defining who we are.

INSTITUTE FOR GENOMIC BIOLOGY
2012 ANNUAL REPORT

We live in a world of complex issues. Climate Change. Antibiotics. Biofuels. Scientists the world over pursue a deeper understanding of these issues. At the Institute for Genomic Biology, we believe the best way to answer these formidable questions is to undertake them together. We challenge convention, innovate, and get creative to discover solutions. Collaboration in a wide variety of disciplines is not simply a part of how we operate. It's the core belief in a new way of thinking.

TABLE OF CONTENTS

defining who we are.

director's message

gene e. robinson

Five years ago, when the Institute for Genomic Biology first opened its doors, we were a dream; we were a vision; we were an inspiration; we were an idea.

Today that dream has come true. We are more than 800 people: faculty, staff, post docs, graduate and undergraduate students, working together toward our common goal to transform life sciences research. We focus on the significant problems facing humanity, such as treating chronic human diseases, managing new and emerging pests and pathogens, and maintaining an abundant and healthy food supply. We also address fundamental questions in science, like the origin of life and how the brain works.

Our researchers represent more than 30 different departments across campus. Working together at the IGB enables them to combine different sub-disciplines of biology with technologies, approaches, and information from disciplines as varied as engineering, computer science, physics, chemistry, mathematics, and the geological, atmospheric, and social sciences. We concentrate on collaborative, interdisciplinary and transformative research. This approach, central to the very nature of the Institute, is one of our great strengths. The breadth of innovation and invention that takes place among our research teams is unique to our facility and grants us multiple paths to discovery. Our cross-disciplinary environment nurtures creativity and leads to breakthrough discoveries.

We are a bioeconomic development engine for the state. Our discoveries are starting to reach the marketplace, and we expect that they will help create a market for well-paid, skilled positions in Illinois. We also are reaching out to our local community, to young people and old, to those already interested in science and to those who aren't so sure. We are sharing our vision, our inspiration and our ideas as ambassadors of science. We have touched lives, from the hundreds of children who attended our learning event Genome Day, to the citizen scientist retiree who shares a lab with a young PhD student as part of the Osher Lifelong Learning Institute.

We are partnering with researchers at other top-flight institutions to leverage our creativity, our hard work and our ability to solve problems. Those partnerships, around the state, the country and the world, are changing the landscape of medicine, fighting poverty and hunger, protecting and improving the environment and advancing fundamental research.

We have enjoyed many successes: The state of Illinois invested $75 million in 2003 to fund the construction and start up of the IGB. In less than a decade we have generated double that amount, via grants and contracts from federal agencies, major corporations and leading philanthropic foundations. That represents a 100 percent return on investment; an achievement we take great pride in. Our scientists have generated more than 75 invention disclosures, more than 35 patent applications, and more than 1,100 scholarly journal articles since the founding of the Institute.

Among our discoveries are:

- A new antibiotic to combat food-borne diseases
- A technique to isolate tumor-seeding cancer cells
- A tiny biological machine capable of locomotion
- A new yeast strain that improves biofuels production
- A genome map of the energy crop *Miscanthus sinensis*

IGB faculty continue to be recognized for their achievements, both our established members as well as those early in their career. This year alone we have seen our faculty awarded a Guggenheim Foundation Fellowship, a Packard Fellowship, a Young Investigator Award from the Animal Behavior Society, and a National Institutes of Health Director's New Innovator Award.

We have enjoyed enormous success thus far, and we are excited to continue to build on that success. New discoveries and technologies are limited only by our imagination and inspiration. We are clearly poised to lead the way forward. Genomic biology will continue to help solve some of the grand challenges in biology, medicine, agriculture and the environment. In five short years the IGB, with its integrative, interdisciplinary and collegial approach, has blazed the trail.

We are on the right path. Our journey continues. Won't you join us?

Gene E. Robinson
Director, Institute for Genomic Biology

IGB OVERVIEW

What is a genome? Within an organism, it's all the DNA: pieces called genes that tell our cells how to make the molecules that living things need to grow, to get energy from food, to do anything, and pieces that help control when and where those molecules are made. Every organism, whether a person, a tree, a microbe, or any other type of living thing, has its own collection of genes; what they are, how they came to be, and how they act together are what make that organism unique. Genomic biology, the foundation of our institute, is the study of how this happens. Established in 2003, the Institute for Genomic Biology (IGB) harnesses new and emerging genomics technologies to advance basic biology research and to apply those innovations to create useful products and high-tech jobs.

Our state-of-the-art facility, officially dedicated in March 2007, has generated more than $150 million in grants and contracts. Our success lies in our setting: We provide space for experts from multiple disciplines to assemble under one roof — within one lab space — to share their knowledge and expertise. More than 130 faculty members from over 30 departments across the University of Illinois, not to mention nearly 600 postdoctoral researchers, graduate, and undergraduate students, come together to pursue fundamental research and undertake some of the greatest challenges that confront our society relating to food, health, and energy.

Within IGB's broad scope of systems biology, cellular and metabolic engineering, and genome technology, specialized teams help us focus on asking big, complex questions and then answering them, experiment by experiment. Just as researchers intermingle and invigorate one another, so these teams intersect, advancing technology transfer, education, and engagement with partners in genomic biology.

Those eight specialized teams, referred to as research themes, are:

Biocomplexity, looking at the collective behavior of biological systems, and focusing on exploring the nature of life on Earth.

Business, Economics and Law of Genomic Biology, concerning university-industry technology transfer; intellectual property protection; and the impact of biotechnology on industry.

Cellular Decision Making in Cancer, investigating cell decisions regarding maintenance, replication, repair, recombination, and programmed cell death.

Genomic Ecology of Global Change, examining how global changes affect the ecosystem and how environmental changes on the function of an ecosystem can be predicted.

Gene Networks in Neural & Developmental Plasticity, researching the structures and functions of gene regulatory networks, how they can be modified to yield biological diversity, and how changes can alter behavioral and developmental diversity and plasticity.

Host-Microbe Systems, employing genomic technologies to study the dynamic interactions between humans and the microbial populations that live inside of them, including beneficial as well as pathogenic microbes.

Mining Microbial Genomes, searching for how metabolites (small molecules with unique, and often medically relevant, properties) are produced and created in microorganisms.

Regenerative Biology & Tissue Engineering, developing a knowledge base and technologies needed to replace or regenerate human tissues and organs, to solve severe health issues and contribute to improving life quality.

The IGB, together with the University of California, Berkeley, and the Lawrence Berkeley National Laboratory, is also part of the Energy Biosciences Institute (EBI), an international effort to develop cellulosic fuels (derived from non-food plants) and harness fossil fuel microbiology to help solve the global energy challenge. The EBI is supported by a $500-million, 10-year award from energy company BP.

Further, we have partnered with leading global health care company Abbott and the Beckman Institute for Advanced Science and Technology on campus to establish the first-ever multidisciplinary research center, the Center for Nutrition, Learning, and Memory, to determine the impacts of nutrition on learning and memory in the human brain.

We invite you to discover on the following pages the combination of collaboration and multidisciplinary expertise that is the unique strength of the IGB.


we are
the researchers
working together
to advance
understanding
legal scholars
microbiologists
entomologists
biochemists
animal scientists
physicists
economists
crop scientists
chemist
geomicrobiologists
electrical/computer engineers

IGB is a hub that connects scientists from a myriad of fields. Microbiologists, physicists, crop scientists, electrical and computer engineers, geomicrobiologists, animal scientists, economists, chemists, biochemists, entomologists, legal scholars and others gather to ask questions of one another, to collaborate and share in the thrill of discovery. Instead of being organized along academic disciplines, we are organized into research groups - called themes - according to specific challenges or problems that confront our society. IGB researchers from all fields gather to brainstorm together — to cross-pollinate. This environment invigorates and enlivens their research projects and often results in new collaborations and new insights.

The IGB is a creative, collaborative environment combining fundamental research with a focus on solving real-world problems in agriculture, health, and energy use. The IGB's large, shared laboratories harness the University's strongly collegial and interdisciplinary culture. Our core facilities house high-end microscopy and imaging instruments. The energetic, talented and enthusiastic core facilities staff strongly encourage innovation and are always available to provide support, not just with instruments but also with experiment design and data analysis. Our computing facilities are equally powerful and outstanding. At its heart, IGB provides space, both intellectual and physical, to conduct intricate, exhaustive, and, above all, exciting research into the mysteries of life.

IGB is a hive of activity. With advances in genomics IGB scientists are improving biofuels, reducing the cost and reliance on fossil fuels. These researchers collaborate with economists, legal scholars and computer scientists to analyze policies and optimize biofuel production from field to refinery. IGB scientists are seeking to increase the efficiency of photosynthesis and breed plants with increased ozone tolerance. These efforts will both advance our understanding of basic biological processes in the face of global warming and also help meet the world's burgeoning food needs. IGB members collaborate with others, within the University and around the world, to understand the role of microbes in human health, solve the challenge of antibiotic resistance, discover new antibiotics, and tackle cancers. Genomics experts team with physicists to understand and visualize how DNA repairs itself. Physicists and microbiologists work together to seek life itself in space, to create cardiac cell-powered biobots, and to further explore the mysteries of microbes.

IGB RESEARCH THEMES

BCXT	*Biocomplexity*
BIOBEL	*Business, Economics and Law of Genomic Biology*
CDMC	*Cellular Decision Making in Cancer*
GEGC	*Genomic Ecology of Global Change*
GNDP	*Gene Networks in Neural & Developmental Plasticity*
HMS	*Host-Microbe Systems*
MMG	*Mining Microbial Genomes*
RBTE	*Regenerative Biology & Tissue Engineering*
EBI	*Energy Biosciences Institute*
CNLM	*Center for Nutrition, Learning, and Memory*

RESEARCH HIGHLIGHTS

ORIGINS OF LIFE QUESTIONS

An interdisciplinary team led by Nigel Goldenfeld (theme leader, BCXT), Swanlund professor of physics, received a five-year, $8-million grant from NASA's Astrobiology Institute (NAI) to study the origin and evolution of life. How does life begin and evolve? Is there life beyond Earth? Why does life exist at all? These are the kinds of questions the team is addressing. Building on groundbreaking work by the late Carl Woese, the project's goal is to characterize the fundamental principles governing the origin and evolution of life anywhere in the universe. The multidisciplinary effort to define and characterize "universal biology" includes leading-edge scientists from the fields of microbiology, geobiology, computational chemistry, genomics, and physics. The team is using genomics to explore deep evolutionary time through computer simulations and laboratory

Members of the Illinois NASA Astrobiology Institute research team, from the Institute for Genomic Biology's Biocomplexity research theme. Top row, from left: Lee DeVille, Nigel Goldenfeld, Charles Werth. Bottom row, from left: Isaac Cann, Rachel Whitaker, Elbert Branscomb, Carl Woese (deceased), Bruce Fouke, Zan Luthey-Schulten, Rod Mackie. Not pictured: Gary Olsen

Distinct patterns of gene activity were discovered in molecular pathways known to be associated with thrill seeking in humans in the brains of novelty-seeking bees, in a NSF/NIH funded study led by professor of entomology and IGB Director Gene Robinson.

investigations, looking for signatures of early collective states of life that would have preceded the rise of individual organisms on earth.

