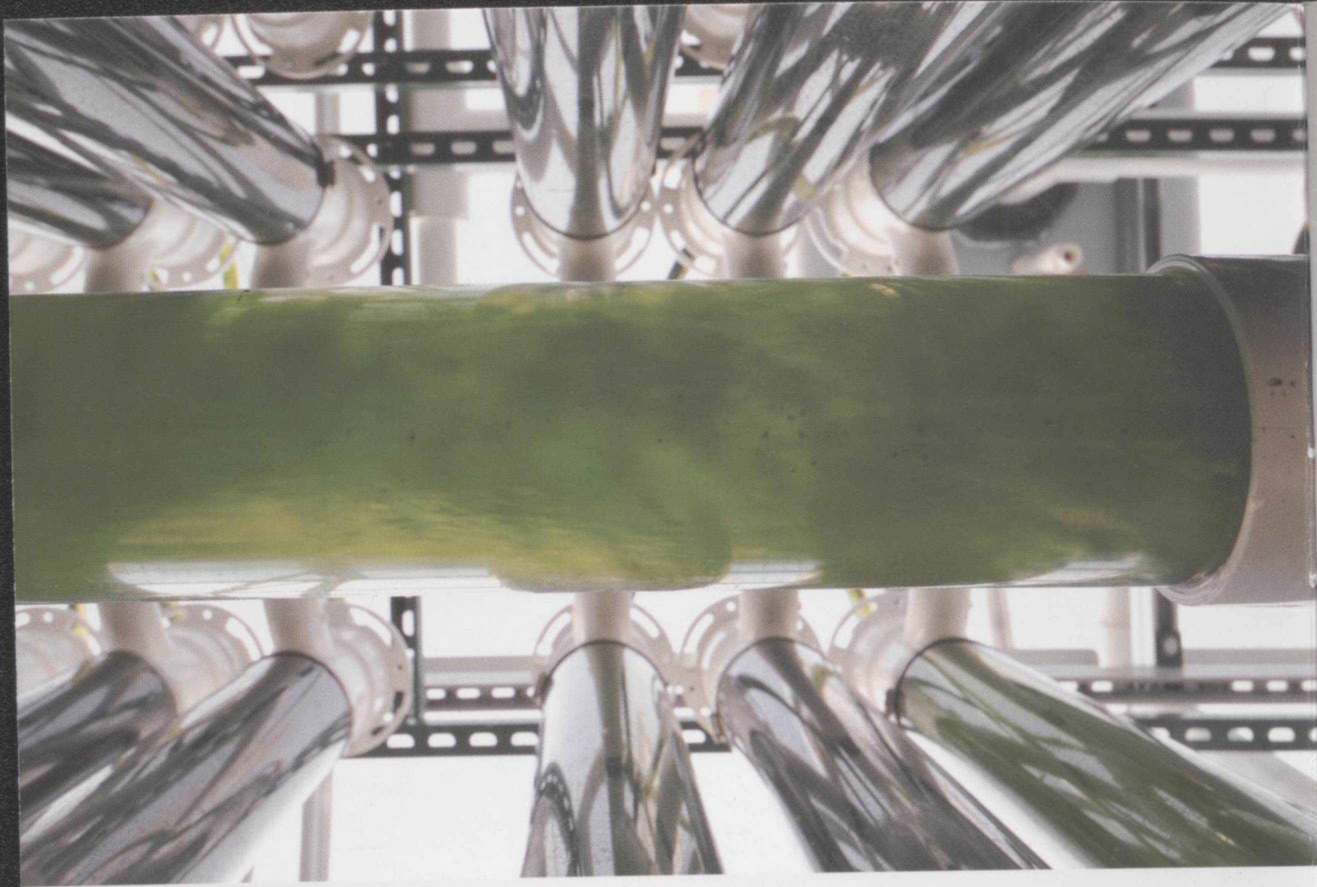
Odyssey

FALL 2010

- Unlocking the equine genetic code
- Engineering horse & rider safety

UK
UNIVERSITY OF
KENTUCKY



Odyssey

Odyssey is published by the Office of the Vice President for Research and covers the latest research advances, innovative scholarship, and outstanding people that are part of UK's research enterprise.

UK serves Kentuckians & the horse industry

The horse is an undeniable emblem of the culture and history of Central Kentucky. Kentucky's signature equine industry contributes $4 billion annually to the economy and generates 80,000 to 100,000 jobs. Since 1987, the University of Kentucky's Maxwell H. Gluck Equine Research Center has been the nexus for scientific discovery, education and outreach on equine health. The Gluck Center, part of the UK College of Agriculture's Department of Veterinary Science, has had an international impact on equine research. Vet Science faculty collaborate on research projects with faculty in the UK colleges of agriculture and medicine, with vets in Central Kentucky and scientists around the world. The Gluck Center has:

- Provided leadership in the sequencing of the complete horse genome and structural characterization of horse genes (see p. 2)
- Developed six major vaccines to protect against strangles, equine influenza, equine rhinopneumonitis, equine viral arteritis, and shaker foal syndrome and validated the efficacy of the equine rotavirus vaccine
- Developed diagnostic tests for contagious equine metritis, Tyzzer's disease, equine protozoal myeloencephalitis, equine herpesvirus myeloencephalopathy, strangles, and equine viral arteritis

