Convergence of Bioscience and Engineering

- Power Shirt
- Counterfeit Drugs
- Interoperable Radio
- Scorpion Venom
- Forget Your Meds?
When I joined Emory in 1996, I was surprised that Emory didn’t have a biomedical engineering department. When I realized Georgia Tech didn’t have one either, I thought it would be the perfect marriage of the faculty in the engineering school at Georgia Tech and the medical faculty at Emory.

– Michael Johns, chancellor of Emory University

The division of labor has made these animals so incredibly successful in cooperative behaviors, but workers and queens are genetically the same.

– Michael Goodisman, professor in the School of Biology

The fiber-based nanogenerator would be a simple and economical way to harvest energy from physical movement. If we can combine many of these fibers in double or triple layers in clothing, we could provide a flexible, foldable and wearable power source that, for example, would allow people to generate their own electrical current while walking.

– Zhong Lin Wang, Regents’ Professor in the School of Materials Science and Engineering

About 50 percent of the samples obtained from the field in Southeast Asia were fakes. They look very real, even down to the hologram in the packaging. It’s very difficult to tell which ones are the fakes and which ones are real.

– Facundo Fernandez, assistant professor in the School of Chemistry and Biochemistry
During emergencies many kinds of situations can come up, including some that no one even anticipated. Those are among the things for which the interoperability project is designed.

– Douglas Cobb, principal research engineer in the Georgia Tech Research Institute (GTRI)

This is something that you could imagine scaling up for commercial use. Our material has the combination of high capacity, easy synthesis, low cost and a robust ability to be recycled – all the key criteria for an adsorbent that would be used on an industrial scale.

– Christopher Jones, professor in the School of Chemical and Biomolecular Engineering

In our 30 years here, we’ve had the opportunity to work with the Army on its missile defense mission as well as grow our sponsor relationships into other areas. Our expansion into the aviation mission area and several forms of systems engineering is keeping our staff of 33 very busy.

– Barry Bullard, director of the Georgia Tech Research Institute’s Huntsville Research Laboratory

This system has been in the field almost 40 years now. Many parts now unavailable were originally manufactured by hand, and would be very expensive to reproduce today just because of the manual labor involved.

– Russell McCrory, Georgia Tech Research Institute senior research engineer
Nanotechnology researchers are developing a microfiber nanogenerator able to generate electricity to power small electronic devices for soldiers in the field, hikers and others whose physical motion could be harnessed and converted to electrical energy.

The February 14, 2008, issue of the journal *Nature* explained how pairs of textile fibers covered with zinc oxide nanowires can generate electrical current using the piezoelectric effect. Combining current flow from many fiber pairs woven into a shirt or jacket could allow the wearer's body movement to power a range of small electronic devices. The fibers could also be woven into curtains, tents or other structures to capture energy from wind motion, sound vibration or other mechanical energy.

“The fiber-based nanogenerator would be a simple and economical way to harvest energy from physical movement,” says Zhong Lin Wang, a Regents’ Professor in the School of Materials Science and Engineering at Georgia Tech. “If we can combine many of these fibers in double or triple layers in clothing, we could provide a flexible, foldable and wearable power source that, for example, would allow people to generate their own electrical current while walking.”

The research was sponsored by the National Science Foundation (NSF), the U.S. Department of Energy and the Emory-Georgia Tech Nanotechnology Center for Personalized and Predictive Oncology.

The microfiber-nanowire hybrid system builds on the nanowire nanogenerator that Wang’s research team announced in April 2007. That system generates current from arrays of vertically-aligned zinc oxide (ZnO) nanowires that flex beneath an electrode containing conductive platinum tips. The nanowire nanogenerator was designed to harness energy from environmental sources such as ultrasonic waves, mechanical vibrations or blood flow.

The nanogenerators developed by Wang’s research group take advantage of the unique coupled piezoelectric and semiconducting properties of zinc oxide nanostructures, which produce small electrical charges when they are flexed. After a year of development, the original nanogenerators – which are two by three millimeters square – can produce up to 800 nanoamperes and 20 millivolts.

The microfiber nanogenerators rely on the same principles, but are made from soft materials and designed to capture energy from low-frequency motion. They consist of DuPont Kevlar® fibers on which zinc oxide nanowires have been grown radially and embedded in a polymer at their roots, creating what appear to be microscopic baby-bottle brushes with billions of bristles. One of the fibers in each pair is also coated with gold to serve as the electrode and to deflect the nanowire tips.

“The two fibers scrub together just like two bottle brushes with their bristles touching, and the piezoelectric-semiconductor process converts the mechanical motion into electrical energy,” Wang explains. “Many of these devices could be put together to produce higher power output.”

Wang and collaborators Xudong Wang and Yong Qin have measured current of about four nanoamperes and output voltage of about four millivolts from a nanogenerator of this type that included
two fibers that were each one centimeter long. With a much-improved design, Wang estimates that a square meter of fabric made from the special fibers could theoretically generate as much as 80 milliwatts of power.

Fabrication of the microfiber nanogenerator begins with coating a 100-nanometer seed layer of zinc oxide onto the Kevlar using magnetron sputtering. The fibers are then immersed in a reactant solution for approximately 12 hours, which causes nanowires to grow from the seed layer at a temperature of 80 degrees Celsius. The growth produces uniform coverage of the fibers, with typical nanowire lengths of about 3.5 microns and several hundred nanometers between each fiber.

To help maintain the nanowires’ connection to the Kevlar, the researchers apply two layers of tetraethoxysilane (TEOS) to the fiber. Finally, the researchers apply a 300-nanometer layer of gold to some of the nanowire-covered Kevlar. The two different fibers are then paired up and entangled to ensure that a gold-coated fiber contacts a fiber covered only with zinc oxide nanowires. The gold fibers serve as a Shottky barrier with the zinc oxide, substituting for the platinum-tipped electrode used in the original nanogenerator.

By allowing nanowire growth to take place at temperatures as low as 80 degrees Celsius, the new fabrication technique would allow the nanostructures to be grown on virtually any shape or substrate.

As a next step, the researchers want to combine multiple fiber pairs to increase the current and voltage levels. They also plan to improve conductance of their fibers.

However, one significant challenge remains ahead for the power shirt – washing it. Zinc oxide is sensitive to moisture, so before the shirts or jackets could be commercially available, the nanowires would have to be protected from the effects of the washing machine, Wang notes.
When Georgia Tech President Wayne Clough broke ground on the first building of the new Biotechnology Complex in May 1998, the shovel heralded more than just new brick and glass.

The four new structures built around the quadrangle became the physical manifestations of one of the most dramatic changes in Georgia Tech’s nearly 125-year history. The 800,000 square feet of new buildings represent the convergence of bioscience and engineering, providing the foundation for a $27 million biomedical engineering research program that is now the second largest among U.S. colleges and universities, according to National
Science Foundation statistics for 2006.

