

Odyssey

University of Kentucky Research

Fall 2007



Lee T. Todd Jr., President
Kumble Subbaswamy, Provost
Chuck Staben, Acting Head,
Office of the Vice President for Research

Agriculture
M. Scott Smith, Dean

Arts and Sciences
Steven Hoch, Dean

Business and Economics
Devanathan Sudharshan, Dean

**Communications
and Information Studies**
J. David Johnson, Dean

Dentistry
Sharon P. Turner, Dean

Design
David Biagi, Acting Dean

Education
James Cibulka, Dean

Engineering
Thomas W. Lester, Dean

Fine Arts
Robert Shay, Dean

Graduate School
Jeannine Blackwell, Dean

Health Sciences
Lori Gonzalez, Dean

Law
Allan W. Vestal, Dean

Medicine
Jay A. Perman, Dean

Nursing
Jane Kirschling, Dean

Pharmacy
Kenneth B. Roberts, Dean

Public Health
Stephen W. Wyatt, Dean

Social Work
Kay Hoffman, Dean

Odyssey

Director
Deborah Weis

Editor
Jeff Worley, jworley@uky.edu

**Associate Editor, Art Director
& Web Designer**
Alicia P. Gregory, apgreg@uky.edu

Designer
Shear & Shear

Photographer
Lee P. Thomas Photography

Printer
Gateway Press

Odyssey is published three times a year by the Office of the Vice President for Research and covers the latest research advances, innovative scholarship, and outstanding people that are part of the University of Kentucky's \$300-million-a-year research enterprise.

To receive a free subscription, contact
UK Research Communications
222 Bowman Hall
University of Kentucky
Lexington, KY 40506-0059
859/257-8297

Member of the University
Research Magazine Association
www.urma.org

An Equal Opportunity University
©2007 University of Kentucky

University of Kentucky Research Fall 2007 Odyssey

Odyssey Turns Silver

This year Odyssey joins a club with only a few select members—research magazines that have been publishing for a quarter of a century or longer. (There are fewer than 10 of us, by my best count.)

Odyssey was founded in 1982 by Susan Stempel, with the support of Wimberly Royster, vice chancellor for research. In charge of producing UK's annual awards report, Susan wanted to put a human face on research at the university and showcase, for the general public, some of the excellent work being done here.

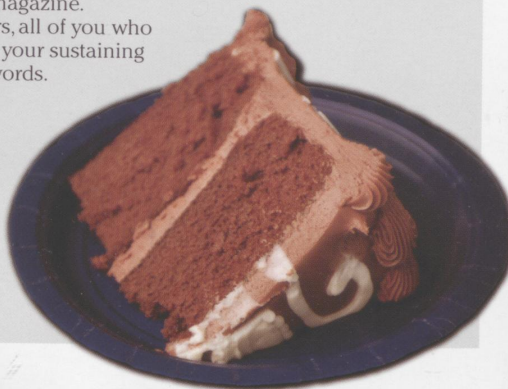
In the past 25 years, the magazine has featured approximately 1,200 faculty and graduate students, whose work has run the full range of research and scholarship. And Odyssey has won over two dozen local, regional and national awards for writing and design.

This—our 50th issue—includes the second part of our coverage of “green energy” research at UK along with three special features. Research Spotlights covers 55 top projects, most of which have previously been featured in the magazine. Our timeline highlights some of the notable events and achievements at UK in the past quarter century, and Movers & Shapers is a gallery of 25 faculty who were, or continue to be, influential and visionary in moving the university forward academically, and enhancing its reputation nationally and internationally. In selecting faculty to be featured in these sections, our staff is very thankful for the thoughtful suggestions we received from our current college deans and others with sharp institutional memories.

If through the years Odyssey has achieved its goal of publicizing research that improves the lives of Kentuckians and others, it's only because hundreds of faculty, staff and graduate students have taken time to explain clearly and imaginatively what it is they do. The magazine counts on our faculty for information and illumination, and we count equally on the support of the UK administration, especially the Office of the Vice President for Research, which funds the magazine.

And we thank our readers, all of you who continue to support us with your sustaining encouragement and good words.

—Jeff Worley, Editor



visit us online

www.research.uky.edu/odyssey**Feature****Coal: Breaking Oil's Chokehold 32**

UK researchers are increasing the efficiency of Fischer-Tropsch, a World War II-era process for converting domestic sources like coal and natural gas to liquid transportation fuels, mapping underground geology for permanent storage of CO₂, creating membranes to separate hydrogen from CO₂, and producing catalysts to efficiently generate hydrogen for fuel cells.

Research Spotlights**Aging & Alzheimer's 2**

Aluminum as a Major Cause?
Cell Pathways to the Disease
Calcium's Role in Cell Death
Early-Stage Alzheimer's
The Nun Study

Agriculture 5

Mare Reproductive Loss Syndrome
Erosion-Free Farming
New Plant-Based Natural Products
Better Animal Health in the Commonwealth

Cancer 7

Breast Cancer Breakthrough
Less Toxic Cancer Treatment
Early Detection of Lung Cancer
Mapping Adult Stem Cell Growth
Revolutionizing Cancer Treatment

Diabetes & Nutrition 10

Fighting Diabetic Blindness
Basic Science in the Fight against Fat
Special Meals to Melt Away the Pounds

Drug & Alcohol Abuse 12

New Treatments for Nicotine & Methamphetamine Abuse
Fighting Drug & Alcohol Abuse
Therapeutic Storytelling

Drug Design & Delivery 14

An Easier Way to Fight Migraines
Push-Button Pain Relief

Education 15

Helping Students with Math & Science
Opening the Door to Science for Girls in Kentucky

**Energy 16**

CAER Turns 30
Spray-Painted Solar Cells
Packaging Green Energy: The Coal/
Sawdust Briquette

**Engineering 17**

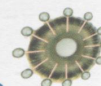
The Metaverse: Visualization & Virtual
Environments
Partnering With Toyota
Partners in Aluminum
Improving Coal Preparation and
Miner's Health

The Environment 19

Fiber Optics in Service to the Environment
Bringing Back the Forest
Putting Mountains of Ash to Work

Literature and the Arts 21

The Electronic Beowulf
Non-Toxic Art
Saxophone Research

**Nanotechnology 23**

Harnessing the Power of the Nanotube
Tiny Disease Fighters
Working Together on the Nanoscale

Space Exploration 25

Building Galaxies from Scratch
Spacecraft of the Future
Configuring the Birth of the First Stars

Women's Health 27

Advancing Women's Health
Good Dental News for Expectant Mothers
Breaking the Cycle of Violence
against Women

Other Key Research 28

New Treatments for Parkinson's
Future Treatments for Spinal Cord
& Brain Injury
Going Smoke-Free
Functional Independence
Telling the Stories That Need to Be Told
Targeting Children's Mental Health

Research Spotlights

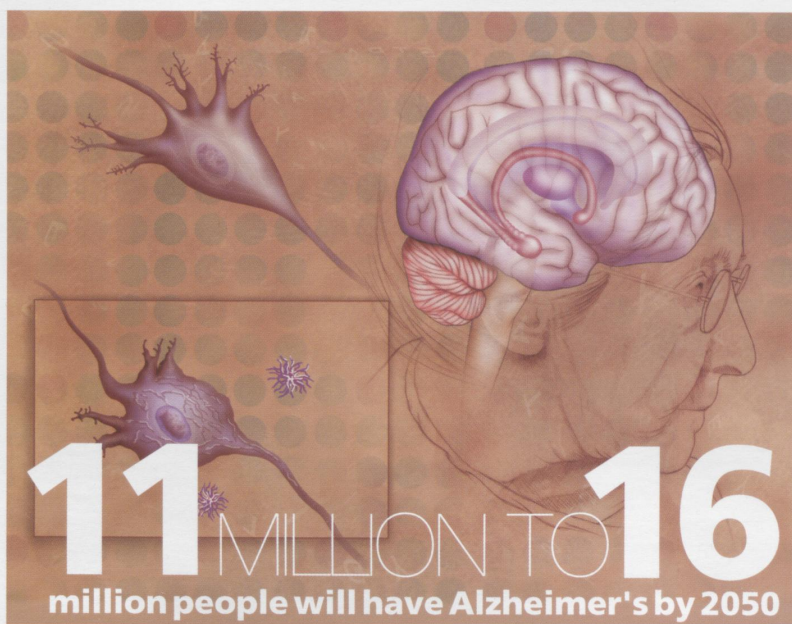
Written by Jeff Worley
and Alicia P. Gregory

Aging & Alzheimer's

Working to Solve the Alzheimer's Puzzle

By now, anyone who follows medical news in this country has heard the statistics. An estimated 5.1 million Americans have Alzheimer's disease. Nearly half of people age 85 and older have Alzheimer's. By 2050, the number of people age 65 and over with this disease will range from 11 million to 16 million unless science finds a way to prevent or effectively treat it. With the establishment in 1986 of the Alzheimer's Disease Research Center at UK's Sanders-

Brown Center on Aging, one of the 10 original centers in the United States, UK positioned itself as a leader in Alzheimer's research. And work has continued at a feverish pace: in 2000 to 2005 alone, 83 extramurally funded projects were under way at Sanders-Brown. The projects featured on the following pages represent only a small fraction of the total research effort in the past 25 years to understand and treat this devastating disease.



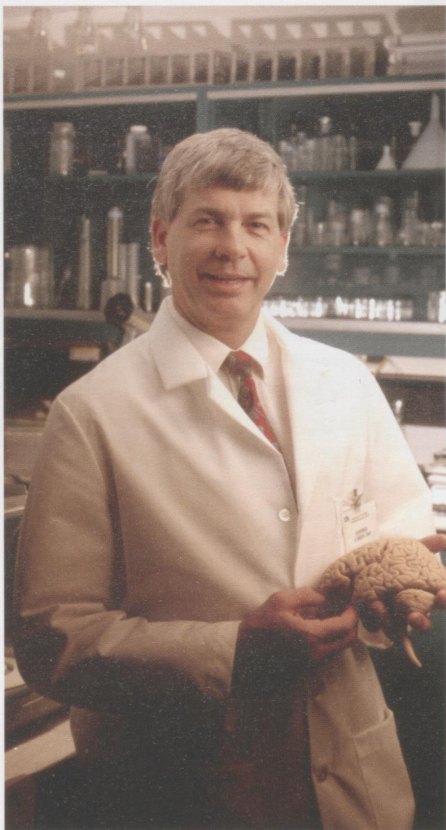
Aluminum as a Major Cause?

In the mid-'80s, William Markesbery, director of the Sanders-Brown center, chemistry professor William Ehmann, and post-doctoral fellow Mark Lovell focused on the possible role of trace metals in the etiology of the disease. Several heavy metals were thought to possibly contribute to the development of Alzheimer's, and, like any good detectives, the researchers began to investigate the list of suspects.

"We looked at aluminum first," says Markesbery, a pathologist and neurologist who has worked at UK since 1972. "The aluminum hypothesis is a reasonable one. Aluminum is the third most common element in the earth; there's aluminum dust in the air of every room in your house."

Using Alzheimer's disease brain specimens taken at autopsy, the researchers first determined bulk levels of aluminum using neutron activation analysis. Next, they utilized UK's (then) new Laser Microprobe Mass Analyzer, state-of-the-art equipment for this work, to further analyze the samples. The conclusion: there was no significant elevation of aluminum in the brain in Alzheimer's disease.

"Although there have been a few research groups through the years that have disputed this finding, other prominent and well-respected groups have agreed with us," says Markesbery.



Cell Pathways to the Disease

In the early- and mid-'90s, the Sanders-Brown center began working at the molecular level to try to understand the mechanisms of Alzheimer's disease. Mark Mattson, a neurobiologist, Mark Lovell, now in the UK chemistry department, and William Markesbery found that beta peptides [short molecules formed from the linking of amino acids] cause nerve cell damage by inducing a free-radical process called "lipid peroxidation" in the nerve cell membranes. Lipids are fatty or waxy substances that constitute, along with proteins and carbohydrates, the principal components of living cells.

"We found that such lipid peroxidation results in the impairment of protein function in the membrane that normally transports ions (sodium and calcium) out of the cell and glucose into the cell," says Markesbery. "This results in excessive elevation of intracellular calcium levels and reduced energy production in the neurons, rendering them vulnerable to degeneration and death."

Calcium's Role in Cell Death

In a separate but complementary project, Philip Landfield, UK professor of pharmacology, and his research group were making other discoveries about calcium's changing role in nerve cells as this relates to Alzheimer's disease. In order for nerve cells to function properly, they must maintain a narrow range of calcium concentrations. Calcium channels increase with age in neurons, flood the cell with calcium, and lead to a host of age-related, nerve cell malfunctions.

Backed by a \$1.4 million NIH award and a \$5 million award from the National Institute on Aging, Landfield's team used a powerful microscope to lower the tip of a microscopic glass tube onto the surface of a dissected nerve cell from an aged rat.

**too much calcium =
nerve cell damage**

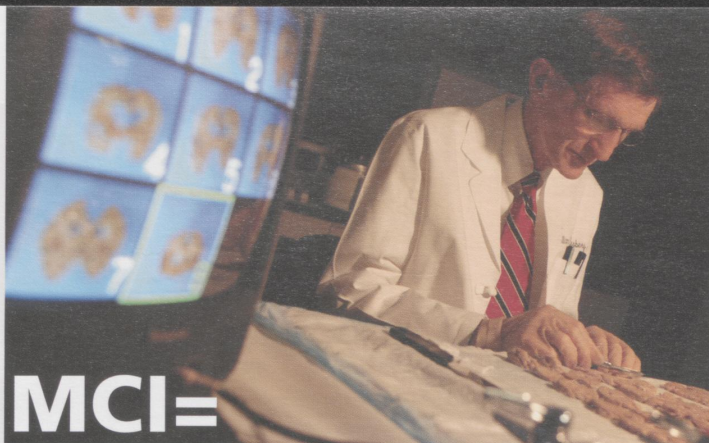
The glass tube was attached to a sensitive electrical amplifier that measured molecular calcium channel activity. Landfield explains: "Every membrane has many different kinds of channels on it. Since we wanted to study only calcium channels, we introduced drugs known to react with and block other types of channels."

The NIH recognized the success and the potential of this work by awarding Landfield's group a \$7.5 million, five-year renewal grant, one of the largest ever awarded to UK faculty solely for research.

Utilizing a new technology called DNA microarray, Landfield began analyzing thousands of genes and genetic pathways to better understand how Alzheimer's progresses. His team also invented and patented technology to extract isolated nerve cells for molecular analysis. Using these approaches, the researchers were able to see which gene pathways were involved in aging and Alzheimer's disease.

"The most important thing to come out of this approach is that we identified hundreds of genes that correlated with the early phases of aging and Alzheimer's," Landfield (standing, below) says. "We were then able to assign identified genes to biological process categories to get an idea of which cellular pathways were being turned on."





MCI= pre-Alzheimer's

Early-Stage Alzheimer's Disease

Early detection and prevention are the keys to fighting Alzheimer's disease, according to Markesbery. And detection of the earliest phase of memory decline has become so important that there is now a term used to describe this research focus: mild cognitive impairment, or MCI.

Several UK researchers, including Stephen Scheff, a professor of anatomy and neurobiology at the Sanders-Brown Center on Aging, are working to better understand MCI. The project is focused on a group of more than 400 people who don't have Alzheimer's, but about half are at high risk of developing the disease because of their family history. All of these subjects have agreed to donate their brains for analysis after they die.

"These participants undergo extensive cognitive testing and represent a unique resource for research into the relation between neuropathologic changes and cognitive performance in aging," Scheff says. "By studying this normal group of volunteers, we're getting closer to being able to detect the earliest possible onset of the disease, and we believe that with early preventive treatment, we can slow the progression of Alzheimer's." Frederick Schmitt, a UK professor of neurology, is working with Scheff on this project.

In separate work on MCI at UK, Allan Butterfield, director of the Center of Membrane Sciences, has done a study of brain tissue of patients who had been diagnosed with MCI, finding that the brains of these patients consistently showed elevated oxidative stress. "The implications of these findings are that such stress may drive the conversion of MCI to Alzheimer's," says Butterfield, also a professor of chemistry. In this work, his lab used proteomics, the large-scale study of proteins' structures and functions, and was the first to identify which brain proteins were modified in Alzheimer's and MCI. "We found a key oxidized protein in common," Butterfield says. "This dysfunctional protein could account for the three major pathological hallmarks of Alzheimer's and MCI, which may relate to loss of memory and cognition."

With early preventive treatment, we can slow the progression of Alzheimer's.

The Nun Study

Since 1986, David Snowdon, a professor of neurology in the UK College of Medicine, has led an ongoing, well-publicized research program that is profoundly changing the way we view aging and old age. Known as the Nun Study, the project involves 678 members of the School Sisters of Notre Dame religious congregation. The sisters, who range in age from 75 to 107, have allowed unprecedented access to their personal and medical histories and undergo rigorous annual mental and physical testing.

Perhaps most remarkably, each nun also has pledged to donate her brain for Snowdon's research after she dies. During the last 15 years, 535 sisters have donated their brains, making the Nun Study a unique resource for scientific discovery.

The study has yielded groundbreaking information about what we can do to help prevent Alzheimer's disease and live active, productive lives well into old age.

The major findings from the study so far:

- If the brain remains free of strokes, dementia-like memory loss and confusion are less likely.
- Folic acid may reduce brain damage from Alzheimer's disease.
- Low linguistic ability in early life is a potent predictor of Alzheimer's disease later in life.
- Expression of positive emotions in early life such as happiness, love and hope is strongly related to longevity.

Agriculture

Mare Reproductive Loss Syndrome

In the equine industry, 2001 may be remembered as the Year of Lost Foals. Mare Reproductive Loss Syndrome hit Central Kentucky hard—an estimated 30 percent of thoroughbred foals died, and the state lost around \$336 million from these deaths in all breeds of horses.

A multi-talented team of UK scientists moved quickly to find out how and why this happened. Roberta Dwyer and David Powell (veterinary sciences) rapidly developed and led an epidemiological survey that associated Eastern Tent Caterpillars with MRLS. Bruce Webb (entomology), Karen McDowell and Mike Donahue (veterinary science), Neil Williams (UK Livestock Disease Diagnostic Center), and Merlin Lindeman (animal sciences) then pooled their expertise to show that the caterpillars caused the disease. A series of studies over the next five years revealed that when horses inadvertently eat the caterpillars, their hairs become embedded in the lining of the horse's alimentary tract. Once that protective barrier is breached, bacteria invade the mare's placenta and fetal tissue—ultimately causing the loss of the fetus.