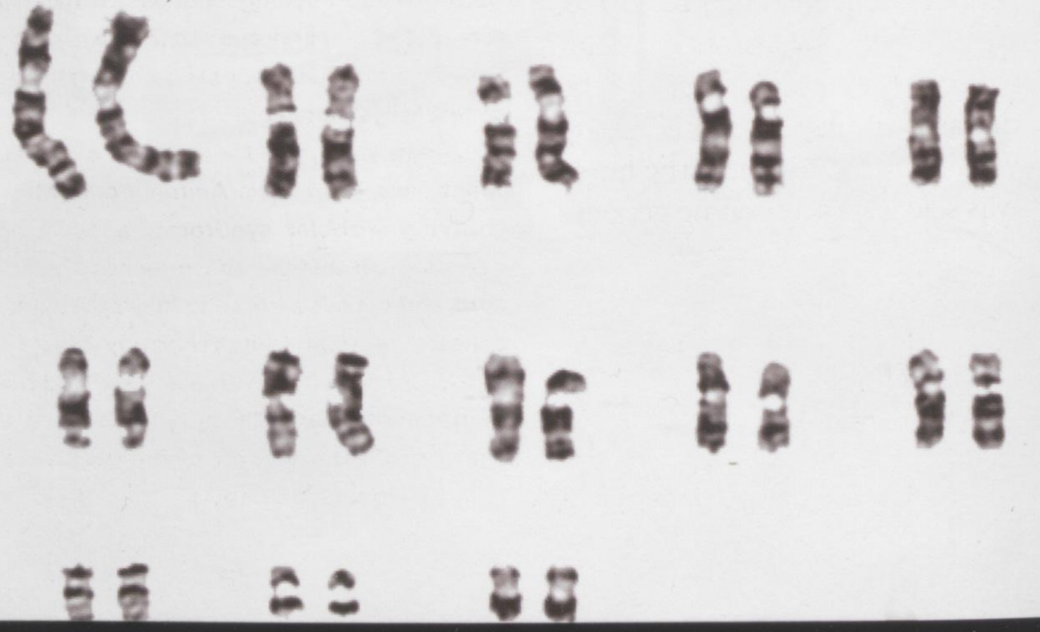
- Developed the enzyme-linked immunosorbent assay (ELISA) test. Based on technology from UK researchers David Watt, Tom Tobin and Daniel Tai, the test detects more than 100 performance-enhancing drugs in horses. These researchers formed WTT, one of UK's first successful spin-off companies. Neogen, an international food and animal safety corporation, acquired WTT in 1991. Since then, Neogen has returned $1.9 million in royalties to UK.

Unlocking the equine genetic code

Genes are destiny. DNA holds the secret to life. "These are phrases that leap to people's minds when you talk about genetics," says Ernest Bailey, an immunogenetics researcher and professor at the UK Maxwell H. Gluck Equine Research Center. "While the human genome project has taught us, unfortunately, that there aren't simple fixes for cancer or heart disease lurking inside our genetic code, the reality is that gene sequencing is to this century what vaccines and antibiotics were to the 20th century."

Bailey's genomics work began in 1994, when he and a group of equine scientists began to discuss their mutual interest in creating a genome map to help them battle equine diseases. With support from the Morris Animal Foundation and the Dorothy Russell Havemeyer Foundation, 70 international scientists came to Lexington in 1995 to start to map the 32 pairs of chromosomes in the horse genome. Each chromosome is a long chain of DNA. The horse genome contains 20,000 genes—pieces of DNA which code for proteins and enzymes.

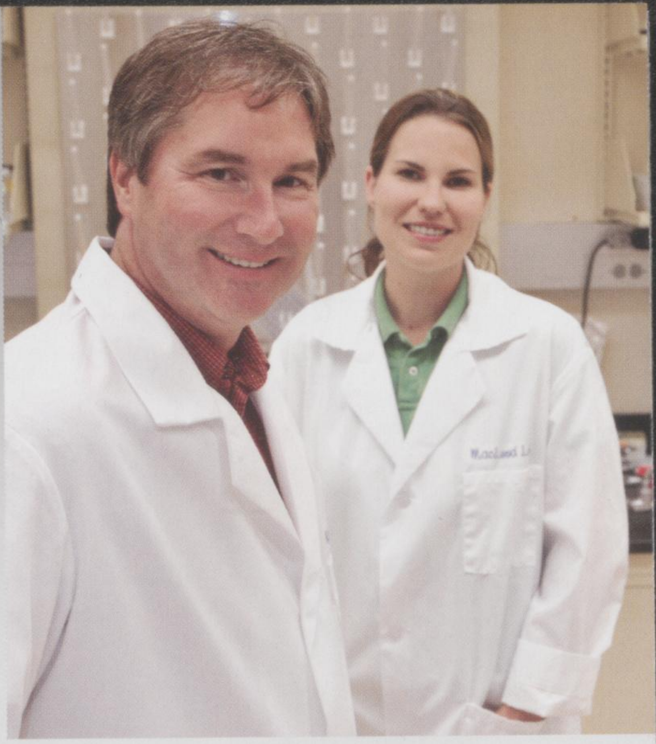
"The human genome project revealed that only 3 percent of DNA makes genes. A whopping 97 percent of DNA does not code for proteins, but this so-called 'junk' has all of the transcribed messages that executed the



design. That 97 percent is where the action is," Bailey says with a smile.

"By 2004 we had our gene map, we could identify point-for-point where the genes for the horse existed, and we could even use the human genome to predict the sequence of the horse genes, but we could not reliably predict the activity of horse genes based on the human sequence. We needed to know what was in that 97 percent of miscellaneous DNA."