The centerpiece academic department is the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University.

Created in 1997, the joint department has emerged as a vibrant and innovative center for education and research in biomedical engineering in which teams of highly interdisciplinary researchers collaborate and network across a global environment. The department combines the design and problem-solving skills of engineering with the medical and biological sciences to improve patient health care and the quality of life for healthy individuals.

Marking its 10th anniversary this year, the Coulter Department continues to build its interdisciplinary programs to tackle the challenges of the 21st century, including cardiovascular disease, nerve injuries, neurological disorders, bone loss and cancer. This article describes a sampling of the department’s research.

Charting Blood Flow in 3-D

For every 1,000 babies born in the United States, two are born with just one functional heart ventricle. Their early years are filled with surgeries that aim to restructure circulation to pump blood directly to the lungs without the heart’s help.

To allow surgeons to get a detailed look at a child’s heart structure before these surgeries, Ajit Yoganathan, a Regents’ Professor and The Wallace H. Coulter Distinguished Faculty Chair in Biomedical Engineering, has developed personalized three-dimensional models of the heart to show a surgeon how well blood would flow through proposed post-surgery configurations. Each model is created using data from a series of magnetic resonance imaging scans of the child’s heart taken at different times in the cardiac cycle.

“We work very closely with the cardiologists and cardiac surgeons to help with surgical planning,” says Yoganathan. “With a better understanding of each child’s unique heart defect, surgeons can improve the surgery outcome and recovery time.”

Yoganathan collaborates with Emory University, Children’s Healthcare of Atlanta, Children’s Hospital of Philadelphia and Children’s Hospital Boston on this project, which is funded by the National Institutes of Health.

Another team of researchers is using magnetic resonance imaging scans to predict where atherosclerotic plaques will form and rupture in arteries based on fluid flow. Plaques form in artery walls because of cholesterol build-up. When they rupture, they can block blood vessels, leading to heart attack or stroke.

“We believe plaques form where blood flow slows down in an artery, maybe due to bends or branches in the artery that cause an eddy to form,” says John Oshinski, an assistant professor in the Coulter Department and Emory’s Division of Radiology.

To find these areas of slower flow, Oshinski collects magnetic resonance images to visualize blood flow patterns in arteries. From the images, Jin Suo, a Coulter Department research engineer, and Don Giddens, dean of the Georgia Tech College of Engineering, Lawrence L. Gellerstedt, Jr. Chair in Bioengineering and Georgia Research Alliance Eminent Scholar, develop computational fluid mechanics models to show specific flow patterns near the artery walls, locations where plaque is likely to form.

Because heart disease can take decades to develop, the researchers plan to monitor flow patterns long-term to investigate how early plaques can be detected and what type of blood flow is present where the plaques form.

W. Robert Taylor, a professor in the Coulter Department and Emory’s Division of Cardiology, and Ray Vito, a professor in the Georgia Tech School of Mechanical Engineering and vice provost of graduate and undergraduate studies, are collaborators on this project funded by the National Institutes of Health.

In related research, Hanjoong Jo, the Ada Lee and Pete Correll Professor in Biomedical Science Foundation statistics for 2006.

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Engineering, has shown that several genes are over-expressed when arteries are exposed to abnormal, nonlinear flow patterns. Expression of these genes leads to inflammation and hypertension, which increase the possibility of plaque building up inside the vessels. With funding from the National Institutes of Health, the Wallace H. Coulter Foundation and the American Heart Association, Jo is developing drugs that inhibit these genes to treat inflammation, atherosclerosis and hypertension.

**Rebuilding the Heart**

The inability of heart muscle to regenerate in the body provides a major obstacle to the clinical treatment of heart attacks — one that researchers in the Coulter Department are trying to overcome.

Todd McDevitt, a Coulter Department assistant professor, is developing new strategies to turn embryonic stem cells into specialized heart muscle cells called cardiomyocytes, which may repair damaged heart muscles. With funding from the American Heart Association, McDevitt is collaborating on this project with Samuel Dudley, a professor of medicine in the Section of Cardiology at the University of Illinois at Chicago.

To be successful, embryonic stem cells must differentiate into the targeted cell type in an efficient, controlled and repeatable fashion. McDevitt’s group aims to define and control the environmental cues that regulate the fate and function of the cells.

To produce a more homogeneous population of cells, McDevitt developed a method to incorporate polymer microspheres into embryoid bodies, which are aggregates of cells derived from embryonic stem cells. He can encapsulate small molecules, growth factors and proteins inside the microspheres to direct the stem cells to become the targeted cell type. This research is funded by the National Science Foundation.

Niren Murthy and Michael Davis, both...
Coulter Department assistant professors, have taken a different approach to improving the way physicians treat heart attacks. They have shown that injecting drug-containing polyketals during a heart attack can improve treatment. Because these biodegradable polymer nanoparticles do not produce inflammation-causing acid when degraded, the body allows intracellular delivery and sustained release of the drugs.

With funding from the National Institutes of Health, the researchers showed improved cardiac regeneration in rats and mice when polyketals were used to deliver drugs during a heart attack. Murthy is also investigating the use of these polyketal particles to facilitate drug treatment of acute lung injury, acute liver failure and lung fibrosis.

Reconnecting Nerves

Motor vehicle accidents, electrical burns, gunshot wounds, cutting incidents and surgical procedures can sever or tear peripheral nerves to varying degrees. Sometimes, these peripheral nervous system injuries result in a gap between two peripheral nerve stumps. Coulter Department professor Ravi Bellamkonda has developed a device for nerve repair that is a potential alternative to the clinical standard of transplanting nerve segments from another part of the body.

In collaboration with Satish Kumar, a professor in Georgia Tech’s School of Polymer, Textile and Fiber Engineering, and Art English, a professor in Emory’s Department of Cell Biology, Bellamkonda has demonstrated that thin polymer films made of aligned nanometer-diameter fibers provide topographical cues to stimulate regeneration without any growth-promoting proteins. Funding for this research was provided by the National Institutes of Health and by the National Science Foundation, through the Georgia Tech/Emory Center for the Engineering of Living Tissues.

Unlike peripheral nervous system injury, injury to the central nervous system is not followed by extensive regeneration because of the hostile growth environment caused in large part by the injury. Central nervous system injuries are commonly the result of motor vehicle accidents, sporting accidents, falls and acts of violence that cause a traumatic brain or spinal cord injury.