Research led by Dan Potter in entomology led to several new and effective options for farm managers to control Eastern Tent Caterpillars. For example, UK tested a new formulation of a compound called abamectin, developed by the J.J. Mauget Company, which manufactures insecticides, fungicides, fertilizers, and antibiotics for tree care, and found it effective for control of tent caterpillars. The insecticide is sent into a tree's leaves and roots through small, shallow drilled holes.

"The product, Abacide 2, showed 100 percent control of the caterpillars in trials done by UK researchers," says Potter. Abamectin is the first effective non-spray caterpillar insecticide on the market where the active ingredient has low toxicity to people and livestock.



Better Animal Health in the Commonwealth

Healthier animals in Kentucky has been the goal of UK's Department of Animal and Food Sciences from its beginning, says chair Bob Harmon, and there are two starting points for this work. "Through basic research, we develop scientific data that can be applied to solve common problems on farms in Kentucky and nationally, and our work is also directed by discussions with our extension faculty, who work with farmers on a daily basis."

Beef cattle research has included studies of nutrient use and efficiency at the cellular, tissue and organ levels, physiology of digestion, animal metabolism, and grazing systems to enhance

profitable production of high-quality beef. Swine nutritionists have helped define the safety of genetically modified feeds and identified diets to reduce environmental impact and odors. Studies of copper needs in dairy cattle have contributed to the definition of copper requirements and to healthier dairy cows. Studies on foal and mare nutrition have helped Kentucky's renowned equine industry produce quality foals. And poultry research has focused on reducing excretion of nutrients and enhancing meat and eggs.

Recently, UK researchers have partnered with a global leader in the animal feed industry—Alltech—to meet the common goals of improving animal health and performance by adding nutritional value to animal feed, and increasing animal health. "In 2004, Alltech, located in Nicholasville, Kentucky, was looking for a research site to help solve emerging challenges to animal agriculture, so they came to us," Harmon says. "And the Alltech-UK Nutrition Research Alliance began."

He adds that the department has several internationally recognized nutritionists who recently chaired committees for the National Research Council to create publications that establish the nutrient requirements for dairy cattle, swine and horses.

"These publications are the gold standard for animal nutrition," Harmon says.

1/4 of all
drugs
come
from
plants

Erosion-Free Farming

A sloping field that has been conventionally tilled can lose the equivalent of 50 tons of topsoil per acre after a heavy rain. This doesn't just hurt the farmland—it costs farmers time and money, and much of that topsoil ends up dirtying Kentucky's waterways.

That's why UK agricultural experts and Kentucky farmers have been studying the benefits of no-till farming since the mid-1960s and working to develop more ecologically friendly tillage methods.

"No-till is the practice of leaving cover crops or the residues of the previous crop to protect the surface of the soil, like a mulch," says Lloyd Murdock, a professor of plant and soil sciences at UK. "No-till prevents soil erosion, improves the quality of the soil, and reduces the cost of farming by eliminating many tillage trips over the field." He adds that this revolutionary method assures a sustainable soil base for good food and crop production for as long as the soils are cropped.

Murdock estimates that about 75 percent of Kentucky's suitable farming acres face some degree of erosion risk—that's 11.4 million acres. "The mulch fights erosion and creates an environment that conserves water in the soil for the benefit of the crop," Murdock says. No-till methods are used for corn, soybeans and wheat.

New Plant-Based Natural Products

The College of Agriculture and its partners in pharmacy and medicine have developed important new technologies from extensive studies of plant biochemistry and drug development. This work has led to the founding of companies whose products have direct agricultural and medicinal applications. This area of research activity is called UK's Natural Products program.

Natural products research at UK's Kentucky Tobacco Research and Development Center (KTRDC) may mean good news for Kentucky farmers. The center is working to discover new products in plants, and utilize plants as novel manufacturing systems for commercial production.

"Around one-fourth of our medicinal drugs are derived from plants. We also use plants as sources of natural spices, food, fibers, and oils," explains Maelor Davies, KTRDC director, who has led the center in the direction of natural products research since coming to UK in 1996. "We're supporting scientists who are looking at native Kentucky plants and their

potential as sources of valuable new materials."

This work at the KTRDC and efforts in other UK centers and colleges have led to several natural products faculty startups.

ParaTechs, the culmination of research by Bruce Webb (entomology), seeks to use insect molecular biology to identify genes from insect parasites and pathogens that can be utilized for insect control and development of natural products.

Oraceuticals, founded by Brad Huang and Jeffrey Ebersole (Center for Oral Health Research), and Cindy Burklow, uses natural products, particularly those derived from Kentucky native flora, which possess anti-inflammatory and antimicrobial properties, to prevent or manage oral infections.

Yaupon Therapeutics, based on research by Linda Dwoskin and Peter Crooks (pharmaceutical sciences), develops small-molecule pharmaceuticals. The researchers have had success with lobeline, an alkaloid from lobelia, a Kentucky native plant, which blocks the desire for methamphetamine.

Cancer

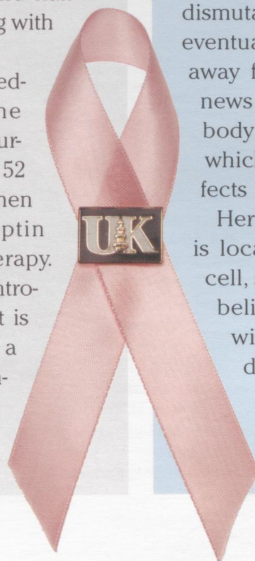
Breast Cancer Breakthrough

Here's a good-news story about an extremely aggressive form of cancer, starring 4,000 women nationwide. These women participated in a clinical trial of a drug called Herceptin, research sponsored by the National Cancer Institute. At issue was the drug's effectiveness in reducing the spread of HER-2 positive breast cancer.

Compared to other types of breast cancer, HER-2 is more likely to metastasize to other organs—even in spite of chemotherapy—and to recur more often after treatment. Of the more than 2,100 women who will be diagnosed with breast cancer this year, 20 to 25 percent will get the bad news that they have this virulent type of cancer.

The trials included women whose HER-2 cancer had not yet spread to other organs, but whose cancers did show a strong tendency to spread. Half of the patients received chemotherapy only, while half received Herceptin along with chemotherapy.

The results were incredibly encouraging: The number of cases of recurrent breast cancer was 52 percent less in the women who received Herceptin along with chemotherapy. "It was absolutely incontrovertible that this benefit is real—this drug can be a life-saver," says UK cancer researcher Edward Romond, who headed up this trial.



Less Toxic Cancer Treatment

People facing several bouts of radiation and chemotherapy to treat cancer realize they may get pretty sick before they can get well. But research conducted by a UK toxicologist suggests that by incorporating a natural body enzyme into existing treatments, the result might be a lot less toxic for patients.

Daret St. Clair, a researcher at the UK Chandler Medical Center, is continuing to study the antioxidant enzyme manganese superoxide dismutase (MnSOD), which may suppress the growth and even eventually help eradicate the existence of cancer. "We're still far away from a non-toxic drug that can stop cancer, but the good news is that this enzyme we've been working with is a natural body enzyme—it is essential for the survival of normal tissue, which makes it an important tool for the fight against toxic effects of other anti-cancer drugs," St. Clair says.

Her previous research has shown that this enzyme, which is located in the mitochondria (the energy producers) of the cell, slows the growth of cancer. Antioxidants like MnSOD are believed to offer protection against free radicals, molecules with unpaired electrons that move through the body and destroy proteins, carbohydrates, lipids, and nucleic acids.

"Our lab is one of the two leading groups in the country with this particular focus on cancer research," St. Clair adds.

Mapping Adult Stem Cell Growth

A discovery in stem cell research may mean good news for cancer patients undergoing chemotherapy and bone marrow transplantation.

Gary Van Zant, a professor of internal medicine in the UK College of Medicine, and Ying Liang, a postdoctoral scholar in internal medicine, have genetically mapped and identified a stem cell gene and its protein product, Laxetin. This is the first time such a complete study on a stem cell gene has been done.

This particular gene is important because it helps regulate the number of adult stem cells in the body, particularly in bone marrow. Researchers hope the gene, along with Laxetin, can be used clinically for ramping up the stem cell count in certain types of cancer patients.

One big obstacle chemotherapy patients face is stem cell loss after treatments. This loss limits the dosage amount and types of chemotherapy

that can be given. But if Laxetin were used to increase the stem cell count, patients would be able to receive increased doses of chemotherapy and recover more quickly. Increased stem cell counts also would be valuable during bone marrow transplants, where stem cell count is critical in helping a patient recover from cancer.

"We're thinking about cancer in a big way," says Van Zant, who also serves as clinical director of the stem cell processing lab at UK. "This is a great example of translational research—from the most basic type of genetic research all the way to possible treatments for patients."

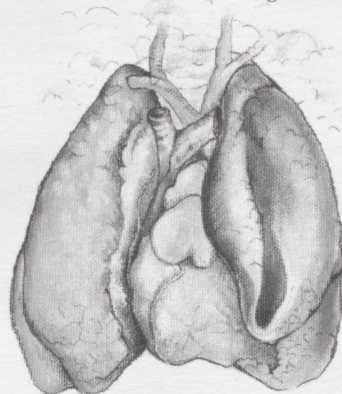


Early Detection of Lung Cancer

Here's a Number 1 not to be proud of: Kentucky has the highest incidence of and death rate from lung cancer in the nation.

A UK team of lung cancer researchers hopes to cut into these grim statistics with a new test that looks at the immune system's response to the most common type of lung cancer. This test accurately predicts the disease years before detection by CT scans, according to a recent study by Edward Hirschowitz and Li Zhong (pulmonary and critical care medicine). Such early detection of non-small-cell lung cancer could significantly improve a patient's chance of survival.

"Cancerous cells express protein antigens that are alien to the body, leading the immune system to produce antibodies that attack the antigens," says Hirschowitz. "Such antibodies can be used as biologic markers for tumors, meaning the presence of the antibodies might signal the presence of cancer cells. We looked at corresponding antibodies that recognize these



WU MOVERS & SHAPERS



Everett McCorvey, the Alumni Association Endowed Professor of Voice and director of Opera, has performed in dozens of cities around the world and theaters across the country, including the Metropolitan Opera and Queen Elizabeth Hall in London. A faculty member since 1991, McCorvey also teaches and mentors students seeking professional singing careers.



In 1977, Tom Dillehay began excavations in Monte Verde, Chile, which showed that there was human habitation in the New World 12,500 years ago—1,300 years earlier than previously believed. His discoveries attracted international attention and have challenged the long-established Clovis theory of the first human arrival in the Americas.



Doris Wilkinson, a faculty member at UK since 1967, has a distinguished record of professional and scholarly achievements, including the founding of the African American Studies and Research Program and the Black Women's Conference at UK. Her honors include the American Sociological Association's Dubois-Johnson Frazier Award, a Ford Fellowship to Harvard, and UK's Hall of Distinguished Alumni Award.

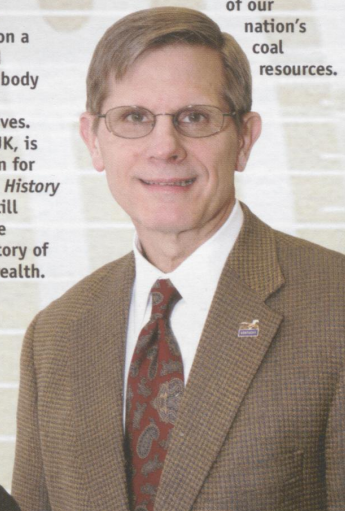
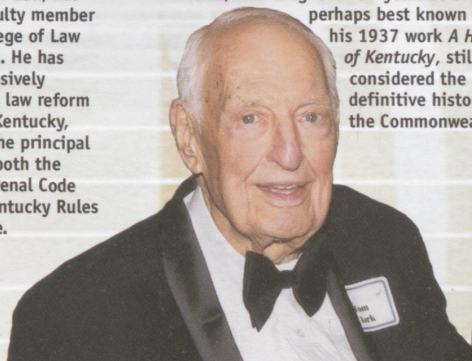
James Cobb has served as director of the Kentucky Geological Survey for the past eight years as it achieved national acclaim for its research in coal, water, geologic hazards, and digital mapping. As survey director and state geologist, he has provided national leadership in public understanding

of our nation's coal resources.



Robert Lawson, the Charles S. Cassis Professor of Law, has been a faculty member in the College of Law since 1966. He has been extensively involved in law reform efforts in Kentucky, acting as the principal drafter of both the Kentucky Penal Code and the Kentucky Rules of Evidence.

Kentucky's most notable historian, Thomas Clark saved from destruction a large portion of Kentucky's printed history, which later became a core body of documents in the Kentucky Department for Libraries and Archives. Clark, who taught for 37 years at UK, is perhaps best known for his 1937 work *A History of Kentucky*, still considered the definitive history of the Commonwealth.



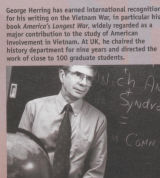
MOVERS & SHAPERS

Terry Binkshel, associate dean for Special Collections and Digital Programs, served from 1974 to 2005 as director of the end history program at UK and is credited with building UK's Louis & Nunn Center for Oral History into one of the nation's top programs. Binkshel was appointed in 1994 to the Advisory Committee on the Records of Congress.

During his 25 years at UK, Roy Berns was known as a gifted teacher and widely respected historian of European Imperialism. One of his important legacies is the Gates Center for the Humanities, an innovative undergraduate program that has been called the best of the university.



Glenn Collins, who joined the UK faculty in 1968, has had a distinguished career in plant genetic transformation and in mentoring students. He led early efforts to bring molecular biology to plant sciences at UK and started the Ag Biotech program. In 1988, the Crop Science Society of America named him Outstanding Researcher of the Year.



George Heering has earned international recognition for his writing on the Vietnam War. In particular his book America's Longest War, widely regarded as a major contribution to the study of American involvement in Vietnam. At UK, he chaired the history department for nine years and directed the work of close to 100 graduate students.



Lou Swift, teacher-scholar of classics for over 30 years at UK, acted as his lifelong commitment to undergraduate education. He was the first to create UK's current curriculum, the Liberal Studies program.

As dean of Undergraduate Studies, he worked to establish Central Kentucky, the Teaching and Learning Center, and the President's Future Faculty program.



Phyllis Wise was professor and chair of the physiology department in the College of Medicine from 1993-2002. Her research is centered on women's health and gender-based biology. Wise spearheaded the successful bid for the NIH-sponsored training program called the Center of Biomedical Research Excellence (CBRE) in Women's Health. The CBRE grant was renewed in 2005 for \$10.3 million.



Patrick Deluca, pharmaceutical sciences, is the author or co-author of over 200 articles and book chapters, and has received numerous research honors, including the First American Association of Pharmaceutical Scientists research award. An expert on formulation of vaccines and peptides, he leads studies on drug-delivery systems and microorganism detection.

In the 1990s Richard Funt, dean of the Carol Martin Gatton College of Business and Economics, took the college's endowment from \$2 million to over \$10 million, which included a \$14 million gift from C.M. Gatton, the largest single private donation to the university's history. Funt is the founding member of the Bluegrass Angels, a group that supports start-up companies in Kentucky.



Remembered as the heart and soul of the Center for Applied Energy Research, Joseph Plisk served as CAER director for 10 years before his death in 1999. He is credited with enhancing the energy center's reputation from a state "watch list" item to an internationally recognized center for research faculty and was well known for his ability to bring diverse groups together to spark new ideas.

Professor of Pharmacy Joseph Plisk has served in more than half a dozen important administrative roles in the 25-year career at UK, including director of ASTCC, the university's first business incubator. His scholarly work includes nearly 100 publications in the fields of law pertaining to pharmacy, and he has been named UK's Great Teacher Award.



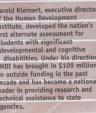
Jacqueline Kismet is well known for her original description of hypoplastic left heart syndrome and for the discovery of Marfan Syndrome. She became the first woman chair of a department (pediatrics) in the College of Medicine in 1976, and taught and mentored medical students and residents for more than 40 years.



Don Wood, emeritus professor of civil engineering, has been a leading authority in the field of hydraulic engineering for more than 50 years. His work in the modeling of complex piping systems has been instrumental in the analysis, wastewater, of water distribution systems. A gifted teacher, he won numerous teaching awards at UK.



William Lyons was a dedicated scholar, teacher, and public servant. He has held a variety of important roles, including director of the Center for Public Policy and Administration and executive director of the Kerner Commission, which established the Lexington-Fayette Urban County Government.



Harold Kistner, executive director of the Bureau of Economic Development, developed the nation's first alternative assessment for students with significant developmental and cognitive disabilities under his direction. HED has brought in \$100 million in outside funding in the past decade and has become a national leader in providing research and technical assistance to state agencies.



Michael Wietzel served as chair of the department of psychology and dean of The Graduate School before becoming UK's first provost in 2002. A leading scholar in forensic psychology and jury decision-making processes, he became president of Missouri State University in 2005.

Guided by dean Wilson, the UK's Medicine moved its curriculum to medical school. Its curriculum has evolved, and its medical residents and residents have grown and matured. In 1993 to 2002, it was under \$20 million, nearly \$50 million. Wilson was dean from 1987 to 2005, a longer term full of medicine than United States.

3,100 die of lung

antigens in the early stages and use them as markers for lung cancer. Taking this approach, the researchers were able to correctly identify nearly 90 percent of the cancer cases with very few false positives. By comparison, CT screening has a false-positive rate of more than 40 percent. Then, using the five most predictive cancer markers, the researchers tested 102 blood samples drawn from participants. The UK team found that the presence and amount of the five antibodies in the blood predicted lung cancer with about 85 percent accuracy. "Our hope is that in five years, this test will be available for doctors to use on high-risk patients," Zhong says.

3,100 Kentuckians

die of lung cancer each year

antigens in the early stages and use them as markers for lung cancer." Taking this approach, the researchers were able to correctly identify nearly 90 percent of the cancer cases with very few false positives. By comparison, CT screening has a false-positive rate of more than 40 percent.