PIG GENOME REVEALED

Working with colleagues in the Netherlands, Scotland, France, South Korea, Japan, China, Denmark, and Italy, Gutgsell professor and geneticist Larry Schook (RBTE), bioengineer Jian Ma (CDMC) and James R. Eiszner Family Chair and chemist Jonathan Sweedler (MMG) published a draft sequence of the pig in *Nature*. Scientists will use the information to breed healthier and meatier pigs and to create more faithful models of human disease. This "reference genome" will speed progress on both fronts, perhaps eventually making it possible for pigs to be engineered to provide organs for transplant into human patients. This project, which took many years and the work of many scientists, was funded in part by the USDA and NIH.

INSECT PERSONALITIES

A study funded by NSF and NIH and led by Gene Robinson, Swanlund professor of entomology and director of IGB, suggests that thrill seeking is not limited to humans and other vertebrates. Some honey bees, too, are more likely than others to seek adventure. The brains of these novelty-seeking bees exhibit distinct patterns of gene activity in molecular pathways known to be associated with thrill seeking in humans. The findings, published in *Science*, offer a new window on the inner life of the bee hive, which once was viewed as a highly regimented colony of seemingly interchangeable workers taking on a few specific roles (nurse or forager, for example) to serve their queen. Now it appears that individual honey bees actually differ in their desire or willingness to perform particular tasks. Researchers used whole genome microarray analysis and found thousands of distinct differences in gene activity in the brains of scouting and non-scouting bees.

The magnitude of the differences was surprising to researchers, given that both scouts and non-scouts are both foragers. Among the many differentially expressed genes were several related to catecholamine, glutamate and gamma-aminobutyric acid (GABA) signaling. The researchers zeroed in on these because they are involved in regulating novelty seeking and responding to reward in vertebrates.

BREAKING DOWN THE WALL

A big barrier to affordable biofuel is the expense of processing hemicellulose, a cell-wall component that makes up about half of the available plant material. Many microbes can ferment cellulose but not hemicellulose. Microbiologist Rod Mackie (BCXT/EBI), a long-distance runner, may have found the dream microbe in a garbage dump while running in Hoopeston, Ill., in 1993. He noticed that the ground was bubbling with microbial activity and took samples.

This bacterium, *Caldanaerobius polysaccharolyticus,* contains all of the proteins and enzymes needed to break down xylan — the most common hemicellulose — transport the fragments into the cell and metabolize them. This microbe is also thermophilic; its enzymes are resistant to temperatures as high as 70°C. Most microbes can survive only at about 37°C, which means the fermentation vats are easily contaminated.

The genes involved in breaking down xylan are located in a single cluster on the microbe's genome. The cluster could be designed as a gene and put into a microbe that normally degrades only cellulose. The next step of the project, which is funded by the Energy Biosciences Institute, is to develop techniques for transferring this gene cluster, which is quite large, into microbes.

GETTING GREENER: IMPROVING PHOTOSYNTHESIS

Plants currently operate at only about one-third of their potential efficiency when it comes to photosynthesis, says Gutgsell professor and plant biologist Stephen Long (GEGC/EBI). Though boosting photosynthesis has the potential to increase yields and reduce the use of water and nitrogen, it has not yet been

(left) Professor of agricultural and consumer economics Madhu Khanna with members of the EBI created a tool to evaluate feedstock profitability. (right) Professor of physics Nigel Goldenfeld, shown here with long-time friend and colleague the late Carl Woese on the right, co-authored a PNAS article on the impact of Woese's discovery of Archaea.

addressed by conventional breeding methods. Long and his team have set about looking for the genetic switches that, if manipulated, could ramp up the plant's ability to harness the sun, consequently making more food. With more than 100 different proteins playing a role in photosynthesis, interacting in countless different permutations, the possibilities were almost limitless. So the team turned to their colleagues at NCSA (National Center for Supercomputing Applications). Together they broke the highly complex photosynthetic system down into a long series of mathematical equations and fed them to into NCSA's supercomputer, which provided a list of "best-bet" interventions.

ENERGY MODELING FOR SUCCESS

Research into biofuel crops such as switchgrass and miscanthus has focused mainly on how to grow these crops and convert them into fuels. But it takes many steps to get from the field to the pump. Biomass must be harvested, transported, stored and delivered. Each step could help or hinder the growth of this new industry. K.C. Ting (EBI), a professor of agricultural and biological engineering, with Energy Biosciences Institute research professor Yogendra Shastri and agricultural and biological engineering professors Alan Hansen (EBI) and Luis Rodriguez (EBI), developed a new computer model to tame the countless variables involved in getting biomass to the refinery. The program, funded by the Energy Biosciences Institute, can run millions of simulations, optimizing operations to bring down costs, reduce greenhouse gas emissions or achieve other goals. The model takes into account regional attributes such as weather, crop yield, farm size and transport distances, and can optimize more than 300,000 variables, including harvest schedules, equipment selection, storage sizing, transport distances and the logistics of moving the biomass from place to place.

ENERGY: CALCULATING PROFITABILITY

Research by Madhu Khanna (BioBEL/EBI), professor of agricultural and consumer economics, and Haixiao Huang, of the Energy Biosciences Institute, has resulted in the Feedstock Cost and Profitability (FCAP) calculator. The FCAP provides an estimate of the breakeven price needed to cover the costs of producing biomass from alternative feedstocks. Feedstocks include crop residues from corn and energy crops like miscanthus, switchgrass, mixed grasses and hybrid poplar. The calculator computes the minimum price per ton of biomass crop that would be needed to cover all the costs of producing the biomass. It runs the scenario on both marginal land and cropland.

SAFER SPINACH

By combining continuous ultrasound treatment with chlorine washing, Hao Feng (EBI), professor of food science and human nutrition, has shown that the total number of food-borne pathogenic bacteria can be reduced by more than 99.99 percent. Feng's pilot study used three pairs of large-area ultrasonic transducer boxes to form a channel through which spinach leaves are exposed to ultrasound while undergoing a continuous-flow chlorine wash. Feng says that combining technologies is the key to bridging the gap between the current capacity and the USDA's target levels. The USDA, which provided funding for the study, is looking for technologies that can achieve a 4 to 6 log reduction in pathogen cells (a 6 log reduction would achieve a million-fold reduction in pathogenic bacteria). The food processing industry can now achieve a 1 log or tenfold reduction. In comparison, Feng's technique yields a 4 log reduction.

35 YEARS LATER: DISCOVERY OF THE THIRD DOMAIN OF LIFE

Swanlund professor of physics Nigel Goldenfeld (theme leader, BCXT) co-authored an article in *PNAS* describing the way in which the late Carl Woese's monumental discovery of *Archaea* was made, its context within the historical development of evolutionary thought, and how it has impacted our understanding of the emergence of life and the characterization of the evolutionary process in its most general form.

NEW ANTIBIOTIC

Nisin, an antibiotic that occurs naturally in milk (a product of bacteria resident in the cow's udder), helps keep milk from spoiling and kills a broad spectrum of bacteria that cause food-borne illness, most notably listeria and clostridium. Chemist and Richard E. Heckert Professor Wilfred A. van der Donk (MMG) reported in *PNAS* on an NIH-funded project that revealed a molecule that is an analog to nisin, but better. In addition to having nisin's antibiotic properties the new molecule, geobacillin, also is more stable at the neutral pH of many foods and pharmaceuticals, and at higher temperatures. Geobacillin also has proved to be three times more active than nisin against the main contagious bacteria responsible for bovine mastitis. Bovine mastitis costs the dairy industry billions each year and is devastating for dairy farmers, as the bacteria can quickly spread throughout a herd. In addition, since mastitis could be caused by a number of different infections, geobacillin's broad-spectrum activity makes it a very attractive treatment option.

RESEARCH HIGHLIGHTS *continued*

BIOFUEL PROFITABILITY

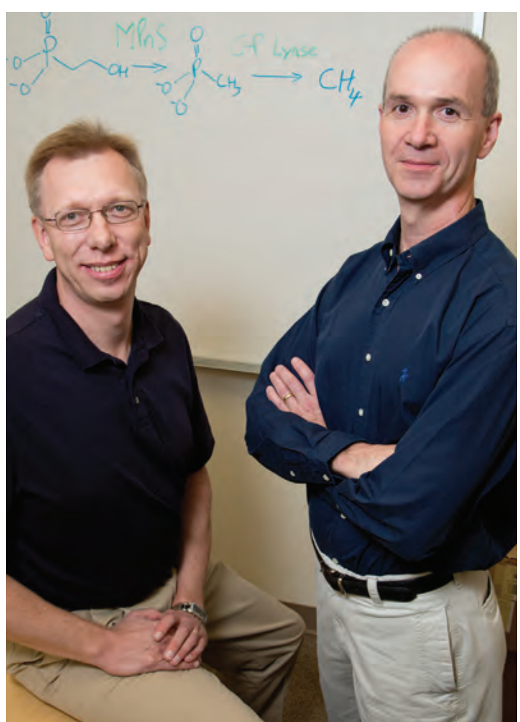
Madhu Khanna (BioBEL/EBI), professor of agricultural and consumer economics, and Haixiao Huang, of the Energy Biosciences Institute, have found that biofuel policies, which induced ethanol production beyond the free-market level, served to increase the competitiveness of the industry over time. The study quantifies the role that certain factors played in reducing the processing costs of corn ethanol in the U.S. by 45 percent while also increasing production volumes 17-fold from 1983 to 2005.

METHANE ORIGIN DISCOVERED

Researchers searching for new antibiotics may have solved a different puzzle. For many years researchers have wondered how Earth's oceans could produce four percent of the world's methane, given that the potent greenhouse gas is normally produced in anaerobic environments such as swamps, not in oxygenated places like the sea. Microbiologist William W. Metcalf (theme leader, MMG) and Richard E. Heckert Professor and chemist Wilfred A. van der Donk (MMG) reported in *Science* that a marine microbe called *Nitrosopumilus maritimus* has the biosynthetic machinery to make methylphosphonate, a molecule that other ocean organisms then metabolize to methane. Because many other microbes in the ocean also possess the same biosynthetic machinery, the team proposes that methylphosphonate-producing organisms are responsible for the sea's 4 percent contribution to the global supply of methane. Their research, funded by the NIH, explores an unusual class of potential antibiotic agents, called phosphonates, already in use in agriculture and medicine.