Transplanting stem cells in a bioactive scaffold designed to provide structural and adhesive support while providing survival signaling cues is one strategy that shows promise for replacing the function of missing or damaged neural cells. However, assistant professor Thomas Barker has developed novel liquid surgical sealants made of peptides that bind to blood-clotting proteins called fibrin. When sprayed on a wound, the sealants quickly solidify to prevent blood loss and close wounds. The system also allows wound repair elements to be loaded into the sealant to speed wound healing. This project is funded by a Wallace H. Coulter Foundation Translational Research Partnership in Biomedical Engineering award.

Associate professor Steve Potter has developed a multi-electrode neuronal stimulator to help control bursts of activity in neural cultures associated with epileptic seizures. Potter has teamed with Emory’s Robert Gross to test this system in vivo and translate it to a non-drug treatment for epilepsy. This project was funded by the Epilepsy Research Foundation and a Wallace H. Coulter Foundation Translational Research Partnership in Biomedical Engineering award.

MEDICAL DEVICES

Assistant professor Charlie Kemp has developed a robot that moves to an object, picks it up and delivers it when a user designates the object and recipient with a green laser pointer. He is collaborating with Jonathan Glass, director of the Emory ALS Center, to study the use of the robot by people with severe motor impairments. This project was funded by a Wallace H. Coulter Foundation Translational Research Partnership in Biomedical Engineering award.

Assistant professor Ajit Yogananthan has developed a robot that moves to an object, picks it up and delivers it when a user designates the object and recipient with a green laser pointer. He is collaborating with Jonathan Glass, director of the Emory ALS Center, to study the use of the robot by people with severe motor impairments. This project was funded by a Wallace H. Coulter Foundation Translational Research Partnership in Biomedical Engineering award.
optimization prior to clinical implementation requires expensive and time-consuming *in vivo* studies.

“We have developed a three-dimensional culture system of the injured host-transplant interface that can be used to evaluate and optimize tissue-engineered strategies,” says Michelle LaPlaca, a Coulter Department associate professor. “We mimic the forces and deformations that brain tissue would see during an actual injury and then monitor the ability of donor cells to rescue the injured cells.”

With the 3-D neural cell culture, LaPlaca can also evaluate neuroprotective pharmaceuticals targeted to mitigate injury. The 3-D cultures were described in the April 2007 issue of *the Journal of Neural Engineering*. This research is funded by the National Institutes of Health and National Science Foundation.

Yadong Wang is using a different strategy to encourage the regeneration of damaged central nervous system neurons. A Coulter Department assistant professor, Wang has shown that incorporating neurotransmitters, such as dopamine or acetylcholine, into a biodegradable polymer spurs the growth of neurites, which are projections that form the connections among neurons and between neurons and other cells.

“Regeneration in the central nervous system requires neural activity, not just neuronal growth factors alone, so we thought a neurotransmitter might send the necessary signals,” explains Wang.

The polymer would be implanted at the damaged site to promote nerve regeneration after an injury. It would then degrade as the neural network forms. The research on acetylcholine-based polymers, supported by the National Science Foundation and the National Institutes of Health, was published in the December 2007 issue of *Advanced Materials*.

The types of scaffolds LaPlaca and Wang propose for nerve regeneration are considered combination products because they contain a mixture of drug, device and/or biologics — which include DNA, cells and proteins in gene therapy, cell therapy and plasma products, respectively. Combination products are increasingly incorporating novel technologies that hold great promise for treating disease and trauma, and advancing patient care.

Two types of combination products are common: tissue-engineered constructs that use a polymer component as a scaffold to deliver or direct cells to restore or replace damaged tissue and vaccine delivery systems that use a polymer as a carrier to enhance the delivery of DNA- or protein-based vaccines to the desired cells.

Julia Babensee, a Coulter Department associate professor, investigates how polymer biomaterials influence immune responses toward the biological component of combination devices. To do this, she investigates how biomaterial contact influences the immune stimulatory capacity of dendritic cells, which traditionally recognize foreign pathogens or “danger signals” and initiate an immune response when they mature.

“Biomaterials that induce dendritic cell maturation and support an immune response are optimal for vaccine delivery systems where protective immunity is sought, whereas biomaterials that inhibit an immune response are desired for tissue-engineered constructs where tolerance is a goal,” says Babensee.

The novel idea is that biomaterials themselves can be used to direct immune responses toward associated biological components. This research is funded by the National Institutes of Health and the National Science Foundation.

With funding from the Arthritis Foundation, the novel idea is that biomaterials themselves can be used to direct immune responses toward associated biological components. This research is funded by the National Institutes of Health and the National Science Foundation.

**IN BRIEF**

**SPIN-OFF COMPANIES**

4-D Imaging creates technologies to improve magnetic resonance imaging and computed tomography data, enabling improved visualization of cardiovascular structures and blood flow patterns. The company is based on research conducted by Dave Frakes, a Ph.D. graduate from the laboratory of Ajit Yoganathan, The Wallace H. Coulter Distinguished Faculty Chair in Biomedical Engineering.

Vivonetics designs and produces innovative molecular beacon probes to detect gene expression in live cells and tissues. Gang Bao, Robert A. Milton Chair in Biomedical Engineering and College of Engineering Distinguished Professor, serves as the company CEO.

**Zenda Technologies**, founded by associate professor Michelle LaPlaca and Emory’s David Wright, aims to commercialize DETECT, a portable device that makes quick neuropsychological assessments, which are important in identifying brain disorders such as concussion and early stages of Alzheimer’s disease.

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SPIN-OFF COMPANIES II

Axion Biosystems aims to commercialize devices that stimulate and record from neural tissue to address applications including high-throughput drug screening and prosthetic devices. The company was founded by graduate students Jim Ross and Swaminathan Rajaraman, research engineer Edgar Brown, Coulter Department professor Steve DeWeerth, and Georgia Tech senior vice provost for research and innovation Mark Allen.

Cardiac-Solutions is a startup company formed to commercialize novel heart valve technologies that involve surgical and minimally invasive platforms. It was co-founded by Ajit Yoganathan, The Wallace H. Coulter Distinguished Faculty Chair in Biomedical Engineering, and Jorge Jimenez, a recent Coulter Department doctoral graduate.

SpherIngenics, co-founded by professor Barbara Boyan, visiting professor Zvi Schwartz and director of design instruction Franklin Bost, is commercializing a method to deliver stem cells non-surgically through the skin for soft-tissue applications such as cranial facial plastic surgery.
Foundation, Babensee is extending her research to determine the best tissue engineering constructs to implant in joints affected by autoimmune rheumatoid arthritis.

**The Complex Brain**

Steve Potter, a Coulter Department associate professor, is studying how brains learn, or more specifically, how they acquire memories and behaviors. The process of learning is thought to correspond to changes in the relationships between neurons in the brain, but exactly how those changes are expressed at the network level is not well-understood.

