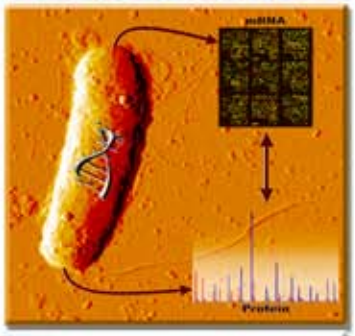
December 2006

OAK RIDGE NATIONAL LABORATORY

Biological and Environmental RESEARCH



Annual Report FY 2006

Oak Ridge National Laboratory (ORNL) conducts basic and applied research and development to create scientific knowledge and technological solutions that strengthen the nation's leadership in key areas of science; increase the availability of clean, abundant energy; restore and protect the environment; and contribute to national security.

OAK RIDGE
National Laboratory

Office of Science
U.S. DEPARTMENT OF ENERGY

Foreword

Scientists and engineers in the Biological and Environmental Sciences Directorate at the Oak Ridge National Laboratory perform research that is supported primarily by the Department of Energy's Office of Science through the Office of Biological and Environmental Research. The directorate consists of the Biosciences Division and the Environmental Sciences Division. We manage a number of research facilities and data archives, including

- the Mouse Genetics User Facility,
- the Center for Structural Molecular Biology,
- the Environmental Remediation Sciences Field Research Center,
- one of the Free Air Carbon Dioxide Enrichment facilities,
- the Atmospheric Radiation Measurement Program Data Archive,
- the Carbon Dioxide Information Analysis Center, and
- the Oak Ridge National Environmental Research Park.

Our research leads to new knowledge and technologies in areas of critical importance to the nation, such as energy security, environmental management, and homeland and national security. We perform research and development that leads to understanding biological systems and their relationship to the environment and to human health, understanding microbial communities and microbe-plant interactions in biogeochemical cycling, unraveling the multiple-scale processes that control contaminant fate and transport in the subsurface, measuring and forecasting ecosystem change, and understanding global climate change. Our work will also lead to highly effective diagnostic and therapeutic techniques based on fusing nanotechnology with biology from the molecular to the systems level. These same systems biology approaches are being applied to bioenergy in plants as feedstocks and microbes as catalysts to provide fuels.

In addition to work supported by the Department of Energy, we perform research and development supported by other federal and state institutions as well as by the private sector.

This report features selected highlights of research conducted by our scientists and engineers during fiscal year 2006. It also summarizes the recognitions and awards received by these researchers. You can learn more about the Biological and Environmental Sciences Directorate by visiting our web site at http://www.ornl.gov/sci/besd/.

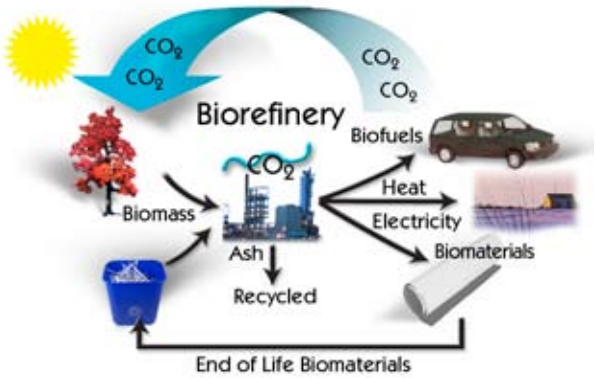
Reinhold C. Mann

ORNL Associate Laboratory Director
Biological and Environmental Sciences
Oak Ridge National Laboratory

Alternative Energy

The biorefinery: a new vision for an integrated bioenergy future

Advances in genetics, biotechnology, process chemistry, and engineering are leading to a new manufacturing concept for converting renewable biomass to valuable fuels and products, generally referred to as "the biorefinery." The integration of crops as a source of raw material and energy with biorefinery manufacturing technologies offers the potential for the development of materials and sustainable power that will lead to a new manufacturing paradigm.



The biorefinery concept replaces petroleum with biomass and minimizes waste.

In an integrated biorefinery, high-value chemicals (e.g., fragrances, flavorings) would be extracted first. Then the plant polysaccharides and lignin would be processed into "value-added" chemicals, building blocks for synthetic products and fuels. The residue from that process may undergo further processing (e.g., to produce syngas), the objective being to reduce the amount of intractable waste at the end of the process. The development of integrated biorefineries would also influence research in plant science and genetics, both to increase yield and to produce a more easily processed feedstock.

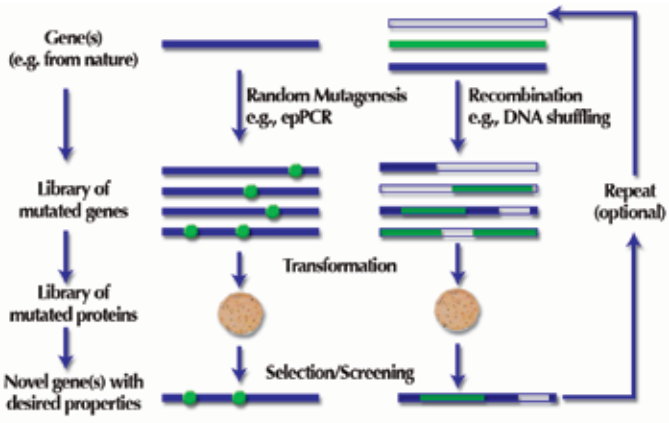
The integration of crops as a source of raw material and energy with biorefinery manufacturing technologies will lead to a new manufacturing paradigm.

A summary of information about the future of biorefineries, which appeared in a review article in *Science*, represents a consensus from a joint workshop in April 2005 involving the Georgia Institute of Technology, Imperial College of London, and ORNL. Among the authors are Brian Davison and Jonathan Mielenz (Biosciences Division) and Timothy Tschaplinski (Environmental Sciences Division).The authors cite a number of available, environmentally friendly chemical processes that could be used in a biorefinery as well as the challenges that remain to bring the concept into practice. They also note that the first generation of biorefineries is already appearing.

A. J. Ragauskas, C. K. Williams, B. H. Davison, G. Britovsek, J. Cairney, C. A. Eckert, J. Frederick, J. P. Hallett, D. Leak, C. L. Liotta, J. R. Mielenz, R. Murphy, R. Templer, and T. Tschaplinski. "The path forward for biofuels and biomaterials," **Science** 311 (5760): 484–89 (2006).

Outlook for cellulase improvement: screening and selection strategies

Cellulose is the most abundant renewable natural resource, and the production of biobased products and bioenergy from less costly renewable lignocellulose is important for sustainable development. A reduction in the production costs of cellulase enzymes, improvements in their performance, and an increase in sugar yields are all vital to reducing the processing costs of biorefineries. Improvements in specific cellulase activities for noncomplexed cellulase



Scheme of directed protein evolution.

Continuous culture using insoluble cellulosic substrates could be a powerful tool for selection of beneficial cellulase mutants.

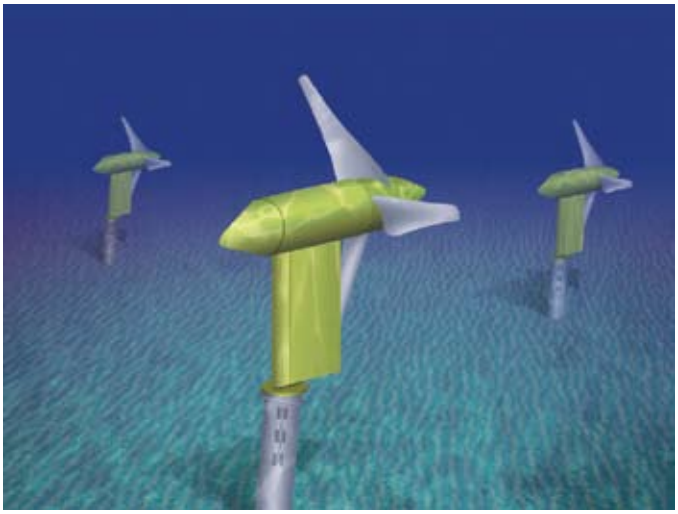
mixtures can be implemented through cellulase engineering based on either directed evolution or rational design for each cellulase component enzyme and on the reconstitution of cellulase components.

Jonathan Mielenz, of the Biosciences Division, is co-author of an article in *Biotechnology Advances* in which the advantages and limitations of quantitative cellulase activity assays using soluble and insoluble substrates are reviewed. In the article, the authors hypothesize that continuous culture using insoluble cellulosic substrates could be a powerful tool for selection of beneficial cellulase mutants from the large library displayed on the cell surface. The past success of rational design campaigns for improving properties of enzymes has been notable, but the results have been costly and slow in coming. In contrast, directed evolution is sufficiently robust that improved biocatalysts can be obtained independently of knowledge of the protein structure and the interaction between enzymes and substrate. The authors conclude that the employment of continuous culture with insoluble cellulosic substrates as the sole carbon source could be a powerful tool to select higher-activity cellulase mutants that are displayed on the cell surface.

Y.-H. P. Zhang, M. E. Himmel, and J. R. Mielenz. "Outlook for cellulase improvement: Screening and selection strategies," **Biotechnology Advances** 24: 452–81 (2006).

Hydropower without dams: the potential for hydrokinetic and wave energy technologies

Compared with conventional hydropower facilities (which typically require the construction of dams, powerhouses, and reservoirs), new hydromechanical devices can capture the energy associated with river currents and ocean waves and convert it to electricity with minimal environmental impacts. Submerged free-flow turbines are expected to have a much smaller impact than conventional turbines on the survival and migration of fish, aquatic and terrestrial habi-



Submerged hydromechanical power generators.

tats, water quality, sediment transport, and visual aesthetic qualities. These new devices have not been well studied, but much information obtained from studies of conventional turbines can be applied. Adding to the uncertainty, there is a fundamental concern about extrapolating the environmental effects from single units to energy farms composed of dozens or hundreds of hydrokinetic turbines.

