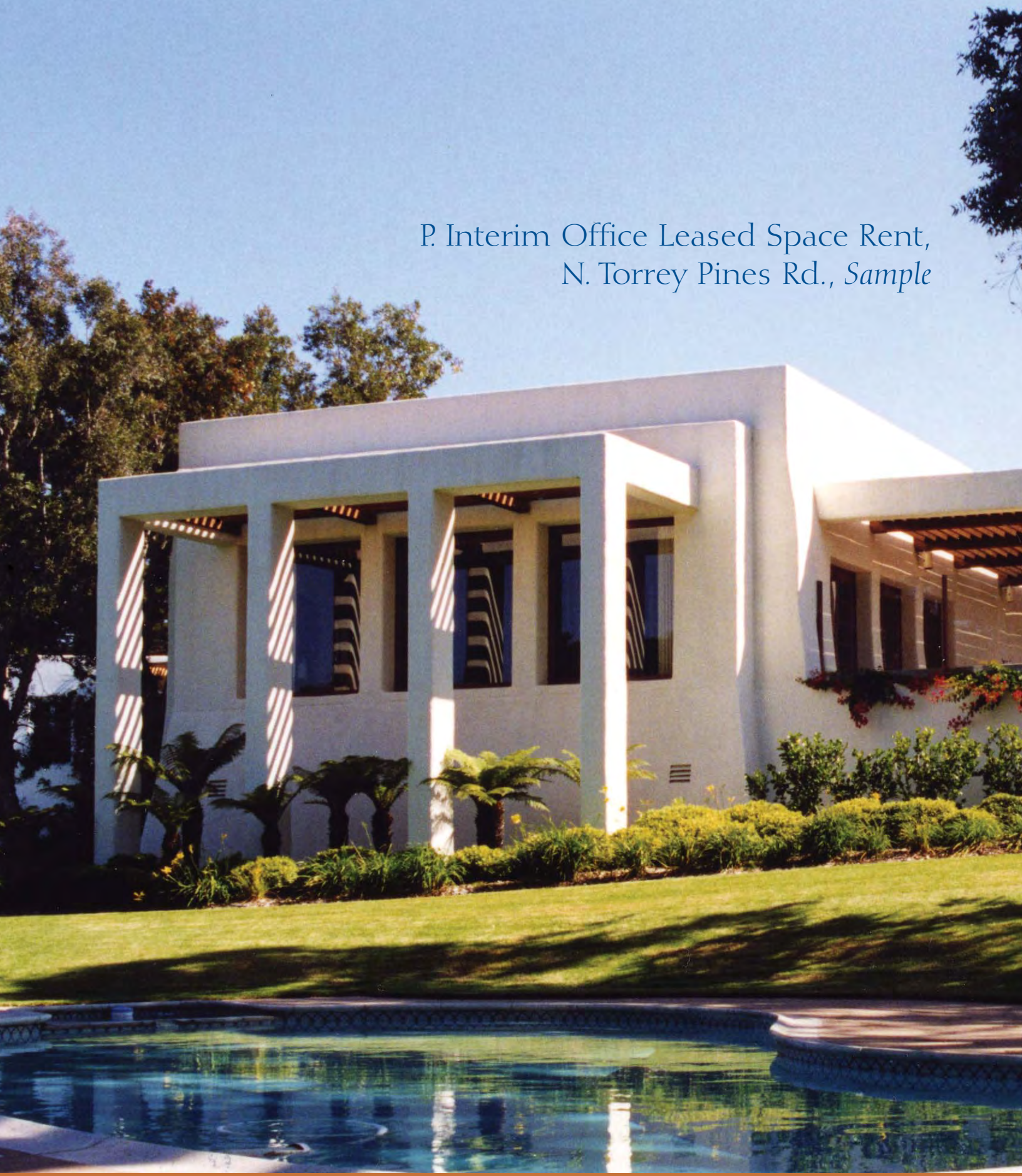
O. Torrey Pines Availability

Above *Canchalagua blooming at Del Mar Mesa Preserve*

TORREY PINES AVAILABILITY

PROJECT	SQUARE FOOTAGE
1. Syngenta sublease Biology space.	15,000
2. Del Mar Partners–formerly Sidney Kimmel	65,000
3. 10865 Altman Row–formerly Sidney Kimmel	22,000
4. Slough Two buildings (office only).	85,000
5. Alexandria Office and lab. Existing 80,000 SF building. Working on entitlements for an additional 76,000 SF.	156,000
6. Torrey Pines Science Park/Slough Four-building project consisting of office and lab space.	106,000
7. Torrey Pines Court La Jolla Multi-building office project.	133,000
8. Alexandria (former Pfizer space) Chemistry labs.	44,000
9. General Atomics Lab space.	18,000
10. Slough (former LIAI space)	50,000
11. Sequenom sublease Lab. Sequenom will relocate for the right opportunity.	70,000
12. Del Mar Partners (former TSRI space) Lab.	70,000
13. Alexandria (former Senomyx space) Lab and office.	85,000
14. Alexandria/Merck sublease Three buildings including chemistry, vivarium and shell space.	166,000
15. CarrAmerica (former Pfizer office space)	54,000
16. Schering Plough sublease. Lab & office.	50,000
TOTAL	1,189,000

P. Interim Office Leased Space Rent, N. Torrey Pines Rd., *Sample*



Above *University House—courtesy of UCSD*

SAMPLE INTERIM OFFICE LEASED SPACE RENT
10280 NORTH TORREY PINES ROAD
ASF TO RSF CONVERSION FACTOR: ASF/.70

Location	Year	RSF	Lease Type	Est. Monthly Base Rent per RSF w/4% annual increases	Estimated Monthly Base Rent	Estimated Annual Base Rent	Est. Electricity Costs Per RSF w/5% annual incr.	Estimated Monthly Expenses	Estimated Annual Expenses	Estimated Monthly Base Rent & Expenses for the Lease Term	Est. Monthly Base Rent & Expenses per RSF	Est. Monthly Base Rent & Expenses per ASF	Estimated Annual Base Rent & Expenses
10280 North Torrey Pines Road													
UCSD Owned Office Building													
7,158 ASF (10,226 RSF)													
	Year 1	10,226	Full Service - Gross net Electricity	$3.29	$33,644	$403,722	$0.25	$2,557	$30,678	$36,200	$3.54	$5.06	$434,400
	Year 2	10,226	same	$3.42	$34,989	$419,871	$0.26	$2,684	$32,212	$37,674	$3.68	$5.26	$452,083

Q. Estimated Budget Overview

Above *Research fields—courtesy of ISU*

PROPOSAL BUDGET

Estimated Budget Overview

Cumulative Budget Period: From 1/1/07 Through 6/30/17

UCSD# 2007-1503

	Host Institution Planning & Development Budget (Jan-June 2007)	EBI Labor	New Hires Start Up Funding	Capital Bldg Expense	Research Equipment (incls. Equip. Replacement)	Research Funding	TOTAL
Year 1	234,571	5,613,101	3,000,000	1,053,600	15,000,000	25,098,728	50,000,000
Year 2	-	8,525,191	3,120,000	1,098,211	8,000,000	29,256,598	50,000,000
Year 3	-	11,338,758	3,244,800	466,060	5,000,000	29,950,382	50,000,000
Year 4	-	14,157,367	3,374,592	466,508	5,200,000	26,801,533	50,000,000
Year 5	-	17,518,730	3,509,576	466,970	5,400,000	23,104,724	50,000,000
Year 6	-	18,219,480	-	557,670	5,600,000	25,622,850	50,000,000
Year 7	-	18,948,259	-	558,160	5,800,000	24,693,581	50,000,000
Year 8	-	19,706,189	-	558,664	6,000,000	23,735,147	50,000,000
Year 9	-	20,494,437	-	559,183	6,200,000	22,746,380	50,000,000
Year 10	-	21,314,214	-	559,718	6,400,000	21,726,068	50,000,000
Total Est. Cost (fully burdened)	$ 234,571	$ 155,835,726	$ 16,248,968	$ 6,344,744	$ 68,600,000	$ 252,735,991	$ 500,000,000
Est. Direct Cost	$ 151,826	$ 100,864,548	$ 10,517,131	$ 6,344,744	$ 68,600,000	$ 163,583,166	$ 350,061,415
Est. Indirect Cost*	$ 82,745	$ 54,971,178	$ 5,731,837	-	-	$ 89,152,825	$ 149,938,585

*This is only an estimate. Indirect costs have been estimated on all categories with the exception of Capital Bldg. Expenses and Research Equipment.

Additional Exhibit: *Patents*

Above *Flying buttress, a sulfide edifice that's home to dense macro- and microfaunal communities. Mothra Hydrothermal Field, Endeavour Segment, Juan de Fuca Ridge—courtesy of J. Delaney and D. Kelley*

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Oliver, David

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Sailor, Michael J.

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Schroeder, J.I., J.M. Kwak, and V.M. Baizabal-Aguirre. Method to Improve Drought Tolerance in Plants. Patent Number 6,635,803, issued October 2003.

Pending:

SD2007-007 Enhancement of Abscisic Acid Sensitivity and Reduction of Water Consumption in Plants

SD2005-027 A Super-Strong Guard Cell Promoter In *Arabidopsis*

SD2004-219 Root-To-Shoot Transport Of Heavy Metals In Plants

SD2001-013 Guard Cell-Expressed Genes For Engineering Of Improved CO2 Influx And Reduced Drought-Induced Water Loss Of Plants

Patents

Issued and Pending, of UCSD Energy Biosciences Institute Project Leaders

SD2000-163 Isolation Of A Gene That Regulates The Strength Of Abscisic Acid Signal Transduction

SD2000-114 Cadmium And Iron Transport By Members Of A Plant Metal Transporter Family In Arabidopsis With Homology To Nramp Genes

SD1999-112 Control Of Plant Water Loss By Use Of Mammalian Type Glutamate Receptors

SD1999-019 Method For Induction Of Drought Tolerance In Plants

SD1998-093 Method To Affect Drought Tolerance In Plants

SD1998-061 Gene Family Of Silicon Transporters, cDNA Encoding Same, And Transgenic Plants Embodying Same That Display Increased Strength And Wind Resistance

SD1996-102 Bioremediation Of Soils Using Transgenic Plants

Shanks, Brent H.

Milam, S.N., and B.H. Shanks. Dehydrogenation Catalyst and Process. U.S. Patent 5,962,757, 1999.

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Wheelock, T.D., and B.H. Shanks. Catalyst and Sorbent Material for the Production of Hydrogen. U.S. Patent allowed not yet issued.

Smith, Richard D.

Dr. Smith has been awarded 27 patents related to advanced technologies and approaches for the characterization of biological systems.

Sung, Shihwu

Anaerobic Sequencing Batch Reactor (ASBR). US Patent 5,185,079, Feb. 1993. (Based on Ph.D. research.)

Temperature-Phased Anaerobic Digestion (TPAD). US Patent 5,746,919, May 1998. (Developed by research under joint supervision of Drs. R. R. Dague and Sung)

van Leeuwen, Johannes

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van Leeuwen, J., D. Grewell, and S.K., Khanal. Ultrasonic Application to Enhance Ethanol Production from Corn Milling Operation. Provisional patent issued ISURF 3385.

van Leeuwen, J., S.K. Khanal, and A.L. Pometto. Purification of Thin Stillage from Dry Corn Milling with Fungi. Provisional patent issued ISURF 3387.

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van Leeuwen, J., A.L. Pometto, and S.K. Khanal. Fungal Process for Converting Lignocellulosic Material to Ethanol. ISURF 3402.

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Issued and Pending, of UCSD Energy Biosciences Institute Project Leaders

Verkade, Alan M.

Published not yet issued but relevant to this proposal:

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Yanofsky, Marty

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Yanofsky, M. F., and S. Liljegren. Enhancing Lignin Biosynthesis in Transgenic Plants. U.S. Patent 6,781,036, 2004.

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Yanofsky, M.F., R. Martienssen, C. Ferrandiz, and Q. Gu. Method of Decreasing Seed Size in a Plant. U.S. Patent 6,541,683, 2003.

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Yanofsky, M.F., and C. Ferrandiz. Seed Plants Characterized by Delayed Seed Dispersal U.S. Patent 6,198,024, 2001.

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Yanofsky, M.F. Seed Plants Exhibiting Early Reproductive Development and Methods of Making Same. U.S. Patent 6,025,543, 2000.

Yanofsky, M.F. Seed Plants Exhibiting Inducible Early Reproductive Development and Methods of Making Same. U.S. Patent 6,002,069, 1999.

Yanofsky, M.F. Seed Plants Exhibiting Inducible Early Reproductive Development and Methods of Making Same. U.S. Patent 6,355,863, 2002.

Yanofsky, M. F., S. Liljegren, and C. Ferrandiz. Selective Control of Lignin Biosynthesis in Transgenic Plants. U.S. Patent 6,768,042, 2004.

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Zhang, Z. Conrad

Dr. Zhang has 20 patents.

Zhao, Yunde

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Additional Exhibit: *Vitae*

Above *Cultures of the photosynthetic eukaryotic alga,* Chlamydomonas reinhardti, *growing on agar plates. Its ease of growth and manipulation have made* Chlamydomonas *a powerful model for investigating fundamental aspects of cell growth and division in higher plants—courtesy of the Salk Institute*

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Education

University of California	BS	1981	Mechanical Engineering
University of California	MS	1983	Mechanical Engineering
University of California	Ph.D.	1995	Environmental Engineering

Positions and Employment

1983-1989	Senior Engineer, Systems Control Technology, Palo Alto, CA
1989-1991	Section Head, Systems Control Technology, Palo Alto, CA
1996-2002	Research Fellow, Institute for Science and Public Policy, and Assistant Professor, Aerospace & Mechanical Engineering, University of Oklahoma
2002-2003	Research Fellow, Institute for Science and Public Policy, and Associate Professor, Aerospace & Mechanical Engineering, University of Oklahoma
2005-2006	Faculty Improvement Leave (sabbatical), École Polytechnique Fédérale de Lausanne (EPFL)
2003-present	Associate Professor, Department of Agricultural and Biosystems Engineering, and Department of Mechanical Engineering, Iowa State University
2006-present	Associate Director, Office of Biorenewables Program, Iowa State University

Honors

2006	EPOBIO Advisory Board - Products from Plants – the Biorefinery Future, EU Planning Project for Framework 7
2005	OECD Fellowship, Biological Resource Management for Sustainable Agricultural Systems
2003-2004	Member, National Research Council Committee on Science and Technology in Armenia
1999	National Academy of Sciences Young Investigator Program

Selected Publications

Anex, R.P., L.R. Lynd, M.S. Laser, A.H., Heggenstaller, and M. Liebman. "Growing Energy, Closing Cycles: The Potential for Enhanced Nutrient Cycling through the Coupling of Agricultural and Bioenergy Systems," Crop Science Journal, *in press.*

Anex, R.P. and Ogletree, A.L. "Life Cycle Assessment of Energy-based Impacts of a Biobased Process for Producing 1,3-Propanediol." In J. Bozell and M. Patel (eds.) *Feedstocks for the Future: Renewables for the Production of Chemicals and Materials,* London: Oxford University Press, 2005.

Anex, R.P. "Something new under the Sun? The Industrial Ecology of biobased materials." Journal of Industrial Ecology, Special Issue on the Industrial Ecology of Biobased Materials, 7(3/4): 1-4, 2004.

Bennett, A.S. and R.P. Anex. Production Costs of Sweet Sorghum Feedstocks and Co-Products. Submitted to *Biomass and Bioenergy,* May 2006.

Bennett, A.S. and R.P. Anex. Production, Transportation and Milling Costs of Sweet Sorghum as a Feedstock for Bioethanol Production. Submitted to *Biomass and Bioenergy*, September 2006.

Bennett, A.S., C.J. Bern, T.L. Richard and R.P. Anex. Corn Grain Drying using Corn Stover Combustion and CHP Systems. Submitted to *Biomass and Bioenergy, October 2006.*

Patents (USA only)

None

Key science and technology achievements

Dr. Anex is the principal investigator of a USDA/DOE-funded project identifying genetic varieties of maize with specific properties attractive for biofuel production and is initiating a breeding program to enhance those properties. The project is also developing innovative harvesting and storage technologies to efficiently and economically move biomass from the field to the factory gate with optimal physical and chemical properties required by biomass conversion processes. He is principal investigator of an NSF-funded project assessing the impacts of widespread adoption of cellulosic biomass conversion technology. Dr. Anex also leads the ISU team integrating two crop biomass cropping systems with nutrient recovery and recycling.

Dr. Anex is an internationally recognized expert in the assessment of biorenewable systems. Dr. Anex was editor of a special issue of the *Journal of Industrial Ecology* on the Industrial Ecology of Biobased Materials which appeared in spring 2004. He has been a member of the editorial board of the *International Journal of Life Cycle Assessment* since 2003. He was the convener of an international workshop on "Assessing the Sustainability of Biobased Materials," held at the University of Oklahoma in 2003. Dr. Anex was a panel member for the US-EC Workshop on Applications of Molecular Biology for the Production of Plants for Biobased Products and Bioenergy, held in Albany, California in April 2004. He was an "Invited Expert", at the EPOBIO Workshop, Products from Plants – the Biorefinery Future, held in Wageningen, Netherlands, May, 2006. Dr. Anex has been an invited speaker at numerous international conferences and workshops on biofues and bioenergy.

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Education

University of California, Davis	BS	1980	Economics of Resource Use
University of California, Davis	MS	1981	Agricultural Economics
University of California, Berkeley	PhD	1987	Agricultural and Resource Economics

Positions and Employment

1987 - 1990	Assistant professor, North Carolina State University
1990 - 1998	Assistant, Associate, and Professor, Iowa State University
1998 to present	Director, Center for Agricultural and Rural Development, Iowa State University

Honors

2002	Quality of Research Discovery, American Agricultural Economics Association
2002	Outstanding journal article, Western Agricultural Economics Association
2002	USDA Secretary of Agricultural Award for outstanding contributions to public policy
2003	Listed in the 4th Edition of Who's Who in Economics as one of the most cited economists for work published from 1990 to 2000.

Selected Publications

Monchuk, D.C, J. Miranoski, D.J. Hayes, and B. A. Babcock. "An Analysis of Regional Economic Growth in the U.S. Midwest." *Review of Agricultural Economics*, forthcoming.

Carriquiry, M. A., and B. A. Babcock. "The Impact of Transportation Costs on Spatial Competition of Grain Buyers: An Iowa Case Study" *Journal of Transportation Research Forum*, 44(Summer 2005):61-76.

Hennessy, D., J.A. Miranowski, and B. A. Babcock. "Genetic Information in Agricultural Productivity and Product Development." *American Journal of Agricultural Economics*, 86(2004):73-87.

Hart, C. E., and B.A. Babcock. "U.S. Farm Policy and the WTO: How Do They Match Up?" *The Estey Centre Journal of International Law and Trade Policy*, 3(2002):119-139.

Wu, J., D. Zilberman, and B.A. Babcock, "Environmental and Distributional Impacts of Conservation Targeting Strategies." *Journal of Environmental Economics and Management,* 41(2001):333-350.

Pautsch, G. R., L. Kurkalova, Babcock, B. A., and C. L. Kling. "The Efficiency of Sequestering Carbon in Agricultural Soils." *Contemporary Economic Policy*, 19(2001):123-134.

Wu, J., and B. A. Babcock. "Metamodeling Potential Nitrate Water Pollution in the Central United States." *Journal of Environmental Quality*, 28(1999):1916-1928.

Wu, J., R. D. Adams, D. Zilberman, and B. A. Babcock. "Targeting Resource Conservation Expenditures." *Choices*, 2nd Quarter, 2000, 33-38.

Babcock, B. A., P. G. Lakshminarayan, J. Wu, and D. Zilberman. "Targeting Tools for the Purchase of Environmental Amenities." *Land Economics*, 73(1997):325-339.

Wu, J., and B. A. Babcock. "Contract Design for the Purchase of Environmental Goods from Agriculture." *American Journal of Agricultural Economics*, 78(1996):935-945.

Pautsch, G. R., B. A. Babcock, C. P. Baumel. "Estimating the Value of Guaranteed Rail Service." *Journal of Transportation Research Forum*, 36(1996):59-73.

Babcock, B. A., J. Wu, P. G. Lakshminarayan and D. Zilberman. "The Economics of a Public Fund for Environmental Amenities." *American Journal of Agricultural Economics*, 78(1996):961-971.

Patents (USA only)
None

Key science and technology achievements
I was appointed Director of the Center for Agricultural and Rural Development (CARD) in 1998 because of my research achievements in three related areas: adoption of technologies by farmers; impact of agricultural policy on farmer's land use decisions; and the development of innovative approaches to modeling how environmental objectives can most efficiently be met while maintaining agricultural productivity. At CARD I direct a staff of talented and productive agricultural and environmental economists who work in all three of these areas. We maintain and develop models of domestic and international production, consumption, and trade of all major agricultural commodities, including grain, oilseeds, cotton, and livestock, in all major exporting and importing countries. These models are used to make 10-year baseline projections that are in turn used to determine the impacts of changes in technology, demand, or policy on prices, production, and trade. These models are viewed as being the best in the world and are used by Congress and USDA to better understand the consequences of changes in policy and technology. We also maintain and develop models of the interaction between land use decisions and environmental quality, which is measured in terms of soil quality (erosion and carbon content) and water quality (nutrients and pesticides). These two sets of models are currently being employed to determine the likely impacts of the dramatic expansion of corn-based ethanol production. A similar effort will be needed to understand the consequences when the low-cost feed stock for ethanol changes from corn to lignocellulose.

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Education

University of Kiel, Germany	Undergraduate studies	1976-1979	Mathematics/Biology
University of Oxford, UK	M.Sc.	1981	Applied Statistics
The Weizmann Institute of Science, Israel	Ph.D.	1986	Life Sciences
Stanford University, USA	Post-doctoral studies	1987-1988	Bioinformatics

Positions and Employment

1989-1998	Research Associate, Stanford University
1995-1998 (part time)	Lecturer in Mathematics, Stanford University
1998-2000	Associate Professor, Iowa State University
2001-2002	Professor, Iowa State University
2002-present	Bergdahl Professor of Bioinformatics, Iowa State University

Honors

Since 2002	Member of the International Faculty of the Graduate School in Bioinformatics and Genome Research, University of Bielefeld, Germany

Selected Publications

Wilkerson, M.D., Schlueter, S.D. & Brendel, V. (2006) yrGATE: a web-based gene-structure annotation tool for the identification and dissemination of eukaryotic genes. Genome Biol. 7, R58.

Wang, B.-B. & Brendel, V. (2006) Genome-wide comparative analysis of alternative splicing in plants. Proc. Natl. Acad. Sci. USA 103, 7175-7180.

Wang, B.-B. & Brendel, V. (2006) Molecular characterization and phylogeny of U2AF1 homologs in plants. Plant Physiol. 140, 624-636.

Gremme, G., Brendel, V., Sparks, M.E. & Kurtz, S. (2005) Engineering a software tool for gene prediction in higher organisms. Information Software Technol. 47, 965-978.

Sparks, M.E. & Brendel, V. (2005) Incorporation of splice site probability models for non-canonical introns improves gene structure prediction in plants. Bioinformatics 21 Suppl. 3, iii20-iii30.

Dong, Q., Lawrence, C.J., Schlueter, S.D., Wilkerson, M.D., Kurtz, S., Lushbough, C. & Brendel, V. (2005) Comparative plant genomics resources at PlantGDB. Plant Physiol. 139, 610-618.

Pan, X., Stein, L. & Brendel, V. (2005) SynBrowse: A synteny browser for comparative sequence analysis. Bioinformatics 21, 3461-346.

Lawrence, C.J., Seigfried, T.E. & Brendel, V. (2005) MaizeGDB - the community resource for access to diverse maize data. Plant Physiol., 138, 55-58.

Schlueter, S.D., Wilkerson, M.D., Huala, E., Rhee, S.Y. & Brendel, V. (2005) Community-based gene structure annotation for the *Arabidopsis thaliana* genome. *Trends Plant Sci.* **10**, 9-14.

Wang, B.-B. & Brendel, V. (2004) The ASRG database: identification and survey of *Arabidopsis thaliana* genes involved in pre-mRNA splicing. *Genome Biol.* **5**, R102.

Brendel, V., Xing, L. & Zhu, W. (2004) Gene structure prediction from consensus spliced alignment of multiple ESTs matching the same genomic locus. *Bioinformatics* **20**, 1157-1169.

Patents (USA only)
None

Key science and technology achievements
Dr. Brendel is an expert in (plant) genome informatics. His flagship project PlantGDB (www.plantgdb.org) serves as the major pan-species plant genomics database in the plant research community. His research has focused on regulation of gene expression at the level of transcription, in particular at the level of splicing. His group has developed several widely used bioinformatics software tools, including the GeneSeqer and GenomeThreader spliced alignment programs. Dr. Brendel has served as the Director of the ISU Summer Institute in Bioinformatics and Computational Biology from 2003-2006 and is on faculty for the successor Summer Institute in Computational Systems Biology.

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Education

University of Vermont	BS	1976	Botany
Michigan State University	MS	1980	Plant Pathology
Michigan State University	PhD	1982	Plant Pathology

Positions and Employment

1982-1987	Research Manager, Pioneer Hi-Bred International, Inc.
1987-1990	Senior Staff Investigator, Cold Spring Harbor Laboratory
1987-1998	Research Fellow, Pioneer Hi-Bred International, Inc.
1998-2003	President and CEO, Torrey Mesa Research Institute
2003-2004	Senior Vice President, Corporate R&D, Diversa Corporation
2004-	Professor, Cell & Developmental Biology, UC San Diego

Honors

2000	Elected to the National Academy of Sciences, USA
2005	University of Vermont, College of Agriculture and Life Sciences Outstanding Alumnus of the Year

Selected Publications

Meeley, R.B., G.S. Johal, S.P. Briggs, and J.S. Walton. A biochemical phenotype for a disease resistance gene of maize. Plant Cell 1992. 4:71-77

Johal, G.S. and S.P. Briggs. The HM1 disease resistance gene in maize encodes a reductase activity. Science 1992. 258:985-987.

Bensen RJ, et al. Cloning and characterization of the maize anther ear 1 gene. Plant Cell 1995. 7: 75-84

Russin WA, et al. Modification of a specific class of plasmodesmata and loss of sucrose export ability in the sucrose export defective1 maize mutant. Plant Cell 1996. 8:645-658

Mena M, et al. Diversification of C-function activity in maize flower development. Science 1996. 274: 1537-1540

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Multani D, et al. Plant-pathogen microevolution: Molecular basis for the origin of a fungal disease in maize. Proc. Natl. Acad. Sci. USA 1998. 95: 1686-1691

Briggs, S. P. Plant genomics: more than food for thought. Proc. Natl. Acad. Sci. USA 1998. 95: 1986-1988
Veit B, et al. Regulation of leaf initiation by the terminal ear1 gene of maize. Nature 1998. 393: 166-168
Hu G, et al. A porphyrin pathway impairment is responsible for the phenotype of a dominant disease lesion mimic mutant of maize. Plant Cell 1998. 10:1095-1105
Goff SA, et al. A draft sequence of the rice genome (Oryza sativa L. ssp. japonica). Science 2002. 296:92-100
Paszkowski U, et al. Rice phosphate transporters include an evolutionarily divergent gene specifically activated in arbuscular mycorrhizal symbiosis. 2002. Proc Natl Acad Sci U S A 99:13324-13329
Guan X, et al. Heritable endogenous gene regulation in plants with designed polydactyl zinc finger transcription factors. Proc Natl Acad Sci U S A 2002. 99:13296-13301
Multani D, et al. Loss of an MDR Transporter in Compact Stalks of Maize *br2* and Sorghum *dw3* Mutants. Science 2003. 302:81-84
Tachikawa K, et al. Regulation of the endogenous VEGF-A gene by exogenous designed regulatory proteins. Proc Natl Acad Sci U S A. 2004 101:15225-30
Güimil S, et al. Comparative transcriptomics of rice reveals an ancient pattern of response to microbial colonization. Proc Natl Acad Sci U S A. 2005 102:8066-70

Patents (USA only)
Issued, 17
Published but not yet issued, 10

Key science and technology achievements
Briggs was the first to isolate and characterize a plant gene for resistance to infectious disease. He was also the first to discover a natural mechanism for plant resistance to infection. Briggs was the first to invent a reverse genetics technology for plants and his system is still widely used for maize research. In 1998, Briggs founded the Torrey Mesa Research Institute (originally named the Novartis Agricultural Discovery Institute) with funding from the Novartis Research Foundation. While there, Briggs produced a draft sequence of the rice genome. This enabled comparative genomics in plants by reference to the recently completed arabidopsis genome sequence, and it provided a framework for genomics in all of the other grass crops (maize, wheat, barley, oats, rye, and sugarcane). Under Briggs' direction, the staff at TMRI created the first plant (arabidopsis) GeneChip, which was released for public use and is still popular; the first reverse genetics technology for arabidopsis, which was followed by and incorporated into the Salk T-DNA collection; the first crop GeneChip (for rice); the first all-exon GeneChip (for arabidopsis); and the first plant proteome (for rice; this remains the most comprehensive plant proteome in the literature). Briggs was the first to use artificial transcription factors to regulate endogenous genes in plants. Briggs has published numerous discoveries about plant development and plant cell death. Recently, Briggs has moved into biomarker discovery and validation in human disease. He has developed protein mass spectrometry technology that enables the identification and relative quantitation of several thousand proteins and phosphoproteins between samples. Briggs has invented the Designed Regulatory Protein (DRP) technology that allows any gene to be specifically activated or repressed by simply adding a DRP to plasma or medium bathing cells. These technologies are being focused on understanding and controlling chronic lymphocytic leukemia, embryonic stem cell fate determination, and infectious disease in plants.

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Education

University of Idaho	BS	1981	Anthropology
Washington State Univ.	MS	1987	Soil Science – Soil Microbiology emphasis
University of Idaho	PhD	1992	Bacteriology

Positions and Employment

1988	Technical Specialist, Pacific Northwest National Laboratory
1988-1989	Scientist 1, Pacific Northwest National Laboratory
1990-1992	Scientist 2, Pacific Northwest National Laboratory
1993-1997	Scientist 3, Pacific Northwest National Laboratory
1998-1999	Scientist 4, Pacific Northwest National Laboratory
2000-2006	Scientist 5, Pacific Northwest National Laboratory
2001-2006	Microbiology Technical Group Leader, Pacific Northwest Nat. Lab.

Honors

2005	Battelle Key Contributor Award (licensing of patented technology)
2003	Battelle Key Contributor Award ((licensing of patented technology)
2002-2003	ASM Outstanding Service Award (Division N chair)
2001-2003	Waksman Foundation of Microbiology Lecturer Award
1999	Highest scoring speaker in first ASM workshop on Molecular Approaches to Environmental Microbiology
1997-1999	Editorial Board, Applied and Environmental Microbiology

Selected Publications

Feist AM, JCM Scholten, BØ Palsson, FJ Brockman, and T Ideker. 2006. "Modeling methanogenesis with a genome-scale metabolic reconstruction of *Methanosarcina barkeri*." Molecular Systems Biology 2:2006.0004. Published online: 31 January 2006

Zhang W, DE Culley, MA Gritsenko, RJ Moore, L Nie, H Scholten, K Petritis, EF Strittmatter, DG Camp, II, RD Smith, and FJ Brockman. 2006. "LC-MS/MS based proteomic analysis and functional inference of hypothetical proteins in *Desulfovibrio vulgaris*." *Biochemical and Biophysical Research Communications* 349(4):1412-1419.

Nie L, G Wu, FJ Brockman, and W Zhang. 2006. "Integrated analysis of transcriptomic and proteomic data of *Desulfovibrio vulgaris*: Zero-Inflated Poisson regression models to predict abundance of undetected proteins." Bioinformatics 22(13):1641-1647.

Zhang W, MA Gritsenko, RJ Moore, DE Culley, L Nie, K Petritis, EF Strittmatter, DG Camp, II, RD Smith, and FJ Brockman. 2006. "A Proteomic view of *Desulfovibrio vulgaris* metabolism as determined by liquid chromatography coupled with tandem mass spectrometry." Proteomics 6(15):4286-4299.

Zhang W, DE Culley, L Nie, and FJ Brockman. 2006. "DNA microarray analysis of anaerobic *Methanosarcina barkeri* reveals responses to heat shock and air exposure." Journal of Industrial Microbiology and Biotechnology 33(9):784-790.

Zhang W, DE Culley, H Scholten, M Hogan, L Vitiritti, and FJ Brockman. 2006. "Global Transcriptomic Analysis of *Desulfovibrio vulgaris* Grown on Different Carbon Sources." Antonie Van Leeuwenhoek 89(2):221-237.

Moser DP, TM Gihring, FJ Brockman, JK Fredrickson, DL Balkwill, ME Dollhopf, BS Lollar, L Pratt, E Boice, G Southam, G Wanger, B Baker, S Pfiffner, L Lin, and TC Onstott. 2005. " *Desulfotomaculum* spp.and *Methanobacterium* spp. Dominate a 4-5 km Deep Fault." Applied and Environmental Microbiology 71(12):8773-8783.

Patents (USA only)

U.S. Patent No. 7,090,774 entitled "METHOD FOR PACKED COLUMN SEPARATIONS AND PURIFICATIONS" issued August 15, 2006. David A. Holman, Cynthia J. Bruckner-Lea, Fred J. BROCKMAN and Darrell P. Chandler.

U.S. Patent No. 7,001,522 entitled "Systems For Column-Based Separations, Methods Of Forming Packed Columns, And Methods Of Purifying Sample Components issued February 21, 2006. Fred BROCKMAN, Cindy Bruckner-Lea, Darrell Chandler, Oleg Egorov, Jay Grate, and Matthew O'Hara.

U.S Patent Application Number: 11/294,713 entitled "Method and Apparatus for Packed Column Separations and Purifications". Application Date: 12/05/2005. Fred Brockman, Cindy Bruckner-Lea, and Darrell Chandler [this is the "Device" extension of U.S. Patent No. 7,090,774]

U.S. Patent No. 6,780,326 entitled "Systems for column-based separations, methods of forming packed columns, and methods of purifying sample components". Issued in 2004. J Grate, O Egorov, DP Chandler, FJ BROCKMAN, and C Bruckner-Lea. 2004.

U.S. Patent No. 6,780,326 entitled "Enhancement of in situ microbial remediation of aquifers". Issued in 1993. JK Fredrickson, FJ BROCKMAN, GP Streile, JW Cary, and JF McBride.

Key science and technology achievements

Dr. Brockman's current major research area is leading a research team investigating syntrophic anaerobic co-cultures and microbial interactions in simple multiple-species communities, using chemostat culturing, fluorescent in situ hybridization, whole genome microarrays, and proteomics. Simple mixed cultures involving syntrophic metabolism are likely to be a key aspect of the most thermodynamically and kinetically efficient conversion of cellulosic and lignocellulosic materials to ethanol and hydrogen. This research uses the Microbial Cell Dynamics Laboratory at PNNL, a DOE quasi-user facility focused on highly controlled and instrumented culturing in chemostats, to include aerobic and anaerobic respiration, fermentative, and photosynthetic metabolisms. Dr. Brockman is also engaged in a number of projects analyzing microbial metagenome sequence.

Other major technical achievements involved the development (and patenting) of automated affinity-based purification of nucleic acids from environmental samples (1998-2001), and a member of a large team of researchers instrumental in the discovery and characterization of indigenous microbial communities in rocks 1 to 5 kilometers below the surface of the earth (2001-present).

Organizer/convener of 5 ASM and DOE national workshops.

Organized/chaired 16 sessions at national meetings.

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Education

University of Missouri-Columbia	BS	1976	Physics
University of Missouri-Columbia	BA	1976	Mathematics
Michigan State University	MS	1977	Mechanical Engineering
Michigan State University	PhD	1980	Mechanical Engineering

Positions and Employment

1976-1980	Graduate assistant, Department of Mechanical Engineering, Michigan State University, Lansing, Michigan
1980-1983	Senior Engineer, Thermodynamics Group, General Dynamics Corporation, Fort Worth, Texas
1983- 1987	Assistant Professor of Mechanical Engineering, Iowa State University
1987- 1993	Associate Professor of Mechanical Engineering, Iowa State University
1993-present	Professor of Mechanical Engineering, Iowa State University, Ames, IA
1993-present	Professor of Chemical and Biological Engineering, Iowa State University
2003- present	Bergles Professor in Thermal Science, Iowa State University
2004 - present	Professor of Agricultural and Biosystems Engineering, Iowa State University

Honors

1991	Young Engineering Faculty Research Award, Iowa State University, College of Engineering
1997	R&D 100 Award, Off-Line Carbon-in-Ash Monitor, Research & Development Magazine
2002	David R. Boylan Eminent Faculty Award for Research, College of Engineering, Iowa State University
2002 - present	Fellow, American Society of Mechanical Engineering International
2004	Visiting Scholar, John Deere Company
2006	Distinguished Iowa Scientist Award, Iowa Academy of Science

Selected Publications

Brown, R. C., Chapter 24. Biomass Energy Conversion, Section 24.3 Bio-fuels, CRC Handbook of Energy Conservation and Renewable Energy, Kreith, F. and Goswami, Y., Eds., CRC Press, 2006.

Brown, R. C., Chapter 19. Resource Availability, Section 19.4 Biomass, CRC Handbook of Energy Conservation and Renewable Energy, Kreith, F. and Goswami, Y., Eds., CRC Press, 2006.

Xu, M., Brown, R. C., and Norton, G. (2006) Effect of sample aging on the accuracy of the International Energy Agency's tar measurement protocol," Energy & Fuels 20, 262-264.

Brown, R. C., Biomass Refineries based on Hybrid Thermochemical/Biological Processing– An Overview, in Biorefineries, Biobased Industrial Processes and Products, Kamm, B., Gruber, P. R., Kamm, M., Eds., Wiley-VCH Verlag, Weinheim, Germany, 2005.

Zhang, R., Cummer, K., Suby, A., and Brown, R. C., Biomass-derived hydrogen from an air-blown gasifier," Fuel Processing Technology 86, 861-874, 2005.

Zhang, R., Brown, R., Suby, A., and Cummer, K., "Catalytic destruction of tar in biomass-derived producer gas," Energy Conversion and Management (2004) 45 (7-8), 995-1014.

Zhang, R., Brown, R. C., and Suby, A., "Thermochemical generation of hydrogen from switchgrass," Energy and Fuels 18, 251-256, 2004.

Mérida, W., Maness, P., Brown, R. C., and Levin, D. B., "Enhanced hydrogen production and removal of carbon dioxide from indirectly heated biomass gasification," International Journal of Hydrogen Energy 29, 283-290, 2004.

Brown, R. C., Biorenewable Resources: Engineering New Products from Agriculture, Iowa State Press, April 2003.

Patents (USA only)

Issued, 9

Published but not yet issued, 2

Key science and technology achievements

Dr. Brown is an expert in thermochemical processing of biomass into energy, fuels, and chemicals. His research in biomass gasification includes studies of carbon conversion, tar measurement and control, hot gas clean-up (particulate matter and inorganic contaminants), hydrogen production, and synthesis of renewable fuels and other biobased products using catalytic and biocatalytic processes. His research in fast pyrolysis includes studies on the evolution and transport of pyrolysis vapors and aerosols, selective condensation of pyrolysis liquids, catalytic and biocatalytic conversion of pyrolysis liquids into fuels and fertilizer, utilization of char byproduct as soil amendment and carbon sequestration agent, and power systems based on pyrolysis liquids. Dr. Brown has also performed techno-economic analyses of bioenergy and biofuel systems. Dr. Brown has contributed to the development of educational programs in bioenergy. In 2003 he helped establish the first-in-the-nation graduate program in Biorenewable Resources and Technology at ISU and published *Biorenewable Resources: Engineering New Products from Agriculture*, a textbook for students interested in the Bioeconomy. Dr. Brown is a Fellow of the American Society of Mechanical Engineers.