Since it’s difficult to study neuronal networks in vivo, Potter has developed imaging tools to study living neurons while they’re growing and forming connections in a petri dish. The dish contains an array of electrodes embedded in the bottom, which creates a two-way connection between the cells and a computer that records all cellular activity and delivers stimuli.

With funding from the National Institutes of Health, Potter is designing the technology to study drug addiction on a cellular level. The neural interface allows neuron cultures to douse themselves with drugs using a robotic “picospritzer.” Potter studies how the network changes as a response to the chemical self-stimulation.

“This may help explain why former cocaine addicts relapse, but more importantly, we may be able to find ways to cure drug addiction through better understanding of drug action in neuronal networks,” says Potter.

Xiaoping Hu, a Coulter Department professor and Georgia
Even before the joint Department of Biomedical Engineering at Georgia Tech and Emory University was created in 1997, the two institutions collaborated on biomedical research. The Emory-Georgia Tech Biomedical Technology Research Center, which established a seed grant program to stimulate research between the medical school at Emory and researchers at Georgia Tech, began cultivating cross-town partnerships in 1987.

But this $400,000-per-year seed grant program wasn’t enough for former Georgia Tech provost Michael Thomas and former executive vice president for health affairs at Emory University Michael Johns. They wanted more collaboration.

“When I joined Emory in 1996, I was surprised that Emory didn’t have a biomedical engineering department,” recalls Johns, who now serves as chancellor of Emory University. “When I realized Georgia Tech didn’t have one either, I thought it would be the perfect marriage of the faculty in the engineering school at Georgia Tech and the medical faculty at Emory.”

To discuss the possibility of a joint biomedical engineering department, Johns and Emory Dean of Medicine Thomas Lawley met with Thomas and Robert Nerem, a mechanical engineering professor at Georgia Tech and director of the Parker H. Petit Institute for Bioengineering and Bioscience, a research institute whose mission is to integrate engineering, information technology and the life sciences in biomedical research.

They formed an advisory committee of Georgia Tech and Emory faculty to develop a set of recommendations for an innovative and unique joint department of biomedical engineering. Leading the committee was Don Giddens, an aerospace engineering professor at Georgia Tech from 1968-1992 who returned from being dean of engineering at Johns Hopkins University to chair the new biomedical engineering department.

“Getting Don to return was absolutely key to the success of the department,” says Thomas. “You can’t have success without quality leadership and Don created an environment of trust, discovery, innovation and enthusiasm with his vision for the department.”

In 2000, The Whitaker Foundation awarded the biomedical engineering department a $16 million leadership-development award. Six million dollars of the grant was used to further develop the undergraduate and graduate programs, hire new faculty and support graduate student fellowships. The other $10 million helped construct the four-story, nearly 100,000-square-foot U.A. Whitaker Building at Georgia Tech, where most of the biomedical engineering faculty offices, laboratories and classrooms are located.

In 2001, the Wallace H. Coulter Foundation awarded a $25 million grant to the department. In recognition of this grant, the combined department is now known as the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University. Included within this grant were operating funds to purchase laboratory equipment and fund endowed chairs, and an $8 million endowment (which now totals $10 million) to provide ongoing funding for translational research.

After Giddens became dean of Georgia Tech’s College of Engineering in July 2002, Larry McIntire joined Georgia Tech as the new department chair. Under his leadership, the Coulter Department garnered almost $17 million in funding from the National Institutes of Health in 2007.

The department has grown to include 45 primary faculty members, 175 graduate students and more than 800 undergraduate students. In the “America’s Best Colleges 2008” edition of U.S. News & World Report, the undergraduate program ranked third and the doctoral program ranked second in the biomedical engineering specialty category.

Just one goal is still in the making: to have the biomedical engineering program ranked number one in the country.

By Abby Vogel
Research Alliance Eminent Scholar in Imaging, and assistant professor Erica Duncan and professor Clint Kilts, both of Emory’s Department of Psychiatry and Behavioral Sciences, are also studying drug addiction, but on the human brain level. In a recent study funded by the Office of National Drug Control Policy and the National Institutes of Health, they used functional magnetic resonance imaging (fMRI) to show that stress may precipitate relapse in cocaine addiction by activating brain areas that mediate reward processing.

As director of the Biomedical Imaging Technology Center at Emory University, Hu is also using fMRI to assess long-term effects of prenatal alcohol exposure on brain development. This project is in collaboration with Claire Coles, a professor in Emory’s Department of Psychiatry and Behavioral Sciences, with funding from the National Institutes of Health.

With funding from the Atlanta VA Rehabilitation Research and Development Center of Excellence for Aging Veterans with Vision Loss, Hu is collaborating with Ronald Schuchard, an associate professor at Emory University and director of the center, to study elderly brain health. They are currently using fMRI to study structural and functional connectivity in the brain during the progression and treatment of age-related macular degeneration.

Lena Ting, a Coulter Department assistant professor, also conducts research relevant to elderly health by studying the loss of balance that leads to falls, a primary cause of injury and accidental death in older adults.

After the brain’s neural pathways are impaired through injury, age or illness, muscles are deprived of the detailed sensory information they need to perform the constant yet delicate balancing act required for normal movement and standing. With funding from the Whitaker Foundation and the National Institutes of Health, Ting has developed a quantitative model that shows how the nervous system reinvents its communication with muscles after sensory loss.

“Knowing this information will help in the development of diagnostic and treatment strategies for balance disorders in older adults,” Ting said.

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**MIDNIGHT TRAIN TO GEORGIA**

The Georgia Cancer Coalition established the Distinguished Cancer Clinicians and Scientists program to recruit to Georgia leading and nationally renowned cancer clinicians and scientists who are engaged in the most promising areas of cancer research. Four Wallace H. Coulter Department of Biomedical Engineering faculty members hold this honor: Ravi Bellamkonda, Melissa Kemp, Shuming Nie and May Dongmei Wang.

Similarly, the Georgia Research Alliance Eminent Scholars program recruits renowned scientists to Georgia from many parts of the world to lead extraordinary programs of research and development with high potential economic development impact for the state. Four Coulter Department faculty members hold this honor: Don Giddens, Barbara Boyan, Xiaoping Hu and Eberhard Voit.
Biomedical engineering professors at Georgia Tech and Emory University are designing systems to detect Alzheimer’s disease earlier, improving the effectiveness of pacemakers and developing cardiovascular implants to increase the durability of heart valve repairs.

Translational research projects like these – which move science from the laboratory bench to the bedside – are possible because of a $25 million grant from the Wallace H. Coulter Foundation in 2001. The grant includes a unique $10 million endowment to provide ongoing funding for translational research.

“This grant was awarded because I believed in the vision and mission of [founding Coulter Department chair] Don Giddens and his strategy to lead the department to be the best in the nation,” says Sue Van, president of the Foundation. “I am delighted that Wallace’s legacy is helping to plant the seeds of the next generation of biomedical engineering applications.”