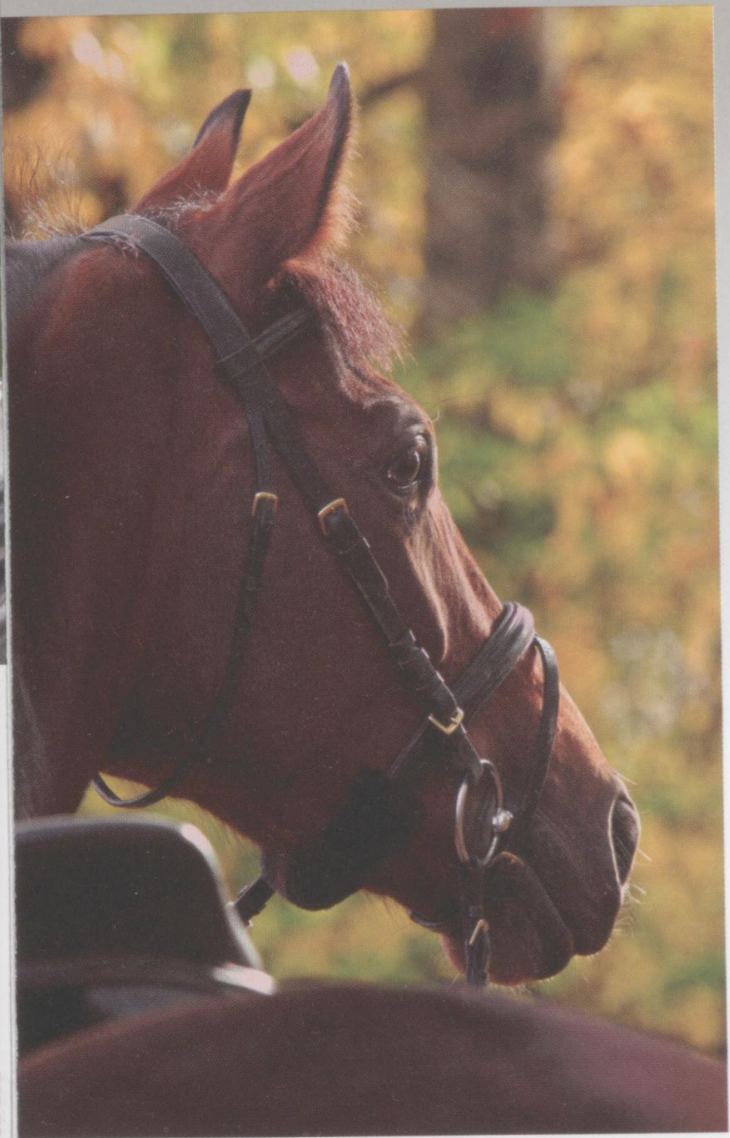
In 2005, when the international group of scientists articulated the "whole horse genome" as their goal, it seemed like a pipedream. Bailey explains that the human genome project cost $3 billion, the chicken genome was $60 million, and the cattle genome was $50 million. "There just isn't that kind of money for an animal we don't breed to eat," he says. But in 2005 the Broad Institute in Boston, where the human genome sequencing took place, was looking for another species to sequence, and, because of the diseases Bailey and his group were wanting to study, the horse was selected. The equine genome



James MacLeod (left), the John S. and Elizabeth A. Knight chair at the Maxwell H. Gluck Equine Research Center, and graduate student Jennifer Janes are both veterinarians in the Department of Veterinary Science.

MacLeod, director of UK's Equine Initiative, came to UK from Cornell in 2004 and studies osteoarthritis in horses. In 2009, he received more than $1 million from the National Science Foundation to develop computer-based methods to study gene expression. "We used to think that one gene produced only one protein, but genome sequencing has revealed that one gene can generate multiple proteins. Through RNA sequencing and our computational strategies, we can sort out these gene products. The methods allow scientists to assess the 'whole forest' (whole genome) before we pick our 'trees' (individual genes) to study at greater detail," says MacLeod.

Janes, who recently received a $100,000 grant from the Morris Animal Foundation, is studying wobbler syndrome, a devastating neurological disease that pinches the spinal cord and causes a horse to lose coordination. Janes is working simultaneously on a Ph.D. at the Gluck Center with MacLeod and board certification in pathology with Dr. Neil Williams, associate director of the UK Livestock Disease Diagnostic Center.



was sequenced in 2006, and by 2007 two assemblies were completed. Bailey adds that a computer algorithm fits the corresponding pieces of DNA together to make an assembly.

The horse genome cost an estimated $15 million, and this newfound genetic treasure trove is online for scientists all over the world to use. Anticipating the next question, Bailey says: "How do scientists use genetics to study diseases? Three ways: you can develop a test for a simple genetic defect, you can study changes in gene expression, and you can study complex diseases that are a combination of genetic and environmental factors."

Thanks to this project, scientists at the Gluck Center have developed a number of simple tests for genetic defects, like mutations that cause dwarfism in miniature horses and a skin-sloughing disease in saddlebreds. But Bailey says the real promise of the horse genome is in studying gene expression. "Everything from what you feed a horse to how much it exercises changes gene expression. We've never had a tool before that allowed us to look at those changes. With complex diseases, like laminitis—a hoof inflammation that ends racing careers—and a number of respiratory conditions, the genome will help us understand the underlying causes and lead to better management practices. Genetics might help us cure some things, but it will absolutely help us develop more effective treatments for the most complex and devastating equine diseases." ■

UK's Livestock Disease Diagnostic Center

Construction crews have been hard at work at the corner of Newtown Pike and Citation Boulevard with the rapid expansion of the University of Kentucky's Livestock Disease Diagnostic Center (LDDC). Funded by a state appropriation, the $28.5 million expansion will double the size of the existing facility, which underscores the importance of protecting the health of Kentucky's animals—a charge the center has had since its creation.