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Education

1964	A.B.	Columbia University, New York, New York
1971	M.D.	University of Chicago, Chicago, Illinois
1971	Ph.D.	University of Chicago, Chicago, Illinois (Pharmacology)

Internship: Pediatrics; Children's Hospital Medical Center, Boston, Massachusetts

Positions and Employment

1971-72	Intern, Children's Hospital Medical Center, Boston, Massachusetts
1972-74	Research Associate, PRAT Program, NIGMS, NIH, Bethesda, Maryland Mentor: Julius Axelrod
1974-76	Senior Staff Fellow, LCS, NIMH, ADAMHA, Bethesda, Maryland
1976-78	Medical Officer (Research), LCS, NIMH, ADAMHA, Bethesda, Maryland
1978-82	Chief, Unit on Neuroendocrinology, LCS, NIMH, ADAMHA, Bethesda, MD
1982-96	Chief, Laboratory of Cell Biology, NIMH, ADAMHA, Bethesda, Maryland
1988-93	Associate Director for Basic Research
1993-95	Acting Director, Division of Intramural Research Programs, NIMH
1996-99	Chief, Section on Genetics NIMH/NHGRI
1999-04	Chief, Laboratory of Genetics, NIMH/NHGRI
2004	Contractor, Laboratory of Genetics, NIMH
2005-	Special Volunteer, NIMH
2005-	Director, Functional Genomics, The J. Craig Venter Institute

Honors/Awards
The E. Gellhorn prize in Neurophysiology, 1970
ADAMHA Administrator's Award for Meritorious Achievement, 1978
University of Chicago Club's Honored Alumnus Award for Professional Excellence, 1979
Arthur S. Flemming Award, 1981
PHS Superior Service Award, 1986
DHHS Distinguished Service Award (Biomedical Research), 1992
Alpha Omega Alpha, Alumnus Member, University of Chicago, 1998
M.D. (honoris causa), University of Lund, Sweden, 1999

Key science and technology achievements
Dr. Brownstein earned his A.B. from the Columbia College and his M.D. and Ph.D degrees at the University of Chicago. After completing an internship at the Boston Children's Hospital, he came to the NIH in 1972 as a Pharmacology Research Associate to work with Julie Axelrod. Initially he studied the pineal gland, but he quickly realized the limitations of the assays that he was using, and began to develop more sensitive techniques for measuring neurotransmitters and their biosynthetic enzymes. He met Miklos Palkovits, who had just devised a novel brain microdissection method, in 1973, and together they mapped many "classical" transmitters and

neuropeptides in the central nervous system. Dr. Brownstein was the first to point out that neurons make and likely release more than one chemical messenger, and the first to show that "hypothalamic hormones" must have much broader roles in the brain and periphery.

Discussions with Harold Gainer resulted in the next phase of Dr. Brownstein's research career. He and Dr. Gainer used pulse-chase studies in vivo to show that vasopressin and oxytocin are synthesized as parts of larger precursor proteins, that these precursors are processed by proteases in vesicles while they are being transported from the cell body to its axon terminals, and that precursor synthesis and processing are both regulated by demand.

Richter and Schmale used molecular biological techniques to characterize the mRNAs encoding the vasopressin and oxytocin precursors. Dr. Brownstein was so impressed by the potential power of the techniques that they used in their studies that he redirected his own efforts. As soon as Hiroto Okayama came to the NIH, Dr. Brownstein ask to work with him, and over a three year period they developed robust protocols for making cDNA libraries and expressing the inserts in mammalian cells. Dr. Brownstein's goal at the time was to use such methods for expression cloning of vasopressin and oxytocin receptors—the next essential step in learning about the biology of these peptide hormones. He and his coworkers ultimately achieved these goals, and they cloned a number of additional important cDNAs. Some of these have proven especially important to members of the mental health community; e.g., cDNAs that encode the serotonin transporter (the target of SSRIs), the dopamine transporter (the target of cocaine), the cannabinoid receptor (the target of a novel and very promising drug for treating obesity and addictive behavior), and the vasopressin V1b receptor (an attractive target for development of antidepressant compounds).

One of the vasopressin receptors that Dr. Brownstein's group cloned was the V2 (kidney) subtype. He understood that mutations in this receptor could very well be responsible for X-linked nephrogenic diabetes insipidus, and rapidly demonstrated that this was indeed the case. This was his reintroduction to human genetics, and he decided to learn more about genetic analyses by working in the NHGRI. He was among the first people there to do high-throughput, fluorescence-based genotyping, and he developed a method for modifying the primers used to study microsatellite markers ("Pig tailing") that was subsequently licensed by Applied Biosystems and applied to all of the primer pairs that they manufactured. To date tens of millions of genotypes have been done with such markers.

In his final years at the NIH, Dr. Brownstein's focus was complex traits genetics and genomics. His team defined causative mutations in a number of genetic disease, ranging from prostate cancer to cataracts, and continued to develop important methods, notably ones for labeling probes for microarray studies. He functioned as a Laboratory Chief, and as the acting Scientific Director of the NIMH's Intramural Research Program. He has served on numerous editorial boards, scientific advisory boards, and review committees, and has received a number of awards, most recently, an honorary Doctorate from the University of Lund in Sweden. In 2005, Dr. Brownstein left the NIH and moved to the J. Craig Venter Institute, Rockville, MD where his is Director of Functional Genomics. He was the founder of Thyreos, the first product of which is a Ras inhibitor that is in phase 2 clinical trials, and co-founder of a number of other companies including Azevan, N-Gene, and SolarGen.

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Education

Princeton University	BSE	1991	Mechanical and Aerospace Engineering
U.C. Berkeley	M.S.	1994	Mechanical Engineering
U.C. Berkeley	Ph.D.	1995	Mechanical Engineering

Positions and Employment

1995-1998	Postdoctoral Research Associate, Combustion Research Facility, Sandia National Laboratories
1998-1999	Senior Member of Technical Staff, Center for Exploratory Systems and Development, Sandia National Laboratories
1999-2003	Assistant Professor, Department of Mechanical Engineering, University of Maryland, College Park (UMCP)
2001-2003	Affiliate Assistant Professor, Dept. of Fire Protection Eng., UMCP
2003-2005	Assistant Professor, MAE Dept., UCSD
2005 - present	Associate Professor, MAE Dept., UCSD
2006 - present	Associate Director, Center for Energy Research, UCSD

Honors

1990	International Gas Turbine Institute Scholarship
1991	Princeton MAE Dike Award – Best undergraduate independent work
1992-1993	Air and Waste Management Association Scholarship, 1st place award
2001	National Science Foundation Early Career Development award
2001	Office of Naval Research Young Investigator Award

Selected Publications

S.G. Buckley, C.S. McEnally, R.F. Sawyer, C.P. Koshland, and D. Lucas, "Metal Emissions Monitoring Using Excimer Laser Fragmentation-Fluorescence Spectroscopy," Combustion Science and Technology, 118: 1-3, p. 171 (1996).

S.G. Buckley, C. Damm, W.M. Vitovec, L.A. Sgro, R.F. Sawyer, C.P. Koshland, and D. Lucas, "Ammonia Detection and Monitoring Using Fragmentation-Fluorescence," Applied Optics, 37:36, pp 8382 - 8391 (1998).

A.L. Robinson, S.G. Buckley, and L.L. Baxter, "In Situ Measurements of the Thermal Conductivity of Ash Deposits," Proc. of the Combustion Institute, Vol. 27, pp 1727-1735 (1998).

S.G. Buckley, A.L. Robinson, and L.L. Baxter, "Energetics to Energy: Combustion and Environmental Considerations Surrounding the Reapplication of Energetic Materials as Boiler Fuels," Proceedings of the Combustion Institute, Vol. 27, pp. 1317-1325 (1998).

A.L. Robinson, H. Junker, S.G. Buckley, G. Sclippa, and L.L. Baxter, "Interactions Between Coal and Biomass When Cofiring," Proc. of the Combustion Institute, Vol. 27, pp 1351-1359 (1998).

S.G. Buckley, H.A. Johnsen, K.R. Hencken, and D.W. Hahn, "Laser-Induced Breakdown Spectroscopy as a Continuous Emissions Monitor for Toxic Metals in Thermal Treatment Facilities," Waste Management, 20, pp 455-462 (2000).

S.G. Buckley, R.F. Sawyer, C.P. Koshland, D. Lucas, "Laser Measurements of Lead and Lead Particulate in Flames," Combustion and Flame, 128 (4) pp 435-446 (2002).

F. Ferioli, P. Puzinauskas, and S.G. Buckley, "Laser-Induced Breakdown Spectroscopy for On-Line Engine Equivalence Ratio Measurements," Applied Spectroscopy 57 (9) pp 1183-1189 (2003).

J. Hybl, G. Lithgow, and S.G. Buckley, "Laser-Induced Breakdown Spectroscopy Detection of Biological Material," Applied Spectroscopy 57(10) pp 1207-1215 (2003).

M. Gharavi and S.G. Buckley, "A Single Diode Laser Sensor for Wide Range Temperature and H2O Concentration Measurements," Applied Spectroscopy 58 (4) pp 468-473 (2004).

S.G. Buckley, "Laser-induced breakdown spectroscopy for toxic metal emission measurements: Experimental considerations and oxygen quenching," Environmental Engineering Science 22 (2) pp 195-204 (2005).

F. Ferioli and S.G. Buckley, "Measurements of Hydrocarbons using Laser-Induced Breakdown Spectroscopy," Combustion and Flame, 144 (3) 435-447 (2006).

Patents (USA only)

- U.S. Patent # 6,085,829 "Regenerator Type Heat Exchanger", July 11, 2000. With R. Mongia, P. Neuhaus, R. Dibble
- U.S. Patent # 6,141,953 "Multi-shaft Reheat Turbine Mechanism for Generating Power", November 7, 2000. With R. Mongia, R. Dibble, G. Touchton

Key science and technology achievements

Buckley's work has focused around the theme of practical combustion diagnostics applied to understanding combustion physics and emissions from power systems. He has experience in:

- Solid fuel combustion – he has worked on improving theory on solid fuel combustion
- Power plant operations and diagnostics – he has made spectroscopic measurements in operating power plants, incinerators, and glass melting furnaces, and has worked on slagging, fouling, and ash deposition in practical systems.
- Applied measurement systems – Buckley's lab is one of the foremost in the U.S. in developing Laser-Induced Breakdown Spectroscopy (LIBS) and tunable diode laser wavelength modulation spectroscopy. These techniques are accurate, yet practical enough to be implemented in the field, for measurement of particles, gas-phase species, and elemental composition. Current projects include development of an in-cylinder engine equivalence ratio sensor and a multi-gas sensor for solid fuel gasification.
- Biofuels engineering – Buckley has worked on cofiring biofuels with coal to take advantage of higher plant efficiencies while minimizing effective CO_2 emisions. This study included interactions between the biofuel and traditional fuel. He is currently working on biodiesel combustion – both fundamentally, at the laboratory scale, and practically, in engines.

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Education

University of Maryland, College Park, MD	BS	1985	Biology
Washington State University, Pullman, WA	M.S.	1988	Plant Pathology
Utah State University, Logan, UT	Ph.D	1992	Biology and Molecular Biology

Positions and Employment

1992-96 Postdoctoral Research Associate, DOE-Plant Research Laboratory, Michigan State University, E. Lansing, MI. & Carnegie Institution of Washington, Stanford CA.

1997-98 Assistant Professor, Louisiana State University Department of Biological Sciences & LA Agricultural Experiment Station, LSU Agricultural Center, Baton Rouge, LA.

1999-03 Assistant Investigator, The Institute for Genomic Research, Rockville, MD.

2003-present Adjunct Faculty, Department of Plant and Soil Science, University of Delaware, Newark, DE.

2003-present Associate Investigator, The Institute for Genomic Research, Rockville, MD.

Honors

2003 World Technology Award in Biotechnology (as a member of the International Rice Genome Sequencing Project Consortium)

2004 U. S. Department of Agriculture Honor Award Recipient (as member of the U. S. Rice Genome Sequencing Consortium)

Selected Publications

The International Rice Genome Sequencing Project. 2005. The map-based sequence of the rice genome. Nature 436:793-800.

Rensink, W.A. and **Buell, C. R.** 2005. Microarray expression profiling resources for plant genomics. Trends in Plant Science 10:603-609.

Rensink, W.A., Lee, Y., Liu, J., Iobst, S., Ouyang, S., and **Buell, C. R.** 2005. Comparative analyses of six solanaceous transcriptomes reveal a high degree of sequence conservation and species-specific transcripts. BMC Genomics 6:124.

Gardiner, J. M., **Buell**, **C. R.,** *et al*. 2005. Design, production, and utilization of long oligonucleotide microarrays for expression analysis in maize. Maydica 50: 425-435.

Rensink, W. A., Hart, A., Liu, J., Ouyang, S., Zismann, V., and **Buell, C. R**. 2005. Analyzing the potato abiotic stress transcriptome using Expressed Sequence Tags. Genome 48:598-605.

Rensink, W. A., Iobst, S., Hart, A., Stegalkina, S., Liu, J., and **Buell, C. R.** 2005. Gene expression profiling of potato responses to cold, heat, and salt stress. Integrative and Functional Genomics 5: 201-207.

Yuan, Q., *et al*. (**C.R. Buell** is senior author) 2005. The TIGR Osa1 rice genome annotation database. Plant Physiology 138:18-26.

Gill, B. S., Appels, R., Botha-Oberholster, A. M., **Buell, C. R.**, *et al.* 2004. A Workshop Report on Wheat Genome Sequencing: International Genome Research on Wheat (IGROW) Consortium. Genetics 168:1087-1096.

Ouyang, S. and **Buell, C. R.** 2004. The TIGR Plant Repeat Databases: A Collective Resource for Identification of Repetitive Sequences in Plants. NAR 32 Database Issue: D360-363.

Ronning, C. M., *et al*. (**C.R. Buell** is senior author). 2003. Comparative analyses of potato Expressed Sequence Tag libraries. Plant Physiology 131: 419-429.

Patents (USA only)

Pseudomonas Avr and Hop proteins, their encoding nucleic acids and use thereof. Application No. 10/114,828 (Awarded)

Potato Genes for Resistance to Late Blight, U. S. Provisional Application No. 60/439,376 (Pending)

Key science and technology achievements

Buell's research has centered on genomic aspects of plant biology and plant pathogens. Buell was centrally involved in the International Rice Genome Sequencing Project, a consortium of laboratories throughout the world focused on sequencing the rice genome. Buell and her group generated 55 Mb of finished rice genome sequence and were instrumental in the bioinformatic analysis of the rice genome. Buell's group has annotated the rice genome, deployed a genome browser for the rice genome (rice.tigr.org), and performed comparative analyses with the rice genome. Buell has authored 27 rice genomics and bioinformatics publications that reflect her international status in rice genomics.

Buell has been a leader in potato structural and functional genomics, generating ~125,000 potato Expressed Sequence Tags (ESTs) and potato cDNA microarrays. Buell and her laboratory examined transcriptional responses in potato during heat, cold, and salt stress and are currently examining expression differences in germplasm with differential tolerances to heat and cold stress. Buell has generated ~1,300 expression profiles of Solanaceae species available to the public through our through Solanaceae Gene Expression Database (www.tigr.org/tdb/potato/). Buell has developed the Comprehensive Phytopathogen Genome Resource (cpgr.tigr.org), that contains all plant pathogen genome sequence data including viruses, bacteria, fungi, stramenopiles, and nematodes, a major resource that will be instrumental in combating plant losses to diseases.

Buell has been engaged in a number of collaborative projects including 1) sequencing ~80,000 pine ESTs (www.tigr.org/tdb/e2k1/pine/index.shtml), 2) fabrication of publicly available arrays for pine and rice 3) bioinformatic support for the NSF maize and rice array projects (www.ricearray.org; www.maizearray.org), 4) sequence and annotation of two bacterial plant pathogens, 5) characterization of rice centromere 8, 6) construction of the TIGR Plant Transcript Assemblies (plantta.tigr.org), 7) construction of the TIGR Plant Repeat Database (www.tigr.org//tdb/e2k1/plant.repeats), and 8) construction of a wheat genome annotation resource (www.tigr.org/tdb/e2k1/tae1/).

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Education

University of California at Berkeley	BS	1967	Mechanical Engineering (With Highest Honors)
University of California at Berkeley	MS	1968	Mechanical Engineering
University of California at Berkeley	Ph.D.	1973	Engineering Science

Positions and Employment

1973- 1975	**NSF Post Doctoral Fellow**, Department of Mechanical Engineering University of California at Berkeley, Berkeley, CA
1975-1990	**Distinguished Member of the Technical Staff**, Combustion Research Department, Sandia National Laboratories, Livermore, CA
1981	**Visiting Scientist**, CNRS Laboratoire de Thermodynamic, University of Rouen, Mont Saint Aignan, France.
1990- present	**Professor of Engineering Physics**, Department of Mechanical and Aerospace Engin., University of California at San Diego, La Jolla, CA
1991	**Visiting Professor**, Department of Chemical Engineering and Chemical Technology, Imperial College, University of London, London, England
1999-2000	**Visiting Scientist,** Institute for Laser Science and Applications, Lawrence Livermore National Laboratories, Livermore, CA.
2000	**Visiting Professor,** Combustion Physics Department, Lund Institute of Technology, Lund, Sweden.
2003-2005	**Visiting Scientist,** Energy and Environment Directorate, Lawrence Livermore National Laboratories, Livermore, CA

Honors

1963-67	University of California Undergraduate Scholarship
1963-67	State of California Scholarship
1968-1970	NASA Predoctoral Fellowship
1973-1975	NSF Post Doctoral Fellowship
1985	AIAA Best Paper in Thermophysics Research "Fluorescence Imaging of a Flame Vortex Interaction

Selected Publications

1. Robert Cattolica "Emission Monitoring of Nitric Oxide with a Mid-IR Solid State Laser," California Energy Commission, ESIG Report 02-20, June 2006.
2. Robert J. Cattolica, David R. Farley, and L. H. Clapp, "Electron Bean Dispersion in Carbon Dioxide," Rarefied Gas Dynamics,"Vol.I,pp.567-574,Cepadues-Editions,Toulouse, France, 1999
3. David R. Farley, Robert J. Cattolica and Leonard H. Clapp, "Propagation of Medium Energy Electrons (10 - 20 keV) in Carbon Dioxide, "Physics of Fluids, Vol. 11, No.1, pp.225-234, 1999.
4. David R. Farley and Robert J. Cattolica, "Spectroscopic Modeling of the CO_2+ $A^2\Pi$ - $X^2\Pi$ (110-010) Renner-Teller Bands in the Electron Beam Fluorescence of Carbon Dioxide," Journal of Quantitative Spectroscopy and Radiative Transfer, Vol. 59, No. 1/2, pp. 25-31, 1998.
5. David R. Farley and Robert J. Cattolica, "Collisional Quenching and Excitation Cross-Sections of the CO_2^+ $A^2\Pi$ (1-3,0,0) and $B^2\Sigma$ (0,0,0) Excited States from Electron-Impact Ionization," Chemical Physics Letters, vol. 274, pp. 445-450, 1997.
6. R. J. Cattolica, "Quenching Effects on Laser-Fluorescence Measurements of OH Rotational Temperature in H_2/O_2/Ar Flames," Combustion Science. and Technology, Vol. 112, pp. 1-13, 1996.
7. David R. Farley and Robert J. Cattolica, "Electron-Beam Fluorescence from the A2ū - X2Πg and the $B^2\Sigma_u$- $X^2\Pi$g Transitions of CO_2+". Journal of Qantitative Spectroscopy and Radiative Transfer," Vol. 56, No. 1, pp. 83-96, 1996.
8. David R. Farley and Robert. J. Cattolica," Multipole Line Strengths for Linear Hund's Case (a) Molecules," Journal of Quantitative Spectroscopy and Radiative Transfer, Vol. 56, No. 5, pp. 753-760, 1996.

Patents (USA only)

None

Key science and technology achievements

Professor Cattolica is Professor of Engineering Physics in the Department of Mechanical and Aerospace Engineering at the University of California at San Diego. He received his Ph.D degree in Engineering Science at the University of California at Berkeley in 1973. His graduate research was in the field of rarefied gas dynamics, developing electon-beam fluorescence spectroscopy in the study of non-equilibrium hypersonic flows. After completing his Ph.D degree he joined the Department of Mechanical Engineering at the University of California, Berkeley as a National Science Foundation Post-Doctoral Fellow (1973-1975) conducting research on applied laser spectroscopy in the study of flame structure. From 1975 to 1990 he was a Distinguished Member of the Technical Staff at Sandia National Laboratories, Livermore, California in the Combustion Research Department developing new laser spectroscopy methods in the study of chemical structure of flames. In 1990 he joined the engineering faculty in the Jacobs School of Engineering at UCSD. His teaching responsibilities in the Department of Mechanical and Aerospace Engineering include: aerodynamics, propulsion, internal combustion engines, compressible flow, physical dynamics, and applied optical spectroscopy. His areas of research include fluid mechanics, optical spectroscopy, combustion, laser and electron beam diagnostics in semi-conductor plasma .instrumentation. Professor Cattolica's current research has been directed to the study of semi-conduction plasmas and in the application of mid-IR quantum cascade lasers for the measurement of trace pollutants from combustion. On the UCSD campus Professor Cattolica has been Chairman of General Campus Subcommittee on Research and the Committee on Laser Safety. He has been the Associate Editor of the Journal of Quantitative Spectroscopy and Radiative Transfer (1991-1994). His professional affiliations include: AIAA (Associate Fellow), APS, and the Combustion Institute. He has consulted in a wide variety of fields including: satellite propulsion, cavitation enhanced drilling technology, performance analysis of power plants, design of multi-stage compressors, and the design of research burners.

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Education

University of Stockholm, Sweden	Ph.D.	1968	Meteorology
University of Stockholm, Sweden	Dr. Sc.	1973	Meteorology

Positions and Employment

Pre-1974	Programmer, combined with Licentiat (Ph.D) and D.Sci studies and various teaching and research duties at the University of Stockholm; latest appointment Associate professor
1969-1971	Fellow of the European Space Research Organization at Oxford University, England
1974-1977	Consultant at the Aeronomy Laboratory of the National Oceanic and Atmospheric Administration (half-time) and Researcher at the National Center for Atmospheric Research Boulder (half-time), Colorado, USA.
1977-1980	Senior Scientist and Director of the Air Quality Division of the National Center for Atmospheric Research, Boulder, Colorado, USA
1980-2000	Director of the Atmospheric Chemistry Division of the Max-Planck-Institute for Chemistry, Mainz, Germany (emeritus, 2000)
1987-1991	Professor (part-time), University of Chicago, Department of Geophysical Sciences, USA
Since 1992	Professor (part-time), Scripps Institution of Oceanography, University of California, La Jolla, USA. Distinguished professor since 2005

Honors

1989	Tyler Prize for Environment
1991	Volvo Environmental Prize
1994	German Environmental Prize (Federal Foundation for the Environment)
1994	Max-Planck-Forschungspreis (with Dr. M. Molina, USA)
1995	Nobel Prize in Chemistry with Dr. M. Molina and Dr. F.S. Rowland
1995	Global UNEP Ozone Award for “Outstanding Contribution to the Protection of the Ozone Layer”

Selected Publications

Pittock, A. B., T. P. Ackerman, P. J. Crutzen, M. C. MacCracken, C. S. Shapiro and R. P. Turco, 1986: Environmental Consequences of Nuclear War, SCOPE 28, Volume I: Physical and Atmospheric Effects, Wiley, Chichester, 359 pp; 2nd edition 1989.

Graedel, T. E. and P. J. Crutzen, 1993: Atmospheric Change: An Earth System Perspective. W. H. Freeman, New York, 446 pp. (book)

Crutzen, P. J., 1996: My life with O_3, NO_x, and other YZO_x compounds (Nobel Lecture). Angew. Chem. Int., **35**, 1758-1777.

Crutzen, P. J., 1971: Ozone production rates in an oxygen-hydrogen-nitrogen oxide atmosphere. J. Geophys. Res., **76**, 7311-7327.

Crutzen, P. J., 1974: A review of upper atmospheric photochemistry. Can. J. Chem., **52**, 1569-1581.

Fishman, J. and P. J. Crutzen, 1978: The origin of ozone in the troposphere. Nature, **274**, 855-858.

Crutzen, P. J., 1979: The role of NO and NO_2 in the chemistry of the troposphere and stratosphere. Ann. Rev. Earth Planet. Sci., **7**, 443-472.

Crutzen, P. J. and F. Arnold, 1986: Nitric acid cloud formation in the cold Antarctic stratosphere: a major cause for the springtime "ozone hole". Nature, **324**, 651-655.

Lelieveld, J. and P. J. Crutzen, 1990: Influences of cloud and photochemical processes on tropospheric ozone. Nature, **343**, 227-233.

Lobert, J. M., D. H. Scharffe, W. M. Hao and P. J. Crutzen, 1990: Importance of biomass burning in the atmospheric budgets of nitrogen-containing gases. Nature, **346**, 552-554.

Lawrence, M. G. and P. J. Crutzen, 1999: Influence of NO_x emissions from ships on tropospheric photochemistry and climate. Nature, **402**, 167-170.

Key science achievements

The research of Paul J. Crutzen has been mainly concerned with the role of chemistry in climate and biogeochemistry, and in particular the photochemistry of ozone in the stratosphere and troposphere. In 1970 he hypothesized that natural ozone production by the action of solar ultraviolet radiation on molecular oxygen (O_2) is mainly balanced by destruction processes, involving NO and NO_2 as catalysts. These catalysts in turn result from the oxidation of N_2O, a product of microbiological nitrogen conversion in soils and waters. He pointed out that NO emissions from large fleets of supersonic aircraft could cause substantial ozone losses in the stratosphere.

In the years 1972-1974 Crutzen proposed that NO and NO_2 could catalyse ozone production in the background troposphere by reactions occurring in CO and CH_4 oxidation.

In 1979-1980 Crutzen and co-workers drew attention to the great importance of the tropics in atmospheric chemistry. In particular, some measurement campaigns in Brazil clearly showed that biomass burning (deforestation) in the tropics was a major source of air pollutants.

In 1982 Crutzen, with Prof. John Birks, drew attention to the risk of darkness and strong cooling at the earth surface as a consequence of heavy smoke production by extensive fires in a nuclear war (‘nuclear winter’). This study and additional studies, showed that more people could die from lack of starvation than by the direct impacts of the nuclear explosions.

In 1986, together with Dr. F. Arnold, Crutzen showed that nitric acid and water vapour could co-condense in the stratosphere at higher temperatures than required for water ice formation, providing a key step in chain of events leading to the so-called Antarctic ‘ozone hole’.

His research over the past 1-2 decades is concerned with the role of clouds in atmospheric chemistry as well as photochemical reactions taking place in marine air.

His current research involves climatic effects of bio-fuel production, in particular the emissions of N2O derived from nitrogen fertilizers (paper under preparation).

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Education

Yale University	B.A.	1963	Chemistry
Harvard University	M.A.	1965	Chemistry
Harvard University	Ph.D.	1968	Chemistry
Harvard Medical School	Postdoctoral	1967-1969	Biochemistry

Positions and Employment

1970-1975	Assistant Professor, Dept. of Chemistry, University of California, San Diego
1975-1981	Associate Professor, Dept. of Chemistry, University of California, San Diego
1981-**present**	Professor, Dept. of Chemistry and Biochemistry, UC San Diego
1983-1984	Visiting Professor, Dept. of Biological Chemistry, Harvard Medical School
1984	Visiting Scientist, Dept. of Biochemistry, Brandeis University
1984-1987	Vice Chairman, Dept. of Chemistry, University of California, San Diego
1987-1988	Chair, Academic Senate, University of California, San Diego
1992-1997	Vice Chair, Medical Biochemistry, Dept. of Chemistry & Biochemistry, UCSD
1996-1999	Head, Division of Biochemistry, Dept. Chemistry and Biochemistry, UCSD
1999-**present**	Adjunct Professor, Department of Immunology, The Scripps Research Inst.
1999-2002	Chair, Department of Chemistry and Biochemistry, UCSD
2002-**present**	Vice Chair, Medical Biochemistry, Dept. of Chemistry &Biochemistry, UCSD
2003-**present**	Professor, Department of Pharmacology, UCSD
2004-**present**	Distinguished Professor of Chemistry, Biochemistry, and Pharmacology, UCSD

Honors

Guggenheim Fellow (1983-1984)
Elected Fellow, American Association for the Advancement of Sciences (1984)
Board of Directors, The Keystone Symposia (1996-**present**) (President and Chair, 1996-2004)
President, Association of Medical and Graduate Departments of Biochemistry (1999-2000)
Avanti Award, Research in Lipid Biochemistry, American Soc. of Biochem. & Mol. Biol., (2000)
Editor-in Chief, Journal Lipid Research (2000-**present**)

Selected Publications (Most recent)

264. Winstead,M.V., Killermann-Lucas,K., and Dennis,E.A., Group IV Cytosolic Phospholipase A_2 Mediates Arachidonic Acid Release in H9c2 Rat Cardiomyocyte Cells in Response to Hydrogen Peroxide, *Prostaglandins and Other Lipid Mediators*. *78,* 55-66 (2005).
265. Rapaka,R.S., Piomelli,D., Spiegel,S., Barzan,N., and Dennis,E.A., Targeted Lipidomics: Signaling Lipids and Drugs of Abuse, *Prostaglandins and Other Lipid Mediators*, 77*,* 223-234 (2005).

266. Boullier,A., Friedman,P., Harkewicz,R., Hartvigsen,K., Green,S.R., Almazan,F., Dennis,E.A., Steinberg,D., Witztum,J.L., and Quehenberger,O., Phosphorylcholine as a Pattern Recognition Ligand for CD36, *J. Lipid Res.*, *46*, 969-976 (2005).
267. Kessen, U. A., Schaloske, R. H., Stephens, D. L., Killermann-Lucas, K., and Dennis, E. A., PGE_2 Release is Independent of Upregulation of Group V Phospholipase A_2 During Long-term Stimulation of $P388D_1$ Cells with Lipopolysaccharide, *J.Lipid Res., 46,* 2488-2496 (2005).
268. Yaksh,T.L., Kokotos,G., Svensson,C.I., Stephens,D.L., Kokotos,C., Fitzsimmons,B., Hadjipavlou-Litina,D., Hua,X.Y., and Dennis,E.A., Systemic and Intrathecal Effects of a Novel Series of Phospholipase A_2 Inhibitors on Hyperalgesia and Spinal PGE_2 Release, *J.Pharmacol.Exp.Ther. 316,* 466-475 (2005).
269. Raetz,C.R.H., Garrett,T.A., Reynolds,C.M., Shaw,W., Moore,J.D., Smith,D.C., Ribeiro,A.A., Murphy,R.C., Ulevitch,R.J., Fearns,C., Reichart,D., Glass,C.K., Benner,C., Subramaniam,S., Harkewicz,R., Bowers-Gentry,R.C., Buczynski,M.W., Cooper,J., Deems,R., and Dennis,E.A., Kdo2-Lipid A Escherichia coli, a Defined Endotoxin That Activates Macrophages Via TLR-4, J. Lipid Res., 47, 1097-1111 (2006).
270. Stephens,D.L., Barbayianni,E., Constantinou-Kokotou,V., Peristeraki,A., Cooper,J., Harkewicz,R., Deems,R.A., Dennis,E.A., and Kokotos,G., Differential Inhibition of Group IVA and Group VIA Phospholipases A2 by 2-Oxoamides, J.Med.Chem, 49, 2821-2828 (2006).
271. Schaloske,R.H. and Dennis,E.A., The Phospholipase A_2 Superfamily And Its Group Numbering System, *Biochim.Biophys.Acta - Molecular and Cell Biology of Lipids*. In Press (2006).
272. Grkovich,A., Johnson,C.A., and Dennis,E.A., Lipopolysaccharide Induced Cyclooxygenase-2 Expression in Human U937 Macrophages is Phosphatidic Acid Phosphohydrolase-1 Dependent, *J.Biol.Chem.* In Press (2006).

Patents 10

Key science and technology achievements

Edward A. Dennis is an expert on phospholipases including their isolation, enzymology, kinetics, inhibition, mechanism of action and role in bioactive mediator production including their role in inflammatory disease. He is currently the Director of the "Lipid Metabolites And Pathways Strategy" (LIPID MAPS) large scale collaborative "Glue Grant" funded by NIH in the amount of $37 million. It involves 12 Cores and 5 Bridges led by 12 senior investigators at UCSD, 6 other universities and a commercial company. In addition, there are some 20 "Participating Investigators" at some 6 other universities, 2 research institutions, and 2 commercial companies. There is also a distinguished international Advisory Board including a Nobel Laureate in the lipids field. LIPID MAPS goals are to establish "lipidomics" as a full scale infrastructure with the ability to detect, identify, and quantitate the hundreds of thousands of individual lipid molecular species in nature. LIPID MAPS is initially focusing on those lipids present in a single mammalian cell and its relationship to disease, but the infrastructure in place is applicable to plant and microbe lipids as well. It has developed an extensive classification database and established an internationally served website that integrates all of lipidomics (www.lipidmaps.org). IP procedures between multiple institutions have been established and now chemicals (mass spec standards) developed by LIPID MAPS are marketed under a "LIPID MAPS" trademark by our commercial partner. Besides large scale inter and intra institutional organizational experience, Dr. Dennis has had considerable experience in the administration/organization of non-profits (Chair of the UCSD Academic Senate, Department Chair, Board Chair and President of the Keystone Symposia, etc.) and industrial organizations. He has consulted widely with industry, founded several biotech startups, served on numerous Scientific Advisory Boards (SABs) and on the Board of Directors of several companies including public companies (NYSE). He has ten patents as well as over 270 publications and edited some 13 books and currently serves as Editor-in-Chief of the Journal of Lipid Research.

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Education

University of California, Berkeley	Biophysics / Brain Research	A.B. (w/Honors) 1970
University of Colorado, Boulder	Neurophysiology	M.A. 1974
University of Colorado, Boulder	Molecular and Cellular Biology	Ph.D. 1976
University of Colorado, Boulder	Molecular Cellular Biology	Postdoctoral 1976-1977

Positions

1969-71	Research Fellow, Animal Behavioral Field Station, UC Berkeley (F. Beach, S. Glickman)
1971-73	Research Fellow, Neurophysiology, University of Colorado, Boulder (S.K Sharpless, P.M. Groves)
1973-76	Research Fellow, Molecular Cellular Biology, University of Colorado, Boulder /Keith R. Porter
1976-77	Postdoctoral Fellow, with Keith R. Porter, University of Colorado, Boulder
1977-82-87	Assistant, Associate, Full Professor of Neurosciences & Bioengineering, UCSD
1996-pres	Founding Director, Center for Research on Biological Systems (CRBS), UCSD
1997-2005	Thrust Leader: Neuroscience and Interdisciplinary Coordinator, NSF National Partnership for Advanced Computational Infrastructure (NPACI) @ San Diego Super Computer Center
1988-pres	Director, National Center for Microscopy & Imaging Research at San Diego**,** UCSD
2001-pres	Founder, National Institutes of Health Biomedical Informatics Research Network (BIRN) and Director of the BIRN Coordinating Center at UCSD

Honors and Appointments:

1970 A.B. with Honors UC, Berkeley; 1974-1976 MDAA Predoctoral Fellow; 1976-77 MDAA Postdoctoral Award; 1980 Awarded Alfred P. Sloan Research Fellowship; 1989 Recipient of the Jacob Javits Neuroscience Investigator Award; 1991 Elected Founding Fellow of the American Inst. Medical and Biological Engineering; 1995 Creativity Award NSF; 2002-2006 Appointed to NIH, National Center for Research Resources, National Advisory Research Resources Council; 2002 Appointed to DOE, Los Alamos National Laboratory's Physics Division Review Committee; 2005 Appointed Scientific Advisory Board Max Planck Inst, Heidelberg; 2006 Appointed Scientific Advisory Board NIMH National Database for Autism Research.

Selected Recent Relevant Publications:

227. Peltier ST and Ellisman MH. 'The Biomedical Informatics Research Network (BIRN).' In: The Grid: Blueprint for a New Computing Infrastructure, eds. I Foster and C Kesselman,Morgan Kaufmann Publishers, San Francisco, 109-120, 2003

229. Newman HB, Ellisman ME, Orcutt JA. 'Data-Intensive e-Science Frontier Research.' Commun ACM, 46(11): 68-77, 2003

236. Casanova H, Bartol T, Berman F, Birnbaum A, Dongarra J, Ellisman MH, Faerman M, Gockay E, Miller M, Obertelli G, Pomerantz S, Sejnowski T, Stiles J, Wolski R. 'The virtual instrument: support for grid-enabled scientific simulations.' Intl J High Perform Comput Applic, 1(18): 3-20, 2004

260. Grethe JS, Baru C, Gupta A, James M, Ludaescher B, Martone ME, Papadopoulos PM, Peltier ST, Rajasekar A, Santini S, Zaslavsky IN, Ellisman MH. 'Biomedical Informatics Research Network: Building a National Collaboratory to Hasten the Derivation of New Understanding and Treatment of Disease.' In: From Grid to Healthgrid, Edited by T. Solomonides et al., IOS Press, Amsterdam, pp.100-109. 2005

261. Martone ME, Peltier S and Ellisman MH. 'Building Grid-Based Resources for Neurosciences.' In: Databasing the Brain, Edited by S.H. Koslow and S. Subramaniun, John Wiley & Sons, Hoboken, pp. 111-22. 2005

263. Akiyama T, Teranishi Y, Nozaki K, Kato S, Shimojo S, Peltier ST, Lin A, Molina T, Yang G, Lee D, Ellisman MH, Naito S, Koike A, Matsumoto S, Yoshida K, Mori H. 'Scientific Grid activities and PKI deployment in the Cybermedia Center, Osaka University.' J Clin Monit Comput. 19(4-5):279-94. 2005
275. Moisan TA, Ellisman MH, Buitenhuys CW, Sosinsky GE. 'Differences in chloroplast ultrastructure of Phaeocystis antarctica in low and high light.' Marine Biol.149: 1281-90. 2006
276. Yamaguchi R, Andreyev A, Murphy AN, Perkins GA, Ellisman MH, Newmeyer DD. 'Mitochondria frozen with trehalose retain a number of biological functions and preserve outer membrane integrity.' Cell Death Differ. Sep 15; [Epub ahead of print] 2006
277. Perez GI, Acton AM, Juriscova A, Perkins GA, White A, Brown J, Trbovich AM, Kim M-R, Fissore R, Xu J, Ahmady A, D'Estaing SG, Li H, Kagawa H, Yokoyama S, Okada H, Mak TW Ellisman MH, Casper RF, Tilly JL. 'Genetic vairance modifies apoptosis suceptibility in mature oocytes via alterations in DNA repair capacity and mitochondrial ultrastucture.' Cell Death Differ. Oct 13; [Epub ahead of print] 2006
278. Lin AW, Peltier ST, Grethe JS, Ellisman MH. 'Case Studies on the Use of Workflow Technologies for Scientific Analysis,' In: Scientific Workflows for eScience, Edited by I.J. Taylor, E. Deelman, D.B. Gannon and M.S. Shields, Springer Publishing, New York. In Press.
279. Wilhelmsson U, Bushong E, Price DL, Smarr BL, Phung V, Terada M, Ellisman MH, Pekny M. 'Redefining the concept of reactive astrocytes – astrocytes reacting to injury remain within their unique domains.' PNAS. In Press.