In recognition of the grant, the biomedical engineering department at Georgia Tech and Emory University was named for Coulter – an engineer, inventor, entrepreneur and visionary whose motto in life was “science serving humanity.” Coulter, who was a student at Georgia Tech in the early 1930s, invented the Coulter Principle, the reference method for counting and sizing microscopic particles suspended in a fluid.

Remembering laboratory technicians hunched over microscopes manually counting blood cells smeared on glass, he developed the Coulter Counter, an automated device that counts red blood cells. Today, 98 percent of complete blood count tests – the most commonly ordered diagnostic test worldwide – are performed on instruments using the Coulter Principle.

The translational research program captures the spirit of Coulter’s own life’s work because the program requires collaboration between a biomedical engineer and a clinician. The results of the program have been so promising with regard to patents issued, companies launched and follow-on capital raised that it has become the template for the Foundation’s national Translational Research Partnership Program.

Since 2001, the partnership between the Coulter department and the Foundation has continued to evolve, most recently with a global focus.

“Again I believed in the vision of [now College of Engineering dean] Don Giddens,” says Van. “He understands that Georgia Tech must continue to expand its reach globally with leading universities in order to succeed in the 21st century.”

In 2007, the Foundation donated $500,000 to establish a seed grant program between Peking University in Beijing, China, and the Coulter Department.

“Coulter fell in love with China when he worked there in the 1930s – it’s where he developed his international perspective, which led to a profound and lifelong fondness for Chinese art, culture and society,” says Van. “It’s a win-win for everybody.”

By Abby Vogel
An emerging field of engineering and life sciences that promises to revolutionize medicine and medical technology is nanomedicine. At Georgia Tech and Emory University, nanomedicine focuses on developing nanoprobes, whose unique properties open the possibility of investigating the dynamics of cellular processes over time and detecting disease in its earliest, most easily treatable, pre-symptomatic stage.

The Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University is the only academic department in the United States to host three National Institutes of Health (NIH) centers focused on nanomedicine. They are:

- The Program of Excellence in Nanotechnology, funded by the National Heart, Lung, and Blood Institute and led by Gang Bao, the Robert A. Milton Chair in Biomedical Engineering and College of Engineering Distinguished Professor;
- The Nanotechnology Center for Personalized and Predictive Oncology, funded by the National Cancer Institute and led by Shuming Nie, The Wallace H. Coulter Distinguished Chair and Director for Nanotechnology and Bioengineering in the Winship Cancer Institute at Emory University; and
- The Nanomedicine Development Center, funded by the NIH Roadmap Initiative in Nanomedicine and led by Bao.

**Detecting Cardiovascular Disease**

The $11.5 million Program of Excellence in Nanotechnology awarded in April 2005 focuses on creating advanced nanotechnologies to analyze cardiovascular disease, which is commonly caused by plaque buildup in arterial blood vessels. Plaques can rupture and block blood vessels, leading to heart attack or stroke.

The center includes Coulter Department biomedical engineers and Emory University cardiologists Kathy Griendling, David Harrison, Charles Searles, W. Robert Taylor and Wayne Alexander.

“Having the cardiologists involved has been very beneficial – they understand the biological and clinical issues that we need to address with the tools we are engineering,” says Bao.

Researchers in the center aim to develop methods to detect plaque at its early stages. For one project, researchers are testing the use of magnetic resonance imaging (MRI) to detect plaque. By injecting magnetic nanoparticle probes that are designed to accumulate at the plaque site, the location of the buildup can be detected in an MRI scan.

In a similar project, Taylor – a professor in the Coulter Department and Emory’s Division of Cardiology – is using quantum dots, nanometer-scale light-emitting particles that have unique optical properties, to visualize proteins present on the surface of blood vessels when plaques are forming. He observes the quantum dots with two-photon excitation laser scanning microscopy.

Another project, led by Bao, is investigating the use of quantum dots to test blood samples for certain enzymes indicative of the stability of plaques, with the goal of determining if a plaque is about to rupture.

Taylor and Niren Murthy, a Coulter Department assistant professor, are evaluating whether inflammation may be the key to detecting plaque at its early stages. Since artery walls swell and become inflamed when plaques begin to form, the researchers have created nontoxic nanoparticles that allow them to image trace amounts of hydrogen peroxide, which is thought to be overproduced by cells when inflammation is present.

**Bringing Cancer into View**

The Emory-Georgia Tech Nanotechnology Center for Personalized and Predictive Oncology began in October 2005 and boasts six projects and five support teams that focus on developing nanotechnologies for cancer applications. The amount awarded is expected to reach $27 million over a five-year period, with $19 million from the National Cancer Institute.

Center researchers are developing nanoparticles to image cancer inside the body and examine metastasis. They are also developing probes to study gene expression of cancer cells and treat cancer.

One group of researchers is targeting tumors with surface-enhanced Raman nanoparticle tags. With antibodies, peptides or small molecules attached, these nanoparticles can be used to target malignant tumors with high specificity and affinity. They also shine considerably more brightly than semiconductor quantum dots and can be spectroscopically detected to locate prostate or kidney cancer cells inside the body.

Bao and Barbara Boyan, the Price Gilbert, Jr. Chair in Tissue Engineering and a Georgia Research Alliance Eminent Scholar in Tissue Engineering, are developing novel molecular beacons to study gene expression in cancer cells.

May Dongmei Wang, a Coulter Department assistant professor and Georgia Cancer Coalition Distinguished Scholar, leads a major effort in integrating biological nanotechnology with computing and bioinformatics for personalized medicine.
“A unique strength of this center is that we have broad faculty expertise from translational bioinformatics to clinical oncology, which will allow us to move some of these technologies into clinical trials in the next two to three years,” says Nie.

**Repairing DNA**

The Nanomedicine Center for Nucleoprotein Machines was awarded in October 2006 and focuses on a nano-sized cellular mechanism that repairs DNA double-strand breaks inside the body. The breaks can be caused by ionizing radiation or ultraviolet light.

The cellular machine, called the non-homologous end-joining complex, has an intrinsic ability to delete, insert and rejoin DNA sequences at the break sites. Researchers at eight institutions are collaborating to better understand the role of each component in the system, the pathway by which it assembles and disassembles, and the signaling and control mechanisms of DNA damage repair.

To track the assembly of the machine’s parts deep within living cells, the researchers are developing new fluorescence probes, protein-tagging strategies, controlled methods of creating double-strand breaks and sensitive high-resolution imaging techniques.

“Our long-term goal is to adapt and redesign these machines to carry out novel functions,” says Bao. “Ultimately, we want to cure common diseases by creating machines that are able to correct genes that are defective in certain people.”