SEX CHROMOSOME EVOLUTION

Two new studies published in *PNAS* exploring sex chromosome evolution suggest that studying the X chromosome is as important as the male-determining Y chromosome. The research on papaya, a multimillion-dollar crop plant, led by plant biologist Ray Ming (EBI), reveals that the papaya sex chromosomes have undergone dramatic changes in their short evolutionary histories (they are about 7 million years old; by comparison, human sex chromosomes began their evolution more than 167 million years ago). Ming said the X chromosome, which is generally overlooked in models of sex chromosome evolution, offered the most surprises. It was



(left) Chemist Wilfred A. van der Donk and microbiologist William W. Metcalf discovered a marine microbe that plays a key role in the production of methane from the Earth's oceans. (right) Developers of the mobile biological robots — from left, Taher Saif, Vincent Chan, Hyunjoon Kong, Rashid Bashir, Kidong Park and Mitchell Collens.

previously thought that only the Y chromosome was dynamic in the early states of their evolution, but Ming's work shows that the X chromosome is equally dynamic. Analyzing the X chromosome is vital to understanding the evolution of sex, he says. The new findings in papaya suggest that the human X chromosome, too, has undergone numerous changes since it first distinguished itself from non-sex chromosomes, Ming said.

The study team also included researchers from the Hawaii Agriculture Research Center; Texas A&M University; the University of Hawaii, Honolulu; the University of Wisconsin, Madison; the University of Edinburgh; the University of Georgia; and Youngstown State University, Ohio. Both studies were led by Ming and were funded by NSF.

HUMAN MILK BENEFITS

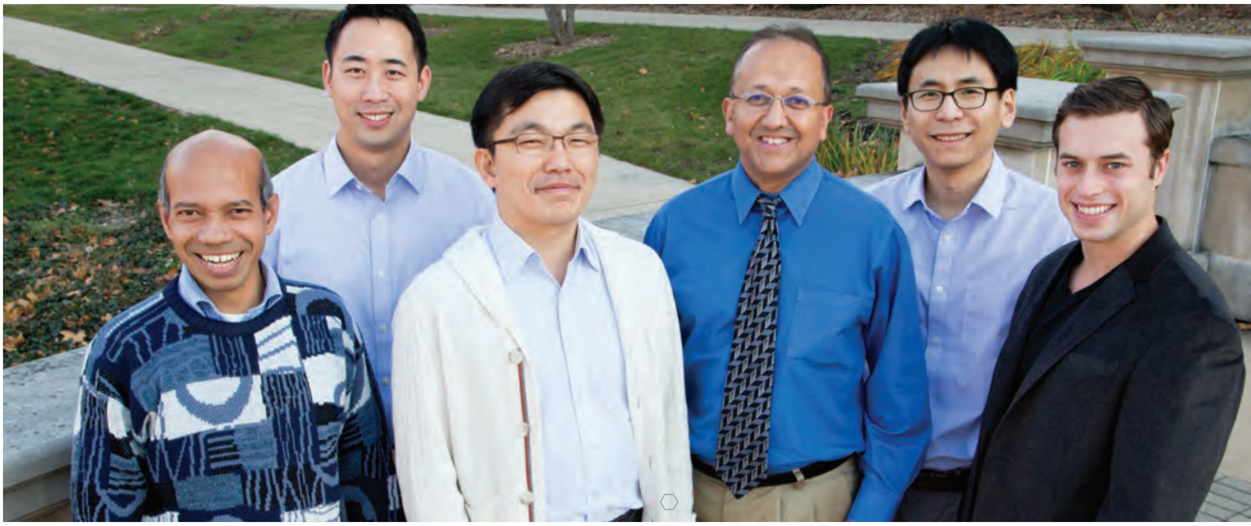
Babies can't digest part of what's in breast milk, but it gives them a big health boost nonetheless, says food science and human nutrition professor and Melissa M. Noel Chair Sharon Donovan (RBTE). As part of a study supported by NIH, Donovan examined molecules called human milk oligosaccharides, or HMOs, and found that they feed beneficial bacteria in the baby's gut. These bacteria can protect against infection and strengthen the immune system. Even though HMOs are a major component of human milk, present in higher concentration than protein, many of their actions in the infant are not well understood.

BIOLOGICAL ROBOTS

With the aid of a 3-D printer, Illinois researchers have fashioned a soft, quarter-inch-long biological robot out of gel-like material and rat heart cells. When the heart cells beat, the robot takes a step. The researchers attached heart muscle cells to a flexible structure made of hydrogel, the same material used to make contact lenses. To make the hydrogel structure, the bio-bot's body, the team used a 3-D printer, which creates solid objects by laying down successive layers of soft materials that fuse together. Each bot has between a few thousand and a few hundred-thousand heart cells. Rashid Bashir (RBTE), Abel Bliss professor of electrical, computer and biological engineering, led the study. The NSF supported this work through a Science and Technology Center (Emergent Behavior of Integrated Cellular Systems) grant.

MISCANTHUS MAP

This year, crop sciences professor and Energy Biosciences Institute program leader Stephen



RESEARCH HIGHLIGHTS *continued*

Microbiologist Rachel Whitaker and her colleagues found two groups of nearly identical microbes that were diverging into different species.

Moose and his colleagues published a map of the *Miscanthus sinensis* genome, a first step towards a full genome sequence. Such a genetic map will help researchers who hope to maximize yields or discover which genes give miscanthus other desirable traits. Because miscanthus belongs to a prominent grass family that includes corn, sorghum and sugarcane this EBI funded work could have applications to those other crops as well. The University of Illinois team included researchers from the Polish Academy of Sciences; the Department of Energy Joint Genome Institute; and the National Institute of Horticultural and Herbal Science, in South Korea.

BUILDING A BETTER TROJAN HORSE ANTIBIOTIC

Bacteria are continually evolving, enabling them to become resistant to various antibiotics. Biochemist Satish Nair (MMG/EBI) and collaborators at Rutgers University and the Russian Academy of Sciences have uncovered one way in which bacteria outwit "Trojan horse" antibiotics. Their findings were published in *PNAS*.

These antibiotics sneak into bacterial cells disguised as a tasty protein meal, for example. Once the bacterial enzymes chew up the disguise, the liberated antibiotic is free to attack a key component of protein synthesis in the bacterium. But Nair's team discovered how the bacteria have modified a common "housekeeping" enzyme, MccF, in a way that enables the enzyme to recognize and disarm the Trojan horse. In previous studies, researchers had found the genes that protect some bacteria from this class of antibiotic toxins, but they didn't know how they worked.

Eventually researchers, doctors and other clinicians will be able to scan the genomes of disease-causing bacteria to find out which ones have genes with the antibiotic-resistant loop in them. That will help clinicians know what kind of antibiotic to give a patient and which ones will be ineffective.

OZONE TOLERANCE

Along with increased global temperatures comes increased ozone at ground level, where it is a pollutant. Lisa Ainsworth (GEGC), professor of crop sciences, and her colleagues found that any increase above the ambient ozone concentration was enough to reduce yield by roughly half a bushel per acre of soybean for each additional part per billion of ozone. Potential increases in background ozone are predicted to increase soybean yield losses by 9 to 19 percent by 2030. Ainsworth uses genomic tools to tease apart the genetic basis of ozone response. Ainsworth and her colleagues, Andrew Leakey (GEGC), Pat Brown (EBI) and Lauren McIntyre (University of Florida), have received a $5.7-million-dollar Plant Genome Grant from the NSF that will enable them to conduct similar studies of ozone tolerance in corn.

Professor of crop sciences Lisa Ainsworth and colleagues are studying the ozone tolerance of soybean and corn.

AGGRESSIVE BEHAVIOR TRAITS

With a mate and a nest to protect, the male three-spined stickleback is a fierce fish, chasing and biting other males until they go away. Animal biology professor Alison Bell (GNDP) and her colleagues, with support from NIH, are mapping the genetic underpinnings of the stickleback's aggressive behavior. The molecular mechanisms underlying complex behaviors such as aggression are a challenge to study because hundreds of genes are involved. However, armed with tools that allow them to see which genes are activated or deactivated in response to social encounters, the team has identified broad patterns of gene activity that correspond to aggression in this fish.

MICROBIAL GENE SWAP

In a study published in *PLoS Biology*, IGB researchers have found the first example of sympatric speciation in a microorganism. The idea of sympatric speciation (one lineage diverging into two or more species with no physical or mechanical barriers keeping them apart) is controversial and tricky to prove, especially in microbes. Darwin showed how species diverge with geographic barriers, but the question has been, how do species diverge if they are living together? That question hadn't been answered well even in macro-organisms that have been studied for hundreds of years.

Microbiology professor and PI Rachel Whitaker (BCXT) and her colleagues focused on *Sulfolobus islandicus* because it is one of few microorganisms that live in distinct "island" populations created by geothermal hot springs. The researchers needed an environment that was not very complex; there are not many organisms that can handle the harsh hot springs environment and the ones that do don't successfully move around much. Their analysis revealed two distinct groups of *S. islandicus* among the 12 strains. The microbes were swapping genes with members of their own group more than expected, but sharing genes with the other group less than expected. And the exchange of genetic material between the two groups was decreasing over time, proving that sympatic speciation was taking place. Suported in part by NSF, the research team included scientists from Arizona State University, the University of California at Davis, and the University of Oxford.

we are
the partnerships forged for greater understanding and discovery

We believe in the power of collaboration at IGB. We believe in the power of gathering perspectives from fellow experts in academia and industry to enhance our collaborative and interdisciplinary research. This approach, fundamental to the very nature of the Institute, is one of our great strengths. For that reason IGB researchers regularly partner with colleagues all around the globe. Sometimes the Institute creates a formal collaboration agreement and sometimes individual researchers simply work together. Either way, the results are the same: greater insight, greater understanding, greater productivity, and greater collegiality. Many challenges that exist are global in scope, whether it's finding new fuel resources, understanding and responding to climate change or feeding the world's growing population. These partnerships enable IGB researchers the opportunity to share our expertise, to speak an international language of science. Our collaborations fuel new ideas and approaches, and energize teams to explore avenues never before considered.

IGB RESEARCH THEMES

BCXT	*Biocomplexity*
BIOBEL	*Business, Economics and Law of Genomic Biology*
CDMC	*Cellular Decision Making in Cancer*
GEGC	*Genomic Ecology of Global Change*
GNDP	*Gene Networks in Neural & Developmental Plasticity*
HMS	*Host–Microbe Systems*
MMG	*Mining Microbial Genomes*
RBTE	*Regenerative Biology & Tissue Engineering*
EBI	*Energy Biosciences Institute*
CNLM	*Center for Nutrition, Learning, and Memory*

PARTNERSHIP HIGHLIGHTS

IMPROVING PHOTOSYNTHESIS

A five-year, $25-million grant from the Bill & Melinda Gates Foundation is helping IGB scientists improve the photosynthetic properties of key food crops.