Patents

1. United States Patent 5,414,261. May 9, 1995. "Enhanced imaging mode for transmission electron microscopy." Inventors: Ellisman, Mark H. (Solana Beach, CA); Fan, Gary G. Y. (San Diego, CA); Price, Jeff (San Diego, CA); Suzuki, Seiichi (Tokyo, JP).
2. United States Patent 5,401,964. March 28, 1995. "Reduced electron scattering phosphor screen for high resolution transmission electron microscope imaging." Inventors: Mancuso, James F. (50 Prospect St., Rowley, MA 01969), Ellisman, Mark H. (Solana Beach, CA); Fan, Gary G. Y. (San Diego, CA).
3. United States Patent 5,594,253. January 14, 1997. "Hybrid luminescent device for imaging of ionizing and penetrating radiation." Inventors: Bueno; Clifford (Sunnyvale, CA); Betz; Robert A. (Fremont, CA); Ellisman; Mark H. (Solana Beach, CA); Fan; Gary G. Y. (San Diego, CA).
4. Patent Pending 634,408. December 8, 2003. "A revolutionary new detector for electron microscopy." Inventors: Ellisman; Mark H.; Nguyen-huu, Xuong.
5. Patent Pending 689,920. June 13, 2005. "Ultra Wide Lens-Coupled CCD Detector System and Transmission Electron Microscopy Using Same". Inventors: Ellisman; Mark H.; Nguyen-huu, Xuong; Peltier, Steven T.; Bouwer, James C.

Key science and technology achievements

Ellisman is a world-renowned neuroscientist and computational biologist. He pioneered many new technologies including the development and application of advanced 3D imaging technologies to obtain new information about cell structure and function. He directs the National Center for Microscopy and Imaging Research (NCMIR), an internationally acclaimed technology development center and research resource established by the National Institute of Health (NIH). His scientific contributions include work on basic molecular and cellular mechanisms of the nervous system, and the development of advanced technologies in microscopy and computational biology. As well as being a pioneer in the development of three dimensional light and electron microscopy, he notably implemented the combined application of these image acquisition tools and computational technologies to achieve a greater understanding of the structure and function of the nervous system. His research group was the first to introduce the idea of "Telemicroscopy" by demonstrating the network-enabled remote use and sharing of a high energy electron microscope in 1992 and then developed practical systems now in use by researchers in the US and abroad. This was the first example of a complete "cyberinfrastructure" system. The NSF and NIH have supported Ellisman and his team to extend these early efforts to build collaboration and data sharing environments for numerous research communities. Most notable of these is the NIH's Biomedical Informatics Research Network (BIRN), which became the exemplar for cyber in biology and is being used to model new cyber developments from medical domains to plant science.

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Education

Rensselaer Polytechnic Institute	BS	1977	Biology
State University of New York at Buffalo	PhD	1981	Pharmacology

Positions and Employment

1998-present: President and Director, The Institute for Genomic Research, Rockville, MD
1992-1998 Vice-President for Research and Director, Department of Microbial Genomics, The Institute for Genomic Research, Rockville, MD
1989-1992: Chief, Section on Molecular Neurobiology, Laboratory of Physiologic and Pharmacologic Studies, National Institute on Alcohol Abuse and Alcoholism, ADAMHA, Rockville, MD
1987-1989: Senior Staff Fellow and Chief, Unit of Receptor Regulation, Receptor Biochemistry and Molecular Biology, Laboratory of Molecular and Cellular Neurobiology, NINDS, National Institutes of Health, Bethesda, MD
1985-1987: Senior Staff Fellow, Laboratory of Neurophysiology, NINCDS, National Institutes of Health, Bethesda, MD
1984-1985: Cancer Research Scientist IV, Department of Molecular Immunology, Roswell Park Memorial Institute, Buffalo, NY
1983-1984: Cancer Research Scientist III, Dept. of Molecular Immunology, Roswell Park Cancer Institute, Buffalo, NY
1982-1983: Research Instructor, Dept. of Biochemistry, State University of NY at Buffalo, Buffalo, NY
1981-1982: Research Associate, Dept. of Pharmacology and Therapeutics, State University of NY at Buffalo, Buffalo, NY

Academic and Professional Honors

2005 Charles Thom Award, Society for Industrial Microbiology
2005 Fellowship, American Academy of Microbiology
2005 Promega Biotechnology Research Award, American Society for Microbiology
2004 AAAS Fellow, American Association for the Advancement of Science
2003 Maryland's Top 100 Women, Circle of Excellence
2002 Ernest Orlando Lawrence Award, Department of Energy

Publications

Fraser, C.M., Casjens, S., Huang, W.M.,. Sutton, G.G., Clayton, R., Lathigra, R., White, O., Ketchum, K.A., Dodson, R., Hickey, E.K., Gwinn, M., Dougherty, B., Tomb, J.F., Fleischmann, R.D., Richardson, D., Peterson, J., Kerlavage, A.R., Quackenbush, J., Salzberg, S., Hanson, M., van Vugt, R., Palmer , N., Adams, M.D., Gocayne, J., Weidman, J., Utterback, T., Watthey, L., McDonald, L., Artiach, P., Bowman, C., Garland, S., Fujii, C., Cotton, M.D., Horst, K., Roberts, K., Hatch, B., Smith, H.O., and Venter, J.C. Genomic sequence of a Lyme disease spirochete, *Borrelia burgdorferi. Nature* 390: 580-586, 1997.

Gardner, M.J., Hall, N., Fung, E., White, O., Berriman, M., Hyman, R.W., Carlton, J.M., Pain, A., Nelson, K.E., Bowman, S., Paulsen, I.T., James, K., Eisen, J.A., Rutherford, K., Salzberg, S.L., Craig, A., Kyes, S., Chan, M-S., Nene, V., Shallom, S.J., Suh, B., Peterson, J., Angiuoli, S., Pertea, M., Allen, J., Selengut, J., Haft, D., Mather, M.W., Vaidya, A.B., Martin, D.M.A., Fairlamb, A.H., Fraunholz, M.J., Roos, D.S., Ralph, S.A., McFadden, G.I., Cummings, L.M., Subramanian, G. M., Mangall, C., Venter, J.C., Carucci D.J., Hoffman, S.L., Newbold, C., Davis, R.W., Fraser, C.M., and Barrell, B. Genome sequence of the human malaria parasite *Plasmodium falciparum*. *Nature* 419: 498-511, 2002.

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Education

The Johns Hopkins University	BA	1968	Natural Sciences
University of Wisconsin, Madison	Ph.D.	1978	Ecological Systems Analysis

Positions and Employment

1978-1995	Senior Associate (1984-95), Senior Analyst (1981-84), Analyst (1979-81) Environment Program, Office of Technology Assessment, United States Congress
1995-2003	Senior Fellow and Vice President for Research, The H. John Heinz III Center for Science, Economics and the Environment.
2003-	Vice President, Environmental and Energy Policy, The Center for the Advancement of Genomics, J. Craig Venter Institute

Honors

1991	Fellow, American Association for the Advancement of Science
1989	Office of Technology Assessment "Distinguished Service Award"
2001-	Board of Directors, Institute of Forest Biotechnology

Selected Publications

Heinz Center Reports:

The State of The Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States, with R. O'Malley and staff of The H. John Heinz III Center for Science, Economics and the Environment, Cambridge University Press, 2002. 288 pp.

Technology Policies for Reducing Greenhouse Gas Emission, with J. Alic. The H. John Heinz III Center for Science, Economics, and the Environment, Washington DC, 1999. 21 pp.

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OTA Assessments:

Environmental Policy Tools: A User's Guide. Office of Technology Assessment, U.S. Congress, Washington DC, 1995. 217 pp.

Changing By Degrees: Steps to Reduce Greenhouse Gases. Office of Technology Assessment, U.S. Congress, Washington DC, 1991. 354 pp.

Catching Our Breath: Next Steps for Reducing Urban Ozone. Office of Technology Assessment, U.S. Congress, Washington, DC, 1989. 237 pp.

Environmental Applications of Genetically Altered Organisms. Special Report, Office of Technology Assessment, U.S. Congress, Washington DC, 1986. 53 pp.

Acid Rain and Transported Air Pollutants: Implications for Public Policy. Office of Technology Assessment, U.S. Congress, Washington, DC, 1984. 323 pp.

Use of Models for Water Resources Management Planning and Policy. Office of Technology Assessment, U.S. Congress, Washington, DC, 1982. 242 pp.

Selected Articles:

Biological solutions to renewable energy, with H.O. Smith and V.C. Venter, 2003, The Bridge, 33:36-40.

The bumpy road to reduced carbon emissions, with R. Bierbaum, Issues in Science and Technology, Summer 2002: 55-57.

Summary of the Heinz Center Report on Coastal Erosion and the National Flood Insurance Program, 2002, with S. Dunn and W. Merrell, Journal of Coastal Research, 18: 568-575.

Environmental policy instrument choice: the challenge of competing goals, 2000, with D. Downing and E. Gunn, Duke Environmental Law and Policy Forum, 10:327-387.

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Steps to reduce U.S. carbon dioxide emissions: technical options and the policies to implement them, with R. Bierbaum. In: Global Climate Change: Linking Energy, Environment, and Equity. J.C. White, Ed., Plenum Press, 1992.

Key science and technology achievements

Robert M. Friedman is Vice President, Environmental and Energy Policy at the Venter Institute. Friedman is the Group Leader of The Policy Center as well as active in several projects ongoing in the Institute's Environmental Genomics Group. Prior to joining the Venter Institute, Friedman was Vice President for Research at The Heinz Center, a nonprofit policy research organization that brings together collaborators from government, industry, environmental organizations, and academia. Among other projects, Friedman was funded by the U.S. Environmental Protection Agency to examine emissions trading and technology policies to lower greenhouse gas emissions. Earlier, Friedman was a Senior Associate at the Office of Technology Assessment, U.S. Congress (OTA), advising Congressional committees on issues involving environmental and natural resources policy. Most of his work focused on the intersection between energy and environmental policy, in particular, acid rain, urban ozone, and climate change.

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Education

University of Notre Dame	BS	1971	Chemical Engineering
University of Wisconsin	PhD	1975	Chemical Engineering

Positions and Employment

1971	Humble Oil and Refining Co
1975-present	Asst, Assoc., Full Professor, Iowa State University
1997-2005	Chair, Chemical (and Biological) Engineering, Iowa State Univerity
2004	Interim Dean, College of Engineering, Iowa State University
various	Visiting Professor, University College London, U. Colorado, U. Canterbury (NZ), RPI

Honors

1990	Outstanding Teacher Award, College of Engineering
1997	Iowa Academy of Sciences Distinguished Scientist
2003	Boylan Award for Outstanding Research, ISU College of Engineering

Selected Publications Relevant to the Proposal

J. E. Hardwick and C. E. Glatz. J. Agricultural Food Chem., 37:1188-1192, 1989. Enzymatic Hydrolysis of Corn Gluten Proteins.

A. J. Weier, B. A. Glatz, and C. E. Glatz. Biotechnol. Prog. 8: 479-485, 1992. Recovery of Propionic and Acetic Acids from Fermentation Broth by Electrodialysis.

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M. Saikumar, C. E. Glatz, and M. A. Larson. J. Crys. Growth 151: 173-179, 1995. Crystallization of Lysozyme at High Pressures.

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Gu, Z., D. A. Rickert, B. A. Glatz, and C. E. Glatz. Lait 79: 137-148, 1999. Feasibility of propionic acid production by extractive fermentation.

C.-M. Zhang and C. E. Glatz. Biotechnol. Prog. 15: 12-18, 1999. Process engineering strategy for recombinant protein recovery from canola by cation exchange chromatography.

F. Zaman, A. R. Kusnadi and C. E. Glatz. Biotechnol. Prog. 15: 488-492 1999. Strategies for recombinant protein recovery from canola by precipitation.

R. Y. Waghmare, X. J. Pan, and C. E. Glatz. J. Crys. Growth 210: 746-752, 2000. Pressure and concentration dependence of nucleation kinetics for crystallization of subtilisin.

K. Ohmori and C. E. Glatz. J. Membrane Sci. 171: 263-271 (2000). Effects of carbon source on microfiltration of *C. glutamicum.*

Y. Okamoto, K. Ohmori, and C. E. Glatz. J. Membrane Sci. 190: 93-106, 2001. Harvest time effects on membrane cake resistance of *Escherichia coli* broth.

T. J. Menkhaus, S. U. Eriksson, P. B. Whitson, and C.E. Glatz. Biotechnol. Bioengr. 77: 148-154 (2002). Host selection as a downstream strategy: Polyelectrolyte precipitation of β-glucuronidase from plant extracts.

X. Pan and C. E. Glatz. Crystal Growth Des., 2: 45-50, 2002. Solvent role in protein crystallization as determined by pressure dependence of nucleation rate and solubility.

Y. Bai, Z. L. Nikolov and C. E. Glatz. Biotechnol. Prog. 18: 1301-1305, 2002. Aqueous extraction of β-glucuronidase from transgenic canola: kinetics and microstructure.

Menkhaus, T. and C. E. Glatz, Biotech. Bioengr. 87: 324-336, 2004. Compatibility of Column Inlet and Adsorbent Designs for Processing of Corn Endosperm Extract by Expanded Bed Adsorption.

Pearson, C., M. Heng, M. Gebert, and C. E. Glatz. Biotech. Bioengr. 87:54-60, 2004. Zeta Potential As A Measure Of Polyelectrolyte Flocculation And The Effect Of Polymer Dosing Conditions On Cell Removal From Fermentation Broth.

Pearson, C., M. Heng, M. Gebert, and C. E. Glatz. Biotech. Bioengr. 87:61-68, 2004. A Study Of Enzyme Partitioning And Enzyme-Polymer Interactions During Polyelectrolyte Flocculation For Cell Removal From Fermentation Broth.

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Zhong, Q., Gu, Z., and C. E. Glatz. J. Agric. Food Chem., 54: 8086-8092, 2006. Extraction of recombinant dog gastric lipase from transgenic corn.

Key science and technology achievements

Dr. Glatz is an expert in recovery and purification of fermentation products, both primary (proteins) and secondary (metabolites including organic acids and oils). He also addresses processing of plant material for fractionation into components targeted for conversion to fuels and chemicals. He has published in the areas of protein purification, plant oil extraction and recovery, cell removal from fermentation broths, and extractive fermentation for volatile organic acid production. Dr. Glatz has also performed economic analyses of bioprocesses.

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Education

University of California, Berkeley	Ph.D.	1986	Agricultural Economics

Positions and Employment

2001 - present	Leader Policy Task Force, Plant Science Institute, Iowa State University
1999-present	Pioneer Hybrid Chair in Agribusiness, Iowa State University
1999-present	Professor of Finance, Iowa State University
1996-present	Professor of Economics, Iowa State University

Selected Honors

2006	Recipient of AAEA Publication of Enduring Quality Award for "Valuing Food Safety in Experimental Auction Markets" American Journal of Agricultural Economics, 1995 by Dermot Hayes**,** Jason Shogren**,;** Seung-Youll Shin**,** and James Kliebenstein
2005	Recipient of the ISU J. H. Ellis Award for Excellence in Undergraduate Introductory Teaching, a University level award for excellence in teaching undergraduate introductory classes
2000-2005	Listed as an outstanding Faculty Member for 2005, 2004, 2003, 2002, 2001, 2000 by the ISU Pan-Hellenic Council and the Interfraternity Council
2003	VEISHA Faculty Member of the Year for the College of Agriculture
1990-2000	Listed in the 4th Edition of Who's Who in Economics as one of the most cited economists for work published

Selected Publications

1. Elobeid, Amani, Simla Tokgoz, Dermot J. Hayes, Bruce A. Babcock, and Chad E. Hart. "The Long-Run Impact of Corn-Based Ethanol on the Grain, Oilseed, and Livestock Sectors: A Preliminary Assessment." CARD Working Paper 06-BP 49. November 2006.
2. Monchuk, D. C., J. A. Miranowski, D. Hayes, and B. Babcock, (2007). "An Analysis of Economic Growth in the U.S. Midwest." Forthcoming in Review of Agricultural Economics.

3. Lence, Sergio H., and Dermot J. Hayes. "EU and US Regulations for Handling and Transporting Genetically Modified Grains: Are Both Positions Correct?" EuroChoices, Forthcoming.
4. Lence, Sergio H., and Dermot J. Hayes. "Genetically Modified Crops: Their Market and Welfare Impacts," American Journal of Agricultural Economics. Volume 87, Issue 4, Pages 935-950. November 2005.
5. Lence, Sergio H., Dermot J. Hayes, Alan McCunn, Stephen Smith, and Bill Niebur. "Welfare Impacts of Intellectual Property Protection in the Seed Industry," American Journal of Agricultural Economics. Volume 87, Issue 4, Pages 951-960. November 2005.
6. Lence, Sergio H., and Dermot J. Hayes. "Technology Fees Versus GURTs in the Presence of Spillovers: World Welfare Impacts." AgBioForum, 8(2&3) September 2005: 172-186.
7. Hurd, H. Scott, Stephanie Doores, Dermot Hayes, Alan Mathew, John Maurer, Peter Silley, Randall S. Singer, and Ronald Jones. "Public Health Consequences of Macrolide Use in Food Animals: A Deterministic Risk Assessment," Journal of Food Protection, 67(5) 2004: 980–992.
8. Lence, Sergio H., and Dermot J. Hayes. "U.S. Farm Policy and the Variability of Commodity Prices and Farm Revenues," American Journal of Agricultural Economics, 84(2) May 2002: 350-351.
9. Fuller, Frank H., and Dermot J. Hayes. "Reconciling Chinese Meat Production and Consumption Data," Economic Development and Cultural Change, 49(1) October 2000: 23-45.
10. Hennessy, David A., and Dermot Hayes. "Competition and Tying in Agri Chemical and Seed Markets," Review of Agricultural Economics, 22(2) June 2000: 389-406.
11. Shogren, Jason F., Seung Y. Shin, Dermot J. Hayes, and James B. Kliebenstein. "Resolving Differences in Willingness to Pay and Willingness to Accept," American Economic Review, 84(1) March 1994: 255-70.
12. Lence, Sergio, and Dermot J. Hayes. "Parameter-Based Decision Making Under Estimation Risk: An Application to Futures Trading," Journal of Finance, 49(1) March 1994: 345-57.

Dermot Hayes is a native of the Republic of Ireland. He obtained a Bachelor of Agricultural Science degree from University College in Dublin in 1981. He entered the Ph.D. program in the Department of Agricultural Economics at Berkeley in the fall of 1981, where he majored in International Trade. Dr. Hayes joined the Department of Economics at Iowa State University in 1986. He became a professor in the Department of Finance in 1999. His research interests include option pricing, crop insurance, intellectual property rights, commodity markets, meat markets and meat exports, agricultural and trade policy and economic and policy issues involving plant science research..

Dermot is currently the Pioneer Hi-Bred international chair in Agribusiness, a Professor in the Department of Economics, and a Professor in the Department of Finance at Iowa State University. He is currently in charge of the public policy task force at the Plant Science Institute at ISU.

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Education

1960 - B.S. Yale University (*cum laude*, physics)
1968 - Ph.D. California Institute of Technology (Bacteriophage ΦXı74: Viral Genes and Functions)
Adviser - Robert L. Sinsheimer

Positions and Employment

1968-1973: Assistant Professor, Department of Bacteriology & Immunology, School of Medicine, University of North Carolina, Chapel Hill
1973-1978: Associate Professor, Department of Bacteriology & Immunology, School of Medicine, University of North Carolina, Chapel Hill
1975-1976: Visiting Scientist, MRC Laboratory of Molecular Biology, Cambridge, England, in the laboratory of F. Sanger
1978-1983: Professor, Department of Bacteriology & Immunology, School of Medicine, University of North Carolina, Chapel Hill
1983- 2004: Kenan Professor, Department of Microbiology & Immunology, School of Medicine, University of North Carolina, Chapel Hill
1987-1988: Visiting Scientist, MRC Laboratory of Molecular Biology, Cambridge, England, in the laboratory of B.G. Barrell
1989-2001: U.S. Editor of DNA Sequence, The Journal of DNA Sequencing and Mapping
1996- : Visiting Faculty, The Institute for Genomic Research, Rockville Maryland
2004- : Professor Emeritus, , Department of Microbiology & Immunology, School of Medicine, University of North Carolina, Chapel Hill
2004- : Distinguished Investigator, The J. Craig Venter Institute, Rockville, Maryland
2005- Chair, Scientific Advisory Board, Synthetic Genomics, Inc., Rockville, Maryland

Honors

1973-1978: Research Career Development Award, National Institute of Allergy and Infectious Diseases
1987-1997: NIH MERIT Award, National Institute of Allergy and Infectious Diseases
1995- : member of the National Academy of Sciences
1995- : fellow of the American Academy of Microbiology
1995- : North Carolina Award in Science
1998- : fellow of the American Academy of Arts and Sciences

Selected Publications

Barrell, B.G., Air, G.M., and Hutchison, C.A.III (1976). Overlapping genes in bacteriophage ΦX174. Nature **264**, 34-41.
Sanger, F., Air, G.M., Barrell, B.G., Brown, N.L., Coulson, A.R., Fiddes, J.C., Hutchison, C.A.III, Slocombe, P.M., and Smith, M.(1977). Nucleotide sequence of bacteriophage ΦX174 DNA. Nature **265**, 687-695.
Farmerie, W.G., Loeb, D.D. Casavant, N.C., Hutchison, C.A.III, Edgell, M.H., and Swanstrom, R. (1987). Expression and processing of the AIDS virus reverse transcriptase in *E. coli*. Science **236**, 305-308.

Fraser, C. M., Gocayne, J. D., White, O., Adams, M. D., Clayton, R. A., Fleischmann, R. D., Bult, C. J., Kerlavage, A. R., Sutton, G., Kelley, J. M., Fritchman, J. L., Weidman, J. F., Small, K. V., Sandusky, M., Fuhrman, J., Nguyen, D., Utterback, T. R., Saudek, D. M., Phillips, C. A., Merrick, J. M., Tomb, J.-F., Dougherty, B. A., Bott, K. F., Hu, P.-c., Lucier, T. S., Peterson, S. N., Smith, H. O., Hutchison, C. A.III and Venter, J. C. (1995). The minimal gene complement of *Mycoplasma genitalium*. *Science* 270, 397-403.

Wrobel, J.A., Chao, S.-F., Conrad, M.J., Merker, J.D., Swanstrom, R., Pielak, G.J., and Hutchison, C.A.III (1998). A genetic approach for identifying critical residues in the fingers and palm subdomains of HIV-1 reverse transcriptase. Proc. Natl. Acad. Sci. USA **95**, 638-645.

Tomita, M., Hashimoto, K., Takahashi, K., Shimizu T.S., Matsuzaki, Y., Miyoshi, F., Saito, K., Tanida, S., Yugi, K., Venter, J.C., and Hutchison, C.A.III (1999). E-CELL: software environment for whole-cell simulation. Bioinformatics **15**, 72-84.

Hutchison, C.A.III, Peterson, S.N., Gill, S.R., Cline, R.T., White, O., Fraser, C.M., Smith, H.O., and Venter, J.C. (1999). Global transposon mutagenesis and a minimal mycoplasma genome. Science **286**, 2165-2169.

Montague, M.G., and Hutchison, C.A.III (2000). Gene content phylogeny of herpesviruses. Proc. Natl. Acad. Sci. USA **97**, 5334-5339.

Mears, M.L., and Hutchison, C.A.III (2001). The evolution of modern lineages of mouse L1 elements. J. Mol. Evol. **52**, 51-62.

Smith, H.O., Hutchison, C.A.III, Pfannkoch, C., and Venter, J.C. (2003). Generating a synthetic genome by whole genome assembly: □X174 bacteriophage from synthetic oligonucleotides. Proc. Natl. Acad. Sci. USA **100**, 15440-15445.

Smith, G.A., Powell, B.C., and Hutchison, C.A.III (2005). Transcriptional analysis of the conserved *ftsZ* gene cluster in *Mycoplasma genitalium* and *Mycoplasma pneumoniae*. J. Bact. **187**, 4542-4551.

Hutchison, C.A. III, Smith, H.O., Pfannkoch, C., Venter, J.C. (2005). Cell-free cloning using phi29 DNA polymerase. Proc. Natl. Acad. Sci. USA**102**, 17332-17336.

Glass, J.I., Assad-Garcia, N., Alperovich, N., Yooseph, S., Lewis, M.R., Maruf, M., Hutchison, C.A. III, Smith, H.O., Venter, J.C. (2006). Essential genes of a minimal bacterium. Proc. Natl. Acad. Sci. U.S.A. **103**,:425-430.

Hutchison, C.A. III, Smith, H.O., Venter, J.C. (2006). Is this life? – The new biological synthesis. The Scientist, January 2006, 38.

Powell, B.C., Hutchison, C.A. III (2006). Similarity-based gene detection: using COGs to find evolutionarily-conserved ORFs. BMC Bioinformatics **7**:31.

Hutchison, C.A. III, Venter, J.C. (2006). Single-cell genomics. Nat. Biotechnol. **24**, 657-658.

Key science and technology achievements

Clyde Hutchison has carried out investigations on biological systems ranging from bacteriophage to mice. The unifying theme of his laboratory has been a continuing search for improved methods to learn about gene function from DNA sequence information. Dr. Hutchison's lab at the University of North Carolina at Chapel Hill has been involved in genomics since before the advent of modern DNA sequencing. Dr. Hutchison and Marshall Edgell dissected the genome of phage phiX174 with restriction enzymes in the 1970's, and he was a member of the team in Fred Sanger's lab that sequenced the phiX174 genome; the first DNA molecule completely sequenced. Since that time Dr. Hutchison has been interested in a variety of projects in viral, bacterial, and mammalian genomics.

At the Venter Institute, Dr. Hutchison is involved in the field of Synthetic Genomics in an effort to chemically synthesize DNA and improve methods for the assembly of large DNA fragments from chemically synthesized oligonucleotides. Synthetic genomics will ultimately allow for the production of synthetic genomes and combinatorial gene synthesis that may be useful for the study and production of useful enzymes and products. The proof of principle was demonstrated in 2003 when the genome of bacteriophage phiX174 was synthetically generated in only 14 days by Dr. Hutchison and his collaborators Hamilton Smith, Cynthia Pfannkoch, and Craig Venter at the Institute for Biological Energy Alternatives.

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Education

University of Bristol	B.S. (Honours)	1981	Biochemistry
University of Bristol	Ph.D.	1984	Biochemistry
The Rockefeller University	Postdoc	1985-1989	

Positions and Employment

1989-1991	Assistant Professor, The Rockefeller University
1992-1995	Assistant Professor, Department of Biology, University of Virginia
1995-1996	Associate Professor (Tenured), Department of Biology, University of Virginia
1995-1996	Director, Advanced Cellular Imaging Facility, University of Virginia
1996-1998	Associate Professor, Cell Biology, The Scripps Research Institute
1998-Present	Professor, Cell Biology, The Scripps Research Institute
1998-2002	Director of Discovery Research, Genomics Institute of the Novartis Research Foundation
1999-2002	Founder, Chief Technical Officer and Senior Vice President, Phenomix Corporation
2000-Present	Professor (Adjunct), Psychiatry Department, University of San Diego
2001-Present	Director, Institute for Childhood and Neglected Diseases
2005-Present	Chairman, Department of Biochemistry, The Scripps Research Institute

Honors

1981	Honors degree, class II(i), University of Bristol
1987-1898	Winston Foundation Postdoctoral Fellowship
1985-1987	NATO Advanced Postdoctoral Fellowship
1991-1993	NIH Director's Shannon Award
1992-1996	W.M. Keck Foundation Junior Faculty Award
1997-2002	*Science* Breakthroughs of the Year 1997, 1998 and 2002
1999	Honma Prize for Life Sciences

Selected Publications

Harmer S.L., Hogenesch J.B., Straume M., Chang H-S., Zhu T., Wang X., Kreps J.A., **Kay S.A.** (2000) Orchestrated transcription of key pathways in *Arabidopsis* by the circadian clock. *Science* 290:2110-2113.

Alabadi, D., Oyama, T., Yanovsky, M., Harmon, F.G., Mas, P., **Kay, S.A**. (2001) Reciprocal regulation between *TOC1* and *LHY/CCA1* within the *Arabidopsis* circadian clock. *Science* 293:880-883.

Imaizumi, T., Tran, H.G., Swartz, T.E., Briggs, W.R., **Kay, S.A.** (2003) FKF1 is critical for photoperiodic-specific light signaling in *Arabidopsis*. *Nature* 426:302-306

Mas, P., Kim, W-Y., Somers, D., **Kay, S.A.** (2003) Targeted degradation of TOC1 by ZTL modulates circadian function in *Arabidopsis*. *Nature* 426:567-570.

Yanovsky, M.J. and **Kay, S.A.** (2003) Living by the calendar: How plants know when to flower. *Nature Review Molecular Cellular Biology* 4:265-275.

Imaizumi, T., Schultz, T.S., Harmon, F.G., Ho, L.A., **Kay, S.A.** (2005) FKF1 F-box protein mediates cyclic degradation of a repressor of CONSTANS in Arabidopsis. *Science* 309:293-297.

Hazen, S.P., Borevitz, J.O., Harmon, F.G., Pruneda-Paz, J.L., Schultz, T.F., Yanovsky, M.J., Liljegren, S.J., Ecker, J.R., **Kay, S.A.** (2005) Rapid array mapping of circadian clock and developmental mutations in *Arabidopsis. Plant Physiol.*138:990-997.

Harmer, S. and **Kay, S.A.** (2005) Positive and negative factors confer phase-specific circadian regulation of transcription in *Arabidopsis*. *The Plant Cell* 17:1926-1940.

Hazen, S.P., Schultz, T.F., Pruneda-Paz, J.L., Borevitz, J.O., Ecker, J.R. and **Kay, S.A.** (2005) *LUX ARRHYTHMO* encodes a Myb domain protein essential for circadian rhythms. *PNAS* 102:0387-10392.

Imaizumi, T. and **Kay, S.A..** (2006) Photoperiodic control of flowering: Not only by coincidence. *Trends in Plant Sci.* 11:550-558.

Zeilinger, M.N., Farre, E.M., Taylor, S.R., **Kay, S.A.**, Doyle III, F.J. (2006) A novel computational model of the circadian clock in Arabidopsis that incorporates PRR7 and PRR9. *Molecular Systems Biology, in press*

Patents (USA only) Issued, 3

Key science and technology achievements

Dr. Steve Kay is Chairman, Department of Biochemistry, Professor of Cell Biology and Director of the Institute for Childhood and Neglected Diseases (ICND) at The Scripps Research Institute (TSRI). His academic research concerns the molecular genetic basis of circadian rhythms in plants, animals and humans. He was also recently the Director of Discovery Research at the Genomics Institute of the Novartis Research Foundation (GNF), where he built a Department to apply functional genomics technology to biomedical research. Dr. Kay was also the principal founder, former Chief Technology Officer and Senior Vice President of Phenomix Corporation, a mouse genetics technology company that raised $32M in Series A financing in February 2002. Appointed Director of ICND in 2001 where researchers are housed in a state-of-the-art, 54,000-square-foot building using genomics, proteomics and advanced microscopic imaging technologies, develop many novel transgenic animal models, and aggressively apply these technologies in an effort to understand the mechanisms of action of a variety of diseases.

As a postdoctoral fellow at the Rockefeller University and then Assistant Professor, he established his research program in circadian rhythms of *Arabidopsis* and *Drosophila*. Joining the NSF Center for Biological Timing at the University of Virginia in 1992, he further developed real-time luciferase reporter technology for measuring transcription in live plants and animals. This technology was used to identify several key clock genes in both systems using forward genetic screens. Dr Kay's work was recognized in 1997, 1998, and 2002 by *Science* for "Breakthroughs of the Year."

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Education

University of Illinois	BS	1980	Agronomy
University of Illinois	M.S.	1982	Plant Breeding
Iowa State University	Ph.D.	1985	Plant Breeding

Positions and Employment

1980-1982	Graduate Research Assistant, University of Illinois
1982-1985	Graduate Research Assistant, Iowa State University
1984-2002	Research Geneticist, USDA, ARS, Ames, Iowa
2002-Present	Professor of Agronomy, Iowa State University
2002-Present	Pioneer Distinguished Chair in Maize Breeding
2002-Present	Director, Raymond F. Baker Center for Plant Breeding
2006-Present	Interim Chair, Department of Agronomy, Iowa State University

Honors

1982-83	Premium for Academic Excellence Award, Iowa State University
1984	The C.R. Weber Award for Excellence in Plant Science, ISU
1985	T.A. Bancroft Statistics Award, Statistical Laboratory, ISU
1990, 1992	Certificate of Merit, USDA
1994	Raymond and Mary Baker Award for Agronomic Excellence, ISU
2002	Elected Fellow of the Crop Science Society of America
2004	Outstanding Paper on Plant Genetic Resources, Crop Science Society of America, Division C7

Selected Publications

Lamkey, K.R. and M. Lee (Eds). 2006. Plant Breeding: The Arnel R. Hallauer International Symposium. Blackwell Publishing, Ames, Iowa.

J. C. Ho, S. Kresovich, and K. R. Lamkey. 2005. Extent and Distribution of Genetic Variation in U.S. Maize: Historically Important Lines and Their Open-Pollinated Dent and Flint Progenitors. Crop Sci. 45: 1891-1900.

Hinze, L., S. Kresovich, J. D. Nason, and K. R. Lamkey. 2005. Population Genetic Diversity in a Maize Reciprocal Recurrent Selection Program. Crop Sci. 45: 2435-2442.

J.S.C. Smith, O.S. Smith, and K.R. Lamkey. 2005. Maize Breeding. Maydica 50:185-192.

Lamkey, K.R. 2004. Seed production in corn and soybean. p. 54-74. In: Andow, D. (ed.) A Growing Concern: Protecting the food supply in an era of pharmaceutical and industrial crops. Union of Concerned Scientists, Washington, D.C.

Labate, J. A., K. R. Lamkey, S. E. Mitchell, S. Kresovich, H. Sullivan, J. S. C. Smith. 2003. Molecular and historical aspects of Corn Belt dent diversity. Crop Sci. 43:80-91.

Hagdorn, S., K.R. Lamkey, M. Frisch, P.E.O. Guimarães, A.E. Melchinger. 2003. Molecular Genetic Diversity among Progenitors and Derived Elite Lines of BSSS and BSCB1 Maize Populations. Crop Sci. 43:474-482.

Lamkey, K. R. and J. W. Edwards. 1999. The quantitative genetics of heterosis. p. 31-48. In: J.G. Coors and S. Pandey (ed.) Proceedings of the International Symposium on the Genetics and Exploitation of Heterosis in Crops, CIMMYT, Mexico City, Mexico, 17-22 Aug. 1997. ASA, CSSA, and SSSA, Madison, WI.

Weyhrich, R. A., K. R. Lamkey, and A. R. Hallauer. 1998. Responses to seven methods of recurrent selection in the BS11 maize population. Crop Sci. 38:308-321.

Patents (USA only)

No patents, but several inbred lines of corn have been developed and made available for licensing.

Key science and technology achievements

The main focus of Dr. Lamkey's research has been quantitative genetics, recurrent selection methodology, and selection theory. His group made the first critical comparison of seven methods of recurrent selection in a common base population (BS11) using constant selection intensity and effective population size. They found, contrary to their other research, that S2-progeny selection was superior to all methods for all measures of selection response. The study was also the first to compare the impact of recombining various numbers of individuals (5, 10, 20, and 30) using a constant selection intensity (20%) and selection method (S1-progeny selection). Results suggest that genetic gain for grain yield can be made by recombining as few as five selected individuals although gains for other traits may suffer in the short term (5 cycles = 10 years). Dr. Lamkey's group has also done extensive analysis of the long-term selection program in BSSS with molecular markers. The molecular marker work in BSSS has demonstrated that large changes in allele frequencies at molecular marker loci occurred following 12 cycles of reciprocal recurrent selection in BSSS and BSCB1. Selection reduced allelic variation by 25% and within population heterozygosity decreased by about 33%. If both populations were considered as one, the loss in total variation was small in comparison to the shift of variation from within populations to between populations. Dr. Lamkey has studied the structure of genetic diversity in the Corn Belt Dent race of maize. This project has been using neutral molecular markers to study the population structure in the Corn Belt Dents, how plant breeding has affected this variation, and how current inbred lines relate to variation that was originally present in the Corn Belt Dents. Dr. Lamkey also has an active research program in the quantitative genetic analysis of heterosis and inbreeding depression.

Dr. Lamkey has a national and international reputation as an expert on corn quantitative genetics and selection response. He has authored or co-authored over 70 papers in refereed journals. He has presented numerous invited lectures at national and international meetings. Dr. Dr. Lamkey has been a member of the Crop Science Socity of America since 1980 and has served as associate editor, technical editor, and editor of *Crop Science*.

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Education

The University of Southern California	PhD	1985	Molecular Biology

Positions and Employment

2006-present	Investigator, The Institute for Genomic Research
2004-2006	Professor, Center for Genomic Sciences, Allegheny-Singer Research Institute, West Penn Allegheny Health System
1998-2004	Director of Genomics, Molecular Staging, Inc, New Haven, CT
1997-1998	Director of Research, MycoGenetics Inc, Philadelphia, PA
1990-1997	Principal Scientist, Life Technologies/BRL/GIBCO (now Invitrogen)
1988-1990	Assistant Professor, Dept. of Neurology and Neuroscience, Cornell University Medical College, New York, NY
1985-1988	Postdoctoral Fellow, Stanford University School of Medicine with Prof. Arthur Kornberg, Nobel Laureate

Selected Publications

Lasken, R. S. and Goodman, M.F. The biochemical basis of 5-bromouracil-induced mutagenesis: heteroduplex base mispairs involving bromouracil in GC to AT and AT to GC mutational pathways. J. Biol. Chem. 259 (1984) 11491-11495.

Lasken, R. S. and Goodman, M.F. A fidelity assay using "dideoxy" sequencing: measurement of sequence dependence and frequency of forming 5-bromouracil-guanine base mispairs. Proc. Natl. Acad. Sci. USA 82 (1985) 1301-1305.

Lasken, R. S. and Kornberg, A. The beta subunit dissociates readily from the *Escherichia coli* DNA polymerase III holoenzyme. J. Biol. Chem. 262 (1987) 1720-1724.

Lasken, R. S. and Kornberg, A. The n' protein of *Escherichia coli* is a DNA helicase. J Biol. Chem. 263 (1988) 5512-5518.

Lasken, R. S., Schuster, D., and Rashtchian, A. Archaebacterial DNA polymerases tightly bind uracil-containing DNA. J. Biol. Chem. 271 (1996) 17692-17696.

Lasken, R. S. Review article. The proliferating cell nuclear antigen: The mechanism to replicate chromosomes and respond to DNA damage. Current Oncology (1998) vol. 5, number 3.