DOE recently sponsored a workshop that brought experts together to discuss the characteristics of hydrokinetic and wave energy technologies, the appropriate environments

Submerged free-flow turbines are expected to have much smaller impacts on the environment than conventional hydropower facilities.

for turbine deployment, environmental concerns associated with deployment, and needed research and mitigation. Among the participants were Glenn Cada and Mike Sale of the Environmental Sciences Division. Guidance was published on how to deal with these concerns to help developers and regulators understand the environmental issues surrounding the new technologies. With support from State Partnership Program funding, ORNL researchers also provided technical assistance to the New York State Energy

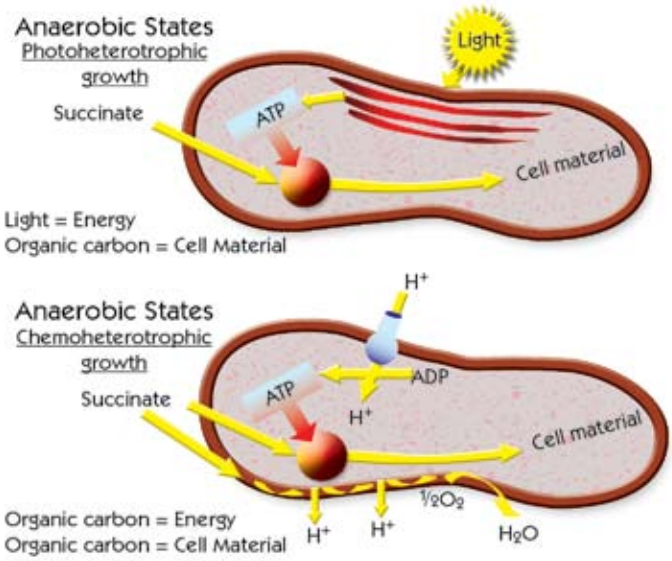
Research and Development Agency and to the developer of a submerged, free-flow turbine array in New York's East River on methods to evaluate the potential for injury to fish and other aquatic animals.

DOE Office of Energy Efficiency and Renewable Energy Wind and Hydropower Technologies Program. **Proceedings of the Hydrokinetic and Wave Energy Technologies Technical and Environmental Issues Workshop**, Washington, D.C., October 26–28, 2005.

C. C. Coutant and G. F. Cada. "What's the future of instream hydro?" **Hydro Review** XXIV (6): 42–49 (2005).

Rhodopseudomonas palustris proteome studied

Rhodopseudomonas palustris is a versatile, widely distributed bacterium whose genome has recently been completed and annotated. Among bacteria, *R. palustris* is exceptional in its metabolic versatility. It can obtain energy from both light and organic compounds, it can grow aerobically or anaerobically, and it can degrade structurally diverse compounds under both aerobic and anaerobic conditions. *R. palustris* also produces hydrogen gas as a by-product of nitrogen fixation, making it a potential biofuel producer, and it has the potential to act as a greenhouse gas sink by converting carbon dioxide into cell mass. Because most of its metabolic states can easily be attained in laboratory settings, *R. palustris* is an ideal model for the study of diverse metabolic modes and their control within a single organism.



Core metabolic states of* R. palustris *studied. Top: basic anaerobic state for growth in light without oxygen. Bottom: basic aerobic state for growth in the dark with oxygen present. (Adapted from Larimer et al. Nat. Biotechnol. 22, 55–60, 2004.)

The team has created the ORNL Rhodopseudomonas palustris Proteome Study Website, a much-needed open-access repository for R. palustris data.

A research team including research staff in the Chemical Sciences and Biosciences divisions is experimenting with *R. palustris* with the long-term goal of obtaining a comprehensive understanding of its diverse metabolic states. As a starting point, the team set out to determine the baseline proteome of a wild-type strain of *R. palustris* under phototrophic and chemotrophic growth conditions. From the resulting dataset, a variety of biological studies can be performed to understand the microbe's life processes and metabolic diversity. The team has created the ORNL *Rhodopseudomonas palustris* Proteome Study Website (http://compbio.ornl.gov/rpal_proteome), a much-needed open-access repository for *R. palustris* data, and plan to make it a powerful and user-friendly site. It is expected to be one of the largest ongoing public resources to date, one that will provide truly open access to proteome results.

N. C. VerBerkmoes, M. B. Shah, P. K. Lankford, D. A. Pelletier, M. B. Strader, D. L. Tabb, W. H. McDonald, J. W. Barton, G. B. Hurst, L. Hauser, B. H. Davison, J. T. Beatty, C. S. Harwood, F. R. Tabita, R. L. Hettich, and F. W. Larimer. "Determination and comparison of the baseline proteomes of the versatile microbe *Rhodopseudomonas palustris* under its major metabolic states," **Journal of Proteome Research** 5 (2): 287–98 (2006).

Earth Science

Field-scale biostimulation study for remediation of uranium-contaminated groundwater

A team of researchers that included members of the Environmental Sciences and Biosciences divisions conducted a "biostimulation" study at the Environmental Remediation Sciences Program Field Research Center on the Oak Ridge Reservation. The research was motivated by the likelihood that metal- and sulfate-reducing bacteria could be stimulated in the subsurface to enhance the reduction of redox-sensitive metals and radionuclides, thereby immobilizing them in situ. An aboveground processing facility was used for the removal of high concentrations of nitrate, metals, and perchloroethylene.

The research will have a significant impact on the Oak Ridge Reservation Groundwater Strategy.

Near-source groundwater processing equipment for the biostimulation project.

The team was able to achieve the "maximum contaminant limit" determined by the U.S. Environmental Protection Agency for uranium in drinking water (< 0.03 mg/L) in situ in the highly contaminated uranium- and nitrate-rich system by stimulating subsurface microorganisms. Both field and laboratory investigations confirmed that metal-reducing *Geobacter* spp. and sulfate-reducing *Desulfovibrio* spp. were stimulated by additions of ethanol (an electron donor) and that they were most likely significant contributors to the reduction of dissolved uranium. The team found that the prescribed groundwater uranium concentrations could be maintained and that solid-phase uranium remains stable under anaerobic conditions for 1 to 2 years.

The research will have a significant impact on the Oak Ridge Reservation Groundwater Strategy (DOE/OR/01-2069&D2), which describes a watershed-based strategy for making decisions about groundwater remediation on the Oak Ridge Reservation.

W. M. Wu, J. Carley, S. Caroll, O. Cirpka, M. W. Fields, M. Fienen, M. E. Gentile, T. Gentry, M. A. Ginder-Vogel, R. F. Hickey, B. Gu, J. Luo, T. L. Mehlhorn, J. Nyman, H. Yan, D. B. Watson, J. Zhou, S. E. Fendorf, P. Kitanidis, P. M. Jardine, and C. S. Criddle. "Pilot-scale in situ bioremediation of uranium in a highly contaminated aquifer II: Reduction of U(VI) and geochemical control of U(VI) bioavailability," **Environmental Science and Technology** 40 (12): 3986–95 (2006).

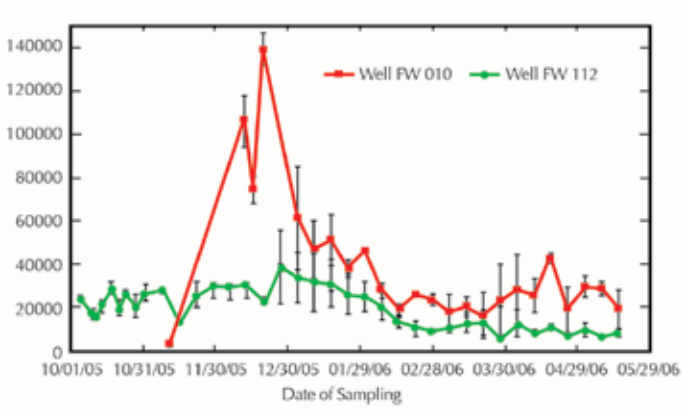
Passive samplers for chromatographic analyses of gases in groundwater reveal high concentrations of hydrogen

Brian Spalding and David Watson, in the Environmental Sciences Division, adapted a simple in situ passive dissolved-gas groundwater sampler (a short length of silicone tubing attached to a syringe) for in situ collection of equilibrium gas samples. After spending several days immersed in groundwater, the device is retrieved, and the sample can be injected from the device directly into a gas chromatograph. Thus it enables a simpler field-collection and sample-handling process than the commonly used "bubble stripping" method for H_2 analyses.

The passive dissolved-gas samplers enable a simpler field-collection and sample-handling process.

The researchers modified a gas chromatograph by sequencing a thermal conductivity detector followed by a reductive gas detector so that linear calibration of H_2 over the range 0.2 through 200,000 ppmv was attained for a 0.5-mL gas sample. Inclusion of the thermal conductivity detector allowed the simultaneous quantification of other fixed gases (O_2, CO_2, He, and Ne) to which the reductive gas detector was not responsive. Uptake kinetics for H_2 and He indicated that the passive sampler reached equilibrium within 12 h of immersion in water. Field testing of these passive samplers revealed unusually large equilibrium gas-phase H_2 concentrations in groundwater, ranging from 0.1 to 13.9% by volume, in 11 monitoring wells surrounding 4 former radiological wastewater disposal ponds at the Y-12 plant in Oak Ridge, Tennessee.

B. P. Spalding and D. B. Watson. "Measurement of dissolved H_2, O_2, and CO_2 in groundwater using passive samplers for gas chromatographic analyses," **Environmental Science and Technology**. Published on the Web: doi 10.1021/es0613310 (2006).



Data from monitoring wells surrounding four former radiological wastewater disposal ponds at the Y-12 plant in Oak Ridge, Tennessee.

Syringe/tubing dissolved gas sampler.

PELCAPs: Permeable environmental leaching capsules for in situ evaluation of contaminant immobilization in soil

Brian Spalding and David Watson, in the Environmental Sciences Division, have devised a generic, nondestructive technique for determining the persistence of contaminants immobilized on soils and sediments. It offers the capability to conveniently and cost-effectively test large numbers of soils and soil treatments for contaminant release and uptake under actual field environmental conditions.

PELCAPs. The volume of each is about 5 cm^3.