Then, using the five most predictive cancer markers, the researchers tested 102 blood samples drawn from participants. The UK team found that the presence and amount of the five antibodies in the blood predicted lung cancer with about 85 percent accuracy.

"Our hope is that in five years, this test will be available for doctors to use on high-risk patients," Zhong says.

Revolutionizing Cancer Treatment

It's a little-known fact that your original cancer probably won't kill you. Cancer is much more dangerous when it moves to other parts of the body and sets up camp, and it's this form of the disease that a team of medical researchers at UK has been fighting—with great success.

In three related studies, this team has done nothing less than revolutionize the treatment of metastasized cancers—tumors that travel to other parts of the body—to extend the life and the quality of life for patients worldwide. The research group through the years has included an all-star lineup led by Phillip Tibbs and Roy Patchell in neurosurgery.

In the most recent study, 101 patients with spinal cord compression caused by metastatic cancer were randomized into two groups: surgery followed by radiotherapy or radiotherapy alone. Radiotherapy is conventional radiation therapy which uses beams that can cover large areas. The trial yielded excellent news. Significantly more patients in the surgery group were able to walk after treatment (84 percent compared to 57 percent).

This study was preceded by two landmark studies of brain metastases. One trial showed conclusively the importance of surgery for patients with a metastasized brain tumor. The second study established that radiation in combination with surgery was a useful treatment and clearly did prevent recurrence of tumors.



Diabetes & Nutrition

Fighting Diabetic Blindness

Here are some sad stats. Diabetes is the leading cause of blindness in people between the ages of 20 and 74. About 40 percent of the 10.3 million people in the United States diagnosed with diabetes will develop diabetic macular edema (DME), a condition that occurs when damaged blood vessels leak and cause retinal swelling. Ultimately, DME can lead to blindness.

But there's hope for this group in the form of a tiny implant device developed at UK. Called Envision TD, the implant was created by P. Andrew Pearson, an associate professor of ophthalmology, and former UK researchers Paul Ashton and Thomas Smith. The device is licensed by Bausch & Lomb.

Envision TD is a tiny polymer shell containing .59 milligrams of a drug placed on the end of a plastic strip. While the patient is awake and under local anesthetic, the device is inserted during a 15-minute procedure through an incision in the white of the eye and sutured in place. Once the device is secure, a tiny port in the polymer shell slowly releases the drug into the eye, reducing retinal inflammation. The patient cannot feel the implant, which delivers medication for up to three years.

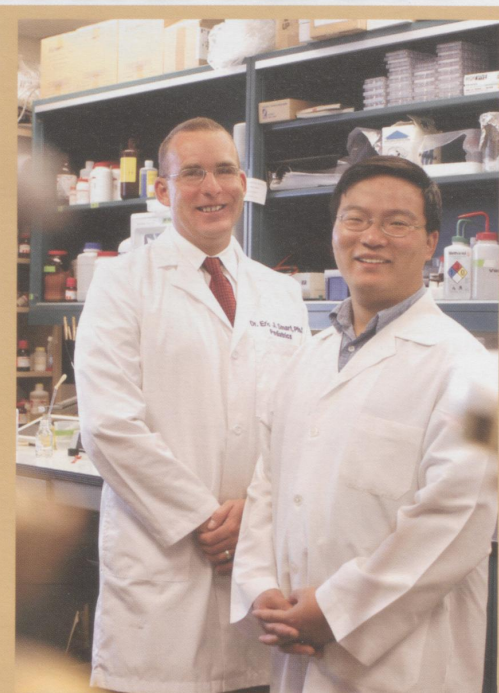
This device is now FDA approved for the treatment of chronic posterior uveitis, inflammation of the middle layer of the eye. Uveitis is responsible for approximately 10 percent of blindness in the United States.

"Two large studies of diabetic macular edema have demonstrated that the vision of about 60 percent of patients improved and 30 percent significantly improved—much better than standard therapy," Pearson says. Based in part on these results, a trial to evaluate an injectable implant for the treatment of diabetic macular edema is now under way, involving 900 patients.

"The results of these studies are encouraging, especially because these patients had failed standard treatment, making their cases difficult," Pearson says.

Envision TD can restore

sight



Basic Science in the Fight against Fat

Twenty years ago in the United States, 5 percent of kids were overweight; today 15 percent are and another 15 percent are headed that way. According to the American Obesity Association, approximately 30 percent of children (age 6 to 11) in this country are overweight, and among adolescents (age 12 to 19), 30 percent are overweight, and nearly 16 percent are obese.

At UK, Eric Smart (pediatrics, above left) has been doing basic research to better understand the physiology of obesity. His research is focused on our body's house-keeper and frontline defender—macrophages—which reach out with a pseudopod to ensnare and gobble up the body's intruders.



20 years ago, **5** percent of U.S. kids were overweight; today 15 percent are and another 15 percent are headed that way.

In his lab at UK's Sanders-Brown Center on Aging, Smart and his staff isolated macrophages from normal-weight mice, then fattened up the mice and took a blood sample, again isolating the macrophages.

Smart and his group isolated pieces of membrane to do a protein search. "What we're looking for is protein change after the mice are obese. What proteins are present now that weren't before? What proteins disappeared?"

Then, in the third stage, the mice were put on strict diets and exercised so they would return to their original weight. "The difference in the proteins that show up in this stage is something very important to look at because it has important clinical implications," Smart says.

"What our animal studies will do is give us good candidates for drugs that can be used in therapy, and then we need to set up our own human study to see if what we've discovered is applicable to kids," he says. "What's crucial is to get kids to lose excess weight as quickly as possible, because the shorter the time you're obese, the less damaging the long-term effects are."

Special Meals to Melt Away the Pounds

It's been widely reported that obesity among children and teens in this country has reached epidemic proportions. But a program at the University of Kentucky continues to help kids and adolescents shed significant weight.

James Anderson, a professor of internal medicine at UK and a weight-loss expert, has been helping children and teens take off weight for nearly 25 years, most recently through his HMR program. HMR is the acronym for Health Management Resources, a national health-care company.

"The great thing about HMR's products," Anderson says exuberantly, "is that there are quite a few meal choices." Entrees, with vegetables, include chicken creole, turkey chili and chicken pasta Parmesan, and are typically 220 calories. Bars (160 calories) and milkshakes (120) are also available.

Along with a monitored, low-calorie diet, the patients attend a 90-minute group session to learn the "how to's" of weight loss, including easy ways to lower fat and calories without feeling hungry, and simple strategies to build physical activity into the daily routine. The last stage involves learning strategies for successful long-term weight management.

Anderson cites the "happy results" on one recently completed program, which included 49 adolescents—11 males and 38 females—age 12 to 18, all of whom were in "obese" and "morbidly obese" categories. By the end of the program, weight loss in this group averaged 33.6 pounds, with 31 of the teens losing more than 10 percent of their initial body weight and 16 kids losing more than 20 percent.

"Self-motivated adolescents can lose substantial amounts of weight in an intensive weight-loss program such as this," Anderson says.



Drug & Alcohol Abuse

New Treatments for Nicotine and Methamphetamine Abuse

Linda Dwoskin is on a search-and-find mission. In two related projects—one focused on nicotine and the other on methamphetamine—she is trying to find small molecules that block receptors and transporter proteins responsible for the “reward” associated with nicotine and methamphetamine use. These molecules might serve as therapeutic agents to help those hooked on the drugs, Dwoskin says. In this work, she is teaming up with UK colleagues Peter Crooks (pharmaceutical sciences) and Michael Bardo (psychology).

“The first project is focused on discovering small molecules that block nicotine receptors, proteins located in neuronal membranes in the brain. We chemically modify these molecules. Then, we see how they interact with specific nicotine receptors and determine their ability to block the rewarding effects of nicotine,” says Dwoskin (pharmaceutical sciences).

The most promising compounds are tested in animals, in this case rats conditioned to press a lever to get IV nicotine. NIH is supporting this work with a grant of more than \$6 million, the largest single award ever received by the College of Pharmacy.

The second project, focused on methamphetamine abuse, is centered on lobeline, an alkaloid from American Indian tobacco. “After determining that lobeline blocked the neurochemical effects of methamphetamine, we found that when rats that press levers to obtain IV methamphetamine are given lobeline, they don’t want the drug anymore. This was very encouraging evidence from animal studies,” Dwoskin says.

This was such good news, in fact, that the researchers patented lobeline as a methamphetamine-blocking agent, and Crooks and Dwoskin began working with investors in 2002 to form a company, Yaupon Therapeutics Inc., to further develop and market lobeline and agents from other native Kentucky plants.

\$6 million

the largest single award
ever received by
the College of Pharmacy



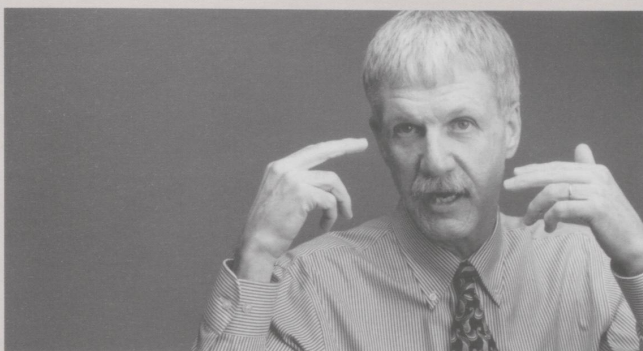
Fighting Drug and Alcohol Abuse

Devising effective ways to counter drug addiction and abuse is the goal of the Center for Prevention Research, which was established at UK in 1987. It was the first such U.S. center funded by the National Institute on Drug Abuse.

"In recent years much of our focus has been on changing the behaviors of smokers," says Richard Clayton, center director and associate dean for research in UK's College of Public Health. For more than 20 years, he has been actively promoting the Cooper/Clayton Method to Stop Smoking, which he developed with UK faculty member Thomas Cooper, a dentist and former heavy smoker. This successful science-based smoking cessation program uses education, skills training and social support in combination with use of the nicotine replacement products.

Ten years ago, Clayton became the director of an experimental program funded by the Robert Wood Johnson Foundation for \$8 million. "We put together an interdisciplinary group—called the Tobacco Etiology Research Network—which consists of 24 scientists from institutions around the country. These scientists have conducted groundbreaking research and have published their results in nearly 75 articles."

Recently, the group studied 912 freshmen for 35 weeks at Purdue University on their use of tobacco, alcohol and marijuana. "We found that a number of students who finish their exams early stay on campus for some partying before going home," Clayton says. "So it's the link between alcohol and tobacco consumption during final exam weeks that causes an increase in smoking rather than the belief that nicotine helps lower stress and intensify concentration, as researchers previously hypothesized."



Therapeutic Storytelling

For the past decade, Carl Leukefeld, director of the UK Center on Drug and Alcohol Research, and several colleagues have been using the Appalachian tradition of storytelling to treat drug and alcohol addiction in several Eastern Kentucky communities, a project funded by the NIH.

Therapeutic storytelling, also called structured stories, is a behavioral intervention to increase the involvement and engagement of people at risk for substance abuse. Therapeutic stories create a familiar situation with an open ending for participants to complete in their own words. Providing an ending gives each person the chance to practice new and individual solutions to difficult and risky situations, Leukefeld explains.

Here's how it works. The therapist tells a scripted story focused on drug or alcohol use that is designed to elicit responses about personal experiences. The group then discusses the damaging role of drugs and alcohol in their own lives.

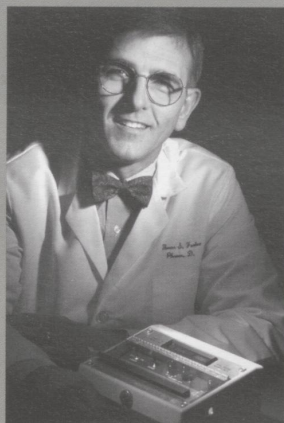
In one trial of 500 people, the control group got traditional interventions, including discussions between a counselor and a client focused on the client's attitudes, behavior and employment—and the other group added structured stories. The storytelling group was more successful in keeping their jobs as compared to the treatment-as-usual group. In addition to its storytelling component, this approach combined social skills training and "thought mapping"—writing thoughts and behaviors on paper to create an "attitudinal road map"—to help substance abusers change their behavior and, ultimately, become drug- and alcohol-free.

Building on the success of this approach, Leukefeld is now involved in a clinical trial that incorporates structured stories for women prisoners reentering their community. The focus is to help women change risky partner relationships.

Drug Design & Delivery

Push-Button Pain Relief

If you find yourself in a hospital bed with a push-button apparatus to control your pain, you can thank UK's Thomas Foster. A longtime professor in the College of Pharmacy, Foster led a team in the early 1980s that did nothing less than revolutionize the way patients receive pain relief.



"Before this time," Foster explains, "there was a one-size-fits-all approach to pain management. But it was clear that the interpretation and intensity of pain is subjective and varies widely among people." His work throughout the next decade with Daniel Kenady (general surgery), Daniel Wermeling (pharmacy) and others led to the design of devices and procedures for a therapy now referred to as patient-controlled analgesia (PCA).

"We ultimately wanted something totally disposable, cheap, easy to use, and simple to operate," Foster says. "And we came up with the idea for a wristwatch PCA device." This device used a special infusor system to deliver intravenous dosages of pain medication when the patient pushed a button on top of the watch. It included a "lock-out" feature, which allows the patient to administer only one dose of medication every six minutes so that overdosing isn't possible.

This concept has evolved, Foster adds. "There are multiple companies worldwide marketing PCA devices and most hospitals have them available for patient use. There are also adaptations of PCAs such as for transdermal delivery—where a patient pushes on a patch and pain medicine is delivered across the skin. Our wristwatch has taken quite a few new forms over the years, but patient-controlled analgesia continues to be a standard of care worldwide."

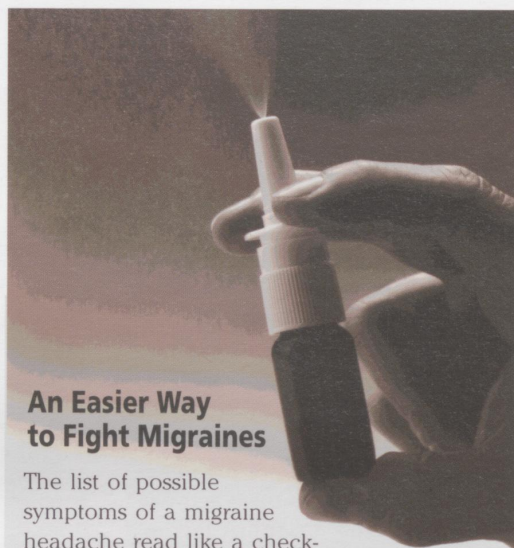
An Easier Way to Fight Migraines

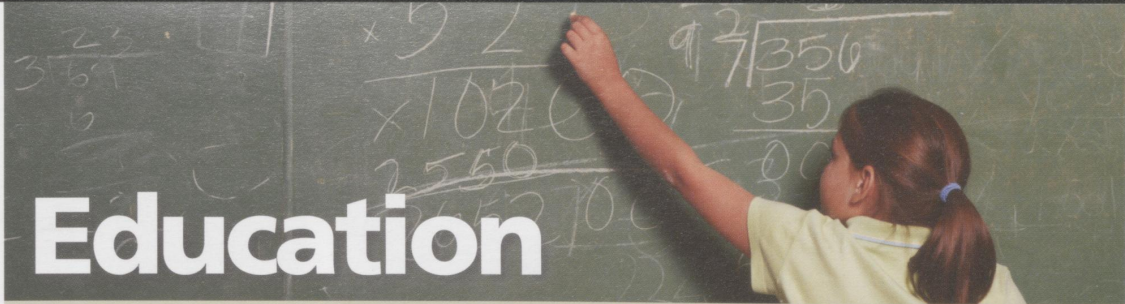
The list of possible symptoms of a migraine headache read like a checklist of human misery: intense throbbing on one or both sides of the head, nausea or vomiting, blurred vision, feeling "attacked" by light, noise or odors, feeling confused, cold or sweaty. And the list goes on. What the sufferer needs is quick relief, which is where the work of Anwar Hussain, a retired UK professor of pharmacy, comes in.

In the 1970s, the effective migraine pain management drug Stadol hit the market, but the drug could be administered only by injection. At UK, Hussain had been working on various drug delivery systems to improve efficacy and reduce side-effects of various drugs. This work led to his development of the Nasal Drug Delivery System, which uses the nasal membrane as the point of introduction to the blood system and is a much more user-friendly method to fight migraines than injection.

Hussain's work led to a patent and the product, Stadol Nasal Spray, was subsequently marketed by Bristol-Myers. To date, his research in the area of drug delivery systems has resulted in 51 patents. His work has generated more than \$14 million in revenue income for UK from patent royalties, and has brought national and international attention to the university's College of Pharmacy.

\$14 MILLION
revenue income from
Hussain's nasal sprays





Education

Helping Students with Math and Science

Increasing students' interest and performance in math and science are two of the overarching goals in an ongoing UK-led program. Called the Appalachian Mathematics and Science Partnership (AMSP), this initiative is being funded by the NSF in the amount of \$24 million over five years—the largest NSF grant ever received by UK.

AMSP's goals are to help strengthen and reform education in math and science in pre-K through grade 12 classrooms in 38 Central and Eastern Kentucky school districts, 9 Tennessee districts, 5 Virginia districts, and several West Virginia districts. What UK and partner universities bring to this project is the latest research in teaching approaches and student learning.

One of the research components of this program involves a radical shift from the traditional "chalk-and-talk" approach to training teachers to implement a hands-on approach—a well-planned series of course activities with a solid research base that help students build an understanding of key science concepts. "What has been lacking in traditional math and science instruction is teaching for understanding so that students can apply math and science skills in a variety of contexts," says Ron Atwood, a UK professor of education.

And this program is already showing results.

"Because of AMSP, we can better serve the students and help them succeed," says Tami Pickett, who teaches in Garrard County, Kentucky.



replacing chalk-and-talk with hands-on learning



Opening the Door to Science for Girls in Kentucky

Igniting youthful curiosity in science is the goal of the UK Girls in Research Program. The focus of this program is to encourage 6th-grade girls to pursue careers in research—particularly drug and alcohol research—according to Carl Leukefeld, professor of behavioral science and director of UK's Center for Drug and Alcohol Research.