Gutgsell professor Stephen Long (GEGC/EBI) is serving as Project Director with Robert Emerson professor Don Ort (theme leader, GEGC) as Associate Director on the project RIPE – Realizing Increased Photosynthetic Efficiency. Increasing photosynthetic efficiency has the potential to not only increase yields but also to increase the efficiency with which crops use water and nitrogen. Investigators hope the project will benefit farmers around the world by increasing productivity of staple food crops, such as rice and cassava. Team members are applying recent advances in photosynthesis research and crop bioengineering, in addition to using computer simulation models of the highly complex photosynthetic system, combined with practical engineering, to identify the best targets for improving photosynthesis efficiency. This project aims to develop a domain ripe for exploitation that will provide part of the yield jump the world needs to maintain food security.

The grant reflects the historic excellence of photosynthesis research on this campus, and the

Stephen Long (right), professor of crop sciences and plant biology, is Project Director on a five–year, $25-million grant from the Bill & Melinda Gates Foundation to improve the photosynthetic properties of key food crops. Don Ort (left), professor of plant biology, is Associate Director.

Seventeen members of the IGB traveled to BGI in Shenzhen, China for a week-long series of learning and discussion workshops.

cutting-edge approaches that have been developed for plant science at the IGB over the past few years by the members of the Genomic Ecology of Global Change and Energy Biosciences Institute research themes. The study will be conducted through an international collaboration with other leading research institutions including the Australian National University, Rothamsted Research (UK), University of Essex (UK), and USDA/ARS.

AFRICAN BIOINFORMATICS

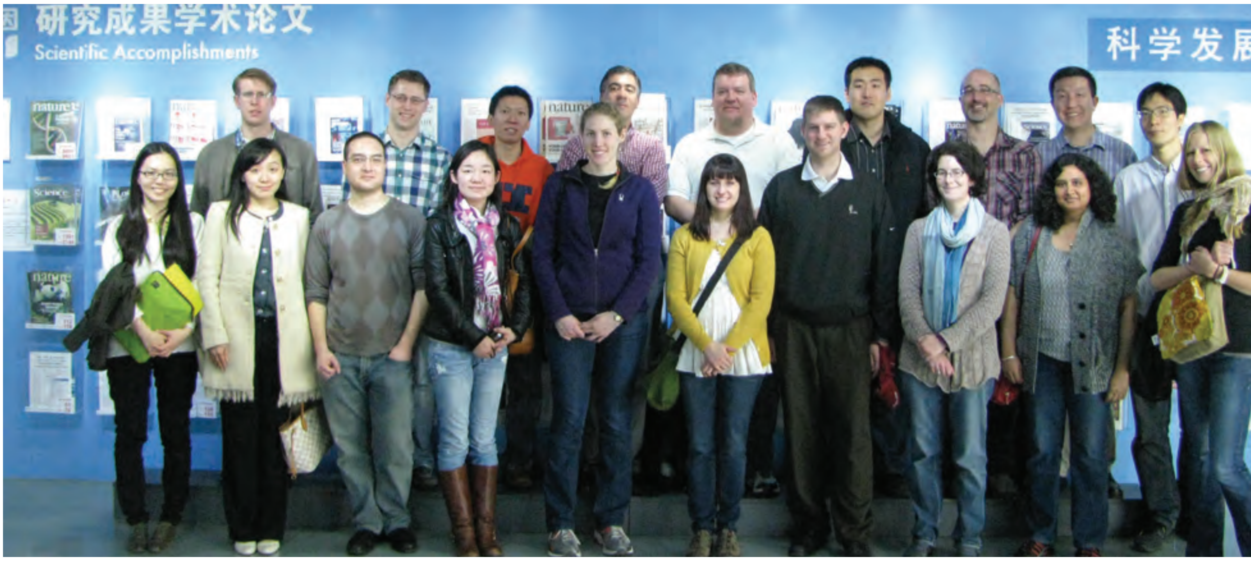
IGB Bioinformatics Director Victor Jongeneel, also Director of the High-Performance Biological Computing (HPCBio) program and NCSA Sr. Scientist, is a key participant in a grant awarded by the Human Heredity and Health in Africa Initiative, or H3Africa, to establish a pan-continental bioinformatics network to aid research. Founded in June 2010, H3Africa is a joint initiative of the African Society of Human Genetics, the National Institutes of Health (NIH), and the Wellcome Trust, a UK-based charity organization, to provide better diagnosis, develop new drugs, and develop personal medicine through the study of genome-environment interactions.

Jongeneel's project, led by Nicola Mulder of the University of Cape Town and involving many research groups across the continent, is known as the H3ABioNet. It aggregates and analyzes large datasets, establishing collaborations among preexisting bioinformatics centers, and training African students and scientists in bioinformatics. By harnessing the existing structures of the African Bioinformatics Network and the African Society for Bioinformatics and Computational Biology, the H3ABioNet will be the first adequately funded and pan-continental bioinformatics network in Africa.

ISOLATING CANCER CELLS

The most dangerous cancer cells are the ones that metastasize, breaking away from the primary tumor and traveling through the body to form a new tumor in another tissue. Fortunately, only a small percentage of cancer cells have the ability to become new tumors. Unfortunately, the tumor-seeding cells are the ones hardest to kill with chemotherapy — and it only takes a lone survivor to mount a resurgence.

A new method to isolate and grow the most dangerous cancer cells could enable new research into how cancer spreads and, ultimately, how to fight it. University of Illinois researchers, in collaboration with scientists at the Huazhong University of Science and Technology in China, published their results in the journal *Nature Materials*. Ning Wang (RBTE),



PARTNERSHIP HIGHLIGHTS *continued*

professor of mechanical science and engineering, who co-led this study funded in part by NIH, believes this technique may open the door for understanding and blocking metastatic colonization, one of the most devastating steps in cancer progression.

INTERNATIONAL GENOMICS EXCHANGE

IGB and the BGI (formerly known as the Beijing Genomics Institute) in China are participating in a series of face-to-face workshops as part of an international exchange of knowledge and ideas. In the first exchange, 17 IGB students and faculty traveled to China for a week-long visit. BGI's mission is to support the development of science and technology, build strong research teams, and promote the development of scientific partnership in genomics. Located in Shenzhen, BGI is the first citizen-managed, non-profit research institution in China. The IGB students and faculty heard four days of lectures about topics such as cancer genomics, applying genomics to biodiversity analysis, metabolomics, metagenomics, disease analysis and comparisons of algorithms for alignment and assembly and other topics in sequencing. The IGB visitors also had time for some sightseeing and hiking. Next, a BGI delegation will spend a week at the University of Illinois campus.

BIOLOGICAL KNOWLEDGE FOR ENERGY SOLUTIONS

The Energy Biosciences Institute (EBI) was formed in 2007 by global energy company BP following an international competition. Illinois, specifically the IGB, is one of three partners that make up the EBI. The 10-year, $500-million project is the broadest research partnership of its kind in the world, interactively approaching all facets of biofuels development and use. The EBI is also unique in including an open collaboration between university and industry scientists — geneticists, biochemists, molecular biologists, atmospheric scientists, economists, biomolecular engineers, and other specialists — working to develop sustainable biofuels to combat global climate change. At Illinois, these researchers are part of research projects and programs dedicated to addressing critical issues in the biofuels industry. The challenges are huge, but the resources to meet them are vast — expertise

(left) The EBI collaborates between locations, with laboratory and office space at the IGB as well as the Energy Biosciences Building in Berkeley, California (pictured). (above) The first interdisciplinary cognition and nutrition research center in the country, the Center for Nutrition, Learning, and Memory partners the IGB with the Beckman Institute, supported by Abbott.

and the finest research facilities at three of the world's most distinguished centers of learning and knowledge, plus the corporate know-how of an experienced international energy company.

The collaboration includes researchers at UC Berkeley and Lawrence Berkeley National Laboratory. BP is the funding partner and provides expertise on industrial technology and commercialization.

NUTRITION AND COGNITION

Abbott and the University of Illinois have collaborated to form the Center for Nutrition, Learning, and Memory (CNLM), which supports interdisciplinary exploration into what compounds in foods might improve learning and memory and, if so, how. CNLM partners the IGB with the Beckman Institute for Advanced Science & Technology, in collaboration with the Division of Nutritional Sciences and the Neuroscience Program. This undertaking is significant as it marks the first interdisciplinary cognition and nutrition research center in the country. IGB's expertise in genomics is critical to the effort and complements Beckman's capabilities in studying learning and memory and for brain imaging. IGB's expertise in model systems also complements Beckman's work on humans. The Center is supported by a five-year commitment from Abbott.

GUT MICROBES

Microbes are everywhere. They help animals digest food, they help plants fix nitrogen and they contribute to some rock formation. In a recent study in *PloS ONE* it appears some microbes also regulate the immune system and related autoimmune diseases such as rheumatoid arthritis. A team of researchers from the Mayo Clinic working with professor of animal sciences Bryan White (BCXT/HMS) found that larger-than-normal populations of specific gut bacteria may trigger the development of diseases like rheumatoid arthritis, and possibly fuel disease progression in people genetically predisposed to this crippling and confounding condition. Using genomic sequencing technology the interdisciplinary team, part of the Mayo Illinois Alliance for Technology Based Healthcare, was able to prove that the gut microbiome can predict susceptibility to certain diseases.

ENZYME FUNCTION IDENTIFICATION

The Enzyme Function Initiative (EFI) is a large-scale collaborative project funded by the National Institute of General Medical Sciences and hosted at the IGB. With literally millions of enzymes of unknown function emerging from genomic sequencing projects, the mission of the EFI is to develop comprehensive strategies to quickly and accurately identify their functions. Led by Gutgsell professor of biochemistry and chemistry John Gerlt (MMG), the EFI brings together experts in bioinformatics, structural biology, computation enzymology, genetics, and metabolomics. EFI collaborators, based at 9 institutions across the US, form a tightly integrated and cohesive program that tests and refines unique approaches to determine enzyme function, using computational and experimental characterization of target enzymes.