The two researchers fabricated "permeable environmental leaching capsules" (PELCAPs) by casting a polyacrylamide matrix into small (~ 5 cm^3), water-permeable cylinders that contain radioisotope-spiked soil. As a proof of principle, they used soils labeled with either ^{85}Sr or ^{134}Cs and leached the PELCAPs in both laboratory tests and in situ by continuously exposing them to groundwater and stream water at two field sites on the Oak Ridge Reservation.

PELCAPs offer a convenient, cost-effective way to test large numbers of soils and soil treatments under field conditions.

Groups of PELCAPs were retrieved, assayed nondestructively for radioisotopes, and then reinstalled repeatedly over a 6-month period. PELCAPs that contained no soil readily leached both ^{85}Sr and ^{134}Cs into laboratory extractants, the groundwater, and the surface water. PELCAPs containing thermally treated soil retained both of the isotopes in laboratory sequential extractions as well as in field tests. PELCAPs containing untreated soil readily leached more than 90% of ^{85}Sr but less than 1% of ^{134}Cs at both field sites. Soils were retained in the PELCAPs and maintained their cation-exchange capacities during the exposure period.

B. P. Spalding and S. C. Brooks. "Permeable environmental leaching capsules (PELCAPs) for in situ evaluation of contaminant immobilization in soil," **Environmental Science and Technology** 39: 8912–18 (2005).

Vadose zone flow and transport of carbon in humid regimes

Efforts to enhance terrestrial organic carbon sequestration have traditionally focused on aboveground biomass and surface soils. An unexplored potential exists in thick lower horizons of widespread, mature soils, and a multiple-scale approach may be necessary to assess the propensity of deep subsoils to sequester organic carbon in situ. A research team

A pedon used in the study of dissolved organic carbon in the subsoil.

The team studied the fate and transport of dissolved organic carbon within a highly weathered soil.

that included staff from the Environmental Sciences Division studied the fate and transport of dissolved organic carbon within a highly weathered soil, involving spatial scales from the laboratory to the landscape.

The team's objectives were to interpret processes observed at various scales and to provide an improved understanding of the mechanisms that control the mobility and sequestration of dissolved organic carbon in deep subsoils within humid climatic regimes. Their multiple-scale approach involved laboratory batch and soil columns (0.2 × 1.0 m), an in situ pedon (2 × 2 × 3 m), a well-instrumented subsurface facility on a subwatershed (0.47 ha), and ephemeral and perennial stream discharge at the landscape scale (38.4 ha).

The laboratory-scale experiments confirmed that the lower soil horizons tend to accumulate dissolved organic carbon but that preferential fracture flow tends to limit sequestration. Intermediate-scale experiments demonstrated the beneficial effects of carbon diffusion into soil micropores. Field- and landscape-scale studies demonstrated the coupled hydrological, geochemical, and microbiological mechanisms that limit the sequestration of dissolved organic carbon and their sensitivity to local environmental conditions.

P. M. Jardine, M. A. Mayes, J. R. Tarver, P. J. Hanson, P. J. Mulholland, G. V. Wilson, and J. F. McCarthy. "Exploring vadose zone flow and transport of dissolved organic carbon at multiple scales in humid regimes, " **Vadose Zone Journal** 5: 140–52 (2005).

Carbon Cycling and Climate Change

Research in military aircraft emissions

Most of the aircraft fuel used by the U.S. Air Force is consumed in high-payload aircraft such as cargo planes (C130Hs) and bombers (B-52s), which are expected to be heavily used into the middle of the twenty-first century, for example, for fighting wars and for humanitarian aid missions. The fixed-wing aircraft can produce significant amounts of gaseous and particulate emissions that are deposited directly into the atmosphere, contributing to changes on both local and global scales in air composition, air quality, radiation balance, and possibly the life cycle of clouds. However, the fate and transport of the gases and ultrafine particulates that are the dominant species in the aircraft exhaust are not well understood at present because current methods are not suitable for measuring them.

The research team at Barksdale Air Force Base.

An ongoing project led by ORNL and involving the Wright-Patterson Air Force Research Laboratory, the U.S. Environmental Protection Agency, and industrial partners sought a reliable means for quantifying exhaust emissions from military aircraft. Observations from the field measurements of a C130H cargo plane in 2005 revealed that the particulate matter was dominated by soot and sulfate. The researchers also determined that for reactive aerosol chemistry and turbulent flow mixing in the exhaust plume, far-field measurements (15 m behind the exhaust) would not provide information that would enable direct identification and quantification of individual aircraft emissions. Extractive sampling by using a nitrogen-gas-driven dilution probe effectively quenches aerosol growth at the probe tip, yielding a reliable means for quantitative determination of aircraft emissions at present. Infrared visualization and on-line chemical measurements (by remote sensing and extractive methods) of the exhaust plume from a B-52 aircraft reveal complex turbulent reactive flow patterns as a function of engine power settings. The data are helping scientists improve their understanding of chemical transformation of the emitted materials and design better measurement strategies for future emissions science research.

Data obtained from military aircraft are helping in the design of better measurement strategies for emissions.

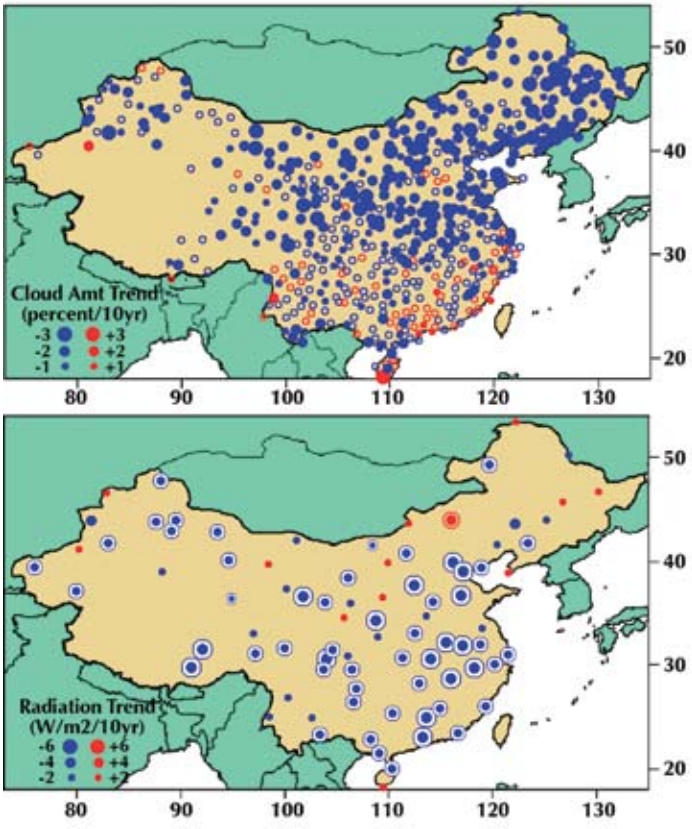
M.-D. Cheng. **The FY 2006 Annual Report on Characterization of B-52 Aircraft Engine Emissions for SERDP**, in review (2006).

M.-D. Cheng, E. Corporan, M. DeWitt, C. Spicer, M. Holdren, K. Cowen, B. Harris, R. Shores, R. Hashmonay, R. Kaganan, J. M. Storey, and J. E. Parks II. "Probing emissions of military cargo aircraft: description of a Joint Field Measurement Program," **Journal of the Air and Waste Management Association,** submitted (August 2006).

Clouds and surface solar radiation trends studied in China

Chinese climate records obtained through a bilateral research agreement between the U.S. DOE and the China Meteorological Administration reveal that much of China has experienced significant decreases in cloud cover over the last half of the twentieth century. This conclusion is supported by analysis of the observed frequency of cloud-free and overcast skies. From 1954 to 2001, total cloud cover and low cloud cover over China have decreased by 0.88% and 0.33% per decade, respectively, while cloud-free days have increased by 0.60% per decade, and overcast days have decreased by 0.78% per decade. Records of cloud amount are especially important in understanding climate change; it would be expected that the decreasing cloud amount would increase surface radiation; however, the opposite was found

Decreasing cloud cover is expected to increase surface radiation; however, the opposite was found over most of China.



Decadal trends in cloud amount (upper) and radiation (lower) over China, 1954–2001. Statistical significance at the 95% level is shown by filled circles in the upper plot, and by rings around the dots in the lower plot.

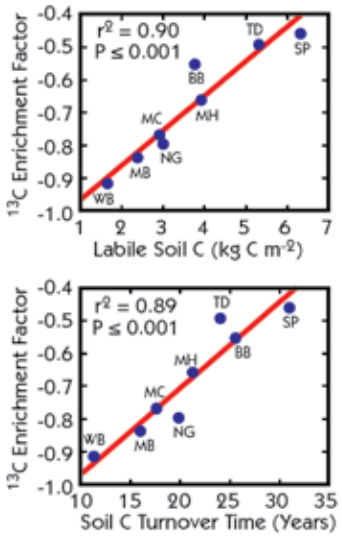
over most of China. Both solar radiation and pan evaporation (which gives an indication of the combined effects of temperature, humidity, solar radiation, and wind) have decreased over most of China. Annual mean solar radiation has decreased by 3.1 W/m^2 per decade, and annual mean pan evaporation has decreased by 39 mm per decade.

Combining these results with findings of previous studies, the researchers postulate that an increasing human-made aerosol burden (mainly SO_2) has produced a fog-like haze over much of China and that the haze has increasingly reflected and absorbed solar radiation and thus has resulted in less solar radiation reaching the surface, despite concurrent decreasing trends in cloud amount and increasing trends in cloud-free sky.

Y. Qian, D. P. Kaiser, L. R. Leung, and M. Xu. "More frequent cloud-free sky and less surface solar radiation in China from 1955–2000," **Geophysical Research Letters** 33: L01812 (2006).

Carbon isotope ratios in forest soil depth profiles related to turnover times

It is well known that forest soils exhibit a natural increase in the abundance of ^{13}C with soil depth, but the mechanisms causing changes in the isotopic composition of carbon through the soil profile are unclear. Some researchers have speculated that the changes are related to carbon turnover times. A better understanding of soil carbon turnover is fundamental to terrestrial carbon-sequestration strategies for mitigating future increases in atmospheric CO_2.



