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Winter 2007

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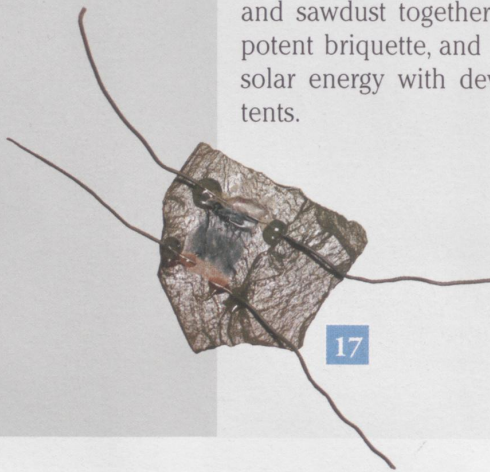
Odyssey

Cover Story

Green Energy

The University of Kentucky is taking "green energy" literally. By playing up Kentucky's agricultural strengths, UK researchers are creating a more stable form of bio-oil, designing new catalysts to produce premium biodiesel, targeting a new way to make ethanol with cornfield leftovers, packaging fine coal and sawdust together in a potent briquette, and looking for cheap ways to capture solar energy with devices spray painted onto rocks or tents.

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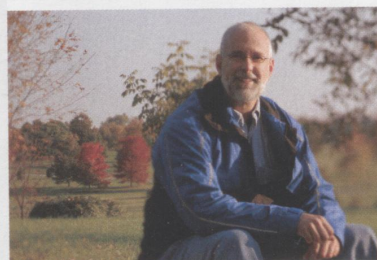
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The University of Kentucky is taking “green energy” literally. Well, if you get right down to it, it’s more like green and gold and amber and brown—plant materials, a.k.a. “biomass,” come in an array of colors.

UK is targeting our country’s oil addiction by playing up Kentucky’s agricultural strengths—the fact that we’re the largest timber producer east of the Mississippi, that our climate offers a long growing season and good annual rainfall—by turning timber waste and crop residues into fuel.

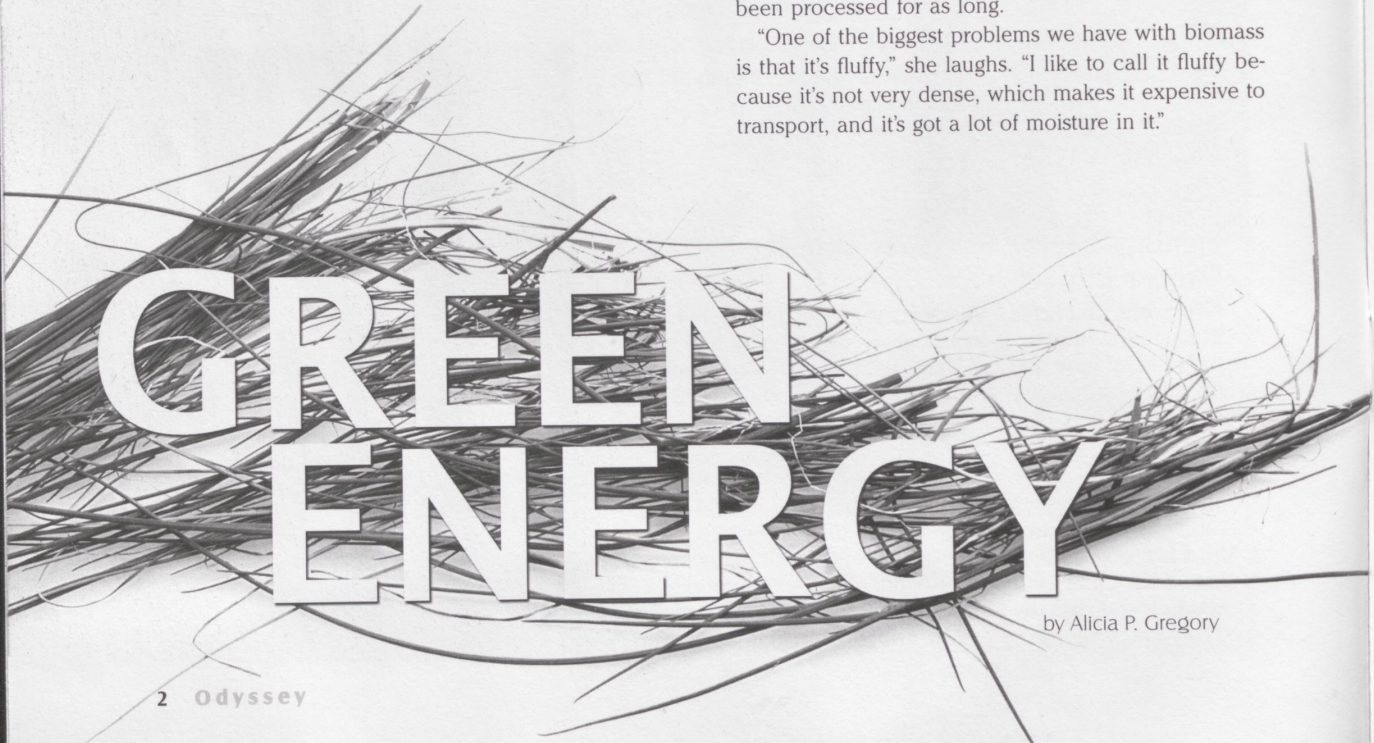
UK researchers are creating a more stable form of bio-oil, a replacement for the crude petroleum we use now to make plastics and chemicals, and targeting a new way to make ethanol with cornfield leftovers, and, eventually, with lawn clippings and cardboard. And UK scientists are designing new catalysts to produce premium biodiesel, packaging fine coal and sawdust together in a potent briquette, and looking for cheap ways to capture solar energy with devices spray painted onto rocks or tents.

By pooling the expertise of scientists in biosystems and agricultural engineering (a joint department of the College of Agriculture and the College of Engineering), chemical and materials engineering, chemistry, mining engineering, and the Center for Applied Energy Research (CAER), UK is expanding the meaning of green energy.

Biomass to bio-oil

“Biomass is just really new coal,” says Czarena Crofcheck, an assistant professor in the biosystems and agricultural engineering department who is working on bio-oil, biodiesel and ethanol projects. “It has the same stuff in it as coal and petroleum. It just hasn’t been processed for as long.

“One of the biggest problems we have with biomass is that it’s fluffy,” she laughs. “I like to call it fluffy because it’s not very dense, which makes it expensive to transport, and it’s got a lot of moisture in it.”



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by Alicia P. Gregory

Crofcheck's colleague on this bio-oil project, Mark Crocker, a chemist who has worked at CAER for three years, explains, "Our idea is to process biomass locally, on a farm or at a lumber mill, convert this biomass to a densified form, such as crude oil, and then perform some kind of stabilization step on it so it can be stored and shipped to a central biorefinery."

Bio-oil is a renewable version of crude petroleum. While 88 percent of all petroleum extracted is processed as fuel, the other 12 percent is converted into a variety of chemical products, including solvents, fertilizers, pesticides, and plastics. And bio-oil can be refined into all of these things.

But why can't bio-oil be stored and shipped now? First, it's corrosive because it's acidic. In fact, if it sits long enough it can eat through its container. Second, it's unstable. Crofcheck says, "That's because to create bio-oil you're causing a chemical reaction to happen by heating it up, and, well, that reaction doesn't want to stop."

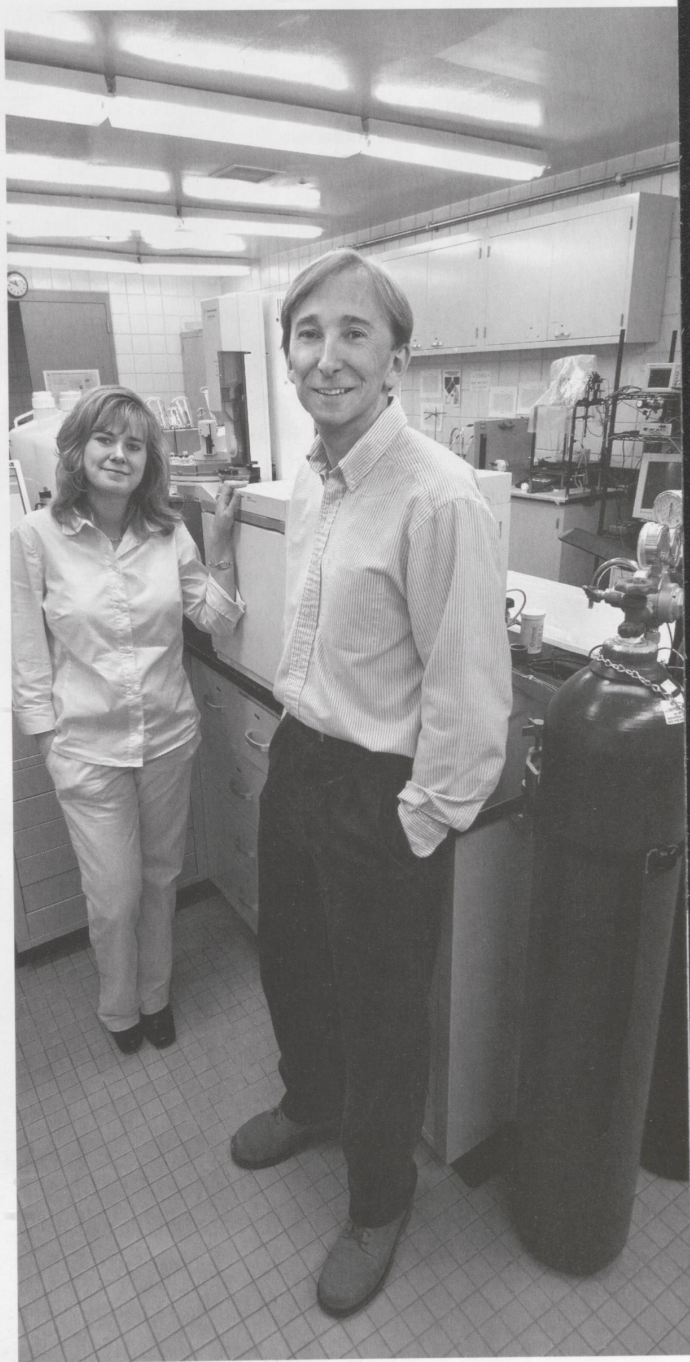
Crocker, a native of the U.K. who worked in Amsterdam at Shell Research for 12 years before coming to the United States, explains, "Crude bio-oils contain a lot of very reactive chemicals, which can undergo complex polymerization chemistry." Polymerization happens when small molecules link up via a chemical reaction to form polymer chains. "You can start off with a nice, clear liquid bio-oil," he says, "and you can end up with something that looks like tar."

"So we want to carry out a quick-and-dirty initial step to convert this crude, unstable, corrosive mixture to something that's stable." And the most important part of this transformation involves removing as much of the oxygen as possible. "Up to 40 percent of the oil is oxygen, in the form of carboxylic acids, aldehydes, ketones, and alcohols," Crocker points out.

"And we do that simply by mixing the oil with a catalyst at a particular temperature," explains Crofcheck, who came to UK as a grad student in 1994 and has been on the faculty since 2001. Catalysts are substances that accelerate a reaction, without being consumed or changed themselves. "Catalysts are a beautiful thing," she says.

Crofcheck and Crocker are using catalysts that work based on a concept called cracking—"taking large molecules and cutting them up into smaller molecules

Czarena Crofcheck (UK biosystems and agricultural engineering) and Mark Crocker (Center for Applied Energy Research) are using catalysts to increase the efficiency of biodiesel production and convert crude, unstable bio-oil into a mixture capable of being stored, shipped and refined into plastics, solvents and fertilizers.



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by breaking bonds. This is a process that has been used for petroleum for a long time. Lots of catalysts are good at cracking, but many go too far—they can break all of the carbon-carbon bonds and leave you with very small molecules that aren't very valuable," says Crocker.

"What we want is mild cracking—just cracking the oxygen-carrying compounds and leaving the heavier compounds, which typically don't contain so much oxygen, intact. This way you're expelling the oxygen—present in the most reactive compounds—in the form of carbon monoxide, carbon dioxide or water."

The type of catalyst that can achieve this "mild cracking" is a layered double hydroxide. "As the name implies these are hydroxides (hydrogen plus oxygen) that contain two or more metals. When you heat up these basic materials, they decompose to mixed oxides, which are even more basic, and, importantly, possess very high surface area." Crocker's hands skim across the top of the table as he explains, "All your chemistry is occurring on the surface of the catalyst, so the higher the surface area, typically the more effective the catalyst is." In other words, the more bio-oil that can come in contact with the catalyst at one time, the faster you can process it.

These same layered double hydroxide catalysts are the future of biodiesel processing, says Crocker.

"The exciting thing about renewable energy research in UK's Department of Biosystems and Agricultural Engineering is that we have projects that involve the beginning of the process, harvesting and storage, the middle, microbial and thermochemical conversion, and the end processing, catalytic stabilization. We run the gamut, and that's a strength."

—Rich Gates

Cracking biodiesel

Biodiesel is a biodegradable and renewable fuel that can be made from vegetable oils (including soy and canola), animal fats or recycled cooking oil. This light-to dark-yellow liquid has also been shown to reduce air pollutants like carbon monoxide and hydrocarbons.

Blends of 20 percent biodiesel and 80 percent petroleum diesel (B20) can be used in unmodified diesel engines, and have been shown to reduce engine wear, run quieter and produce less smoke than regular diesel. B100, or 100 percent biodiesel fuel, can be used in a regular diesel engine, but has a tendency to degrade natural rubber gaskets and hoses.

Kentucky produces 54 million bushels of soybeans each year, with 11 pounds of oil processed from each bushel. The state currently has one biodiesel refinery, Griffin Industries in Butler, Kentucky, with a 2-million-gallon-per-year capacity. Two more refineries are slated to open within the next year. Green Earth Bio Fuels, with a projected capacity of 3.2 million gallons per year, will open in Estill County. And Owensboro Grain's 50-million-gallon refinery, advertised as the nation's largest soy biodiesel plant, will open next to the company's existing vegetable oil refinery.

Biodiesel is already being used in 18 vehicle fleets across the state, including the Cincinnati/Northern Kentucky Airport, East Kentucky Power Cooperative, Kentucky Public School Systems, Kentucky State Resort Parks, Murray State University, and the University of Kentucky.

Nationwide biodiesel use is increasing—70 million gallons in 2005 compared to 30 million gallons in 2004. But biodiesel is still more expensive to produce than petroleum diesel.

New catalysts are key to increasing the efficiency, and lowering the cost, of biodiesel processing. The catalysts used now are homogeneous—both the catalysts and the vegetable oil/methanol mixture are liquid. "You basically have a huge vat in which you're processing the oil and methanol, and you have to wait for everything to convert," Crofcheck explains. "And while you're waiting, what was converted at the very beginning starts to convert into something else, something you don't want. And that's because the liquid catalyst needs to swoosh around until it comes in contact with everything."

Crocker and Crofcheck say a heterogeneous (solid) catalyst is the necessary alternative. "If we could move the liquid through a solid catalyst, there would be less contact time and less risk of these so-called side reactions that create stuff you don't want," she says.