The Kentucky Department of Agriculture established the LDDC in the early 1970s as a way to quickly diagnose disease outbreaks in farm animals. The lab, now operated by the University of Kentucky, offers tests to help veterinarians diagnose and treat diseases. Partnering with the state veterinarian's office, the LDDC's new statewide Animal Health Information Management System can track local disease patterns and warn farm managers and veterinarians of emerging epidemics.

The LDDC also identifies disease outbreaks by conducting necropsies—animal autopsies—on livestock, companion, and wild animals. Director Craig Carter emphasizes that the LDDC is a "life lab": "Everything we do is to save lives. The information gained from the loss of one animal might save 10 or 20 or 100." The center conducts the most equine necropsies in the world due to its proximity to Central Kentucky's horse farms. The LDDC handles 3,000 necropsies and 60,000 clinical cases per year. The American Association of Veterinary Laboratory Diagnosticians recently awarded the LDDC national accreditation, "a gold star" in Carter's words, for its testing procedures for all species.

LDDC faculty members specialize in pathology, clinical pathology, bacteriology, molecular biology, serology, clinical toxicology, virology, and epidemiology. The center's current research projects include studies on wobbler syndrome, contracted foal syndrome, contagious equine metritis, *Lawsonia intracellularis*, and uterine artery rupture. ■

Engineering horse & rider safety

"Athletes shouldn't die if they make one small mistake." This phrase was uttered over and over at the press conferences following the death of Olympic luger Nodar Kumaritashvili in Vancouver last winter. In the weeks after this tragic incident, the speed of the course, the height of the walls and the protective systems were much discussed, emphasizing the responsibility of sports course designers to provide the safest competition environment possible. A research team at UK led by Suzanne Smith is delving into what she calls the "emerging specialty" of sport-safety engineering.

Smith, a mechanical engineer who studies motion, says, "There are direct parallels in other sports, including automotive racing and the equestrian sport of eventing." Eventing, an Olympic sport which will be featured at the World Equestrian Games in Lexington, is the triathlon of equestrian sports, including dressage, cross country and stadium jumping.

To put the risk of injury during the cross country phase in perspective, Smith cites some statistics. If a horse stops suddenly and the rider falls off, there's a 2 percent chance of injury. If the horse falls and the rider falls, there's a 7 percent chance the rider will be seriously injured. "But if the horse summersaults—catches its front legs on a jump and flips over, sometimes landing on the rider—there's more than a 30 percent chance the rider will be seriously injured or killed." These

so-called "rotational falls" are rare, but devastating. And they happen when the horse contacts something that's immovable, and cross country features a wide range of immovable objects, like fences, gates and walls.

A decade ago British engineers developed the "frangible pin" safety system. These break-away pins allow part or all of the jump to collapse if hit with enough impact. While these pins have been widely implemented, they don't address the safety of other kinds of jumps—that's where Smith comes in. With funding from the U.S. Equestrian Federation and the U.S. Eventing Association, a dozen UK faculty and students from mechanical, materials, biosystems and agricultural engineering, and construction management are working together to develop new standards and evaluate new devices to improve eventing safety.

The UK team is studying the physics involved through motion tracking (using high-speed cameras that capture a thousand frames per second) to test new safety devices. The team is simulating the force of a horse striking a jump with a lab sledgehammer—the kind civil engineers use to test bridges. "We can measure the amount of force required to activate a safety device," Smith explains. "In cross country, horses contact the obstacles 25 percent of the time, and they hit hard. With another horse and rider coming up to that obstacle in two to four minutes, the device has to be reset. We're trying to evaluate the difference between a 'regular' hard hoof strike and one that precedes a catastrophic accident to fine tune new devices."

At the 2010 Lexington Rolex Three-Day Event, one of the five four-star events worldwide, the UK team premiered a wood-foam composite fence they developed. "It has the traditional look of wood but has a foam center, so it gives and breaks at a certain force," Smith explains. "This composite was used in a practice fence in the warm-up area at the Rolex.

"By testing our designs, and designs that have been developed all over the world, we can help the sport establish standards for safety devices, and advise course builders on the right way to implement these devices to save the lives of riders and horses." ■

Read more about these equine health and safety stories at www.research.uky.edu/odyssey/equine.

UK successfully secures stimulus funds

The University of Kentucky has received $92.6 million in competitive federal grant funding through the American Recovery and Reinvestment Act of 2009 (ARRA). UK's Vice President for Research James W. Tracy says, "In these tough economic times, the things that will push UK closer to Top 20 status remain the same—great people, new facilities and leading-edge technology. UK is using these funds to advance its Top 20 research agenda, to attract excellent faculty, and train the next generation of scholars and scientists."

UK's ARRA grants, which run the gamut from plant-based fuels to autism training for teachers, not only fulfill national goals on renewable energy and job creation, they also tackle our "Kentucky Uglies." This term, coined by UK President Lee T. Todd, Jr., describes the conditions that have held Kentuckians back for generations—poverty, poor health care and illiteracy. By addressing our state's biggest health problems, like obesity and diabetes, the University of Kentucky can help people live healthier, more productive lives.