This three-year program, funded by the National Institute on Drug Abuse, includes a weeklong camp at

the university for three consecutive years in June, mentoring relationships, and five Saturday Academies throughout each school year at participants' local community colleges. All expenses are paid. Girls who entered the 6th grade in the fall semester in 21 Eastern Kentucky counties can apply for this program.

This initiative also involves the participation of teachers and parents through a series of workshops. Teachers receive two-day training sessions each summer for three years in science, research and gender equity, and a small stipend.

"What I liked the most about camp this past summer was the field trip to the tobacco research lab. It was fun learning about the use of tobacco for medicine. The reason I joined the program was, I want a job

in medical research," says Chandria Bennett from London, Kentucky.

"The Girls in Research Program has been wonderful for our girls," says Crystal Smallwood, a Pike County teacher who has a daughter in the program. "They have experienced what it's like to live on a college campus and attend classes, and they have been taught the dangers of smoking and of drug and alcohol abuse. Because our girls did so many hands-on science classes and participated in wonderful Saturday sessions, all of them easily scored 'Distinguished' on the 2006 CATS Test." The Commonwealth Accountability Testing System (CATS) is designed to improve teaching and student learning in Kentucky.

To date, 111 girls have participated in this innovative program.

Energy

Spray-Painted Solar Cells

John Anthony (chemistry) sees the future of solar energy as a can of spray paint. It's a far cry from the solar panels you see on houses today. Instead, these new solar cells are tiny, organic semiconducting crystals developed by Anthony that convert sunlight into electricity. "These plastic solar cells are going to be flexible, portable and disposable," he says.

Anthony, with scientists at Cornell and Northwestern, is working on three different solar energy projects funded by the Army, the Navy, and the Defense Advanced Research Projects Agency. (Rodney Andrews, Center for Applied Energy Research, is working with Anthony on one of these projects.) These solar cells can be spray painted onto any surface, a concept that particularly intrigues the U.S. military. The cells could be spray painted onto the sides of a tent, a panel on the back of a soldier's uniform, or an inflatable structure.

"Special forces soldiers carry about 14 pounds of batteries. Since they don't have the capability of recharging them in the field, they have to carry replacements," Anthony explains. "We're trying to replace that 14 pounds with a couple little cans of spray paint. These guys bed down during the day and operate at night. They could spray out their solar cell during the day, plug their batteries into it, go to sleep, and when they wake up could pick up their charged batteries; then they'd be off and running.

"The Department of Defense has immediate and specific needs, but in a broader sense we're making materials that could eventually be put into everybody's house and everybody's car," he adds.



CAER Turns 30

In October, the University of Kentucky's Center for Applied Energy (CAER) will turn 30. The center was established during the 1970s' energy crisis, and since then has gained an international reputation for cutting-edge energy research that has led to important commercial applications. CAER was an early leader in synthetic fuels and is known for its work on coal combustion to produce electricity (which accounts for 85 percent of coal use), control of air emissions from coal-fired power plants, technology to process minerals, advanced carbon-fiber composites for environmental cleanup, and the reuse of coal combustion by-products. Energy companies from around the world use CAER's catalyst testing facilities, and hundreds of clients each year benefit from CAER's problem-focused services.

Packaging Green Energy: The Fine Coal/Sawdust Briquette

Can the unlikely marriage of two common waste products in Kentucky lead to a new, viable commercial product? A team of UK researchers thinks so. Darrell Taulbee, B.K. Parekh (Center for Applied Energy Research), and Rick Honaker (mining engineering) are creating a premium fuel by taking fine coal and sawdust—and packaging them as a briquette.

These briquettes offer an alternative to the huge quantities of fossil energy, primarily natural gas and coal, which are currently used in ethanol and biodiesel production. They could also be used to produce green power at utility plants.

In the process of mining, 15 to 20 percent of the coal generated is "fine coal"—tiny particles with the consistency of flour. Typically this fine-coal material is disposed of in sludge-like ponds called slurry impoundments. "We used to throw away 20 percent of the fine coal we produced, but now we're down in the 5 to 10 percent range," explains Parekh. This 'cleaner' number is due in part to a separation process he developed called the Ken-Flote column, which allows

coal-preparation plants to clean and recover these tiny coal particles.

And what about the sawdust connection? Five years ago our state produced three-quarters of a million tons of sawdust in Eastern Kentucky alone. Sawdust hills have typically been left behind from timber operations. So the UK team decided to link up the leftovers from coal plants and lumber mills.

The researchers' scenario involved taking the fine coal directly from the column flotation unit, dewatering it, mixing it with the sawdust, adding a binder, and pressing it into a briquette. The binder is the "glue" that holds the sawdust and fine coal together.

"The most impressive result of the project so far is the production of a high-energy fuel with a heating value exceeding 13,000 Btu per pound from 90 percent fine coal and 10 percent wood waste," Honaker explains. "We've had several meetings with potential investors and utility companies who are interested in briquettes because of their need to respond to CO₂ emission concerns."



Improving Coal Preparation and Miner's Health

The health of the mining industry and the health of miners are the dual focus of three projects under way in UK's mining engineering department. The Advanced Surface Enhancement Project involves using infrared and laser-based technologies to create a molecularly smooth, hardened surface that will decrease the wear and corrosion rate of coal-preparation plant equipment, and may decrease plant maintenance by 20 percent.

A second project is developing new, automated methods to recover coal from abundant thin seams (many of the thicker reserves have been depleted), and improving methods of handling coal slurry to minimize the need for impoundments and guarantee their integrity.

Due to advances in remote-controlled equipment, longer cuts are possible in underground coal mines. However, extended cuts can present problems for the ventilation system.

Meeting this challenge, a third project by mining engineers at UK has resulted in improved ventilation for miners by reducing methane concentrations to safe levels at the face of underground mines where extended cuts are made. Mining engineer Andrzej Wala has been using Computational Fluid Dynamics (CFD) to analyze complex airflow fields and various contaminants at the mine face. His research has shown that CFD is an effective analytical tool for mining engineers to use to create safer, more productive, and environmentally friendly underground mines.

Engineering

The Metaverse: Visualization & Virtual Environments

A forest fire rages and UK mechanical engineer Jim McDonough is right in the thick of it. But his skin doesn't feel the flames and his lungs aren't choked by the smoke—this is a “virtual” fire. He's surrounded by a life-size image of the blaze, projected on the walls of an ordinary room. As he is “immersed” by the fire, he observes how it moves and discovers how to control it.

This new “virtual reality” using front-projected computer images to immerse the viewer in a pixel-based world—called the Metaverse—was created in 2001 by UK computer scientists Jim Griffioen, Ken Calvert, Zongming Fei, Christopher Jaynes, and Brent Seales. This work, backed by the NSF, led to a number of applications—teleconferencing, scientific modeling, virtual art exhibits, digital library collections, and virtual surgery—and grew into the UK Center for Visualization & Virtual Environments.

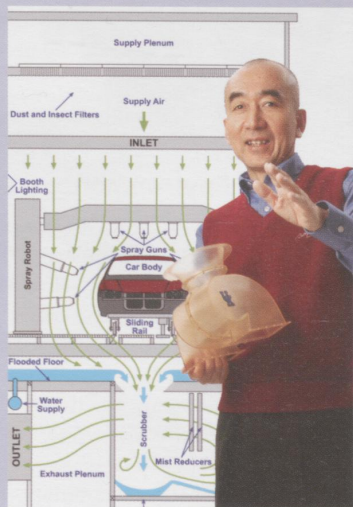
Two of the leading-edge projects at the center include Ruigang Yang's work on 3-D reconstruction and Samson Cheung's work in surveillance privacy protection. Yang (computer science) specializes in acquisition—capturing the 3-D image of an object using a group of cameras. His hardware then routes the resulting pixels to a “light portal,” a 3-D display.

Cheung (electrical and computer engineering) is creating software that can manipulate video surveillance all the way down to the pixel level. For example, surveillance footage is needed for a jury trial. To protect the identity of bystanders in the video, Cheung can “erase” these individuals, and embed their images into a secure watermark. The complete video can be restored, if needed. Cheung's work is addressing society's need for greater surveillance at home and work, but without compromising the right to privacy.

To protect the identity of bystanders

in surveillance footage, UK's Samson Cheung can “erase” individuals and embed their images into a secure watermark.





50 percent

of the energy consumption in the automobile assembly process is taken up by painting

Partnering with Toyota

Sometimes serendipity becomes an important matchmaker. This was the case for UK mechanical engineer Kozo Saito, who crossed paths with Fujio Cho at a meeting of the Japan Club of Central Kentucky 20 years ago.

Cho, then president of Toyota's Georgetown, Kentucky, plant (and now chairman of the board of Toyota Motor Corporation) asked Saito about his current

work at UK. Their conversations continued and, 10 years later, led to a solution to one of the automobile industry's most costly problems—the waste of electrical energy and paint during the coating process.

“Close to 50 percent of the energy consumption in the automobile assembly process is taken up by painting,” Saito says. “Wasted paint due to overspray costs nearly \$1 billion a year for a typical, large automobile company.” Saito responded to this challenge by developing a much more efficient scrubber for the painting process. Scrubbers suck up, much like a vacuum cleaner, the wasted paint.

A few months later, based on graduate student Abraham Salazar's computational fluid dynam-

ics model, Saito developed the Vortecone Scrubber, which looks a bit like a four-foot-tall meat grinder. The patented device has significantly improved overspray capture while using much less energy than conventional scrubbers. “Paint capturing efficiency is 98.2 percent, and the Vortecone uses half the energy that's sapped by old-style scrubbers.”

Saito's scrubber is currently being used in seven Toyota facilities worldwide, including the headquarters plant, and the UK-Toyota partnership continues to flourish. Last March, Toyota gave UK \$1 million to support a new Institute of Research for Technology Development in the College of Engineering, to be headed up by Saito.

Partners in Aluminum

From its founding in 1999, the Center for Aluminum Technology (CAT) in UK's College of Engineering has had a targeted mission: to partner with industry to make advances in the aluminum industry that benefit all of us. “Here at UK's Coldstream Research Campus, we provide the brainpower to work on problems that the industry identifies,” says Subodh Das, center director, “and then industry can apply this basic research and roll it into actual production.”

Today, the results of some of CAT's first projects are reaching fruition. One of the center's original projects, completed in 2004, focused on lowering incidents of aluminum ingot cracking to save energy and costs. In partnership with seven companies and organizations, CAT developed mathematical modeling software that can predict cracking propensity. The software evaluates casting speed, metal temperatures, and a variety of other casting parameters. “Using this software, we were able to achieve lower cracking by 50 percent, and we created a tool that is now available for use by the entire industry,” Das says.



Business and economics and engineering faculty partner with CAT through UK's Sloan Center for a Sustainable Aluminum Industry. Ten current research projects include recycling programs, aluminum energy efficiency, continuous casting of aluminum, and the use of aluminum in the automotive industry.

“CAT is the premier technology and business research organization in the world for aluminum research,” Das says.

The Environment



250,000
acres

Bringing Back the Forest

Over 250,000 acres of land in Kentucky have been impacted by surface mining, and another 1.6 million acres have been slated for coal extraction. Most of the land mined since 1978 has been heavily compacted, making it unsuitable for deep growth of any kind.

"The ground is so compressed that water can no longer percolate into and through it," explains Don Graves, an extension professor in the UK Department of Forestry. "It was all re-vegetated with tall fescue

and sericea lespedeza [a noxious weed], both of which only serve as undesirable ground cover."

Now, backed by grants totaling nearly \$5.5 million from the U.S. Forest Service and the Department of Energy, UK researchers are taking the lead in a project to reclaim 3,000 acres in areas around Prestonsburg, Hazard and Madisonville, Kentucky. UK is partnering with experts from state government and industry in this six-year project.

The researchers are using novel deep ripping methods to produce loose material so that tree roots can

Fiber Optics in Service to the Environment

When most people think about fiber optics, they think of telephone or cable service. One UK researcher has taken fiber optics beyond communications to produce highly sensitive environmental monitoring tools.

Since 1995, Sylvia Daunert, a professor of chemistry, has been working on NSF-funded research to produce fiber optic sensors that use bacteria genetically engineered to glow in the presence of very low—but still dangerous—levels of toxic substances. This bioluminescence is created by altering the same proteins that make fireflies and jellyfish glow.

She has studied the toxic substances arsenic and antimony, a chemical used in matches. "We've used various proteins that can emit different colors," Daunert says, "and now we can detect many toxic substances at the same time just by looking at which color—red, green or blue—is emitted." The bacteria Daunert and her colleagues use is a non-toxic strain of *E. coli*, which is widely used in biotechnology.

Daunert creates her bioluminescent bacteria by using natural bacterial genes that recognize small amounts of toxic substances. "We

trick the bacteria by hooking up the gene that recognizes a toxic compound to what we call the reporter gene—the one that generates the bioluminescent signal," she says. "So as the toxic compound enters the cell, it is recognized by the gene."

The advantage of using these optic fibers for environmental monitoring lies in their ability to act as remote sensors. "You can place a fiber at a polluted site, just leave the fiber there, and monitor what is happening from miles away."



easily penetrate the earth and water can percolate into the soil rather than run off, carrying sediment into the streams. "This work will result in high-value hardwood timber that can be used to manufacture furniture, hardwood floors, and decorative furnishings," says Graves, who is heading up UK's part in this project, which will end in 2008. "It will also increase wildlife habitat."

"What we hope is to replace a fescue desert with a total forest community," Graves adds.



Putting Mountains of Ash to Work

When coal burns to generate electricity, it leaves ash behind. Coal-burning utilities have traditionally stored this ash in ponds or have simply created mountains of the stuff near the utility site.

Mountains? What exactly is the magnitude of this problem?

In 2002, 4.6 million tons of ash were produced in Kentucky, of which only half a million tons were utilized, mostly in concrete, so 4.1 million tons were stored. In addition, 6.1 million tons of scrubber by-products were generated and 1.2 million tons were used, mostly to make wallboard for home construction. Scrubbers remove sulfur and nitrogen compounds resulting from coal combustion before the air is released. Putting this stored ash to use has been a longtime concern for electric utilities.

This is where expertise at UK's Center for Applied Energy Research (CAER) comes in. CAER researchers Tom Robl and Jack Groppo are heading up a project on advanced coal-ash processing to improve the quality of fly ash from burned coal. The higher-quality ash improves the durability and strength of the concrete. The result is that coal-burning utilities can become more economical, since fly ash becomes a marketable product rather than a nuisance to be disposed of. The technology was first tested in Ghent, Kentucky, at the Ghent Station power plant.

In addition, developments in ash-processing technology at CAER—specifically, a new approach that takes raw land-filled ash in a slurry form and separates it in a four-step process—have the potential to generate high-quality products, serving existing markets such as concrete, and new markets such as filler.

UK has three patents on aspects of the process with one patent pending. "This process can turn mountains of coal ash into commercially competitive products, including some that will greatly reduce greenhouse gas emissions and create new jobs for Kentuckians," says Robl.

Literature & the Arts

The Electronic Beowulf

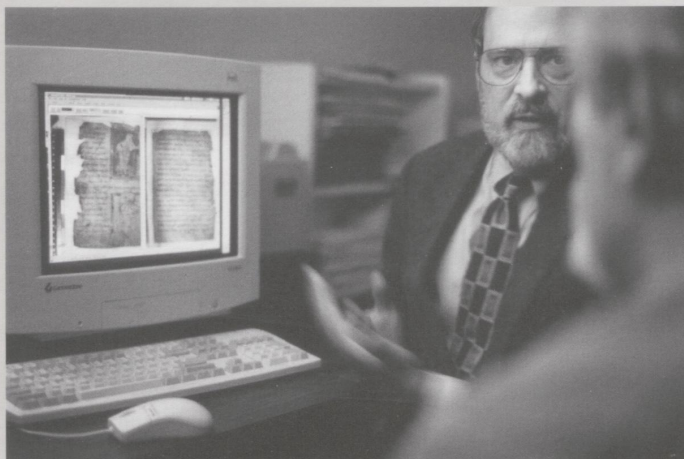
"Beowulf," the great Old English poem, survives in a single manuscript that was badly damaged by fire in 1731, and it deteriorated further before being rebound in 1845. Making innovative use of a digital camera, ultraviolet fluorescence, and fiber-optic backlighting, Kevin Kiernan (English) set out in 1993 to rescue this time-honored text and literally bring it to light for scholars to study. The result of his work was a two-volume compact disk called *The Electronic Beowulf*, published in 1998.

With support from the UK Center for Computational Sciences, Kiernan assembled an archive of digital images that provide not only high-quality facsimiles of what is readily visible in the manuscript, but also of hundreds of letters and parts of letters covered by frames designed to

preserve the fragile text after the edges were seared in the fire.

Kiernan's work has virtually changed everything about the way scholars study what is considered the most important work of Old English literature. Now, scholars interested in the construction of the original gatherings of the manuscript are able to place once-adjoining leaves side by side again, or examine in great detail the color and texture of the vellum leaves by magnifying the images. And with the help of image processing programs, faded passages are now more legible.

This project won the 2001 Beatrice White Prize awarded by the English Association (United Kingdom) for outstanding scholarly work in the field of English literature before 1590.



Saxophone Research

If you ask Miles Osland, UK professor of saxophone and director of jazz studies, how his research is coming along, he might smile, but he also has a ready answer.

"Our research focuses on developing and using new techniques in our performances, and combining these techniques in musically exciting ways," says Osland, the recipient in 2004 of a \$24,000 UK Research Support Grant. His project was titled "Development, Documentation and Dissemination of New Works for Saxophone."

Osland used this grant to commission three works by major international composers who have proven themselves to be "technically adventurous," he says. The three commissioned works were "The Concerto for Alto Saxophone and Wind Orchestra," by English composer Mike Mower, "MOSAX Overdrive for Saxofonvartett" by Sweden's Anders Åstrand, and "Four Miniatures from Brazil" by Brazilian composer Hudson Nogueira. All three pieces were performed in 2005 at UK.

"These performances were very well received," Osland says. "Musicians can be researchers too."



Non-Toxic Art

Making art—printmaking, for example—is challenging. It can also be toxic.

Toxic elements first seeped into the printmaking world with the invention of oil paint, says UK art professor Gerald Ferstman. New, often hazardous, chemicals were needed to break down oil-based inks. Common household chemicals like turpentine and nail polish remover are among the more than 100 toxic substances used by traditional printmakers. Some of the known side effects from continuous exposure to these chemicals include birth defects, central nervous system damage, asthma and emphysema, and systemic poisoning of the lungs, liver, kidneys, and heart.