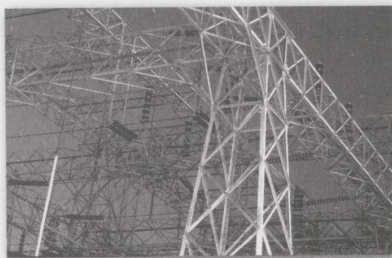
"One specific class of these layered double hydroxides has been very effective, and we're putting a patent together on that," says Crocker, noting that a solid catalyst allows you to separate your catalyst from the product much easier. "Right now biodiesel producers can't reuse the catalyst," Crofcheck says. "They wash it out and dispose of it, but with a solid catalyst, you'd be able to reuse it."

"And from where I sit, in biosystems and ag engineering, I think that's interesting because a lot of what we do is look at the processes farmers or industry have been doing for a long time and see if we can make them better," Crofcheck says, with an intensity that shows she clearly enjoys her work.

Rich Gates, head of the department, adds, "The exciting thing about renewable energy research in UK's Department of Biosystems and Agricultural Engineering is that we have projects that involve the beginning of the process, harvesting and storage, the middle, microbial and thermochemical conversion, and the end processing, catalytic stabilization. We run the gamut, and that's a strength."

A billion tons and what do you get?

"The U.S. Department of Energy and the U.S. Department of Agriculture have a goal of using 1 billion tons of biomass annually," says Scott Shearer, a biosystems and agricultural engineering professor who focuses on the harvesting side of the biomass equation. The DOE and USDA came up with this number in response to mandate to figure out how to replace 30 percent of



U.S. petroleum consumption with biofuels by 2030.

This is a daunting challenge. Biomass currently supplies just over 3 percent of the total U.S. energy consumption. However, the joint report issued in April 2005 states that, yes, 1 billion tons is doable—looking just at forestland and agricultural land, the United States has the potential for over 1.3 billion dry tons of biomass per year. This includes biomass from overgrown forest floors (dry material that needs to be cleared away to protect against forest fires), grains used for biofuels and crop residues.

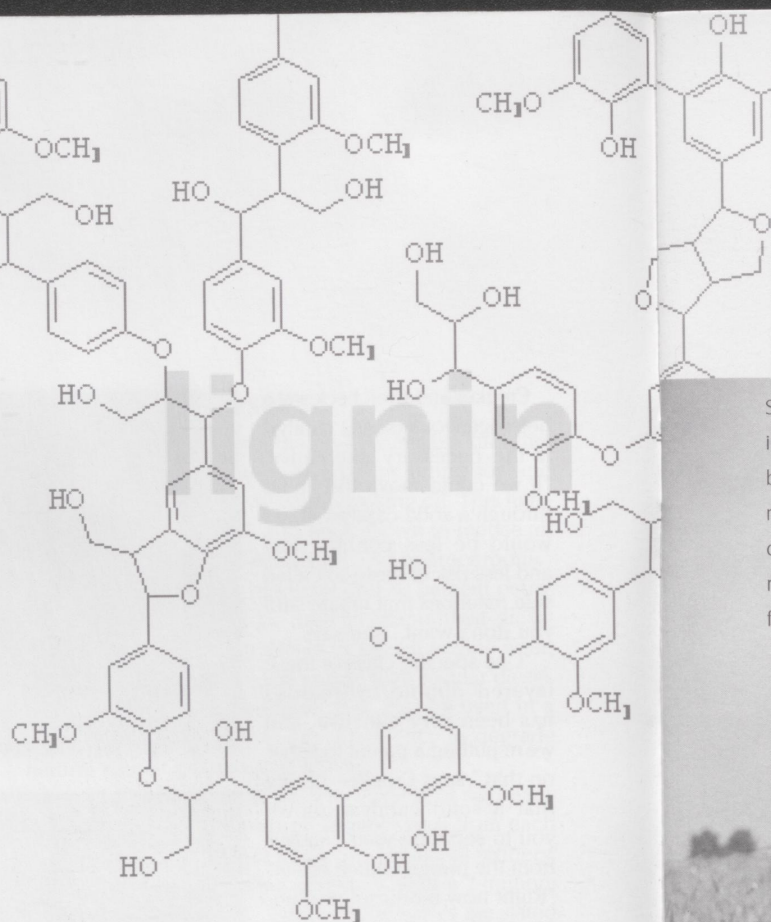
The report calls for a 50 percent increase in corn, wheat and other grain yields, harvest technology capable of recovering 75 percent of crop residues, and 55 million acres of cropland, idle cropland and cropland pasture to be dedicated to the production of perennial bioenergy crops.

Shearer says candidly, "If the government puts economic incentives in place, we're going to see more people growing dedicated energy crops, and that may be a pretty important thing for Eastern Kentucky and areas that are less intensively cropped." Of Kentucky's 26 million acres, less than a fourth of the state (6 million acres, primarily corn and soybeans) are intensively cropped.

"Dedicated energy crops—specially bred corn or forage crops like switchgrass and wheat straw—will only become feasible once we put an infrastructure in place to process and transport biomass. It's a chicken-and-egg type thing," Shearer says, smiling. "If somebody's willing to pay for it, there will be people willing to produce it—but right now we don't have the infrastructure for those producers to move the product."

"If you grow soybeans or canola, you're going to want to make biodiesel, and if you have corn, you're going to want to make that into ethanol. So we need to use things that are not otherwise being used," Crofcheck adds.

And Shearer, whose 20-year career at UK has focused on precision agriculture—using technology to increase crop yields—echoes her. "The feedstock that's not being used, particularly in Kentucky, is corn residue." And that's where a new way to make ethanol comes into the picture.



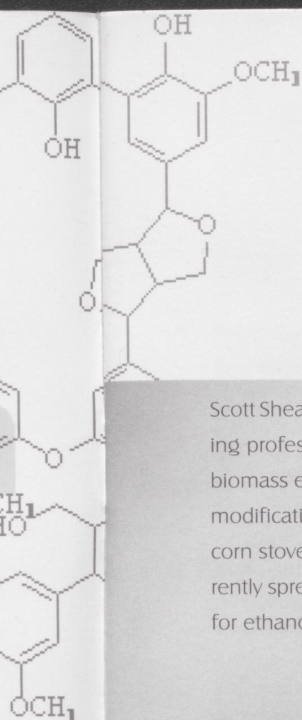
Ethanol: it's not about kernels anymore

"The reason we have so much ethanol production today is not necessarily as a replacement for petroleum, but rather because of the EPA restrictions on fuel-based air pollution," Shearer says. Plants grown for ethanol production absorb carbon dioxide as they grow, and ethanol reduces pollutants (carbon monoxide, particulates and ozone) produced by gasoline combustion. "Ethanol is also added to fuel as an octane booster."

His cohort Mike Montross, an associate professor whose expertise lies in drying, storing and processing grains, adds, "Ethanol is replacing MTBE, another octane booster, because scientists are now finding it in groundwater. They've discovered MTBE doesn't break down."

The Department of Energy reports a downside to ethanol—lower fuel economy. A 10 percent ethanol blend (which has been approved for use by every automobile manufacturer) reduces slightly the miles per gallon compared to pure gasoline. The DOE ethanol fact sheet states, "Engines are being designed that take advantage of the high-octane benefits of ethanol while increasing fuel efficiency."

Ethanol also has its critics. Some say it takes more energy to make ethanol (from the fertilizer to grow the corn, to the fuel used to harvest and transport it, to the energy to process it) than it generates. Biosystems



Scott Shearer, a biosystems and agricultural engineering professor, focuses on the harvesting side of the biomass equation. He's making low-cost equipment modifications that would allow farmers to harvest corn stover—the leaves, cobs and husks that are currently spread back on the field—a potential feedstock for ethanol.



Matt Barton

and agricultural engineering chairman Rich Gates says to some extent it's a numbers game.

"It all depends on how you define inputs and outputs in this argument. For example, co-products such as the distillers grain—that can be processed into animal feed—can be valuable and aren't included in all the balances. The latest values from the National Renewable Energy Lab assert that the energy balance is positive. Some studies gloss over energy costs of extracting, refining and distributing petrol-fuels. There is no simple answer to this, but there is definitely economic opportunity and a need for alternative fuels."

Fifty U.S. facilities currently produce ethanol, and 16 states, including Kentucky, have their own tax incen-

tive programs to bolster ethanol. Kentucky currently has two ethanol plants—Commonwealth Agri-Energy in Hopkinsville (with a capacity of 33 million gallons per year) and Parallel Products in Louisville (5 million gallons per year). Two more plants on the way include Bluegrass BioEnergy in Fulton County (with a proposed yearly capacity of 55 million gallons) and Agri Fuels in Brandenburg (50 million gallons per year).

In the United States, ethanol is produced primarily from starch in corn kernels, and this is not sweet corn, the kind we eat, but feed corn that is ground into animal feed. Most of the 4 billion gallons of ethanol produced in 2005 came from 13 percent of the U.S. feed corn crop.

In the field, corn kernels (i.e., grain) make up about half of the above-ground biomass, and corn stover (the stalks, leaves, cobs, and husks currently left in the field) make up the other half.

Most ethanol is made by "dry milling," a process with six key steps. 1) Kernels are ground into a fine powder, 2) liquid is added and the temperature is increased, 3) enzymes are added to break down the long chains of starch into short chains of glucose (sugars), 4) yeast is added for fermentation (converts glucose to ethanol and carbon dioxide), 5) the mixture is distilled (removing the ethanol from solid materials—compounds that can be processed into livestock feed—and water), and 6) the remaining water is removed to produce pure ethanol.

But converting corn stover or any other biomass material—wood, paper, grass—into ethanol is a whole other ball game. The fundamental challenge in making "cellulosic ethanol" lies in the fact that instead of breaking down starch into sugars, this conversion requires tearing apart the cell wall of the plant (the cellulose, hemicellulose and lignin) to get sugars. This so-called lignocellulose material is tough stuff. Lignin is the reason corn grows tall and wood is rigid. It has a much more complex chemical makeup than starch. Montross, who's worked on biomass preprocessing at UK for seven years, says, "Biomass has a lot of sugar, but right now nobody really knows how to get to it. That's where Sue Nokes comes in."

Some like it warm

"We want to get to the cellulose, but the lignin wraps around the cellulose, so it's difficult," says Nokes, an associate professor with expertise in producing industrial enzymes through fermentation. She is the principal investigator on a project to adapt bacteria to make cellulosic ethanol. And her UK team includes Herb Strobel

in chemical and materials engineering, and Bert Lynn in chemistry.

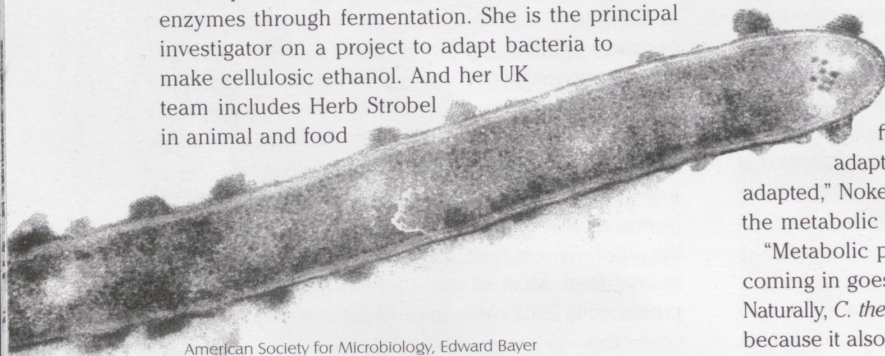
Strobel, who's been at UK for 16 years and specializes in anaerobic microbiology, says, "We're using *Clostridium thermocellum*—a bacterium that likes heat. It's found in compost piles, hot springs, soil and other warm environments that contain decaying plant matter. *C. thermocellum* and organisms like it are critical—without their help we'd be up to our eyeballs in plant material."

So why is this organism a good candidate for ethanol production? "Because it has its own enzyme system," Nokes explains in a way that makes it clear why students have voted her an outstanding teacher more than a half-dozen times since she came to UK in 1995. "*C. thermocellum* naturally feeds on cellulose. With corn you have to buy and add enzymes because yeast don't have any of their own. But this guy can do the whole thing—take the plant material, break it into sugar and ferment it. And in general, industrial processes that are warmer go faster, so the fact that they like it warm is just another way to capitalize on their natural ability."

The first step in this project involved "growing" bacteria that could withstand increasing amounts of ethanol. "*C. thermocellum* can naturally tolerate ethanol at less than a 1 percent concentration," Strobel explains. "We gradually increased the ethanol to 'train' the organism to adapt. This was time consuming, but with patience, and a few tricks, it was possible to select strains that tolerate 5- to 15-fold higher concentrations of ethanol than normal. One trick we used was growing the organism in slightly reduced temperatures. In some way—we're still studying how—this helps the organism adjust to the higher ethanol levels."

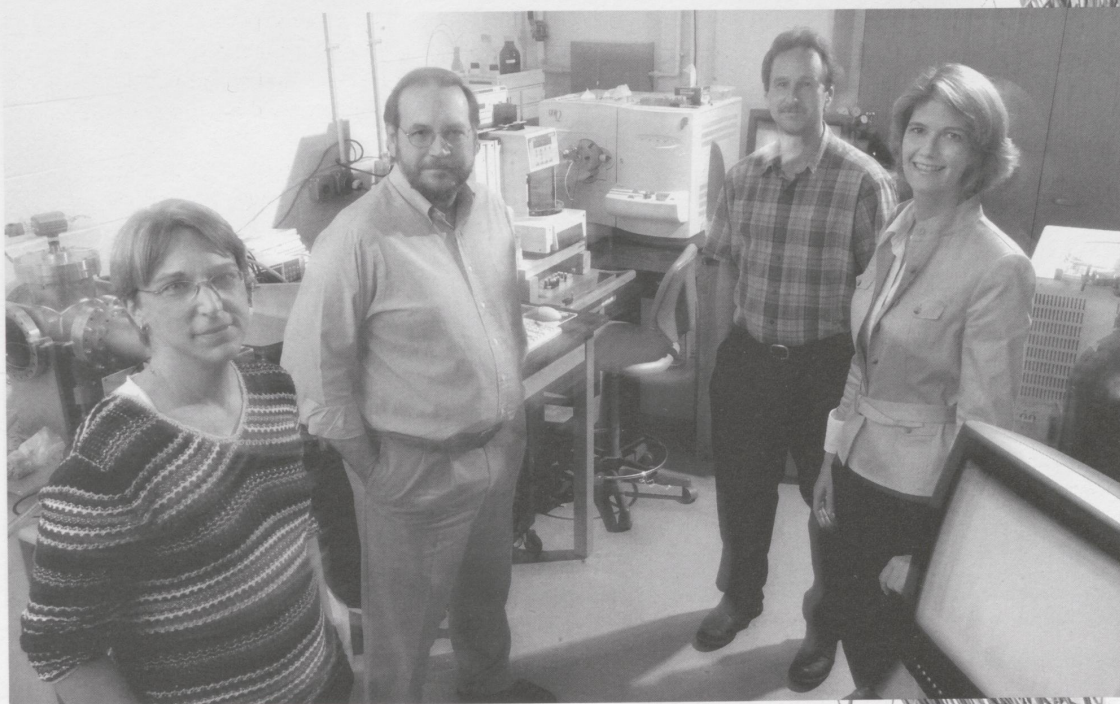
Once the team had their "super bacteria," they began comparing them to normal bacteria. "We're trying to find out what the organisms that have adapted do differently from those that haven't adapted," Nokes says. "Specifically, we're zeroing in on the metabolic pathways and membrane fluidity."