CAER to expand with $11.8 million NIST grant

The U.S. Commerce Department's National Institute of Standards and Technology (NIST) awarded $11.8 million in ARRA funding to support the expansion of UK's Center for Applied Energy Research (CAER). This grant is being matched with $3 million from the Commonwealth of Kentucky and $1 million from UK to complete the $15.8 million project. CAER Director Rodney Andrews is the principal investigator on this grant which will significantly expand the 30-year-old center with a new 36,000-square-foot building dedicated to research in the biomass and biofuels industries, advanced distributed power generation and storage, and technologies for electric vehicles. The facility will include labs for process development, prototype manufacturing and testing, as well as applied research on batteries, capacitors, solar energy materials, and biofuels. The project is expected to be completed in summer 2011.

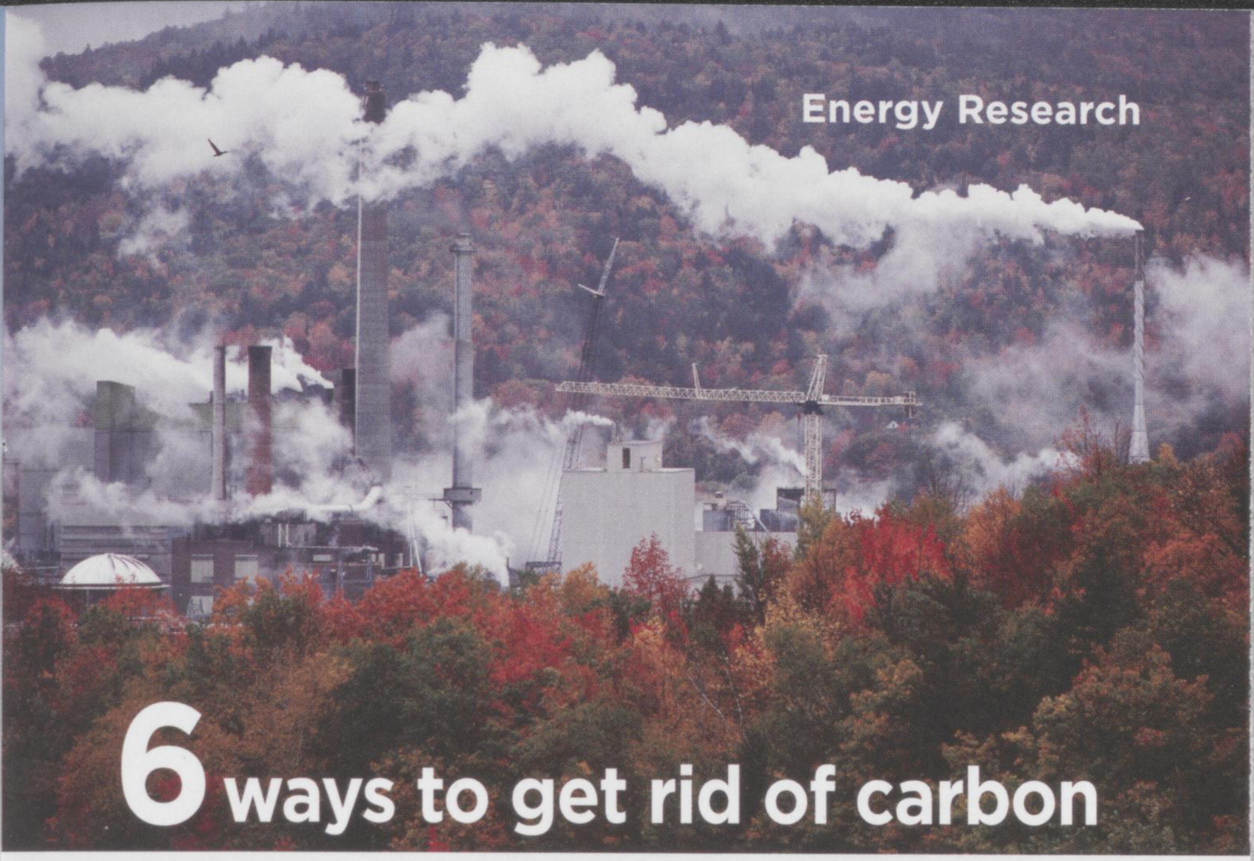
UK wins $6.4 million grant for rodent laboratory

UK received a $6.4 million ARRA grant to build a new laboratory for collecting, maintaining and storing rodent sperm and embryos for use in genetic research on conditions like cardiovascular disease. The grant from the National Center for Research Resources, part of the National Institutes of Health, will support the 9,026-square-foot laboratory's construction as part of a fourth-floor renovation of the Sanders-Brown Center on Aging. The laboratory will be comprised of three facilities, in which researchers will cryogenically preserve sperm and embryos; provide sterile barriers to maintain research-project integrity; and isolate specimens of specific strains with certain microbial characteristics to meet researchers' needs. UK Vice President for Research James W. Tracy is the principal investigator on the project. The laboratory will serve researchers from across the university.

UK gets $6 million grant to promote electronic health records

The U.S. Department of Health and Human Services awarded more than $6 million in ARRA funding to UK to assist Kentucky physicians with maximizing the use of electronic health records. UK will establish the first Kentucky-based Health Information Technology Regional Extension Center (REC) solely focused on serving Kentucky health care practitioners. This investment will help grow the emerging health information technology industry, which is expected to support tens of thousands of jobs ranging from nurses and pharmacy techs to IT technicians and trainers. UK's REC partners include the University of Louisville, Kentucky's Area Health Education Centers, Health Care Excel, and HealthBridge. Carol Steltenkamp, UK's chief medical information officer, says that electronic health records will improve patient care across the state: "RECs will focus on helping health care practitioners in small practices, and small-community and critical-access hospitals, on how best to utilize electronic medical records and health information technology."