Frank B. Dean, J. Nelson, T. Giesler, and **R. S. Lasken**. Rapid Amplification of Plasmid and Phage DNA Using Phi29 DNA Polymerase and Multiply-Primed Rolling Circle Amplification. Genome Research 11(6) (2001) 1095-1099.

Faruqi AF, Hosono S, Driscoll MD, Dean FB, Alsmadi O, Bandaru R, Kumar G, Grimwade B, Zong Q, Sun Z, Du Y, Kingsmore S, Knott T, **Lasken RS**: High-throughput genotyping of single nucleotide polymorphisms with rolling circle amplification. *BMC Genomics* 2001, 2:4.

Dean, F. B., Hosono, S., Fang, L., Wu, X., Faruqi, A. F., Bray-Ward, P., Sun, Z., Zong, Q., Du, Y., Du, J., Driscoll, M., Song, W., Kingsmore, S. F., Egholm, M., **Lasken, R. S.**

Comprehensive human genome amplification using multiple displacement amplification. Proc. Natl. Acad. Sci. U S A (2002) 99(8) 5261-5266.

Hosono S, Faruqi AF, Dean FB, Du Y, Sun Z, Wu X, Du J, Kingsmore SF, Egholm M, **Lasken R.S**. Unbiased Whole Genome Amplification Directly From Clinical Samples**.** *Genome Res,* (2002) vol 13, 954-964.

Lasken, R. S., and Egholm, M. Whole genome amplification: abundant supplies of DNA from precious samples or clinical specimens, Trends in Biotechnology, v. 21, No. 12, December 2003, 531-535.

Lasken, R. S., Seiyu Hosono, and Egholm, M. Multiple Displacement Amplification (MDA) of Whole Human Genomes from Various Samples. DNA Amplification: Current Technologies & Applications. Eds. Vadim V. Demidov & Natalia E. Broude. Horizon BioSci. Press (England)

Arumugham Raghunathan, Harley R Ferguson, Jr., Carole J Bornarth, Mark Driscoll, and **Roger S. Lasken.** Genomic DNA amplification from a single bacterium. Applied and Environmental Microbiology (2005) 71, 3342-3347

Roger S. Lasken. Whole genome amplification using the Multiple Displacement Amplification Reaction. Modern Laboratory Techniques
Ed. Jan Kieleczawa, Jones and Bartlett

Thomas Kvist, Birgitte K. Ahring, **Roger S. Lasken**, and Peter Westermann. Specific single-cell isolation and genomic amplification of uncultured microorganisms. *Appl Microbiol Biotechnol*, In Press

Book editor and chapters

Lasken RS. Whole genome amplification from genomic DNA

Lasken RS. Whole genome amplification from single bacterial cells
Whole Genome Amplification. Eds. Simon Hughes and **Roger S. Lasken**, Scion Publishing Limited, Oxfordshire, UK

Patents - Issued, 5

Key science and technology achievements

As the first employee of Molecular Staining Inc (MSI), Dr. Lasken built a genomics department of 20 scientists and developed MDA amplification which is licensed under the brand names TempliPhi and GenomiPhi (GE Healthcare- Amersham Bioscience), and REPLI-g (Qiagen). He is the lead inventor on a patent enabling these products which have more than $10 million in annual sales. As Professor of Genomic at the Center for Genomic Sciences, Allegheny-Singer Research Institute, he developed methods for genotyping microbial pathogens using MDA from human clinical specimens. He was Director of Research at MycoGenetics Inc. where he used high throughput automated enzyme reactions for pharmaceutical screening. He was PI for a DOE SBIR grant ($1,250,000), an NIDDK STTR ($2,279,000), and is currently funded by an R01 from the NHGRI/NIH for development of whole genome amplification methods. He was Assistant Professor at Cornell University Medical College, Dept. of Neurology and Neuroscience studying DNA replication in brain cells. His postdoctoral work was with Arthur Kornberg on the enzymology of DNA replication at Stanford University. At the Institute for Genomics Research he is currently developing new metagenomic methods for discovery and genomic sequencing of unculturable organisms. Single cell genotyping is being used to analyze virulence factors for *Borrelia burgdorferi* (Lyme disease) and pathogens of the human respiratory track.

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Education

St. Cloud State University	BS	1968	Biology and Chemistry
Syracuse University	Ph.D.	1973	Genetics
New York Botanical Garden	PostDoc	1972-1974	Fungal Genetics and Metabolism

Positions and Employment

1974-1989	Scientist, Sr. Scientist, Supervisor, Director, Miles Laboratories (Bayer)
1989-1993	Director, Vice President, Panlabs Inc.
1993-1997	President, Chairman, Lasure and Crawford, Inc.
1997-2000	President, Lasure and Associates, Inc.
2000-	Staff Scientist, Pacific Northwest National Laboratory

Honors

1986	St. Cloud State University Alumna of the Year
1992	Chair, Division O, American Society for Microbiology
1996	President, Society for Industrial Microbiology
2006	Fellow, American Association for the Advancement of Science

Selected Publications

Dai, Z., K.S. Panther, L. J. Hubbard, J.K. Magnuson, S.E. Baker and **L. L. Lasure** (submitted)

The G protein beta subunit regulates spore germination, vegetative growth and asexual sporulation of *Aspergillus niger* in response to nitrogen sources

Baker, S.E., C.F. Wend, D. Martinez, JK Magnuson, E.A. Panisko, Z.Dai, K.S. Bruno, K Anderson, M. Monroe, D.S. Daly and **L.L. Lasure** (2007)

Genome and proteome analysis of industrial Fungi, in "Exploitation of Fungi", G.D. Robson, P. van West and G.M. Gadd Eds, Cambridge University Press

Lei, C. , Y. Shin, J.K. Magnuson, G. Fryxell, **L.L. Lasure**, D.C. Elliott, J. Liu and E.J. Ackerman (2006)

Characterization of functionalized nanoporous supports for protein confinement, Nanotechnology 17: 5531-5538.

Magnuson, J.K. and **Lasure, L.L. (**2004)
Organic acids from fungi: past successes and future prospects, Chapter 11, in Advances in Fungal Biotechnology , Kluwer Academic Publishers

Dai, Z., X. Mao, J.K. Magnuson and **L.L. Lasure** (2004)
Identification of Genes Associated with Morphology in *Aspergillus niger* by Using Suppression Subtractive Hybridization, Applied and Environmental Microbiology 70: 2474-2485.

Bennett, J. W. and L.L. Lasure (1991). *More Gene Manipulations in Fungi,* Academic Press, San Diego.

Patents

L.L. Lasure and Z. Dai.
Isolated polynucleotides and methods of promoting a morphology in a fungus (US Patent Application 20030215950, Filed: May 19, 2003)

L.L. Lasure and Z. Dai.
Promoters and terminators from fungal genes and their use for protein and chemical production. (patent application filed August 2004)

Dai, Z and L. L. Lasure
Provisional patent application (Improved Ethanol Production)
serial number 60/841,722 was filed 31 Aug 2006

Key science and technology achievements

Lasure has fifteen years industrial research experience in microbial process discovery, development and improvement for enzymes, organic acids and other primary metabolites at Miles Laboratories and ten years experience as a research manager at Miles.
She has five years experience in business development and contract research including microbial process discovery, development and improvement for secondary metabolites and drug discovery at Panlabs, Inc.; this included the successful management of the rapid growth of the Panlabs USA Laboratory from 30 to 100 research scientists. From 1997 to 2000 she founded several companies that provided consulting and marketing services to the pharmaceutical and bioprocess industries. At PNNL Lasure established and manages the Fungal Biotechnology Team and the Fungal Genomics Project funded by the EERE Office of Biomass Programs.

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Education

Harvard University	BA	1978	Biological Sciences
University of California–Berkeley	PhD	1986	Botany

Positions and Employment

1998-present	Associate Professor & Professor, Dept. of Agronomy, Iowa State University, Ames, IA
1987-1998	Assistant Professor & Associate Professor, Dept. of Plant, Soil & Environmental Sciences University of Maine, Orono, ME
2000, 2001, 2005	Visiting Scientist, C.T. de Wit Graduate School of Production Ecology & Resource Conservation, Wageningen University, Wageningen, The Netherlands
1994-1995	Visiting Scientist, Dept. of Agronomy and Range Science, University of California, Davis, CA

Honors

2001-2004	Pioneer Agronomy Professorship, Iowa State University
2000-2004	Agroecology Section of the Ecological Society of America
2003, 2004, 2006	Panel member, USDA National Research Initiative, Biology of Weedy and Invasive Plants
1998-2005	Associate editor, *Crop Science*
1993-2002	Associate editor, *Ecological Applications*

Selected Publications

Schulte, L.A., M. Liebman, H. Asbjornsen, and T.R. Crow. *In press.* Agroecosystem restoration through strategic integration of perennials. Journal of Soil and Water Conservation.

Burkart, M., D. James, M. Liebman, and E. van Ouwerkerk. 2006. Integrating principles of nitrogen dynamics in a method to estimate leachable nitrogen under agricultural systems. Water Science and Technology 53(2): 289-301.

Heggenstaller, A.H. and M. Liebman. 2006. Demography of *Abutilon theophrasti* and *Setaria faberi* in three crop rotation systems. Weed Research 46: 138-151.

Heggenstaller, A.H., F.D. Menalled, M. Liebman, and P.R. Westerman. 2006. Seasonal patterns in post-dispersal seed predation of *Abutilon theophrasti* and *Setaria faberi* in three cropping systems. Journal of Applied Ecology 43: 999-1010.

Liebman, M. and D.N. Sundberg. 2006. Seed mass affects the susceptibility of weed and crop species to phytotoxins extracted from red clover shoots. Weed Science 54: 340-345.
McAndrews, G.M., M. Liebman, C.A. Cambardella, and T.L. Richard. 2006. Residual effects of composted and fresh solid swine manure on soybean growth and yield. Agronomy Journal 98: 873-882.
O'Rourke, M.E., A. Heggenstaller, M. Liebman, M.E. Rice. 2006. Post-dispersal weed seed predation by invertebrates in conventional and low-external-input crop rotation systems. Agriculture, Ecosystems and Environment 116: 280-288.
Sadaka, S.S., T.L. Richard, T.D. Loecke, and M. Liebman. 2006. Determination of compost respiration rates using pressure sensors. Compost Science and Utilization 14: 124-131.
Schwarte, A.J., L.R. Gibson, D.L. Karlen, P.M. Dixon, M. Liebman, and J.-L. Jannink. 2006. Planting date effects on winter triticale grain yield and yield components. Crop Science 46: 1218-1224.
Westerman, P.R., M. Liebman, A.H. Heggenstaller, and F. Forcella. 2006. Integrating measurements of seed availability and removal to estimate weed seed losses due to predation. Weed Science 54: 566-574.
Burkart, M., D. James, M. Liebman, and C. Herndl. 2005. Impacts of integrated crop-livestock systems on nitrogen dynamics and soil erosion in western Iowa watersheds. Journal of Geophysical Research-Biogeosciences 110, G01009, doi:10.1029/2004JG000008 (on-line).

Patents (USA only)
None.

Key science and technology achievements
My research group focuses on cropping system diversification, soil amendments, and weed ecology and management. Included within the scope of our work are experiments involving crop rotations, cover crops, green manures, intercrops, animal manures, composts, and insects and rodents that consume weed seeds. Much of the approach I take toward studying the crop-soil-weed interface is described in *Ecological Management of Agricultural Weeds* (Cambridge University Press, 2001), which I co-authored with Drs. Charles Mohler and Charles Staver. Recently, I have become involved in research examining the environmental impacts of using new crops and native perennial grasses for biofuel production. I serve as chair of the interdepartmental Graduate Program in Sustainable Agriculture, and am a member of the graduate faculties in Ecology and Evolutionary Biology, Biorenewable Resources and Technology, and Crop Production and Physiology.

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Education

Universidad Nacional Autónoma de México	B.S.	1965	Ingeniero Químico (Chemical Engineer Degree)
University of Freiburg, West Germany		1967	Polymerization Kinetics
University of California, Berkeley	Ph.D.	1972	Physical Chemistry

Positions and Employment

1967-1968	Assistant Professor, Universidad Nacional Autónoma de México
1975-1979	Assistant Professor, University of California, Irvine
1979-1982	Associate Professor, University of California, Irvine
1982-1989	Senior Research Scientist, Jet Propulsion Laboratory, Caltech
1989-2004	Professor, Dept. of Earth, Atmospheric & Planetary Sciences and Dept. of Chemistry; Lee and Geraldine Martin Professor of Environmental Studies (1992-97); Institute Professor (1997); MIT
2004-	Professor, University of California, San Diego

Honors

1983	Tyler Ecology and Energy Prize
1987	American Chemical Society Esselen Award
1987-1988	American Association for the Advancement of Science Newcomb-Cleveland Prize
1989	NASA Medal for Exceptional Scientific Achievement
1993-present	Member, National Academy of Sciences
1995	Nobel Prize in Chemistry
1996	Doctor Honoris Causa, Universidad de Buenos Aires, Argentina
1996	Doctor Honoris Causa, University of East Anglia, Norwich, England
1996-present	Member, Institute of Medicine
1997	Honorary Degree, Doctor of Science, Yale University
1997	Honorary Degree, Doctor of Laws, University of Calgary, Canada
1998	Willard Gibbs Medal Award
1999	UNEP Sasakawa Prize
2000-present	Member, Pontifical Academy of Sciences
2001	Honorary Degree, Doctor of Science, University of Miami

2002	Medalla al Mérito Ciudadano , Legislature of the Mexico City Government, Mexico
2003	Environment Award, Heinz Family Foundation
2003	Doctor of Science Honoris Causa, Tufts University, Massachusetts
2003-present	Member, El Colegio Nacional, Mexico

Selected Publications

1. R.Y. Zhang, I. Suh, J. Zhao, D. Zhang, E.C. Fortner, XX. Tie, L.T. Molina, and M.J. Molina, "Atmospheric new particle formation enhanced by organic acids," Science, 304 (5676): 1487-1490 (2004).
2. L.C. Marr, LA. Grogan, H. Wohrnschimmel, L.T. Molina, M.J. Molina, T.J. Smith, and E. Garshick, "Vehicle traffic as a source of particulate polycyclic aromatic hydrocarbon exposure in the Mexico City metropolitan area," Environmental Science & Technology, 38 (9): 2584-2592 (2004).
3. M.J. Molina, A. V. Ivanov, S. Trakhtenberg, and L. T. Molina, "Atmospheric evolution of organic aerosol," Geophys. Res. Lett., 31, L22104, doi:10.1029/2004GL020910 (2004).
4. J.C. Chow, J.G. Watson, J.J. Shah, C.S. Kiang, C. Loh, M. Lev-On, J.M. Lents, M.J. Molina, and L.T. Molina, "Megacities and atmospheric pollution," Journal of the Air & Waste Management Association, 54 (10): 1226-1235 (2004).
5. R. Volkamer, L.T. Molina, M.J. Molina, T. Shirley, and W.H. Brune, "DOAS measurement of glyoxal as an indicator for fast VOC chemistry in urban air," Geophysical Research Letters, 32 (8): Art. No. L08806 (2005).
6. B. Zuberi, K.S. Johnson, G.K. Aleks, L.T. Molina, M.J. Molina, and A. Laskin, "Hydrophilic properties of aged soot," Geophysical Research Letters, 32 (1): Art. No. L01807 (2005).
7. D. Salcedo, K. Dzepina, T. B. Onasch, M. R. Canagaratna, Q. Zhang, J. A. Huffman, P. F. DeCarlo, J. T. Jayne, P. Mortimer, D. R. Worsnop, C. E. Kolb, K. S. Johnson, B. Zuberi, L. C. Marr, L. T. Molina, M. J. Molina, R. M. Bernabé, B. Cardenas, C. Márquez, J. S. Gaffney, N. A. Marley, A. Laskin, V. Shutthanandan, J. L. Jimenez, Characterization of Ambient Aerosols in Mexico City during the MCMA-2003 Campaign with Aerosol Mass Spectrometry. Part I: Quantification, Shape-Related Collection Efficiency, and Comparison with Collocated Instruments. Atmos. Chem. Phys. Discuss. 5, 4143-4182 (2005).
8. D. Salcedo, K. Dzepina, T. B. Onasch, M. R. Canagaratna, J. T. Jayne, D. R. Worsnop, J. S. Gaffney, N. A. Marley, K. S. Johnson, B. Zuberi, L. T. Molina, M. J. Molina, V. Shutthanandan, Y. Xie, J. L. Jimenez, Characterization of ambient aerosols in Mexico City during the MCMA-2003 campaign with Aerosol Mass Spectrometry – Part II: overview of the results at the CENICA supersite and comparison to previous Studies, Atmos. Chem. Phys. Discuss. 5, 4183-4221 (2005).

Key science and technology achievements

Professor Molina has been involved in developing our scientific understanding of the chemistry of the stratospheric ozone layer and its susceptibility to human-made perturbations. He was a co-author, with F. S. Rowland, of the 1974 publication in the British magazine Nature, of their research on the threat to the ozone layer from chlorofluorocarbon (CFC) gases that were being used as propellants in spray cans, as refrigerants, as solvents, etc. More recently, Professor Molina has also been involved with the chemistry of air pollution of the lower atmosphere. He is also pursuing interdisciplinary work on tropospheric pollution issues, working with colleagues from many other disciplines on the problem of rapidly growing cities with severe air pollution problems. Professor Molina has served on the President's Committee of Advisors in Science and Technology (1994-2000), and on many other advisory boards and panels. He is a member of the US National Academy of Sciences and the Institute of Medicine, and of the Pontifical Academy of Sciences. He has received numerous awards for his scientific work including the Tyler Ecology and Energy Prize in 1983, the UNEP-Sasakawa Award in 1999, and the 1995 Nobel Prize in Chemistry.

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Education

Wartburg College	BA	1991	Mathematics with computer science minor
University of Iowa	MS	1993	Statistics
University of Iowa	PhD	1996	Statistics

Positions and Employment

1996-2000	Assistant Professor, Department of Mathematics and Statistics, University of Nebraska – Lincoln
2000-2002	Assistant Professor, Department of Statistics, Iowa State University
2002-present	Associate Professor, Department of Statistics, Iowa State University

Selected Publications

Yang, C., Guo, R., Jie, F., Nettleton, D., Peng, J., Carr, T., Yeakley, J.M., Fan, J.-B., Whitham, S.A. (2006). Spatial and temporal analysis of *Arabidopsis thaliana* gene expression in response to *Turnip mosaic virus* infection. *Molecular Plant-Microbe Interactions*. In press.

Ithal, N., Recknor, J., Nettleton, D., Hearne, L., Maier, T., Baum, T.J., Mitchum, M.G. (2006). Parallel genome-wide expression profiling of host and pathogen during soybean cyst nematode infection of soybean. *Molecular Plant-Microbe Interactions*. In press.

Ruppert, D., Nettleton, D., Hwang, J.T.G. (2006). Exploring the information in *p*-values for the analysis and planning of multiple-test experiments. *Biometrics*. In press.

Nettleton, D. (2006). A Discussion of statistical methods for design and analysis of microarray experiments for plant scientists. *The Plant Cell*. **18** 2112-2121.

Nettleton, D., Hwang, J.T.G., Caldo, R.A., Wise, R.P. (2006). Estimating the number of true null hypotheses from a histogram of *p*-values. *Journal of Agricultural, Biological, and Environmental Statistics*. **11** 337-356.

Jia, H., Nettleton, D., Peterson, J.M., Vazquez-Carrillo, G., Jannink, J.-L., Scott, M.P. (2006). Comparison of transcript profiles in wild-type and o2 maize endosperm in different genetic backgrounds. *The Plant Genome*. In press.

Skibbe, D.S., Wang, X., Zhao, X., Borsuk, L.A., Nettleton, D., Schnable, P.S. (2006). Scanning microarrays at multiple intensities enhances discovery of differentially expressed genes. *Bioinformatics*. **22** 1863-1870.

Caldo, R.A., Nettleton, D., Peng, J., Wise, R.P. (2006). Stage-specific suppression of basal defense discriminates barley plants containing fast- and delayed-acting Mla powdery mildew resistance alleles. *Molecular Plant-Microbe Interactions*. **19** 939-947.

Nettleton, D., Wang, D. (2006). Selective transcriptional profiling for trait-based eQTL mapping. *Animal Genetics*. **37** 13-17.

Swanson-Wagner, R. Jia, Y., DeCook, R., Borsuk, L., Nettleton, D., Schnable, P.S. (2006). All possible modes of gene action are observed in a global comparison of gene expression in a maize F1 hybrid and its inbred parents. *Proceedings of the National Academy of Science*. **103** 6805-6810.

Wang, D., Nettleton, D. (2006). Identifying genes associated with a quantitative trait or quantitative trait locus via selective transcriptional profiling. *Biometrics*. **62** 504-514.

DeCook, R., Lall, S., Nettleton, D., Howell, S. H. (2006). Genetic regulation of gene expression during shoot development in Arabidopsis. *Genetics*. **172** 1155-1164.

DeCook, R., Nettleton, D., Foster, C.M., Wurtele, E. (2006). Identifying differentially expressed genes in unreplicated multiple-treatment microarray timecourse experiments. *Computational Statistics and Data Analysis*. **50** 518-532.

Shen, L., Gong, J., Caldo, R. A., Nettleton, D., Cook, D., Wise, R. P., Dickerson, J. A. (2005). BarleyBase—an expression profiling database for plant genomics. *Nucleic Acids Research*. **33** D614-D618.

Caldo, R. A., Nettleton, D., Wise, R. P. (2004). Interaction-dependent gene expression in *Mla*-specified response to barley powdery mildew. *The Plant Cell.* **16** 2514-2528.

Lall, S., Nettleton, D., DeCook, R., Che, P., and Howell, S. H. (2004). QTLs associated with adventitious shoot formation in tissue culture and the program of shoot development in Arabidopsis. *Genetics*. **167** 1883-1892.

Manly, K. F., Nettleton, D., and Hwang, J. T. G. (2004). Genomics, prior probability, and statistical tests of multiple hypotheses. *Genome Research.* **14** 997-1001.

Fernando, R. L., Nettleton, D., Southey, B. R., Dekkers, J. C. M., Rothschild, M. F., and Soller, M. (2004). Controlling the proportion of false positives (PFP) in multiple dependent tests. *Genetics*. **166** 611-619.

Puthoff, D. P., Nettleton, D., Rodermel, S. R., Baum, T. J. (2003). Arabidopsis gene expression changes during cyst nematode parasitism revealed by statistical analyses of microarray expression profiles. *The Plant Journal*. **33** 911-921.

Key science and technology achievements

My current research interest is developing statistical methods for the design and analysis of experiments in plant and animal genomics. I have considerable experience with microarray technology, mapping of quantitative trait loci, and the integration of such studies to understand how genes act together to carry out key biological processes. I have played a key role on over 30 research projects related to these areas in the past three years.

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Education

Massey University	B.Sc. Hon., 1st Class	1977	Biochemistry
Massey University	Ph.D.	1982	Biochemistry

Positions and Employment

1985 - 1988	Senior Scientist, Molecular Biology, Native Plants Inc., Salt Lake City, UT
1988 - 1993	Assistant Professor, Department of Biochemistry and Biophysics, ISU
1993 - 1998	Associate Professor, Department of Biochemistry and Biophysics, ISU
1998 – present	Professor, Department of Biochem. Biophys. & Mol. Biol., ISU
1999 - present	Director, Center for Designer Crops, ISU
2001 – present	Director, W.M. Keck Metabolomics Research Laboratory, ISU

Honors

2003	Iowa State University, College of Agriculture, Outstanding Achievement in Research Award
2005	Iowa State University, College of Agriculture, Team Research Award
2006	State of Iowa, Regents Award for Faculty Excellence

Selected Publications

Ke J, Wen, T-N, ES Wurtele, ES, **Nikolau, BJ**. 2000. Coordinate regulation of the spatial and temporal expression of the nuclear and chloroplastic encoded genes of the heteromeric acetyl-CoA carboxylase. *Plant Physiology*. 122:1057-1071.

McKean AM, Che, P, Achenbach, S, Wurtele, ES, **Nikolau, BJ**. 2000. Molecular cloning and characterization of the cDNA and gene coding for the nonbiotinylated subunit of 3-methycrotonyl-CoA carboxylase. *Journal of Biological Chemistry*. 275:5582-5590

Che, P., E.S. Wurtele and **B.J. Nikolau**. 2002. Developmental and environmental regulation of 3-methylcrotonyl-CoA carboxylase expression in Arabidopsis. *Plant Physiology*. 129: 616-624

Fatland, BL, Ke, J, Anderson, M, Mentzen, W, Cui, L-W, Allred, C, Johnston, JL, **Nikolau**, BJ, Wurtele, ES. 2002. Molecular characterization of a novel heteromeric ATP-citrate lyase that generates cytosolic pool of acetyl-CoA in Arabidopsis. *Plant Physiology*. 130: 740-756.

Nikolau, BJ, Ohlrogge, JB, Wurtele, ES. 2003. Plant Biotin-Containing Carboxylases. Minireview. *Archives of Biochemistry and Biophysics*. 414: 211-222.

Bino RJ, Hall RD, Fiehn O, Kopka J, Saito K, Draper J, **Nikolau BJ**, Mendes P, Roessner-Tunali U, Beale MH, Trethewey RN, Lange BM, Wurtele ES, Sumner LW (2004) Potential of metabolomics as a functional genomics tool. *Trends in Plant Sciences.* 9: 418-425

Jenkins H, Hardy N, Beckmann M, Draper J, Smith AR, Taylor J, Fiehn O, Goodacre R, Bino RJ, Hall R, Kopka J, Lane GA, Lange BM, Liu JR, Mendes P, **Nikolau BJ**, Oliver SG, Paton NW, Rhee S, Roessner-Tunali U, Saito K, Smedsgaard J, Sumner LW, Wang T, Walsh S, Wurtele ES, Kell DB (2004) A proposed framework for the description of plant metabolomics experiments and their results. *Nature Biotechnology.* 22: 1601-1606.

Fatland B, **Nikolau BJ**, Wurtele ES (2005) Reverse genetic characterization of cytosolic acetyl-CoA generation by ATP-citrate lyase in Arabidopsis. *Plant Cell*. 17: 182-203

Sluszny C, Yeung ES, **Nikolau BJ.** 2005 *In situ* probing of the biotic-abiotic boundary of plants by laser desorption/ionization time-of-flight mass spectrometry. *Journal of the American Society of Mass Spectrometry*. 16: 107-115

Dietrich CR, Perera MADN, Yandeau M, Meeley RB, **Nikolau BJ**, Schnable PS (2005) Characterization of two gl8 paralogs reveals that the b-ketoacyl reductase component of fatty acid elongase is essential for maize (Zea mays L.) development. *Plant Journal.* 42: 844-861.

Patents (USA only)

Schnable, P.S. et al. 2000. Isolation and use of cuticular lipid genes. US Patent #6,060,644

Nikolau, B.J. et al. 2005. Materials and methods for the alteration of enzyme and acetyl-CoA levels in plants. US Patent #6,942,994

Key science and technology achievements

Nikolau's research has focused on functional genomics of metabolism. He has published over 85 peer-reviewed and invited publications in the area of metabolism and biochemistry. His research has been funded contiguously for nearly 20 years from highly competitive federal funding agencies (e.g., National Science Foundation, Department of Energy, and US Department of Agriculture). He is the Director of the Center for Designer Crops, which encompasses 12 faculty members at Iowa State University whose research is focused on plant metabolism. He is also the Director of the W.M. Keck Metabolomics Research Laboratory at Iowa State University, which is a centralized facility that provides researchers the analytical hardware needed for high throughput metabolomics analysis of biological samples. Dr. Nikolau's major achievement is the deciphering the structure and regulation of the complex metabolic processes that are central to the generation of high energy biomolecules that have utility as biorenewable feedstocks.

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Education

U.S. Naval Academy	BS	1966	Mathematics & Physics
University of Liverpool	MSc	1968	Physics
University of California, San Diego	PhD	1976	Earth Sciences

Positions and Employment

1967-1973	Communications Officer & Main Propulsion Asst, the nuclear submarine SSBN Lewis & Clark Chief Engineer, the nuclear submarine SSBN Kamehameha, U.S. Navy
1976-1977	Postgraduate Research Geophysicist, Scripps Inst. of Oceanography, UCSD
1977-1980	Assistant Research Geophysicist, Scripps Institution of Oceanography, UCSD
1980-1982	Associate Research Geophysicist, Scripps Institution of Oceanography, UCSD
1982-1984	Associate Professor of Geophysics, Scripps Institution of Oceanography, UCSD
1984-2002	Director, Cecil H. & Ida M. Green Institute of Geophysics and Planetary Physics, UCSD
1984-present	Professor of Geophysics, Scripps Institution of Oceanography, UCSD
2002-2006	Deputy Director & Associate Vice Chancellor – Marine Affairs, Scripps Institution of Oceanography
2006 - present	Associate Vice Chancellor – Research Affairs; Director, UCSD Center for Earth Observations & Applications

Honors

Trident Scholar, U.S. Naval Academy	1965-1966
Graduate, 3rd in Class, U.S. Naval Academy	1966
Summer College Intern Program, U.S. Dept. of State	1966
Fulbright Scholar, United Kingdom	1966
Woods Hole Visiting Scholar	1980
Newcomb-Cleveland Prize from American Assoc. for Advancement of Science	1980
Fellow, American Geophysical Union	1989
Maurice Ewing Medal, American Geophysical Union & US Navy	1994
Secretary of the Navy/Chief of Naval Operations Oceanography Chair	1996-2002
Member, American Philosophical Society	2002-
President, American Geophysical Union (46,000 members)	2004-2006
Past-President, American Geophysical Union	2006-2008

Selected Publications

Suyehiro, K., J.-P. Montagner, R.A. Stephen, E. Araki, T., Kanazawa, J. Orcutt, B. Romanowicz, S.Sacks, and M. Shinohara (2006), "Ocean Seismic Observatories.", Oceanography **19**(4),
Taesombut, N., F. Uyeda, AA. Chien, L. Smarr, T. DeFanti, P. Papadopoulos, J. Leigh, M. Ellisman, and J. Orcutt (2006), "The OptIPuter: High-Performance, Q0S-Guaranteed Network Service for Emerging E-

Science Applications." IEEE Communications Magazine **44**(5), 38-45, 10.1109/MCOM.2006.1637945.
Berger, J., J.A. Orcutt, and F. Vernon (2005). "HighSeasNet: Providing Internet to the UNOLS fleet: A model for real-time Internet data collection from the ORION platforms." Sea Technology **46**(6), 17-20.
Orcutt, J. (2005) "Global scale sensor networks – opportunities and challenges" Information Processing in Sensor Networks. 434, 10.1109/IPSN.2005.14s40965.
Sutherland, F.H., F.L. Vernon, and J.A. Orcutt (2004). "Results from OSNPE: Improved teleseismic earthquake detection at the seafloor." Bull. Seismological Soc. of Am. **94**(5) 1868-1878.
Blackman, D.K., C. de Groot-Hedlin, P. Harben, A. Sauter, and J. Orcutt, (2004). "Testing low/very low frequency acoustic sources for basin-wide propagation in the Indian Ocean." Jour. Acoustical Soc. Am. **116**(4), 2057-2066, 10.1121/1.1786711.
Sutherland, F.H., F.L. Vernon, and J.A. Orcutt (2004). "Results from OSNPE: Improved teleseismic earthquake detection at the seafloor." Bull. Seismological Soc. of Am. **94**(5) 1868.
Orcutt, J. (2003) "The Ocean Research Interactive Observatory Networks (ORION) program." EOS Trans AGU **46**(40), 44, 10.1029/2003EO400005.
Stephen, R.A., F N. Spiess, J.A. Collins, J.A. Hildebrand, J.A. Orcutt, K.R. Peal, F.L. Vernon, and F.B. Wooding (2003). "Ocean seismic network pilot experiment." Geochemistry Geophysics Geosystems **4**(910), 1092, 10.1029/2002GC000485,2003.
Sandwell, D.T., S. Gille, and J. Orcutt (2003). "Bathymetry from space is now possible." EOS **84**(5), 37, 44.
Newman, H.H., M.H. Ellisman, and J.A. Orcutt (2003), "Data-intensive e-science frontier research." Communications of the ACM, **46**(11), 68-77.

Key science and technology achievements

Orcutt was the first to detect a molten magma chamber beneath the linear mid-ocean ridge or volcano using seismic methods. He was first to apply geophysical inverse theory to the analysis of marine controlled-source seismic data to derive a realistic elastic seismic structure for the ocean crust and uppermost mantle. With Professor Chris Chapman (Cambridge) he developed the first geophysical inverse method for inverting seismic waveform data for the elastic structure of the ocean crust. During the RISE experiment in 1979 he served as co-Chief Scientist with the team that discovered 400°C "black smoker" vents on the East Pacific Rise. The AAAS Newcomb-Cleveland Prize was awarded for this – the best paper in Science in 1980. During the 80's Orcutt was one of the founding fathers of the NSF Ridge InterDisciplinary Global Experiments (RIDGE) to examine the structure and dynamics of the globe-encircling mid-ocean ridge. The program continues today as a major NSF experimental undertaking. Beginning in 1973, Orcutt joined the ocean bottom seismograph group at Scripps and IGPP. Since then he has seen the instrumentation through several major technological transitions to today's leading ocean bottom seismograph. The Scripps Ocean Bottom Seismograph Instrument Pool (OBSIP) now includes more than a hundred instruments and supports the bulk of the world's seafloor seismic experiments today. The Scripps instruments have been used to begin new programs in France and Britain and commercial concerns are now using these for offshore measurements. Orcutt is the PI for the NSF Real-time Observatory, Analysis, and Data management Network (ROADNet) and the NSF Laboratory for Ocean Observatory Knowledge Integration Grid (LOOKING) projects. He is leading the program to provide the software, middleware, and hardware for the NSF Ocean Observatories Network (OOI) cyberinfrastructure. The OOI is funded in this year's budgets for $309.5M to begin the process of developing a permanent presence in the oceans for collecting long-term time series data – a new approach to oceanography for the 21st Century. Orcutt is the Director of the UCSD Center for Earth Observations & Applications. He is also the PI for the largely state-funded Southern California Coastal Ocean Observing System (SCCOOS) and the BP Institute at Scripps.

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Education

University of Kansas	BS	1979	Chemical Engineering
University of Wisconsin	PhD	1984	Chemical Engineering

Positions and Employment

1976-1977	Research Assistant, University of Iceland
1978-1979	Research Assistant, University of Kansas
1980-1984	Research Assistant, University of Wisconsin
1984-1990	Assistant Professor, University of Michigan
1990-1995	Associate Professor, University of Michigan
1995-Present	Professor, UCSD

Honors

1979	Award for outstanding graduate research, University of Kansas
1984	NATO Fellow
1987-1992	FIRST Award from the NIH
1991-1995	George Granger Brown Professorship, University of Michigan
1993	Chemical Engineering Research Award, University of Michigan
1995	Fellow, the American Institute for Medical and Biomedical Engineering
1996	Fulbright Fellowship and Ib Henriksen Fellow
2000	Hougen Professorship, University of Wisconsin
2001	Lindbergh-Carrel Prize
2001	Bayer Lectures Honoree
2002	FPB/AiChE Award
2006	UCSD Chancellor's Associates Award in Science and Technology
2006	Election to the National Academy of Engineering

Selected Publications

1. B. O. Palsson, S. Fathi-Afshar, D. F. Rudd, and E. N. Lightfoot (1981), "Biomass as a Source of Chemical Feedstocks," *Science*, **213**, 513-517.
2. C. G. Economou, M. Morari, and B. O. Palsson (1986), "Internal Model Control: Extension to Non-linear Systems," *Ind. Eng. Chem. Process Des. Dev.*, **25**, 403-411.
3. Ozturk, B. O. Palsson, A. R. Midgley, and C. R. Halberstadt (1989), "Transtubular Bioreactor: A Perfusion Device for Mammalian Cell Cultivation," *Biotechn. Techn.*, **3**, 55-60.
4. J. D Keasling and B. O. Palsson (1989), "ColE1 Plasmid Replication: A Simple Kinetic Description from a Structured Model," *J. theor. Biol.*, **141,** 447-461.
5. M. Javanmardian and B. O. Palsson (1991), "High-density Photoautotrophic Algal Cultures: Design, Construction, and Operation of a Novel Photobioreactor System," *Biotechnology and Bioengineering*, **38**, 1182-1189.
6. B.O. Palsson, S-H Paek, R.M. Schwartz, M. Palsson, G-M Lee, S. Silver and S.G. Emerson (1993), "Expansion of Human Bone Marrow Progenitor Cells in a High Cell Density Continuous Perfusion System," *Bio/Technology*, **11**, 368-372.
7. S.E. Merritt and B.O. Palsson (1993), "Loss of Antibody Productivity is Highly Reproducible in Multiple Hybridoma Subclones," *Biotechnology and Bioengineering*, **42**, 247-250.
8. Varma, B.W. Boesch, and B.O. Palsson (1993), "Stoichiometric Interpretation of *Escherichia coli* Glucose Catabolism under Various Oxygenation Rates," *Applied and Environmental Microbiology*, **59:8**, 2465-2473.

9. C-G. Lee and B.O. Palsson (1994), "High-Density Algal Photobioreactors Using Light Emitting Diodes," *Biotechnology and Bioengineering*, **44**, 1161-1167.
10. A. Varma and B.O. Palsson (1994), "Stoichiometric Flux Balance Models Quantitatively Predict Growth and Metabolic By-Product Secretion in Wild Type *Escherichia coli* W3110, *Appl. Environ. Microbiol*., **60:10**, 3724-3731.
11. Varma and B.O. Palsson (1994), "Metabolic Flux Balancing: Basic Concepts, Scientific and Practical Use," *Bio/Technology*, **12**, 994-998.
12. C.A. Peng and B.O. Palsson (1995), "The Importance of Non-Homogeneous Concentration Distributions Near Walls in Tissue Engineering Bioreactors," special issue on Transport Phenomena, *Industrial & Engineering Chemistry Research*, **34**:3239-3245.
13. J.S. Edwards and B.O. Palsson, "The *Escherichia coli* MG1655 *in silico* metabolic genotype; Its definition, characteristics, and capabilities," *Proc. Natl. Acad. Sci. (USA)*, **97**: 5528-5523 (2000).
14. J.S. Edwards, R.U. Ibarra, and B.O. Palsson, "In silico predictions of *Escherichia coli* metabolic capabilities are consistent with experimental data," *Nature Biotechnology*, **19**: 125-130 (2001).
15. M.W. Covert and B.O. Palsson, "Transcriptional Regulation in Constraints-Based Metabolic Models of *Escherichia coli*," *Journal of Biological Chemistry*, **277**: 28058-28064 (2002)**.**
16. R.U. Ibarra, J.S. Edwards, and B.O. Palsson, "*Escherichia coli* K-12 undergoes adaptive evolution to achieve *in silico* predicted optimal growth," *Nature,* **420**: 186-189 (2002).
17. Papin, J.A., Price, N.D., Wiback, S.J., Fell, D.A., and Palsson, B.O., "Metabolic Pathways in the Post-Genome Era," *Trends in Biochemical Sciences*, **28**:250-258 (2003).
18. Reed, J.L., Vo, T.D., Schilling, C.H., and Palsson, B.O., "An expanded genome-scale model of *Escherichia coli* K-12 (iJR904 GSM/GPR)," *Genome Biology*, **4**:R54.1-R54.12 (2003).
19. Famili, I., Forster, J., Nielsen, J., and Palsson, B.O., "*Saccharomyces cerevisiae* Phenotypes can be Predicted Using Constraint-based Analysis of a Genome-Scale Reconstructed Metabolic Network," *PNAS*, **100**: 13134-13139, (2003).
20. Fong, S.S. and Palsson, B.Ø., "Metabolic gene-deletion strains of *Escherichia coli* evolve to computationally predicted growth phenotypes," *Nature Genetics*, **36**(10): 1056-58, (2004).
21. Price, N.D., Reed, J.L. and Palsson, B.Ø., "Genome-scale Models of Microbial Cells: Evaluating the consequences of constraints", *Nature Reviews Microbiology*, **2**:886-897 (2004).
22. Reed, J.L., Famili, I., Thiele, I., and Palsson, B.Ø., "Towards multidimensional genome annotation", *Nature Reviews Genetics*, **7**(2): 130-41 (2006).