The center will receive between $10 and $12 million from the NIH for five years and almost $3 million from the Georgia Research Alliance, a public-private partnership of Georgia universities, businesses and government created to build the state’s technology industry.

*By Abby Vogel*
therapeutic tools for balance and movement disorders,” says Ting.

Engineering Solutions for Musculoskeletal Problems

Professor Barbara Boyan uses basic science knowledge to engineer novel approaches for restoring tissues and function for patients suffering from musculoskeletal problems. This effort includes the development of more effective bone graft materials, improved design of dental and orthopedic implants that interface with bone tissues, and methods for delivering cells to sites of injury without the need for invasive surgical procedures.

Boyan also aims to better understand the mechanisms involved in bone and cartilage growth and loss, and conditions such as osteoporosis and osteoarthritis. Estimates suggest that osteoporosis, a condition in which bones lose mass, become weak and can break from a minor fall, affects more than 10 million people. Osteoarthritis is a condition in which cartilage is lost from the ends of the bones, resulting in pain and reduced function. It affects most individuals as they age, but is most severe in women over 50.

With funding from the National Institutes of Health, the National Science Foundation, the Department of Defense and Children’s Healthcare of Atlanta, Boyan discovered biochemical differences between male and female bone and cartilage cells in both animals and humans – differences that she believes probably affect a person’s risk for these diseases.

“The area of research that has intrigued me most is whether females possess special steroid hormone receptors or whether their receptors just operate differently,” says Boyan, the Price Gilbert, Jr. Chair in Tissue Engineering and a Georgia Research Alliance Eminent Scholar in Tissue Engineering.

Boyan’s ultimate goal is to understand why some people – women, in particular – have a greater propensity for osteoarthritis and osteoporosis.

A person’s gender is not the only risk factor for developing osteoporosis. Some people choose careers that induce osteoporosis. Such is the case for astronauts, who lose 1 to 2 percent of their bone mass for each month that they spend in space.

Hanjoong Jo, the Ada Lee and Pete Correll Professor in Biomedical Engineering, is investigating which genes may be responsible for the loss of bone mass in space or in paraplegic individuals. To do this, Jo conducts bone cell experiments in two simulators: a random positioning machine that rotates cells in a manner that tricks them into thinking they are in microgravity conditions, and a rotating wall vessel that models microgravity conditions by maintaining continuous free-fall.

Jo is also investigating ways to prevent bone loss or reverse it. He found that putting bone cells on a vibrator for a few minutes per day under microgravity conditions would retain bone mass, and he is currently studying the genes responsible for this turnaround. Jo’s work is supported by the National Institutes of Health.

Looking at the Big Picture

Professor Eberhard Voit uses mathematics to study the interactions between the components of biological systems and how these interactions give rise to the function and behavior of such systems, a field called computational systems biology.

Voit, who is the David D. Flanagan Chair in the Coulter Department and Georgia Research Alliance Eminent Scholar in Biological Systems, is studying Parkinson’s disease and schizophrenia. Symptoms of the two neurological disorders differ, but the hormone dopamine plays a role in both. Dopamine production is suppressed in individuals with Parkinson’s disease and increased in schizophrenic individuals.

Voit has teamed with Gary Miller, an associate professor in Emory’s Department of Environmental and Occupational Health, to develop a mathematical model of the dopamine network to better understand how genetic, environmental and pharmacological factors alter how dopamine functions in healthy neurotransmission and neurodegenerative diseases.
The researchers plan to use the model in conjunction with biological and clinical studies conducted at Emory University to screen novel therapeutics aimed at altering dopamine function and decreasing the symptoms of both disorders. This interdisciplinary research is being funded by the Woodruff Health Sciences Center’s Predictive Health Initiative at Emory University.

To expand systems biology research at Georgia Tech, Voit spearheaded the creation of Georgia Tech’s new Integrative BioSystems Institute (IBSI), a collaboration of the Colleges of Science, Engineering and Computing. He also serves as its inaugural director.

An active IBSI member is Melissa Kemp, a Coulter Department assistant professor and Georgia Cancer Coalition Distinguished Professor. She is using systems biology approaches to understand complex cancer pathways involved in drug-resistant acute lymphoblastic leukemia, a type of cancer of the white blood cells. Children with lymphoblastic leukemia exhibit a diverse response to chemotherapy, with about one-fourth of them relapsing with drug-resistant disease.

In collaboration with Harry Findley, an associate professor in Emory’s Department of Pediatrics, Kemp is studying the role of the protein NF-κB in drug resistance of leukemia cells. NF-κB activity is responsible for cell death decisions and increases when reactive oxygen species – such as oxygen ions, free radicals and peroxides – are present.

“Many chemotherapeutic agents produce reactive oxygen species as a side-product, which increases active NF-κB levels. Unfortunately, drug-resistant cells appear to be better at eliminating these oxygen species,” explains Kemp.

With funding from Georgia Tech’s Health Systems Institute and the Georgia Cancer Coalition, Kemp is developing individualized computational models to identify key enzymes involved in regulating NF-κB. With pediatric patient samples from Findley, she can test an individual’s enzyme levels to predict the likelihood of drug resistance.

Biomedical engineering has witnessed rapid expansion in the last decade. Advances in molecular biology, biophysics and nanotechnology are transforming the understanding of disease, and how it is diagnosed and treated. With all four buildings in the Biotechnology Complex now filled with researchers, Georgia Tech’s commitment to bioscience and engineering is clear, and the Coulter Department is leading the way.

Comments and conclusions expressed in this article are solely the responsibility of the faculty members making them and do not necessarily represent the official views of the National Institutes of Health or the National Science Foundation.

A strong focus of the undergraduate biomedical engineering curriculum in the Coulter Department is problem-based learning, a student-centered instructional strategy in which students work in small collaborative groups to solve open-ended problems with a faculty member serving as facilitator.

To read more about problem-based learning, see the article at: gtresearchnews.gatech.edu/reshor/rh-ws08/coulter-education.html.
Michael Goodisman could be called the Maury Povich of the yellow jacket world. In his laboratory, Goodisman determines the paternity of yellow jackets to study family dynamics within a colony. Even though only one family lives within a colony, each yellow jacket queen mates with several males, creating a complex family tree.

“Social insects such as yellow jackets have been described as one of the greatest achievements of evolution because of the incredible cooperative nature of their societies,” says Goodisman, an assistant professor in Georgia Tech’s School of Biology. “I wanted to know why the females would risk this cooperative nature by having multiple partners.”

Mating with multiple partners can also lead to disease and wasted time and energy, according to Goodisman. Plus, each new yellow jacket has siblings and half-siblings during the same breeding season, allowing for potential conflict and in-fighting between the subfamilies.

“Weird things can start happening within families, so we looked to see if there was any evidence of this kind of selfish behavior within the colony,” explains Goodisman, whose projects are funded by the National Science Foundation (NSF).