Read more about UK ARRA-funded research at www.research.uky.edu/arra/pr.



6 ways to get rid of carbon

In Kentucky coal is king: more than 90 percent of our electricity comes from coal. Nationally 50 percent of power production is coal based. Coal is abundant (the United Sates still has 300 billion tons of coal) and cheap (Kentucky has the fourth lowest energy costs in the nation, thanks to coal). Coal puts Kentuckians to work and attracts industries that require cheap power. But coal's carbon dioxide (CO_2) impact is huge: in 2007 the state's 20 coal-fired electric power plants emitted 90.3 million tons of CO_2.

Curbing these CO_2 emissions is at the top of the White House's energy agenda, but what will happen to Kentucky when the proposed limits become law? In 2009 the National Association of Manufacturers and the American Council for Capital Formation released a study asserting that one of the proposed laws would result in a loss of 25,000 to 35,000 Kentucky jobs and a 64 percent increase in electricity rates by 2030.

Scientists at the University of Kentucky's Center for Applied Energy Research (CAER) and the Kentucky Geological Survey (KGS) are actively seeking solutions to coal's carbon dioxide-related environmental impact. They are finding short-term fixes that will allow today's power plants to concentrate CO_2 and then bury it underground or convert it with algae, and studying long-term solutions for more efficient, lower emissions power production.

1 Concentrate it

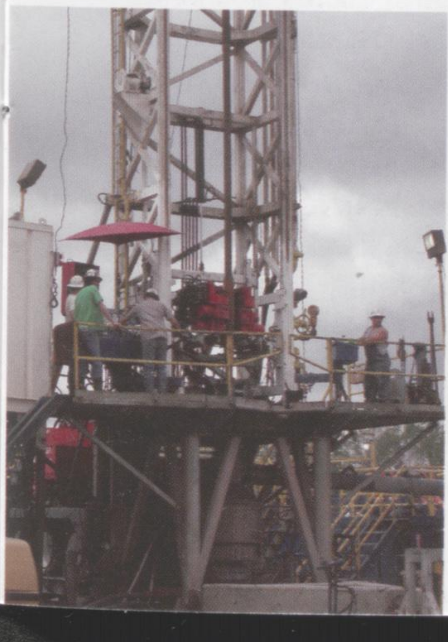
"Energy companies need to know the roadmap before they actually take the journey," says CAER's Jim Neathery as he explains that while companies are concerned about the environmental impact of CO_2, they are hesitant to choose a new technology to lower emissions before a law is enacted. "In order to keep our electricity affordable, utilities don't want to pour a huge investment into a technology that won't get them to the level of the law." He explains that when the federal guidelines come out, CAER's Carbon Management Research Group will have the know-how to recommend the right technology for each power plant and make that technology as affordable as possible. This group is a consortium of university researchers, state agencies and power companies—American Electric Power, Big Rivers Electric Corporation, Duke Energy, East Kentucky Power Cooperative, E.ON U.S., and Electric Power Research Institute.

This CAER group is working on chemical capture of CO_2 from the flue gas that billows out of a coal-fired power plant. The focus is to create better solvents and catalysts to speed up the chemical process of separating and concentrating CO_2 (in order to pipe it for underground storage or convert it to biomass) and recycling solvents to save money. Established with a $1.5 million E.ON U.S. grant, CAER's two-and-a-half story, 0.1-megawatt pilot plant enables the scientists to test their new chemicals, simulating coal-fired power production on a small scale. The group is also studying a long-term solution, a technology called "chemical looping combustion." This more efficient option takes nitrogen out of the equation, but will require a total redesign of power plants. "It's a complex system that we still need to work out. It's 15 to 20 years away," says Neathery.

2 Bury it

Deep rock reservoirs thousands of feet below Kentucky are a potential burying ground for coal's CO_2 downside. With data on oil and gas drilling that dates back to 1818, the Kentucky Geological Survey (KGS) is leading UK's research on geologic sequestration of CO_2.

With state funding, KGS and its industrial partners chose a test site to inject CO_2 underground. In the summer of 2009, an 8,126-foot well was drilled four miles southeast of the Ohio River in Hancock County, Kentucky. The target was a deep, thick rock formation called the Knox Group, found under much of the U.S. Midwest. The Knox Group is dolomite—a fine-grained rock that underlies approximately two-thirds of Kentucky. More than 18,000 barrels of salt water and 300 tons of CO_2 were injected into the well. KGS geologist Rick Bowersox says, "The project showed that an industrial CO_2 storage well drilled into those subsurface conditions would require about 120 acres to store 1 million tons of CO_2, or about 3,500 acres of reservoir to store 30 million tons. Seven to 10 wells like this one would be required to store 30 million tons of CO_2." Such well capacity would have handled 33 percent of the 90.3 million tons of CO_2 emitted by coal-fired plants in 2007.