Patents (USA only); Issued, 27; Published but not yet issued, 22

Key science and technology achievements: Professor Palsson has had a 25 year career in chemical engineering and biotechnology. His work has included bioreactor designs; ranging from cell therapy to therapeutic protein production to photobioreactors. He has established 4 start-up companies based on these technologies and other inventions. His current genome-scale systems biology research at UCSD focuses on: (1) the reconstruction of genome-scale biochemical reaction networks, (2) the development of mathematical analysis procedures for genome-scale models, and (3) the experimental verification of genome-scale models with current emphasis on cellular metabolism and transcriptional regulation in E. coli and Yeast. The primary applications of genome-scale metabolic models are for designing microbial strains for fermentation of bio-feed stocks to chemicals and biofuels, and for antibiotic development in pathogenic strains. Human metabolic models can be used for a variety of clinical and health care applications. In addition Professor Palsson developed methods for industry-scale econometric assessment of the market viability of fermentation derived products that were applied in the last energy crisis in the early 1980s when biologically derived materials were being considered as alternatives to petro-chemically derived ones.

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Education

Temple University	BA	1969	Biology
Utah State University	MS	1979	Aquatic Ecology
Utah State University	Ph.D.	1983	Wildlife Ecology
Harvard University	Certificate	2001	University Administration

Positions and Employment

2001-2005	Vice President for University Extension and Dean of Continuing Education, Utah State University. Tenured Professor, College of Natural Resources
1996-2000	National Director of Conservation – Ducks Unlimited, Inc.
1996-1999	Executive Director (interim) – Ducks Unlimited de Mexico
1990-1996	National Director – Ducks Unlimited's Agricultural Program
1985-1990	Associate Professor and Extension Wildlife Specialist, Texas A7M University
1983-1985	Assistant Professor and Extension Wildlife Specialist, Pennsylvania State University

Honors

2003	Friend of Agriculture Award – Utah Department of Agriculture and Food
2003	President's Award – Utah Association for Continuing Education
1996	Outstanding Service Award – Central Valley Habitat Joint Venture, North American Waterfowl Management Plan
1989	Outstanding Service Award – Southwest Regional Office, US Fish and Wildlife Service
1982	Outstanding Paper Presentation – Utah Chapter of The Wildlife Society

Key science and technology achievements

Jack Payne is the Vice President for Extension and Outreach at Iowa State University. He recently was the Vice President and Dean for University Extension at Utah State University. His responsibilities included serving as the Director of the Utah Cooperative Extension Service and Dean of Continuing Education.

Dr. Payne has experience at three of the nation's finest and largest land-grant institutions, including Pennsylvania State University, where he served on the faculty of the School of Forest Resources and as the state's Extension wildlife specialist, working with private, non-industrial forest landowners. Later, at Texas A&M University, he was a faculty member in the Fisheries

and Wildlife Department, and was the Extension wildlife specialist for South Texas, where he integrated wildlife habitat into Texas ranching operations, and, as previously mentioned, at Utah State University.

After leaving Texas A&M University, Payne had a long career with Ducks Unlimited (DU), most recently serving as their National Director of Conservation. While at Ducks Unlimited, some of his successes included the development of DU's Private Lands Program with agriculture; the development of a national conservation easement program and the expansion of their Mexican program to Central and South America.

Payne received his M.S. in Aquatic Ecology and his Ph.D. in Wildlife Ecology from Utah State University. He also is a graduate of the Institute for Educational Management at Harvard University. He is a tenured professor in the Department of Natural Resources Ecology and Management at Iowa State University. He recently was elected to a four year term as Chair of the Policy Board of the Board on Agriculture for the nation's land grant university system.

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Education

University of Virginia	BS	1982	Environmental Sciences
University of Washington	MS	1987	Oceanography
Columbia University	Ph.D.	1992	Geosciences

Positions and Employment

1984-1988	Research Assistant, Los Alamos National Labs, Los Alamos, NM
1987-1992	Graduate Research and Teaching Assistant, Columbia University Faculty Fellow
1992-1994	Res. Scientist, Dept. Earth & Planetary Sciences, American Museum of Natural History
1994 - 2000	Oceanography Professor, Sea Education Association, Woods Hole, MA
2000- 2001	Interim Dean, Sea Education Association, Woods Hole, MA
2001 - Present	Adjunct Faculty, Sea Education Association, Woods Hole, MA
2001 – Present	Director, Scripps Center for Educational Outreach Connections

Selected Publications

Franks, S., J. McDonnell, C. Peach, E. Simms and A. Thorrold (2006) Education and Public Outreach: A Guide for Scientists, *Oceanography*, 19 (4) http://www.tos.org/epo_guide/index.html

Franks, S., C.L. Peach, J. McDonnell and A. Thorrold (2005) Broader Impact: Guidance for Scientists about Education and Outreach, *Eos Transactions 86 (12), American Geophysical Union*

Key outreach achievements

Peach's career has been focused on supporting the interplay between science and education by spearheading new initiatives in education and public outreach. She is currently the PI and SIO Director for the Center for Ocean Science Education Excellence – California and Director of the Scripps Center for Educational Outreach Connections. Peach has taken a national leadership role in geosciences education and public outreach (EPO). Peach served a three-year term as the Education and Diversity subcommittee Chair on the NSF Geoscience Directorate Advisory Committee. She served as Chair of NSF's 2nd Geosciences Education Working Group and co-authored the committee report that serves as a guide for the Geoscience Directorate's EPO

planning. Peach has given numerous presentations at national professional society meetings on strategies for engaging the research community in EPO and serves on several committees focused on the EPO associated with large science initiatives or programs (Integrated Ocean Observing System; Centers for Ocean Sciences Education Excellence Council; Sea Education Association Board).

Prior to her arrival at SIO, Peach spent 7 years as an oceanography professor and interim Dean at SEA (Sea Education Association), a private non-profit organization dedicated to undergraduate education in ocean sciences. As an SEA faculty member Cheryl served as a seagoing research scientist and taught college undergraduates both on shore and at sea. Dr. Peach has dedicated herself to teacher professional development, serving as chief scientist for SEA's K-12 teacher programs. Cheryl was P.I. for *Research at SEA*, a 5-year, National Science Foundation, teacher professional development program for middle and high school science teachers. As Interim Dean at SEA in both 1997 and 2000-2001, Cheryl assumed an administrative position that involved interacting with students, parents and employees, providing academic guidance to the faculty and developing new programs.

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Education

George Mason University, VA	BS	1976	Biology
University of Idaho	MS	1983	Bacteriology
University of Idaho	PhD	1987	Bacteriology

Positions and Employment

1976-1988	Full time, Research Associate, Dept. Bacteriology & Biochem., University of ID
1988-1993	Assistant Professor, Dept Food Science & Human Nutri., Iowa State University
1993-1998	Associate Professor, Dept Food Science & Human Nutri., Iowa State University
1998-present	Professor, Dept Food Science & Human Nutri., Iowa State University
2000-2006	Director, NASA Food Technology Commercial Space Center, ISU
2006-present	Associate Director, ISU Institute for Food Safety and Security

Honors

1988	Outstanding Staff Researcher Award, Dept of Bacteriology & Biochem., U of Id
1991	National Corn Growers Association and ICI Americas Corn Study Tour Award
2006	USA State Department Speaker and Specialist Award as Keynote Speaker at Cytalia XI Food Safety Symposium, Madrid, Spain

Selected Publications

Crawford, D.L., A. L. Pometto III, and R.L. Crawford. 1983. Lignin degradation by *Streptomyces viridosporus*: Isolation and characterization of a new polymeric lignin degradation intermediate. Appl. Environ. Microbiol. *45*:898-904.

Pometto III, A. L. and D.L. Crawford. 1986. Catabolic fate of *Streptomyces viridosporus* T7A-produced, acid-precipitable polymeric lignin upon incubation with ligninolytic *Streptomyces* species and *Phanerochaete chrysosporium*. Appl. Environ. Microbiol. *51*:171-179.

Pometto III, A. L. and D.L. Crawford. 1986. The effects of pH on lignin and cellulose degradation by *Streptomyces viridosporus*. Appl. Environ. Microbiol. *52*:246-250.

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Adhi, T.P., R.A. Korus, A. L. Pometto III, and D.L. Crawford. 1987. Lignin degradation and production of microbially modified lignin polymers by *Streptomyces viridosporus* in a slurry bioreactor. Appl. Biochem. Biotechnol. *18*:291-301.

Wang, Z., D.L. Crawford, A. L. Pometto III, and F. Rafii. 1989. Survival and effect of wild type, mutant and recombinant *Streptomyces* in soil eco system. Can. J. Microbiol. *35*:535-543.

Pasti, M.B., A. L. Pometto III, M.P. Nuti, and D.L. Crawford. 1990. Lignin-solubilizing ability of actinomycetes isolated from termite (*Termitidae*) gut. Appl. Environ. Microbiol. *56*:2213-2218.

Khiyami, M. A., A. L. Pometto III, and R. C. Brown. 2005. Detoxification of Corn Stover and Corn Starch Pyrolysis Liquors by Ligninolytic Enzymes of *Phanerochaete chrysporium*. J. Ag. Food Chem. 53:2969-2977

Khiyami, M. A., A. L. Pometto III, and R. C. Brown. 2005. Detoxification of Corn Stover and Corn Starch Pyolysis Liquors by *Pseudomonas putida* and *Streptomyces setonii* Suspended Cells and PCS Biofilms. J. Ag. Food Chem. 53:2978-2987.

Khiyami, M.A., A. L. Pometto III, and W. J. Kennedy. 2006. Lignolytic Enzyme Production by *Phanerochaete chrysosporium* in PCS Biofilm Sitrred Tank Bioreactor. J. Ag. Food Chem. 54: 1693-1698.

Patents (USA only)

Issued

Crawford, D.L. and A. L. Pometto III. 1983. Biologically produced Acid Precipitable Polymeric Lignin. U.S. Patent No. 4,478,747. Canadian Patent No. 1202189.

Pometto III, A. L. and B. Lee. 1991. Degradable plastic high molecular weight polyethylene biodegradation by aerobic ligninolytic microorganisms. US patent No. 5,145,779.

Pometto III, A. L., A. Demirci, and K. Johnson. 1997. Plastic composite supports for immobilized-cell bioreactors. US patent No. 5,595,893.

Published but not yet issued

van Leeuwen, J., A. L. Pometto III, and S.K. Khanal. 2006. Purfication of thin stillage from dry corn milling fungi ISURF #033871

Key science and technology achievements

Dr. Pometto has over thirty years of research experience in academia. At the University of Idaho, he was part of the Don L. Crawford bacterial lignin biodegradation team for twelve years. We were the first research group to confirm bacterial biodegradation of lignin. He joined Iowa State University in 1988 to develop a research program in industrial microbiology. During his tenure at ISU he has developed a novel biofilm reactor with immobilized- and suspend-cells for enhanced production for ethanol, lactic acid, succinic acid, ligninases, fungal products, and bioremediation of corn stover and corn starch pyrolysis oils. He also lead the ISU effort to evaluate the biodegradability of degradable plastics such as polylactic acid, and starch polyethylene films. Currently he is the leader for Food and Fuels platform in the Institute for Food Safety and Security. The goal of this platform is to take a proactive role in the development of biofuel co-products with functional feed attributes for cattle, swine and poultry.

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Education

University of California, Davis	BS	1985	Chemistry
University of California, Davis	PhD	1990	Physical chemistry

Positions and Employment

1992 – 1996	Assistant Professor, Univ. of California, Riverside
1994 – 2001	Research Associate, Statewide Air Pollution Research Center
1996 – 2000	Associate Professor, Univ. of California, Riverside
2000 – 2001	Professor, Univ. of California, Riverside
2001- present	Professor, Univ. of Calif., San Diego, Dept. of Chemistry and Biochemistry
2001 – present	Professor, Univ. of Calif., San Diego, Scripps Institution of Oceanography

Honors

American Society for Mass Spectrometry Research Award, 1994
National Science Foundation Young Investigator Award, 1994
Special Creativity Award, National Science Foundation, 1997
Smoluchowski Award (GaeF, German Aerosol Society), 1998
Kenneth T. Whitby Award (American Association for Aerosol Research), 1999
UC CONNECT Most Innovative New Product Award, 1999
R&D Magazine Invention Award, 2000
Arthur F. Findeis Award (Analytical Chemistry Division/American Chemical Society), 2000

Selected Publications

Toner, S. M.; Sodeman, D. A.; Prather, K. A., Single particle characterization of ultrafine and accumulation mode particles from heavy duty diesel vehicles using aerosol time-of-flight mass spectrometry. *Environmental Science & Technology* **2006,** 40, (12), 3912-3921.

Spencer, M. T.; Prather, K. A.; Shields, L. G., Chemical analysis of used and new petroleum-based lubricants using ATOFMS. *Atmospheric Environment* **2006,** 40, 5224-5235.

Qin, X. Y.; Prather, K. A., Impact of Biomass Emissions on Particle Chemistry during the California Regional Particulate Air Quality Study. *International Journal of Mass Spectrometry* **2006,** 258, 142-150.

Sullivan, R. C.; Prather, K. A., Recent advances in our understanding of atmospheric chemistry and climate made possible by on-line aerosol analysis instrumentation. *Analytical Chemistry* **2005,** 77, (12), 3861-3885.

Sodeman, D. A.; Toner, S. M.; Prather, K. A., Determination of single particle mass spectral signatures from light-duty vehicle emissions. *Environmental Science & Technology* **2005,** 39, (12), 4569-4580.

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Whiteaker, J. R.; Prather, K. A., Detection of pesticide residues on individual particles. *Analytical Chemistry* **2003,** 75, (1), 49-56.
J. R. Whiteaker, D. T. Suess & K. A. Prather. Effects of meteorological conditions on aerosol composition and mixing state in Bakersfield, CA. *Environ. Sci. and Technol.* **2002**, 36, 2345-2353.
Suess, D. T.; Prather, K. A., Reproducibility of single particle chemical composition during a heavy duty diesel truck dynamometer study. *Aerosol Science And Technology* **2002,** 36, (12), 1139-1141.
Song, X. H. et al. Source apportionment of gasoline and diesel by multivariate calibration based on single particle mass spectral data. *Analytica Chimica Acta* **2001,** 446, (1-2), 329-343.
Bhave, P. V.; Fergenson, D. P.; Prather, K. A.; Cass, G. R., Source apportionment of fine particulate matter by clustering single-particle data: Tests of receptor model accuracy. *Environmental Science & Technology* **2001,** 35, (10), 2060-2072.
Angelino, S.; Suess, D. T.; Prather, K. A., Formation of aerosol particles from reactions of secondary and tertiary alkylamines: Characterization by aerosol time-of-flight mass spectrometry. *Environmental Science & Technology* **2001,** 35, (15), 3130-3138.
S. A. Guazzotti, K. R. Coffee & K. A. Prather. Continuous measurements of size-resolved particle chemistry during INDOEX-Intensive Field Phase 99. *Journal of Geophysical Research-Atmospheres,* **2001**, 106, 28607-28627.
E. E. Gard et al. Direct Observation of Heterogeneous Chemistry in the Atmosphere. *Science* **1998**, 279, 1184-1187.

Patents (USA only)
Issued, 2
Published but not yet issued, 2

Key science and technology achievements
The Prather group's work on aerosols focuses on understanding the link between air pollution, health, and climate. Her group focuses on the development and application of novel methods for measuring air pollution and the impacts of aerosols on climate. Prather invented a unique on-line technique, aerosol time-of-flight mass spectrometry, for measuring the size and chemical composition of individual aerosol particles via mass spectrometry. The mass spectral fingerprints are used to link atmospheric particles with specific sources. This allows the establishment of the relative impacts of specific sources on human health and climate. Specifically, the Prather group focuses on measuring biomass emissions, diesel and gasoline vehicles, dust, sea spray, and the impacts of agricultural activities on dust and pesticide resuspension. By probing the chemical associations (or mixing state) of the aerosols, the Prather group is able to provide impact into the climate forcing potential of the particles. Details on how effectively a particle forms a cloud, termed the indirect effect, is the most poorly understood component of climate change. In order to reduce the uncertainties in the effect of aerosol chemistry on cloud formation, the Prather group performs studies into how effectively particles from specific sources affect cloud formation. They have been involved in numerous measurement campaigns measuring both the gas phase and particles in various regions of the United States as well as in other regions of the world including India, Mexico City, and Asia.

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Education

Utrecht University	MS	1995	Molecular Genetics and Biochemistry
Utrecht University	PhD	2000	Plant Molecular Biology

Positions and Employment

2000-2001	Junior Scientist, Utrecht University, The Netherlands
2002-2003	Postdoctoral Associate, Torrey Mesa Research Institute
2003-	Staff Scientist, The Institute for Genomic Research

Honors

2004	TIGR Rodbell research fellowship award

Selected Publications

Kuang,H., Wei,F., Marano,M.R., Wirtz,U., Wang,X., Liu,J., Shum,W.P., Zaborsky,J., Tallon,L.J., Rensink,W., Lobst,S., Zhang,P., Tornqvist,C.E., Tek,A., Bamberg,J., Helgeson,J., Fry,W., You,F., Luo,M.C., Jiang,J., Robin,B.C., and Baker,B. (2005) The R1 resistance gene cluster contains three groups of independently evolving, type I R1 homologues and shows substantial structural variation among haplotypes of *Solanum demissum*. Plant J. 44, 37-51

Rabinowicz,P.D. and Rensink,W. (2005) Ways to get from plant genomes to phenomes: via yeast. Genome Biol. 6, 310

Rensink,W., Hart,A., Liu,J., Ouyang,S., Zismann,V., and Buell,C.R. (2005) Analyzing the potato abiotic stress transcriptome using expressed sequence tags. Genome 48, 598-605

Rensink,W.A. and Hazen,S.P. (2006) Statistical issues in microarray data analysis. Methods Mol. Biol. 323, 359-366

Rensink,W.A. and Buell,C.R. (2005) Microarray expression profiling resources for plant genomics. Trends Plant Sci. 10, 603-609

Rensink,W.A., Lee,Y., Liu,J., Iobst,S., Ouyang,S., and Buell,C.R. (2005) Comparative analyses of six solanaceous transcriptomes reveal a high degree of sequence conservation and species-specific transcripts. BMC. Genomics 6, 124

Rensink,W.A., Iobst,S., Hart,A., Stegalkina,S., Liu,J., and Buell,C.R. (2005) Gene expression profiling of potato responses to cold, heat, and salt stress. Funct. Integr. Genomics 5, 201-207

Rensink,W.A. and Buell,C.R. (2004) Arabidopsis to rice. Applying knowledge from a weed to enhance our understanding of a crop species. Plant Physiol 135, 622-629

Rensink,W.A., Schnell,D.J., and Weisbeek,P.J. (2000) The transit sequence of ferredoxin contains different domains for translocation across the outer and inner membrane of the chloroplast envelope. J. Biol. Chem. 275, 10265-10271

Rensink,W.A., Pilon,M., and Weisbeek,P. (1998) Domains of a transit sequence required for in vivo import in Arabidopsis chloroplasts. Plant Physiol 118, 691-699

Key science and technology achievements

Rensink started his scientific research in protein targeting within plant cells. This work resulted in the discovery of key features of the targeting signal that are required for proper targeting and translocation across the chloroplast membranes. For the past six years, Rensink's research has focused on bioinformatics and plant genomics. Rensink was involved in the development of expression platforms for the model species, *Arabidopsis thaliana*. At the Torrey Mesa Research Institute, Rensink identified and functionally analyzed disease resistance genes in the rice genome as well as worked on the unraveling transcriptional networks involved in plant pathogen interactions. In his position at the Institute for Genomic Research, Rensink has participated in a number of Expressed Sequence Tag (EST) projects and analyzed plant EST data sets to identify species specific transcripts. As some bioenergy crops such as switchgrass and Miscanthus will be cultivated in marginal agricultural areas, understanding of environmental stress responses will be a key factor in the successful deployment of bioenergy crops. Using global expression profiling, Rensink has identified signature expression profiles in potato that provide biomarkers for different types of environmental stress, stress sensitivity, or stress tolerance. Using a systems approaches in which expression profiling experiments, prior databases knowledge and other high throughput data types are integrated, Rensink is constructing a global interaction network for environmental stress responses. Such a network can be used for the identification of key regulatory genes within the network involved in stress tolerance that can be applied to engineering of stress tolerant varieties.

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Education

Chung-Shing University, Taichung, Taiwan	B.S.	1988	Chemistry
The American University, Washington, D.C.	M.S.	1993	Chemistry

Positions and Employment

1991-1993	Teaching Assistant, The American University
1993-1998	Molecular Tool, Inc., Scientist
1998-2001	Celera Genomics, Scientist
2001-2002	Celera Genomics, Manager, Sequencing R&D
2002-present	Director of New Technology Development, J. Craig Venter Institute, Joint Technology Center
2003-present	Scientific Director, J. Craig Venter Institute, Joint Technology Center

Awards and Honors

1999	Celera Genomics, Special Presidential Award

Selected Publications

Goldberg SMD, et al. (2006). A sanger/pyrosequencing hybrid approach for the generation of high-quality draft assemblies of marine microbial genomes. *Proc Natl Acad Sci U S A* 103**:**11240-11245.

Rogers YH, and Venter JC, (2005). Massively parallel sequencing. *Nature* 437, 326-327.

Venter JC, et al. (2004). Environmental Whole Genome Shotgun Sequencing: The Sargasso Sea. *Science*. 304(5667):66-74.

Mural RJ, et al. **(**2002). A Comparison of Whole-Genome Shotgun-Derived Mouse Chromosome 16 and the Human Genome. *Science*. 296(5573):1661-71.

Venter JC, et al. (2001). The Sequence of the Human Genome. *Science*. 291(5507):1304-51.

Adams MD, et al. (2000). The Genome Sequence of *Drosophila melanogaster*. *Science*. 287(5461):2185-95.

Rogers YH, Anderson S., Boyce-Jacino MT, Jiang-Baucom P, Huang EZ (1998). Covalent Attachment of Nucleic Acid Molecules onto Solid-Phases via Disulfide Bonds. *Anal Biochem*. 266(1):23-30.

Head SR, Parikh K, RogersYH, Bishai W, Goelet P, Boyce-Jacino MT (1998). Solid-phase Sequence Scanning for Drug Resistance Detection in Tuberculosis. *Mol Cell Probes.* 13(2):81-7.

Bogdanov VL, Rogers YH, Lan G, Boyce-Jacino M (1998). Multicolor Instrumentation for Direct Fluorescent Detection of Nucleic Acids on Microchips. *SPIE Proc*. 3259:156-164.

Reynolds JE, Rogers YH, Head SR, Anderson S, Goelet P, Boyce-Jacino MT (1997). Sequence Composition Analysis Using Solid-Phase Primer Extension. *CRC publications.*

Huang EZ, Rogers YH (1997). Competitive Enzymatic Assay of Biotin. *Methods in Enzymology.* 279:304-308.

Head SR, Rogers YH, Parikh K, Boyce-Jacino MT (1997). Nested Genetic Bit Analysis (N-GBA) for Mutation Detection in the *p*53 Tumor Suppressor Gene. *Nuc Acids Res.* 25:5065-5071.

Ives JT, Rogers YH, Bogdanov VL, Huang EZ, Boyce-Jacino MT, Goelet P (1996). Fluorescence Detection Applied to Non-Electrophoretic DNA Diagnostics on Oligonucleotide Arrays. *SPIE Proc.* 2680:258-269.

Boyce-Jacino MT, Reynolds JE, Nikiforov TT**,** Rogers YH, Saville C, McIntosh T, Goelet P, Knapp MR (1994). High volume molecular genetic identification of single nucleotide polymorphisms using Genetic Bit Analysis: Application to human genetic disease. *Am J Hum Genet* 55(3):A2088.

Nikiforov TT, Rogers YH (1995). The Use of 96-Well Polystyrene Plates for DNA Hybridization-based Assays: The Evaluation of Different Approaches to Oligonucleotide Immobilization. *Analytical Biochemistry* 227:201-209.

Nikiforov TT, Rendle RB, Goelet P, Rogers YH, Kotewicz ML, Anderson S, Trainor GL, Knapp MR (1994). Genetic Bit Analysis: a Solid Phase Method for Typing Single Nucleotide Polymorphisms. *Nuc Acids Res* 22:4167-4175.

Nikiforov TT, Rendle RB, Kotewicz ML, Rogers YH (1994). The Use of Phosphorothioate Primers and Exonuclease Hydrolysis for the Preparation of Single-Stranded PCR Products and Their Detection by Solid-Phase Hybridization. *PCR Methods and Apps.* 3:285-291.

Patents

Anderson S, Rogers YH. Covalent Attachment of Nucleic Acid Molecules onto Solid-Phases via Disulfide Bonds (continuation of *US patent number 5,837,860). US patent number 6,030,782*.

Boyce-Jacino MT**,** Rogers YH, Goelet P. Method for Determining Nucleotide Sequence of a Poly-Nucleotide by Oligonucleotide Extension on an Array. *US patent number 6,294,336.*

Friedman M, Rogers YH, Boyce-Jacino MT. Gene Pen Devices for Array Printing. *US patent number 6,235,473*.

Key science and technology achievements

A recognized leader in the field of designing and deploying large-scale DNA sequencing projects and pipelines, Yu-Hui C. Rogers joined the Venter Institute in 2002. She currently serves as both Scientific Director and Director of New Technology Development at the J. Craig Venter Institute Joint Technology Center. Ms. Roger's areas of expertise include development, implementation, and management of DNA sequencing facilities and nucleic acid technology development. Before joining the Venter Institute, she was the Manager of Sequencing Research and Development at Celera Genomics. She was instrumental in the development and implementation of the Celera high-throughput sequencing pipeline that allowed the human genome sequence to be completed in 14 months. In addition, she was responsible for implementing and managing a forensic resequencing pipeline at Celera. This pipeline was specifically set up to perform the mtDNA resequencing on the World Trade Center (WTC) victim and reference samples for the purpose of identifying the WTC victims.

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Education

Cornell University	Agronomy	B.S.	1981
Iowa State University	Plant Breeding and Cytogenetics	Ph.D.	1986
Max-Planck-Institut, Köln, Germany	NIH Postdoctoral Fellow		1986-1988

Positions and Employment

1986-1988	NIH Postdoctoral Fellow, Laboratory of Heinz Saedler, Max-Planck-Institut für Züchtungsforschung, Köln, Germany
1988-1998	Assistant and Associate Professor, Iowa State University
1998-present	Professor, Iowa State University
1999-present	Founding Director, Center for Plant Genomics
2002-2006	Associate Chair and Chair, Interdepartmental Genetics Graduate Program
2005-present	Associate Director, Plant Sciences Institute

Honors

Raymond and Mary Baker Agronomic Excellence Award, 2000
College of Agriculture Research Team Award, 2005

Selected Publications

Stinard PS, DS Robertson, **PS Schnable** (1993) Genetic isolation, cloning, and analysis of a *Mutator*-induced, dominant antimorph of the maize *amylose-extender1* locus. **Plant Cell** 5:1555-1566.

Civardi L, YJ Xia, K Edwards, **PS Schnable**, BJ Nikolau (1994) The relationship between the genetic and physical distances of the cloned *a1-sh2* interval of the *Zea mays* L. genome. **Proc Natl Acad Sci** 91:8268-8272.

Bensen RJ, GS Johal, VC Crane, JT Tossberg, **PS Schnable**, RB Meeley, SP Briggs (1995) *Anther ear 1* of maize encodes a cyclase. **Plant Cell,** 7:75-84.

Cui XQ, RP Wise, **PS Schnable** (1996) The *rf2* nuclear restorer gene of male-sterile, T-cytoplasm maize. **Science,** 272:1334-1336.

Liu F, X Cui, HT Horner, H Weiner, **PS Schnable** (2001) Mitochondrial aldehyde dehydrogenase activity is required for male fertility in maize (*Zea mays* L.). **Plant Cell**, 13:1063-1078

Yao H, Q Zhou, J Li, H Smith, M Yandeau, B Nikolau, **PS Schnable** (2002) Meiotic recombination across the 140-kb multigenic maize *a1-sh2* interval. **Proc Natl Acad Sci**, 99:6157-6162.

Nakazono M, F Qiu, L Borsuk, **PS Schnable** (2003) Laser capture microdissection, a tool for the global analysis of gene expression in specific plant cell types: Identification of genes

differentially expressed in epidermal cells or vascular tissues of maize. **Plant Cell**, 15:583-596.
Chou HH, AP Hsia, D Mooney, **PS Schnable** (2004) PICKY: an oligo microarray design tool for large genomes. **Bioinformatics**, 20:2893-2902.
Emrich SJ, S Aluru, Y Fu, TJ Wen, M Narayanan, L Guo, DA Ashlock, **PS Schnable** (2004) A strategy for assembling the maize (*Zea mays* L.) genome. **Bioinformatics**, 20:140-147.
Hochholdinger F, L Guo, **PS Schnable** (2004) Cytoplasmic regulation of the accumulation of nuclear-encoded proteins in the mitochondrial proteome of maize. **Plant Journal**, 37:199-208.
Dietrich CR, MADN Perera, M Yandeau-Nelson, RB Meeley, BJ Nikolau, **PS Schnable** (2005) Characterization of two *gl8* paralogs reveals that the 3-ketoacyl reductase component of fatty acid elongase is essential for maize (*Zea mays* L.) development. **Plant Journal**, 42:844-861.
Fu Y, SJ Emrich, L Guo, TJ Wen, S Aluru, DA Ashlock, **PS Schnable** (2005) Quality assessment of maize assembled genomic islands (MAGIs) and large-scale experimental verification of predicted genes. **Proc Natl Acad Sci**, 102:12282-12287.
Skibbe DS, X Wang, X Zhao, LA Borsuk, D Nettleton, **PS Schnable** (2006) Scanning cDNA microarrays at multiple intensities increases the number of statistically significant differences detected. **Bioinformatics**, 22:1863-1870
Swanson-Wagner R, Y Jia, R DeCook, LA Borsuk, D Nettleton, **PS Schnable** (2006). All possible modes of gene action are observed in a global comparison of gene expression in a maize F_1 hybrid and its inbred parents. **Proc Natl Acad Sci**, 103(18):6805-10.
Emrich SJ, WB Barbazuk, L Li, **PS Schnable** (2006) Gene discovery and annotation using LCM-454 transcriptome sequencing. **Genome Research**, in press.
Fu Y, T-J Wen, YI Ronin, HD Chen, L Guo, DI Mester, Y Yang, M Lee, AB Korol, DA Ashlock, **PS Schnable** (2006) Genetic dissection of intermated recombinant inbred lines using a new genetic map of maize. **Genetics**, in press.

Patents (USA only)
Issued, 6

Key science and technology achievements
Dr. Schnable is a professor in the departments of Agronomy and Genetics, Development & Cell Biology. He also serves as the Associate Director of Iowa State University's Plant Sciences Institute and as the director of ISU's Center for Plant Genomics. Established in 1998, the Center for Plant Genomics provides cutting-edge genomics resources, including laser-capture microdissection, microarray, proteomic, and TGEC- and mass spec-based high-throughput genotyping capabilities to the research community. His own expertise is in the areas of genetics, molecular biology and genomics of maize, but he collaborates with researchers in diverse fields, including biochemistry, plant breeding, plant physiology, bioinformatics, computer science and engineering. His research interests include maize genome structure, heterosis, meiotic recombination, cytoplasmic male sterility, cuticular wax biosynthesis, and the development of new genomic technologies and bioinformatics approaches. He has extensive experience in assembling and managing diverse teams of scientists to conduct large, complex research projects. Schnable serves on variety of scientific advisory boards and is an elected member of the American Association for the Advancement of Science Section Committee of the Agriculture, Food and Renewable Resources Section and the maize genetics executive committee.

Nicholas J. Schork, PhD **Professor of Psychiatry/Biostatistics**

EDUCATION/TRAINING			
University of Michigan, Ann Arbor, MI	DEGREE *(if applicable)*	YEAR(s)	FIELD OF STUDY
University of Michigan, Ann Arbor, MI	BA	1982-1985	Philosophy
University of Michigan, Ann Arbor, MI	MA	1986-1992	Philosophy
University of Michigan, Ann Arbor, MI	MA	1988-1991	Applied Statistics
	PhD	1991-1994	Epidemiology

Positions and Honors.

1984-1994 Computer Analyst, Div. of Hypertension, Dept. of Internal Medicine, University of Michigan
1994-1995 Assistant Professor, Dept. of Genetics, Case Western Reserve University
1994-2001 Associate Research Scientist (adjunct), The Jackson Laboratories
1995-1997 Assistant Professor, Dept. of Epidemiology and Biostatistics, Case Western Reserve University
1995-1997 Assistant Professor (secondary), Dept. of Genetics, Case Western Reserve University
1995-1998 Assistant Professor (adjunct), Dept. of Biostatistics, Harvard University
1995-2001 Staff Scientist (adjunct), Dept. of Biostatistics, The Cleveland Clinic Foundation
1997-2001 Associate Professor, Dept. of Epidemiology and Biostatistics, Case Western Reserve University
1998-2001 Associate Professor (adjunct), Dept. of Biostatistics, Harvard University
1999-2001 Vice-President Statistical Genomics, Genset Corporation (on sponsored leave from CWRU)
2001- Professor, Department of Psychiatry, University of California, San Diego
2004- Professor, Department of Family & Preventive Medicine, University of California, San Diego
2003- Professor (adjunct), Dept. of Molecular and Experimental Medicine, Scripps Research Institute

Selected peer-reviewed publications.

(Recent publications selected from over 183 peer reviewed publications)

Schork NJ, Fallin D, Lanchbury JS. Single nucleotide polymorphisms and the future of genetic epidemiology. Clin Genet 2000 58:250-64

Fallin D, Schork NJ. Accuracy of haplotype frequency estimation for biallelic loci via the expectation-maximization algorithm for unphased diploid genotype data. Am J Hum Genet 2000 67:947-59

Schork NJ, Nath SK, Fallin, D, Chakravarti A: Linkage Disequilibrium Analysis of Bi-allelic DNA Markers, Human Quantitative Trait Loci, and Threshold-Defined Cases and Controls. Am J Hum Genet 2000 67:1208-18

Le Stunff C, Fallin D, Schork NJ, Bougneres P. The insulin gene VNTR is associate with fasting insulin levels and development of juvenile obesity. Nat Genet 2000 26:444-46

Fallin D, Cohen A, Essioux L, Chumakov I, Blumenfeld M, Cohen D, Schork NJ. Genetic analysis of case/control data using estimated haplotype frequencies: application to APOE locus variation and Alzheimer's disease. Genome Res 2001 11:143-51

Schork NJ, Fallin D, Thiel B, Xu X, Broeckel U, Jacob HJ, Cohen D. The future of genetic case-control studies. Adv Genet 2001 42:191-212

Schork NJ. Genome partitioning and whole-genome analysis. Adv Genet 2001 42:299-322

Stoll M, Cowley Jr. AW, Tonellato PJ, Greene AS, Kaldunski ML, Roman RJ, Dumas P, Schork NJ, Wang Z, Jacob HJ. A Genomic-Systems Biology Map for Cardiovascular Function. Science 2001 294:1723-26

Morrison SJ, Qian D, Jerabek L, Thiel BA, Park IK, Ford PS, Kiel MJ, Schork NJ, Weissman IL, Clarke MF: A genetic determinant that specifically regulates the frequency of hematopoeitic stem cells. J Immunol 2002 168: 635-42

Schork NJ. Power Calculations for Genetic Association Studies Using Estimated Probability Distributions. Am J Hum Genet 2002 70:1480-89

Larribe F, Lessard S, Schork NJ. Gene mapping via the ancestral recombination graph. Theor Pop Biol 2002 62:215-29

Schork NJ, Gardner JP, Zhang L, Fallin D, Thiel B, Jakubowski H, Aviv A: Genomic association/linkage of sodium lithium countertransport in CEPH pedigrees. Hypertension 2002 40:619-28

Wen G, Mahata SK, Cadman P, Mahata M, Ghosh S, Mahapatra NR, Rao F, Stridsberg M, Smith DW, Mahboubi P, Schork NJ, O'Connor DT, Hamilton BA: Both rare and common polymorphisms contribute functional variation at CHGA, a regulator of catecholamine physiology. Am J Hum Genet 2004 Feb, 74(2):197-207

Nievergelt CM, Smith DW, Kohlenberg JB, Schork NJ: Large-scale integration of human genetic and physical maps. Genome Res 2004 Jun;14(6):1199-205

Greenwood TA, Rana BK, Schork NJ: Human haplotype block sizes are negatively correlated with recombination rates. Genome Res. 2004 July;14(7):1358-61

Jorgenson E, Tang H, Gadde M, Province M, Leppert M, Kardia S, Schork N, Cooper R, Rao, Boerwinkle E, Risch N (2004). Ethnicity and human genetic linkage maps. American Journal of Human Genetics Dec 30;76(2) [Epub ahead of print]

Reiner AP, Ziv E, Lind DL, Nievergelt CM, Schork NJ, Cummings SR, Phong A, Burchard EG, Harris TB, Psaty BM, Kwok PY (2005): Population structure, admixture, and aging-related phenotypes in African-American adults: The Cardiovascular Health Study. American Journal of Human Genetics. 2005 Mar;76(3):463-77.

Salem R, Wessel J, Schork NJ: A Comprehensive Review of Haplotyping Software and Methods for Use with Unrelated Individuals. Human Genomics 2005;2(1):39-66.

Nievergelt CM, Daniel F. Kripke, Thomas B. Barrett, Elyssa Burg, Ronald A. Remick, A. Dessa Sadovnik, Susan L. McElroy, Paul E. Keck Jr., Nicholas J. Schork, John R. Kelsoe. Suggestive evidence for association of the circadian genes PERIOD3 and ARNTL with bipolar disorder. Molecular Psychiatry 2005 141:234-241.

O'Connor DT. Pleiotropic efects of novel trans-acting loci influencing human sympathochromaffin secretion. Physiol Genomics. 2006 25(3):470-9.

Niculescu AB, Lulow L, Ogden C, Salomon DR, Schork NJ, Caligiuri M, and Lohr JB: PhenoChipping of Psychotic disorders: a novel approach for deconstructing and quantitating psychiatric phenotypes. Molecular Psychiatry (in press).