FLEXIBLE DNA

Gutgsell Professor of Physics and Howard Hughes Medical Institute investigator Taekjip Ha (theme leader, CDMC) published an article in *Science* offering evidence that the classical model of DNA as a stiff but bendable rod doesn't hold for short strings of base pairs. By using a newly developed technique allowing for the study of DNA in a state more similar to natural replication rather than traditional ligase-based assays, Ha et al. produced looped and extremely flexible DNA. This discovery helps to explain the bending biologically crucial to many DNA-protein interactions, as well as clarify issues in DNA modeling.

we are
a source of educational opportunity and learning

STUDENTS / RESEARCHERS / FACULTY & AFFILIATES

452/216/142

Opportunities for learning and education abound at the IGB. Students and faculty alike come to the IGB to grow in their experience, determined to share their passion for shaping the future. Within our collegial, interdisciplinary space, we share in an array of learning avenues and partake of an infrastructure built of educational possibilities. We naturally become involved and engaged: we contribute, we question and we strive. It's an exciting, scintillating environment because it is highly collaborative; the ultimate in crowd sourcing. IGB researchers recognize the importance of bringing energy, curiosity and unique perspectives to our endeavors. Learning together results in an outpouring of creative energy that yields transformative results.

IGB RESEARCH THEMES

BCXT	*Biocomplexity*
BIOBEL	*Business, Economics and Law of Genomic Biology*
CDMC	*Cellular Decision Making in Cancer*
GEGC	*Genomic Ecology of Global Change*
GNDP	*Gene Networks in Neural & Developmental Plasticity*
HMS	*Host-Microbe Systems*
MMG	*Mining Microbial Genomes*
RBTE	*Regenerative Biology & Tissue Engineering*
EBI	*Energy Biosciences Institute*
CNLM	*Center for Nutrition, Learning, and Memory*

Just as the IGB is a hub that connects scientists from all different fields, it also connects learners from all over the world, who come to the IGB to be part of a grand interdisciplinary undertaking. The IGB is a place where we learn by doing, and we pride ourselves in providing the very best facilities for those activities. Students learn to use the latest analytical tools, taught by staff that love what they do and are excited to share their expertise. In addition to their own projects, researchers can join the synthetic biology competition of iGEM, where they learn to work in teams, solve problems and think outside the box, enroll in the certificate in entrepreneurial management program to learn the nuances of the business world, or attend lectures by world-class researchers and then cogitate on what they learned with faculty, staff, and fellow students in the open areas of the IGB laboratories.

EDUCATION AND LEARNING HIGHLIGHTS

VERTICALLY INTEGRATED TRAINING WITH GENOMICS

The IGB and the School of Integrative Biology received a $3.2 million training grant from the National Science Foundation. The grant, Vertically Integrated Training With Genomics (VInTG), addresses two big research questions, or "grand challenges," in biology: How do genomes interact with the environment to produce biological diversity, and how are biological systems integrated from molecules to ecosystems?

With hundreds or even thousands of animal and plant genome sequences becoming available, nearly all levels of biological inquiry are becoming "genome-powered." Consequently, Andy Suarez (GNDP, entomology and animal sciences) and his co-PIs, Gene Robinson (IGB Director, Swanlund professor of entomology), Carla Cáceres (animal biology and program in ecology, evolution and conservation biology), Sandra Rodriguez-Zas (GNDP, animal sciences), and Owen McMillan (Smithsonian Tropical Research Institute), believe the time is ripe to integrate these fields with a more traditional, taxonomic approach.

Through the grant, graduate students are studying organisms or groups of organisms from genome to its evolution, ecology and behavior. This means

(below) The National Science Foundation awarded the Institute for Genomic Biology and the School of Integrative Biology a $3.2 million training grant, led by Principal Investigator Andrew Suarez (below, left) with co-PIs Gene Robinson, Carla Cáceres, and Sandra Rodriguez-Zas. (right) The entirely student led iGEM (International Genetically Engineered Machine) team from Illinois competes annually in the regional and international jamborees.

that graduate students interested in biological fieldwork on a given organism are learning about genomic tools that are available, and those interested in benchwork and bioinformatics are conducting biological fieldwork in order to put that research in a broader, species-specific context.

In addition to being interdisciplinary, the program has students working in research teams, rather than individual students interacting with individual advisers.

The Smithsonian Tropical Research Institute (STRI), one of the world's premier tropical research institutes and a partner in the grant, is hosting students at their research facility in Panama. Students can access STRI's large, diverse and long-term study sites and databanks for a wide variety of organisms and ecosystems in Panama.

NSF's Integrative Graduate Education and Research Traineeship (IGERT) is a highly regarded grant program that was founded in 1998 and has, thus far, provided interdisciplinary research training to approximately 5,000 graduate students.

IGEM AT IGB

For the past five years IGB has supported the University of Illinois iGEM team. The International Genetically Engineered Machine (iGEM) competition, which began at MIT a decade ago, gives student teams an opportunity to work in the emerging discipline of synthetic biology and design a biological system that can be implemented in a living organism, such as bacteria. In doing so, they give these organisms new traits that are not found in nature. For example, past iGEM teams have altered the behavior of a bacterial cell so that it moves a certain way in response to a stimulus, and have changed the appearance of the cell by expressing pigments that change the cell's color.

Students who take part in Illinois' iGEM team gain experience working in a group environment, exploring biology and science, and performing cutting-edge, self-directed research in a field that is continually evolving. Teams are composed of and run by undergraduates from various backgrounds including bioengineering, molecular and cellular biology, physics, electrical engineering, and integrated biology.

The project design and competition format is an exceptionally motivating and effective teaching method. Since 2008, more than 50 Illinois undergrads have competed in the annual regional and international jamborees,

EDUCATION AND LEARNING HIGHLIGHTS *continued*

earning medals most years. Projects have included a bacterial filing cabinet, a bacterial decoder, a model-guided cellular engineering web program, and a medical biosensor. iGEM is entirely student led; they design their own project, and do all the work, reinforcing what they are learning in the classroom with hands-on experience.

SCIENCE SKILLS, BUSINESS SAVVY

More than 20 students graduated from the Certificate in Entrepreneurship and Management (CEM) program in 2012 and are ready to help bring research and ideas to the marketplace. The IGB has collaborated with the Illinois College of Business to create CEM, a program for entrepreneurially minded students in engineering, life sciences, and related disciplines who are interested in understanding the business, economic, and legal issues in scientific and high technical start-up ventures. Participants who have the scientific and high-tech skills to do groundbreaking research will learn the business savvy needed to bring discoveries to market.

The program is geared for doctoral students, post-doctoral students, practicing scientists, and academic professionals. Students learn traditional ins and outs of entrepreneurship, such as creating a business plan and managing intellectual property, but they also study topics specific to the life sciences, such as commercializing technology, managing the FDA approval process, protecting their research and conducting clinical trials. In addition to classroom learning, students gain experience by working in groups on specific innovations.

MICROSCOPY

The Core Facilities at the IGB is a state-of-the-art resource for biological microscopy and image analysis, providing researchers at the IGB and across campus with the training, tools, and expertise needed to meet their goals. The latest addition to the IGB's Core Facilities microscopy and imaging capabilities is an objective inverter,

which augments an existing nonlinear optical microscope. This allows for non-invasive imaging of live intact organs and tissues, specifically enabling such possibilities as neural imaging, measuring intestinal stem cell proliferation in living tissue, or real time observation of developmental changes in germ cells in testis. One of the many pieces of equipment that director Glenn Fried and assistant director Mayandi Sivaguru provide guidance and support for, the Core Facilities also aid in designing and interpreting experiments, and help to educate and train over one hundred new users a year on their instrumentation.

SUPERCOMPUTING

The IGB provides personal assistance and user instruction for computer usage through the Computer and Network Resource Group. A highly parallel shared memory supercomputer named Ember has recently been added to the server cluster that allows for complex programs and large quantities of information to be processed. Originally funded by the NSF and gifted to the IGB from the National Center for Supercomputing Applications (NCSA), the Ember computing system is managed by the HPCBio group as part of the IGB biocluster, adding 1536 cores and eight terabytes of memory spread across four nodes. Ember runs a Linux operating system, and can be used in many research applications for students including chemistry, fluid mechanics, imaging, and genomics and transcriptomics research. Ember's very large shared memory— 2 terabytes in a single system—enables it to run these applications very efficiently.

(left) Entrepreneurially minded students in engineering, life sciences, and related disciplines benefit from classroom and experiential learning in the Certificate in Entrepreneurship and Management (CEM) program. (right) An augment to a nonlinear optical microscope, this objective inverter is one of the many instruments available as part of the IGB's Core Facilities microscopy and imaging capabilities.


we are
the community learning and giving back to our members
citizen scientists
young learners
students
middle school
local contact
global reach
university members
native americans

2007

The Osher Lifelong Learning Institute (OLLI) launched

2008

Launched with the Engineering
Partnered of Engineering Girls
College the first Engineering camp
to host in Math (GAMES) camp
Adventures in (GAMES) Congress on
and Science Congress with
1st Pan American Bioenergy with
Plants and Bioenergy to catalyze the
the key aim to between better
collaborations nations for bioenergy
American sustainable bioenergy
and sustainable – Mérida, México
systems.

2009

1st annual Energy Biosciences Institute Biofuels and Law Regulation Conference hosted by the Energy Biosciences Institute

2nd year to host Girls Adventures in Math Engineering and Science (GAMES) camp

2010

A library of SciFlix Videos created.
Professor Bruce Fouke explains how the flow of bateria migration affects of the development and color variation the devefacies at Yellowstone National travertine facies at Yellowstone National Park's hot spring system

2nd annual Energy Biosciences Institute Biofuels and Law Regulation Conference, with the theme, "The Renewable Energy Legistration Puzzle: Putting the Pieces Together"

2nd Pan American Congress on Plants and Bioenergy with the theme "Plants as New Sources of Energy" – Sao Paulo, Brazil

2011

Summer Internship for Native Americans in Genomics (SING) aimed at discussing the uses, misuses and limitations of genomics as a tool for Native American communities

Art of Science 1.0 Images exhibited some of the University of Illinois research addressing significant problems in the environment, energy, agriculture and medicine

3rd annual Energy Biosciences Institute Biofuels and Law Regulation Conference, with the theme, "Exploring Cutting Edge Legal Issues at the Nexus of Bioenergy"

IGB members are committed to sharing their exciting and fascinating scientific research with the general public, whether that research helps us understand global warming or the emergence of infectious diseases, or simply appreciate beautiful and otherworldly images captured with high-tech instruments. Embracing the concept of "Where Science Meets Society," the IGB hosts events intended to not only raise the awareness of the transformative research taking place at the Institute, but also to encourage the interaction between IGB members and the greater community. IGB shares the enthusiasm and expertise of its students, staff and faculty by providing innovative outreach and education programs, and even art exhibits. Researchers are great believers in life-long learning and so share their experiences and passion with students of all ages, from pre-schoolers to students of the Osher Lifelong Learning Institute, all of whom are 50 years of age or older. Other efforts include open houses, seminars, exhibits, and even an educational video series. The IGB also hosts conferences on one-of-a-kind and specialized topics in order to encourage interactions across disciplines that would not normally occur.