This danger is what prompted Ferstman and his colleague in art, Ross Zirkle, to create non-toxic techniques to keep their students safe and keep their craft alive, an art that dates back to the Middle Ages when warriors had artisans etch intricate designs on weapons.

"Ross's grandfathers were both pressmen for newspapers," says Ferstman. "One developed dermatology problems from handling inks and eventually died of cancer."

The researchers experimented with a water-based ink that can be used in all printmaking techniques and worked to improve and adapt new non-toxic products. Zirkle's research centered on waterless lithography. The result was a "very workable" system of ink and modifiers that provides a safe, economic and reliable alternative to oil- and solvent-based lithography.

"The bottom line is, nobody should have to risk their health to make art," Ferstman says.



A sad note: In March 2007, Ross Zirkle (left) died after a nine-month battle with cancer. A UK faculty member since 1997, he received UK's Great Teacher Award in 2006.

Nanotechnology



Tiny Disease Fighters

Armed with therapeutic drugs, nanoparticles injected into the body move along in the bloodstream toward their target—a cancer cell. These nearly invisible legions of stealthy, infinitesimal specks invade the target cell and deliver diagnostic or therapeutic agents.

Over the past four years, this scenario has been fine-tuned by Mike Jay (right, above) in the UK College of Pharmacy and his former colleague in the college, Russ Mumper. It's an approach that holds great promise for diagnosing and treating various cancers and fighting viruses like HIV.

An important step in the researchers' nanoparticle tinkering is their use of "recognition molecules" that are attached to the surface of the particles. With this chemical tinkering, the particles can be directed to specific parts of the body, for example, a receptor on a tumor. "Whether injected or dried and incorporated into a tablet, the particles head for the cancer cell and bind to a receptor," Mumper explains. "The cancer cell engulfs the particle and, in doing so, engulfs the drug that will leach out into the cell and kill it."

In 2000, believing strongly in the therapeutic potential of this process, Mumper and Jay founded NanoMed Pharmaceuticals Inc. In the last two years, their work has "taken off," Jay says. Initial studies have shown that their nanoparticles are safe and biocompatible, and they have been shown to overcome the resistance that tumors develop to many chemotherapeutic agents. Testing of their nanoparticles, loaded with the anti-tumor drug Idarubicin, is under way in an animal model of leukemia.

"My greatest hope," says Jay, "is that what we discovered and developed will be used to help people who have diseases that are especially hard to treat."

Nanotubes,

only a few atoms in circumference, are stronger than steel, and can conduct electricity.

Working Together on the Nanoscale

With \$20 million in grant funding and industry partners including Lexmark, Cypress Semiconductor, Quanteon, the Painting Technology Consortium, and Loxel Imaging Systems, UK's Center for Nanoscale Science and Engineering (CeNSE) is the nexus for nanotechnology research at UK and for joint U of L and UK nanotechnology projects.

CeNSE research covers nanoelectronic devices, nanoscale materials, biosensors, chemical/environmental sensors, and nanotechnology education and commercialization.

Two dozen UK faculty are involved in CeNSE, including center director Vijay Singh (electrical and computer engineering), who is studying sensors and solar cells for commercial and military applications, and Ushi Graham (Center for Applied Energy Research), who is focusing on carbon nanotube docking stations for fuel catalysts and leading a Toyota/UK project on fuel cells based on nanocatalysis.

Eric Grulke (chemical and materials engineering) is studying nanocomposites for space radiation shielding and recently developed the nanoCLEAR anti-reflective lens system with Optical Dynamics in Louisville, Kentucky. This system is a new method for producing anti-reflective eyeglass lenses.

Zhi Chen and Todd Hastings (electrical and computer engineering) are developing photonic and electrochemical sensors, including, in collaboration with Parkinson's researcher Greg Gerhardt, sensors that measure in real time neurotransmitters in the brain.

Bruce Hinds (chemical and materials engineering) is studying water transport and chemical gatekeeping in carbon nanotubes and has teamed with pharmacy researcher Audra Stinchcomb to use nanotubes to improve topical and transdermal drug delivery.

In addition, Bob Yokel (pharmacy), along with several CeNSE researchers, is leading a new multidisciplinary consortium on nano-toxicology with the University of Louisville. And Leonidas Bachas (chemistry) is using nanoscience and molecular biology for environmental remediation and self-organization of nanoparticles.

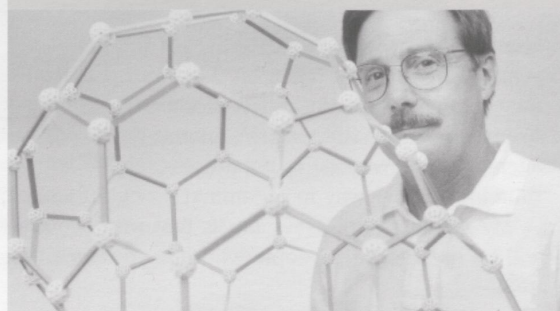
Harnessing the Power of the Nanotube

A chain of nanotubes able to span the 250,000 miles between the Earth and the moon could be loosely rolled into a ball the size of a poppy seed. These hollow, cylindrical structures measure only a few atoms in circumference, are stronger than steel, and can conduct electricity.

Carbon nanotube research at UK started nearly 25 years ago when Peter Eklund (formerly in physics and astronomy, below) began to study nanotube-containing carbon materials. He developed an arc-discharge method for producing nanotubes, allowing his group to produce larger amounts of material at higher purity. Eklund and chemists Robert Haddon, Mark Meier and Jack Selegue worked together on purification technologies similar to those developed in earlier work on fullerenes (a.k.a. buckyballs—hollow spheres with 60 symmetrically arranged carbon atoms). Nanotubes differ only in that they are strands rather than spheres.)

This collaboration, with the addition of Frank Derbyshire at the Center for Applied Energy Research (CAER), eventually led to an NSF Materials Research Science and Engineering Center (MRSEC) on Advanced Carbon Materials at UK. Under the MRSEC award, CAER researchers Rodney Andrews, David Jacques and Apparao Rao began to concentrate on methods for producing larger quantities of multi-walled carbon nanotubes for applications such as high-strength composites, super-capacitors and batteries, and biological sensors.

Today, with support from the Army Research Laboratory, the CAER group produces several kilograms per day of high-purity nanotubes and supplies materials to UK nanotube researchers in biomedical engineering, chemistry, chemical and materials engineering, electrical engineering, and mechanical engineering, as well as to collaborators at other institutions and in industry.



Space Exploration

Spacecraft of the Future

Suzanne Weaver Smith's current research is really out there. Out in space, deep space.

Among her projects to develop novel computer modeling and laboratory testing methods for spacecraft, Smith, an associate professor of mechanical engineering, is focusing on "gossamer materials"—strong, very thin, ultralightweight, and highly flexible materials that can be tightly compacted for launch and then deployed once in space.

Large expanses of reflective gossamer material could provide the propulsion of futuristic solar sail spacecraft into deep space. Or, nearer to Earth, this material might be utilized in support structures for next-generation space telescope mirrors, for deployable satellite solar energy collectors or for sun shields.

With the help of supercomputers, Smith has worked to predict the gossamer material's motion response to dynamic disturbances such as those commonly found in space. Predicting the motion of the gossamer spacecraft requires computing the motion at thousands of finite points within it, a computational process involving millions of equations. With a better understanding of how these gossamer spacecraft respond to disturbance, Smith and her team could then redesign the material, including implementing intricate patterns within it, much like crimping hair, to amplify its strength and stability.

"Ultimately, if you can compute the solutions and predict the motion response, you can help design stronger materials and better spacecraft," Smith says. "We can test for degradation and performance under various conditions, and then change the design to produce the response we require."



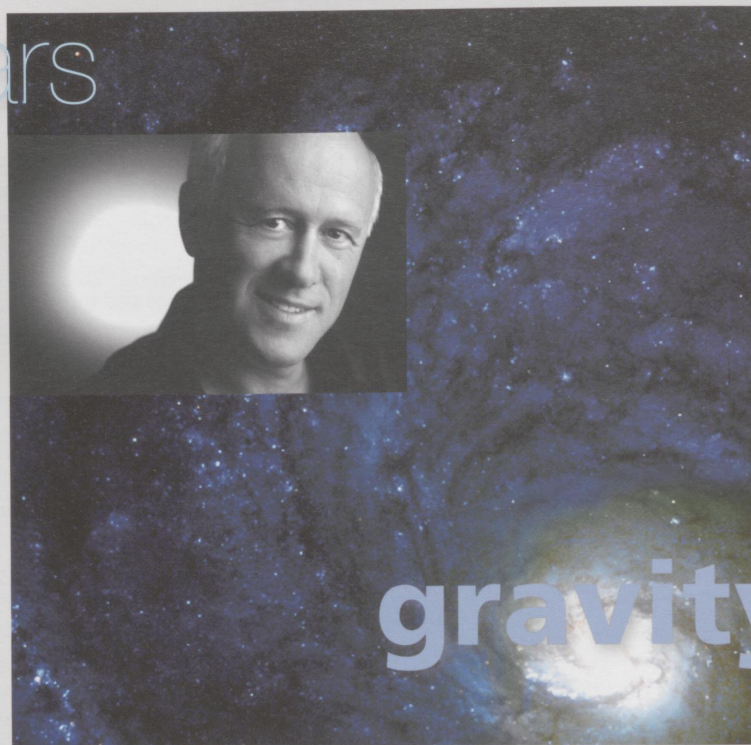
quasars

Configuring the Birth of the First Stars

Gary Ferland, a professor of physics and astronomy, is also a genealogist of sorts. His ongoing project involves tracing the birth of the very first stars in the universe.

To accomplish this formidable task, he studies quasars—small, intense celestial sources of radiation characterized by large changes in wavelength—and his “partner” in this research is the Hubble Space Telescope, our eye on the universe that can see billions of light years away. “The Hubble ‘observes’ quasars through spectroscopy, a way of separating electromagnetic radiation according to wavelengths,” explains Ferland, who analyzes data downlinked from the space telescope.

In his work, he uses an advanced computer program that simulates astronomical objects like quasars and supernovae. He admits the fundamental challenge of such a project is numerically simulating what goes on in a quasar. “In astronomy we can’t do an experiment as you can in physics. All we can do is observe what comes to us,” he says. “There’s an old saying in the field: ‘Those who can do, do; those who can’t, simulate.’”



gravity

Building Galaxies from Scratch

Isaac Shlosman keeps his own personal galaxies in the basement. Below ground, in the UK Chemistry-Physics building, his galaxies pulse on a cluster of computers. Created by software written by Shlosman and his team, this 3-D, animated model may one day help scientists grasp the formation and evolution of galaxies.

“Galaxies are the building blocks of this universe, and inside each galaxy there is the part we can see—ordinary luminous matter like stars—and the part we can’t see, so-called dark matter,” explains Shlosman, a professor in the physics and astronomy department.

Scientists measure dark matter by the gravity it produces. “After the Big Bang, the universe was perfectly uniform and homogenous—like an even spread of butter on toast,” he says, “but gravity stepped in. Because

the universe is relatively young, less than 14 billion years old, gravity was only partially successful in clumping the matter. Ordinary luminous matter falls into traps prepared by dark matter, so it clumps together with the dark matter.”

He explains that this clumping forms two types of galaxies: disks (circles with spiral arms) and ellipsoids (3-D ovals). How the universe decides which kind to form is the question he and his team are trying to answer with his computer models by letting gravity operate virtually to clump the matter.

These simulations are rooted in reality: the latest observations from world-class telescopes across the globe. These glimpses into space, combined with analysis of images from the Hubble Space Telescope, allow him to “see how the individual galaxies behave.”

Women's Health

Advancing Women's Health

"Why do some diseases affect women more than men? Why do women respond to some drugs and therapies differently than men? What environmental factors and behaviors most influence women's health? We don't know. But we want to find out. And we need the help of women of all ages from communities across Kentucky," says Leslie Crofford, director of the Center for the Advancement of Women's Health.

The center is leading the Kentucky Women's Health Registry, which is collecting information to track health trends and recruit women to participate in medical trials. Crofford hopes to collect data from 25,000 Kentucky women over the next 10 years. (To participate,

visit www.kywomensregistry.com.) The center is reaching out to women through research, student and resident training, and health information workshops, as well as primary care with an emphasis on prevention.

Crofford came to the center to continue her studies on rheumatic diseases, including arthritis and fibromyalgia—chronic, widespread muscle pain, accompanied by fatigue. In 2005 the journal *Arthritis & Rheumatism* published her study on Pfizer's drug Lyrica™, which was shown to significantly reduce the pain of fibromyalgia and improve sleep. "The inflammatory and stress-related diseases I study are much more common in women, so it's a natural fit."



Breaking the Cycle of Violence against Women

The safety of women and girls is the goal of the university's innovative Center for Research on Violence Against Women. The center began in 2002 and is led by Carol Jordan, who spent eight years on the executive staff of former Governor Paul Patton.

The program grew out of a recognized need to strengthen interdisciplinary research and graduate education that focuses on violence against women and to improve the status of women in higher education. It began as a small operation, but under Jordan's leadership has quickly grown into a nationally recognized center with four staff, four endowed chairs and professorships, 11 faculty associates, and two graduate students.

The first UK Women's Safety Study done in 2004, one of the largest studies ever to address the safety of college women, revealed that 36.5 percent of 1,010 female undergraduate and graduate students had been sexually or physically assaulted, or stalked. In response to these data, UK President Lee T. Todd Jr. committed an additional \$1.25 million to support improvements in campus safety. A follow-up evaluation study is under way this year.

Other center projects are analyzing trends in domestic violence protective orders over the past decade, investigating patterns in sentencing and parole board decisions in cases where victims of domestic violence kill the offender, and exploring patterns of homicide in cases of intimate partner violence through a review of autopsy records of women who have been murdered.

Good Dental News for Expectant Mothers

In 2006 expectant mothers received some good news—treatment for periodontal disease is safe during pregnancy.

UK's John Novak and James Ferguson took part in the largest clinical trial ever to try to determine the connection between maternal periodontal disease and increased risk of pre-term birth and low birthweight. The results were published in November 2006 in the *New England Journal of Medicine*.

"Dental treatment is not usually recommended during the first trimester because this is such an important time in fetal development," says Novak, associate director of the College of Dentistry's Center for Oral Health Research. Ferguson is chair of the College of Medicine's Department of Obstetrics and Gynecology. This project was backed by a five-year NIH grant.

The study enrolled 823 women with periodontal disease, which is caused by bacterial plaque and toxins that accumulate under the gums. The volunteers, between 13 and 17 weeks pregnant, were divided into two groups: those who received periodontal treatment (cleaning the root to remove bacteria and toxins from below the gums) before the 21st week of pregnancy and a control group that received the same treatment after delivery.

The study also concluded that treatment for periodontal disease did not reduce the risk for pre-term delivery, low birthweight, smaller fetal growth, or serious levels of hypertension, but may increase the risk for spontaneous abortions and stillbirths.



Other Key Research

New Treatments for Parkinson's

Parkinson's disease affects more than one million people in North America, progressively impairing control of body movement and often leading to immobility. In 1999, UK joined the fight against Parkinson's by establishing a Morris K. Udall Parkinson's Disease Research Center of Excellence (one of 12 in the United States) to develop new treatments and therapies.

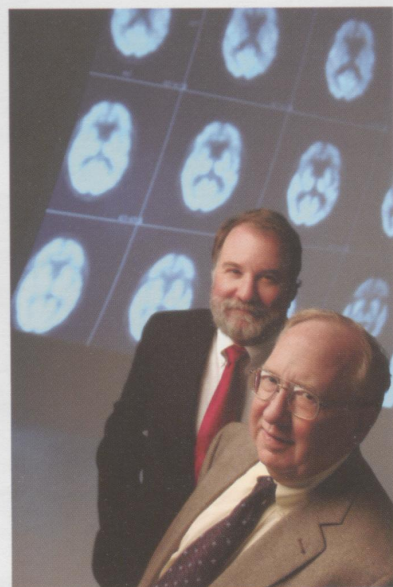
Researchers at the center, directed by Greg Gerhardt (anatomy and neurobiology, left below), focused their work from the outset on a protein called glial cell-line derived neurotrophic factor (GDNF), which is produced by cells in the brain and required for the normal development and differentiation of dopamine cells.

In 2002 Gerhardt, Don Gash (anatomy and neurobiology, right below), and John Slevin (neurology and molecular and biomedical pharmacology) launched the first U.S. clinical trial of GDNF, sponsored by Amgen, a large biotech company that holds a patent on GDNF. The 10 patients in the UK trial had programmable pumps implanted in their abdomen, a system that delivered GDNF directly to a second implant—a small, multi-port catheter in the brain. The catheter dispersed the drug over a broad area in the brain involved in Parkinson's.

At the two-year point, all 10 patients had completed the Phase I leg of the trial, and all of those who had gotten GDNF reported that their lives had improved dramatically. No one reported any significant side effects.

But citing safety concerns and potential side effects of this drug, Amgen stopped the trial in 2004.

"This was a severe setback for the patients in our study, of course," says Gerhardt, "but the trial showed us that GDNF was definitely something to be further investigated." The UK research group then began working with a "brother" of GDNF, a molecule called Neurturin, which hits the same targets as GDNF. A California company, called Ceregene, has since sponsored a clinical trial, currently in Phase II, using this new molecule.



Coalfield

PROGRESS

INSIDE: Volleyball team captures district crown

Mt. Sterling Advocate

Telling the Stories That Need to Be Told

Al Cross says UK's Institute for Rural Journalism and Community Issues has a simple goal: Help rural journalists report on the stories that matter, and report them accurately and well—no matter how controversial or complex the issues may be. Cross (journalism and telecommunications), the director and only full-time employee of the institute, came to UK after a 26-year career at the Louisville *Courier-Journal*, 15 of it as the chief political writer.

Creation of the institute was partly driven, Cross explains, by the widespread buyout by large newspaper chains of rural daily and weekly papers in the 1980s and 1990s. "Many of them cut staffs and lost their focus on local issues. Stories on issues central to the sustainability of rural communities—on education, the environment, economic development, and healthcare—were simply going untold."