"Metabolic pathways affect how much of the sugar coming in goes to ethanol versus acetate and lactate." Naturally, *C. thermocellum* doesn't produce much ethanol, because it also makes acetate (vinegar) and lactate (an



American Society for Microbiology, Edward Bayer

Some like it warm: from left to right, Sue Nokes (UK biosystems and agricultural engineering), Bert Lynn (chemistry), Herb Strobel (animal and food sciences), and Barbara Knutson (chemical and materials engineering). This research team is targeting *Clostridium thermocellum*, a bacterium that likes heat and feeds on cellulose, as a new way to make ethanol with cornfield leftovers, and, eventually, with lawn clippings and cardboard.



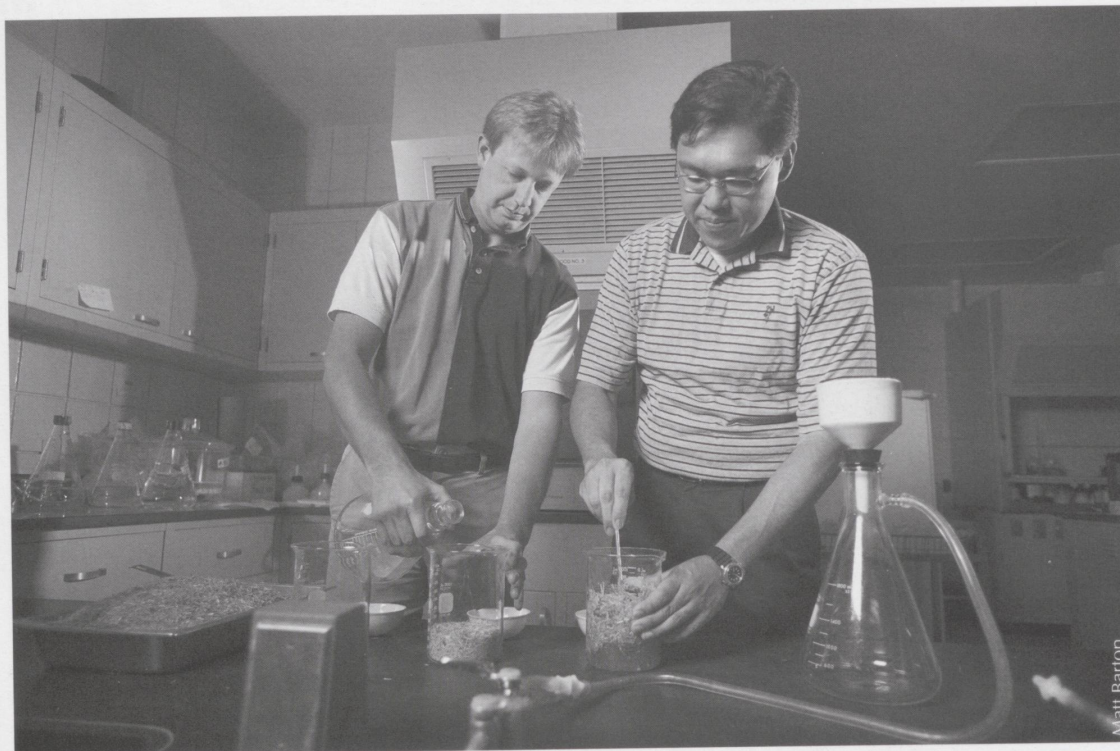
acid used to preserve fermented foods like cheese, yogurt and sauerkraut). "We want to shift its metabolism more toward ethanol."

Membrane fluidity has to do with the way ethanol can dissolve—break down, like a detergent—the organism's membrane. Nokes says, "If we can strengthen the membrane, we can boost the bacteria's resistance to ethanol."

How do you convert biomass with these bacteria? "Right now we think you'll have to grind up the biomass—make it into small pieces of uniform size—then whether or not you have to treat it with an acid or base is still up for discussion." Nokes explains that pretreating will separate the cellulose from the hemicellulose and lignin, the bacteria will be added to convert the cellulose into glucose, the mixture will be fermented, and then ethanol will be separated by distilling—heating it up and boiling it off.

"If we can figure out how to produce ethanol from cellulose instead of from starch, I think everyone will go to making it from cellulose," she says. "It's a cheaper feedstock and there's more of it. We're hoping that down the road we could essentially convert the corn ethanol plants, and just replace

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Mike Montross (left), whose expertise lies in drying, storing and processing grains, and research analyst Wei Chen add enzymes that convert wheat straw to sugar for fermenting into ethanol.

corn with plant materials.

"Think about cities. We collect yard waste like leaves and lawn clippings, put it in our little paper bags, and it gets hauled off to the dump. Why don't we do something else with it?" Nokes asks enthusiastically. "The conversion gets a little more complicated if it's a mix of stuff, but that's where we want to go."

Shearer says that if you single out corn residue as the feedstock for cellulosic ethanol, one of the major hurdles is simply accumulation. And Crofcheck adds, "This biomass is just not valuable enough to buy a special piece of equipment to get it off the field." Montross and Shearer are tackling this problem head-on by adjusting the combine harvester to catch the leaves, cobs and husks but leave the stalks in the field. "What comes out the back of the combine right now is everything but the grain. All of the biomass is

returned to the field. We want to make modifications to the equipment the farmers already have, at a cost where the farmer derives a profit for collecting the biomass," says Shearer.

"When you look at biomass accumulation, one of the things we're always concerned about, especially in Kentucky, is leaving enough residue on the soil surface." He says this is critical for two reasons. "We talk about erosion, and of course that's vital, but there's also the carbon content of the soil. Maintaining soil organic matter content is important to agricultural productivity in subsequent years."

And in their study, Shearer says, the stalks were the best field protectors. "The high lignin content in the stalks is valuable for erosion control because the stalks degrade slowly, while leaves and husks break down very quickly."

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Montross adds, "Until we've figured out an economical way to process biomass into ethanol, and until there's someone who actually wants it and is willing to pay for it, cellulosic ethanol isn't going to happen. But that's the direction we're headed."

Speaking of new markets for green energy, Shearer, Montross and Darrell Taulbee, a chemist at the Center for Applied Energy Research (CAER), are partners on a project to turn biomass into briquettes. 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 existing utility plants. And while some of these nuggets are 100 percent biomass, others are an innovative mix of mill and coal waste.

Packaging green energy: the fine coal/sawdust briquette

"There's a growing demand for green energy, but there are a lot of problems getting green energy into the market—transportation, low density," says Taulbee, who has worked at CAER since 1980. "So the question becomes, how do you overcome these problems?"

The answer: Briquettes.

Mining Engineering Professor Rick Honaker points out that any powder that is compressed into a solid nugget is a briquette. "We use briquettes all the time. Charcoal, medicinal pills, dog food, cat food—it's all briquetted."

Taulbee, Honaker and B.K. Parekh, a coal expert from CAER, are partners on a project that began in 2002 to create a premium fuel, for use in industrial boilers like those at utility companies, by taking two waste materials—fine coal and sawdust—and packaging them as a briquette. "It just simply made sense," says Taulbee, whose words are measured and tinged with an accent that hints at his Eastern Kentucky roots. "This is a way that you can put two waste materials together and address all of the problems that you had trying to market them individually."

In the process of mining, 20 to 30 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.

These impoundments hold wastewater and impurities

"We recognized a unique situation in Eastern Kentucky. Here were slurry impoundments right next to mountains of wood waste. Why not link up these coal plants and lumber mills?"

—Rick Honaker

that result from coal washing and processing. A bulkhead or embankment is made of coarse coal refuse and acts as a dam. The sizes of the ponds and bulkheads vary, but impoundments are often hundreds of feet deep and hold millions of gallons of slurry. Parekh notes that these waste ponds are under increasing scrutiny because of potential safety and environmental risks. And Taulbee recites a staggering statistic: "There's 2 to 5 billion tons of waste coal material in the United States."

"And Kentucky has 500 million tons of fine coal in slurry impoundments," says Parekh. Taulbee interjects, "To put that in perspective, Kentucky only mines 100 million tons of coal each year. We throw away enough each year to run a small industrial country of 10 to 20 million people."

Parekh, who earned a master's in physical chemistry from Vikram University in his native India before pursuing a master's degree and doctorate in minerals processing at Penn State, continues, "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." That's due in part to Parekh's research that started back in 1985. His device, the Ken-Flote column, allows coal-preparation plants to clean and recover these tiny coal particles. With a number of competing "column flotation" companies selling their units, he says, "this process is becoming very popular in the coal industry."

So what's the problem with using this fine coal? First, it's wet.

"The product that comes out of these machines is 20 percent solids and 80 percent water," Parekh explains. Through a process called dewatering, the coal company can reduce the moisture content to about 35 percent, and then can mix the fine coal with larger, coarser coal and sell it to utility companies. But industry regulations limit the amount of fine material coal companies can mix in with regular coal. "And if you want to make briquettes, 35 percent moisture won't cut it."

"The numbers we want are 20 percent water and 80 percent solid. That's not easy," Parekh says. "So the main emphasis of my work has been going after these ultra-fine particles, recovering them, and then producing a very low-moisture product."

And there's a second problem, says Taulbee. You can't transport fine coal by itself. "If you ship this fine coal out of Kentucky by train, even though it's



Binder specialist Darrell Taulbee (left), coal expert B.K. Parekh and mining engineer Rick Honaker are partners on a project to create a premium fuel, for use in industrial boilers like those at utility companies, by taking two waste materials—fine coal and sawdust—and packaging them as a briquette.

wet when it starts out, the surface layer will be dry before it gets to Florida. It's going to be blowing out the back of the railcar."

The same goes for sawdust. Because it's so lightweight, it's not economical to transport more than 40 miles, says Honaker, who has been at UK since 2000 and earned his Ph.D. in mining and minerals engineering at Virginia Polytechnic Institute & State University.

Taulbee, who has a Ph.D. in analytical chemistry from UK, says, "In 2002 one of the first things we discovered was that Kentucky is the largest timber producer east of the Mississippi. At that time we were producing three-quarters of a million tons of sawdust in Eastern Kentucky alone. The utilization rate of sawdust statewide was 35 percent, but it was lower in Eastern Kentucky."

"And that simply has to do with the lack of industrial development in the region," Honaker points out. "We recognized a unique situation in Eastern Kentucky. Here were slurry impoundments right next to mountains of wood waste. Why not link up these coal plants and lumber mills?"

So with funds from the U.S. Department of Energy, the team set out to find the least expensive means to produce briquettes, and they determined that if you

located a 50-ton-per-hour briquetting operation at an active coal-preparation plant, you could make briquettes valued at \$17 per ton. Honaker says, "We looked at all of the costs—equipment, sawdust transportation, labor, etc.—and came up with \$17 per ton."

"Compared to \$40 to \$45 per ton for coal, you can't beat it," says Parekh. And with the fine coal's BTU (heating energy value) at 13,000 to 14,000 per pound, and the sawdust's BTU at 6,000 per pound, this briquette is a premium fuel source.

The team's scenario involved taking the fine coal directly from the column flotation unit, dewatering it, mixing it with the sawdust, adding the binder, and pressing it into a briquette. The binder—the most expensive item in the briquetting process (they budgeted \$8 per ton for the binder alone)—is the "glue" that holds the sawdust and fine coal together. "We've identified several multi-component formulations that work well, but we haven't released the names of those yet," says Taulbee with a smile, alluding to the fact that his competition would love to know the make-up of his binders.

Honaker adds, "Darrell had over 50 different chemicals that he tried. He went through the list, crossing out those that exceeded the \$8-per-ton target price, that didn't measure up with compressive strength, and

that couldn't endure drop-shatter tests. This was our biggest achievement in the whole project—finding the binders that make economic sense."

Holding the smooth, nearly two-inch by a half-inch briquette, Taulbee explains that the binder reduces the amount of energy you have to exert to form the briquette. "So you mix the fine coal and sawdust and add the binder, then you feed it through a machine that compresses the powder under high pressure for less than 2 seconds. The briquette comes out shiny and hot," Taulbee says. "The two-inch size was simply the size of the die on the briquetting machine we rented to start this project."

The die size is going to correlate with the amount of pressure you need and how much power the process will consume. For example, producing wood pellets takes 10 to 15 tons of force. We only need 1 to 2 tons because we're using a binder."

But before they tested which compounds performed best as binders, they needed to find out what kind of sawdust worked best and what mix of sawdust and fine coal was optimal.

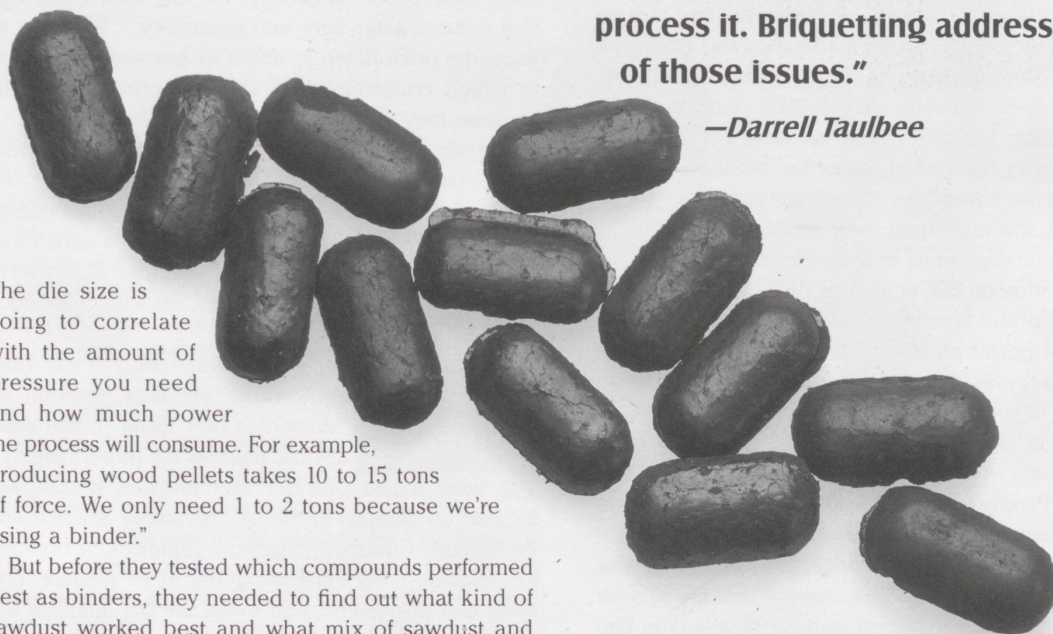
"The harder woods, like hickory, beech and oak, yield higher density sawdust than trees like poplar, maple or willow. And higher-density sawdust gives us a higher compressive strength briquette," says Taulbee.

And it turns out that 10 percent sawdust, 90 percent coal is the right combination. "The sawdust actually reduces the strength of the briquette. Initially, the wood absorbs some of the moisture in the coal and it swells," explains Honaker. But as the briquette cures (or dries) the wood shrinks, which weakens the briquette.

With new funding from the Kentucky Office of Energy Policy, the team will tackle the two biggest obstacles

"If you look at agricultural waste, seasonal availability is a problem. A utility company can't just run in the summer. People want electricity year-round. There are storage problems with biomass. You have to keep it dry, and you have to invest additional capital to transport and process it. Briquetting addresses all of those issues."