Goodisman wondered if yellow jacket workers would kill new queens that had a different father or if they were more likely to turn their sister larvae into reproducing queens instead of sterile workers. Turning a worker into a queen is easier than it seems – it simply requires a comb nest with larger holes. The larger holes signal to the workers to feed the developing larvae different food, resulting in queens.

“You can actually take developing workers and if they’re young enough, put them into queen cells and they will develop into queens,” explains Goodisman.

Goodisman, graduate student Jennifer Kovacs and Eric Hoffman, formerly a postdoctoral researcher at Georgia Tech who is now an assistant professor at the University of Central Florida, tested the paternity of each insect to investigate whether any of the males in a colony fathered more queens than workers.

Similar to human paternity tests, comparing DNA sequences of two yellow jackets can show if one is related to another. Goodisman determined the genetic makeup of each of the queen’s male mates. He then determined what proportion of workers and new queens each male sired.

The results from the DNA fingerprinting showed that males fathered an equal number of queens and workers in a colony, allowing Goodisman to believe there is no conflict within a colony because of multiple mating.

“Instead of intense competition, yellow jackets seem to exhibit extreme cooperative and helping behaviors,” notes Goodisman. Results of this study were published in the journal Molecular Ecology.

Because Goodisman found no disadvantage to having mixed families in the colony, he believed there must be a benefit to the colony for each queen having multiple partners.
Goodisman, Hoffman and Kovacs compared the number of times a yellow jacket queen mated to how successful her colony was. Success was judged based on the number of worker and queen cells in the nest. The findings of this study were published in the journal *Evolution*.

No correlation was found between the number of mates and the number of worker cells. However, queens that effectively mated four or more times produced significantly more queen cells in the comb than queens that effectively mated fewer than four times.

Colonies typically survive only one year, so the number of queens produced at the end of the season represents the entire reproductive output of the colony and, by extension, the original queen. Only inseminated queens survive the winter and emerge in the spring. Thus, Goodisman found that the benefit to multiple mating is that the queen's colony is more successful.

Another avenue of Goodisman’s research is to investigate how yellow jacket development leads to a caste system with queens, males and workers – each with a different role in the colony. The queens mate with males to produce new queens and workers, but don't require a male to produce new males. The female workers maintain and expand the colony, while the roles of new queens and males are limited to reproduction.

“The division of labor has made these animals so incredibly successful in cooperative behaviors, but workers and queens are genetically the same,” explains Goodisman.

Dressed in protective gear, graduate student Jennifer Kovacs and assistant professor Michael Goodisman collect yellow jacket nests from an Atlanta home.
The division of labor has made these animals so incredibly successful in cooperative behaviors, but workers and queens are genetically the same.

- Michael Goodisman, an assistant professor in the School of Biology
Goodisman aimed to determine how these insects start with the same DNA but end up as such different insects. With help from Hoffman and graduate student Brendan Hunt, Goodisman learned that yellow jackets of the same developmental age express many genes in common regardless of their caste or gender. They also found that certain genes are turned on or off to create the different castes.

This study was published in the journal *BMC Biology*. Goodisman plans to continue this gene expression research in collaboration with Soojin Yi, also an assistant professor in Georgia Tech’s School of Biology.

“We’re going to use more sophisticated techniques to look at thousands of genes at once to really make big statements about how different queens are from workers and males,” says Goodisman.

Decision-making within a colony also intrigues Goodisman. Different events occur in the colony based on the time of year. For example, the queen constructs a nest and rears the first cohort of workers in the spring. Once the workers mature, they take over the task of colony maintenance and expand the nest by constructing a worker nest throughout the spring and summer. At the end of the summer, the colony begins to produce males and new reproductive queens.

“We want to know who’s telling the workers to stop making more workers and start making queens, so we’re studying the life cycle of yellow jacket colonies,” explains Goodisman. “Is it an environmental cue or possibly a cue from the queen?”

Even though some people think that yellow jackets are just a backyard nuisance, there are benefits to having yellow jackets around, contends Goodisman. They kill insects, suppress fly populations and eat road kill, he says.

And he’s quick to point out, “Yellow jackets are not here for our pleasure. They’re reproducing, surviving and doing a great job at it.”

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**C O N T A C T**

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“Social insects such as yellow jackets have been described as one of the greatest achievements of evolution because of the incredible cooperative nature of their societies. I wanted to know why the females would risk this cooperative nature by having multiple partners.”

- Michael Goodisman, an assistant professor in the School of Biology

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Yellow jackets live in a caste system — there are queens, males and workers.
Georgia Tech researchers were part of a global effort to identify and shut down the producers of counterfeit anti-malarial drugs. As part of their contribution to chemical analysis, the researchers developed faster sample screening techniques.

Georgia Tech researchers were part of a three-continent, multi-organization effort known as “Operation Jupiter” that successfully identified and shut down manufacturers who were flooding Southeast Asia with counterfeit – and ineffective – anti-malarial drugs.

With 11 different organizations, including the Centers for Disease Control and Prevention (CDC), the World Health Organization (WHO), the Wellcome Trust – and ultimately the international law enforcement agency INTERPOL – the effort provided Chinese officials with enough information to shut down the drugmakers.

Beyond the human health cost of failing to effectively treat hundreds of thousands of malaria cases, the fake drugs could be fueling development of malarial strains that may become resistant to the most sophisticated drug now available to treat the disease: artesunate. That’s because counterfeiters sometimes include small quantities of the real drug in their fakes, possibly to fool simple quality tests. By not killing the malaria parasites, the small artesunate doses could facilitate development of resistance.

As their part of the investigation, Georgia Tech researchers used mass spectrometry techniques to analyze nearly 400 drug samples provided by public health authorities. They also developed methods to speed up analysis, including an ionization process that reduced the time required to test a drug sample from 30 minutes to just a few seconds.

Activities aimed at addressing the widespread problem of counterfeit anti-malarial drugs were reported February 12 in the journal *PLoS Medicine*. Georgia Tech’s efforts to develop faster analytical techniques were sponsored by the National Science Foundation, while the sample analysis was supported by a small grant from WHO.

Malaria kills more than a million people each year worldwide, and is a risk for about 40 percent of the world’s population. Most victims would survive – if they had access to the proper drugs.

“About 50 percent of the samples obtained from the field in Southeast Asia were fakes,” says Facundo Fernandez, an assistant professor in Georgia Tech’s School of Chemistry and Biochemistry. “They look very real, even down to the hologram in the packaging. It’s very difficult to tell which ones are the fakes and which ones are real.”

When Fernandez began analysis of the drug samples, he assumed that they would not include real active ingredients. But his graduate students Christina Hampton and Leonard Nyadong soon discovered that the counterfeiters were making their fake anti-malarials with a broad range of mostly expired pharmaceuticals.