The idea for the institute began in late 2000, when Kentuckian Al Smith, longtime newspaper editor and host of Kentucky Educational Television's political show *Comment on Kentucky*, and other leading journalists shared their mutual concern about what they saw as the declining quality of rural newspapers. They agreed something needed to be done to combat the ill effects of what Smith calls "the Wal-Marting of Main Street in America"—the loss of small-town ownership of local news media, banks and retail establishments to large conglomerates.

The institute's focus on rurality led Cross to begin the online Rural Blog, which is now regular reading for hundreds of journalists who cover rural issues. "The defining characteristic of rurality is isolation. And I know from personal experience that there are thousands of good rural journalists in America. Or those that could be good. But they don't get a chance to rub shoulders or share ideas with people like themselves. And that's what the institute is here to do."

Going Smoke-Free

A decade ago, almost anybody you might have asked in Central Kentucky—the heart of tobacco country—about a policy requiring restaurants and bars to go smoke-free would have likely shrugged with a dismissive, "No way."

But Ellen Hahn in UK's College of Nursing decided to take on this Mission Impossible, and in April of 2004 was pleased—and more than a little surprised—that Lexington-Fayette Urban County Council enacted a smoke-free ordinance in all establishments open to the public. The EPA has classified secondhand smoke as a cause of cancer in humans, leading to around 3,000 lung cancer deaths and 42,000 heart disease deaths in adult nonsmokers in the United States each year.

Hahn and colleagues have conducted a series of health and economic impact studies of Lexington's smoke-free law. A study published last February on the effects of Lexington's smoke-free law showed that employment at Lexington restaurants grew by 3 percent after the smoke-free law went into effect, while employment in bars remained basically the same. And a study by the UK College of Nursing has reported a 31.9 decrease in adult smoking since Lexington's smoke-free ordinance passed.

"Over 2,000 municipalities in the United States have some sort of smoke-free laws," Hahn says, "and now 13 other Kentucky communities have followed Lexington's lead."



Future Treatments for Spinal Cord and Brain Injury

After traumatic injury to a person's brain or spinal cord, time is the major factor in the ultimate severity of that injury. Much of the damage to the injured nervous tissue occurs during the first several hours and days following the incident, which suggests that "secondary injury" might be prevented by early treatment with neuroprotective drugs.

Edward Hall, director of the UK Spinal Cord & Brain Injury Research Center (SCoBIRC), is leading a team of scientists who are testing various drugs that might inhibit secondary injury to the brain or spinal cord. This team includes Jim Geddes, Patrick Sullivan, Kathryn Saatman, and Alexander Rabchevsky (SCoBIRC), Stephen Scheff (Sanders-Brown Center on Aging) and Joe Springer (physical medicine and rehabilitation).

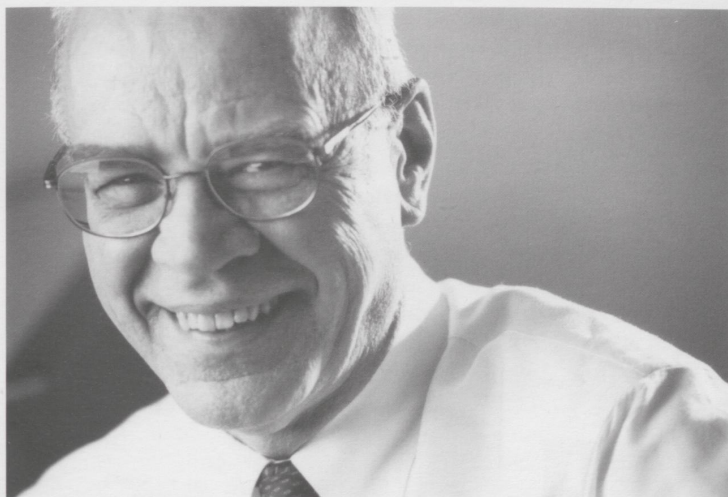
Three different types of drugs are currently being tested. These drugs block the damaging effects of oxygen free radicals, prevent the loss of energy production in cells' mitochondria, and inhibit the degradation of nerve cell proteins by an enzyme known as calpain. One of those treatments, using the drug cyclosporine A, is currently being tested in severely brain-injured patients by SCoBIRC Clinical Director Byron Young.

Hall was a pioneer in the discovery and development of the steroid drug methylprednisolone, the only approved drug that has been shown to be effective for the treatment of spinal cord injury. But he is hopeful that the protective effects of the

newer types of drugs now being tested by his group will far surpass the benefits of methylprednisolone in treating the estimated 11,000 Americans who suffer a spinal cord injury each year and the 1.5 million who sustain traumatic brain injuries.



(from left) Edward Hall, George Smith, Alexander Rabchevsky, and Patrick Sullivan



Targeting Children's Mental Health

Understanding childhood violence is the focus of the new UK Center for the Study of Violence Against Children (CSVAC). The culmination of eight years of multidisciplinary work by faculty from the College of Social Work and the College of Medicine, this center of excellence began in 1999 with the creation of the Comprehensive Assessment and Training Services (CATS) Clinic.

CATS is funded by the Kentucky Cabinet for Health & Families to serve maltreated children and their caregivers, and assist the cabinet in planning for children's safety and long-term welfare. The clinic will serve as the living laboratory for CSVAC's research, education and training activities.

In addition to current state and federal funding, CSVAC will be supported by the H. Otto Kaak Chair in Early Childhood Mental Health in the College of Social Work. The creation of the Kaak Endowed Chair was made possible through a pledge of \$3 million from R. Bruce Bacon of Michigan. Bacon, a native of Cadillac, Michigan, and his wife, Barbara, have a strong commitment to improving the lives of impoverished children and families. Bacon created and endowed the chair after attending a lecture given by Kaak, who is an expert on childhood attachment disorders and a CSVAC co-founder.

Kaak is professor of psychiatry and pediatrics at the UK College of Medicine. Other CSVAC co-founders include Virginia Sprang and James Clark, associate professors of social work, and Allen Brenzel, associate professor of psychiatry.

Functional Independence

What does it mean to be independent? For people who suffer spinal cord injuries or simply face the normal decline of aging, muscle activity makes all the difference.

In 2006 the UK College of Health Sciences hired Charlotte Peterson and Esther Dupont, who previously worked together at the University of Arkansas, to jump-start the Functional Independence Research Center. With more than \$1 million in NIH grants, Peterson and Dupont are working closely with communication specialists, physical therapists and athletic trainers in the college to build a research program focusing on maintaining both communication and mobility.

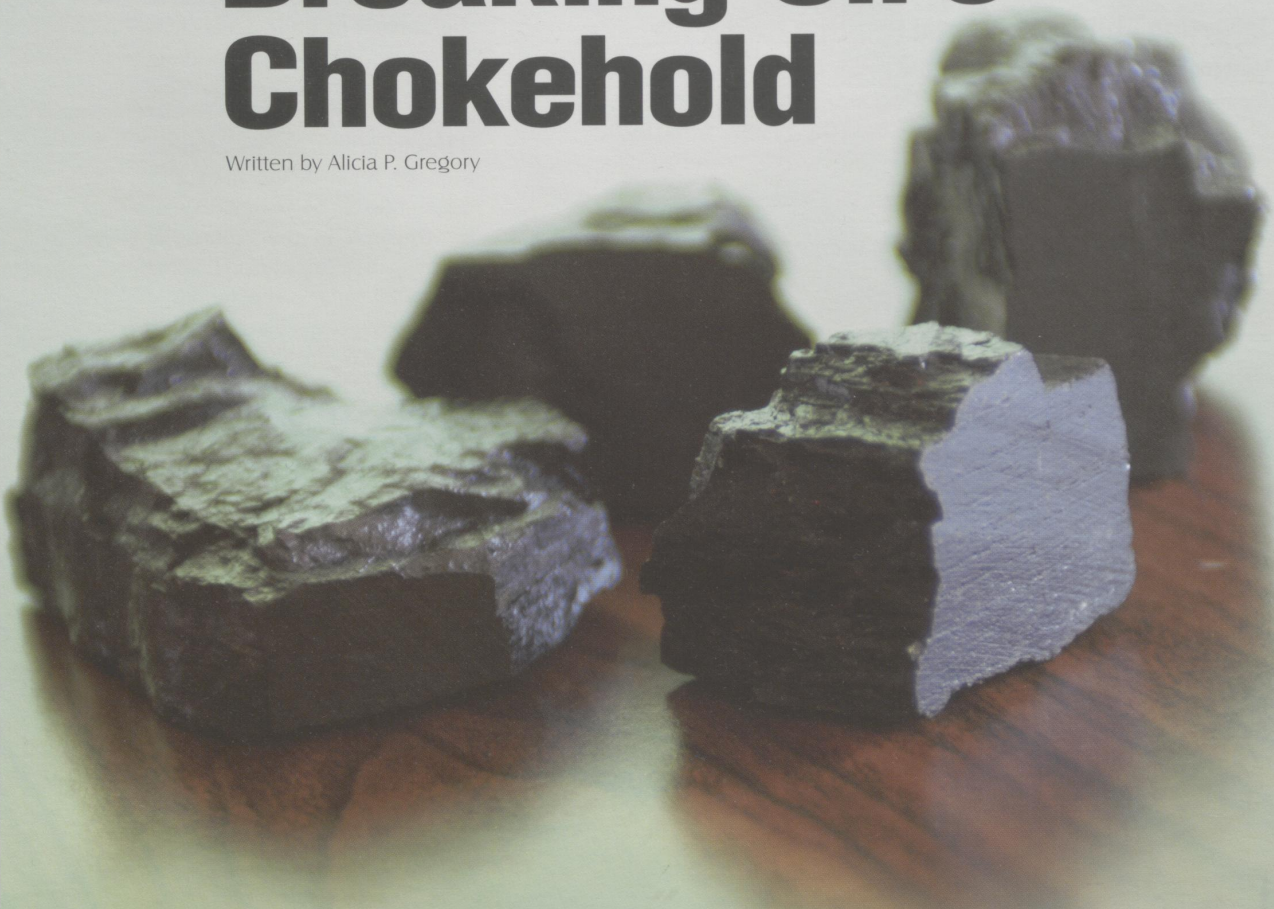
Peterson, who has spent more than 20 years in the field and now serves as the associate dean for research in the college, is focusing on adult stem cell activity during muscle regeneration, with an emphasis on the effects of aging and obesity. She is also studying the basis for differences in muscle response to exercise.

Dupont, who has more than 15 years' experience in muscle loss research, is focusing on the mechanisms of muscle wasting. She is studying the role of muscle stem cells and cell death during disuse, spinal cord injury and aging, as well as bone changes resulting from muscle loss. Peterson's and Dupont's goal is to develop targeted interventions to maintain muscle mass, thereby preventing frailty and loss of functional independence. ■

Coal:

Breaking Oil's Chokehold

Written by Alicia P. Gregory



Climate change is a hot topic, and it's getting unprecedented play. On TV, talking heads connect the dots between melting glaciers and human-produced greenhouse gases. In our living rooms and classrooms Al Gore's "An Inconvenient Truth" is passionately persuasive as it asks, in bold letters over images of Hurricane Katrina, "Did the planet betray us or did we betray the planet?"

But does science back the fact that the press and the pundits have declared the debate on man-made global warming over? Not exactly.

Gore's linchpin ice core sample shows a clear correlation between carbon dioxide (CO₂) and temperature, and he says this cause-and-effect relationship is complicated. But a lesser-known British documentary, "The Great Global Warming Swindle," says subsequent ice core surveys show Gore's got the relationship backward. Researchers from around the world, including Harvard and NASA scientists who say their data was misconstrued in the February 2007 Intergovernmental Panel on Climate Change report that backed Gore's premise, show the rise in temperature precedes the rise in CO₂ by 800 years, not the other way around.

Despite this debate, the issue of global warming has, importantly, bolstered scientists' efforts to find more efficient and responsible ways to produce energy.

UK geologist Brandon Nuttall says, "To me, the debate over whether CO₂ causes global warming or global warming in turn increases CO₂ is fairly irrelevant. Humanity has never served itself well in failing to take care of the things we throw away."

UK's Gerald Huffman, director of the Consortium for Fossil Fuel Science, says, "Regardless of their opinions on global warming, most scientists I know believe the only sensible way to reduce CO₂ or any other emissions from fossil fuel combustion is to increase efficiency."

In the short term, the University of Kentucky's efficiency efforts center on Kentucky's most abundant natural energy resource—coal. By improving the ways we convert coal, we can produce more energy while limiting CO₂ byproducts.

How can we transition today's petroleum-based gasoline and diesel production to cheap, domestically available coal? UK research teams are refining Fischer-Tropsch synthesis, a World War II-era process for converting coal and natural gas into liquid trans-

portation fuels. And as part of the nationwide push for "carbon sequestration," UK geologists are mapping underground spaces that can become permanent storage sites for CO₂.

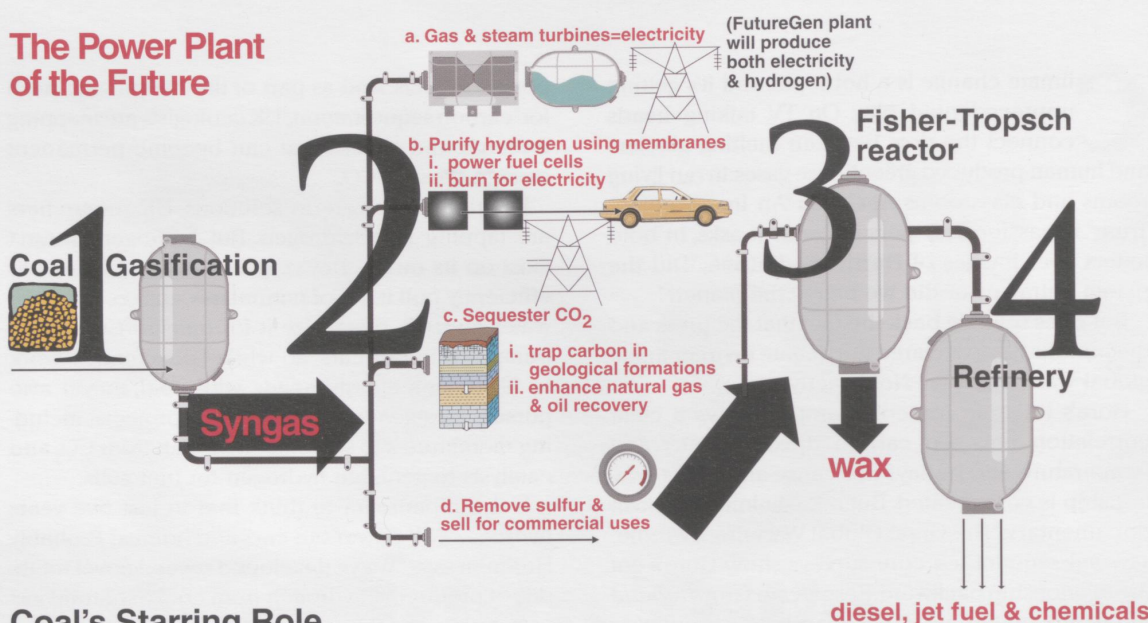
Looking for long-term solutions, UK researchers are tapping into hydrogen. But hydrogen doesn't exist on its own—they've got to figure out how to efficiently pull it out of natural gas, coal, biomass, or water, purify it, pressurize it for transport, and then pump it into our cars. So while UK scientists work to fill today's energy needs with coal, they'll also pursue next-generation hydrogen projects, including membranes to separate hydrogen from CO₂ and catalysts to generate hydrogen for fuel cells.

Is it a pipedream to think that in just five years hydrogen will power our cars and homes? Probably. Huffman says, "We've developed several novel methods of producing hydrogen from coal or natural gas with little or no production of CO₂. But I think the first use of hydrogen for transportation is at least 10 to 15 years into the future—probably in fleets of buses in large urban areas before it fuels personal vehicles."

Nuttall says, in response to the Bush administration's view that climate change is bad for business, "I see this whole global warming thing as an opportunity. If the climate question makes us consider efficiency, alternative and renewable fuels, and carbon sequestration, there will be lot of business and investment opportunities in developing the technologies we'll need. Climate change is only 'bad for business' if the sole path to the future is the status quo."

How much coal does the United States have left? The American Coal Foundation estimates that nearly 300 billion tons of recoverable coal remain. In 2006, U.S. coal production increased 2.6 percent over the previous year to 1.2 billion tons. If the growth rate of 2.6 percent per year holds, it will take 77 years to mine all 300 billion tons of our coal.

The Power Plant of the Future



Coal's Starring Role

"When I came to UK, Kentucky was going to be the Saudi Arabia of the West," says a grinning Burt Davis. The patriarch of the Center for Applied Energy Research (CAER), Davis has spent his 30-year career at UK studying clean-fuel technology.

So why hasn't coal broken oil's chokehold on us? It's a matter of efficiency, he says. "In the late '50s, I started working for a petroleum company. When you looked at the cost—from finding the oil, pumping it out, pipelining it—you were getting 95 percent of the energy into your gas tank. It was exceptionally efficient. Now, if you take coal, you've got to do a lot more work to turn it into liquid fuel. You only get 70 percent of the energy you started with into your gas tank. Today it's still easier to pump oil out of the ground than it is to dig coal and convert that coal to liquid.

"But here's the thing. We—Kentucky and the United States—have much more energy in the form

of coal than the world does in petroleum. And we're finding ways to increase the efficiency of coal conversion."

How much coal does the United States have left? The American Coal Foundation estimates that nearly 300 billion tons of recoverable coal remain. In 2006, the United States produced 1.2 billion tons of coal (a 2.6 percent increase over 2005). If the growth rate of 2.6 percent per year holds, it will take 77 years to mine all 300 billion tons of coal. If the growth rate increases due to increased demand, we'll run out sooner.

Kentucky, one of the big three coal producers along with Wyoming and West Virginia, generates more than 90 percent of the state's electricity from coal, and more than 50 percent of the nation's electricity is produced from coal. It's a cheap power source, especially considering the rising cost of natural gas. And coal has the potential to overhaul our transportation fuel infrastructure by

providing emissions-free diesel. (For more on clean diesel, see "Fischer-Tropsch: A New Lease on Some Old Technology," p.40.)

Davis says the United States would no longer need to battle the fluctuating price of imported petroleum if we could produce our own fuel domestically. "Each year 60 percent of our oil is imported. Some of that oil comes from unstable parts of the world, but two of the three countries that we import the largest amounts of crude from are our nearest neighbors—Canada and Mexico."