Recent research has identified possible relationships between ^{13}C enrichment factors and labile soil carbon inventories (upper) and soil carbon turnover times (lower) in forest ecosystems along a climate gradient in the southern Appalachian Mountains.

This research confirms an inferred link between soil ^{13}C enrichment factors and soil carbon dynamics.

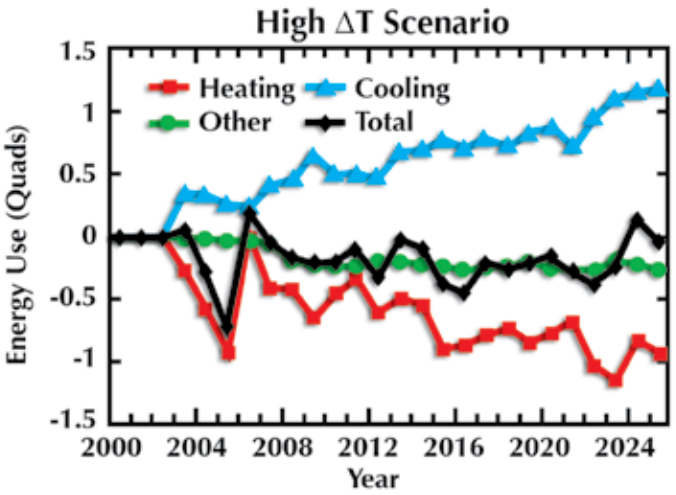
Recent research by Charles Garten and Paul Hanson in the Environmental Sciences Division has produced estimates of forest soil carbon turnover times and has demonstrated their association with ^{13}C enrichment factors (a measure of change in carbon isotope composition with soil depth). This research represents the first empirical confirmation of an inferred link between soil ^{13}C enrichment factors and soil carbon dynamics and relates the values to environmental variables and major soil carbon pools. This new work shows that environmental factors, soil carbon partitioning, and vertical changes in ^{13}C:^{12}C soil ratios are interrelated and that measurements of carbon isotope ratios are a potential indicator of carbon dynamics in undisturbed forest soils.

C. T. Garten, Jr., and P. J. Hanson. "Measured forest soil C stocks and estimated turnover times along an elevation gradient," **Geoderma** (2006), doi:10.1016/j.geoderma.2006.03.049.

C. T, Garten, Jr. "Relationships among forest soil C isotopic composition, partitioning, and turnover times," **Canadian Journal of Forest Research** 36: 2157–67 (2006).

Responses of energy use to climate change

Observed increases in the concentrations of atmospheric CO_2 are expected to continue, leading to continued increases in near-surface air temperatures. As temperatures change, so too will the amount of energy required for heating and cooling buildings, with fossil fuel emissions increasing as a result. A team of researchers led by Stan Hadley (Engineering Science and Technology Division) and David Erickson (Computer Science and Mathematics Division) melded the results of detailed climate and energy economics models and ran simulations for the United States for the years 2000 through 2025. "Business-as-usual" climate model simulations for the period were used to drive a detailed numerical economics model based on a low-temperature (1.2°C) and a high-temperature (3.4°C) response to CO_2 doubling.



The study concluded that in the high-temperature scenario, the use of air conditioning would more than offset the energy savings realized by reduced heating.

The researchers found that energy for heating in the low-temperature-change scenario was relatively consistent in the end years of the simulation but that it continued to decline in the high-temperature-change scenario, making projected net energy use in the high-temperature case slightly lower than in the low-temperature case by 2025. In northern regions, the net energy requirements would be lower because the climate would be warmer, but southern and western regions of the United States would experience increases in energy use as air-conditioning needs increased with rising temperatures. As a whole, increases in carbon emissions from higher air-conditioning needs would more than offset decreases in carbon emissions from reduced heating needs.

Increases in carbon emissions from higher air-conditioning needs would more than offset decreases in carbon emissions from reduced heating needs.

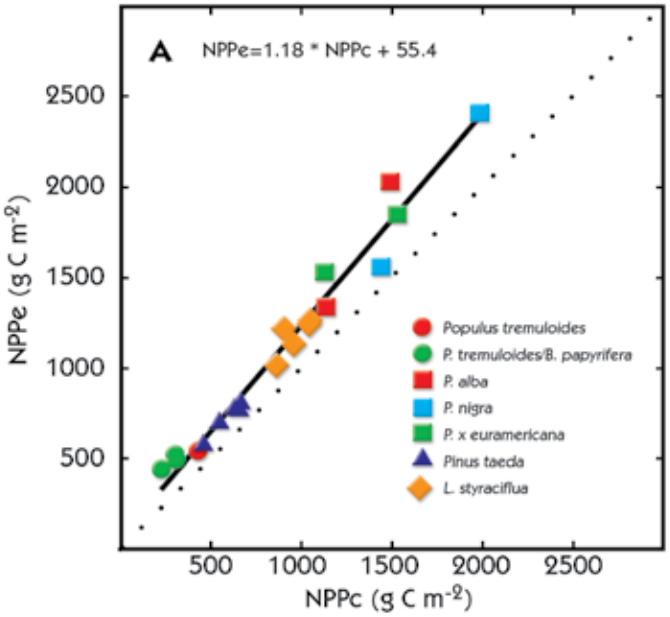
S. Hadley, D. J. Erickson III, J. Hernandez, C. Broniak and T. J. Blasing. "Responses of energy use to climate change: A climate modeling study," **Geophysical Research Letters** 33 (17): L17703 (2006).

Forest productivity increases in a CO_2-enriched atmosphere

Climate change predictions from models are highly dependent on assumptions about feedback between the biosphere and the atmosphere. One critical feedback occurs if carbon uptake by the biosphere, its net primary productivity (NPP), increases in response to the fossil-fuel-driven increase in atmospheric CO_2, thereby slowing the rate of increase in atmospheric CO_2.

A research team led by R. J. Norby (Environmental Sciences Division) analyzed the response of NPP to elevated CO_2 (~550 ppm) in four free-air CO_2 enrichment (FACE) experiments in forest stands. The research showed that the response of forest NPP to elevated CO_2 is consistent across a broad range of productivity, with a stimulation at the median of 23 ±2%. The surprising consistency of response

Results of this research have provided a benchmark to evaluate predictions of ecosystem and global models.



The relationship between the current net primary productivity (NPPc, 376 ppm) and the elevated NPP (NPPe, 550 ppm) proved to be remarkably consistent with a median increase of 23%.

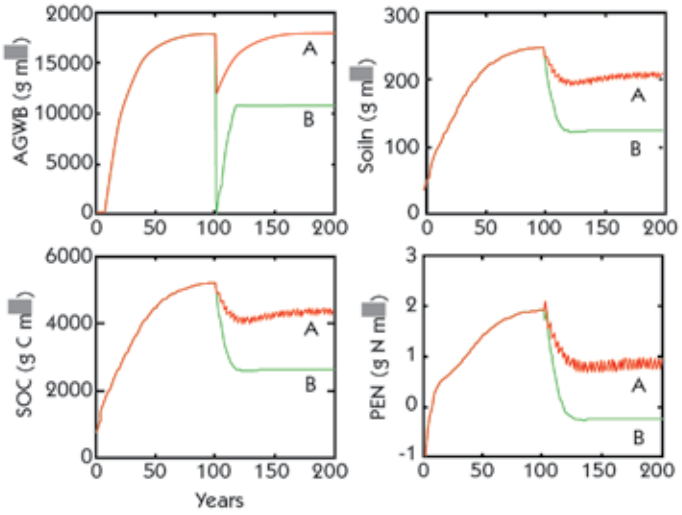
across diverse FACE sites provides a benchmark to evaluate predictions of ecosystem and global models and allows researchers to focus (1) on unresolved questions about carbon partitioning and retention and (2) on spatial variation in NPP response caused by the availability of other growth-limiting resources.

R. J. Norby, E. H. DeLucia, B. Gielen, C. Calfapietra, C. P. Giardina, J. S. King, J. Ledford, H. R. McCarthy, D. J. P. Moore, R. Ceulemans, P. De Angelis, A. C. Finzi, D. F. Karnosky, M. E. Kubiske, M. Lukac, K. S. Pregitzer, G. E. Scarascia-Mugnozza, W. H. Schlesinger, and R. Oren. "Forest response to elevated CO2 is conserved across a broad range of productivity," **Proceedings of the National Academy of Sciences** 102: 18052–56 (2005).

Ecosystem models may help forecast coastal forest recovery following hurricanes

Hurricanes can have widespread impacts on upland forest resources of coastal regions in the southeastern United States, leaving forest stands in need of restoration or rehabilitation. However, little is currently known about how soil quality affects the potential for post-disturbance forest recovery and how various post-disturbance management practices affect the sustainability of recovering ecosystems on sandy, nutrient-poor soils.

Measurements of soil carbon and nitrogen can be used to define thresholds to ecosystem recovery.



Sustainable ecosystem recovery after forest thinning is illustrated by line "A" and unsustainable recovery after clear-cutting is illustrated by line "B." (AGWB: predicted tree wood biomass, SOILN: soil nitrogen, SOC: soil carbon, and PEN: potential excess soil nitrogen under different regimes of prescribed burning.)