Biography

Nicholas Schork is currently a Professor of Psychiatry and a Professor of Biostatistics at the University of California at San Diego. He is also Director of Bioinformatics at the UCSD Moores Cancer Center, Co-Director of the UCSD Center for Human Genetics and Genomics, and Associate Director of Research at the UCSD Stein Institute for Research on Aging. Prior to his appointment at UCSD, Dr. Schork was an Associate Professor of Epidemiology and Biostatistics at Case Western Reserve University in Cleveland, Ohio and an Associate Professor of Biostatistics at Harvard University. He was also formerly the Associate Director of the Program for Population Genetics at the Harvard School of Public Health, as well as an Adjunct Associate Staff Scientist at the Jackson Laboratory in Bar Harbor, Maine. Between 1999 and 2000 Dr. Schork took a leave of absence to conduct research as the Vice President of Statistical Genomics at the French Biotechnology company, Genset, where he helped guide efforts to construct the first high-density map of the human genome. Dr. Schork research interests concern theoretical and applied aspects of the genetic basis of multifactorial traits and conditions, and has been selected as a member of a number of scientific journal editorial boards, is a frequent participant in U.S. National Institutes of Health-related steering committees and review boards, and has also been on the advisory board of five different companies. Dr. Schork has published over 200 scientific articles and book chapters on the analysis of complex, multifactorial traits and diseases. Dr. Schork earned a B.A. in Philosophy, an M.A. in Philosophy, an M.A. in Statistics, and a Ph.D. in Epidemiology all from the University of Michigan in Ann Arbor, Michigan.

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Education

Iowa State University	BS	1983	Chemical Engineering
California Inst. of Tech.	Ph.D.	1989	Chemical Engineering

Positions and Employment

2005-present	Professor, Department of Chemical and Biological Engineering, Iowa State University
1999-present	Adjunct Professor, Department of Bioengineering, Rice University
1999-2005	Professor, Department of Chemical Engineering, Iowa State University
1999	Professor, Bioengineering, Rice University
1999	Professor, Chemical Engineering, Rice University
1997-1999	Associate Professor, Bioengineering, Rice University
1993-1999	Associate Professor, Chemical Engineering, Rice University
1988-1993	Assistant Professor, Chemical Engineering, Rice University

Honors

1992	NSF Young Investigator Award
1994	Professional Progress in Engineering Award, Iowa State University
2000	American Institute of Medical and Biological Engineering, Fellow
2004	Van Lanen Award, Div. of Biochemical Technology, American Chemical Society
2005	ISU Foundation Award for Outstanding Achievement in Research

Selected Publications (from >60)

Sriram, G., González-Rivera, O. and Shanks, J. V. 2006. Determination of Biomass Composition of *Catharanthus roseus* Hairy Roots for Metabolic Flux Analysis, *Biotech.. Progress, online.*

Sriram, G., D. B. Fulton, and Shanks, J. V. Metabolic flux analysis of *Catharanthus roseus* hairy roots by using biosynthetically directed fractional ^{13}C labeling and bondomer balancing, invited manuscript for submission to *Phytochemistry*.

Hong, S.-B., Peebles, C., Shanks, J. V., San K.-Y., and Gibson, S. I. 2006. Expression of the *Arabidopsis* feedback-insensitive anthranilate synthase holoenzyme and tryptophan decarboxylase genes in *Catharanthus roseus* hairy roots. *J. Biotechnol*., **122**, 28-38.

Shanks, J. V. 2005. Phytochemical engineering: Combining Chemical Reaction Engineering with Plant Science, *AIChE Journal* **51**, 2-7.

Sriram, G., Fulton, D. B., Iyer V., Peterson, J. M., Zhou, R., Westgate, M. E., Spalding, M. H. and Shanks, J. V. 2004. Quantification of Compartmented Metabolic Fluxes in Developing

Soybean (*Glycine max*) Embryos by Employing Biosynthetically Directed Fractional ^{13}C Labeling, 2-D [^{13}C, ^{1}H] NMR and Comprehensive Isotopomer Balancing. *Plant Physiol.* **136**: 3043-3057.

Sriram, G. and Shanks, J. V. 2004. Improvements in Metabolic Flux Analysis using Carbon Bond Labeling Experiments: Bondomer Balancing and Boolean Function Mapping. *Metabol. Eng,* **6***,* 116-132.

Peebles, C., Hong, S.-B., Gibson, S. I., Shanks, J. V., and San, K.-Y. 2005. "The Transient Effects of Over-expressing Anthranilate Synthase α and β subunits in *Catharanthus roseus* Hairy Roots," *Biotech. Progress*, **21**(5): 1572-1576.

Hughes, E. , Hong , S.-B., Shanks, J. V., San K.-Y., Gibson, S. I., 2004. Expression of a Feedback-Resistant Anthranilate Synthase in *Catharanthus roseus* Hairy Roots Provides Evidence for Tight Regulation of Terpenoid Indole Alkaloid Levels. *Biotechnol. Bioeng.,* **86**, 718-727.

Hughes, E., Hong, S.-B., Gibson, S. I., Shanks, J. V. , San K.-Y., 2004. Metabolic Engineering of the Indole Pathway in *Catharanthus roseus* Hairy Roots and Increased Accumulation of Tryptamine and Serpentine, *Metabolic Engineering*, **6**, 268-276.

Morgan, J. and Shanks, J. V. 2002. Metabolic flux analysis of plant secondary metabolism using a biogenetic organizational approach. *Metabolic Engr.* **4***,* 257-262.

Hansen, A. and Shanks, J. V., 2002. Plant Metabolic Engineering-Entering the S Curve," *Metabolic Engineering*, **4**, 1-2.

Hughes, E. and Shanks, J. V., 2002. Metabolic Engineering of Plants for Alkaloid Production," *Metabolic Engineering*, **4**, 41-48.

Rijhwani, S. K., Ho, C.-H. and Shanks, J. V., 1999. *In vivo* ^{31}P and Multilabel ^{13}C NMR Measurements for Evaluation of Plant Metabolic Pathways" *Metabolic Engineering,* **1**, 12-25.

Hughes, J. B., Shanks, J., Vanderford, M., Lauritzen, J. and Bhadra, R., 1997. Transformation of TNT by Aquatic Plants and Plant Tissue Cultures," *Environmental Sci. and Tech.,* **31**, 266-271.

Shanks, J. V. and Bailey, J. E., 1988. Estimation of Intracellular Sugar Phosphate Concentrations in *Saccharomyces cerevisiae* Using ^{31}P Nuclear Magnetic Resonance Spectroscopy, *Biotechnol. Bioeng*., **32**, 1138-1152.

Key science and technology achievements

Dr. Shanks is an expert in biochemical engineering and metabolic engineering, with particular emphasis on the quantification of metabolic reaction pathways in plants and microbes for the production of renewable chemicals and fuels. Her research in quantifying carbon flux includes using in situ ^{13}C NMR techniques with mathematical analysis to monitor fluxes in primary carbon metabolism; HPLC and LC/MS^n to measure secondary metabolites; and ^{14}C to track the fate of very low levels of metabolites. Her research using comprehensive flux maps of central carbon metabolism includes studies of the partitioning of carbon into protein and oil in different genotypes of developing soybean embryos and studies of the fermentation of five and six carbon sugars simultaneously by *E. coli* for the synthesis of chemicals and fuels. Dr. Shanks was a member of the National Research Council Committee that produced the report Biobased Industrial Products: Priorities for Research and Commercialization. She served as Chair-Elect, Past-Chair, and Chair of the BIOT Division for the American Chemical Society from 2000-2002.

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Education

University of Missouri	BS	1966	Physics
University of Missouri	MS	1966	Physics
Stanford University	MS	1972	Physics
University of Texas/Austin	PhD	1975	Physics

Positions and Employment

1974-1976	Research Associate and Lecturer, Princeton University Observatory
1976-1979	Junior Fellow, Harvard Society of Fellows; Depts. Physics/Astronomy
1978-1979	Research Affiliate, Department of Physics, Yale University
1979-1980	Assistant Professor, Astronomy and Physics Departments, University of Illinois at Urbana-Champaign
1981-1985	Associate Professor, Astronomy and Physics Departments, UIUC
1985-2000	Professor, Astronomy and Physics Departments, UIUC
1985-2000	Director, National Center for Supercomputing Applications, UIUC
1997-2000	Director, National Computational Science Alliance, UIUC
2000-present	Professor, Computer Science and Engineering, University of California at San Diego
2000-present	Director, California Institute for Telecommunications and Information Technology, UCSD

Honors

2006	IEEE Computer Society Tsutomu Kanai Award for distributed computing systems achievements
2006	ESRI Lifetime Achievement Award
2005-Present	Harry E. Gruber Chair, UCSD
2005-Present	Crick-Jacobs Fellow, Salk Institute
1995	Member, National Academy of Engineering, Section 5
1994	Fellow, American Academy of Arts and Sciences
1991	Fellow, American Physical Society
1990	Franklin Institute's Delmer S. Fahrney Gold Medal for Leadership in Science or Technology

Selected Publications (selected from last three years out of ~ 120 lifetime publications).

Smarr, L. The Ocean of Life: Creating a Community Cyberinfrastructure for Advanced Marine Microbial Ecology Research and Analysis (a.k.a. CAMERA). Strategic News Service® Invited Special Letter, March 21 (2006)

Taesombut, N, F. Uyeda, A.A. Chien, L. Smarr, T.A. DeFanti, P. Papadopoulos, J. Leigh, M. Ellisman, J. Orcutt. The OptIPuter: High-Performance, QoS-Guaranteed Network Service for Emerging e-Science Applications. IEEE Communications, 4, 38- 45 (2006)

Smarr, L. and P. Papadopoulos, Guest Editors. Introduction--The Cyberinfrastructure Backplane: The Jump to Light Speed. Cyberinfrastructure Technology Watch Quart., 1, 2-4 (2005).

Smarr, L., J. Ford, P. Papadopoulos, S. Fainman, T. DeFanti, M. Brown, J. Leigh. The OptIPuter, Quartzite, and Starlight Projects: A Campus to Global-Scale Testbed for Optical Technologies Enabling LambdaGrid Computing (invited paper). Optical Fiber Communication Conference & Exposition and the National Fiber Optic Engineers (2005)

Kim, K., S. Jenks, L. Smarr, A. Chien, and L-Chen. Zheng. A Framework for Middleware Supporting Real-Time Wide-Area Distributed Computing. Proceedings of 10th IEEE International Workshop on Object-Oriented Real-Time Dependable Systems (WORDS 2005), Sedona, AZ, February 2-4, 2005, pp. 231-240.

Ellisman, M. M., Brady, D. Hart, F-P. Lin, M. Müller, L. Smarr. The Emerging Role of Biogrids. Comm. of the ACM, 47, 52-57 (2004).

Smarr, L., A.A. Chien, T. DeFanti, J. Leigh, P.M. Papadopoulos. The OptIPuter. Comm. of the ACM, 46, 58-67 (2003)

DeFanti, T.A., J. Leigh, M.D. Brown, D.J. Sandin, O. Yu, C. Zhang, R. Singh, E. He, J. Alimohideen, N.K. Krishnaprasad, R. Grossman, M. Mazzucco, L. Smarr, M. Ellisman, P. Papadopoulos, A. Chien, J. Orcutt. Teleimmersion and Visualization with the OptIPuter. in Telecommunication, Teleimmersion and Telexistence: Susumu Tachi, editor, Ohmsha/IOS Press, 25-71 (2003).

Patents (USA only) **None**

Key science and technology achievements

Smarr has worked for thirty years among the university, government, and private sectors to create a national-scale information infrastructure that enables new forms of collaborative digital science. As founding director of the National Center for Supercomputing Applications and the National Computational Science Alliance, Smarr has driven major contributions to the development of the national information infrastructure: the Internet, the Web, the emerging Grid, collaboratories, and scientific visualization. During this time, he has pursued basic research in a wide variety of fields, first in general relativity, then computational and observational astronomy, now in the computer science of large-scale optical network middleware. Smarr is the founding director of the California Institute for Telecommunications and Information Technology, a UCSD/UCI partnership focused on inventing the collaborative research environment for the digital future. Smarr is currently Principal Investigator on the NSF OptIPuter LambdaGrid project, the Moore Foundation's CAMERA marine microbial metagenomics project, and is Co-PI on the NSF LOOKING ocean observatory prototype.

Hamilton O. Smith
Scientific Director, Synthetic Biology and Bioenergy Groups, J.Craig Venter Institute
Executive Vice President, Co-chief Scientific Officer, Synthetic Genomics Inc.
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TEL: 240-268-2637; hsmith@venterinstitute.org

Education

University of Illinois, Urbana, Illinois	1948-50		
University of California, Berkeley	1950-52	A.B.	Mathematics
Johns Hopkins University School of Medicine	1952-56	M.D.	

Positions and Employment

1964-1967	Research Associate, Department of Human Genetics, University of Michigan
1967-1969	Assistant Prof. of Microbiology, Johns Hopkins University School of Medicine
1969-1973	Associate Prof. of Microbiology, Johns Hopkins University School of Medicine
1973-1981	Professor of Microbiology, Johns Hopkins University School of Medicine
1975-1976	Sabbatical leave in Zurich: Institute für Molekularbiologie II der Universität Zurich
1981-1998	Professor of Molecular Biology and Genetics, JHU School of Medicine
1990-1991	Sabbatical leave in Vienna, Austria at the Institute of Molecular Pathology
1997-1998	Investigator, The Institute for Genomic Research, Rockville, Maryland
1998-2002	Director, DNA Resources, Celera Genomics Corp, Rockville, Maryland
2002-2004	Scientific Director, Institute for Biological Energy Alternatives (IBEA)
2004-	Scientific Director, Synthetic Biol. and Bioenergy Grps, J.Craig Venter Institute
2005-	Executive Vice President, Co-chief Scientific Officer, Synthetic Genomics Inc.

Honors

	Phi Beta Kappa
1975-76	Guggenheim Fellow
1978	Nobel Prize in Medicine and/or Physiology
1979	Doctor of Science, University of Illinois
1980	Elected to the National Academy of Sciences
1980	American Cancer Society Distinguished Research Professor
2004	Doctor of Humane Letters, honoris causa, Johns Hopkins University

Selected Publications

Levine, M & Smith, H.O. 1964. Sequential gene action in the establishment of lysogeny. Science 148,1581.

Smith, H.O. and Wilcox, K.W. 1970. A restriction enzyme for Hemophilus influenzae. I. Purification and general properties. J. Mol. Biol. 51, 379-391.

Kelly, T.J., Jr. and Smith, H.O. 1970. A restriction enzyme for Hemophilus influenzae. II. Base sequence of the recognition site. J. Mol. Biol. 51, 393-409.

Friedman, E. A. and Smith, H.O. 1972. An adenosine triphosphate-dependent deoxyribonuclease from H.influenzae Rd. II. Purification and general properties of the enzyme. J. Biol. Chem. 247, 2846-2853.

Smith, H.O. and Friedman, E.A. 1972. An adenosine triphosphate-dependent deoxyribonuclease from Hemophilus influenzae Rd. II. Adenosine triphosphatase properties. J. Biol. Chem. 247, 2854-2858.

Friedman, E.A. and Smith, H.O. 1972. An adenosine triphosphate-dependent deoxyribonuclease from Hemophilus influenzae Rd. III. Substrate specificity. J. Biol. Chem. 247, 2859-2865.

Roy, P.H. and Smith, H.O. 1973. The DNA methylases of Hemophilus influenzae Rd. I. Purification and properties. J. Mol. Biol. 81, 427-444.

Roy, P.H. and Smith, H.O. 1973. The DNA methylases of Hemophilus influenzae Rd. II. Partial recognition site base sequences. J. Mol. Biol. 81, 445-459.

Smith, H.O. and Nathans, D. 1973. A suggested nomenclature for bacterial modification and restriction systems and their enzymes. J. Mol. Biol. 81, 419-423.
Smith, H.O., Kelly, T.J., Jr. and Roy, P.H. 1974. Enzymatic methods for sequence analysis applied to DNA restriction and methylation sites. Methods in Enzymology 29, 282-294.
Wilcox, K.W. and Smith, H.O. 1975. Isolation and characterization of mutants of H. influenzae deficient in an adenosine 5'-triphosphate-dependent deoxyribonuclease activity. J. Bacteriol. 122, 443-453.
Nathans, D. and Smith, H.O. 1975. Restriction endonucleases in the analysis and restructuring of DNA molecules. Ann. Rev. Biochem. 44, 273-293.
Orlosky, M. and Smith, H.O. 1976. Action of ATP-dependent DNase for Hemophilus influenzae on crosslinked DNA molecules. J. Biol. Chem. 251, 6117-6121.
Smith, H.O. and M.L. Birnstiel. 1976. A simple method for DNA restriction site mapping. Nucleic Acids Research. 3, 2387-2398.
Birnstiel, M.L., Schaffner, W., and Smith, H.O. 1977. DNA sequences coding for the H2B histone of Psammechinus miliaris. Nature 266, 603-607.
Clarkson, S.G., Kurer, V., and Smith, H.O. 1978. Sequence organization of a cloned tDNAmet fragment from Xenopus laevis. Cell 14, 713-724.
Sisco, K.L. and Smith, H.O. 1979. Sequence specific DNA uptake in Haemophilus transformation. Proc. Natl. Acad. Sci. USA 76, 972-976.
Smith, H.O. 1979. Nucleotide sequence specificity of restriction endonucleases. Science 205, 455-462.
Smith, H.O. and Marley, G. 1980. Purification and properties of HindII and HindIII endonucleases from Haemophilus influenzae Rd. Methods in Enzymology. 65, 104-108..
Lee, J.J., Smith, H.O., and Redfield, R.J. 1989. The organization of the Haemophilus influenzae Rd genome. J. Bacteriol. 171, 3016-3024.
R. D. Fleischmann et. Al. 1995. Whole-Genome Random Sequencing and Assembly of *Haemophilus influenzae* Rd. *Science* 269, 496-512.
Fraser, C.M. et.al. The Minimal Gene Complement of M. genitalium. Science 270, 397-403, 1995.
Venter, J.C., Smith, H.O., Hood, L. A New Strategy for Genome Sequencing. Nature 381, 364-366, 1996.
Venter, J.C., et.al. Shotgun Sequencing of the Human Genome, Science 280, 1540-1542, 1998.
Fraser, C.M. et.al. Science 281, 375-388, 1998. Chromosome 2 sequence of the human malaria parasite
Plasmodium falciparum: Plasticity of a eukaryotic chromosome, Science 282, 1126-1132, 1998.
Adams, M.D. et,al. The Genome Sequence of Drosophila melanogaster. Science, **287**, 2185-2195 (2000).
Venter JC. et.al. The sequence of the human genome. Science. 2001 Feb 16;291(5507):1304-51.
Smith, H.O. et.al. (2003). Generating a synthetic genome by whole genome assembly: phiX174 bacteriophage from synthetic oligonucleotides. Proc. Natl. Acad. Sci. USA. 100: 15440-5.
Glass JI, et.al. Essential genes of a minimal bacterium. Proc Natl Acad Sci U S A. **103**:425-30, 2006.
Hutchison, C.A. III, Smith, H.O., Pfannkoch, C., Venter, J.C. (2005). Cell-free cloning using phi29 DNA polymerase. Proc. Natl. Acad. Sci. USA**102**, 17332-17336.

Key science and technology achievements

Hamilton O. Smith discovered the first TypeII restriction enzyme and determined the sequence of its cleavage site in 1968. In 1978, he was a co-recipient (with D. Nathans and W. Arber) of the Nobel in Medicine for this discovery. Subsequently, he studied DNA methylases and nucleases in Haemophilus influenzae Rd and discovered this organism's sequence-specific DNA uptake during genetic transformation. In 1994-5 he collaborated with J.C. Venter at The Institute for Genomic Research to sequence H. influenzae by whole genome shotgun sequencing and assembly. In 1998, he joined Celera Genomics Corporation where he participated in the sequencing of the Drosophila and human genomes. In 2002, he left Celera to join the Institute for Biological Energy Alternatives. In 2004, this was merged into the newly formed J. Craig Venter Institute where he is currently leading the synthetic biology and biological energy groups. In late 2005, he became one of the founders of a new company, Synthetic Genomics, Inc.

Richard D. Smith
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Education

Lowell Technologies Institute, U.Mass, Lowell, MA	B.S.	1971	Chemistry
University of Utah, Salt Lake City, UT	Ph.D.	1975	Physical Chemistry

Positions and Employment

1976 – 1978	Research Scientist, Battelle Memorial Institute, Pacific Northwest Division, Richland, WA
1978 – 1984	Senior Research Scientist
1984 – 1988	Staff Scientist
1988 – 2001	Sr. Staff Scientist and Group Leader
1997 – present	Chief Scientist, Environmental Molecular Sciences Laboratory
2001 – present	Battelle Fellow
2003 – present	Director, NCRR Proteomics Research Resource for Integrative Biology

Honors

1983	R&D 100 Award for development of Supercritical Fluid Chromatography-MS
1988	R&D 100 Award: Rapid Expansion of Supercritical Fluid Solutions Process
1988	R&D 100 Award: Capillary Electrophoresis-Electrospray Ionization-MS
1989	Battelle-Northwest Director's Award for Excellence
1990/91	AWU-DOE Distinguished Lecturer
1998	R&D 100 Award: Rapid Microdialyzer
1998	R&D 100 Award: MICLEAN/MICARE Process
1999	R&D 100 Award: Electrodynamic Ion Funnel
2000	Battelle Inventor of the Year
2000	Pacific Northwest National Laboratory Mentor of the Year
2003	ACS Award for Analytical Chemistry
2003	R&D 100 Award for development of FT-MS for High Throughput Proteomics
2004	Federal Laboratory Consortium Award for the Electrodynamic Ion Funnel

Selected Publications (from a total of more than 600)

"Ultrasensitive Proteomics using High-Efficiency On-Line Micro-SPE-NanoLC-NanoESI MS and MS/MS", Y. Shen, N. Tolic, C. Masselon, L. Pasa-Tolic, D. G. Camp II, K. K. Hixson, R. Zhao, G. A. Anderson and R. D. Smith, **Anal. Chem**., 76, 144-154 (2004).
"Improved detection of multi-phosphorylated peptides in the presence of phosphoric acid in liquid chromatography/mass spectrometry", J.-K. Kim, D. G. Camp II and R. D. Smith, **J. Mass Spectrom.**, 39, 206-215 (2004).
"Nanoscale Proteomics", Y. Shen et al., **Anal. Bioanal. Chem.**, 378, 1037-1045 (2004).
"FTICR Mass Spectrometry for Qualitative and Quantitative Bioanalyses", J. S. Page, C. D. Masselon, and R. D. Smith, **Current Opin. Biotech.**, 15, 3-11 (2004).
"Integrative Analysis of the Mitochondrial Proteome in Yeast", H. Prokisch et al., **PLoS Biology**, 2, 795-804 (2004).
"Proteomic analyses using an accurate mass and time tag strategy", L. Pasa-Tolic, C. Masselon, R. C. Barry, Y. Shen and R. D. Smith, **BioTechniques**, 37, 621-639 (2004).
"Global profiling of *Shewanella oneidensis* MR-1", E. Kolker et al., **Proc. Nat. Acad. Sci.**, 102, 2099-2104 (2005).
"Global Whole-Cell FTICR Mass Spectrometric Proteomics Analysis of the Heat Shock Response in the Radioresistant Bacterium *Deinococcus radiodurans*", A. K. Schmid, M. S. Lipton, H. Mottaz, M. E. Monroe, R. D. Smith, and M. E. Lidstrom, **J. Proteome Res.**, 4, 709-718 (2005).
"Advanced nanoscale separations and mass spectrometry for sensitive high-throughput proteomics", Y. Shen and R. D. Smith, **Expert Rev. Proteomics**, 3, 431-447 (2005).
"Ultra-sensitive and Quantitative Characterization of Proteomes", R. D. Smith, K. Tang and Y. Shen, **Molecular BioSystems**, 2, 221-230 (2006).
"Application of the Accurate Mass and Time Tag Approach to the Proteome Analysis of Sub-cellular Fractions Obtained from Rhodobactersphaeroides 2.4.1. Aerobic and Photosynthetic Cell Cultures", S. J. Callister et al., **J. Proteome Res.**, 5, 1940-1947 (2006).

Patents (USA only)

Dr. Smith has been awarded 27 patents related to advanced technologies and approaches for the characterization of biological systems.

Key science and technology achievements

Richard D. Smith, Ph.D., is a Battelle Fellow and Chief Scientist in the Biological Sciences Division at Pacific Northwest National Laboratory (PNNL) in Richland, WA. Dr. Smith is also Director of the NIH NCRR Biomedical Technology Resource Center for Integrative Biology, the NIAID Biodefense Proteomics Research Center for Identifying Targets for Therapeutic Interventions using Proteomics, and a U.S. Department of Energy supported High Throughput Proteomics Laboratory. His research has involved the development and application of advanced analytical methods and instrumentation, with particular emphasis on high resolution separations and mass spectrometry, and their applications for the characterization and study of complex biological systems (particularly proteomics and metabolomics). He has lead the development of extensive high throughput measurement capabilities based upon cutting-edge technologies developed at PNNL and elsewhere. His research contributions have included the advancement of methods for the ultra-sensitive characterization of proteomes. His more recent responsibilities have included the development of advanced informatics tools for proteomics research and the development of advanced capabilities for the study of microbial communities.

RICHARD C. J. SOMERVILLE
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Professional Preparation

Pennsylvania State University (1958-1961), Meteorology, B. S., 1961
New York University (1961-1966), Meteorology, Ph. D., 1966

Appointments

1979-present: Professor of Meteorology, Scripps Institution of Oceanography, UCSD
1974-1979: Scientist & Section Head, National Center for Atmospheric Research
1971-1974: Meteorologist, NASA Goddard Institute for Space Studies
1971-1974: Adjunct Professor, Columbia University and New York University
1969-1971: Research Scientist, Courant Institute of Mathematical Sciences, NYU
1967-1969: Research Associate, NOAA Geophysical Fluid Dynamics Laboratory
1966-1967: Postdoctoral Fellow, National Center for Atmospheric Research

Selected Publications

Somerville, R. C. J., and S. F. Iacobellis, 1999: Single-column models, ARM observations, and GCM cloud-radiation schemes. *Phys. Chem. Earth* (B), **24**, 733-740.

Lane, D. E., R. C. J. Somerville, and S. F. Iacobellis, 2000: Sensitivity of cloud and radiation parameterizations to changes in vertical resolution. *J. Climate*, **13**, 915-922.

Iacobellis, S. F., and R. C. J. Somerville, 2000: Implications of microphysics for cloud-radiation parameterizations: Lessons from TOGA-COARE. *J. Atmos. Sci.*, **57**, 161-183.

Somerville, R. C. J., 2000: Using single-column models to improve cloud-radiation parameterizations. *General Circulation Model Development: Past, Present and Futur*e, Academic Press, D. Randall (ed.), 641-657.

Lane, D. E., K. Goris, and R. C. J. Somerville, 2002: Radiative transfer through broken clouds: Observations and model validation. *J. Climate*, **15**, 2921-2933.

McFarquhar, G. M., S. Iacobellis, and R. C. J. Somerville, 2003: SCM simulations of tropical ice clouds using observationally based parameterizations of microphysics. *Journal of Climate*, **16**, pp. 1643-1664.

Iacobellis, S. F., G. M. McFarquhar, D. L. Mitchell, and R. C. J. Somerville, 2003: The sensitivity of radiative fluxes to parameterized cloud microphysics. *Journal of Climate*, **16**, pp. 2979-2996.

Shell, K., R. Frouin, S. Nakamoto, and R. Somerville, 2003: Atmospheric response to solar radiation absorbed by phytoplankton. *Journal of Geophysical Research*, **108**, (D15), 4445, doi:10.1029/2003JD003440, 2003.

Berque, J., D. Lubin, and R. C. J. Somerville, 2004: Infrared radiative properties of the Antarctic Plateau from AVHRR Data. Part I: Effect of the snow surface. *Journal of Applied Meteorology*, **43**, pp. 350-362.

Lane-Veron, D. E., and R. C. J. Somerville, 2004: Stochastic theory of radiative transfer through generalized cloud fields,. *Journal of Geophysical Research*, 109, D18113, doi:10.1029/2004JD004524.

Biography

Richard C. J. Somerville is Distinguished Professor at Scripps Institution of Oceanography, University of California, San Diego. He received the Ph. D. degree in meteorology from New York University in 1966 and has been a professor at Scripps since 1979.

Somerville is a theoretical meteorologist. His research is focused on critical physical processes in the climate system, especially the role of clouds and the important feedbacks that can occur as clouds change with a changing climate. Using a broad spectrum of observations, ranging from satellite images of storm systems to detailed measurements of microscopic cloud particles, Somerville compares computer simulations with reality. His work has led to many innovations and important improvements in climate models. He is an authority on the prospects for climate change in coming decades.

Somerville comments frequently on climate and environmental issues for the media and has also trained schoolteachers, testified before the United States Congress, briefed United Nations climate change negotiators, and advised government agencies on research, education and outreach. Among many honors, Somerville is a Fellow of both the American Association for the Advancement of Science and the American Meteorological Society. He has received awards from the American Meteorological Society for both his research and his popular book, *The Forgiving Air: Understanding Environmental Change*. He is a Coordinating Lead Author for the most recent major climate science assessment report of the Intergovernmental Panel on Climate Change, to appear in 2007.

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Education

Fudan University, Shanghai, China	BS	1982	Biochemistry
University of Ghent, Ghent, Belgium	Ph.D.	1987	Plant Molecular Biology

Positions and Employment

1989 – 1995	Project Leader, ICI/ZENECA Seeds, Slater, Iowa
1996 –	Director, Plant Transformation Facility, Iowa State University, Ames, Iowa
1998 – 2002	Associate Professor (adjunct), Department of Agronomy, Iowa State University, Ames, Iowa
2002 – 2006	Associate Professor, Department of Agronomy, Iowa State University, Ames, Iowa
2003 –	Director, Center for Plant Transformation, Plant Science Institute, Iowa State University, Ames, Iowa
2005 –	Leader, BioPharmaceutical Initiative, Plant Science Institute, Iowa State University, Ames, Iowa
2006 –	Professor, Department of Agronomy, Iowa State University, Ames, Iowa
2006 –	Director of Graduate Education, Interdepartmental Plant Physiology Major, Iowa State University, Ames, Iowa

Honors

1984 – 1987	The Rockefeller Foundation Fellowship
1987 – 1989	The European Economic Community (EEC) fellowship

Selected Publications

Torney, F, Frame, B, **Wang, K**. Maize. *In*: Tropical Crop Biotechnology. E.C. Pua and M. Davey (eds.), Springer-Verlag, Berlin Heidelberg, Germany, pp 73-105 (2007).

Frame, B. R., McMurray, J. M., Fonger, T. M., Main, M. L., Taylor, K., W., Torney, F. J., Paz, M., M., **Wang, K**. Improved *Agrobacterium*-mediated transformation of three maize inbred lines using MS salts. Plant Cell Reports, 25: 1024-1034 (2006).

Frame, B., **Wang, K.** Maize (*Zea mays*). In: *Agrobacterium* Protocols (2nd edition), K. Wang (ed.). Humana Press. Totowa, New Jersey, USA, pp. 185-200 (2006).

Wang, K. (editor) *Agrobacterium* Protocols (2nd edition). Humana Press. Totowa, New Jersey, USA, (2006).

Paz, M., Martinez, J. C., Kalvig, A., Fonger, T., **Wang, K.** Improved cotyledonary node method using an alternative explant derived from mature seed for efficient *Agrobacterium*-mediated soybean transformation. ***Plant Cell Reports,*** 25: 206-213 (2006).

Wang K, Frame B. Maize Transformation. *In*: Transgenic Crops of the World: Essential Protocols. I. Cutis (ed). Kluwer Academic Publisher, the Netherlands, p 45-62 (2004).

Shou, H., Bordallo, P., **Wang, K.** Expression of the Nicotiana protein kinase (NPK1) enhanced drought tolerance in transgenic maize. ***Journal of Experimental Botany,*** 55: 1013-1019 (2004).

Shou, H., Frame, B., Whitham, S., **Wang, K.** Assessment of transgenic maize events produced by particle bombardment or *Agrobacterium*-mediated transformation. ***Molecular Breeding,*** 13:201-208 (2004).

Shou, H., Bordallo, Fan, J., Yeakley, J. M., Bibikova, M., Sheen, J., **Wang, K**. Expression of an active tobacco MAP kinase kinase kinase enhances freezing tolerance in transgenic maize. ***Proc. Natl. Acad. Sci. (USA),*** 101: 3298-3303 (2004).

Chikwamba, R.K., Scott, M.P., Mejia, L.B., Mason, H.S., **Wang, K**. Localization of a bacterial protein in starch granules of transgenic maize kernels. ***Proc. Natl. Acad. Sci. (USA)*** 100: 11127-11132 (2003).

Chikwamba, R., McMurray, J., Frame, B., Scott, P., Mason, H., **Wang, K**. Expression of a synthetic *E. coli* heat labile enterotoxin B sub-unit (LT-B) in maize. ***Molecular Breeding*** 10: 253-265 (2002).

Frame, B.R., Shou, H., Chikwamba, R., Zhang, Z., Xiang, C, Fonger, T., Pegg, S-E., Li, B., Nettleton, D., Pei, P., **Wang, K..** *Agrobacterium*-mediated transformation of maize embryos using a simple binary vector system. ***Plant Physiology***, 129:13-22 (2002).

Key science and technology achievements

The research program of Dr. Wang's graduate study and postdoctoral research period was to understand the T-DNA (transfer DNA) transfer mechanisms of the Ti (tumor inducing) plasmid from *Agrobacterium tumefaciens* (a soil bacterium that has natural ability to deliver DNA to plants) to the plant genome. Dr. Wang was the senior author for two papers published in Cell and Science describing the critical DNA sequences and factors that were essential for this DNA transfer process. This knowledge was one of the major contributions to the design of vector systems for plant transformation. During 6.5 years of industry research period, I led a team of researchers and developed a proprietary transformation technology – whisker-mediated transformation – for maize. Currently, Dr. Wang is a Professor of Plant Molecular Biology at the Department of Agronomy at Iowa State University (ISU). She is the Director of Graduate Education of Interdepartmental Plant Physiology Major, the Director of Center for Plant Transformation and the Leader for BioPharmaceuticals of Plant Science Institute. Dr. Wang is an expert in plant genetic transformation and gene expression. Her research focuses on the development of advanced technology for crop genetic transformation. The Plant Transformation Facility directed by Dr. Wang provides services and expertise in genetic transformation of corn, soybean and rice for academic researchers. In addition, her research programs also include development of corn-based edible vaccines for livestock, elucidation of the molecular mechanisms by which plants respond to environmental stress and hormonal signals, development of stress-tolerant crops, and development of cellulase producing corn for biorenewable material. Recently, Dr. Wang is invited to contribute a review article entitled "Developing genetic transformation of corn to improve bioenergy yields" to Current Opinion in Biotechnology.

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Education

Southwest State University	B.S.	1984	Chemistry, Minor Mathematics
Michigan State University	M.S.	1986	Inorganic Chemistry
Michigan State University	Ph.D.	1989	Inorganic Chemistry

Positions and Employment

July 1998-Present	Pacific Northwest National Laboratory, Program Manager, Commercialization Manager and Product Offering Manager
Dec 1995-July 1998	National Corn Growers Association, Director-Research & Business Development
Jan 1993-Dec 1995	Pacific Northwest National Laboratory, Senior Research Scientist
Oct 1991- Jan 1993	Michigan Biotechnology Institute, Research Scientist II
Sept 1989-Sept 1991	Michigan Biotechnology Institute, Research Scientist I
Sept1984-Aug 1989	Michigan State University, Research and Teaching Assistant

Honors

2004	Key Contributor Award – Battelle
2001	Key Contributor Award - Battelle
1997	R&D 100 Award

Selected Publications

Werpy, T.A., Ph.D. Thesis: "Synthesis, Characterization, and Catalytic Properties of a New Family of Tubular Silicate-Layered Silicate Intercalation Complexes."**,** Department of Chemistry, Michigan State University, East Lansing, Michigan, 1991.

Werpy, T.A., Michot, L.J., Pinnavaia, T.J. "New Tubular Silicate-Layered Silicate Nanocomposite Catalyst. Microporosity and Acidity." ACS Symposium Series, 437 (Novel Materials and Heterogeneous Catalysis), 119-128, 1990.

Werpy, T.A., Michot, L.J., Pinnavaia, T.J. "Adsorption Properties of a Tubular Silicate-Layered Silicate Intercalation Complex Formed From Imogolite and Montmorillonite." Clay Res., 8(1-2), 47-52, 1989.

Werpy, T.A., Johnson, I.J., Pinnavaia, T.J. "Tubular Silicate-Layered Silicate Intercalation Compounds: A New Family of Pillared Clays." J. Am. Chem. Soc., 110, 25, 1988.

Patents (USA only)
17 Patents

Key science and technology achievements
At Pacific Northwest National Laboratory, Dr. Werpy has developed and managed several projects supported by the DOE for developing renewable technologies. These projects have included catalytic conversion of succinic acid derived from fermentation to produce 1,4-butanediol, gama-butyrolactone and tetrahydrofuran; catalytic conversion of succinic acid to maleic anhydride; conversion of lactic acid to acrylic acid using novel reaction schemes; and conversion of sorbitol and other sugars to form propylene glycol, ethylene glycol, and other polyol chemicals. His current research is directed to synthesis and characterization of catalytic materials for application in aqueous media, process design for integrated chemical and bio-based processes, and separation technologies for recovery and purification of organic acids. All of these efforts are directed at creating value added products from renewable resources that are economically competitive with petrochemical routes. This work has led to 17 issued and pending patents. In addition, early work on succinic acid conversion has led to an R&D 100 award. Dr. Werpy has presented over 20 national and interanational talks on the conversion of renewable materials to value added chemicals and has written a book chapter on the conversion of succinic acid to value added chemicals.

Dr. Werpy also serves as an adjunct professor in the Chemical Engineering Department at Michigan State University.