The diagram above illustrates how coal could play a key role in tomorrow's hydrogen economy, how CO₂ could be stored underground through geologic sequestration, and how coal can provide us with the transportation fuels and chemicals we need today. UK researchers Gerald Huffman, Doug Kalika and Burt Davis walk us through the necessary steps for making more of our coal resources.

1

Coal Gasification

It all comes down to carbon. Made from ancient plant material, this stuff gives coal most of its energy. A single carbon molecule is the genesis of fuel production.

To produce liquid fuel, coal must be broken down into its most basic ingredients through gasification—applying heat under pressure to convert coal into a gaseous mixture, primarily hydrogen and carbon monoxide, called synthesis gas, or syngas.

hydrocarbon molecules we use to power our vehicles and planes—gasoline, diesel and jet fuel.”

Huffman, a UK physicist, says his interest in energy research started in the mid-’70s after the first Arab oil embargo. “I was working as a research scientist at the U.S. Steel Corporation Research Center in Pennsylvania. At that time, U.S. Steel was not only the world’s leading steel producer, they were also the third-leading coal producer in the United

States. We were encouraged to get into coal utilization research and, somewhat to my surprise, I found it fascinating.”

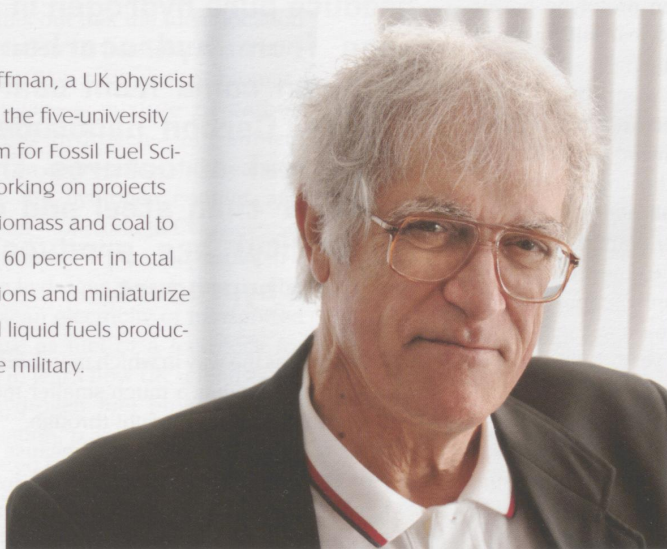
Since 1986, he has managed the Consortium for Fossil Fuel Science (CFFS), a partnership of five universities (UK, West Virginia, Utah, Pittsburgh, and Auburn) led by UK, which has focused on the development of alternative sources for transportation fuel.

“Both the production and combustion of liquid fuels from coal produce a lot of carbon dioxide,” says Huffman.

“We’ve just started a new contract with the Department of Energy to combine biomass—

agricultural and lumber waste—with coal to make liquid fuels. Theoretical calculations indicated that if you combine 30 percent biomass with 70 percent coal to produce your syngas, you can make a savings of up to 60 percent in total CO₂ emissions.” Huffman adds that coupling biomass with coal would make good use of what is currently a waste material and could significantly extend the lifetime of our national coal resource.

Gerald Huffman, a UK physicist who leads the five-university Consortium for Fossil Fuel Science, is working on projects to marry biomass and coal to save up to 60 percent in total CO₂ emissions and miniaturize coal-based liquid fuels production for the military.



“Carbon monoxide is a C1 molecule—it contains a single atom of carbon,” explains Gerald Huffman, loosening his tie. “When you gasify coal, you produce a mixture of carbon monoxide and hydrogen called syngas. From syngas, you can make other C1 molecules such as methane [the principal component of natural gas] and methanol [the simplest alcohol, used as an anti-freeze, solvent and fuel]. You can also produce the more complicated

Electricity & Hydrogen

Coal gasification is one of the most versatile and cleanest ways to convert coal into electricity, hydrogen and other valuable energy products. And it's the cornerstone of the DOE's FutureGen prototype power plant. This \$1 billion, 10-year initiative will build the world's first coal-based, "near-zero-emissions" power plant. Gasification, turbines to produce electricity, membranes to selectively remove hydrogen from processed syngas, and technology to remove and sequester CO₂ are all vital components in the FutureGen power plant project.

Focusing on the third element of this process, Doug Kalika is improving membrane separation performance on the molecular level. For the past three years, Kalika's polymer research group in the UK chemical and materials engineering department has partnered with Benny Freeman's membrane team at the University of Texas at Austin. The leading-edge work resulting from this partnership has turned membrane science on its head.

"Membranes are incredibly energy efficient, simple and reliable, and they've been used for many kinds of gas separations over the years," says Kalika, who in May 2007 received the Henry Mason Lutes Award for Excellence in Teaching in the College of Engineering, the eighth award he's received in more than 17 years of teaching undergrads at UK.

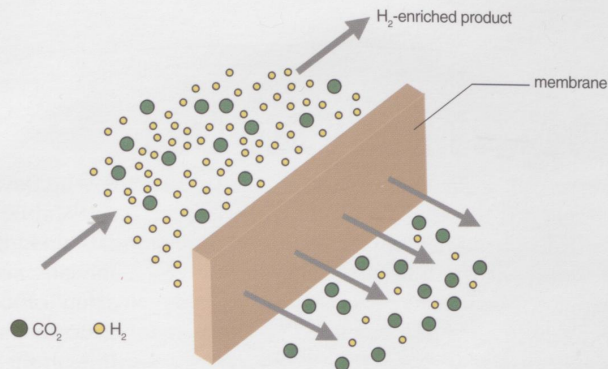
"Our membranes are called 'reverse-selective,' because we're reversing what's ordinar-

Under a DOE contract, Gerald Huffman and Naresh Shah (Consortium for Fossil Fuel Science) developed a method to produce pure hydrogen in a single step from hydrocarbon gases that can come from coal-derived syngas. Carbon nanotubes (tiny, cylindrical structures that are stronger than steel and conduct electricity) are produced as a valuable byproduct.

ily perceived as the way in which membranes work—as a size filter. Hydrogen, a much smaller molecule than CO₂, would ordinarily fly right through."

That's a problem, he explains, because the processing of syngas results in mixtures of hydrogen and CO₂, where hydrogen is the primary component. "In membrane separations you want to avoid having your majority component be the one that passes through the membrane, as this increases overall processing costs. Our reverse-selective membranes are synthesized from polymer material that has a natural chemical affinity for CO₂. As a result, 10 times more CO₂ than hydrogen permeates across the membrane, where it can be captured for eventual sequestration.

"A big advantage of our reverse-selective membranes has to do with pressure," Kalika continues. "Ideally, you want to keep hydrogen at high pressure." And that's because hydrogen is very light. You need to increase the pressure to condense it in order to efficiently transport



it. "Our process retains the hydrogen on the high-pressure side of the membrane. This eliminates a costly re-compression step that would be required with traditional size-selective membranes. So our membranes offer an additional cost advantage."

Kalika points out that the ideal location for this separation to take place is inside a power plant. "You take coal or biomass, produce syngas—a mixture of carbon monoxide and hydrogen—and subject the syngas to an appropriate 'shift' reaction to maximize the hydrogen content, and convert carbon monoxide to CO_2 . Reverse-selective membrane separation results in a high-pressure hydrogen stream that can be burned for clean electricity or transported off-site for use as fuel or a feedstock for chemicals." (To learn how UK scientists are improving hydrogen fuel processors, see "Hydrogen Nation," p. 38.) "At the same time, CO_2 is recovered rather than being released into the atmosphere."

But today we're not quite ready to employ hydrogen for transportation.

An alternative is to use coal gasification for the production of more traditional transportation fuels like diesel. After coal is gasified, the syngas is cleaned to remove sulfur, which can be sold for other industrial purposes. This purification is critical because sulfur and other chemicals could poison the next step: the Fischer-Tropsch (FT) reaction.

The partnership between UK's Doug Kalika, pictured here, and University of Texas researcher Benny Freeman is turning membrane science on its head. Instead of letting tiny hydrogen molecules fly right through and retaining CO_2 like traditional membranes, the team's "reverse-selective" membranes keep hydrogen and let CO_2 pass through for capture and eventual storage.



Cap-and-trade

How can the United States reduce carbon emissions? One idea, a national cap-and-trade program, would limit the level of carbon that can be emitted by an industry. Companies that hold their emissions below the cap can sell their remaining "carbon credits" to other industries. Companies that exceed their limit must purchase credits. If such a program is implemented, CO_2 producers like power plants, ethanol plants and cement plants would have an economic incentive to capture CO_2 and pipe it into the ground for long-term storage. (For more, see "Underground Carbon," p. 43.)

Hydrogen Nation



By studying ways to speed up low-temperature reactions, boost surface area and prolong catalyst lifespan, Burt Davis (left) and Gary Jacobs are making molecular-level discoveries that will directly affect the function of tomorrow's fuel processors.

Burt Davis reminisces about his days at Mobile in the 1960s: "Hydrogen lines ran along the ceiling in the hallways to the labs, and every Friday afternoon the safety officer would get a broom, hold it up to the pipes and walk along the lines. If there was a significant leak, the broom would ignite." He chuckles and adds, "That was the safety procedure of the day."

"Hydrogen is the only gas that will auto-ignite. So if you've got a leak, you've got a flame. And it's so light that it can escape through much smaller holes than other gases."

Davis's partner on hydrogen is Gary Jacobs. He earned his Ph.D. in 2000 from the University of Oklahoma, worked as a postdoc in Davis's lab, and since 2001 has been a full-time chemical engineer at CAER. He explains, "Trying to compress and pump hydrogen through a pipeline is very energy intensive, because hydrogen is so light. And if you want to deliver it as a liquid, you have to cryogenically freeze it. That's very expensive."

How hydrogen will be delivered to the consumer is still a big question mark. Jacobs describes three possibilities. "Option one: large stationary plants. Gasified coal or biomass could feed those plants, and the resulting CO_2 could be sequestered. But then the hydrogen would have to be compressed to be sent through pipelines, which means you'd need a whole new pipeline infrastructure—you can't send hydrogen through the same pipelines as gasoline and natural gas."

Option two: a smaller stationary unit. "You might pipe natural gas to your home and you'd have a small fuel processor in your garage to convert methane to hydrogen. Smaller amounts of CO_2 could be emitted than what would normally be produced from an internal combustion engine running on gasoline."

Option three, "onboard reforming," would take place in the vehicle itself. He explains you'd add the fuel—natural gas (methane) or alcohols (methanol, ethanol) that can travel through existing pipelines—then the fuel processor (a series of critical catalytic reactions that, coupled with a fuel cell, could power the vehicle) would convert the liquid or gas to hydrogen. Again, this option could emit less CO₂ than the internal combustion engines we use today.

"The problem with onboard reforming," Jacobs explains, "is that residual carbon monoxide (CO) from the hydrogen production steps of a fuel processor is a poison for fuel cell catalysts. To convert this CO, you need very active and stable catalysts in order to reduce the size and weight restrictions of the fuel processor."

This is where Davis and Jacobs come in. Their work, sponsored in part by the Kentucky Office of Energy Policy, centers on low-temperature water-gas shift catalysts, which are the heart of the fuel processor. Water-gas shift is a chemical reaction in which water and carbon monoxide react to form carbon dioxide and hydrogen.

Water-gas shift is nothing new—it's the chemistry behind the catalytic converters mandated by the EPA in 1975 to reduce toxic emissions on vehicle exhaust systems. The problem with water-gas shift reactions: they're exothermic—a lot of the energy is released as heat.

At the table in Davis's CAER office, Davis sketches a chart with CO conversion and temperature as he explains, "Chemical reactions happen very fast at high temperatures—and speed is a good thing—but for exothermic reactions, you run into a wall very quickly."

"The thermodynamic barrier," Jacobs adds. "Because the reaction generates heat, as the temperature is increased carbon monoxide conversion decreases."

"So basically, our low-temperature water-gas shift catalysts aim to make practical use of this CO conversion limit," says Davis.

Jacobs adds, "But at low temperatures, the reaction slows down. So, to achieve high CO conversion for a prolonged period of time at low temperature, you need a very active and stable catalyst. And if we're going to do onboard reforming, it has to be with

a catalyst that can withstand the frequent startup-shutdown cycles we put our vehicles through. It's one thing to activate a catalyst and run a reaction, but to shut it down and start it up many times is a whole new ballgame for catalyst design."

Platinum and ceria catalysts are the focus of the team's research. (Ceria, or cerium oxide, is used in the walls of self-cleaning ovens.) When ceria is linked with platinum, the goal is to create as much surface area between the two components as possible. "Catalysis is all about the surface, because that's where the reaction takes place," Jacobs says. "In essence, we activate the catalyst by digging out oxygen atoms from the surface of ceria to create a defect."

And in this case a "defect" is a good thing. At these defects, water molecules "activate" when they are chemically split apart to form special oxygen-hydrogen groups. These OH groups, in turn, react with carbon monoxide to form what is called an intermediate molecule on the surface of the catalyst.

The next critical step is breaking the carbon-hydrogen (C-H) bond of this molecule to convert it to CO₂, and, as an added bonus, generate more hydrogen for the fuel cell. Davis and Jacobs found that by adding more platinum to ceria, they could break this bond faster. And in a project sponsored by Honda Research Incorporated USA, the CAER team confirmed Honda's discovery that by adding sodium to zirconia, a material related to ceria, you can electronically weaken the C-H bond.

"Breaking this bond is the rate-limiting step that can slow down our process like a traffic bottleneck," says Jacobs. "Say, you're on I-75," adds Davis, "and construction takes two lanes of traffic down to one. It takes you 20 more minutes to get to work. You're able to speed up the flow by widening the bottleneck. In our case, by adding promoters like platinum and sodium to ceria, and by increasing the contact area between them, we are able to attack the C-H bond and turn over the intermediate molecule more rapidly."

By studying ways to speed up low-temperature reactions, boost surface area and prolong catalyst lifespan, Davis and Jacobs are making molecular-level discoveries that will directly affect the function of tomorrow's fuel processors.

Fischer-Tropsch: A New Lease on Some Old Technology

Discovered by two German scientists in the 1920s, the FT process uses a catalyst (a reaction accelerator) to convert syngas to hydrocarbons. Combustible hydrocarbons are the main components of fossil fuels (petroleum, coal and natural gas).

The hydrocarbons come out of the FT reactor as wax, and about 10 percent of this wax is approved by the USDA to preserve fruits and vegetables. "Did you know that the cucumbers or apples you get at the grocery store have a thin layer of Fischer-Tropsch wax on them?" CAER scientist Burt Davis asks, adding that it's a profitable byproduct: today the going rate for edible wax is four times that of transportation fuel.

The rest of the wax is "cracked" (long molecules are chemically broken into shorter ones), a process called upgrading, to yield 20 percent low-quality gasoline and 80 percent high-quality diesel. "This is far superior to any diesel on the market made from petroleum, because it has no nitrogen or sulfur—no emissions," says Davis from his office in the 30-year-old CAER building.

FT diesel has a high cetane number (the diesel equivalent of octane for gasoline). "In Europe, this is great because they use predominantly diesel vehicles. In America we've shied away from diesel in favor of flex-fuel vehicles." These are cars and trucks that can run on a mixture of gasoline and ethanol. "We'd get a big savings if we'd invest in FT and produce diesel vehicles that take advantage of this high-quality, no-emissions fuel. We'd get more miles per gallon."

A Brief History of Fischer-Tropsch

The original process was discovered by German researchers Franz Fischer and Hans Tropsch in the 1920s, and within 10 years commercial plants were built in Germany. Coal-based fuels powered the German war machine through the 1940s.

The only commercial Fischer-Tropsch (FT) plant in the United States was in Brownsville, Texas, in the early 1950s. (It shut down when cheap oil from the Middle East made FT production too pricey by comparison).

Today, there are only pilot-scale FT plants in the United States. Worldwide, the only commercial FT plants are in South Africa (Sasol, which produces liquid fuels from coal, and PetroSA, from natural gas) and Malaysia (Shell, natural gas). "Fifty percent of the airplanes that take off from Johannesburg every day are fueled by coal," says Center for Applied Energy Research scientist Burt Davis.

Huffman's CFFS team is tackling one downside to FT diesel—leaky rubber gaskets. He explains, "Alterations need to be made in the molecular structure of the fuel to properly swell gaskets to make seals. We don't want trucks and planes dripping fuel all over the place."

Huffman says efficiency is why a process from the 1920s is once again gaining momentum. "For a long time scientists didn't seem interested in Fischer-Tropsch. It's an established commercial process, so why would you want to do research on that?"

But improving industrial processes is the hallmark of engineering, Huffman says, adding, "Once in a great while you invent a completely new thing; that's the revolutionary side. But most of research is on the evolutionary side. Gee, what if we had stopped doing research on airplanes 50 years ago—they're commercial. We'd still be flying around in those little prop planes."

"Everything in FT has improved," says Davis. "The catalyst for FT is much more active—instead of working for one or two months, now they run for years."

Just 10 minutes away from the UK campus, in the basement of CAER, Davis shows off his 16 Fischer-Tropsch reactors. Over the whirl of experiments under way, he describes the catalyst testing his team does for large and small companies. "Our Fischer-Tropsch lab is the largest, open-access, non-commercial liquefaction lab in the country. We make and test promoters, chemicals that can be added to the cobalt and iron catalysts used



in FT. Our objective is to discover which properties give the catalyst superior performance."

Just how expensive would it be to do FT on a grand scale? Davis estimates that a commercial plant based on coal which would do all three steps—gasification, FT and upgrading—would cost \$6 billion and produce 50,000 barrels of high-quality diesel per day. "Let's put this in perspective. For starters, you'd have to invest \$125,000 to produce a barrel of fuel per day. This initial investment is what makes companies reluctant to build FT plants. But operation of the plant can produce transportation fuels for about \$15 per barrel, so that once the plant is paid for, the production cost of the fuel would be low. And at current prices—with crude oil at \$65 per barrel—the plant could be very profitable."

Who has the most incentive to try FT? The military, says Huffman decisively. The single largest user of foreign oil is the U.S. military.