IGB RESEARCH THEMES

BCXT	*Biocomplexity*
BIOBEL	*Business, Economics and Law of Genomic Biology*
CDMC	*Cellular Decision Making in Cancer*
GEGC	*Genomic Ecology of Global Change*
GNDP	*Gene Networks in Neural & Developmental Plasticity*
HMS	*Host-Microbe Systems*
MMG	*Mining Microbial Genomes*
RBTE	*Regenerative Biology & Tissue Engineering*
EBI	*Energy Biosciences Institute*
CNLM	*Center for Nutrition, Learning, and Memory*

2012

Citizen Scientist, a collaboration of OLLI, the Beckman Institute for Advanced Science and Technology and the IGB

Genome Day seeks to educate all ages about genomes, genes, and DNA

High Performance Biological Computing (HPCBio) created to provide a single, straightforward point of access, open to researchers from all campus units, helping them to find solutions to their biomedical data management and analysis problems

Mahomet-Seymour Junior High School Science Club tour of the IGB facilities with a lecture on Climate change and Global warming

Art of Science 2.0

3rd Pan American *Congress on Plants and Bioenergy* focused on progress toward sustainable fuels from a Federal and Industry perspective in Brazil and N. America

4th annual *Energy Biosciences Institute Biofuels and Law Regulation Conference* with the theme, "Focusing in on the Renewable Fuel Standard (RFS2)"

ACTIVITY HIGHLIGHTS

COMPUTATIONAL COLLABORATION

Biology is increasingly becoming a large-scale, data-driven science. Biologists around the world are producing data on the same scale as astronomy or particle physics, but at many more centers. This is particularly true for genomic biology.

High Performance Biologic Computing (HPCBio), a collaborative effort between several partners in the university community, was created to supply infrastructure, user support, training, and applied R&D capability in computational genomics. Led by IGB Director of Bioinformatics and NCSA Sr. Scientist Victor Jongeneel, the center draws on the genomics research capabilities of the IGB faculty and affiliates, the expertise of the Roy J. Carver Biotechnology Center and their bioinformatics unit, and the supercomputing power and technical capacity of the National Center for Supercomputing Applications (NCSA).

CLUB TOURS

Approximately 20 science club students from an area junior high school came to the IGB to learn about the genomic ecology of environment change and global warming. They also received an extended tour of the IGB Core Facilities and what kind of research graduate and postdoctoral fellows across the campus are performed using those core facilities. The following week the *(left) Attendees were able to hear from leaders in bioenergy from around the globe at the 3rd annual Pan American Congress on Plants and Bioenergy, organized by the Energy Biosciences Institute. (right) Left to right, Illinois' Timothy Slating, speaker Karl Simon from the EPA, and Jay Kesan at EBI Law and Regulation Conference.*

students learned how climate change could affect coral reefs and how the IGB Core Facilities microscopes and systems helped accomplish various research goals.

INTERNATIONAL PLANT CONGRESS

Speakers and researchers from around the world attended the 3rd annual Pan American Congress on Plants and Bioenergy organized by the Energy Biosciences Institute (EBI) and hosted by the I Hotel. The meeting encompassed discussions of feedstock genomics and breeding, feedstock culture, feedstock handling and logistics, biofuel production, biofuel systems analysis, and environmental sustainability, from the established sugarcane ethanol industry in Brazil to the emerging prospects of algae. The Congress was organized by Gutgsell professor of crop sciences and former EBI Deputy Director Stephen Long (GEGC/EBI) and EBI Assistant Deputy Director Jenny Kokini, along with Nicholas Carpita of Purdue University, Marcos Buckeridge of Brazilian Bioethanol Science and Technology Laboratory (CTBE), and Rowan Sage of the University of Toronto.

BIOFUELS LAW

The annual Energy Biosciences Institute Biofuels and Law Regulation Conference, now in its fourth year, focuses on the multitude of legal and regulatory issues impacting the ongoing commercialization of advanced biofuels. This year's topic revolved around the concerns surrounding the implementation of the federal Renewable Fuel Standard (RFS2), with unique sessions discussing current economic evaluations of the RFS2; industry perspectives on the RFS2; and feedstock availability and agricultural impacts of the RFS. With leading academic, scientific, government, and industry experts, the conference provided opportunities for in-depth discussion between and among speakers and audience members. Professor of law Jay Kesan (theme leader, BioBEL) and regulatory associate Timothy Slating supplied moderation and guidance.

GENOMICS FOR NATIVE AMERICANS

IGB hosted a weeklong program for Native Americans in genomics that included everything from learning to do DNA extraction and genotyping and illustrating how genomics is currently used as a tool in history, natural resources and biomedical research, to a discussion about integrating indigenous and scientific ideas and values. The workshop, Summer Internship for Native Americans in Genomics (SING), was led by associate professor of anthropology Ripan Malhi (RBTE) and helps create lasting bonds between the participants and faculty, all Native Americans from around the United States and

ACTIVITY HIGHLIGHTS
continued

Canada. The program is intended to expand the education of indigenous people in the science of genetics, discuss the implications of that research and enable them to collaborate more with other scientists, both Native and non-Native. In addition to bonding over science, participants bond over intense and complex discussions and role-play on the ethical, legal and social implications of research within Native American communities. Ultimately the internship created a sense of community for Native Americans in academic settings. The workshop also exists to increase the number of Native Americans in science research, leadership and teaching careers at all levels.

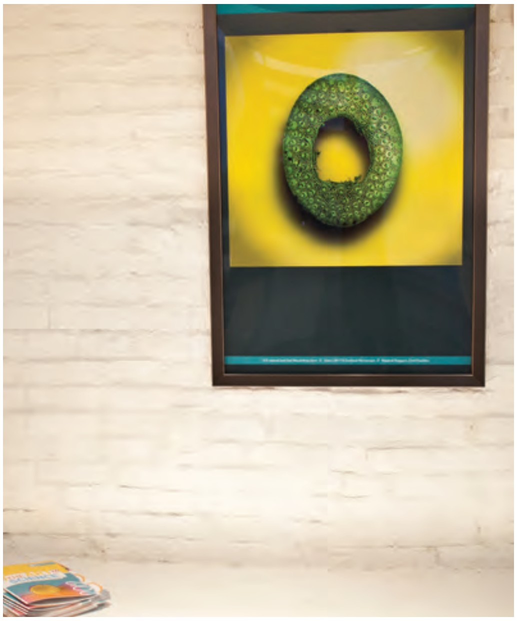
SCIFLIX

From global warming and sustainable energy resources to the emergence of infectious disease and rapid advancements in biotechnology, science plays a vital role in everyday life. SciFlix videos are short, instructional clips that present a clear and concise summary of concepts and discoveries in global science, hosted by professor of geology Bruce Fouke (BCXT/EBI). This outreach project is designed to augment and update the scientific education curriculum currently being taught in local schools, emphasizing a systems-level integrated understanding of basic concepts.

THE ART OF SCIENCE

This year's exhibit of the *Art of Science: Images from the Institute for Genomic Biology* featured research that addresses significant problems in the environment, health, energy use and production, and fundamental research. The images were created using research instrumentation in IGB's Core Facilities, which provides state-of-the-art resources for biological microscopy and image analysis for faculty and students from across campus and to scientists in the Research Park. Core Facilities staff train more than 100 new users on research instrumentation every year.

One of several artworks on display at the annual exhibition "The Art of Science: Images from the Institute for Genomic Biology" at indi go gallery.



The exhibit illustrated the IGB's commitment to scientific discovery and the collaborative spirit that makes it all possible. The event was attended by more than 250 community members, students, faculty, and staff, who enjoyed the melding of progressive scientific ideas with innovative state-of-the-art imaging techniques. In addition, Countryside Middle School students received their own, guided tour.

Many attendees from the community commented that they didn't realize the IGB was working on such a vast scope of problems that affect society as a whole. Bringing the general public into contact with the scientific community remains one of the goals of this ongoing exhibition.

GENOME DAY

IGB hosted the inaugural Genome Day at the Orpheum Children's Science Museum to introduce the ideas of genes, genomes, DNA and evolution, in an entertaining and engaging *(left) IGB Fellow Chris Thibodeaux breaks down the genetic code to attendees of Genome Day at the Orpheum Children's Science Museum. (right) Jo Pride works with students within an IGB lab as part of the citizen scientist program, a component of the Osher Lifelong Learning Institute (OLLI).*

way. Almost 500 attendees participated in the 16 different activities, including investigating planarian flatworms, learning how organisms are related to each other on the Tree of Life, extracting strawberry DNA to make necklaces, and dancing with plants on the big screen. Participants ranged from pre-schoolers to grandparents. Genome Day is part of IGB's mission to promote activities and undertake projects to engage K-12 students, as well as the broader east-central Illinois community, to present the key concepts of the research taking place at the IGB in an approachable manner for all ages.

CITIZEN SCIENTISTS

IGB faculty members are not only advancing life sciences research and stimulating bio-economic development in Illinois, they also are enriching the minds of area residents age 50 and over as part of the Osher Lifelong Learning Institute (OLLI). Membership in OLLI enables students to engage in learning for the joy of it – topics range from art to zoology. IGB scientists share their latest research in fields such as microbiology, neuroscience, and genomics. IGB faculty say interacting with OLLI students has been one of the most exceptional teaching experiences of their career.

In addition, IGB has partnered with the Beckman Institute for a "citizen-scientist" program in which OLLI students are invited into specific labs, trained by a graduate student and then contribute to the work of the lab. This approach fits the team-based research model of the IGB perfectly, plus OLLI students become ambassadors for, not just the IGB, but for science in general. All students, whether OLLI or IGB, agree: the experience has been deeply and mutually rewarding.

IGB
METRICS

PUBLICATIONS

FY12 – 217 papers published, 7 in *Science* and *Nature*

Science Papers:

"Copy number variation of multiple genes at Rhg1 mediates nematode resistance in soybean."
Cook,D.E.; Geon Lee,T.; Guo,X.; Melito,S.; Wang,K.; Bayless,A.; Wang,J.; Hughes,T.J.; willis,D.K.; Clemente,T.; Diers,B.W.; Jiang,J.; Hudson,M.E.; Bent,A.F.
Science, 2012:1-5.

"Molecular determinants of scouting behavior in honey bees."
Liang,Z.S.; Nguyen,T.; Mattila,H.R.; Rodriguez-Zas, S; Seeley,T.D.; Robinson,G.E.
Science, 2012;335:1225-1228.