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http://www.ucsd.edu/pharm ; http://research.calit2.net/cibio
http://www.calit2.net/research/areas/degem ; http://www.jcsg.org

Education
Michigan State University, BS, Honors College (Physics, Chem & Biochem) 1967
The University of Chicago, Ph.D., Biophysics and Physics, 1975
Harvard University, Postdoctoral, Molecular Biology, 1976 –1978

Positions and Employment
1969-1970 Danforth Teaching Scholar, Biological Sciences, The University of Chicago
1975-1976 G.D. Searle Visiting Scientist, UK Biophysics Department
1976-1978 Research Fellow, The Biological Laboratories, Harvard University
1976-1978 Tutor in Biochemical Sciences, Harvard University
1978 Instructor, Physiology Course, Marine Biological Labs
1978-1983 Assistant Professor, Biochemical Sciences and Biology, Princeton University
1979-Prsnt Visiting Scientist, Biology Department, Brookhaven National Labs
1984-1988 Program Director, Biological Instrumentation, NSF
1986-1988 Program Director, Biological Centers Program, NSF
1988 Program Director, Special Projects, Instrumentation and Resources, NSF
1988-1992 Division Director, Instrumentation and Resources, NSF
1992-prsnt Research Associate Professor of Biophysics, Johns Hopkins School of Medicine
1992-1999 Deputy Associate Director, Biological and Environmental Research, DOE
1993-1996 Division Director, Medical Applications and Biophysical Research, DOE
1994-1998 Associate Director/Principle Deputy, Energy Research (Science) DOE
1995-1998 Chief of Staff, Energy Research (Science), DOE,
1999-prsnt Associate Vice Chancellor, Research, UCSD
1999-prsnt Adjunct Professor, Pharmacology and of Chemistry-Biochemistry, UCSD
1999-prsnt Senior Fellow, San Diego Supercomputer Center (SDSC), UCSD
1999-prsnt Senior Scientist, Center for Research on Biosystems (CRBS)

(Selected) Honors, Awards, Appointments
Phi Eta Sigma,1964; Beta Beta Beta,1965; Phi Kappa Phi,1966; Danforth Teaching Scholar,1969-1970; Sigma XI,1977; NSF Superior Accomplishment Award,1987; SES Presidential Rank Award, Meritorious Executive,1997; Vice President Al Gore, National Performance Review Leadership Award,1998; Research in Computational Molecular Biology Distinguished Service Award, "Lifetime Contributions in Computational Biology,"1999; Medical Informatics Visiting Lecturer, National University Hospital, National University of Singapore,1999, 2000; Chair, Special Review Group BISTI,2000-2004; Chair, Special Review Group on Computational Neuroscience,2002-2004; Member, National Science Foundation Biological Sciences Advisory Committee (BIOAC),1999-2005; President Elect, Life Science Society,2006.
Recent University Research Appointments: Director, Digitally enabled Genomic Medicine (DeGEM); 2001-present; Co-PI, Joint Center for Structural Genomics (JCSG), 2000-present, and of Community Cyberinfrastructure for Advanced Marine Microbial Ecological Research and Analysis (CAMERA), 2005-present. Major Community Service: Chair, Science Advisory Board, Bioinformatics Center ((BII) Singapore; Chair, External Advisory Committee, C.U. MAGNet: NIH National Center for Biomedical Computing; Chair, NIH NCRR – UCSD CRBS National Biomedical Computing Resource; Member, Advisory Committee, LBNL Director's Review for Scientific Computing; Member, Advisory Committee, NCRR UCSF Resource for Biocomputing, Visualization and Informatics; Member, Advisory Committee; Pittsburgh Supercomputer Center Research Resource for Biological Computing; Member, Steering Committee, Center for Research on Biological Systems (CRBS), UCSD; Member, Advisory Committee, National Center for Microscopy and Imaging Research, UCSD; Member, National Academy of Science, Math Board Study on Advanced Scientific Computing; Strategic Advisor and Member, Executive

Committee, SDSC, UCSD; Member, Executive Committee, CEOA, UCSD; Member, DOE Biological and Environmental Science Advisory Committee (BERAC).

Selected, Recent Relevant Publications

Scientific overview papers in integrative, quantitative and computational biology include*:*

John Wooley (1989), Computational Biology, Trends in Biotechnology, 7, 126-132

John C. Wooley and David T. Kingsbury, (1992), Computational Biology, NSF, Arlington, Virginia.

Su-Yun Chung and John C. Wooley (1997), "The Likely Impact of Developments in Computer-based Information, Networking and Research: A Perspective from the Biological Sciences," in Equipping Science for the 21st Century, ed. John Irvine, Ben Martin, Dorothy Griffiths and Roel Gathier, Edward Elgar Press, Cheltenham, United Kingdom.

Wooley, J. (1999), "Trends in Computational Biology," J. Comput. Biol. 6 (3-4), 459-74

Teresa Head-Gordon, T. and John C. Wooley (2001) "Computational Challenges in Structural and Functional Genomics" IBM Systems Journal 40 265-296

Clair Fraser and John Wooley (2002) Microbial Genomics Report to NSF, Washington D.C.

John Wooley (2004), Building a Cyberinfrastructure for the Biological Sciences (CIBIO), Report to NSF Biological Sciences Advisory Committee, NSF, Washington D.C.

John Wooley and Herb Lin (2005), Catalyzing Inquiry at the Interface of Computing and Biology, National Academy of Science Press, Washington, D.C.

Maynard Olson et al. (2005), Mathematics and 21st Century Biology, NAS Press, Washington, D.C.

An overview reference for the development of CyberMetaGenomics is*:*

Arzberger et al. (2007) Community Cyberinfrastructure for Advanced Marine Microbial Ecological Research and Analysis" PLoS Biology, January 16, 2007.

Our recent, experimental structural-genomics-solved structures involve more than 300 proteins; all coordinates of which have been submitted to the PDB; these structures are described in routine publications to allow the community to exploit the structural information. The details of our highthroughput system or pipeline, and the bioinformatics core that underpins and directs the experimental research discovery path for the Joint Center for Structural Genomics are given in the following papers:

Leslie, S. A, et al. (2002) Structural Genomics of the Thermatoga maritime Proteome implemented in a High-throughput Structure Determination Pipeline. Proc. Natl. Acad. Sci (USA) 99, 11644-11699.

A. Godzik, et al. (2003), Challenges of Structural Genomics I : Bioinformatics. BioSilico, 1, 36-41.

Key Scientific, Technological and Executive Achievements

Having participating in the development of novel light and electron microscopic tools for studying atomic structure in materials and biological molecules, Wooley provided the first evidence for the structure of the chromatin subunit particle, the nucleosome, and confirmed the macromolecular arrangement with neutron and x-ray scattering. Extending these studies into the organization of small ribonucleoproteins and messenger RNA-protein complexes, Wooley established important aspects of protein chemistry and RNA-protein interactions for the structures now known to be involved in the dynamics of RNA metabolism and splicing. More recently, he has established a structural bioinformatics platform for target selection in structural genomics and the use of remote homology detection algorithms; the approach also underpins the community cybermetagenomics or CAMERA efforts at UCSD. To maximize the value of high through-put structure determination, he is extending community annotation tools and collaborating on automated function prediction, which will be essential for metagenomics and for exploiting the diversity of microbes for pharmacology, medicine, energy and the environment. Overall, these bioinformatics and computational biology efforts are part of the cyberinfrastructure development at UCSD. Along with invigorating and/or creating programs for instrumentation and instrument development, minority postdoctoral training, interdisciplinary graduate education, and other infrastructure for the biological sciences, Dr. Wooley created the first federal programs for funding research in bioinformatics and computational biology, and has been involved in strengthening the interface between computing and biology for more than a decade. On behalf of NSF, he established the basis for a comprehensive cyberinfrastructure (i.e., the pervasive use of information technology, networking, and scientific computing) for the biological sciences (see http://research.calit2.net/cibio). Dr. Wooley also chaired and edited a National Academy of Sciences report "Catalyzing Inquiry at the Interface between Computing and Biology," a landmark publication (Dec 2005) explicating the progress in applying computing to biology, reviewing its current state from successes to limitations and challenges, and setting a path for future, novel implementations.

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Education

Ph.D. Chemistry, University of Connecticut, 1988
B.S., Chemistry from Lanzhou University, 1982

Positions and Employment

Dec. 2005 - present	Battelle Pacific Northwest Division at Pacific Northwest National Laboratory
Mar. 2005 – Nov. 2005	Accelergy Corp., Vice President of R&D
Jan. 1994 – Feb. 2005	Akzo Nobel Chemicals Inc. Central Research, Senior Scientist and Section Head
Nov 1992 - Jan 1994	Johnson Matthey Inc. Senior Chemist
1991 - 1992	Northwestern University, Research Assistant Professor
1988 - 1991	Northwestern Univ., Catalysis Center, Research Associate to Professor Wolfgang Sachtler

Honors

1997-2004	Akzo Nobel Tiger award (An award granted over a period of seven years). This is the third and most recent highest technical award throughout the history of the Akzo Nobel R&D.
1996-2003	Six consecutive excellent technical achievement awards. Presentation of new technology leads to Akzo Nobel management at annual top management.
1999-2001	A member of Directors, Catalysis Society of Metropolitan New York
1998-1999	Chairman, Catalysis Society of Metropolitan New York
1999	Member of the organization committee, NACS
	Co-Editor of a Special Issue of Applied Catalysis
	Member of Honor Societies of Phi Beta Kappa, Phi Kappa Phi, and Phi Lambda Upsilon
1988	C.E. Waring Excellent Graduate Student Award

Selected Publications (selected from over 60 publications)

- "Direct conversion cellulose to 5-Hydroxymethylfurfural (HMF)", Haibo Zhao, Johnathan E. Holladay, Z. Conrad Zhang*, ***Nature***, in preparation
- "Converting sugars to 5-Hydroxymethylfurfural (HMF) in ionic liquids", Haibo Zhao, Johnathan E. Holladay, Z. Conrad Zhang*, ***Science***, submitted

- "A new route to improved glucose yields in cellulose hydrolysis", Haibo Zhao, Johnathan E. Holladay, Yong Wang, John M. White, Z. Conrad Zhang, ***Journal of Biobased Materials and Bioenergy,*** submitted.
- "An unusual inverse temperature dependent pathway for cellulose decrystallization in trifluoroacetic acid", H. Zhao, J. Holladay, J.M. White, Y. Wang, Z. C. Zhang, ***Biomacromolecules,*** submitted.
- "Studying cellulose fiber structure by SEM, XRD and acid hydrolysis", Zhao, H.; kwak, J. H.; Zhang, Z. C.; Wang Y.; Arey, B. W.; White J. M.; Holladay J. E.; ***Carbohyd. Polymers, 2006,*** Accepted.
- "Catalysis in Ionic Liquids", Z. C. Zhang, ***Advance in Catalysis,*** **2006**, 49, 153.
- "Structural Elucidation of Thiophene Interaction with Ionic Liquids by Multinuclear NMR Spectroscopy", B.-M. Su, S. Zhang and Z. C. Zhang, ***J. Phys. Chem.***, **2004**, 108 (50), 19510.
- "Extractive Desulfurization and denitrogenation of Fuels Using Ionic Liquids." Shuguang Zhang, Qinglin Zhang, and Z. Conrad Zhang, ***Ind. Eng. Chem. Res.***, **2004,** *43,* 614-622.
- . "Novel Properties of Some Ionic Liquids in Sulfur Removal from Fuels", Richard Zhang, Z. Conrad Zhang, Royal Society of Chemistry, ***Green Chemistry,*** **2002**, 4 (4), 376.

Patents (USA only)

Dr. Zhang has 20 patents.

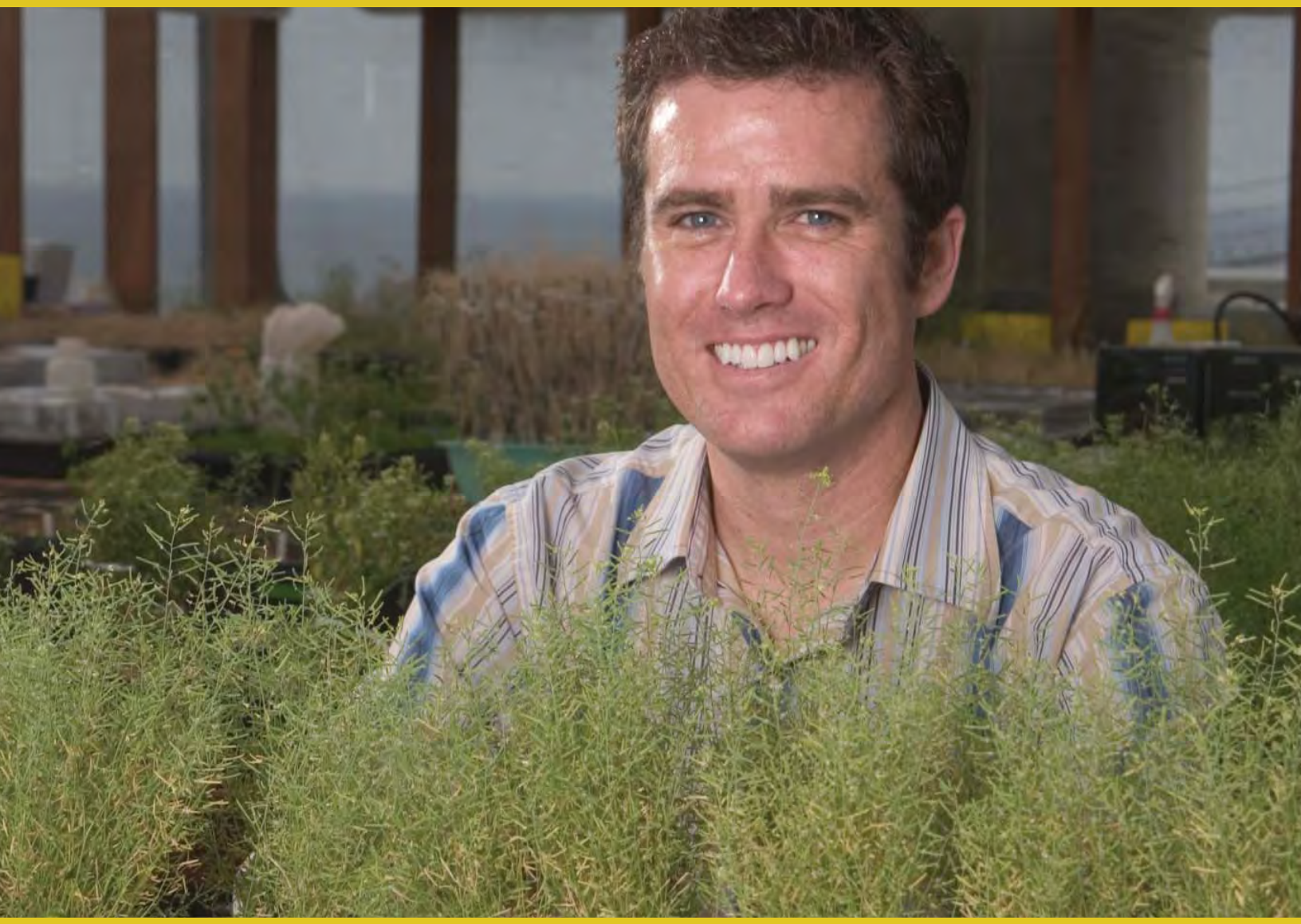
Key science and technology achievements

Over the years, Dr. Zhang has built a broad networks with business leaders and research institutes. Prior to joining PNNL in 2005, he joined Akzo Nobel Research in 1994, where he established and led a highly productive and innovative catalysis team with diverse capabilities. Some of the programs /projects on emerging technologies that he initiated and led include nanotechnology, biocatalysis, ionic liquids, novel products and catalytic processes. Before joinging Akzo, Dr. Zhang worked for Johnson Matthey (1992-1994).

Among Dr. Zhang's technical achievements: Invented a breakthrough catalytic chemistry for the activation and functionalization of C-H bond in saturated hydrocarbons; breakthrough catalyst technology for hydrodechlorination of chlorocarbons; a catalytic process that enabled a separation process for the recycle of an excess chlorocarbon feed in a production process; novel applications of ionic liquids for sulfur removal from fuels.

Based on his work on metal cluster catalysts on Brösted acidic and Lewis acidic supports, Dr. Zhang introduced the concept of basicity associated with noble metal atomic clusters. This theory satisfactorily rationalizes the difference in electronic and catalytic properties between atomic clusters and larger nanoclusters, particularly in bifunctional catalysts. He developed a new mechanism related to the stability of nanosized metal cluster catalysts, which led to a novel catalytic process for catalytic cracking of ethylene dichloride to vinyl chloride monomer with much improved economics over the existing thermal process. His team invented and developed novel catalytic processes for branched surfactant products that have superior performance over the conventional surfactants; developed new zeolites suitable for general fine chemical synthesis; and invented high throughput systems for catalyst screening tests.

Additional Exhibit: *Selected Publications*



Above *Jeff Long in a* Arabidopsis thaliana *greenhouse—courtesy of Salk Institute*

Relevant Publications from the Past Five Years

Submitted by scientists from UCSD, ISU, Venter Institute, Battelle, Salk and the Scripps Research Institute who have expressed interest in pursuing research within the EBI.

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Additional Exhibit: *Letters of Commitment - UCSD CBEST Participants*

Above *California Creamcup at Torrey Pines State Reserve*

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Office of the President
1750 Beardshear Hall
Ames, Iowa 50011-2035
515 294-2042

November 14, 2006

Dr. Marye Anne Fox
Chancellor
University of California, San Diego
9500 Gilman Drive, 0005
La Jolla, CA 92093-0005

Dear Marye Anne:

Iowa State University is extremely pleased to be a partner with the University of California, San Diego, in the competition for the BP Energy Biosciences Institute. We have great respect for UCSD as an outstanding research and educational institution, and we especially admire UCSD's academic excellence and leadership in the biological sciences, which is critically important to this biofuels initiative.

With its strengths in agriculture and engineering, chemistry, fundamental research in the biosciences and its commitment to the application of plant sciences to agronomy, I believe Iowa State University brings very significant complementary strengths to this partnership. In fact, the three institutions make a formidable team in the competition for the BP Energy Biosciences Institute. Iowa State is firmly committed to this project, and I pledge the full cooperation of this university—its resources and its many partners—in the efforts led by UCSD to obtain this contract, and, more importantly, to the success of the Institute should it be awarded to UCSD, with Iowa State as a partner.

We are working with our state legislature and governor to obtain additional resources to support expanded opportunities in bioenergy, including a new building to house some of the research, new infrastructure for a field laboratory at our nearby Agronomy Farm, and additional faculty positions in plant science, microbial science, and production and bioprocessing to expand our capabilities in energy biosciences. The state legislative session does not convene until January, but our preliminary discussions with legislators of both parties have indicated significant interest in working with ISU to determine and obtain the level of state support needed for ISU's participation in a successful partnership with UCSD and the Venter Institute.

We are very proud of the leadership Iowa State has already provided in the research and development of biorenewable fuels and other bio-based products, and of the many very significant advancements made by our outstanding faculty. We are excited about the tremendous potential of our partnership with UCSD in the BP Energy Biosciences Institute competition, and we look forward to a continuing partnership with your university.

I would be happy to provide additional information about Iowa State University's deep commitment to helping our nation and world develop its vast biorenewable resource potential, while maintaining the sustainability and quality of our natural environment. This is one of Iowa State University's highest priorities as a leading land-grant university serving the people of Iowa, the United States and the world.

Sincerely,

Gregory L. Geoffroy
President

J. Craig Venter

INSTITUTE

November 20, 2006

Arthur B. Ellis, Ph.D.
Vice Chancellor for Research
University of California, San Diego
Office of Research Affairs
9500 Gilman Drive, 0043
La Jolla, CA 92093-0043

Subject: Energy Biosciences Institute

Dear Dr. Ellis:

The Venter Institute is delighted to be one of four collaborating institutions proposing to develop a world-renowned Energy Biosciences Institute on the campus of University of California at San Diego in partnership with, and funded by, BP.

The Venter Institute has world-class expertise in the development and application of genomics to a number of basic and applied research areas including, biological energy, environmental genomics, synthetic biology, microbiology, plant biology, and human genomic medicine. High-throughput technologies such as DNA sequencing, DNA amplification, bioinformatics, gene expression, and protein identification are the hallmarks of the Institute.

Numerous scientists and staff members from throughout the Venter Institute have been involved in the proposed research agenda being developed by University of California at San Diego and hope to maintain their involvement in the future

The Venter Institute is prepared to commit the necessary personnel and resources to the University of California at San Diego in the event that the UCSD Energy Biosciences Institute is chosen for funding by BP.

Regards,

J. Craig Venter, Ph.D.
President and Chairman

9704 Medical Center Drive / Rockville, MD 20850 / phone 240-268-2751 / fax 240-268-4007

Battelle
The Business of Innovation

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November 15, 2006

Dr. Arthur B. Ellis
Vice Chancellor
Office of Research Affairs
University of California, San Diego
9500 Gilman Drive
La Jolla, CA 92093-0043

Dear Dr. Ellis: Art

Battelle's Pacific Northwest Division (PNWD) is extremely pleased to be a partner with the University of California, San Diego (USCD), in the competition for the BP Energy Biosciences Institute. We have great respect for UCSD as an outstanding research and educational institution, and we especially admire UCSD's academic excellence and leadership in the life sciences, which is critically important to advancing the use of biofuels. We also have great respect for the other partners on the team.

I believe Battelle PNWD brings significant complementary strengths to this partnership, and that the partnership is a formidable team in the competition for the Energy Biosciences Institute. Battelle PNWD is firmly committed to this endeavor, and I pledge the full cooperation of our organization – its resources and its many partners – in the efforts led by UCSD to establish the Energy Biosciences Institute, and, more importantly, to the success of the Institute should it be established at UCSD. We are very proud of the leadership Battelle PNWD has already provided in the research and development on biofuels and other bio-based products and processes, and of the many significant advancements in biomass pre-treatment, bioreactor design, fungal biology and enzymatic research made by our outstanding scientists and engineers.

I would be happy to provide additional information about Battelle's deep commitment to helping our nation and world develop its vast biorenewable resource potential, while maintaining the sustainability and quality of our natural environment.

Sincerely yours,

Douglas Ray
Vice President, Pacific Northwest Division
Battelle Memorial Institute

The Salk Institute for Biological Studies

November 15, 2006

Dr. Arthur B. Ellis
Vice Chancellor
Office of Research Affairs
University of California, San Diego
9500 Gilman Drive
La Jolla, CA 92093-0043

Dear Dr. Ellis:

The Salk Institute for Biological Studies is pleased to be a partner with the University of California, San Diego, in the competition for the BP Energy Biosciences Institute. UCSD is an outstanding research and educational institution, and its academic excellence and leadership in the life sciences are critical to the biofuels initiative.

The Salk Institute brings significant complementary strengths to this partnership, and will make a formidable team in the competition for the BP Energy Biosciences Institute. The Salk Institute is committed to this project, and will cooperate with UCSD in its efforts to secure funding.

We are proud of The Salk Institute's research and development of biorenewable fuels and other bio-based products, and of the significant advancements made by our faculty. We look forward to the potential of the partnership with UCSD in the BP Energy Biosciences Institute competition.

We would be glad to provide additional information about The Salk Institute's commitment to helping our nation and world develop its vast biorenewable resource potential, while maintaining the sustainability and quality of our natural environment.

Sincerely,

Kim E. Witmer
Vice President and
Chief Financial Officer

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THE SCRIPPS RESEARCH INSTITUTE

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November 15, 2006

Vice Chancellor Arthur B. Ellis
University of California, San Diego
Office of Research Affairs
9500 Gilman Drive, 0043
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Re: BP Energy Sciences Institute Proposal

Dear Vice Chancellor Ellis:

I would like to express the full support of The Scripps Research Institute (TSRI) for the subcontract preproposal submitted by Dr. Steve A. Kay in the context of the BP Energy Sciences Institute Proposal. The Scripps Research Institute has always stood at the forefront of basic biomedical science, a vital segment of medical research that seeks to comprehend the most fundamental processes of life. Now, through this proposal, we are excited to expand our existing plant research into the area of biofuels research.

Over the past several years, TSRI has made major investments to support plant research facilities, including a 12,000 sq ft greenhouse facility with climate control. Research is further supported by Affymetrix chipping capabilities, a Sequencing Facility, and a Mass Spectroscopy Facility on site. TSRI also maintains facilities for NMR, electron microscopy, DNA microarrays, flow cytometry, instrumentation and design, protein and nucleic acid core, and x-ray crystallography. Dr. Kay is proposing 8 FTE's to accomplish the goals of his proposal. TSRI is fully committed to support these researchers in their quest to investigate cell wall biosynthesis and identifying and improving key factors affecting biomass yield and conversion efficiency.

Please do not hesitate to contact me if you would like to discuss further details.

Sincerely,

Douglas A. Bingham

DAB:tl

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Additional Exhibit: *Incentives and Letters of Support*

Above *Powell-Focht Bioengineering Hall—courtesy of UCSD*

GOVERNOR ARNOLD SCHWARZENEGGER

November 20, 2006

The Right Honorable Lord Browne of Madingley
Group Chief Executive
BP, PLC
1 St. James's Square
London, SW1Y4PD
United Kingdom

Dear Lord Browne,

I am writing to express my strong support for the proposals by the University of California, Berkeley and the University of California, San Diego for BP's new Energy Biosciences Institute (EBI).

As you know from our discussions, I am enthusiastic about BP's long-term technology strategy and its focus on energy biosciences and renewable fuels. It is a great honor that two California research universities have been selected to compete for this important and transformational research initiative. California is the ideal setting for this venture given its rich culture of innovation and discovery, outstanding research tools and unparalleled intellectual capital. There is no comparable environment that provides the same level of expertise, breadth of capabilities and access to scientific resources.

As we have discussed, it is a top priority of my administration to advance renewable energy technology. California has already made great strides in recognizing the dangers of global warming and in addressing our energy challenges and opportunities. In the last year alone we have made remarkable progress, including signing into law the Global Warming Solutions Act, the first statewide effort to cap greenhouse gas emissions across all sectors of California's economy, launching the Million Solar Roofs Initiatives that will bring 3,000 megawatts of clean energy online by 2017, requiring the State to acquire 20 percent of electricity from renewable sources by 2010 and issuing a detailed BioEnergy Action Plan, which targets the production and use of biofuels and biomass for electricity. The BP initiative would be another major step forward for California in this area and would receive the highest attention from my administration to help ensure its success.

All of the institutions invited to compete for the EBI are world-class. However, I believe that with our track record of innovation and entrepreneurial spirit, California and the EBI are a perfect match. With a workforce and business climate dedicated to discovery and research advances ranging from the work of pioneering physicist E.O. Lawrence, to the birth of Silicon Valley, to our modern-day biotech clusters including emerging stem cell research centers, California stands as a ready partner to BP.

California and my administration are prepared to work with you to make the EBI a reality and ensure its success. To supplement the University of California's proposals, I pledge $40 million to support construction of appropriate facilities for the EBI if one of the UC campuses is selected by BP. Thank you again for your consideration and for BP's commitment to new and cleaner energy sources.

Sincerely,

Arnold Schwarzenegger

UNIVERSITY OF CALIFORNIA, SAN DIEGO

UCSD

BERKELEY · DAVIS · IRVINE · LOS ANGELES · MERCED · RIVERSIDE · SAN DIEGO · SAN FRANCISCO

SANTA BARBARA · SANTA CRUZ

OFFICE OF THE CHANCELLOR

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November 22, 2006

Lord John Browne
Chief Executive, British Petroleum
1 St. James Square
London SW1 Y4PD
United Kingdom

Dear Lord Browne:

I am writing to express the University of California at San Diego's strong support for the BP Energy Biosciences Institute (EBI) and our proposal to site this in La Jolla. We are very pleased to be one of the five institutions worldwide to be invited to participate in this competition. This reflects UC San Diego's considerable successes since its creation in the early 1960s around the Scripps Institution of Oceanography.

The selection of the UC San Diego bid would place the EBI in the leading biotech research center in the United States and the world. The extraordinary connections between UC San Diego and the biotech community will ensure the ready commercialization of the technologies developed here when appropriate. Certainly the integration into one of the largest energy markets globally will be straightforward.

Hiring additional outstanding faculty will be a key element of the EBI. UC San Diego is in a dynamic growth mode and the number of UC San Diego faculty is slated to grow substantially over the next decade. Much of this growth will add faculty whose intellectual interests will be important to the success of the BPI initiative. At a minimum, we are committed to adding ten new FTE, with associated start-up packages, during this period for the broad range of energy biosciences directly relevant to the BPI, which could include plant sciences, microbial biology, genomic research, chemistry & biochemistry, bioengineering, cyber infrastructure, energy technology, economics, political sciences, and climate. In turn, we will ask that BP join us in making it possible to recruit the top scholars in these fields by providing, through the contract for the EBI, sufficient funds to endow ten chaired positions at $500,000 ($750,000 for the Jacobs School of Engineering) to be identified as "BP Energy Science Professor." These chairs will enable us to recruit as many FTE as possible in the initial stages of the EBI.

In addition to the faculty support dedicated to the future of the EBI, California Governor Arnold Schwarzenegger has pledged $40 M in California state support for EBI building construction in the event either of the two University of California campuses is successful in their proposals. As you are aware from other letters, legislators of both parties show strong support for locating the EBI in California.

I look forward to working with you during the next months as we pursue a partnership in energy biosciences with our partners from Iowa State University, the Salk Institute, The Scripps Research Institute, the J. Craig Venter Institute, and Battelle Memorial Institute. Please do not hesitate to contact me if I may be of service.

Sincerely,

Marye Anne Fox

Marye Anne Fox
Chancellor

DIANNE FEINSTEIN
CALIFORNIA

COMMITTEE ON APPROPRIATIONS
COMMITTEE ON ENERGY AND NATURAL RESOURCES
COMMITTEE ON THE JUDICIARY
COMMITTEE ON RULES AND ADMINISTRATION
SELECT COMMITTEE ON INTELLIGENCE

United States Senate

WASHINGTON, DC 20510-0504
http://feinstein.senate.gov

November 20, 2006

The Right Honorable Lord John Browne
Group Chief Executive
BP
1 St. James Square
London, SW1Y4PD
United Kingdom

Dear Lord Browne:

I am writing in full support of the proposals by the University of California Berkeley and the University of California San Diego in response to British Petroleum's (BP) decision to create a $500 million Energy Bioscience Institute (EBI). BP is to be commended for creating a center that will focus on developing new, more efficient biofuels as a way to combat climate change.

As you know, California has recently enacted a groundbreaking climate change law that will require the State to reduce greenhouse gas emissions by 25% by 2020. Implementing this law will require a new generation of clean and renewable energy sources, which will likely be developed in California. Given California's leadership role on climate change, it seems that California would be a natural fit for the EBI.

I wholeheartedly support both UC Berkeley and UC San Diego's proposals and hope that California will be chosen as the home for BP's EBI. Thank you in advance for your consideration of these proposals. I look forward to learning of the outcome of this competition. Best regards.

Sincerely,

Dianne Feinstein
United States Senator

DF:rm

Congress of the United States
Washington, DC 20515

November 15, 2006

Lord John Browne
Chief Executive, British Petroleum
1 St. James Square
London, SW1Y4PD
United Kingdom

Dear Lord Browne,

We would like to express our strong support for the University of California at San Diego's comprehensive and visionary proposal to participate in the groundbreaking Energy Bioscience Institute (EBI) project. We are proud that UC San Diego is one of only five institutions worldwide invited to participate in this competition. We commend the effort to create and fund a cutting-edge institute to investigate and research the application of bioscience and biotechnology to the energy challenges that we now face -- with a primary focus on biofuels. We believe it offers the potential to address various energy, environmental and national security concerns in the United States.

It is our understanding that EBI initially will concentrate on achieving large-scale production of biofuels, beginning with biomass feedstocks and resulting in the creating of an integrated bio-fuels refinery. Achieving this goal will require ground-breaking interdisciplinary research in such fields as plant and microbial genetics, agronomy, and chemical, biological and metabolic engineering. UC San Diego already has in place world-class resident expertise in each of these fields.

In close partnership with one of America's top agricultural research schools, Iowa State University, and the internationally renowned J. Craig Venter Institute, UC San Diego has assembled a phenomenal proposal. The BP EBI will be prominently located among the well-known entrepreneurial environment of collaboration and innovation in San Diego and surrounding regions that has spawned dozens of leading biotechnology and pharmaceutical companies and other economic engines in the areas of development and research.

Further, San Diego is an excellent location for the EBI project given California's leadership and commitment to reducing carbon emissions as well as encouraging breakthroughs in clean fuel and related technologies to drive our economy of the future. The remarkable confluence of factors for this proposal presents an ideal environment for the BP EBI.

We are impressed by the depth and the broad scope of the UC San Diego proposal and believe it would facilitate the goals of the EBI endeavor. The research of biotechnology is certainly a worthy cause, and we are confident that UC San Diego has much to contribute. Thank you for your time and attention to this important matter.

Sincerely,

Susan A. Davis
Member of Congress

Duncan Hunter
Member of Congress

Ken Calvert
Member of Congress

Darrell Issa
Member of Congress

Brian Bilbray
Member of Congress

Bob Filner
Member of Congress

MoCs
CC: Chancellor Marye Anne Fox, UCSD
Dr. John Orcutt, UCSD
Mr. Jim Breson, BP EBI Project Manager

COMMITTEES
CHAIR, BUDGET SUBCOMMITTEE ON HEALTH & HUMAN SERVICES
VICE CHAIR, AGRICULTURE
TRANSPORTATION AND HOUSING SUBCOMMITTEE ON CALIFORNIA PORTS AND GOODS MOVEMENT
GOVERNMENT MODERNIZATION, EFFICIENCY AND ACCOUNTABILITY
JOINT LEGISLATIVE BUDGET
JOINT LEGISLATIVE AUDIT

California State Senate

SENATOR
DENISE MORENO DUCHENY
FORTIETH SENATE DISTRICT

SELECT COMMITTEES
CHAIR, CALIFORNIA-MEXICO COOPERATION
CHAIR, COLORADO RIVER
CHAIR, OVERSIGHT OF THE UC ENERGY LABS
DEFENSE AND AEROSPACE INDUSTRY
GLOBAL ENVIRONMENT
CALIFORNIA'S HORSE RACING INDUSTRY
PERCHLORATE CONTAMINATION
MOBILE AND MANUFACTURED HOMES

October 30, 2006

Sir John Browne
The Lord Browne of Madingley, FREng
Chief Executive
British Petroleum
1 St. James's Square
London, SW1Y 4PD
United Kingdom

Dear Lord Browne:

I am writing to express my enthusiasm and support for the University of California San Diego's (UCSD) proposal to work with your organization, British Petroleum (BP), to create a $500 million Energy Bioscience Institute (EBI). The establishment of a world-class bioscience and biotechnology center to develop new biofuels to power our future is of utmost importance to meeting our energy needs while sustaining our environment and resources.

By locating the Energy Bioscience Institute in Southern California, BP would be tapping into a wealth of knowledge, experience, and resources that UCSD has to offer. Proximity to the Pacific Ocean, and the Imperial Valley and Salton Sea in California, along with the intellectual capital of UCSD and Iowa State University, will elevate BP's place as leader of biofuels research and engineering. Access to the Pacific Ocean, Imperial Valley, and Salton Sea will provide the EBI diverse environments and opportunities for research, development, and production of new biofuels.

Following the announcement that UCSD was among a handful of candidates to build the Institute, I met with Dr. John Orcutt to discuss the significance of your plans and UCSD's potential role. I offered whatever assistance I might lend now and in the future as a member of the California Legislature and as Chair of the Senate Budget Committee. While I would be supportive of your endeavors wherever they might reside in our State, I am convinced that San Diego would be, by far, your optimal site to locate a facility of this caliber.

The State of California is at the forefront of leadership and commitment to reduce carbon emissions as well as encourage breakthroughs in clean fuels technologies. Please be assured that California will work diligently with BP and the EBI to maintain seamless cooperation and support across all of our public organizations and agencies.

CAPITOL OFFICE
STATE CAPITOL, ROOM 4081
SACRAMENTO, CA 95814
PH (916) 651-4040
FAX (916) 327-3522

CHULA VISTA OFFICE
637 3RD AVENUE, SUITE C
CHULA VISTA, CA 91910
PH (619) 409-7690
FAX (619) 409-7688

IMPERIAL VALLEY OFFICE
1224 STATE STREET, SUITE D
EL CENTRO, CA 92243
PH (760) 335-3442
FAX (760) 335-3444

COACHELLA VALLEY OFFICE
53-990 ENTERPRISE WAY, SUITE 14
COACHELLA, CA 92236
PH (760) 398-6442
FAX (760) 398-6470

I thank you for your consideration of this important scientific and educational proposal by the University of California San Diego. I believe British Petroleum and UCSD can work together to make a better future for us all. Please feel free to contact me at (619) 409-7690, should you have any questions.

Sincerely,

DENISE MORENO DUCHENY
State Senator, 40th District

DMD/jmh
cc: Governor Arnold Schwarzenegger
Senator Don Perata

STATE CAPITOL
P.O. BOX 942849
SACRAMENTO, CA 94249-0075
(916) 319-2075
FAX (916) 319-2175

DISTRICT OFFICE
9909 MIRA MESA BLVD., SUITE 130
SAN DIEGO, CA 92131
(858) 689-6290
FAX (858) 689-6296

Assembly
California Legislature

GEORGE A. PLESCIA
ASSISTANT REPUBLICAN LEADER
ASSEMBLYMAN, SEVENTY-FIFTH DISTRICT

COMMITTEES
VICE CHAIR:
GOVERNMENTAL ORGANIZATION
MEMBER:
BUDGET
VETERANS AFFAIRS

E-MAIL
assemblymember.plescia@assembly.ca.gov
WEBSITE
http://www.assembly.ca.gov/plescia

November 15, 2006

Lord John Browne
Chief Executive, British Petroleum
1 St. James Square
London, SW1Y4PD
United Kingdom

Dear Lord Browne:

By unanimous agreement, we the Assemblymembers and Senators of the California State Legislature who represent the San Diego region are writing to express our united and enthusiastic support for UC San Diego's proposal in response to British Petroleum's (BP) announcement to create a $500 million Energy Bioscience Institute, or EBI, on or adjacent to a major research university. We are very proud of UCSD as one of only five institutions worldwide to be invited to participate in this competition, and commend BP for taking the initiative to create and fund a cutting-edge center to investigate the application of bioscience and biotechnology to the energy challenges we all face. We applaud the new directions being proposed for the Institute, particularly the application of modern biology and genetics to energy problems. Previous such applications have concentrated largely on advances in human health and medicine.

Given the leadership role California has played and continues to play in driving global advances in science, environmental protection, and technology development, there could be no more logical a location for such a research endeavor at this time than the State of California, and most particularly the San Diego region. As you are certainly aware, San Diego has a rich history as a uniquely entrepreneurial environment of collaboration and innovation that has spawned dozens of leading biotechnology and pharmaceutical companies. San Diego boasts an unusual degree of cooperation across the academic, corporate, and public sectors that is not found elsewhere.

UC San Diego, partnering with one of America's top agricultural research schools, Iowa State University, and the internationally renowned J. Craig Venter Institute, has assembled a phenomenally competitive proposal for the BP EBI, which will occupy a place of pride and prominence here in our region. Taken with the similar creativity and innovation of its partner institutions, the UC San Diego proposal creates an optimal scenario for BP's EBI that is unsurpassed.

We are very appreciative of your consideration of UC San Diego's candidacy for this timely and visionary research endeavor, and stand ready to provide whatever assistance

we might to help facilitate this effort. Thank you for your efforts on this important issue, and please don't hesitate to contact us if we can be of service to you. We look forward to being kept apprised of your progress.

Sincerely,

George A. Plescia
Assemblyman, 75th District

Christine Kehoe
Senator, 36th District

Shirley A. Horton
Assemblywoman, 78th District

Mark Wyland
Assemblyman, 74th District

Lori Saldaña
Assemblywoman, 76th District

JERRY SANDERS
MAYOR

November 3, 2006

Lord John Browne
Chief Executive, British Petroleum
1 St. James Square
London, SW1Y4PD
United Kingdom

Dear Lord Browne:

I am writing to express my support for UC San Diego's proposal for British Petroleum's (BP) $500 million Energy Bioscience Institute (EBI) to be located on or adjacent to a major research university. San Diego is extremely proud of UCSD as one of only five institutions worldwide to be invited to participate in this competition, but recognizes this as a reflection of the university's considerable successes since its creation in the early 1960's.

BP is to be commended for taking the initiative to create and fund a cutting-edge, world class center to investigate the application of bioscience and biotechnology to the energy and environmental challenges with which we are now faced. This is a welcome development, and one, which offers tremendous potential in terms of addressing both environmental and national security concerns.