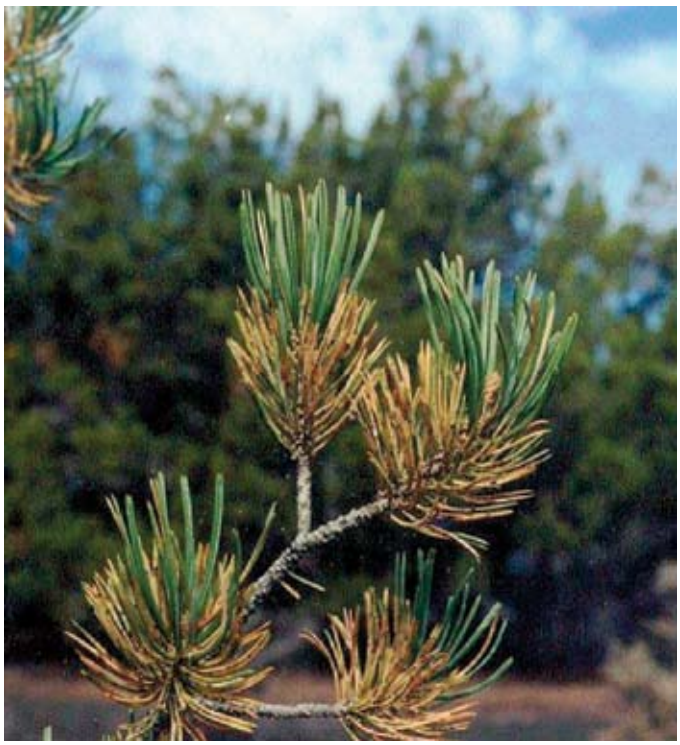
Recent research on military installations by Charles Garten and Tom Ashwood, researchers in the Environmental Sciences Division, has addressed ways of forecasting soil quality thresholds to ecosystem recovery following disturbance and of predicting the effect that common land management practices (e.g., prescribed burning and tree harvesting) have on forest sustainability. The research results from field studies and a model-based analysis suggest that measurements of soil carbon and nitrogen can be used to define thresholds to ecosystem recovery and that nutrient limitation can be a key constraint on the recovery and sustainability of desired future ecosystem conditions following forest disturbance on the southeastern coastal plain.

C. T. Garten, Jr., and T. L. Ashwood. "Modeling soil quality thresholds to ecosystem recovery at Fort Benning, GA, USA," **Ecological Engineering** 23: 351–69 (2004).

C. T. Garten, Jr. "Predicted effects of prescribed burning and harvesting on forest recovery and sustainability in southwest Georgia, USA," **Journal of Environmental Management** 81 (4): 323–32 (2006).

Make better predictions to manage systems under changing climatic regimes

Climatic change assessments and models tend to focus on how large-scale alterations in climate may alter vegetation. However, a major challenge in dealing with the effects of climatic change now and in the future comes in trying to predict the secondary and cascading effects in ecosystems. Vegetation responds to changes in climate, but it also creates distinct microclimate patterns; ecosystem processes are affected by both the general climate and these microclimate patterns.



A piñon infested with scale insect (2 years of needles; one infected, the other new growth).

Insects impact millions of hectares of U.S. forest annually at a cost of over two billion dollars, and their effect is expected to increase with climatic warming. Predicted increases in insect outbreaks can cause rapid changes in vegetation with concomitant changes in microclimate. Understanding how herbivores indirectly alter the soil microclimate will enable scientists to make better predictions about how to manage systems under changing climatic regimes. As reported in *Soils Science Society of America Journal*, a research team at Northern Arizona University led by Aimee Classen (Environmental Sciences Division) used an herbivore removal experiment to test the hypothesis that herbivore alteration of plant architecture impacts soil microclimate. They found that herbivores have major impacts on soil microclimate, impacts sufficient to drive changes in ecosystem processes and similar to predicted climatic-change scenarios over the next century. Herbivory reduced precipitation interception by 51% and increased soil moisture by 35% and soil temperature by 29%. These results suggest that herbivores can have large impacts on microclimate and should be considered when making predictions on how to manage ecosystems.

These results suggest that herbivores can have large impacts on microclimate.

A. T. Classen, S. C. Hart, T. G. Whitham, N. S. Cobb, and G. W. Koch. "Insect infestations linked to shifts in microclimate: important climate change implications," **Soil Science Society of America Journal** 69: 2049–57 (2005).

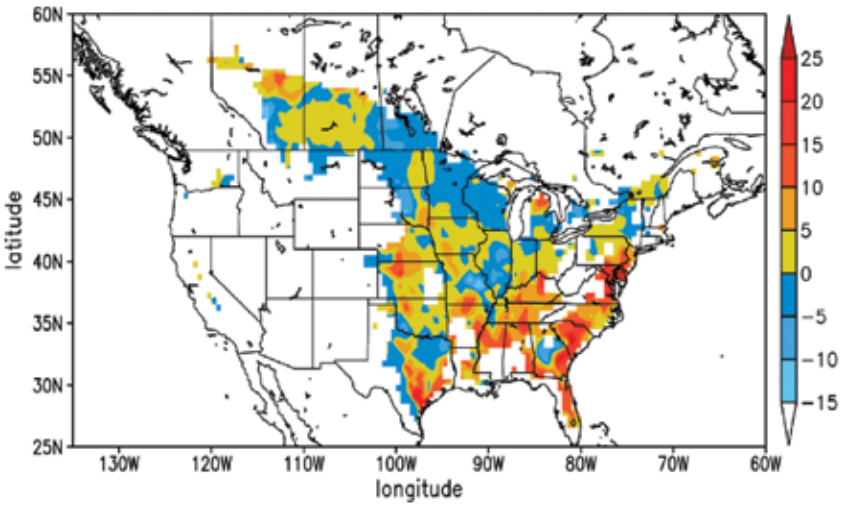
Estimating the impact of recent climate change on soil carbon sequestration

Field experiments indicate that changes in climate affect soil carbon stocks in various ways, depending on the soil and regional climate. Thus the changing climate can complicate the prediction of changes in carbon stocks and fluxes due to human activities. Researchers from ORNL and University of Illinois coupled estimates of potential soil carbon change with a coupled climate-biosphere-ocean model to look at the impact of recently observed climate change on soil carbon sequestration activities. Integrating potential carbon sequestration dynamics into the Integrated Science Assessment Model (ISAM) allowed the researchers (1) to estimate the effect of climate change on sequestration activities and (2) to separate changes in carbon stocks due to regional changes in climate and weather from those caused by intentional sequestration strategies.

Change in soil carbon following a change to no-till in croplands was incorporated into the terrestrial component of ISAM. Results indicate that 5% of the soil carbon sequestered from no-till activities between 1980 and 2000 was caused by climate changes. The extent to which soil carbon sequestration was augmented or lessened is due to soil

The extent to which soil carbon sequestration was augmented or lessened is due to soil attributes and feedbacks between climate and biophysical variables.

attributes and feedbacks between climate and biophysical variables (e.g., temperature, soil moisture, decomposition rates, and changes in crop yields and residue production). Model results also indicated that an additional 3% of soil carbon accumulation in 2000 was due to previous changes in land cover (e.g., conversion of cropland to forest).



Positive and negative values (in %) indicate an increase or decrease, respectively, in soil carbon sequestration occurring between 1981 and 2000 because of changes in climate and the atmospheric CO_2 concentration.

A. K. Jain, T. O. West, X. Yang, and W. M. Post. "Assessing the impact of changes in climate and CO_2 on potential carbon sequestration in agricultural soils," **Geophysical Research Letters** 32: L19711 (2005).

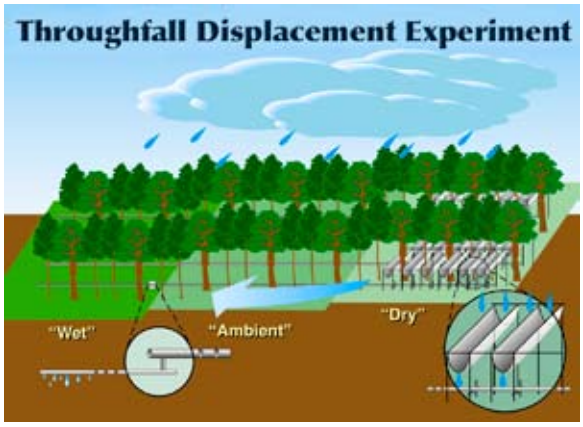
Unique field experiment emphasizes the sensitivity of forest water use to drought

Water availability could become an issue in the eastern United States if potential changes in regional precipitation are realized. ORNL scientists working at the Throughfall Displacement Experiment have been examining the sensitivity of deciduous forests to increases and decreases in precipitation since 1993. The researchers use sensors to measure water flow in trees and have related seasonal patterns of soil water potential and treatment-specific differences in forest water use to precipitation amount.

Across four years in which water use was measured (2000–2003), the researchers found a strong correlation between seasonal water use and the water stress integral, a cumulative index of drought severity and duration. These differences were explained by the primary effect of soil water availability on leaf and whole-plant physiology, with surprisingly little influence from drought-induced changes in canopy development, leaf area production, leaf senescence, or changes in vertical root distribution among treatment plots. Seedlings and saplings proved to be more sensitive than mature trees to soil water availability, largely because of their shallow root placement within the soil profile. The researchers concluded that even though droughts in deciduous forests tend to occur late in the growing season, soil water deficits of the magnitude observed in the four-year study have the potential to affect patterns of forest succession and local and regional forest water budgets.

Soil water deficits of the magnitude observed in the study can affect patterns of forest succession and forest water budgets.

S. D. Wullschleger and P. J. Hanson. "Sensitivity of canopy transpiration to altered precipitation in an upland oak forest: Evidence from a long-term field manipulation study," **Global Change Biology** 12: 97–109 (2006).



The Throughfall Displacement Experiment simulates possible wet/dry extremes in precipitation for the southeastern United States.

Systems Biology

The black cottonwood genome sequenced

Gerald Tuskan (Environmental Sciences Division) led an international team that has successfully drafted the genome sequence of the black cottonwood (*Populus trichocarpa*), the first tree genome to be sequenced. Unveiling the genome of *Populus*, a model woody perennial, provides an unprecedented opportunity to explore its unique biology at a fundamental level. Such information will greatly improve our ability to (1) use trees as a renewable source of energy, (2) enhance carbon storage in managed tree farms, and (3) understand mechanistic ecosystem responses to global climate change.

Integration of "shotgun" sequence assembly with genetic mapping enabled chromosome-scale reconstruction of the genome. More than 45,000 putative protein-coding genes were identified. Analysis of the assembled genome revealed a whole-genome duplication event; about 8000 pairs of duplicated genes from that event survived in the *Populus* genome. A second, older duplication event is indistinguishably coincident with the divergence of the *Populus* and *Arabidopsis* lineages. (*Arabidopsis*, an herbaceous annual and the first plant to be sequenced, was used as a source of comparison during the sequencing of *Populus*.) Nucleotide substitution, tandem gene duplication, and gross chromosomal rearrangement appear to proceed substantially more slowly in *Populus* than in *Arabidopsis*.