—Darrell Taulbee



to commercialization they've found so far.

Obstacle #1: Straight out of the machine, these briquettes are fragile. Taulbee says, "They tend to have a low compressive strength when they're first produced, and that prevents you from immediately handling them and loading them onto railcars." They need to cure—sit in a dry place for a few days up to a week or go through some type of drying process.

Obstacle #2: The more significant problem, says Taulbee, is that the moisture in the coal prevents consistent feed rates to the briquette machine. "If you can't get consistent feed rates, you can't get a consistent



product." The team will test four different methods to see which is best for making the tiny coal particles flow better.

And what they find may soon make its way to a commercial operation. Leaning back and crossing his arms, Taulbee says, "We need to demonstrate this on a larger scale in the field."

"We've had several meetings with potential investors and utility companies who are interested in this because of their need to respond to CO₂ emission concerns," explains Honaker. The United States currently has no cap on CO₂ emissions, but limits are in the works.

Kunlei Liu, who joined CAER last year and has expertise in clean combustion technology and emissions control research, says, "A Congressional proposal, the Climate Stewardship Act of 2005, introduced by Senator John McCain, would mandate CO₂ emission reductions in the United States for facilities emitting 10,000 metric tons of greenhouse gas per year. As now proposed, this legislation would apply to all coal-fired power generation units in Kentucky. From what I see, the legislation on CO₂ emissions isn't a question of yes or no, it's about how soon."

So coal power plants are eager to mix in as much green energy as they can. And they're investigating all kinds of renewable biomass. Taulbee explains, "If you look at agricultural waste, seasonal availability is a problem. A utility company can't just run in the summer. People want electricity year-round. There are storage problems with biomass. You have to keep it dry, and you have to invest additional capital to transport and process it."

"Briquetting addresses all of those issues. You can simply transport these coal-sawdust briquettes by train, just like you would a chunk of coal. And if you build the proper briquette, it can resist water so you can store it outside. People want to use biomass. Utilities are willing to pay for it, and they sell their electricity at a premium. There's money to be made in a green way."

And speaking of green, the greenest energy of them all—sunlight—may soon be producing electricity for your home and car.

Solar cells on the cheap

John Anthony and Rodney Andrews see 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. Andrews, CAER carbon materials group manager, proudly says the heavy, brittle and expensive silicon panels (which run about \$12,000 for three kilowatts, including wiring) are old news.

"We're on the opposite end of the spectrum," says Anthony, who holds the Gill Professorship in Chemistry. "Our goal is to make cheap solar cells." These solar cells, a.k.a. photovoltaic cells, are tiny semiconductors that convert solar light into electricity. "We want to bring the price down to about \$1 per watt—the mark at which consumers will start adopting solar cells because they are essentially disposable."

Why do we need a new kind of solar cell? Current silicon panels are 17 percent efficient (and, of course, that's related to the fact that solar cells produce energy only while the sun is shining). Anthony's early-stage test cells are about 1 percent efficient. And while they're working on improving efficiency, he says, efficiency isn't everything.

"The cost is going to be significantly lower than silicon," says Anthony, whose previous research on the same kind of molecules he's using in the solar cells was geared toward flexible flat-panel displays. This work led to Outrider Technologies, a company located on campus at the UK Advanced Science and Technology Commercialization Center. "Our organic, i.e., plastic, solar cells are going to be flexible, portable and disposable, and those are the qualities our military partners are interested in."

The UK researchers, with scientists at Cornell and Northwestern, are working on three different solar energy projects funded by the Army, the Navy, and the Defense Advanced Research Projects Agency (DARPA). The Army project utilizes a UK strength—the Advanced Carbon Nanotechnology Program (ACNP). Headed by Janet Lumpp in electrical and computer engineering, ACNP includes a subgroup on energy conversion, led by Anthony. And Andrews, a chemical engineer whose work covers several parts of this program, quips, "I'm everybody's nanotube dealer."

What's the bright idea? Cheap solar cells. John Anthony (left), who holds the Gill Professorship in Chemistry, and Rodney Andrews, Center for Applied Energy Research carbon materials group manager, are creating plastic solar cells with nanotubes.

"We can make about two-and-a-half kilograms of nanotubes each day, which means, as far as we know, we have the largest academic capacity in the world. A couple companies beat us, but nobody in academia."

And what do nanotubes have to do with solar cells? Nanotubes—cylindrical carbon molecules that are efficient conductors of heat and exhibit extraordinary strength and unique electrical properties—are a cutting-edge replacement for the metal needed for conductivity. "Compared to metal," says Andrews, "nanotubes are great because they're flexible, they're durable, they don't break over time, and they don't rust."

Anthony, a semiconductor expert, explains, "What you have with a plastic solar cell is two electrodes—one made of nanotubes and the other a transparent conducting polymer or very thin aluminum—and sandwiched between those two electrodes is what we call the active layer. It's where all the business happens."

And that "business" can be summed up as: "When strong light pulls an electron away from the material, it leaves a positive charge behind, called a hole. The whole impetus for the work that the electrons do, in any electronic device, is that the electrons are screaming around trying to find another hole to recombine with," says Anthony.



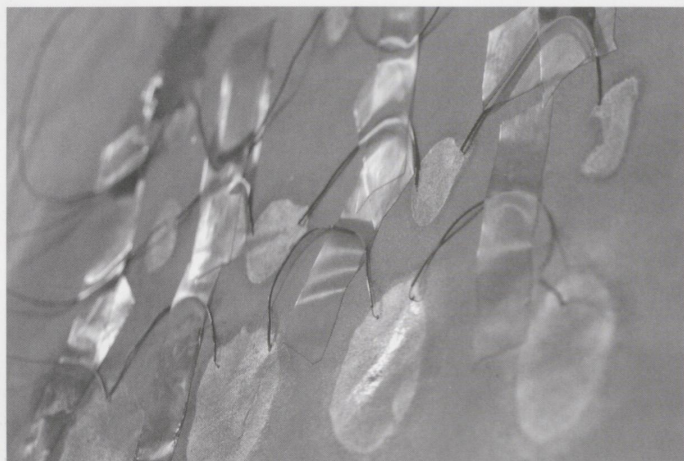
Andrews says, with a laugh, "There are a whole bunch of physicists that are going to give you a hard time about that explanation."

Nodding, Anthony says, "I know. It's not exactly right. But electrons and holes—that's what it's all about. Pulling them apart and letting them recombine. You've got to love that fundamental balance of nature."

Taking advantage of what happens in biology, specifically a phenomenon called self-assembly, is the team's goal. "Self-assembly is a process whereby molecules are designed so that they find each other and arrange themselves in a particular fashion," Anthony explains. "This process is why there is life. DNA, the double helix, is formed by self-assembly."

"Applying this to an electronic system, we stick little bits and bobs onto the molecules—it's like Tinker Toys—so that when you dissolve them in a solution

GREEN ENERGY



John Anthony sprays a blue semiconductor mixture onto paper coated with silver cathode dots to demonstrate the ease with which solar cells can be fabricated in the field. Connect the cells with a few wire electrodes, and a solar-cell array is born.

and you spray that out, the solution evaporates, the molecules start getting closer and closer until they recognize, 'Hey, this is the part I want to interact with,' and they stick together."

Andrews adds, "Where self-assembly really comes in handy is when you're working at the nano scale. You can set up these molecules to arrange themselves in the shape you need."

The active layer of one of these solar cells is less than 100 nanometers thick—"that's one-6,000th of a human hair," Andrews says. "You can't get in there with a pair

of tweezers to push stuff around, so self-assembly does the work for you. We use this process to grow an array of nanotubes that all line up the same way—like a piece of carpet—with 'fingers' that stick up."

"Rodney's nanotube fingers stick up, and my active layer fingers stick down. This maximizes the surface area, the interaction between the conductive bit and the semiconductive bit," says Anthony.

Andrews gives a little more detail: you've got two types of semiconductors, n-type and p-type. "We're tailoring the nanotubes so they better match, and accentuate, the electronic properties of the active layer."

"N-doped nanotubes like to hang out with electrons, and p-doped tubes like to hang out with the holes, the positive charge," Anthony says, laughing at this oversimplification and adding that the technical term for this is "work function." "It's nice because work function gives you a definite number, and the whole point is to get Rodney's nanotubes' energy, the work function for the n-doped and p-doped tubes, to line up with the energy level in the n-type and p-type molecules I make."

And what has all of this electronic fiddling accomplished? "The first-ever demonstration of a spray-painted solar cell," Anthony says with a smile. "DARPA wanted us to show spray painting was possible, but we took it one step further. One of the postdocs on the project took a rock out of his garden, and we spray painted a working solar cell onto it." Now, why would the military be interested in a spray-painted rock?

"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 says. "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 they can pick up their charged batteries and they're off and running. And when they're done with the solar cell, they just kick it into the sand and it's gone."

Anthony and Andrews list a number of surfaces solar cells could be spray painted onto—the sides of

a tent, a panel on the back of a soldier's uniform, an inflatable structure, and, beyond military use, your driveway, the roof or your car.

Anthony says, "Right now we're trying to increase the efficiency of these cells, but we're also trying to create a device with a lifetime of about a week. The idea being that these could be used for emergency disaster relief or short military operations."

Andrews adds, "The Department of Defense has been very generous and very helpful because they have immediate demands and very specific needs, but through these projects we're making materials that could eventually be put into everybody's house and everybody's car."

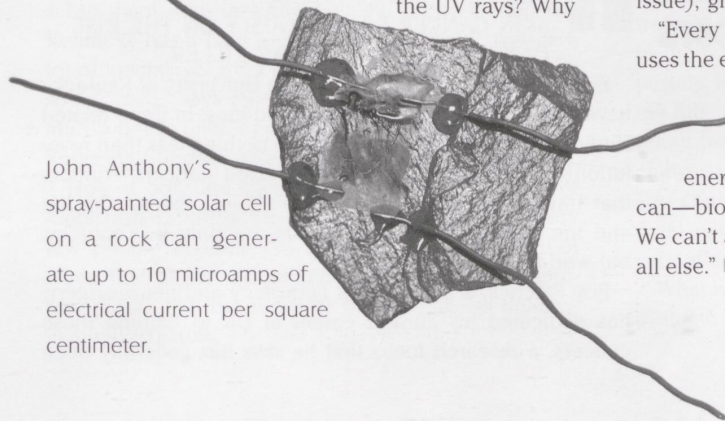
"A friend of mine said what he envisions is a roller system that goes across the roof of your house. It's automatic. Every week the thing just rolls out a new segment of solar cells," Anthony says. "And if you can spray paint the roof of your car for a few cents and that's going to generate some power for you, why not?"

The "why not?" is driving the UK team to explore the possibility of capturing UV to produce electricity. Anthony says, "We just submitted a proposal to the Navy on down-conversion—taking really powerful ultraviolet light and converting its energy down to something that's more useful for solar cells."

Andrews adds, "In Kentucky, the problem with using solar for large-scale energy production is it's too cloudy. But when it's cloudy you still get substantial UV."

"That's why you sunburn on a cloudy day," Anthony says. "You know how people put these films on their windows to keep out the UV rays? Why

John Anthony's spray-painted solar cell on a rock can generate up to 10 microamps of electrical current per square centimeter.



not actually absorb the UV and do something useful with it by turning it into electricity? If we can adapt our technology, a whole new range of possibilities will open up."

Green starts at home

Green energy means different things to different people, and most view it as a way to wean our country off foreign oil. But University of Kentucky researchers understand that the potential of green energy is based in the combined power of ethanol, bio-oil, biodiesel, briquettes, clean-coal technologies, solar cells, and more.

As Rich Gates puts it: "It's hard to predict which combination of technological innovation, market and consumer forces, and government incentives will link up to be successful, so a broad-based examination of the technical roadblocks is critical to improving our knowledge."

"Some of the problems we're addressing won't have solutions for years, and that is why investment in higher education is so important. We are working for future generations, not only for the fuel we pump into our cars this week."

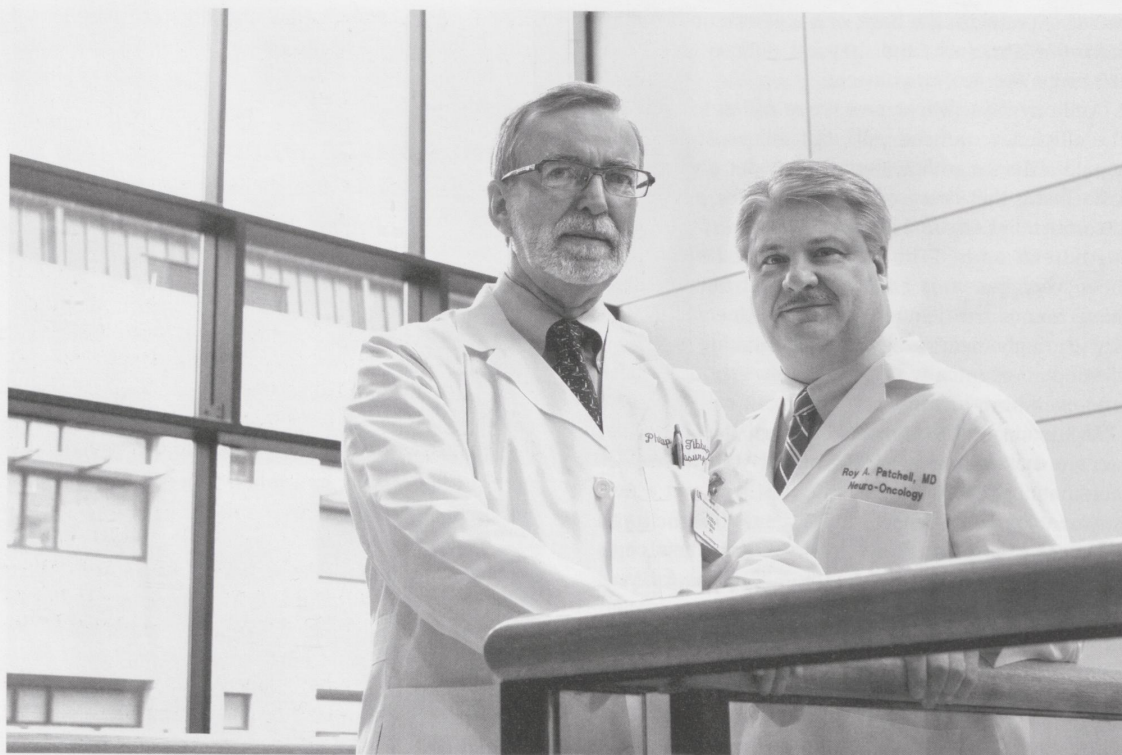
Scott Shearer adds, "We've forgotten the lessons we learned back in the '70s. Look at the number of SUVs and pickups on the road if there's any question in your mind about that. We need to focus more on our individual energy use."

To underscore this point, Burt Davis, director of the clean fuels and chemicals group at CAER (whose research on making liquids from coal, along with other projects on hydrogen and catalyst advances, will be covered in part two of this article in the Fall 2007 issue), gives a staggering analogy.

"Every man, woman and child in the United States uses the equivalent of 16 six-packs of energy every day."