"Synthesis of methylphosphonic acid by marine microbes: A source for methane in the aerobic ocean."
Metcalf,W.W.; Griffin,B.M.; Cicchillo,R.M.; Gao,J.; Janga,S.C.; Cooke,H.A.; Circello,B.T.; Evans,B.S.; Martens-Habbena,W.; Stahl,D.A.; van der Donk,W.A.
Science, 2012;337(6098):1104-1107.

"A gain-of-function polymorphism controlling complex traits and fitness in nature."
Prasad,K.V.S.K.; Song,B.-H.; Olson-Manning,C.; Anderson,J.T.; Lee,C.-R.; Schranz,M.E.; Windsor,A.J.; Clauss,M.J.; Manzaneda,A.J.; Naqvi,I.; Reichelt,M.; Gershenzon,J.; Rupasinghe,S.G.; Schuler,M.A.; Mitchell-Olds,T
Science, 2012;337(6098):1081-1084.

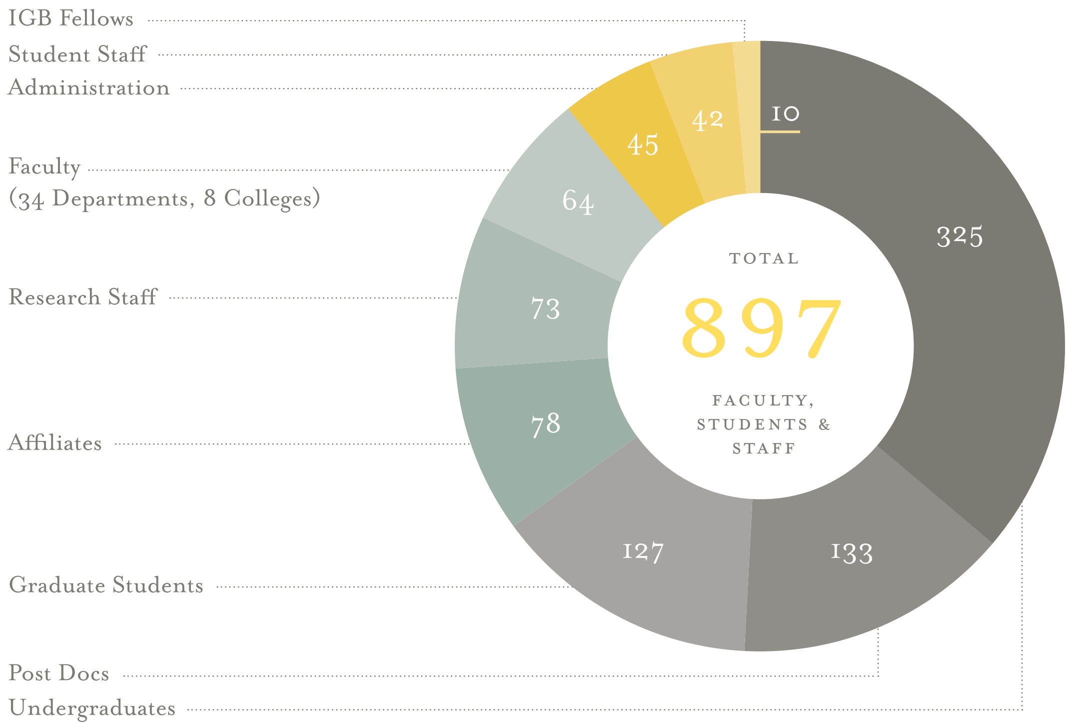
"Extreme Bendability of DNA Less than 100 Base Pairs Long Revealed by Single-Molecule Cyclization"
Vafabakhsh R.; Ha T.
Science, 2012;337(6098):1097-1101

"Circadian rhythm of redox state regulates excitability in suprachiasmatic nucleus neurons."
Wang,T.A.; Yu,Y.V.; Govindaiah,G.; Ye,X.; Artinian,L.; Coleman,T.P.; Sweedler,J.V.; Cox,C.L.; Gillette,M.U.
Science, 2012;337(6096):839-842.

Nature Paper:

"Analyses of pig genomes provide insight into porcine demography and evolution"
Groenen,M.A.M.; Archibald,A.L.; Uenishi,H.; Tuggle,C.K.; Takeuchi,Y.; Rothschild,M.F.; Rogel-Gaillard, C.; Park,C.; Milan,D.; Megens,H.; Li,S.; Larkin,D.M.; Kim,H.; Frantz,L.A.F.; Caccamo,M.; Ahn,H.; Aken,B.L.; Anselmo,A.; Anthon,C.; Auvil,L.; Badaoui,B.; Beattie,C.W.; Bendixen,C.; Berman,D.; Blecha,F.; Blomberg,J.; Bolund,L.; Bosse,M.; Botti,S.; Bujie,Z.; Bystrom,M.; Capitanu,B.; Carvalho-Silva, D.; Chardon,P.; Chen,C.; Cheng,R.; Choi,S.; Chow,W.; Clark,R.C.; Clee,C.; Crooijmans,R.P.M.A.; Dawson,H.D.; Dehais,P.; De Sapio, F.; Dibbits,B.; Drou,N.; Du,Z.; Eversole,K.; Fadista,J.; Fairley,S.; Faraut,T.; Faulkner,G.J.; Fowler,K.E.; Fredholm,M.; Fritz,E.; Gilbert,J.G.R.; Giuffra,E.; Gorodkin,J.; Griffin,D.K.; Harrow,J.L.; Hayward,A.; Howe,K.; Hu,Z.; Humphray,S.J.; Hunt,T.; Hornshoj,H.; Jeon,J.; Jern,P.; Jones,M.; Jurka,J.; Kanamori,H.; Kapetanovic,R.; Kim,J.; Kim,J.; Kim,K.; Kim,T.; Larson,G.; Lee,K.; Lee,K.; Leggett,R.; Lewin,H.A.; Li,Y.; Liu,W.; Loveland,J.E.; Lu,Y.; Lunney,J.K.; Ma,J.; Madsen,O.; Mann,K.; Matthews,L.; McLaren,S.; Morozumi,T.; Murtaugh,M.P.; Narayan,J.; Nguyen,D.T.; Ni,P.; Oh,S.; Onteru,S.; Panitz,F.; Park,E.; Park,H.; Pascal,G.; Paudel,Y.; Perez-Enciso, M.; Ramirez-Gonzalez, R.; Reecy,J.M.; Rodriguez-Zas, S.; Rohrer,G.A.; Rund,L.; Sang,Y.; Schachtschneider,K.; Schraiber,J.G.; Schwartz,J.; Scobie,L.; Scott,C.; Searle,S.; Servin,B.; Southey,B.R.; Sperber,G.; Stadler,P.; Sweedler,J.V.; Tafer,H.; Thomsen,B.; Wali,R.; Wang,J.; Wang,J.; White,S.; Xu,X.; Yerle,M.; Zhang,G.; Zhang,J.; Zhang,J.; Zhao,S.; Rogers,J.; Churcher,C.; Schook,L.B.
Nature, 2012, 491, 7424, 393-398

PEOPLE



ECONOMIC DEVELOPMENT

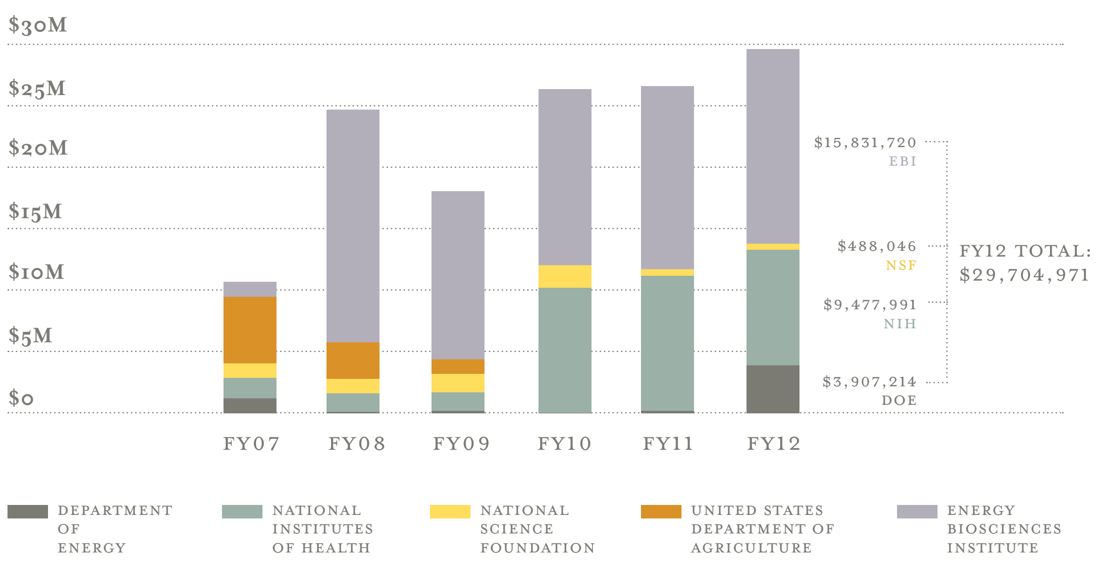
FY12
17 Disclosures
7 Patent Applications
2 Patents Issued
1 License Optioned

Total
79 Disclosures (28 EBI)
39 Patent Applications (10 EBI)
6 Patents Issued
5 Licenses Optioned

IGB CORE FACILITIES USAGE

FY12 Users
107 Research Groups
(294 active users)

FUNDING



AWARDS

2012

AWARDS

Plant biologist **Elizabeth Ainsworth** (Genomic Ecology of Global Change) received the Charles Albert Shull Award by the American Society of Plant Biologists for her research on current and potential impacts of global and environmental change on plant ecosystems. This annual award is designed to recognize young researchers for outstanding investigations in the field of plant biology.

Chemist **Ryan Bailey** (Cellular Decision Making in Cancer) was named one of the world's top young innovators by Technology Review. The list, called the TR35, honors the top innovators under the age of 35 for contributions in diverse fields such as biomedicine, energy, the web, computing, and other developing areas.

Animal biologist **Alison Bell** (Gene Networks in Neural & Developmental Plasticity) received the 2012 Young Investigator Award from the Animal Behavior Society. The award is given to one researcher each year that has made significant contributions to the field of animal behavior as a new investigator.

Hyunjoon Kong (Regenerative Biology & Tissue Engineering) of the department of chemical and biomolecular engineering was named a recipient of the 2012 Engineering Dean's Award for Excellence in Research. This award is made annually to four assistant professors in the College of Engineering, in recognition of their outstanding research conducted over the previous year.