You are likely aware of the leadership being demonstrated by the State of California in the field of renewable energy and related new technologies; indeed, there could be no more appropriate location for BP's EBI. Within California, however, San Diego is leading the way, in committing to reduce our carbon footprint on the environment and to forge ahead aggressively in developing a "clean technology" sector, adopting alternative energy sources, green building materials and water treatment systems. For example, I recently signed the U.S. Mayors Climate Protection Agreement, which includes goals promoting renewable energy, conserving water resources, and sustainable growth. To this end, the potential synergies and partnerships that would accrue to BP from a San Diego EBI are literally without equal.

In close partnership with one of America's top agricultural research schools, Iowa State University, and the internationally renowned J. Craig Venter Institute, UCSD has assembled a rigorous and highly competitive proposal for the BP EBI. The Institute would be prominently located in the uniquely entrepreneurial and innovative environment of the San Diego region, which has created dozens of leading biotechnology and pharmaceutical companies. With its partner institutions, the UCSD proposal creates an optimal scenario for the BP EBI that separates it from the field by orders of magnitude.

As Mayor of San Diego, I am committed to advancing sustainable policy goals and will welcome BP into the collaborative and competitive community fabric of this region. My office stands ready to assist however we might, in order to facilitate this endeavor. Thank you for your initiative in creating this important research enterprise and for your favorable consideration of UCSD's proposal.

Sincerely,

JERRY SANDERS
Mayor
City of San Diego

cc: Chancellor Marye Anne Fox, UCSD
Dr. John Orcutt, UCSD
Jim Breson, British Petroleum, EBI General Project Manager

THE CITY OF SAN DIEGO

November 22, 2006

Mr. Steven Briggs, Ph.D.
Professor of Cell and Developmental Biology
University Of California, San Diego
9500 Gilman Drive
La Jolla, California 92093-0346

Dear Mr. Briggs:

Subject: City of San Diego's support for the University of California San Diego (UCSD) Grant Application to British Petroleum, November 2006

The City of San Diego has a comprehensive approach and successful track record in fostering the development and expansion of targeted biotechnology and high tech industries. The San Diego region is internationally known for the unique collaboration between government, research and development institutions, and private sector firms that are attuned to its science and technology sectors.

In order to support expanding life science and technology industries, the City of San Diego's City Council created the Business and Industry Incentive Program, Council Policy 900-12, in 1993. This program was created to improve the business climate of the City by providing certain financial incentives, and permit assistance to a variety of business investors. This program serves as the City's primary economic development platform. The City's Business Expansion and Retention (BEAR) Team has worked with biotechnology and high technology firms such as Pfizer Global Research, Johnson and Johnson, General Atomics Aeronautical, Cardinal Health, Qualcomm, the Salk Institute, the Burnham Institute, the Scripps Institute and other firms and research institutions expanding in San Diego. The City amended the CP 900-12 in 2001 to include sustainable energy as a targeted industry cluster.

San Diego is already established as one of the nation's leading life science centers and is poised to lead the way in sustainable energy research. The Milken Institute in 2004 named San Diego the top biotech cluster in the nation and estimated that the life science industry in San Diego was responsible for $5.8 billon of the region's gross product. Life science and technology cluster businesses located within the City of San Diego employ 119,000 people. Life science companies alone generated $747 million in venture capital funding in 2004. The San Diego region is third in the U.S in number of biotech firms receiving venture capital, second in the Small Business Innovation Research (SBIR) and in Small Business Technology Transfer (SBTR) awards to biotechnology firms.

Attached is a summary of the "incentives" available to targeted industries such as those developing sustainable bio based energy products and services. In addition the City of San Diego commits to identifying opportunities for locating "pilot" sustainable energy research projects at City owned locations.

The City's new Clean Tech Business Development Officer will be hired in early January 2007 and will collaborate closely with UCSD's initiatives.

Sincerely,

Scott Kessler
Deputy Director, Economic Development Division

TD

Attachment:

cc: Honorable Mayor Jerry Sanders
Jim Waring, Deputy Chief, Land Use and Economic Development
Toni Dillon, Business Development Officer

THE CITY OF SAN DIEGO

Attachment to:
Dr. Steven Brigg's Letter
Support for UCSD Grant Application
November 22, 2006

Business Incentives

City of San Diego Business & Industry Incentive Program

The Business & Industry Incentive Program was created by the San Diego City Council in 1993 to improve the business climate of the City by providing certain financial incentives, and permit assistance to a variety of business investors. This program serves as the City's primary economic development platform, and its incentives may be combined with those from other City programs such as the *Enterprise Zone Program*, the *Business Finance Program*, and with other incentives offered through the City's Redevelopment Agency or through State and Federal programs.

The Business & Industry Incentive Program is administered by the City Planning and Community & Investment Department's BEAR (Business Expansion Attraction & Retention) team. Eligible companies enter into an "Incentive Agreement" with the BEAR team to access the incentives and services provided under this program.

Eligibility is determined by assessing whether businesses are consistent with the City's current Community & Economic Development Strategy and:

- Provide significant revenues and/or jobs that contribute to a sound and healthy economy; or
- Promote the stability and growth of City taxes and other revenue; or
- Construct appropriate development in older parts of the City; or
- Are being induced by other jurisdictions to relocate from San Diego.

Eligible businesses can receive ministerial "off-the-shelf" incentives approved at the staff level such as:

- Assistance in determining the density entitlements or development requirements for real property ("due diligence") and in obtaining any necessary permits required for land developments or to modify an existing building or other structure; and/or
- A 40% reduction in water and 60% sewer capacity fees in areas served by the City's utility departments.

For more Information contact Toni Dillon, Business Development Officer, City of San Diego
TDillon@sandiego.gov or 619.533.4279

These same businesses may also receive other discretionary "custom-tailored" incentives recommended by staff and approved by the San Diego City Council, such as:

- A rebate of all or a portion of the personal (unsecured) property taxes paid on "economic revitalization manufacturing property" for a period of up to five (5) years pursuant to Section 5108 of the California Revenue & Taxation Code.
- A reimbursement of all or a portion of building and/or development-related fees collected by the City in connection with the issuance of building permits for new commercial and industrial buildings and structures.

Available Business Incentives

Firms that enter into a City of San Diego Incentive Agreement administered with The City Planning & Community Investment Department's Business Expansion Attraction and Retention (BEAR) Team or the Enterprise Zone Program are eligible to receive permit assistance and financial incentives. In cooperation with other City departments, the BEAR Team directly administers three business development programs authorized by Council Policies 900-12, 100-12 and 400-09:

1. The Business Cooperation Program
2. The Guaranteed Water for Industry Program
3. The Business & Industry Incentive Program;

1. Business Cooperation Program

- Provides technical use tax allocation assistance. Participating firms receive ongoing tax rebates equal to .25/dollar of new tax revenue reported to the City Auditor's Department.
- A business tax/development fee credit equal to .45/dollar (45 basis points on the total sale or purchase price). Participating firms can pay their annual business license tax and/or fees arising from new facility development with credit earned by allocating their taxes to the City. Firms that are given this option can "cash in" any unused credit at a later time.

2. Guaranteed Water of Industry Program

- Provides a guaranteed uninterruptible supply of potable and reclaimed water for irrigation, cooling, research, product development, and production activities during drought conditions.
- Provides ongoing cost savings to businesses through discounted rates for reclaimed water usage (.80/HCF, currently a 42% discount).
- May provide one-time cost savings on water capacity charges.
- All industrial firms located in the "Optimized Zone" which currently includes the communities of *University, Mira Mesa, Scripps Miramar Ranch, and Miramar Ranch North.*

For more Information contact Toni Dillon, Business Development Officer, City of San Diego
TDillon@sandiego.gov or 619.533.4279

3. Business & Industry Incentive Program

- Companies receive due diligence
- Expedited permit review
- Business Advocacy to resolve project dilemmas
- Discounted water (40% reduction) and sewer (60% reduction) capacity fees.

Enterprise Zones (EZ)

The City of San Diego has just received notice that its Enterprise Zone application which includes portions of the city of San Diego and the neighbor cities of Chula Vista and National City has been approved.

Companies that locate within an Enterprise Zone can claim tax credits and other program assistance:

Tax credits available under the program:

- Enterprise Zone employers can earn $31,500 or more in tax credits over a five year period for each qualified employee.
- Enterprise Zone business owners can claim tax credits for sales or use tax paid on the first $1 million in qualified equipment purchases.
- Corporations can claim the credit on the first $20 million of qualified purchases.
- Part of the cost of certain property purchased for exclusive use in the Enterprise Zone may be deducted as a business expense in the first year it is placed in service.
- Lender's to Enterprise Zone businesses are able to take a deduction from income allowed on the amount of "net interest" earned on loans made to a trade or business located exclusively in the Enterprise Zone.

Other program assistance:

- No-cost Job Referral Service that can be used to find qualified employees whose wages can be claimed as tax credits
- Development permit expediting and assistance
- Reductions and waivers on certain development fees
- Access to specialized technical and financial assistance programs
- Net operating loss carries forward.

When Enterprise Zone firms enter into an Incentive Agreement with the City Planning and Community Investment Department's Incentive Zone Team, they are provided with due diligence advocacy and development permit expedite assistance. Currently, Housing Impact Fees

For more Information contact Toni Dillon, Business Development Officer, City of San Diego
TDillon@sandiego.gov or 619.533.4279

are waived for projects located in the state designated Enterprise Zone within the city of San Diego limits.

Business Tax Credits

Applicable business tax credits available are discussed in the section above on Enterprise Zones.

Industrial Development Bonds

Through a Joint Powers Agency the City of San Diego and California Communities can offer companies the ability to apply for IDB tax-exempt municipal bonds with interest rates substantially lower than commercial financing rates. These bonds are long-term financing with amortization periods up to 30 years (depending on the useful life of the assets financed). Certain public benefits must result from tax-exempt IDB issuance and the State and Federal governments impose certain limitations. Land, buildings and equipment are eligible uses of these funds with the minimum bond amount for land and building being $1 million and for equipment $250,000. The maximum bond issuance for manufacturers during an application period is $10 million.

Eligibility requirements include:

- At least 75% of the equipment and/or facilities financed must be directly involved in the manufacturing process;
- $10 million is the maximum amount of capital expenditures permitted for a company in the city of issuance for the period beginning three years before, and extending three years after, the date of bond issuance (the Internal Revenue Code also limits the aggregate amount of tax-exempt debt outstanding for a company at any one time to $40 million);
- Acquisition of an existing building can be financed by IDB's if at least 15% of the proceeds are used to remodel/rehabilitate the building;
- The State of California approval authorities are especially interested in retention/creation of jobs (typically 20 jobs/per $1 million of IDB's).

Credit enhancement is required to market non-profit bonds. It typically takes the form of a Letter of Credit (LC) issued by a commercial bank. In some instances, a third-party guarantee from some other investment grade entity may be substituted for an LC or the bonds may be privately place with a qualified financial institution. Up to two points of the up-front transaction cost can be financed and amortized over the bond term.

Interest rates on these bonds can vary; however the rates are at least 2% below conventional rates. The City's fees include: an application fee from $1,250 -$2,500 and .25% origination fee.

For more Information contact Toni Dillon, Business Development Officer, City of San Diego
TDillon@sandiego.gov or 619.533.4279

Congress of the United States
Washington, DC 20515

November 15, 2006

Mr. James E. Breson
Project General Manager
BP Corp. North America, Inc.
Energy Biosciences Institute
P.O. Box 3092
Houston, TX 77253-3092

Dear Mr. Breson:

We are writing as members of Iowa's congressional delegation to indicate our strong support of Iowa State University's partnership with the University of California-San Diego and the J. Craig Venter Institute to develop BP's Energy Biosciences Institute (EBI).

Iowa State University has long been a leader in the area of biofuels and bioproducts. Iowa State University faculty have produced breakthroughs in new crop varieties to enhance biofuel yield, new processes to maximize biofuel production, and new methods to produce biofuels from waste materials previously thought unusable. These breakthroughs have opened the door to the advances that will need to be made as our nation increases its use of alternative sources of fuel and energy.

As members of Iowa's congressional delegation, we are committed to building the future of the bioeconomy by actively supporting the research and discovery taking place at Iowa State University. Over the years, we have worked closely with the university to expand its capacity to perform the cutting-edge research necessary to develop the next generation of biofuels and bioproducts. With excellent facilities, researchers and staff, Iowa State University continues to be at the forefront of discovery of this evolving industry. We are confident that the university has successfully positioned itself to capitalize on its past successes and continue to blaze the trail of discovery in biofuels and bioproducts.

We look forward to continuing our partnership with Iowa State University and providing the necessary support needed for it to continue to be one of the nation's premier research institutions in biofuels and biobased products. To that end, our offices are eager to learn more from the November 28 "Call to Action Summit" at ISU which will help develop recommendations for the policies and the future investments in facilities and faculty that may be needed to support the UCSD/ISU/Venter proposal for the EBI.

We believe a partnership involving BP, the University of California-San Diego, the Venter Institute and the State of Iowa, through Iowa State University, will have a world-wide impact on the advancement of the bioeconomy. We look forward to working toward the success of the Energy Biosciences Institute.

Thank you very much.

Sincerely,

Charles Grassley
U.S. Senator

Tom Harkin
U.S. Senator

Tom Latham
Member of Congress

Jim Nussle
Member of Congress

Jim Leach
Member of Congress

Leonard Boswell
Member of Congress

Steve King
Member of Congress

November 8. 2006

Mr. James E. Breson
Project General Manager
BP Corp. North America. Inc.
Energy Biosciences Institute
P.O. Box 3092
Houston, TX 77253-3092

Dear Mr. Breson:

We are writing as leaders of the Iowa General Assembly to indicate our strong support of Iowa State University's partnership with the University of California-San Diego and the J. Craig Venter Institute to develop BP's Energy Biosciences Institute (EBI).

Iowa State University is exceptionally well positioned to participate in this opportunity. ISU has rapidly developed into one of the world's leading research and development institutions in the plant sciences and biorenewable resources. ISU faculty have already produced breakthroughs in new crop varieties to enhance biofuel yield, new processes to maximize biofuel production, and new methods to produce biofuels from waste materials previously thought unusable.

These efforts are very well aligned with the priorities of the State of Iowa. We view the production of bio-based fuels and materials as a critical component of Iowa's present and future economy. In recent years, the Iowa Legislature has adopted numerous tax and other policies to provide incentives for the production and utilization of bio-based renewable fuels such as ethanol and biodiesel. State financial assistance has been provided to help build many of the biofuels production facilities already in operation in the state. At Iowa State University, the Iowa Legislature has provided capital funding for key research facilities including the Molecular Biology Laboratory and the Carver Plant Sciences Co-Laboratory. Legislative funding is currently being used at ISU for direct support of cutting edge research and commercialization work in advanced ethanol production, biomass gasification, and biobased products.

The state of Iowa is prepared to make additional investments in energy research and biosciences. While we cannot make a firm commitment in advance of the 2007 Legislative Session, which starts next January, we commit to working closely with ISU to determine those needs and support them in the 2007 Legislative Session as strongly as possible. To that end, legislators from key committees will be attending the November 28 "Call to Action Summit" at ISU which will help develop recommendations for the

policies and the state investments in facilities and faculty that may be needed to support the UCSD/ISU/Venter proposal for the EBI, as well as support for other opportunities Iowa may have to accelerate the development of this critical industry.

We believe a partnership involving BP, the University of California-San Diego, the Venter Institute and the State of Iowa, through ISU, will have a world-wide impact on the advancement of the bioeconomy. We look forward to working toward the success of the Energy Biosciences Institute. Thank you very much.

Thank you very much.

Sincerely,

The Honorable Jack Kibbie
State Senator

The Honorable Christopher Rants
State Representative

The Honorable Mary Lundby
State Senator

The Honorable Chuck Gipp
State Representative

The Honorable Michael Gronstal
State Senator

The Honorable Patrick Murphy
State Representative

policies and the state investments in facilities and faculty that may be needed to support the UCSD/ISU/Venter proposal for the EBI, as well as support for other opportunities Iowa may have to accelerate the development of this critical industry.

We believe a partnership involving BP, the University of California-San Diego, the Venter Institute and the State of Iowa, through ISU, will have a world-wide impact on the advancement of the bioeconomy. We look forward to working toward the success of the Energy Biosciences Institute. Thank you very much.

Thank you very much.

Sincerely,

The Honorable Jack Kibbie
State Senator

The Honorable Christopher Rants
State Representative

The Honorable Mary Lundby
State Senator

The Honorable Chuck Gipp
State Representative

The Honorable Michael Gronstal
State Senator

The Honorable Patrick Murphy
State Representative

THE greater DES MOINES
partnership

November 16, 2006

Mr. James E. Breson
Project General Manager
BP Corp. North America, Inc.
Energy Biosciences Institute
P.O. Box 3092
Houston, TX 77253-3092

Dear Mr. Breson:

The Greater Des Moines Partnership, the regional economic and community development organization serving Greater Des Moines, strongly supports Iowa State University's (ISU) partnership with the University of California-San Diego and the J. Craig Venter Institute to develop BP's Energy Biosciences Institute (EBI).

The Partnership is dedicated to expanding our renewable fuels capacity, energy efficiency technology, and incentives to grow the use of such products and processes in our joint efforts with ISU, our biotechnology companies, and other critical industry partners to make Central Iowa the center of the emerging bioenergy industry in the United States.

ISU is leading the way in finding new and innovative solutions to the challenges facing biofuels and biobased products research and development. The commitment by the university to provide leadership in advanced renewable fuels is exemplified in their upcoming "A Call to Action Summit" to be held on November 28, 2006. This summit is a great example of how ISU is reaching beyond its campus to work with stakeholders from all sectors of the bioeconomy to advance research and discovery in this critical area. The Central Iowa business community continues to work closely with ISU to expand its capacity to perform the cutting-edge research necessary to develop the next generation of biofuels and bioproducts.

In summary, it is clear that a partnership involving BP, the University of California-San Diego, the Venter Institute and the State of Iowa, through ISU, will have a world-wide impact on the advancement of the bioeconomy. The Partnership looks forward to working with you toward the success of the Energy Biosciences Institute. Thank you in advance for your consideration.

Sincerely,

Martha Willits
President & CEO

The Partnership Building • 700 Locust St. • Suite 100
Des Moines, IA 50309 • tel 515-286-4950 • fax 515-286-4974
www.desmoinesmetro.com

AMES CHAMBER OF COMMERCE
1601 Golden Aspen Drive, Suite 110 ◆ Ames, IA 50010
t: 515.232.2310 ◆ f: 515.232.6716 ◆ www.ameschamber.com

November 16, 2006

Mr. James E. Breson
Project General Manager
BP Corp. North America, Inc.
Energy Biosciences Institute
P.O. Box 3092
Houston, TX 77253-3092

Dear Mr. Breson:

On behalf of the Ames Chamber of Commerce, I appreciate this opportunity to voice our support of Iowa State University's partnership with the University of California-San Diego and the J. Craig Venter Institute to develop BP's Energy Biosciences Institute (EBI).

We have a long term relationship with Iowa State University, and we know firsthand the leadership the University has given in the biorenewable fuels industry. The dynamic innovations that come from their faculty, programming, and the Iowa State University Research Park are unparalleled in their contributions to the scientific and research communities as well as the global bioeconomy.

The Ames business community, including and surrounding Iowa State University, already plays a significant role in biotechnology through the fields of agriculture, veterinary medicine, genetics, pharmaceuticals, engineering, plant sciences, nanosciences, bio-agronomics and more. With close attention to education, economic development and quality of life, Ames will continue to meet the needs of biotech companies and researchers long into the future.

The Ames community is committed to sustaining and further development of this perfect climate for biotechnology by actively supporting the research and development occurring at Iowa State University. We are convinced that a partnership between BP, the University of California-San Diego, the Venter Institute, and Iowa State University will have a tremendous impact on our nation and our world, and will help shape the future of the bioeconomy.

Thank you for your time and consideration.

Sincerely,

Eve A. Doi
Associate Director of Chamber Relations

UNIVERSITY
COMMUNITY
OPPORTUNITY
AMES
IOWA

BIOCOM

November 14, 2006

Lord John Browne
Chief Executive, British Petroleum
1 St. James Square
London, SW1Y4PD
United Kingdom

Dear Lord Browne:

BIOCOM leads the advocacy efforts of the Southern California life science community with more than 500 members including biotechnology and medical device companies, universities, basic research institutions, and service support firms. As the largest regional life science trade organization in the world, we would to express our support for UC San Diego's proposal in response to British Petroleum's (BP) announcement to create a $500 million Energy Bioscience Institute, or EBI, on or adjacent to a major research university. UCSD and the San Diego region are uniquely qualified as a site for this critical center.

As you are probably aware, the San Diego region is consistently ranked as one of the top three biotechnology research hubs in the country. The unique needs of California, with its more stringent environmental laws and large potential market make San Diego a logical choice. Location of the Institute in San Diego may speed acceptance and commercialization of technologies developed there. Expedited integration into one of the worlds largest energy markets would be but one of the many benefits.

The San Diego biotechnology hub has a well-earned reputation for being uniquely collegial. It boasts three world-class universities, two of them public, including UCSD. UCSD has many renowned biotechnology research institutes within a 10 mile radius. The entrepreneurial spirit of the scientists of our region has fostered the creation of over 500 biotechnology companies in the San Diego region, many using discoveries from UCSD and its neighboring research institutes. This pre-existing synergy would be invaluable for the Energy Bioscience Institute in tapping the tremendous resources available.

We are very proud of UCSD as one of only five institutions worldwide to be invited to participate in this competition, and commend BP for taking the initiative to create and fund a cutting-edge center to investigate the application of bioscience and biotechnology to the energy challenges we all face. We applaud the new directions being proposed for the Institute, particularly the application of modern biology and genetics to energy problems. Previous such applications have concentrated largely on advances in human health and medicine.

4510 EXECUTIVE DRIVE, PLAZA ONE, SAN DIEGO, CA 92121 TEL 858-455-0300 FAX 858-455-0022 WWW.BIOCOM.ORG

UC San Diego, partnering with one of America's top agricultural research schools, Iowa State University, and the internationally renowned J. Craig Venter Institute, has assembled an extremely competitive proposal for the BP EBI, which will occupy a place of pride and prominence here in our region. Taken with the similar creativity and innovation of its partner institutions, the UC San Diego proposal creates an optimal scenario for BP's EBI that is unsurpassed.

We commend your efforts on this issue of global importance, and encourage your strongest consideration of the UCSD proposal for this visionary research endeavor. Please do not hesitate to contact me if we can be of service to you or answer any questions you may have about the many positives the San Diego region can bring to the Energy Bioscience Institute. Thank you for your consideration of our comments.

Sincerely,

Joe Panetta
President & CEO
BIOCOM

Additional Exhibit: *Miscellaneous*

Above *Scripps Pier at sunset—courtesy of John Wooley*

San Diego

San Diego is a coastal Southern California city located in the southwestern corner of the continental United States. As of 2006, the city has a population of 1,311,162 people. It is the second largest city in California and the eighth largest in the United States. The larger metropolitan area is the seventeenth-largest in the United States, with a population over 2.9 million. It lies just north of the Mexican border and is a home for United States Navy, United States Coast Guard and United States Marine Corps bases, many miles of beaches, and a mild Mediterranean climate. The annual mean temperature is 64.4˚ Fahrenheit (18˚C). San Diego's economy centers on tourism, trade, agriculture, ship-building, the military, biotechnology, computer science and electronics.

The University of California, San Diego (UCSD) and nearby research institutes on Torrey Mesa provide a base for technological innovation, and there are numerous high-tech and biotech companies in the area, such as Qualcomm, Neurocrine, Illumina, and Genentech of Oceanside. Major tourist attractions include the city's beaches and bays, Balboa Park with its many museums, the San Diego Zoo, Sea World, San Diego Wild Animal Park and Old Town, the site of the original Spanish settlement.

Downtown San Diego is located on San Diego Bay. Balboa Park lies on a mesa to the northeast. It is surrounded by several dense urban communities and abruptly ends with Mission Valley to the north. Coronado and Point Loma separate San Diego Bay from the ocean. Ocean Beach is on the west side of Point Loma. Mission Beach and Pacific Beach lie between the ocean and Mission Bay, a man-made aquatic park. La Jolla, an affluent community, lies north of Pacific Beach. Mount Soledad in La Jolla offers views from northern San Diego County to Mexico.

Mountains rise to the east of the city, and beyond the mountains are desert areas. Cleveland National Forest is a half-hour drive from downtown San Diego. Numerous farms are found in the valleys northeast of the city. The city of San Diego itself has deep canyons separating its mesas, creating small pockets of natural parkland scattered throughout the city.

Military bases in or near San Diego include U.S. Navy ports, Marine Corps bases, and Coast Guard stations. San Diego is the home port of the largest naval fleet in the world, including two Navy supercarriers (the USS Nimitz and the USS

Above *USA, California, San Diego, skyline at dusk, March 2006*

Ronald Reagan), five amphibious assault ships, several Los Angeles-class submarines, and many smaller ships.

Four Navy vessels have been named USS San Diego in honor of the city.

History

The area has long been inhabited by the Kumeyaay people. The first European to visit the region was Portuguese explorer Juan Rodriguez Cabrillo, who sailed his flagship, the San Salvador, from Navidad (Mexico). Cabrillo claimed the bay for Spain and named the site San Miguel. In November of 1602, Sebastian Vizcaíno arrived with his flagship "San Diego," sent north by Spain from Navidad in Mexico. Vizcaíno surveyed the harbor and what is now Mission Bay and Point Loma, naming the area for the Spanish Catholic saint St. Didacus (More commonly known as San Diego). November 12, 1602, the first Christian religious service of record in California was conducted by Fray Antonio de la Ascensión, a member of Vizcaíno's expedition, to celebrate the feast day of San Diego.

In 1769, the Presidio of San Diego (military post), which overlooks Old Town, was established at almost the same time as Mission San Diego de Alcalá was founded by the Franciscan friars led by Junípero Serra. By 1797 the mission boasted the largest native population in Alta California (over 1,400 neophytes lived in and around the mission proper). Mission San Diego de Alcalá's fortunes declined in the 1830s after the decree of secularization was enacted, as was the case with all of the missions.

With the end of the Mexican-American War and the gold rush of 1848, San Diego was designated the seat of the newly-established San Diego County and was incorporated as a city in 1850. In the years before World War I, the anti-capitalist labor union IWW had a major impact on labor struggles in San Diego.

Significant U.S. Naval presence began in 1907 with the establishment of the Navy Coaling Station, which gave further impetus to the development of the town. San Diego hosted two World's Fairs, the Panama-California Exposition in 1915 and the California Pacific International Exposition in 1935. Many of the Spanish/Baroque-style buildings in the city's Balboa Park were built for these expositions (especially for the one in 1915). Intended to be temporary structures, most remained in continuous use until they progressively fell into disrepair. All were eventually rebuilt using castings of the original facades to faithfully retain the architectural style.

Above *Surfer at Torrey Pines Reserve*

After World War II, the military played an increasing role in the local economy. But at the end of the Cold War the local economy experienced a downturn due to cutbacks in the local defense and aerospace industry. San Diego leaders sought to diversify the city's economy, and San Diego has since become a major center of the emerging biotech industry. It is also home to telecommunications giant Qualcomm.

Downtown San Diego has been enjoying an urban renewal since the 1980s, beginning with the opening of Horton Plaza, the revival of the Gaslamp Quarter, and the construction of the San Diego Convention Center. The Centre City Development Corporation (CCDC), San Diego's downtown redevelopment agency, has transformed what was a largely abandoned downtown into a glittering showcase of waterfront skyscrapers, live-work loft developments, five-star hotels and a slew of cafes, restaurants and shops.

The North Embarcadero is slated to have parks in addition to a waterfront promenade. And Balboa Park will be linked to downtown with a view corridor. In the meantime, the city is committed to a "smart growth" development scheme that would increase density along transit corridors in older neighborhoods (the "City of Villages" planning concept.) The latest accomplishment of CCDC has been the recent inauguration of PETCO Park. The once-industrial East Village adjacent to the new ballpark is now the new frontier in San Diego's downtown urban renewal.

Economy

National defense is a major employer in the city and the region as a whole due to a large presence of military installations. Tourism is also a major industry owing to the city's climate and other major attractions. Major tourist destinations include the San Diego Zoo and its sister park, the Wild Animal Park, Seaworld San Diego,

Below *Balboa Park*

Balboa Park and the city's numerous beaches.

San Diego is also home to companies that develop wireless cellular technology. Qualcomm Incorporated was founded and is headquartered here, and the company is the county's largest private-sector technology employer (excluding hospitals), with more than 6,000 employees in San Diego. Other companies also have research and development labs in San Diego, principally focused on cloning Qualcomm's CDMA cellular technology.

The economy of San Diego is also influenced by its port, which includes the only major shipbuilding yard on the West Coast, as well as the naval base.

Climate

San Diego enjoys mild, sunny weather throughout the year. Average monthly temperatures range from about 57° Fahrenheit (14°C) in January to 72 Fahrenheit (22°C) in July, although late summer and early autumn are typically the hottest times of the year. Snow and ice do not occur in the wintertime. "May-gray and June-gloom," a local saying, refers to the way in which San Diego sometimes has trouble shaking off the fog that comes in during those months. Temperatures soar to very high readings only on rare occasions, chiefly when easterly winds bring hot, dry air from the inland deserts (these winds are called "Santa Anas"). The average annual precipitation is less than 12" (300 mm), resulting in a borderline arid climate. Rainfall is strongly concentrated in the cooler half of the year, particularly December through March. The summer months are virtually rainless. Rainfall is variable from year to year and from month to month, and San Diego is subject to both droughts and floods. Thunderstorms and hurricanes are very rare.

Climate in the San Diego area often varies dramatically over short geographical distances, due to the city's topography (the Bay, and the numerous hills, mountains, and canyons). Frequently, particularly during the "May-gray June-gloom" period, a thick *marine layer* cloud cover will keep the air cool and damp within a few miles of the coast, but will yield to bright cloudless sunshine between about 5 and 15 miles inland—the cities of El Cajon and Santee for example, rarely experience the cloud cover. This phenomenon is known as microclimate.

Crime

San Diego has had a declining crime rate since the early 1990s. In September of 2006, San Diego was named the fourth safest city in the nation.

Education

According to education rankings released by the U.S. Census Bureau, 40.4% of San Diegans ages 25 and older hold bachelor's degrees. The census ranks the city as the ninth smartest city in the United States based on these figures.

Cuisine

Owing to its privileged position on the Pacific Ocean and its warm Mediterranean-like climate, San Diego enjoys an abundance of quality produce and dining. The renowned Chino Farms in nearby Rancho Santa Fe provides fresh organic produce both to local restaurants and two restaurants in San Francisco and other cities. There is also a wine growing

industry in San Pasqual Valley and Temecula.

Given its ethnic and cultural mix, it is not surprising that San Diego has a wide range of cuisines. One can find Mexican, Italian, French, Spanish, Filipino, Greek, Latin, German, Indian, Central and East Asian, Middle Eastern and Pacific Islander food throughout the city. In addition, there are numerous seafood restaurants and steakhouses. The city's long history and close proximity to Mexico has endowed the area with an extensive variety of authentic Mexican restaurants. Regional homemade specialties, border fare and haute cuisine are all readily available.

San Diego's warm, dry climate and access to the ocean have also made it a center for fishing and for growing fruits and vegetables. Long a center of the tuna industry, San Diego benefits from an abundant supply of seafood.

Many of the most popular restaurants can be found in the Gaslamp Quarter, Little Italy, La Jolla, Hillcrest and Old Town. Local specialties include:

- Mexican *(carne asada, rolled tacos, California burritos, burritos, fish tacos, enchiladas, carne asada fries, and ceviche)*
- Woodfired, California-style pizza
- Salads made from fresh, local produce *(including Caesar, Greek, Mixed, and Caprese Salads)*
- Southern Italian pastas, panini, and pizzas
- Shish kebab, shashlyk, and Gyros
- Southeast Asian specialties of all kinds.
- Locally produced, artisan bread
- Local Wines *(San Pasqual Valley, Rancho Bernardo)*
- A vibrant craft brewing community featuring 22 brewpubs, microbreweries and one regional specialty brewery (Stone Brewing). San Diego brewers have become famous for pioneering several specialty beer styles, most notably the American Double India Pale Ale. Three San Diego County breweries are consistently rated in the Top 10 breweries in the world by RateBeer.com (AleSmith Brewing Company, Pizza Port/Port Brewing, and Stone Brewing Co.). Unfortunately, none of San Diego's old breweries (such as Aztec Brewing Company) survived the spread of big national brewing companies.
- Locally produced (from the mountains near Julian) hard and sweet apple cider
- Various fruits and vegetables (including avocados, tomatoes, mushrooms, olives, eggplant, oranges, lemons, limes, strawberries, grapefruit, grapes, apples, pomegranates, persimmons and melons)

Sites of Interest

San Diego is a major tourist destination, attracting visitors from all over the world. Among the many attractions are its beaches, climate, and deserts. Noted San Diego tourist attractions include:

- Del Mar Beach
- Crystal Pier
- Balboa Park*
- Belmont Park
- Berkeley, ferryboat *
- Birch Aquarium at Scripps Institution of Oceanography
- Black's Beach nude beach
- Cabrillo National Monument at Point Loma
- Chicano Park
- Downtown San Diego
- Gaslamp Quarter
- Hillcrest, San Diego, California Neighborhood
- La Casa de Estudillo *
- La Jolla
- Little Italy
- MCAS Miramar Marine Corps Air Station Miramar and Miramar Airshow

Above *Sunset Cliffs*

Club	Sport	League	Stadium
San Diego Padres	Baseball	MLB (National League)	PETCO Park
San Diego Chargers	American Football	AFL 1961-69, NFL 1970-Present	Qualcomm Stadium
San Diego Fusion	Soccer	NPSL	Helix High School
San Diego Gauchos	Soccer	USL	Southwestern College
San Diego Surf Dawgs	Baseball	Golden Baseball League	Tony Gwynn Stadium
So Cal Scorpions	American Football	WPFL	Edward's Stadium
San Diego Siege	Basketball	National Women's Basketball League	Harry West Gym
San Diego Wildcats	Basketball	ABA	TBA
San Diego Riptide	American Football	Arena Football League	IPay One Center

- Mission Bay Park
- Mission Beach Roller Coaster at Belmont Park
- Mission San Diego de Alcalá *
- Mount Soledad
- Old Globe Theatre
- Old Mission Dam in Mission Trails Regional Park *
- Old Town
- Pacific Beach
- Petco Park
- Point Loma
- Presidio of San Diego *
- Qualcomm Stadium
- Salk Institute for Biological Studies
- San Diego Aerospace Museum
- San Diego Chinese Historical Museum
- San Diego Wild Animal Park
- San Diego Zoo
- Seaport Village
- SeaWorld
- Star of India, barque sailing ship *
- Torrey Pines Golf Course
- Torrey Pines State Reserve
- Union Station*
- University of California, San Diego
- USS Midway (CV-41), aircraft carrier museum

** National Historic Landmarks*

San Diego is about two hours south of Los Angeles, California and north adjacent to Tijuana, Baja California, Mexico.

San Diego is served by the mainstream daily newspaper, the Union-Tribune and its online portal, signonsandiego.com, online newspaper Voiceofsandiego.org, and the alternative newsweeklies, City Beat and San Diego Reader. Another newspaper with high readership in the region is the North County Times, which serves San Diego's North County area. Business publications include San Diego Metropolitan magazine, San Diego Business Journal and San Diego Daily Transcript.

San Diego's television stations include XETV-TV 6 (FOX), KFMB 8 (CBS), KGTV 10 (ABC), KPBS 15 (PBS), KBNT 17 (Univision), XHAS-TV 33 (Telemundo), K35DG 35 (UCSD-TV), KNSD 39 (NBC), XHDTV-TV 49 (MNTV), KUSI 51 (Independent), and KSWB 69 (CW).

Biofuels: A new approach to energy independence

By Arthur B. Ellis
November 23, 2006

California has long been a trendsetter in technological innovation and environmental progress. What our state does is closely followed by the rest of the nation.

That's why the California Global Warming Solutions Act of 2006 – the first bill designed to achieve quantifiable reductions in greenhouse gases – is once again forcing the rest of the country to take note. Signed into law two months ago, it requires industries to reduce carbon dioxide and other greenhouse gas emissions 25 percent by 2020.

This bold, bipartisan effort by Gov. Arnold Schwarzenegger and the Legislature is expected to push the development of innovative green technologies, create an estimated 83,000 new jobs and increase income in the state by more than $4 billion through the expanded purchasing power of companies that see substantial decreases in their energy costs, according to the Climate Action Team, the state entity responsible for implementing the law.

Because of California's clout as the sixth-largest economy in the world, the effort is also likely to become a national model, prompting industries to implement many of the green and energy-saving technologies developed here. And it will stimulate research to develop new energy-saving technologies and alternatives to fossil fuels, especially in California.

Here at the University of California San Diego, we have embarked on a new initiative to apply our expertise in plant sciences, microbiology, systems biology, physical sciences, engineering, economics, climate, metagenomics and cyberinfrastructure to the development of alternatives to fossil fuels. We have created a pioneering enterprise called the Center for Bio-Energy Science and Technology, or CBEST, through which we intend to bring biology to the forefront of creating renewable and reliable clean energy as well as compete for major research grants in biofuels.

This interdisciplinary center, while based here, will bring together scientists from a variety of fields at UCSD and other institutions – such as Iowa State University, the Salk Institute, the Scripps Research Institute and the Battelle Memorial Institute in Washington state – to explore and advance biofuels science, engineering and technology. It will also involve a long-term relationship with the J. Craig Venter Institute, a nonprofit research institute dedicated to the advancement of the science of genomics.

Over the past decade, research universities such as UCSD have successfully applied advances in our understanding of the human genome to the development of new pharmaceuticals and other treatments targeted to specific diseases and means of improving human health. Through CBEST, we intend to apply our knowledge of the plant genome as well as biotechnology to new sources of energy that are more environmentally friendly than the fuels now in use.

While industry will undoubtedly see the economic value of bringing such technologies to the marketplace, we believe it is our responsibility as a publicly supported research institution to jump-start the fundamental research

that will enable companies to develop commercial solutions down the road.

One of the basic research challenges facing scientists in the United States and other parts of the world today is how to efficiently transform cellulose into sugars that can be converted into ethanol for energy. Brazil has weaned itself away from imported oil by converting its sugar crops into ethanol-based fuels. But in the United States, where other plants are the major crops, that's a bigger challenge, because converting cellulose to ethanol is a much less cost-effective process.

If we can use biotechnology to develop new enzymes that can break down plant cell walls or learn from the plant genome how to biologically degrade cellulose easily into sugars, we will not only be able to efficiently turn corn into alcohol, we may be able to convert much of agricultural waste into useful fuel.

There are other critical questions we intend to address with CBEST: How can we begin to replace increasingly expensive imported oil and natural gas reserves with biologically produced fuels or biofuels? How can we use biofuels to limit increases in greenhouse gases that are responsible for global warming and climate change? With the new requirements for businesses to reduce carbon dioxide emissions in California, how do we create competitive industries that will have markets outside our state where no such restrictions exist?

Biofuels won't be the panacea for our energy future. That's why, in addition to its primary focus on the development of advanced biofuels, CBEST will also conduct research on broader applications of biosciences to energy, including developing ways to improve the recovery of oil and to sequester carbon dioxide from the atmosphere to reduce global warming.

The development of biofuels here at UCSD makes perfect sense for a region that is one of the nation's centers of biotechnology and for a state with a major agricultural economy. With CBEST, we intend to help California remain the nation's trendsetter in technological innovation and environmental progress for many years to come.

■ Ellis is vice chancellor for research at UC San Diego.

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