Now students like a six-pack of cola, but they can't handle 16," he says with a chuckle. "It's an enormous amount of energy. It's stupid not to look at every resource we can—biomass, ethanol, biodiesel, hydrogen, and coal. We can't afford to look at one thing to the exclusion of all else." ■

Phillip Tibbs (left) and Roy Patchell in the Department of Neurosurgery have teamed with other UK researchers on three clinical trials that have led to landmark changes in the treatment of metastatic cancer.



Research Trifecta!

In three studies, UK team sets new worldwide standard of care for migratory cancers

by Jeff Worley

Recent headlines trumpet the bad news about cancer: FIVE-YEAR SURVIVAL FOR LUNG CANCER NO BETTER IN LAST 30 YEARS. SKIN CANCER DANGEROUSLY ON THE RISE. CANCER REMAINS OUR #2 KILLER.

But some cancer researchers at the University of Kentucky have been making very different headlines. In three related studies, this medical 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 not only in Kentucky, but worldwide.

Roy Patchell, a professor of neurology and neurosurgery, has dedicated his 20-year career at UK to battling these cancers, a research focus that he says has generally been

"unpopular" among most cancer researchers.

"Well, maybe 'unpopular' isn't the best word," says Patchell. "The truth is, our work is almost unique in the world of neuro-oncology because the prevailing thought has been that patients with serious neurological metastases aren't going to live very long, so it's better to focus your research efforts elsewhere." This idea is so ingrained, there's even a term for it, he says: *therapeutic nihilism*. "But we've been able to show that these tumors are treatable, and that if they are treated correctly and aggressively, most patients live longer, better-quality lives than if the metastases are ignored."

Patchell stresses that this work has been a team effort. The research group through the years has included an all-star lineup of UK medical researchers: Phillip Tibbs and Byron Young in neurosurgery; William Markesbery, a neurologist, neuropathologist and longtime director of the UK Sanders-Brown Center on Aging; Mohammed Mohiuddin formerly at UK and now head of a cancer center in Pennsylvania; and William Regine, also formerly at UK and now professor of radiation oncology at the University of Maryland. Patchell also credits another member of this group, Richard Kryscio in statistics, calling him "a genius with numbers."

Over 200,000 new brain metastases occur in patients in the United States every year.

Metastasized tumors begin somewhere else in the body, and through a process that's not fully understood break out from the original site and slide into the bloodstream. They flow someplace else, attach themselves there, and—too often—begin to thrive. "Because Kentucky has a high percentage of smokers, we see a lot of metastases from lung cancer to the brain or the spinal cord," says Patchell, who came to UK in 1985 after a neuro-oncology fellowship at Memorial Sloan-Kettering Cancer Center in New York City.

How deadly are these tumors? "If cancer did not metastasize, hardly anyone would die from it. Very few people actually die from the local tumor; but when that tumor moves and sets up camp in important places like the brain or liver, it can be deadly," Patchell explains.

Putting Some Backbone into Spinal Cord Cancer Research

One common site where traveling cancers settle, and can cause intense pain and disability, is the spine. Spinal metastasis typically results in compression of the spinal cord, the result of the cancer first growing in the bone and then enlarging and pressing on the spinal cord.

"This is a very common complication," says Patchell. "It happens in about 10 percent of all patients with cancer." And Patchell has a special interest in this type of metastasis: both of his parents had spinal compressions and both died of cancer.

Spinal compression was treated early on with surgery, Patchell explains, but the wrong kind of surgery. In the 1930s, laminectomies became standard procedure to deal with cancerous spinal compression—a surgeon would remove a portion of the bony arch, or lamina, on the back side of a vertebra. This procedure, which is typically done to relieve back pain that isn't helped by more conservative treatments, didn't treat the tumor, though.

"So surgery had a bad name in connection with the treatment of this spine cancer," Patchell says, "and was abandoned in favor of conventional radiation and high-dose steroids." But the problem with radiation, he points out, is that it doesn't work very quickly, and the tumors continued to grow. "In fact, half the patients treated with radiation got better and half didn't improve. Frequently, people got worse."

To help more people, surgery came back into the picture, but a different approach was tried—direct decompressive surgery—which did seem to work. "Surgeons would remove the tumor, which was in front of the spine, and this had a lot of advantages in theory," explains Phillip Tibbs, Patchell's longtime partner in the fight against migratory cancer. "By doing this, you relieved the compression, prevented the tumor from growing back, and could then reconstruct chewed-up bone by using metallic rods or super glue. You could rebuild the spine and make it solid. Anecdotal evidence told us that this approach was generally very effective."

What was needed was a clinical trial to scientifically evaluate this operation. Tibbs continues: "There had

"Our work is almost unique in the world of neuro-oncology because the prevailing thought has been that patients with serious neurological metastases aren't going to live very long, so it's better to focus your research efforts elsewhere."

—Roy Patchell

been uncontrolled clinical trials before, but, unfortunately, the patients selected for surgery in the past had good, overall prognoses anyway, and so it's not surprising that they ended up doing well in nonrandomized studies." In designing the UK trial, Patchell says the key concept was objectivity: "We wanted to do a randomized trial, which means people are allocated at random, by chance alone, to receive one of two clinical interventions."

In this study, which began in the early '90s, 101 patients (70 UK cancer 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 are not concentrated; these beams can cover large areas if necessary. Patchell headed up this study, which also included researchers at the University of Michigan, the M.D. Anderson Cancer Center at the University of Texas, the University of Pittsburgh, and Brown University.

Patients in the study had a variety of types of cancer—including lung, breast or prostate cancer—which had spread to their bones, and had a life expectancy of at least three months. The primary measure of success in this trial was the patient's ability to walk.

The trial yielded excellent news. Significantly more patients in the surgery group were able to walk after treatment (84 percent compared to 57 percent). Those in the surgery group also retained the ability to walk significantly longer than those with radiotherapy alone. Thirty-two patients entered the study unable to walk; over three times as many patients in the surgery group regained the ability to walk compared with patients in the radiation-only group. In addition, surgical treatment substantially reduced the use of steroids and painkillers.

"The results were so convincing that the study was ended two years early," says Patchell, his face easing into a smile. "You have to have a hugely positive trial for

that to happen." This study, which was funded by grants from the National Cancer Institute (more than \$1 million) and the National Institute for Neurological Disorders and Stroke, was published in 2005 in *Lancet*, one of the world's most prestigious scientific journals.

"This trial has already changed the way that this fairly common condition is treated around the world and has made a big impact on the quality of cancer patients' lives everywhere," says Tibbs, who joined the UK Department of Surgery in 1980.

Revolutionizing Treatment for Brain Metastases

"Phil and I were both interested in neuroscience and just hit it off," Patchell says, winding the clock back three decades. Patchell, then a UK med student, met Tibbs, a neurosurgery resident, in the early '70s. "And we were both disciples of Dr. David B. Clark, a wonderful old-school neurologist who was here at the time. He launched the careers of many future neuroscientists, including Dr. William Markesbery, Phil, me, and many others."

Tibbs adds, with a grin, "Dr. Clark was almost a god-like figure to us. His neurological skills and his patient skills were so finely-tuned that students would practically fight each other to go on Grand Rounds with him. I used to take *dates* along with me when I went with him on these rounds," Tibbs chuckles. "That's how impressive Dr. Clark was."

Tibbs and Patchell were inspired by Clark's example, and their work led to two landmark studies that changed the standard of care for patients with brain metastases—the most common type of migratory cancer.

In 1986, Patchell designed a study to determine if surgery was the most effective way to treat brain metastases, and he assembled a talented team at UK that included Tibbs, Markesbery and Young. Forty-eight lung cancer patients with a single brain metastasis took part in this study and were randomly assigned to either the group of 25 patients who underwent surgical removal of the tumor followed by radiotherapy, or to the radiotherapy-only group of 23 patients.

The results of this trial, published in the *New England Journal of Medicine* in 1990, showed conclusively the importance of surgery for patients with a metastasized brain tumor. In the surgical group, only 20 percent of patients experienced recurrence of the tumor in the brain, as opposed to 52 percent of patients in the ra-

diation group. The length of survival was significantly longer in the surgical group, and the patients treated with surgery remained functionally independent nearly five times longer.

"This was a significant study that changed the way brain metastasis patients were treated," says Patchell. "And this isn't a trivial thing—metastatic brain tumors are the most common brain tumors in adults and outnumber primary brain tumors—those tumors that begin in the brain—by at least 10 to 1. Over 200,000 new brain metastases occur in patients in the United States every year. So this study has affected tremendous numbers of people in this country and worldwide."

They had shown that surgery worked. The next question that needed to be answered was: Is postoperative radiotherapy necessary?

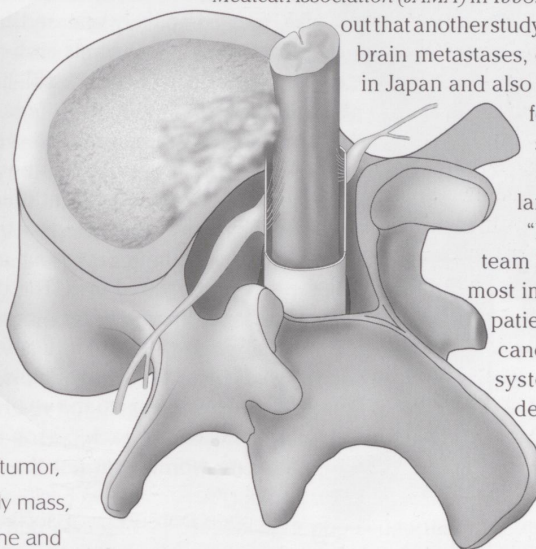
"I originally wanted to do this study to prove once and for all that patients didn't need radiation therapy," says

Patchell, the study's principal investigator. "I

thought that it had long-term side-effects, and that patients would be much better off without it. Well, this just goes to show that we can be wrong in our



Spinal metastasis typically results in compression of the spinal cord. The cancerous tumor, depicted here as a cloudy mass, first grows inside the bone and then enlarges and presses on the spinal cord.



predictions," he says emphatically, "and shows why these trials need to be done."

This randomized trial involved other university-affiliated cancer treatment centers and included 95 patients who had a single metastasis to the brain. Forty-nine patients were given postoperative whole-brain radiotherapy (conventional radiotherapy given to the entire brain to eliminate any residual disease), and 46 patients received no further treatment.

"The main thing we wanted to find out," says Tibbs, "was if there would be a recurrence of a tumor anywhere in the brain. We were also interested in length of survival, cause of death, and the patient's ability to function independently."

The results showed that a brain tumor recurred far less frequently in the radiotherapy group than in the observation group (18 percent recurrence compared to 70 percent). And, it turned out, patients in the radiotherapy group were less likely to die of neurological causes than patients in the control group (14 percent died compared to 44 percent in the control group). "This trial established that radiation was a useful treatment and clearly did prevent recurrence of tumors," says Patchell.

The study was published in the *Journal of the American Medical Association (JAMA)* in 1998. And Patchell points

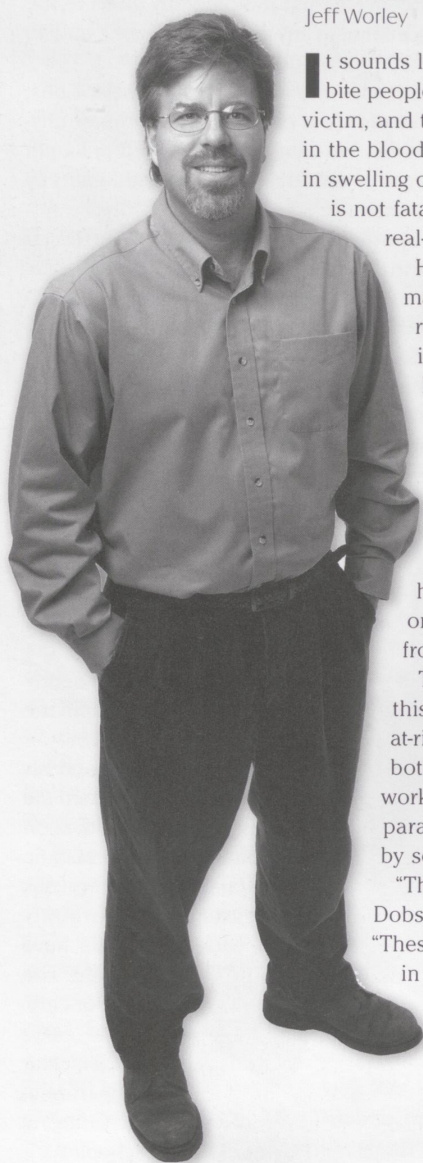
out that another study on radiotherapy for brain metastases, conducted recently in Japan and also published in *JAMA*, found virtually the same results nearly a decade after the landmark UK study.

"Dr. Patchell and his team have performed the most important studies on patients with metastatic cancer to the nervous system. His carefully designed trials have transformed the 'standard of care' worldwide," says Jay Loeffler, chair of the Department of Radiation Oncology at Harvard Medical School. ■

The annual online issue of *Odyssey* (www.research.uky.edu/odyssey/exclusive) will take you along on journeys to French Polynesia, Kyrgyzstan, Japan, and Ethiopia as we highlight the work of several UK researchers and educators far from our borders. Their projects range from helping to develop the curriculum of American Studies in Kyrgyzstan to the beef safety issue in Japan to the social dynamics of population shifts in Ethiopia. The common denominator of these projects is advancing knowledge and improving people's lives. So cruise onto our website and enjoy the trip. The story of UK entomologist Stephen Dobson and his work to help eliminate a mosquito-borne disease in French Polynesia is reprinted here.—JW

Mosquito Birth Control

Jeff Worley



It sounds like the plot of a horror flick. Mosquitoes on some distant tropical island bite people and deposit worms in their blood. These worms grow and mate inside the victim, and the adult female worms produce thousands of larval worms that circulate in the blood. The worms can block and damage the lymph system, which can result in swelling of the legs and other extremities. This swelling, known as "elephantiasis," is not fatal, but results in severe disability and social stigma. Welcome to the very real-world scenario of human lymphatic filariasis.

Human filariasis, a close relative of the dog heartworm, affects only humans. This is a globally important disease, occurring in 80 countries. Currently, 120 million people have filariasis, 40 million people are seriously incapacitated, and 1.2 billion people are at risk, according to Stephen Dobson, an associate professor of entomology in the University of Kentucky College of Agriculture.

When Dobson talks about filariasis, his expression turns solemn; his words precise and direct. Photographs mounted in the hallway outside his office constantly remind him of the importance of his mission: children with elephantiasis, their legs swollen to four times their normal size, toes completely encased in a red glove of their own skin. And a huge blown-up photo of his arch nemesis—*Aedes polynesiensis*—landing on human flesh with its six stilt-like legs, the hungry needle protruding from its face dipping down to feed.

The scientists heading up this project envision a 1-2 punch to eradicate this disease. The first strike will be a massive campaign to treat the entire at-risk population with the potent drugs diethylcarbamazine and albendazole, both of which have been used to treat other worm diseases. Albendazole works by keeping the worm from absorbing sugar (glucose), so that the parasite loses energy and dies. The drugs have been donated to this project by several major pharmaceutical companies.