Gerald Tuskan (right) and Tim Tschaplinski, Environmental Sciences Division.

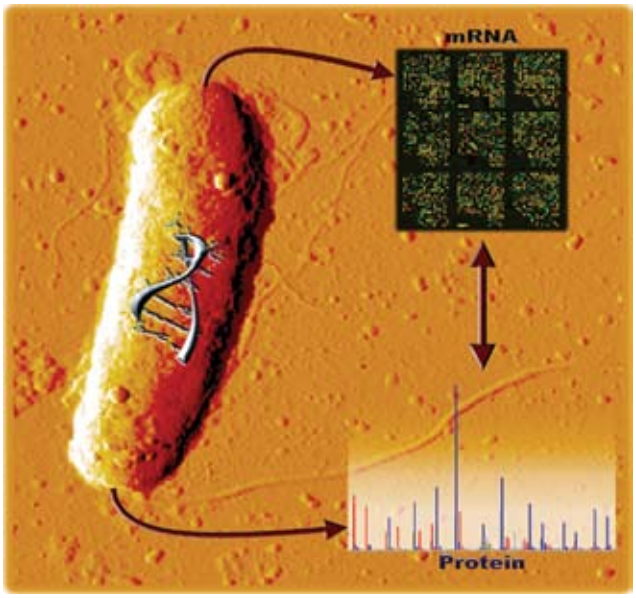
Populus has more protein-coding genes than *Arabidopsis*, ranging on average from 1.4 to 1.6 putative *Populus* homologs for each *Arabidopsis* gene. However, the relative frequency of protein domains in the two genomes is similar; overrepresented exceptions in *Populus* include genes associated with lignocellulosic wall biosynthesis, meristem development, disease resistance, and metabolite transport.

The team drafted the gene sequence of the black cottonwood, the first tree genome to be sequenced.

G. A. Tuskan et al. "The genome of black cottonwood, *Populus trichocarpa* (Torr. & Gray)," **Science** 313: 1596–1603 (2006).

Studies investigate the effect of chromium and strontium on *Shewanella oneidensis* MR-1

Shewanella oneidensis MR-1 possesses remarkable metabolic versatility and is a model environmental microorganism. Its complete genome sequence has been determined by the DOE Joint Genome Institute. Research teams including members of the Biosciences, Environmental Sciences, and Chemical Sciences divisions investigated the interactions of *S. oneidensis* MR-1 with chromium and strontium.



The bacterium* Shewanella oneidensis *MR-1 responds to hexavalent chromium by a complicated process involving gene regulation, protein expression, and metabolite production. Integrated experiments involving gene and protein measurements and imaging provided detailed information about dynamic molecular-level responses to this toxic metal.

Hexavalent chromium, Cr(VI), is a highly soluble metal pollutant, while Cr(III) is sparingly soluble and relatively innocuous. In situ microbial bioreduction of Cr(VI) to Cr(III) by bacteria such as MR-1 may serve as a potential strategy for the detoxification and immobilization of chromate. Brown et al. (2006a) describe the initial stress response pathways following acute chromate exposure via transcriptomic and proteomic analyses. This study described the largest complement of expressed *S. oneidensis* proteins published to date and provided important broad insights into the complex Cr(VI) stress response of *S. oneidensis*. Results were contrasted by studies described by Chourey et al. (2006) where longer intervals of Cr(VI) exposure resulted in the induction of MR-1 prophage-related genes being the dominant response. These global studies in *S. oneidensis* now allow more focused studies on several potentially important key genes involved in Cr(VI) reduction.

The research teams investigated the interactions of S. oneidensis MR-1 with chromium and strontium.

The researchers also examined the physiology and transcriptome dynamics of *S. oneidensis* MR-1 in response to strontium, Sr(II), exposure. Strontium is a common groundwater contaminant present at various DOE field sites, including the DOE Environmental Remediation Sciences Program (ERSP) Field Research Center (FRC) at Oak Ridge National Laboratory. *Shewanella* spp., as well as Fe(III) oxide and bacteria coated with Fe(III) oxides, have been shown to sorb Sr(II), thus affecting the fate and transport of such inorganic contaminants in natural aqueous environments. MR-1 was found to be highly resistant to Sr(II), and a link between iron metabolism and microbe-mediated metal precipitation was suggested (Brown et al. 2006b).

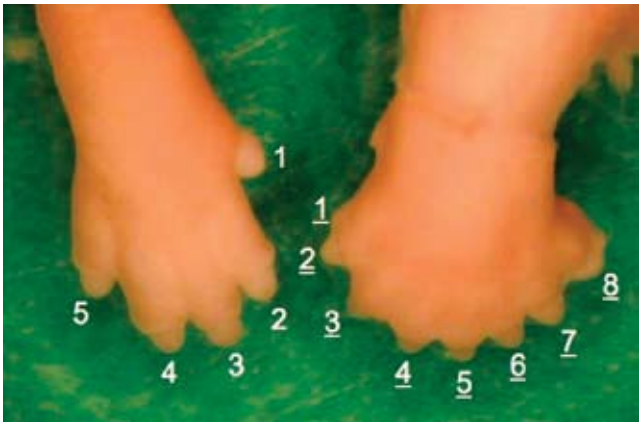
S. D. Brown, M. R. Thompson, N. C. VerBerkmoes, K. Chourey, M. Shah, J. Zhou, R. L. Hettich, and D. K. Thompson. "Molecular dynamics of the *Shewanella oneidensis* response to chromate stress," **Molecular and Cellular Proteomics** 5: 1054–71 (2006a).

S. D. Brown, M. Martin, S. Deshpande, S. Seal, K. Huang, E. Alm, Y. Yang, L. Wu, T. Yan, X. Liu, A. Arkin J. Zhou, and D. K. Thompson. "Cellular response of *Shewanella oneidensis* to strontium stress," **Applied Environmental Microbiology** 72 (1): 890–900 (2006b).

K. Chourey, M. R. Thompson, J. Morrell-Falvey, N. C. VerBerkmoes, S. D. Brown, M. Shah, R. L. Hettich, M. Doktycz, and D. K. Thompson. "Global molecular and morphological effects of chronic chromium exposure on *Shewanella oneidensis* MR-1," **Applied Environmental Microbiology** 72 (9): 6331–44 (2006).

Cilia regulate key cellular signaling events

Dr. Edward Michaud (Biosciences Division) participated in a study with colleague Dr. Bradley Yoder (University of Alabama at Birmingham) on the role that cilia play in cellular signal transduction, the communication among cells that is essential to an organism's development. Cilia are antennae-like organelles that extend from the surface of most cells in the mammalian body, where they receive biochemical cues from neighboring cells. Studying them is important because of their role in normal development and organ function. Abnormalities in cilia lead to numerous disorders, including kidney disease and skeletal defects. The team found that multiple components of the "Sonic hedgehog" (Shh) signal transduction pathway, which include the Glioma (Gli) transcription factors, are localized in the tips of cilia found in mice. They showed that mice with a mutation in a key cilia gene, *Tg737*, have abnormal cilia with altered Shh pathway activity, which causes skeletal patterning defects.



Development of five digits in a normal mouse (left) or polydactyly in a cilia mutant mouse (right) depends on Shh signal transduction by cilia.

The data suggest that cilia are cellular sensors with a direct role in the regulation of Shh pathway activity.

Precise regulation of Shh signal transduction is important for the proper development and function of many tissues, including the limbs. In limbs, a balance between Gli activators and Gli repressors of the Shh pathway controls the development of digit number. In mice that lack cilia, there is a failure to convert Gli3 from an activator of the pathway to a repressor, resulting in disruption of the pathway and the development of too many digits. "The data suggest that cilia are cellular sensors with a direct role in the regulation of Shh pathway activity," said Michaud.

C. J. Haycraft, B. Banizs, Y. Aydin-Son, E. J. Michaud,and B. K. Yoder. "Gli2 and Gli3 localize to cilia and require the intraflagellar transport protein polaris for processing and function," **PLoS Genet** 1: e53 (2005).

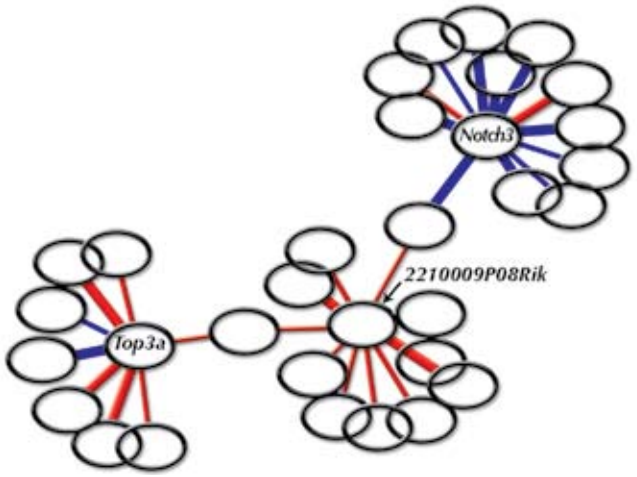
E. J. Michaud and B. K. Yoder. "The primary cilium in cell signaling and cancer," **Cancer Research** 66: 6463–67 (2006).

Algorithms identify gene regulatory networks for low-dose radiation response

Genes with common functions often exhibit correlated expression levels, which can be used to identify sets of interacting genes from microarray data. Microarrays typically measure expression across genomic space, creating a massive matrix of co-expression that must be mined to extract only the most relevant gene interactions. Brynn Voy (Biosciences Division) and colleague Michael Langston (University of Tennessee) developed a novel graph theoretical approach to extract differentially co-expressed genes from microarray data. They applied the new approach to transcriptome data collected from spleens of genetically diverse mice exposed to low doses of X rays. Using the graph-based algorithms, the team was able to extract sets of genes that might interact in networks to mediate the response to the radiation. This novel method allows a new understanding of biological mechanisms that determine the health outcome from radiation or other environmental exposures.

Clustering built upon graph algorithms extracts sets of perfectly interconnected genes.