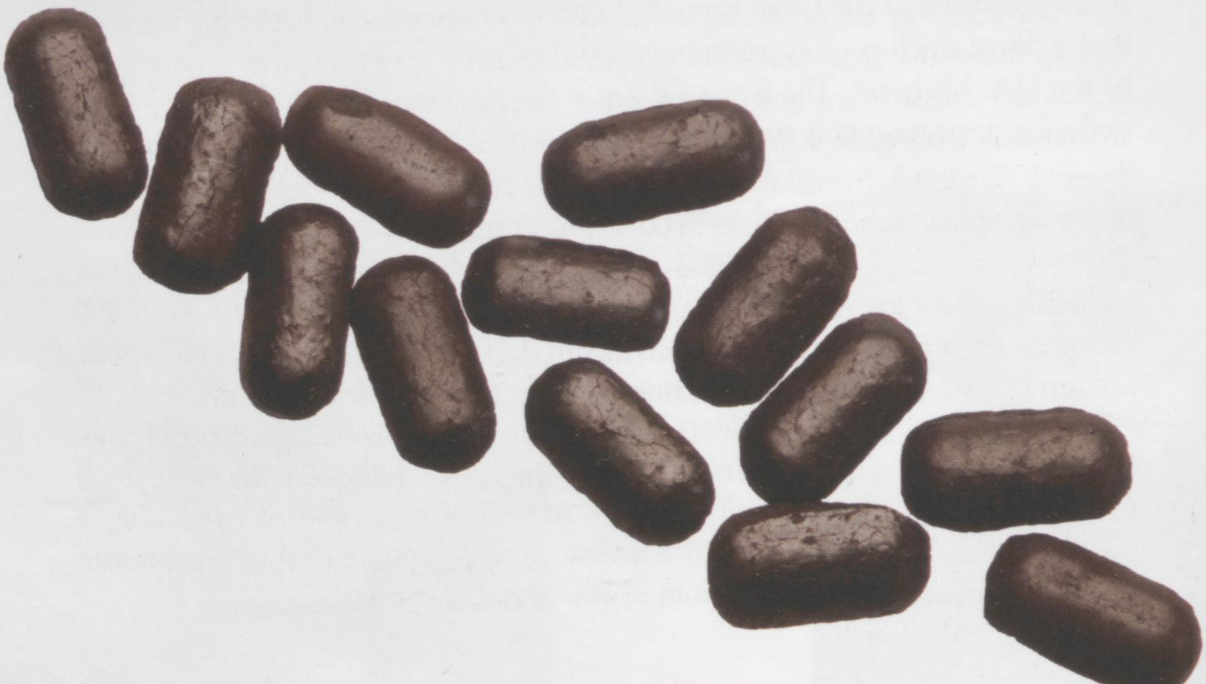


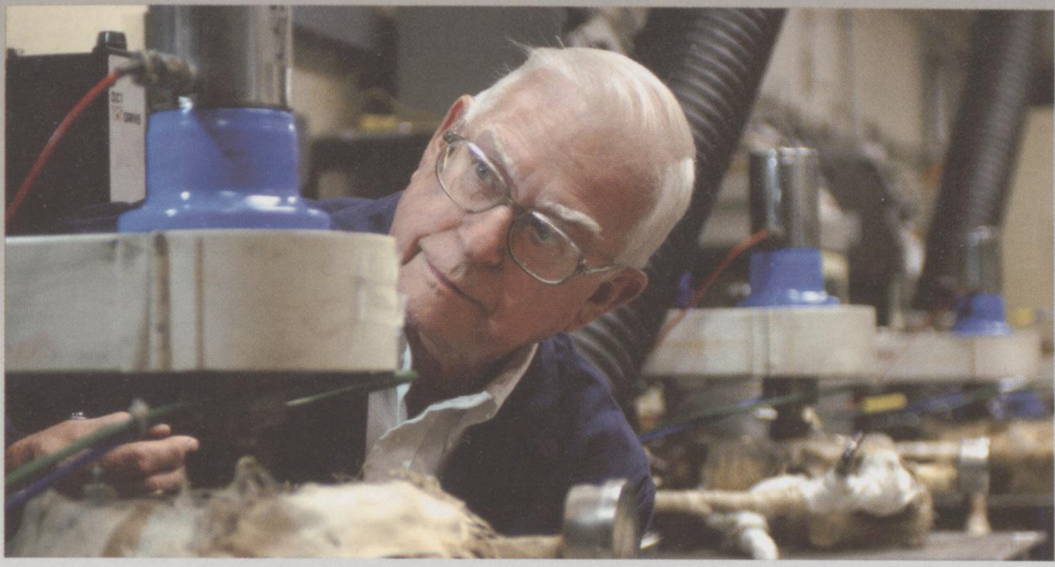
3 Briquette it

"There's a growing need for green energy from biomass, but there are a lot of problems getting biomass into the market—transportation, low density, capital investment," says Darrell Taulbee, who has worked at CAER since 1980. How do you overcome these problems? Briquettes. (Think charcoal, medicinal pills, dog and cat food.)

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 are often hundreds of feet deep and hold millions of gallons of slurry. Kentucky has 500 million tons of fine coal in slurry impoundments. Taulbee says, "We throw away enough each year to run a small industrial country of 10 to 20 million people."

Instead of throwing that potential energy away, Taulbee and his team are making fine coal/biomass briquettes. They've developed ways to process the wet fine coal and combine it with sawdust, agricultural residues (wheat straw and corn stover), energy crops (switchgrass and fescue), and weeds from fields on reclaimed surface mines to make durable, energy-dense briquettes. In December 2008, more than four tons of this so-called "engineered fuel" was combusted for heat at the East Kentucky Correctional Complex in West Liberty, Kentucky. Taulbee says if Kentucky follows the lead of other states and adopts an RPS (Renewable Portfolio Standard), which requires that a specific portion of the electricity consumed in the state come from renewable sources, briquettes would be the cheapest and fastest way to comply.





4 Liquefy it

Burt Davis, who has spent his 30-year career at UK studying clean-fuel technology says, "Today it's still easier to pump oil out of the ground than it is to dig coal and convert that coal to liquid. But here's the thing. We—Kentucky and the United States—have much more energy in the form of coal than the world does in petroleum. And we're finding ways to increase the efficiency of coal conversion."