"The initial strategy is give drugs to everyone in the affected areas," says Dobson, who came to UK after doing postdoc work at Yale for two years. "These pills are analogous to the yearly treatment given to dogs for heartworm in the United States—each person takes one dose a year." The pills kill the immature worms, but not the adult worms, which live in the human

Stephen Dobson, an associate professor of entomology, is part of an international team working to eradicate human lymphatic filariasis and dengue. In his UK lab, he and his team are using the bacterium *Wolbachia* to damage the mosquito's reproductive capabilities.

lymphatic system for up to five years. So to stop the transmission cycle, the entire population must take the pills for at least five years to prevent new infections, while waiting for the adult worm to die of old age.

"But here's the problem: we know that lymphatic filariasis transmission cannot be stopped in some areas using drugs alone. On some South Pacific islands, for example, drug treatment has continued for decades, yet the disease persists." One explanation, Dobson says, is insufficient participation in the drug program—if people experience strong side effects after taking the pills, they are less likely to take them the next year. "So in conjunction with this strategy, our approach is to help break the transmission cycle by targeting the mosquito population."

To do this, he and his team are using *Wolbachia*, a type of bacterium that infects arthropods and that can significantly damage the reproductive capabilities of its hosts. "We hope to sterilize the mosquito population by releasing many *Wolbachia*-infected males." (Only female mosquitoes bite and transmit disease.) Sterility will cause the mosquito population to dwindle. In the next generation, continued releases of sterile males into the smaller mosquito population results in even more sterility, due to the higher ratio of sterile to fertile males, and as this process is repeated, eventually the last female mates with a sterile male, and "it's 'game over' for the mosquito," Dobson says.

He has shown that this approach works in the lab, so now what?

"The next step is to test the strategy in field conditions," he says. He and his team are currently building large outdoor cages in French Polynesia, cages which will be populated with mosquitoes collected from the field. The researchers will then release sterilized males into the cages to see if they can survive and compete with normal males for mates. "The long-range goal is to be able to suppress these mosquito populations in areas where they cause tremendous human suffering."



Matt Barton

In a related project, Dobson is the U.S. representative on a team of scientists from Australia, Thailand, Vietnam, and Japan leading a campaign to improve methods to control mosquitoes that transmit the dengue virus. This tropical disease can result in high fever, severe muscle and joint pains, and death. Similar to human filariasis, new dengue infections can be transmitted only by mosquitoes. The project is funded by a \$10 million grant from the Bill and Melinda Gates Foundation, as part of its Grand Challenges in Global Health initiative.

Dobson was chosen to lead the U.S. part of this research because of his groundbreaking work at UK creating new *Wolbachia* infections in mosquitoes, including *Aedes aegypti*, the main carrier of dengue and yellow fever. The researchers do this by injecting mosquito eggs with a strain of *Wolbachia* that passes from mother to offspring. Once established, the infection can spread without assistance into the mosquito population through a mechanism called "cytoplasmic incompatibility," the same mechanism used to make mosquitoes sterile in the filariasis project.

"Dobson's work is a significant step towards completely replacing a population that can transmit dengue with one that can't," says Steven Sinkins, quoted in a *New Scientist* article in October 2005. Sinkins studies *Wolbachia* at the University of Oxford in England. ■

University Research Professors 2006-2007

Alan Daugherty: Genetically Modifying Serendipity

The bad news: It's the 10th biggest killer in the country, it has no effective treatment except for risky surgery, and it affects a rapidly rising demographic. The good news: Alan Daugherty's groundbreaking research may lead to prevention—or even a cure.

Daugherty, a professor of medicine and physiology, received a University Research Professorship to continue his study of aortic abdominal aneurysm (AAA), a disease that predominantly affects males over 55. Few people have heard of the disease, and even fewer study it—making Daugherty's work all the more important.

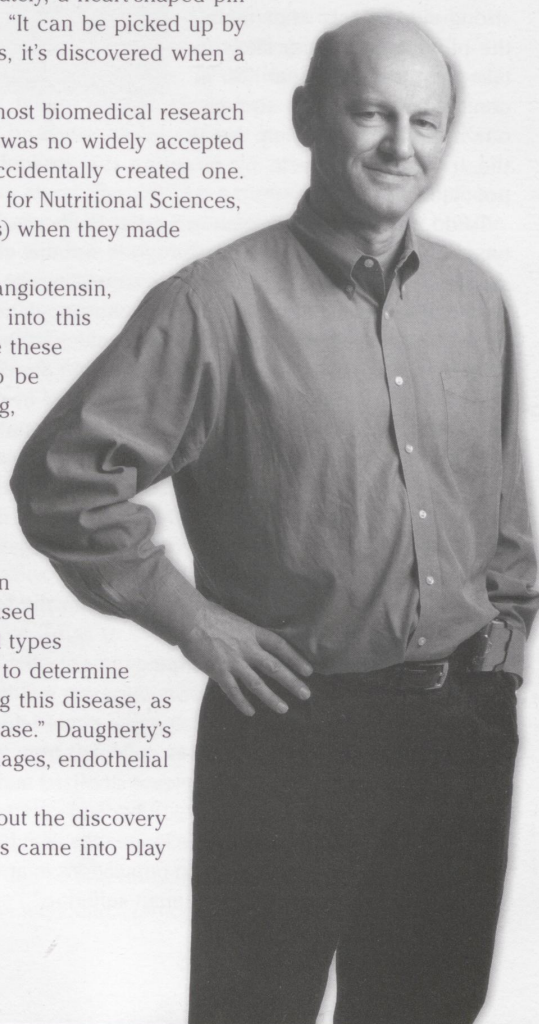
For reasons that are still unknown, AAA begins with a bulge in the aorta; the bulge eventually ruptures, causing massive internal bleeding. "At the moment, it's a disease that you usually don't know you have until the thing bursts and you bleed out into your belly," says Daugherty, who wears, appropriately, a heart-shaped pin to attach his medical center name tag to his shirt pocket. "It can be picked up by vague symptoms of lower pain." Most of the time, he says, it's discovered when a patient goes into an exam for something else.

Part of the reason so little is known about AAA is that most biomedical research depends on information from animal models, and there was no widely accepted animal model for AAA until 2000—when Daugherty accidentally created one. Daugherty and Lisa Cassis, director of the Graduate Center for Nutritional Sciences, were researching atherosclerosis (hardening of the arteries) when they made a fortuitous discovery.

"Lisa and I were doing studies in which we infused angiotensin, a very common substance that controls blood pressure, into this specific strain of mice," he says. "And we began to notice these big bulges in their abdomens." The bulges turned out to be AAA. When Daugherty and Cassis published their finding, the scientific community adopted their animal model as a way to study the mechanisms of the disease.

The research professorship funding will help Daugherty, who also serves as the Gill Foundation Chair in Preventive Cardiology and the director of the Cardiovascular Research Center, to conduct the expensive genetic manipulation required to study the disease in mice. "Our project is based mostly on the fact that your aorta has several different cell types that respond to angiotensin II," he explains. "We're trying to determine the type of cell in the aorta that is responsible for starting this disease, as well as those responsible for the progression of the disease." Daugherty's lab has narrowed down the possible cell types to macrophages, endothelial cells and smooth muscle cells.

Daugherty uses the word "serendipity" when he talks about the discovery of the animal model. "A very unusual set of circumstances came into play here, and we simply capitalized on our good luck."



by David Wheeler

Daret St. Clair: A Heart for Cancer Research

Daret St. Clair was only five when she heard the story that would determine the course of her life. Her school teacher in Bangkok, Thailand, had assigned the class to read a story about Marie Curie, the first woman to win a Nobel Prize. "The story really fascinated me," says St. Clair, who speaks with a strong Thai accent. "Even as a very young girl, I realized there was a future for girls in science."

For St. Clair, the future has come. A professor in the Graduate Center for Toxicology, she received a University Research Professorship to continue her trailblazing work in cancer treatment. Unlike most cancer researchers, St. Clair focuses on protecting healthy organs, particularly the heart, during treatment. "Generally, the focus is on how best to kill the cancer, not usually on what happens to the non-cancerous organs," she explains, as sunlight pours into her UK office. "We are unique in that sense."

The problem is clear: When a drug is powerful enough to kill cancerous cells, it often destroys

healthy tissue in the process. St. Clair's research will potentially provide a way to avert this complication—with the help of an enzyme called MnSOD.

MnSOD, or manganese superoxide dismutase, is a crucial component in the respiration process. "When we inhale air, we make energy, and that energy activates the mitochondria," St. Clair says. But this process also generates a toxic substance called superoxide. To combat superoxide, humans need MnSOD. "Without it, we cannot live," she says.

Her study of this enzyme began to pay off when she discovered that MnSOD suppresses the growth of cancerous tumors. That finding drew the attention of the National Cancer Institute, which awarded her a \$600,000 grant in 1998.

Not only does MnSOD suppress the growth of cancer, but it may also lower the risk of heart problems that result from cancer treatment. St. Clair is researching the possibility that cancer drugs destroy too much MnSOD, thereby triggering heart disease. Her observation: MnSOD resides in the mitochondria—and 40 percent of a heart cell's volume consists of mitochondria. "It's extremely important that the heart has this enzyme."

If the amount of the enzyme decreases during cancer treatment, the already-strained heart may be pushed to its limit. In contrast, if the amount of the enzyme increases, the heart could be protected during treatment. "Can we make the body create

more of this enzyme? And how?" St. Clair asks. "If we cannot make more of this enzyme, can we prevent it from being destroyed by the drug?"

Using the professorship funding as seed money, St. Clair will work to answer these questions by developing a program that will expand her research into other tissues, such as the brain. "This expansion is a team effort that will include Dr. Mary Vore in toxicology, Dr. Allan Butterfield in membrane sciences, and several oncologists in the Markey Cancer Center. We're excited about the opportunity to translate our basic research into patient care."



Jonathan Phillips: Seeking Chaos in the Dirt

Some people associate the George Clinton song "Atomic Dog" with early 1980s rhythm and blues, others with the hip-hop artists who sampled it a decade later. Jonathan Phillips associates the song with chaos analysis in earth surface systems. The song happened to be on the radio when Phillips had a Eureka moment. "To this day, I think of the paper that resulted from it as "The Atomic Dog Paper,"" says Phillips, a professor in the Department of Geography.

His research, which proposes that there is no single, stable, "natural" landscape toward which nature is tending, may one day help humans plan for sudden changes in their environment. In the meantime, his work has added a new recipe for the geosciences. To follow the ingredients, you start with geomorphology—the study of processes occurring at or near the earth's surface. Then you add a dash of chaos theory, which emphasizes the influence of initial conditions on the end product of a process.

"In other words, the tiniest variation in initial conditions can lead to much different outcomes further down the line," says Phillips, who came to UK in 2000 from a faculty position at Texas A&M. "But chaos theory runs right into a major problem with the geosciences—the initial conditions are unknown and unknowable. We can't rewind the clock and see what was there 10 years ago, much less a hundred or a billion."

But Phillips has overcome that obstacle. "In the earth sciences, we often deal with what's called 'partially specified systems,'" he begins. We know the qualitative relationships between two things—relationships of width, depth, velocity, or friction, for example. But quantitative relationships are another matter. "You can't

really come up with a number or a specific equation that will apply to changing conditions in a tobacco field in Kentucky, a pine forest in South Carolina, or a desert in Libya. All you have are the qualitative relationships."

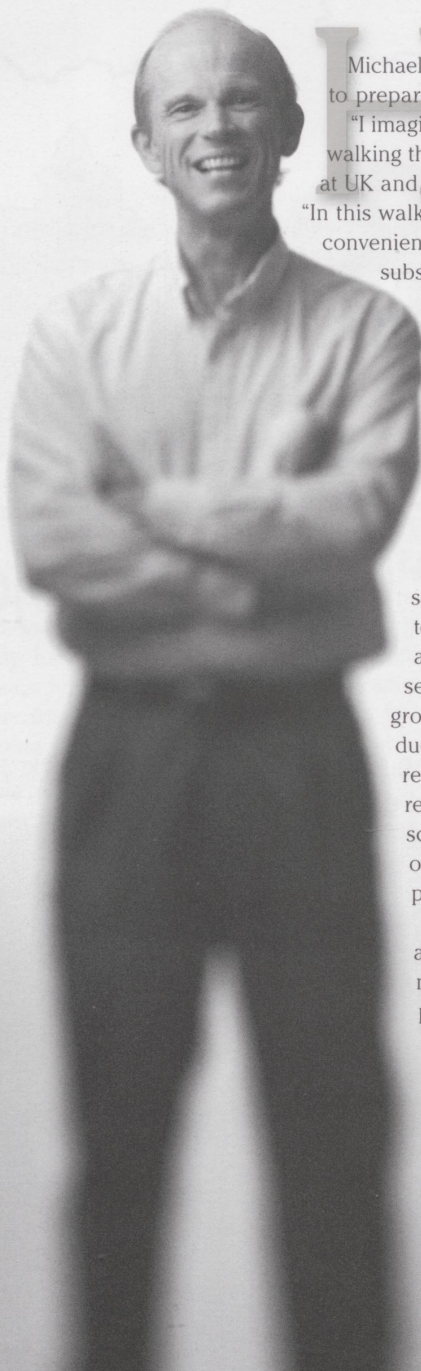
For a concrete example of such a relationship, imagine a hillside. Though many geographic factors are interacting simultaneously to determine the hillside's characteristics, Phillips knows that if vegetation increases, soil erosion decreases. And in general, a wetter climate means lots of trees, a dryer climate means grassland, and a very dry climate means desert. There is no specific equation to determine how climate affects landscape, but qualitative relationships help Phillips understand the results of nature's interactions. "Basically I figured out a way to analyze the presence of 'chaos' based on just those qualitative relationships," he says.

With his research funding, Phillips will examine such relationships to detect evidence of abrupt environmental changes at sites such as the Cumberland Plateau and Red River Gorge in Kentucky, the Ouachita Mountains of Arkansas, and the Texas Coastal Plain. At each location, he will study various features of the landscape to discern how it has responded to changes in climate, land use and sea level. "If we can find the clues or signatures that abrupt environmental change leaves behind, this would enable us to better prepare for abrupt changes in the future."

Despite the esoteric language on his chalkboard, Phillips occasionally hints of a simpler time his career. "Almost every kid likes to play in the mud and play around in streams," he says, smiling. "I found a way to make a living at it."

[www.research.
uky.edu/odyssey](http://www.research.uky.edu/odyssey)

Michael Bardo: Neuromechanisms of Novelty Seeking



The UK Board of Trustees first awarded University Research Professorships in 1977. The goal of these \$35,000, one-year professorships is to enhance scholarly research and awareness of UK's research mission by recognizing outstanding faculty.

Wow do you get teenagers to say no to drugs? Michael Bardo envisions a new approach: using virtual reality games to prepare adolescents for face-to-face encounters in the real world. "I imagine a high-risk adolescent donning a virtual reality helmet and walking through a series of 'trials,'" says Bardo, professor of psychology at UK and director of the Center for Drug Abuse Research Translation. "In this walk through a virtual city, there's the gym, the laundromat, the convenience store. And there's the alley—where a guy is selling illegal substances. What do you do?"

If teens practice saying no in Virtual World—and are rewarded for it, by moving up to a more challenging level of the game, for instance—they are more likely to say no in a real-life situation, according to Bardo. "Just as your arms become stronger from lifting weights, your brain's inhibitors become stronger with exercise. When you're out in the real world, having done these virtual exercises, you presumably would be able to tap into that inhibitory control more easily."