The technique is based on creating a graph from a genome-scale correlation matrix thresholded to include only the correlations most likely to signify functional relationships. A graph-based approach offers advantages over traditional clustering methods, such as the ability for nodes (genes) to be members of multiple subgraphs. Perfectly interconnected gene sets (cliques) and other dense graph structures are extracted and analyzed for differential connectivity and node composition. The correlation graph is also queried independently of clique to extract edges that are impacted by



Guilt by association: When represented graphically, the function of a poorly annotated gene (center) can be inferred from its links with the known functions of better-annotated genes.

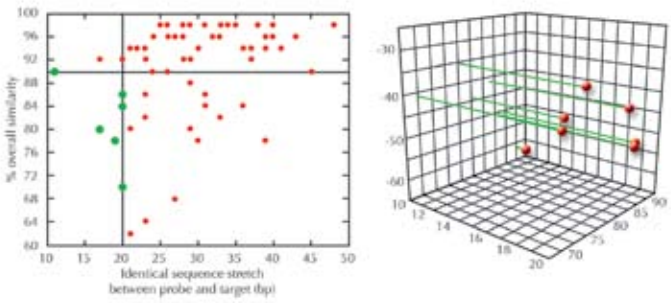
radiation. Graph structures are then analyzed for enrichment in biological pathways relevant to the condition of interest (e.g., response to radiation) to prioritize subsets of genes for further study. Membership in cliques and other graph structures can also be used to infer the function of poorly annotated genes, based on their co-expression with genes of known function ("guilt by association"). While the method was developed for the low-dose radiation response, it is extensible to any biology of interest and to other types of data, expanding its utility to the research community at large.

B. H. Voy, J. A. Scharff, A. D. Perkins, A. M. Saxton, B. Borate, E. J. Chesler, L. K. Branstetter, and M. A. Langston. "Extracting gene networks for low-dose radiation using graph theoretical algorithms," **PLoS Computational Biology** 2(7): 0757–66 (2006).

Improvements in environmental microarray specificity and sensitivity

Microarrays can be useful for environmental studies because they allow us identification and understanding of the different types of microbial roles in various biogeochemical processes based on the genes they contain. However, ensuring both the specificity and sensitivity of environmental microarrays is critical, as the gene probes on such microarrays have to be able to distinguish between thousands of closely related genes that are often in low abundance in environmental samples.

Most microarray probe design algorithms were created for use in single organism studies and use only one criterion to ensure specificity, such as the percentage of similarity. Members of the Environmental Sciences Division research staff participated in studies that showed that probe behavior and specificity may be more reliably predicted by examining multiple probe characteristics. The team found that by simultaneously considering the percentage of similarity, the longest identical stretch, and free energy of the hybridization, they could relax the individual criteria while more accurately ensuring the specificity of the probes. The level of specificity achieved using these criteria should provide at least species-level resolution in most cases and is critical for using microarrays in systems with mixed microbial species such as natural environments. Based on these findings, the researchers developed new probe design algorithms and a new program and applied them to design a functional gene array containing more than 24,000 probes for genes involved in important microbially driven processes relevant to bioremediation and to carbon cycling and sequestration.



Relationship between overall sequence similarity, identical sequence length, free energy, and nonspecific probe hybridization behavior.

Currently, microarrays require large amounts of nucleic acids, DNA or RNA, to ensure detection. To increase the sensitivity and applicability of microarrays to environmental samples where microbial species may be in low abundance, these researchers have also developed and optimized two separate techniques that allow unbiased amplification of nucleic acids from whole microbial communities. Through these amplification techniques it is now possible to analyze such communities with over 1000 times less starting material, allowing access to microbial communities and species that were previously not available for study using these techniques.

The achieved level of specificity should provide at least species-level resolution in most cases.

H. Gao, Z. K. Yang, T. J. Gentry, L. Wu, C. W. Schadt, and J. Zhou. "Microarray-based analysis of microbial community RNAs by whole community RNA amplification (WCRA)," **Applied Environmental Microbiology.** doi:10.1128/AEM.01771-06 (2006) (in press).

X. Li, Z. He, and J.-Z. Zhou. "Selection of optimal oligonucleotide probes for microarrays using multiple criteria, global alignment and parameter estimation," **Nucleic Acids Research** 33: 6114–23 (2005).

J. Liebich, C. W. Schadt, S. C. Chong, Z. He, S. K. Rhee, and J.-Z. Zhou. "Improvement of oligonucleotide probe design criteria for functional gene microarrays in environmental applications," **Applied Environmental Microbiology** 72: 1688–91 (2006).

L. Wu, X. Liu, C. W. Schadt, and J.-Z. Zhou. "Microarray-based analysis of subnanogram quantities of microbial community DNAs by using whole-community genome amplification," **Applied Environmental Microbiology.** 72: 4931–41 (2006).

Achievements and Awards

Science features poplar gene sequencing

A team of more than 100 researchers, led by ORNL's Gerald Tuskan and Daniel Rokhsar of the Joint Genome Institute, completed the gene sequence for the black cottonwood tree, the first effort to sequence the genome of a woody plant. Other team members at ORNL are Lee Gunter, Udaya Kalluri, and Tongming Yin.

***Science* 313, (1596–1603), 2006.**

Gerald Tuskan

An article describing the research was featured on the cover of the September 15 issue of *Science* magazine (313, pp. 1596–1603). A news article in the same issue (p. 1556) referred to black cottonwoods as "the lab rats of the tree world" because they have a small genome amenable to genetic manipulation and because they grow quickly and thus provide quick results. As a member of the poplar genus, the black cottonwood is a representative of trees prized commercially as a source of lumber and paper pulp and as a potential source of biomass. Further research is expected to improve the ability to use trees as a renewable resource, refine carbon-storage strategies, and aid in the study of global climate change. (See the article in the "Systems Biology" section.)

Black cottonwoods are the "lab rats of the tree world" because their small genome is easy to manipulate and because they grow quickly and thus provide quick results.

Jeremy Smith appointed the first Governor's Chair in JIBS

Internationally recognized biophysicist Jeremy Smith was the first appointee to a University of Tennessee–ORNL Governor's Chair position. His appointment is in the UT-ORNL Joint Institute for Biological Sciences.

Jeremy Smith

Smith previously was the chair of Computational Molecular Biophysics at the University of Heidelberg in Germany. His research interests involve understanding biological molecules such as proteins using computer simulation and neutron scattering. His research is interdisciplinary, involving chemistry, physics, computational science, and biology. A leading expert in applying neutron scattering to important biological questions, he will be among the first scientists to perform research using the Spallation Neutron Source.

Our goal is to bring some of the best scientists in the world to Tennessee. The impact of their work can make a lasting difference for our state's future.
— Tennessee Gov. Phil Bredesen, announcing Smith's appointment

The Governor's Chair program is designed to attract top scientists to four UT-ORNL joint institutes. Governor's Chair scientists have joint appointments as tenured UT faculty and distinguished ORNL research staff.

Gerald Tuskan is JGI lead scientist

Gerald Tuskan of ORNL was named lead scientist for the Laboratory Science Program (LSP) of the Joint Genome Institute (JGI), of which ORNL is a member laboratory.

Under Tuskan's leadership, the LSP worked to identify a list of candidate organisms for sequencing (i.e., microbes and plants). The soybean sequence was approved as the first large-scale LSP project because of its unique seed chemical composition. It is one of 15 plant genomes to be sequenced in the next 3 years. An LSP draft proposal plan and white

papers were developed for large and small sequencing projects.

Tuskan participated in several JGI LSP planning meetings and in a JGI review, visited all five core laboratories, and scheduled visits to other labs, such as Argonne and Brookhaven, to promote LSP. He also met with the ORNL community.

In addition, ORNL increased its involvement in JGI, proposing several successful JGI–MGP (Microbial Genome Program) sequencing projects (e.g., *Leptospirillum, Thermoanaerobacterium, Populus* endosymbionts).

Gary Sayler named JIBS director

Gary S. Sayler has been appointed the first director of the Joint Institute for Biological Sciences (JIBS), established by the University of Tennessee and ORNL. He will lead the development of the research and development program at JIBS, including staffing, expanding the funding base, and establishing collaborations between ORNL and UT and with other research institutions worldwide. Sayler was Beaman Distinguished Professor of Microbiology, Ecology, and Evolutionary Biology at UT before being named to the JIBS post.

Gary Sayler

JIBS is one of four state-funded ORNL–UT joint institutes. Construction on the JIBS facility on ORNL's west campus began in summer 2006.

The Institute will focus on three core research areas, biology, energy, and health. Its objective is to advance science and technology for a better understanding of complex biological systems and their relationship with human health and the environment.

The goal of JIBS is to advance science and technology for a better understanding of complex biological systems and their relationship with human health and the environment.

Davison elected AIMBE Fellow and receives Charles D. Scott Award

Brian Davison

Brian Davison has been elected a Fellow of the American Institute for Medical and Biological Engineering (AIMBE). He was inducted as a Fellow at the Annual AIMBE Meeting at the National Academy of Sciences. The election was based on his many distinguished contributions to the field as well as his demonstrated interest, concern, and involvement with critical issues affecting medical and biological engineering.

The Charles D. Scott Award for Contributions to the Field of Biotechnology for Fuels and Chemicals was presented to Brian Davison in recognition of his distinguished contributions to the field as a whole and to the annual Symposium on Biotechnology for Fuels and Chemicals. The award cites his innovation in fundamental and applied biotechnology, insight into bioprocessing fundamentals, and commitment to facilitate commercialization of products from renewable resources.

In 20 years at ORNL, Davison has conducted biotechnology research in various areas, including bioconversion of renewable resources, nonaqueous biocatalysis, systems analysis of microbes, biofiltration of volatile organic compounds, mixed cultures, immobilization of microbes and enzymes, metal biosorption, and extractive fermentations. His work has resulted in more than 90 publications and six patents. He co-chaired the fifteenth to twenty-sixth Symposia on Biotechnology for Fuels and Chemicals and served as the editor of *Proceedings in Applied Biochemistry and Biotechnology* from 1994 through 2005.

Achievements and Awards

Bogard is Distinguished Texas State Alumnus

James S. Bogard received the 2006 Distinguished Alumni Award from the Texas State Alumni Association in October. Texas State University–San Marcos is the largest campus in the Texas State University system and the sixth-largest in the state. Bogard obtained his B.S. degree in chemistry from Texas State.