In the basement of the Center for Applied Energy Research, Burt Davis shows off his 16 Fischer-Tropsch reactors and describes the catalyst testing his team does for large and small companies. "Our Fischer-Tropsch lab is the largest, open-access, non-commercial liquefaction lab in the country." Fischer-Tropsch is a World War II-era process that makes liquid fuels from coal and natural gas.

CAER's Burt Davis estimates that a commercial plant based on coal which would do all three steps—gasification, Fischer-Tropsch synthesis and upgrading—would cost \$6 billion and produce 50,000 barrels of high-quality diesel per day.



CFFS has just recently started work on a Department of Defense contract, which was secured with the help of Senator Mitch McConnell, looking at FT fuel production. Huffman says, "If we can make fuels domestically, the United States won't have to rely on petroleum-based fuels from unstable parts of the world." The military needs about 300,000 barrels of oil to fuel their jets, tanks and trucks each day. A 50,000 barrel-a-day FT plant, times six plants, is doable, he says.

"They spend \$300 a gallon—that's the real estimate of the military's cost to get fuel to the battlefield. The problem is transportation. Ultimately, the military would like to produce fuels closer to where they use them. We're looking at how to miniaturize, so to speak, the FT process so you could build a plant on a military base in Iraq and use local resources to make the fuel."

A single battlefield fuel. That's the military's goal. Right now they use a combination of jet fuel, diesel and gasoline to run their

planes, tanks and trucks. A single fuel is not a new idea, says Davis. "In doing some research on the history of catalysis in the agriculture archives outside Washington, D.C., I saw that in the 1920s they were talking about two things: a single fuel for the military and using ethanol instead of gasoline. Not much has changed over the years."

But with an ever-increasing supply of CO₂, the need to do something with it other than vent it into the atmosphere is growing. The best solution to this problem may be right under our feet.

Underground Carbon

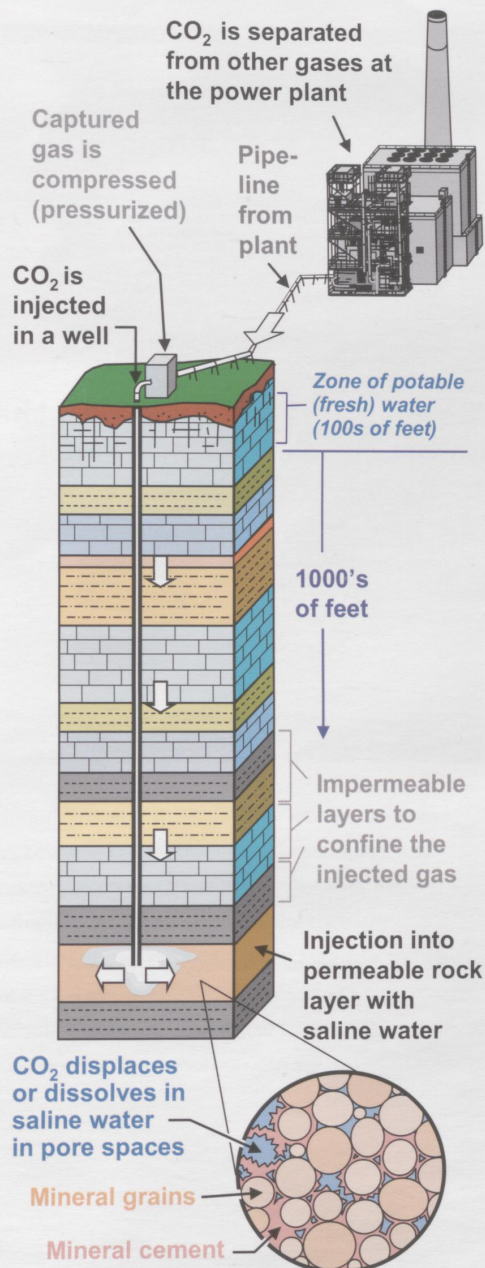
Deep rock reservoirs thousands of feet below Kentucky are a potential burying ground for coal's CO_2 downside. Kentucky Geological Survey (KGS) scientists Brandon Nuttall and Stephen Greb are investigating underground rock formations as part of two multi-state, DOE-funded partnerships centered on the nation's carbon sequestration future.

These groups are looking at two kinds of sequestration. The first is terrestrial—storing CO_2 in soils and wetlands. The second type is geologic—storing CO_2 in depleted oil and gas reservoirs, unmineable coal seams and saline reservoirs. With data on oil and gas drilling that dates back to 1818, KGS is leading UK's geologic research.

"When you think of an oil or gas reservoir, imagine a glass jar full of marbles," says Nuttall, an Eastern Kentucky University geology grad who's been at KGS since 1977. He's a self-proclaimed "computer guy" whose expertise in databases and computer mapping mesh well with petroleum geology and stratigraphy—the study of layered rocks. "The marbles are like the grains of the rock—but you'll note that there are spaces between the marbles, and that space is described in two basic ways. First, volume—the capacity to hold fluid—a.k.a. porosity. Second, permeability—how well the space is connected. Permeability controls how well things like oil, gas and water can move through the rock.

"You also need a seal. It's like the lid on the jar. It's something that will prevent the migration of whatever's down there. How do we know that reservoirs and seals exist underground? Because we've found oil and gas fields where those resources have been trapped underground for millions of years. How well can those old reservoirs hold CO_2 ? We don't know, but it's something people across the country will soon be testing."

Nuttall leads the KGS team in the Midwest Geologic Sequestration Consortium (Kentucky, Indiana and Illinois), a partnership managed by the Illinois State Geological Survey. His research focuses on shale—a fine-grained rock that underlies approximately two-thirds of Kentucky. In Eastern Kentucky that shale is up to 1,600 feet thick; in Western Kentucky it's more than 400 feet thick. Shale typically functions as a seal for oil and gas. It's a lot less porous than other rocks, so it's a good cap.



(Illustration by Stephen Greb)



Shale—a fine-grained rock that underlies approximately two-thirds of Kentucky—keeps oil and gas from migrating underground.

But Kentucky's pitch black Devonian shale is unique. Its color and smell indicate the presence of preserved organic matter (plant material) mixed in with the rock. Nuttall pulls a saran-wrapped sample from his shelf. As he unwraps it, a sharp odor fills his office. "That smell tells you it's got a lot of organic content. This is a sample from Knott County I collected at 2,900 feet. With samples like this, I've found a relationship between the organic matter content of the shale and how much CO₂ it can potentially store.

"My hypothesis is that we can recover methane, a.k.a. natural gas, by injecting CO₂ into this organic-rich shale. CO₂ is a little bit smaller than the methane, so it has a tendency to stick to the shale more effectively than methane does, and it displaces the methane. The research I've done in Eastern Kentucky shows that it's a 5-to-1 deal—five volumes of CO₂ will replace one volume of methane. You're storing CO₂ and you're recovering methane that you can sell."

Nuttall admits this concept isn't new in Kentucky. "We began producing natural gas from shale in Western Kentucky around the time of the Civil War. In Eastern Kentucky it started in the 1890s. We know shale can produce methane—we've got a long history.

"And for more than 30 years, oil companies in West Texas have been injecting CO₂ into their depleted oil and gas fields to increase the pressure and force the oil to the surface, and, as an added bonus, the CO₂ dissolves into the oil and changes its viscosity or flow characteristics, making it easier to get it out.

"As far as I can tell," Nuttall says, "shale itself will never be a primary CO₂ storage zone, simply because you're probably not going to be able to put in as much CO₂ as a power plant can generate on a daily basis, quickly enough. Shale has the capacity to do it, but it doesn't have the permeability." Here's where economics come in, he explains. If the price of natural gas is high enough and the price of CO₂ is low enough, it may be economical to use CO₂ to increase production of methane, and shale will come into its own for sequestration.

But it's much more likely that the bulk of carbon sequestration will be focused on saline reservoirs. Stephen Greb, an artist, K-12 earth science speaker and geologist at KGS for the past 20 years, says, "These are deep underground rocks with saline water in them."



And these are much lower than underground water wells, which are about 300 feet deep, compared to reservoir depths of more than 2,500 feet. "Most people tend to think of underground water as caves and conduits, but that's not what most saline reservoirs are.

"Using Brandon's marble analogy, shrink the marbles down to the size of sand grains. There are still spaces between those grains, just like the spaces you see between the marbles. Those microscopic pores between each rock grain act like a sponge that fills with very salty water deep underground.

"The DOE FutureGen proposal that went out last year said they want to store a million tons of CO₂ per year for 30 years. That means one really big saline reservoir or a group of reservoirs." By analyzing oil and gas drilling data, Greb and other geologists at KGS, and around the nation, are trying to locate the biggest and potentially best reservoirs for carbon sequestration. "Saline reservoirs can be sandstones or

Brandon Nuttall at the Kentucky Geological Survey says because CO₂ is smaller than methane, it has a tendency to stick to shale more effectively than methane does, and it displaces the methane.

"The research I've done in Eastern Kentucky shows that it's a 5-to-1 deal—five volumes of CO₂ will replace one volume of methane. You're storing CO₂ and you're recovering methane that you can sell."

Sandstones make up most saline reservoirs—deep underground rocks that hold saline water. These are much lower than underground water wells, which are about 300 feet deep, compared to reservoir depths of more than 2,500 feet.



carbonate rocks. And we've found a lot of oil and gas in sandstones and carbonates.

"We're looking for reservoirs at least 2,500 feet. Because of the pressure at that depth, any injected CO_2 would exist in what's called supercritical conditions," Greb explains, as you go deeper beneath the surface of the earth, pressure and temperature increase. In this high-pressure, high-temperature "supercritical" state, CO_2 has the density of a liquid but the properties of a gas. "You can inject about 10 times the volume of CO_2 into a space when it's supercritical than you could in the same space at lower pressure. In Kentucky, we estimate that at depths of more than 2,500 feet CO_2 gas should convert to a supercritical state."

Locally, saline research is focused on the Mt. Simon sandstone (the largest and one of the deepest sandstone formations in the Midwest, stretching from Illinois to Indiana and Kentucky). In the center of Kentucky and north to Cincinnati, the Mt. Simon occurs at depths of 3,000 to 4,000 feet, and in Eastern and Western Kentucky it's 10,000 to 20,000 feet deep. The depth itself is a challenge, Greb says, simply because most of the 150,000 records at KGS are for oil and gas wells at less than 1,500 feet. "Drilling that deep for oil has not been economical," he explains. "And it's going to be an economic question for sequestration as well."

Greb leads the KGS team that's part of the Midwest Regional Carbon Sequestration Partnership (MRCSP), which includes Kentucky, Indiana, Ohio, Pennsylvania, West Virginia,

New York, Michigan, and Maryland. This partnership is managed by Battelle, a global science and technology company headquartered in Columbus, Ohio.

"The Nation's Engine Room," Greb states the slogan for the MRCSP region with an easy smile. "One in six Americans live here. One-fifth of the electricity in the United States is generated here. And coal-fired power plants play a huge role."

In Phase I of this partnership, the scientists pooled existing data, including oil and gas wells and pipeline infrastructure, and identified current CO₂ sources. "Representatives from each of the states got together and mapped the subsurface geology," Greb says. "Phase II involves more detailed investigations of what we mapped and small-scale injection testing, including a demonstration project here in Northern Kentucky at the East Bend power plant."

"The Mt. Simon sandstone is at a depth of 3,000 to 4,000 feet in that area. We've just finished doing seismic analysis—shooting vibrations into the ground that reflect back and give you a picture of the subsurface geology. The next steps will be to drill a well, get rock samples, and test the permeability, porosity and water chemistry of the saline reservoir and overlying rocks that will act as a seal above the reservoir. From that data we'll determine if the reservoir is suitable for injection. If it is, we'll run computer models to simulate how far CO₂ will likely spread at that pressure and plan the injection test. Tests like this are under way all over the United States."

But ironically, the biggest challenge to this testing is getting CO₂. "With all of the CO₂ we put into the air, actually finding CO₂ that we can inject for a test is hard, and expensive, because you've basically got to use beverage-grade CO₂, the stuff designed for soda carbonation." Until the infrastructure is built to economically capture CO₂ at a power plant or other industrial source, and then pipeline CO₂ directly from that source, large-scale sequestration demonstrations will be expensive. Greb says large-scale and long-term projects are currently being planned under Phase III of DOE's carbon sequestration program.

"We have to look at all the geologic options," he says, adding that if a national cap-and-trade program is enacted, power plants wanting to earn credits by



Stephen Greb, an artist, K-12 earth science speaker and Kentucky Geological Survey scientist, is looking for saline reservoirs in sandstones deep underground. Sandstones—rocks with microscopic pores that act like a sponge to soak up salty water—hold great promise for long-term CO₂ storage.

sequestering CO₂ will need to use the resources close to them.

"What's under your power plant, ethanol plant, cement plant? These folks all produce a lot of CO₂ and could end up using this technology in the future. It's going to be increasingly important for many industries looking for new plant sites to consider the area's geologic sequestration options."

But an important question remains: What happens when CO₂ goes wrong underground? Case in point: Lake Nyos in Cameroon. Nuttall relates the tale: "This is a very deep lake in an old volcano. Over a long period of time, a massive amount of CO₂ leaked from the magma below the volcano into the lake. Because the lake was so deep, the CO₂ stayed at the bottom of the lake—until one day in 1988 it exploded to the surface all at once." Because CO₂ is denser than air, it hugged the ground, flowed down two nearby valleys, and suffocated 1,800 people and 3,500 livestock.

Obviously, this was a catastrophic CO₂ event. "What's interesting is how they fixed it," Nuttall says. "They installed a floating 'straw' into the lake, basically a pipe that went very deep. They used a pump to prime the straw, and now CO₂ just continuously bubbles up, so it doesn't accumulate to dangerous levels." Greb notes, "We won't be injecting CO₂ into deep volcanic lakes." But to avoid a similar dangerous scenario, he says, significant research is under way to examine the natural seals above potential reservoirs and methods for monitoring injection sites.

How will scientists know that injected CO₂ is staying where it should? And how can they tell the difference between injected gas that is leaking back to the surface and CO₂ that results from normal biologic activity in the soil? KGS geologist Marty Parris is exploring these questions.

"In a carbon sequestration project, the goal is to keep CO₂ in the subsurface reservoir," says Parris. "But for both man-made and natural reasons, such as improperly plugged wells and faults, there could be leakage from a reservoir even before injection. And

"What's under your power plant, ethanol plant, cement plant? It's going to be increasingly important for many industries looking for new plant sites to consider the area's geologic sequestration options."—Stephen Greb

if it's leaking naturally, you're just going to enhance that leak potential by pressurizing the reservoir with CO₂. The only way we'll know if there is a leak is if we have a baseline database." Parris will create this database with over 2,000 gas samples, including soil, atmospheric and natural gases from underground reservoirs across Kentucky. This data will be invaluable for coal-fired power companies in selecting future sequestration sites.

Greb sums things up: "In our state for sure, but in the country as well, the resources we have now are the ones we are going to use. I tell people all the time, we can't get rid of anything. We need everything—biomass, nuclear, water, coal, oil, gas—and every year we need more and more because population increases and our need for cheap energy grows. So we've got to figure out the best way to use what we have, and we need to do it in a way that doesn't cause environmental harm."

And the biggest resource Kentucky has is coal. By pursuing Fischer-Tropsch reactions to make clean diesel from coal and by mapping potential CO₂ burying grounds, the University of Kentucky is leading the push for "clean coal" and a cleaner, greener tomorrow. ■

Odyssey
Fall 2007

Parting Shots

The past is the only dead thing that smells sweet.

—EDWARD THOMAS

The past is a foreign country; they do things differently there.

—L. P. HARTLEY

Events in the past may be roughly divided into those which probably never happened and those which do not matter.

—W. R. INGE

Telling the future by looking at the past assumes that conditions remain constant. This is like driving a car by looking in the rearview mirror.

—HERB BRODY

The future belongs to those who believe in the beauty of their dreams.

—ELEANOR ROOSEVELT

I would feel more optimistic about a bright future for man if he spent less time proving that he can outwit Nature and more time tasting her sweetness and respecting her seniority.

—E. B. WHITE

There is always one moment in childhood when the door opens and lets the future in.

—GRAHAM GREENE

Don't look back—something might be gaining on you.

—SATCHELL PAIGE

My future starts when I wake up every morning... Every day I find something creative to do with my life.

—MILES DAVIS

The future, according to some scientists, will be exactly like the past, only far more expensive.

—JOHN SLADEK

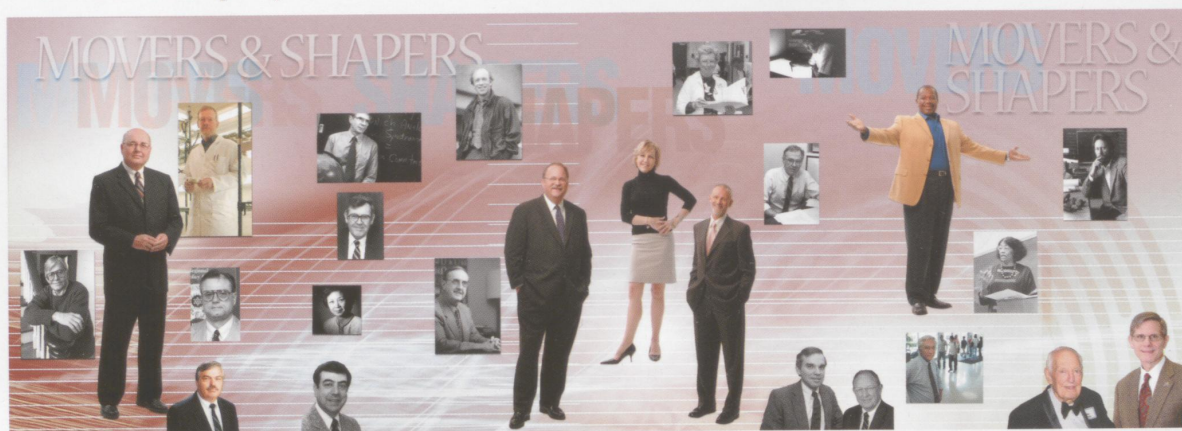
Most of our future lies ahead.

—DENNY CRUM

Odyssey

222 Bowman Hall
University of Kentucky
Lexington, Kentucky 40506-0059

Who are these people? Look inside.



www.research.uky.edu/odyssey

UK UNIVERSITY OF KENTUCKY
Research