The reasons why adolescents choose to use drugs vary, he says, but biology plays a significant role. Some people are prone to enjoy things like eating unusual foods, climbing mountains, and parachuting from airplanes; these teens are high-novelty seekers or high-reward seekers. Studies have shown that this group tends to find drug use more satisfying. Some of them, due to their biological makeup, also have trouble exercising restraint. These high-novelty seekers are the focus of Bardo's research, which he continues to carry out with Tom Kelly, scientific director of the center, Don Lynam, former professor of psychology at UK, and Nancy Grant Harrington, associate professor of communication.

To learn more about these traits in humans, Bardo studies animals. "You can't really get down to the detailed, precise neuromechanisms without using animal models," he says, pointedly.

"Rats, like people, vary in their preferences. You can expose a group of animals to a drug, but they don't react the same," he says. "Some are apparently biologically prepared to find the drug more rewarding than other rats we test. We're interested in individual differences in the brain that we can use to predict which animals will be the high responders and which animals will be the low responders."

By using microdialysis (extraction of chemicals from the brain) and microinjection (injection of chemicals into the brain), Bardo can perform specific experiments on rats to identify the mechanisms at work in novelty-seeking and inhibition. He can then translate the findings to humans by targeting the analogous parts of the human brain.

If we can understand the biological connection between novelty-seeking and inhibition processes, argues Bardo, we can identify adolescents who are most at risk for substance-abuse disorder—before their first drug experience. "And then we can intervene." ■

Fighting Back:



The Marty Driesler Cancer Project

by Jeff Worley

Cancer hits Kentucky hard: Our state has the fourth highest cancer death rate in the nation. And cancer hits eastern and southeastern Kentucky the hardest. Between 1998 and 2002, over 3,500 people in this region died from lung, esophageal or liver cancers.

Why is cancer so deadly in this area of Kentucky?

"Two reasons: late diagnosis and the aggressive nature of these cancers," says Alfred Cohen, now retired, who led UK's Markey Cancer Center for the past six years. "So it became crystal clear that without innovative strategies for earlier detection and state-of-the-art treatment in this high-risk population, deaths from these cancers would continue to rise."

This dire need gave rise to a unique government-university partnership initiated by 5th-District Congressman Hal Rogers, whose district in eastern and southeastern Kentucky encompasses nearly one-third of the state. Rogers, a Kentucky native, secured federal research funds—to the tune of \$1.7 million (first and second year)—for a project that would help people in this area, and he looked to the University of Kentucky to help bring this idea to life.

He named the project in honor of Marty Driesler, a UK graduate, who served as chief of staff in Rogers's Washington, D.C., office for 12 years. After a three-year battle with lung cancer, she died in November 2003.

In February 2004 Rogers and UK President Lee T. Todd Jr. announced a first-of-its-kind health-care initiative to fight deadly cancers throughout the 29 counties of the 5th Congressional District. Researchers at the UK Markey Cancer Center were enlisted to develop early-detection studies focused on lung, liver and esophageal cancers, and to work with regional and local physicians and hospitals.

"Local health-care providers in this district are the key to the success of the Driesler project," says Susanne Arnold, an associate professor of medicine at UK and an eighth-generation Kentuckian who is directing the lung cancer studies. "This partnership is the key to better health for Kentuckians. We hope to reach more people in our state through the strong relationships they have with their primary care physicians. It also allows them to be screened, diagnosed and treated near their homes instead of traveling to centers like UK," she adds.

Banking on Evidence from Biospecimens

The blood, urine or other biological specimens physicians collect from their patients every day are the cornerstone of the Driesler project.

"We're banking a variety of biospecimens from our 5th-District participants at higher risk of developing lung or esophageal cancer to measure genes, proteins and other molecules—biomarkers—which may tell us about the likelihood that someone will develop cancer or already has an early stage of cancer," says Andre Baron, director of the Biomarker Research Program at the Markey Cancer Center. These specimens are frozen for current and

future use by scientists in Kentucky and across the country.

Baron stresses that these biospecimens are for research use, not clinical use. "As we gather more and more information from these patient samples, we hope to develop a biomarker test that will detect early-stage cancer better than CT scans can. It's a gold mine for discovering and developing a cancer screening test."

Battling Lung Cancer

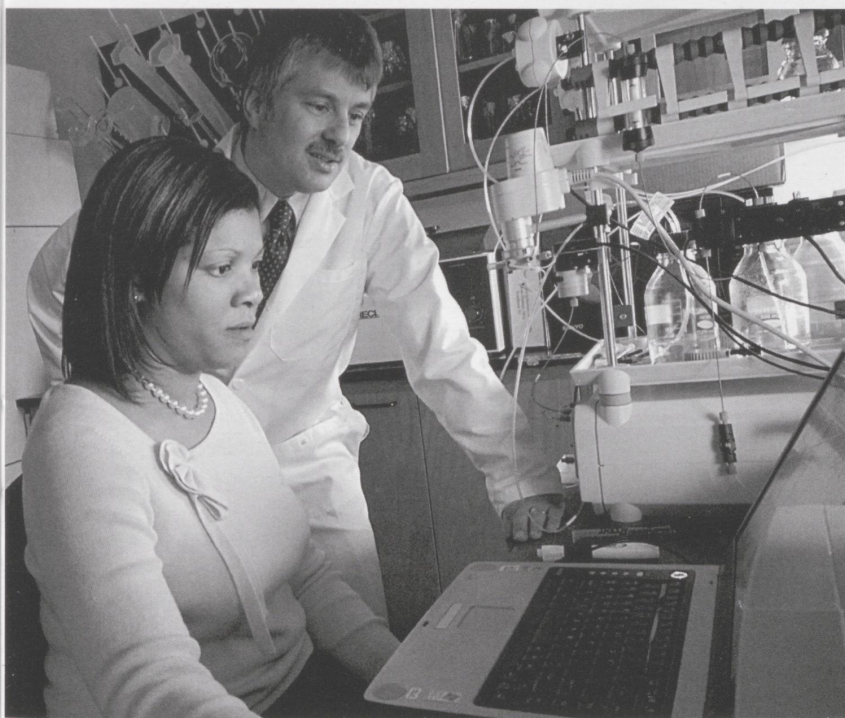
Biomarkers are one guidepost to detect the presence of cancer, but other techniques such as computed tomography (CT), more typically referred to as a CAT scan, are also being put into play.

CT involves body imaging in which

a thin X-ray beam rotates around the patient. Small detectors measure the number of X-rays that make it through the patient, and a computer analyzes the data to construct a cross-sectional image of a targeted area. These images can be stored, viewed on a monitor or printed on film. "By combining CT scanning with approaches such as pulmonary function testing—breathing tests that can detect emphysema—we hope to find the group of patients at highest risk for lung cancer and detect those cancers earlier," says Arnold. Early-stage lung cancer has cure rates of 60 to 80 percent, compared to less than 20 percent for more advanced disease.

In this work, the Driesler project has joined forces with the Kentucky Lung Cancer Research Program to use CT scans to screen people in the 5th District at very high risk of developing lung cancer. Up to 1,000 participants age 55 to 75 with a long-term heavy smoking history and poor lung function will be screened periodically for three years then followed for another two years.

continued on p. 30



Andre Baron, seen here with staff technician Monica King, is director of the Biomarker Research Program at UK's Markey Cancer Center. As part of the Driesler project, biospecimens from people at high risk of developing lung or esophageal cancer are banked for present and future studies.

Early Detection—Are CT Scans the Answer?

When he talks about the importance of the Driesler project, Eric Bensadoun doesn't pull punches. "There isn't any greater health-care problem in Kentucky than lung cancer. It is a scourge of this state," says Bensadoun, a specialist in pulmonary medicine who came to UK from the University of British Columbia in Vancouver in 1999.

Bensadoun's role in the project is to oversee the results of the screening CT scans. What he's looking for are shadows, which represent nodules and may indicate the presence of cancer. And this is precisely where the challenge comes in, because some nodules are cancerous and some aren't.

"Due to the high incidence of smoking in the region, we're dealing with a high-risk population, which means that in a way participants are 'pre-selected' for having a high risk of lung cancer or manifesting a cancer." However, despite this increased risk some nodules turn out to be old scars, likely from a fungal infection, rather than cancer, Bensadoun explains. "So interpreting these scans can be tricky."

Once he reviews the scans, he talks with the patient's physician about the best course of action. "If the scan is normal, then the patient returns for annual screening for two more years as part of the project. If nodules are discovered, then further testing such as a biopsy or, depending on the nodule's size, surgery may be recommended."

Bensadoun stresses the benefits of local community involvement in the Driesler project. "It's a huge advantage to have partnerships with the different community physicians who know the patients, and their patients know them. It makes a big difference when you get medical guidance from your own physician."

BOLD Moves to Fight Lung Cancer

The fourth-leading cause of death of people in Kentucky and other parts of the United States is referred to by an acronym few people are familiar with: COPD. This condition, chronic obstructive pulmonary disease, includes the common maladies emphysema, asthma and bronchitis, and it's a disease with an ugly and clear connection to cancer: people who have COPD are three to five times more likely to develop lung cancer than those who don't have it.

"Of course the big risk factor for COPD, at least in the United States, is cigarette smoking," says David Mannino, associate professor of medicine and director of the Pulmonary Epidemiology Research Laboratory at UK. "Between 70 to 85 percent of people with COPD in this country are either current smokers or have smoked."



David Mannino, associate professor of medicine and director of the Pulmonary Epidemiology Research Laboratory at UK, and Susanne Arnold, an associate professor of medicine, are studying lung cancer in the 5th Congressional District as part of the Marty Driesler project. Kentucky has the highest lung cancer death rate in the United States.

Mannino is heading up another arm of the Driesler project, focused on COPD. He explains that this local effort is part of an ongoing international study, called the Burden of Lung Disease project (BOLD), to determine the percentage of the world's population with COPD. "This study has been completed in five countries and is currently under way in another eight," says Mannino, who is heading up the BOLD study in Kentucky.

"But let's get back to the COPD-smoking connection," Mannino says. "Smoking isn't the only culprit. People who work where they're exposed to dust, vapors, gasses, or fumes are twice as likely to develop COPD." In establishing this connection, he is also looking at early life exposures. He estimates that 60 to 80 percent of people in Kentucky's 5th District grew up in homes heated by an oil-, coal-, or wood-burning stove, or an open fireplace.

To determine the prevalence and causes of lung disease in this area, Mannino enlisted the help of UK's Survey Research Center to recruit qualified volunteers to come to one of five area hospitals for a pulmonary test and to fill out a questionnaire focused on lifestyle choices and medical history. When Mannino closed the study last July, 576 people in the district, age 40 or older, had agreed to participate.

"Our survey includes questions about respiratory symptoms and disorders, smoking, occupational exposures, physical health history, and emotional health," Mannino says. As part of the pulmonary test, volunteers exhale into a spirometer, a

plastic tube that measures air volume and flow rate in the lungs.

Mannino and his colleagues will evaluate the data they've gathered to determine the extent of the COPD problem in the 5th District. "We hope that once the causes and prevalence of this disease are known, local public-policy decisions and interventions based on our data can be better targeted," he says.

Acid Reflux & Esophageal Cancer

We've all seen the ads on TV: A woman groaning and holding her stomach. Then the visual pops up of her digestive tract, liquid in her stomach spurting back up into the esophagus, the hollow, muscular tube that carries food and liquids from the throat to the stomach. The liquid usually contains acid, which can inflame and damage the esophagus.

The woman might simply have a mild case of heartburn. But she may be suffering from Gastroesophageal Reflux Disease (GERD), which can trigger Barrett's Esophagus, an inflammation of the esophagus in which the cells in the lining become cancerous. About one in 10 people with chronic heartburn develop Barrett's, and people with the condition are 30 times more likely to develop esophageal cancer.

How serious is this type of cancer? According to UK's Nicholas Nickl, a gastroenterologist and co-principal investigator of this arm of the Driesler project, this cancer is statistically very bad news. "Esophageal cancer is the third most common cancer of the digestive tract and the seventh-leading cause of cancer-related

Regular CT scans can detect early lung cancer

As reported in the *Los Angeles Times* last October, early detection of lung tumors by using advanced CT imaging yields an estimated 10-year survival rate of more than 90 percent, and smokers and others at high risk should be routinely screened for the disease, according to a study published in the *New England Journal of Medicine*.

The study of more than 30,000 patients shows that the scans are as cost-effective and beneficial as mammography is for breast cancer. "This is compelling evidence that you can use CT screening to find lung cancer, and when you find it early and take it out early, you can cure a high percentage of patients," says Claudia Henschke of Cornell University's Weill Medical College in New York, who led the study.

Laurie Fenton, president of the Lung Cancer Alliance, joined Henschke in calling for routine screening. The results "flip lung cancer survival statistics on their head," she says.

Research Outreach

deaths worldwide. Every year over 13,000 people in the United States are diagnosed with Barrett's, and more than 12,000 of them die from it."

Kentucky's 5th District has one of the highest rates of esophageal cancer in the nation, but nobody knows why. "That's part of the point of the study," says Nickl.

To gather more information about the causes of GERD and its link with Barrett's Esophagus, Nickl and his UK colleague Houssam Mardini, an assistant professor of gastroenterology, have spearheaded a study to explore the link between acid reflux and esophageal cancer. An additional goal is to develop educational programs that will help people with acid reflux steer clear of more severe disease. The researchers hope to enroll 1,000 people from three 5th-District counties—Pulaski, Laurel and Whitley—which have esophageal cancer rates among the highest in the country. So far, 110 participants have enrolled.

Specifically, the researchers want to understand the association between Barrett's and a variety of risk factors, including smoking, drinking, duration of reflux symptoms, frequency of symptoms, and use of medication to control symptoms. The volunteers go to one of the participating hospitals in the three-county area, answer a questionnaire about their lifestyle, diet and medical history, and, if they choose to have an endoscopy (a long, lighted tube is inserted through the mouth to evaluate the esophagus and stomach), that data will be included in the study results. Patients are also interviewed and donate blood samples.

Nickl credits Mardini with shaping this project from the beginning. "We developed various informational brochures that we are making available at

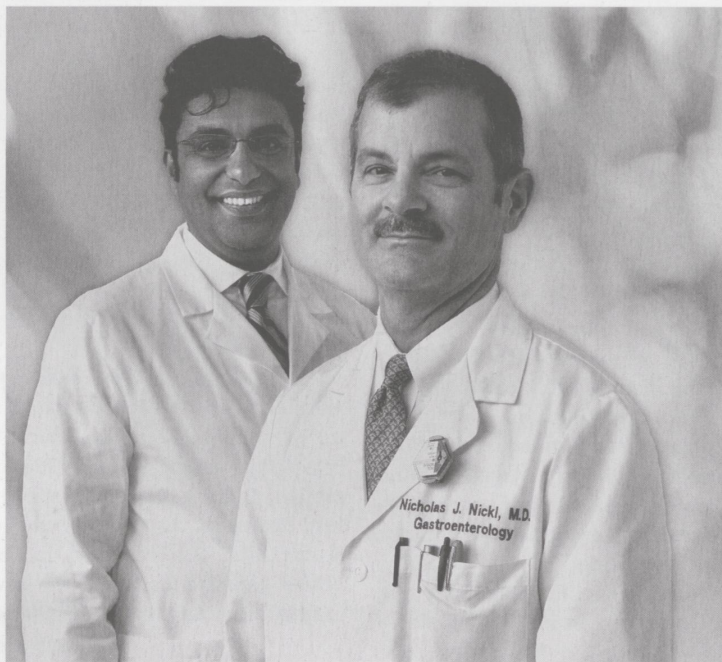
pharmacies, for example, and to the participants who come in for a screening," says Mardini, who earned an M.D. in his native Syria and a master's in public health at the University of Pittsburgh before coming to UK in 2003.