James Bogard

Patent awarded for implant sensors

A patent for a method of implanting microelectromechanical systems (MEMS) sensors for monitoring orthopedic implants was awarded to Thomas Thundat of ORNL and Rick Komistek of the University of Tennessee. Thundat, a pioneer in MEMS technologies, is an ORNL corporate fellow; Komistek is a professor of biomedical engineering and a leading musculoskeletal researcher.

Thomas Thundat

The invention has been licensed to Zimmer, Inc., of Warsaw, Indiana, a market leader in orthopedic implants.

Complete joint replacements for knees and hips are widely used, but wear limits the useful lifetime of these devices. Current research in this area is aimed at extending the usable lifetimes of orthopedic implants through better materials design, simulation models, and advanced techniques for modular replacement of worn friction surfaces. To extend device lifetime, makers of implants need to be able to monitor the wear forces and loads on them. The ORNL invention enables accurate measurement of wear and force parameters that can be incorporated into research and clinical implants for continuous or periodic assessment. It can incorporate different sensor types to monitor surrounding physiological parameters and sense the presence of infection. The invention is suitable for use with many different implant types—including artificial knee, hip, shoulder, and elbow joints—and may find use in applications where bone is involved.

To extend device lifetime, makers of implants need to be able to monitor the wear forces and loads on them. The ORNL invention enables accurate measurement of wear and force parameters.

ORNL toxicity guidelines published as book chapter

An ORNL team made up of Annetta Watson (team leader), Dennis Opresko, and Bob Young of the Toxicology and Hazard Assessment Group have authored a book chapter documenting the team's development of chemical warfare agent exposure guidelines for community emergency preparedness (acute exposure guideline levels and reference doses). "Cholinesterase Inhibitors as Chemical Warfare Agents: Community Preparedness Guidelines," is Chapter 5 in *Toxicology of Organophosphate and Carbamate Compounds*, published by Elsevier/Academic Press in North America and Europe. The guidelines developed by the ORNL team, which currently are used by civilian regulatory and emergency response personnel, will be more readily available to user communities as a part of the book.

Researchers use light to trap, transport proteins

Three ORNL researchers are among the authors of a paper outlining a new method of using a beam of light to trap protein molecules and make them dance in space. The paper earned a place in the *Proceedings of the National Academy of Sciences Early Edition* and appeared in *Applied Physical Sciences, Biophysics*.

It's kind of like a tractor beam in "Star Trek," but this is science, not science fiction.
—Nathan Lewis

The authors include Thomas Thundat, Gil Brown, and Bruce Warmack of ORNL; Nathan Lewis of the California Institute of Technology; and Dean Hageman, James Harkins IV, and Chuck Witkowski of Protein Discovery, Inc.

The technique, photoelectrophoretic localization and transport (PELT), involves shining a highly focused beam of light on semiconductor material and using electric fields to move the proteins. A photocurrent focused at the illuminated areas of the semiconductor creates force-field traps. PELT is useful for separating, concentrating, and analyzing proteins quickly with high sensitivity and selectivity. Researchers using it can steer DNA or other biomolecules for transport in three dimensions and separate them according to size and isoelectric point. The technology has applications for medical diagnostics and as a discovery tool for investigating photo-induced effects of a semiconductor-liquid interface.

Biosphere Monitoring Symposium at AAAS

Stan Wullschleger

Stan Wullschleger of ORNL was the organizer of "Biosphere Monitoring and Ecosystem Forecasts: Sensing the Pulse of the Planet," a symposium presented at the 2006 annual meeting of the American Association for the Advancement of Science to explore the use of monitoring and modeling tools to track how climate change is affecting ecosystems. Tom Wilbanks of ORNL was the co-organizer.

The symposium highlighted sensing technologies, biosphere monitoring platforms, and ecosystem forecasting models that can be useful in predicting the impact of climate change on terrestrial, freshwater, and marine ecosystems. As natural resources are increasingly compromised by local, regional, and global pressures, ecologists are challenged to detect environmental change across all scales and to help policy makers integrate the knowledge gained into a framework that includes social and political issues. The symposium focused on the need to develop and use integrated Earth-observing systems to monitor the planet and forecast ecological change.

Coupled Carbon-Cycle Symposium at AAAS

Wilfred Post

Wilfred Post, David Erickson, and Anthony King of ORNL organized the symposium "Advancing Coupled Carbon Cycle—Climate Models: Current Progress, Future Challenges" at the American Association for the Advancement of Science annual meeting for 2006. Speakers in the symposium presented concepts and algorithm developments in coupling terrestrial and marine carbon biogeochemistry with the earth's climate system to advance coupled carbon-climate modeling capabilities to meet the requirements of predicting climate change.

Research was presented that involved collaboration among climate scientists, terrestrial ecologists, ocean biologists and geochemists, and computer scientists. These scientific findings and new research approaches outlined new directions in developing an understanding of problems to be solved in addressing potential future climate change resulting from human and natural perturbations to the global carbon cycle-climate system. Speakers included Anthony King and Forrest Hoffman (ORNL), Bala Govindasamy (Lawrence Livermore National Laboratory), Atul Jain (University of Illinois), Peter Thornton (National Center for Atmospheric Research), Akihiko Ito (Ecosystem Change Research Program — i.e., the Japanese Earth Simulator, Yokohama, Japan), and Christian Reick (Max Planck Institute for Meteorology, Hamburg Germany).

Achievements and Awards

Symposium on Biotechnology for Fuels and Chemicals

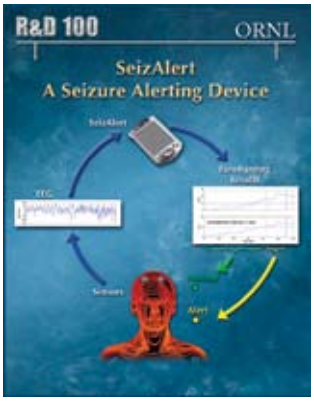
Jonathan Mielenz

The 28th annual "Symposium on Biotechnology for Fuels and Chemicals," hosted by ORNL's Jonathan Mielenz, attracted almost 500 participants from 24 countries. The 5-day symposium, held in Nashville, was one in a series of symposia focusing on improving the science, technology, and economics of producing fuels and chemicals through biotechnology. It was held under the auspices of the American Association for the Advancement of Science and managed by the Society for Industrial Microbiology.

The biotechnology symposia provide a forum for experts from around the world to gather and discuss research breakthroughs and opportunities for commercialization of bioenergy technologies. More than 62 talks and 255 posters were presented. Of those attending, 145 were from outside the United States and 38% were from industries.

SiezAlert seizes R&D 100 Award

SeizAlert, a wearable device that alerts the wearer that an epileptic seizure is coming, was a winner of a 2006 R&D 100 Award. Because of the many millions of people affected by epilepsy, many of whom cannot be treated successfully to stop seizures from occurring, SeizAlert has the potential for extensive application.



Lee Hively, Vladimir Protopopescu, Kara Kruse, and Nancy Munro developed the technology. Hercules Development Corporation has licensed it for commercialization.

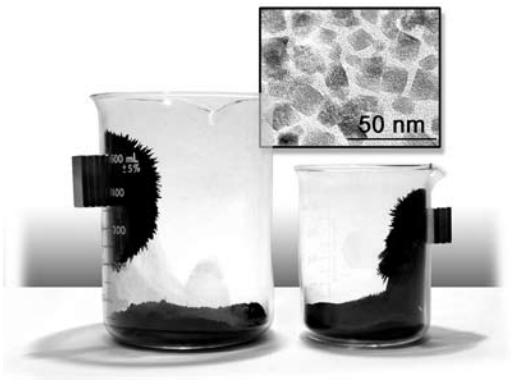
SeizAlert uses software to conduct advanced real-time analysis of brain waves transmitted wirelessly from small electrodes worn on the scalp. It can forewarn epilepsy patients up to 4.5 hours before seizures occur, allowing them to take measures such as taking medications, avoiding activities that could become hazardous in a seizure, lying down, or contacting a doctor. The underlying technology could also be used to predict heart arrhythmias, track breathing problems, and detect the onset of septic shock.

Epilepsy affects roughly 3 million Americans who are in constant fear of the next seizure event and injuries that could result.

SiezAlert was also honored in 2006 with a Federal Laboratory Consortium, Southeast Region, Excellence in Technology Transfer Award.

R&D 100 Award goes to Nanofermentation

Nanofermentation,™ a new approach for producing extremely fine, highly crystalline powders of various materials, received an R&D 100 Award recognizing it as one of the best technologies of 2006. Lonnie Love, Tommy Phelps, Adam Rondinone, Yu Roh, Chuanlun Zhang, and Ji-Won Moon of ORNL, and Bob Lauf, formerly of ORNL, are the developers.



Biomagnetite and Zn-doped magnetite.

The process works at or near room temperature using conventional industrial equipment, straightforward fermentation processes, and naturally occurring bacteria. The bacteria synthesize large quantities of tailored nanoparticles, which can be used in applications such as magnetic media, xerographic toner, catalysts, pigments, water treatments, ferrofluids, and coatings.

The inventors hope the availability of a low-cost method of mass-producing highly uniform, size-controlled (5- to 100-nm) magnetite nanoparticles will stimulate the development of new applications and help realize the potential of the field of nanotechnology.

Nanofermentation also received one of *R&D Magazine*'s inaugural MICRO/NANO 25 awards.

Nanofermentation promises to allow the production of tailored nanomaterials in economical quantities, potentially stimulating the development of new and extended applications.

Annetta Watson receives Life Career Award

Annetta Watson

ORNL researcher Annetta Watson was presented a Life Career Award at the Twenty-Second Annual International Conference on Soils, Sediment, and Water, at the University of Massachusetts–Amherst.

The award was presented for scientific accomplishment and technical services to the government and its agencies and cites Watson's "career providing sound technical support and critical insight to the establishment of general public, workplace and deployment exposure limits for many toxic compounds, including chemical warfare agents."

The annual conference is presented by the Northeast Regional Environmental Public Health Center and the School of Public Health, University of Massachusetts–Amherst.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