Technology from the 1920s is finding a new—more efficient—life at CAER, thanks to $5.26 million in federal funds secured by Congressmen Hal Rogers and Geoff Davis. The funds will build a Process Development Unit (PDU) critical for ongoing research in Fischer-Tropsch (FT) synthesis, a process that can convert coal to liquid. To produce liquid fuel, coal must be broken down into its most basic ingredients through gasification—applying heat under pressure to convert coal into a gaseous mixture, primarily hydrogen and carbon monoxide, called syngas. Discovered by two German scientists in the 1920s, the FT process uses a catalyst (a reaction accelerator) to convert syngas to hydrocarbons. The hydrocarbons come out of the FT reactor as wax that is "cracked" (long molecules are chemically broken into shorter ones) to yield 20 percent lower-quality gasoline and 80 percent high-quality diesel. FT diesel is cleaner than traditional petroleum diesel because nitrogen and sulfur are removed in the process, resulting in fewer undesirable emissions.

The PDU will allow CAER to test novel technologies to convert coal, gas, biomass, and coal/biomass mixtures to liquid fuels while reducing the overall carbon footprint of the process. The PDU will be capable of producing a barrel a day of finished products, which will be supplied to other universities and the government for testing in a range of diesel and jet engines.

5 Cement it

A favorite of ancient Rome's architects to today's skyscraper designers, concrete is a durable but dirty material. CAER's Jack Groppo explains, "Concrete is made up of basically three ingredients: coarse aggregate (crushed stone), fine aggregate (sand), and Portland cement which acts as the glue that holds it all together." For every ton of new Portland cement, one ton of CO_2 is released from the kilns that bake it. CAER is looking at ways to replace some of that dirty Portland cement with coal combustion byproducts (CCBs) like fly ash. This ash can be used as a raw ingredient in concrete or as a substitute for around 20 percent of the Portland cement. Groppo says, "The concrete will contain coarse aggregate, fine aggregate, Portland, and fly ash. You need 20 percent less Portland. Since you use less Portland, you produce less CO_2 to make the same amount of concrete." And fly ash has other benefits: it makes stronger, longer lasting concrete.

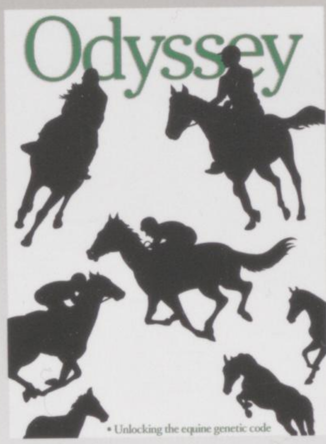
Groppo's work is part of the Center for Coal-Derived Low Energy Materials for Sustainable Construction, which is supported with funds secured by Senator Mitch McConnell. The center's goal is to develop low energy consuming, low CO_2 emitting construction materials from CCBs. This research, which will be tested inside a new kiln, is housed at CAER in a building constructed with concrete made from 20 percent fly ash from a Kentucky power plant. Groppo adds, "We are in the process of constructing two new buildings that will most assuredly also require fly ash concrete because we believe in the research we conduct—fly ash makes concrete better."

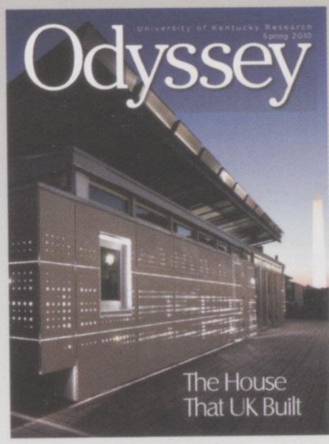
6 Convert it

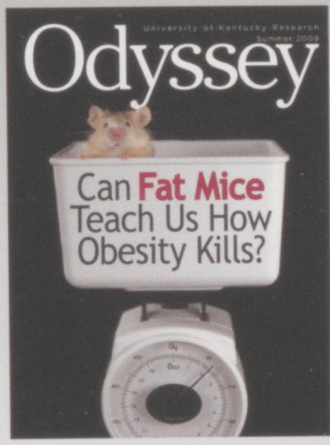
"They're not plants, and they're not animals," CAER scientist Mark Crocker says. He's talking about algae, in particular a species of pond scum he's studying that might just be a coal-fired power plant's CO_2 solution. "Our concept is biological sequestration: capturing the CO_2 at the power plant site and turning it into biomass. And we're looking at algae for this purpose because they are the fastest photosynthesizing organisms known to man." Algae take in carbon dioxide (CO_2) and water (H_2O), convert it to biomass (a mixture of proteins, carbohydrates and lipids), and exhale oxygen (O_2). Energy from sunlight drives these chemical reactions.

Inside a greenhouse at CAER, 144 vertical tubes (called photobioreactors), and numerous PVC pipes make up an 8.5-thousand-liter system that exposes the algae to sunlight in a continuous cycle. Coal-fired flue gas is fed in, it mixes with algae in a nutrient-rich liquid, algae consume the CO_2 as they grow, algae are harvested, and nutrients are recycled. Crocker says everything that comes out of this system can be re-used. The resulting lipids can be converted to diesel fuel. The algae can be sent to an anaerobic digester to make methane gas, which can drive a turbine to generate electricity, or can be chemically converted to make bio-oil. "By making valuable products, this system improves the overall economics of CO_2 capture. You use the carbon twice." ■

Read more about these six projects at www.research.uky.edu/odyssey/carbon.







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Alicia P. Gregory, Editor

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