What do Nickl and Mardini hope to accomplish through his project?

"What we'd like to see, first of all, is that our public education campaign did some good—that people who otherwise would not have had screening did so and that it prevented some of them from getting cancer," says Mardini.

"The Marty Driesler Cancer Project is a prime example of how university research can transform an entire region," says UK President Lee T. Todd Jr. "This is precisely the type of research a Top 20 public research university should be conducting—work which is impacting conditions that have long held this state back from reaching its full potential." ■

For more information on the Marty Driesler Cancer Project, visit www.martydrieslercancerproject.org. For more on the Kentucky Lung Cancer Research Program, visit www.kentuckylungcancer.org. For the Kentucky Clinical Trials Network, see www.kyctn.org.



Nicholas Nickl (right) and Houssam Mardini in the Department of Gastroenterology have spearheaded a study to explore the link between acid reflux and esophageal cancer in Kentucky's 5th District. Esophageal cancer is the third most common cancer of the digestive tract.

Meditate on This New Finding

Anybody who practices the ancient art of meditation will tell you it helps them feel more relaxed and attentive. But does it also enhance performance?

Bruce O'Hara, an associate professor of biology at the University of Kentucky, and graduate student Prashant Kaul wanted to find out, so they devised a study to see how meditation might affect the ability to do a boring task during the mid-afternoon, a time when attention often flags. O'Hara and Kaul used a "psychomotor vigilance task," which has long been used to quantify the effects of sleepiness on mental acuity. The test involves staring at a computer screen and pressing a button as soon as a lighted image pops up.

Typically, people take 200 to 300 milliseconds to respond, but sleep-deprived people take much longer, and sometimes miss the stimulus altogether. Ten UK students were tested before and after 40 minutes of either sleep, meditation, reading, or light conversation, with all subjects trying all conditions.

The results surprised O'Hara. "We found that meditation was the only intervention that immediately led to superior performance, even though none of the volunteers were experienced at

meditation. Every single student who meditated showed improvement," says O'Hara. But, he admits, "Why it improves performance, we don't know."

But what about the heralded power nap? Didn't it fare at least as well as meditation?

"No, everybody got worse with a nap," says O'Hara, "because we had the volunteers start the test immediately after they woke up. A 40-minute nap does tend to improve performance, but only after an hour or so to recover from grogginess."—JW

Bruce O'Hara, associate professor of biology, with graduate students Prashant Kaul and Ling Liu, found that to enhance mental acuity meditation is more effective than a power nap.



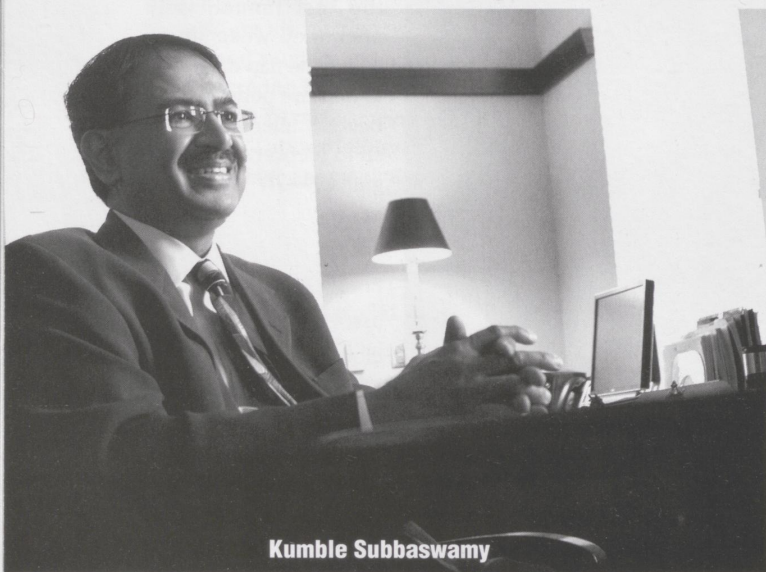
Subbaswamy Is New UK Provost

Kumble Subbaswamy has returned to his old Kentucky home—the University of Kentucky. For nearly 20 years, “Swamy,” as his friends and colleagues call him, was a faculty member and department chairman in physics and astronomy, and an administrator in the College of Arts and Sciences at UK. As provost, Subbaswamy, who most recently was dean of the College of Arts and Sciences at Indiana University, is UK’s chief academic officer, overseeing 16 colleges, UK Libraries and the Graduate School.

“I feel truly honored and excited to be back at UK in an academic leadership position at this critical juncture in its history,” Subbaswamy says. “As a ‘complete’ university—a flagship land-grant university with an on-campus medical school—UK has the opportunity to be a national model for the expanded role a 21st-century public university should play in the state, nation and the world.”

“Dr. Subbaswamy comes to us with a deep understanding for—and love of—this institution, combined with a record of excellence at other leading universities,” says UK President Lee T. Todd Jr.

“Lexington is where I have spent the most time in my life, and both my children were born here,” Subbaswamy says. “My family and I are happy to be back in the Bluegrass.”—Jay Blanton



Kumble Subbaswamy

Minimum Wage Study Turns Up Surprising Results

Is a higher minimum wage good for workers? You’d think so, but Aaron Yelowitz, a UK associate professor of economics who piloted a study of a recent minimum wage hike in Santa Fe, New Mexico, would answer the question by saying, “That all depends.”

“What we found is that the living wage hike to \$8.50 an hour the city enacted in 2004 that applied to all private businesses was a good thing for most workers who kept the jobs they had. But this change had an extremely large and negative effect on those with less than 12 years of education,” explains Yelowitz, whose findings have been cited in *The Wall Street Journal* and numerous other publications and broadcasts.

Using mathematical estimations that utilized other areas of New Mexico to control for a variety of economic factors, this study found that after the wage hike, the likelihood of unemployment for employees in Santa Fe went up by 3.3 percent. For less-educated employees, however, the results were much higher, with their likelihood of unemployment increasing 8.3 percent.

If low-wage employees retained employment following the increase, one would expect a significant increase in wages in Santa Fe, Yelowitz reasoned, but there was no statistically significant increase in wages. “This suggests the possibility that less-skilled employees were replaced with more-skilled employees—already earning more than \$8.50 an hour.” Also, he says, some lower-wage workers took home smaller paychecks because employers cut back on overtime in order to absorb the higher hourly rate they were required to pay.

“My research showed that Santa Fe’s labor market lost 540 jobs because of the wage hike, almost all of them among less-educated adults,” says Yelowitz. “Although minimum wages are intended to help poor workers, this was, unfortunately, not the case in Santa Fe.”—JW

UK Researcher Pinpoints Chronic Wasting Disease Transmission

University of Kentucky researcher Glenn Telling's study of infectious prions in deer with chronic wasting disease (CWD) is the subject of a story in a recent edition of the prestigious journal *Science*. Prions are proteins that naturally exist on the surface of nerve cells in the brain of every human and animal, but that somehow change shape and cause damage.

CWD is a neurological disease of deer and elk that produces small lesions in the brains of infected animals. It is similar to mad cow disease in cattle and scrapie in sheep, usually fatal diseases affecting the nervous system and marked by intense itching and loss of muscular control.

The study found the disease is transmitted by animals' blood and saliva, raising concern about animal-to-animal contact with the infected fluids. CWD is known to be transmissible between animals; however, until this study, the exact mode of transmission wasn't known. Although the spread of CWD to humans has not been reported, scientists believe it is possible.

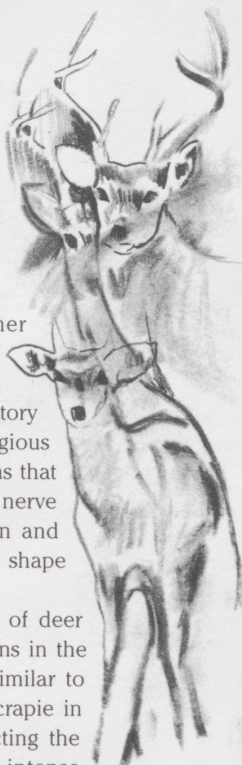
For more about Glenn Telling's research on prions, see "Beware the Shape Shifter" in the Spring 2003 *Odyssey* (www.research.uky.edu/odyssey/issues.html).—JW

UK Gets \$1.8 Million for Math Outreach

Math enrichment in two Kentucky counties is the focus of a new University of Kentucky project funded by a \$1.8 million grant from the National Science Foundation. The grant, known as Algebra Cubed, is funding 10 UK science, math or engineering graduate fellows each year for three years as math specialists in Bath and Powell counties, and also funding 10 teachers who will serve as mentors to the fellows.

The goal of this project is to sharpen the math skills and improve the content knowledge of middle- and high-school students in the two counties. UK graduate students will work on-site with teachers and students 10 hours a week.

"We're introducing new ways of understanding mathematics," says Richard Millman, a UK mathematics professor, who is heading up this project. "And our students are learning teaching skills firsthand from the mentors." Bath and Powell counties were chosen for the grant be-



cause of their low percentage of high-school graduates that go on to earn bachelor's degrees and the desire of teachers and school administrators for improved mathematics instruction.

"To receive a grant of this amount in math is absolutely wonderful for our students, community and teachers," says Nancy Hutchinson, Bath County superintendent.

Rachelle Bouchat, a teaching assistant in math at UK, is one of the graduate students taking part in this program. "Algebra Cubed has allowed me to see firsthand the math preparation students are receiving and has given me the opportunity to help improve students' math skills so that they can be successful in both college and in life." Bouchat works at Powell County High School in Stanton, Kentucky, with Algebra 1, Algebra 2, and geometry classes. "The most rewarding part of this is to see the light bulb go off in a student's head when they suddenly see how to solve a problem."

"The university is a strong supporter of enhancing math skills in rural Eastern Kentucky, and this grant continues to build on two of our ongoing programs: UK's Appalachian Mathematics and Science Partnership and the Appalachian Rural Systemic Initiative," says UK President Lee T. Todd Jr.—JW

UK Climbs in National Research Rankings, Hits Record \$290 Million in Funding

The University of Kentucky moved up two spots in the national rankings used to measure research. The National Science Foundation ranks UK 34th among all public universities and 50th among all private and public universities for R&D expenditures.

UK had another record-breaking year in the nationally competitive arena of grants and contracts, bringing in \$290,365,000 in new, externally funded sponsored projects. President Lee T. Todd Jr. says that this amount, a 6 percent increase over last year's total, demonstrates the university's increasingly high standing among research institutions, as well as a commitment by UK to be a catalyst for positive change in Kentucky. This is the fifth straight year UK has exceeded \$200 million in new grants and contracts.

"Because UK is one of the few universities in the country with colleges of agriculture, engineering, and pharmacy, and a complete medical center on one campus, our broad, collaborative research program directly benefits many people every day," says UK Provost Kumble Subbaswamy.—DW

Good Dental News for Expectant Mothers

Two UK researchers were part of a team that recently studied the connection between periodontal disease and pre-term delivery. The clinical trial concluded that while treatment for periodontal disease is safe for pregnant women, it does not reduce the risk for pre-term delivery, low birthweight, smaller fetal growth, or serious levels of hypertension.

The study, 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, was published in November 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 John Novak, professor and associate director of UK's College of Dentistry's Center for Oral Health Research. "Periodontal surgery would normally be delayed until after the pregnancy." James Ferguson, professor and chair in the College of Medicine Department of Obstetrics and Gynecology at UK, worked with Novak on this project, which was backed by a five-year grant from the National Institutes of Health.

The study, which began in March 2003, enrolled 823 women from Hennepin County Medical Center in Minneapolis, the University of Kentucky in Lexington, University of Mississippi/Jackson Medical Mall in Jackson, Mississippi, and Harlem Hospital/Columbia University in New York.

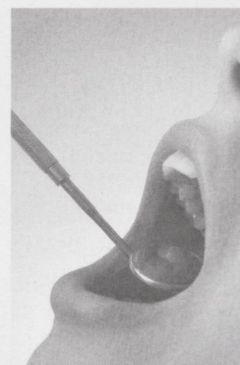
All of the women had periodontal disease, which is caused by bacteria, plaque and other toxins that erode the gum line. The volunteers, between 13 and 17 weeks pregnant upon entering the study, were divided into two groups: Those who received periodontal treatment (root planing and scaling—scraping the root to clean off toxins below the gums) before the 21st week of pregnancy and a control group that received the same treatment after delivery.

"Dental care during pregnancy has long been an issue dominated by caution more than data," says Larry Tabak, director of the National Institute of Dental and Craniofacial research. "The finding that periodontal treatment during

pregnancy did not increase adverse events is important news for women, especially for those who will need to have their periodontal disease treated during pregnancy."

For more on John Novak's research, see "A Mouthful of Evidence" in the Spring 2003 *Odyssey* (www.research.uky.edu/odyssey/issues.html).

—JW



UK Research Now Featured on the ResearchChannel

University of Kentucky research is now reaching more than 22 million U.S. households, thanks to the ResearchChannel, a nonprofit media and technology organization that connects UK investigators with a global audience through cable and satellite distribution. Viewers can also tap into UK research projects through live web streaming and a video-on-demand library that is available 24-hours a day, seven days a week at www.researchchannel.org.

Several scientists in UK's Center for Visualization and Virtual Environments have been featured recently, including Ruigang Yang, an assistant professor of computer science, and Samson Cheung, an assistant professor of electrical and computer engineering.

Yang's project deals with a new approach to 3-D reconstruction in a visual display that he calls a "Light Portal." In general, this portal will create a 3-D display that does not require the use of 3-D glasses. In order to create multiple angles, Yang uses an array of cameras to capture an object.

Video surveillance for security purposes is the focus of Cheung's work. He has created programs that can manipulate video surveillance all the way down to the pixel level. For example, if such a video is being used in a court case, bystanders can be "erased." But these images can be easily retrieved from the video if necessary because images are embedded into a secure watermark.

For more information on these and other UK faculty featured on the ResearchChannel, visit www.research.uky.edu.—JW

Odyssey
Winter 2007

Parting Shots

"I was going to buy a copy of *The Power of Positive Thinking*, and then I thought: What the hell good would that do?"

—RONNIE SHAKES

"A great many people think they are thinking when they are really rearranging their prejudices."

—WILLIAM JAMES

"The real purpose of books is to trap the mind into doing its own thinking."

—CHRISTOPHER MORLEY

"A conclusion is the place where you got tired of thinking."

—HAROLD FRICKLESTEIN

"All war is a symptom of man's failure as a thinking animal."

—JOHN STEINBECK

"Accuracy of observation is the equivalent of accuracy of thinking."

—WALLACE STEVENS

"Avoid the crowd. Do your own thinking independently. Be the chess player, not the chess piece."

—RALPH CHARELL

"The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them."

—SIR WILLIAM BRAGG

"Thinking is more interesting than knowing, but less interesting than looking."

—JOHANN WOLFGANG VON GOETHE

"Today, if you are not confused, you are not thinking clearly."

—IRENE PETER

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Fighting Back: The Marty Driesler Cancer Project, p. 28

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