Stephen Long (Genomic Ecology of Global Change, Energy Biosciences Institute) of the department of crop sciences and plant biology received the Marsh Award for Climate Change Research, presented by the British Ecological Society, an annual award recognizing outstanding contributions to climate change research. Open to ecologists from anywhere in the world, Long received the award at the institute's annual meeting at the University of Birmingham. Stephen was also named the recipient of the Charles F. Kettering Award by the American Society of Plant Biologists, for his work in the role of photosynthesis in mitigating climate change, and changes in the physical environment. This award was established by an endowment from the Kettering Foundation in 1962 to recognize excellence in the field of photosynthesis.

Associate professor of statistics **Ping Ma** (Gene Networks in Neural & Developmental Plasticity) won The Canadian Journal of Statistics award, for his paper *Nonparametric Regression with Cross-Classified Responses.* The Statistical Society of Canada presents this award each year to the author of an article published in the journal, in recognition of the quality of the paper's methodological innovation and presentation.

Chemist **Doug Mitchell** (Mining Microbial Genomes) was named one of Genome Technology magazine's Seventh Annual Young Investigators for his work in toxin biosynthesis. Nominated by established principal investigators in their field, these individuals are under five years into a faculty appointment and recognized for using genomics tools to study promising new research. Doug was also awarded a 2012 Packard Fellowship in Science and Engineering from the David and Lucile Packard Foundation. Designed to support highly creative researchers in the natural and physical sciences or engineering, only 16 Fellowships are awarded each year to professors early in their careers.

Sua Myong (Cellular Decision Making in Cancer) of the department of bioengineering received the National Institutes of Health Director's New Innovator Award for 2012, one of 81 researchers receiving awards to pursue visionary science.

Cell and developmental biologist **Phillip Newmark** (Regenerative Biology & Tissue Engineering) and plant biologist **Elizabeth Ainsworth** (Genomic Ecology of Global Change) were named as University Scholars, a program created to recognize the university's most talented teachers, scholars and researchers.

Christopher Rao (Energy Biosciences Institute, Regenerative Biology & Tissue Engineering) of the department of chemical and biomolecular engineering received the 2012 Outstanding Young Researcher award, from the Computing and Systems Technology (CAST) Division of the American Institute of Chemical Engineers (AIChE). This award is given to an individual under the age of 40 in recognition of outstanding contributions to the field of chemical engineering computing and systems technology.

Huimin Zhao (Mining Microbial Genomes) of the department of chemical and biomolecular engineering was awarded a 2012 Guggenheim Foundation Fellowship. Professor Zhao was one of 181 distinguished scholars chosen to receive the annual award, on the basis of achievement and exceptional promise.

IGB FY12 PATENTS ISSUED

2 U.S. Patents Issued:

Patent # 7,985,837
"Two Component Bacillus Lantibiotic and Methods for Producing and Using the Same"
Lisa Cooper, Wilfred van der Donk, Amanda McClerren

Patent # 8,173,406
"Deconstructing Lignocellulosic Biomass with a Two-Stage Method"
Bin Zhou, Xiaojuan Wang, Bin Wang, Jose De Frias, Hao Feng

MEMORIAL
TO
CARL R. WOESE
1928 - 2012

The Right Direction

By Nigel Goldenfeld

Carl Woese was not a well-known personality outside of microbiology and evolutionary biology, but he forever changed our understanding of the biosphere and its evolution. His work led to a fundamental revision of the classification of taxa, one that is now beginning to be taught in high school textbooks. Carl was the classic outsider; a lone and dedicated visionary overthrowing a century of dogma and established thought to bring about a revolution that has touched every area of modern biology.

When I think of Carl Woese, at least scientifically, there are three important things to bear in mind: the what he did, the how he did it, and the why he did it. Everyone knows about the what: the discovery of the Archaea. The scientists know the how: the development and extension of sequencing technology, a forerunner of today's genomic revolution. But hardly anyone, not even scientists, ask themselves "Why?" Why did this man choose to spend 10 years of his life working in isolation on terribly dull and repetitive experiments? The answer was his single-minded focus on evolution.

While others focused primarily on the determination of the structure of the genetic code, Carl was immediately drawn to its evolution. His most groundbreaking achievement was his use of primitive nucleic acid sequencing technology to compare ribosomal RNA sequences from diverse organisms, mostly microbes, and to report in 1977, with George Fox, the first scientifically based phylogenetic tree of life — in essence a map that revealed the large-scale organization of life and the early course of evolution. Subsequent discoveries and correlations solidified his vision.

Parodying Newton, he once quipped "If I have seen further than others, it is because I was looking in the right direction."

Carl's discoveries showed that all life on Earth is related and descended from an ancestral state that existed around 3.5 billion years ago, with the key elements of the modern cell already in place. He regarded the rapidity of this initial phase of life to be the most remarkable aspect of his discoveries, implying that prior to this time, the nature of the evolutionary process must have had a different tempo and mode from that of the present epoch. He proposed early on, and would later demonstrate through theoretical analysis and computer simulations, that this could have arisen from a collective state of life without a well-defined distinction between phenotype and genotype, characterized by large-scale endosymbiosis — thus no real notion of individual organism, species or gene.

One development that Carl did not anticipate was his profound impact on microbial ecology. Microbial ecosystems are the foundation of the Earth's biosphere. Yet, before his sequence-based phylogenetic framework there was no meaningful way to survey the microbes that make up the natural microbial world, because it is hard to culture the vast majority of these organisms. With Carl's phylogenetic reference framework based on sequences, microbiologists could isolate rRNA fragments (and later rRNA genes) from the environment for sequence analysis, and thus identify and study environmental organisms. Microbial ecology was boosted from a moribund state to one of the most vibrant fields of biology, with important ramifications for personalized medicine, as evidenced by the ongoing Human Microbiome Project.

In one of my many memories of Carl, he is in his office at Morrill Hall, lounging indecorously in his ancient chair, the one with a thick pad of washroom towels taped to the arms as a primitive and zero-budget forerunner of ergonomic design. His feet are up on the desk, really a lab bench. Later he is pecking at a grubby keyboard attached to a SUN workstation that is a decade's worth of Moore's Law behind the times. Behind him is a giant poster of Miles Davis and an American flag adorns the wall facing his lab bench. In this room, 25 years previously, Carl unraveled the history of life on Earth. Or at least the last 3.8 billion years of it. But today, he is about to give me my first biology lesson. I make a careful but genuine expression of respect and gratitude, to let him know that I know who he is. He acknowledges with a slight lowering of the head, the eyes closing gently, and then he starts to talk. He has no interest in telling me what I can read in books and papers. He wants to know what I think. Carl Woese wants to know what I think about evolution! Clearly this is a man without pretentions.

Although he pursued his life's work with a dedication, intensity and even gravitas that has rarely been matched, Carl also had perhaps the cleverest and most idiosyncratic sense of humor that I have ever encountered: subdued, subtle and witty or off-scale rambunctious and sometimes even bawdy. Very little in between. He didn't tell jokes. He jested. His humor was sometimes unfettered by good taste; but it always reflected the fact that he looked at life in a very different way than did other people.

Those with whom he was able to share his passions found him brilliant, witty, brutally honest, humble, and generous. He was a true iconoclast. Thank you, Carl, for helping us look in the right direction.

Carl Woese was a founding member of the IGB and helped create our Biocomplexity research theme. He passed away at the age of 84 in his home in Urbana, Illinois on December 30, 2012 after a long battle with cancer.

Portions of this text were taken from "Evo-Revo: Carl R. Woese, revolutionary evolutionary biologist (1928-2012)" *written by Nigel Goldenfeld, Institute for Genomic Biology and Department of Physics, University of Illinois at Urbana-Champaign, and Norman R. Pace, Department of Molecular, Cellular and Developmental Biology, University of Colorado.*

GIVING & DONOR ROLL

Thank you to all the individuals, foundations, corporations, and organizations that have supported the Institute for Genomic Biology. All gifts received to the Institute for Genomic Biology from July 1, 2007 to June 30, 2012 are included in the Honor Roll. Gifts may include any of the following: cash, stock, matching gifts, grants, bequests, planned gifts, gifts-in-kind, real estate, and paid life insurance.

Great care was taken to ensure the accuracy of the Honor Roll listings. We would appreciate you alerting us to any errors or omissions. Please direct your inquiries to Melissa McKillip, IGB Development and Outreach Director, at mmckilli@illinois.edu or (217) 333-4619.

American Chemical Society

American Society of Plant Biologists

Anonymous

Helaine S. Banner

Alison M. Bell

Janet Bercovitz & Garth Gersten

Domenico Bernoco

BodyWork Associates

BP Amoco Chemical Company

Isaac Cann & Tae Hosotani

Carle Foundation Hospital

Center for Integration of Medicine and Innovative Technology

Mark & Jasmine Chao

The Christopher Family Foundation

Noelle Cockett

James J. Davis

Evan H. DeLucia

Michael C. Dietze

Donald Danforth Plant Science Center

Sharon M. Donovan

Dow AgroSciences

Henry L. & Judith K. Dykema

A. Bryan & Jody M. Endres

Tobias & Annette Erb

ExxonMobil Foundation

Peter B. & Kim B. Fox

GenScript USA Inc.

John A. Gerlt & Jennifer M. Quirk

Stephen Gleit

Great Lakes Bioenergy Research Center

Howard O. Grundy

Jiawei Han

Kathleen T. Harleman

Herculesstichting

Richard H. & Susan M. Herman

Integra Lifesciences

Integrated DNA Technologies

David E. Irwin

Byron W. & J. Kim Kemper

Paul J. A. Kenis

Jay P. Kesan

Andrew Leakey & Elizabeth Ainsworth

The Leffman Family

George Lewin

Harris Lewin & Rosane Oliveira

Sara Lewin

Lytmos Group, LLC

Melissa J. McKillip

Melvin & Tanya Meyers

Microsoft Corporation

Ray R. Ming

Robert E. Morgan

Ohio AgriBusiness Association

Donald R. Ort

Mel & Marjory Radford

Gene E. & Julia O. Robinson

Lawrence B. & Frances A. Schook

Gerald W. Shea

David D. Sigman

Deborah H. Skehen

James M. Slauch

The Society for Experimental Biology

SomaLogic, Inc.

Steven F. Stoddard

Syngenta Biotechnology Inc.

Xiuchun Tian

USA Scientific

Wilfred van der Donk

Wake Forest University

Herbert E. Whiteley

Carl* & Gabriella Woese

**Deceased*

We work with our faculty, our students, our community, and our partners to solve the real-world problems facing society today. We pursue fundamental research and pioneer advances in the life sciences. And we look forward to the discoveries that await.

DESIGNED BY MIRHEE LEE / PHOTOGRAPHY BY KATHRYN COULTER, L. BRIAN STAUFFER, DON HAMERMAN, JASON LINDSEY, AND BRUCE DAMONTE / PRINTING BY ORIGINAL SMITH PRINTING

Institute for Genomic Biology
University of Illinois at Urbana-Champaign
Where science meets society