“We found old and ineffective anti-malarials like chloroquine,” he adds. “We found antibiotics like erythromycin. We found all sorts of drugs that basically have no effect on resistant malaria parasites.”

Mass spectrometry provides a very effective means of identifying samples by accurately determining their molecular weight. But the conventional analysis can be time-consuming – especially in the preparation of samples.

Fernandez and his Georgia Tech group developed a faster method that allows them to analyze hundreds of samples in a single day.
Their goal was to make mass spectrometry analyses responsive to time constraints required by law enforcement agencies involved in anti-counterfeiting.

“These are methods that let you analyze a solid sample without any significant preparation,” he explains. “You can take a tablet, put it in front of the instrument with an ionization source, and you get a quick snapshot of what’s in the sample. It provides a very high throughput pipeline to identify samples quickly.”

The Operation Jupiter team ultimately provided enough information that Chinese authorities were able to shut down the manufacturers, which were sophisticated operations able to accurately mimic the packaging and holographic seals of legitimate pharmaceutical companies.

Fernandez and his students remain involved in anti-counterfeiting activities and hope to obtain additional funding to continue supporting the efforts. They are now investigating fake anti-malarials sold in Africa, analyzing assortments of drugs sold in markets there and studying other faked drugs, such as tamiflu.

Large pharmaceutical companies can afford to pursue counterfeiting themselves, Fernandez noted, but in many cases, drugs sold in developing nations come from small companies that cannot afford private investigators and law firms to go after the counterfeitters.

“The problem is not over,” he cautions. “There are more fakes and more fake producers. But at least this is a beginning. Having an opportunity to do some good in this area is very satisfying.”

About 50 percent of the samples obtained from the field in Southeast Asia were fakes. They look very real, even down to the hologram in the packaging.

- Facundo Fernandez, an assistant professor in the School of Chemistry and Biochemistry

Graduate student Leonard Nyadong demonstrates an ionization technique that speeds up the testing of samples.
Georgia Tech Researchers are Covered in the News Media

More than 150 news outlets covered Georgia Tech’s development of a “microfiber nanogenerator” that scavenges mechanical energy from the environment to produce small quantities of electrical current that could power nanometer-scale devices. The foundation for the microfiber nanogenerator consists of nanowires made from zinc oxide grown onto ordinary textile fibers and alternately coated with gold. When the coated fibers rub together — moved by body motion or even the wind — they produce current through the combined piezoelectric and semiconducting properties of the zinc oxide nanowires. Among the outlets covering the research were the Associated Press, BBC, Christian Science Monitor, ComputerWorld, FOX News, MSNBC, National Public Radio, Newsday, Newsweek, PC Magazine, The New York Times, Scientific American, Small Times, Technology Review, Time, USA Today, The Washington Post, and Wired. A research team headed by Zhong Lin Wang in the School of Materials Science and Engineering developed the device, which was detailed in the journal Nature. (See the article on page 4 of this issue of Research Horizons).

Georgia Tech assistance to the Naval Surface Warfare Center in developing a new generation of micro-electromechanical fuzes for weapons produced coverage in Advanced Materials and Processes, Aviation Week & Space Technology, Chemical Engineering Progress, Design News, EDN, Electronic Engineering Times, Photonics Spectra and Small Times, among others. Georgia Tech Research Institute research engineer Jason Nadler developed a technique for consistently producing tiny copper structures that can be incorporated into integrated circuits. Once the circuits are created, the structures are converted to millimeter-diameter explosives.

A “sensor necklace” that can tell when patients or test subjects take a magnetically-tagged pill could improve compliance with doctor-prescribed medications and improve the accuracy of drug trials. Developed by researcher Maysam Ghovanloo in the School of Electrical and Computer Engineering, the work has received note in Electronics Weekly, The Engineer, Photonics Spectra, TechJournal South, Technology Review, and ZD Net. As many as one in three adults fail to take medications as prescribed. (See the article on page 36 of this issue of Research Horizons).

A sensor system that continuously monitors the air around persons prone to asthma attacks could help researchers better understand the environmental causes of the breathing distress. The new system, developed by a research team headed by GTRI principal research scientist Charlene Bayer, would be worn in the pockets of a vest. The new “asthma vest” was covered by The Engineer, Journal of Life Sciences, New Scientist, Popular Science, Technology Review, United Press International, The Vancouver Sun, and many other medically-related Web sites. (See the article on page 40 of this issue of Research Horizons).

A low-cost material for capturing carbon dioxide from the smokestacks of coal-fired power plants and other producers of the greenhouse gas received significant media attention. Energy Daily, Environmental Protection, IEEE Spectrum, R&D Magazine and Wired were among the outlets reporting on the work, led by Christopher Jones in the School of Chemical and Biomolecular Engineering. (See the article on page 32 of this issue of Research Horizons).
Georgia Tech Faculty and Staff Receive Recognition

Three faculty members shared the 2007 Nobel Peace Prize with former Vice President Al Gore and the Intergovernmental Panel on Climate Change for their roles in sounding the warning concerning global warming and climate change. They are: School of Public Policy professor Marilyn Brown, and professor Robert Dickinson and associate professor Ron Rong Fu, both of the School of Earth and Atmospheric Sciences.

Three faculty members were selected as 2008 Sloan Research Fellows: School of Biology associate professor King Jordan and College of Computing assistant professors Nick Feamster and Adam Kalai.

Yuri Bakhtin, an assistant professor in the School of Mathematics, Adam Kalai, an assistant professor in the College of Computing, and Johnna Temenoff, an assistant professor in the Coulter Department of Biomedical Engineering, received National Science Foundation Faculty Early Career Development (CAREER) awards.

Yuhong Fan and Francesca Storici, both assistant professors in the School of Biology; Melissa Kemp, an assistant professor in the Coulter Department of Biomedical Engineering, and Ming Yuan, an assistant professor in the Stewart School of Industrial and Systems Engineering, were selected as Georgia Cancer Coalition Distinguished Cancer Scholars for 2008.

The Atlanta Chapter of the American Institute of Architects awarded its Emerging Voices Award to College of Architecture visiting instructor Edwin Akins II.

College of Architecture visiting assistant professor Tristan Al-Haddad won one of 12 commissions from the city of Atlanta to create a piece of original public art to be installed in a city park.

Professor Jean-Luc Bredas from the School of Chemistry and Biochemistry has earned the distinction of Fellow of the Materials Research Society.

Michael Cathcart, a principal research scientist in the Georgia Tech Research Institute’s Electro-Optical Systems Laboratory, was selected as a senior member of the Institute of Electrical and Electronic Engineers.

William J. Cook, Chandler Family Chair and professor in the Stewart School of Industrial and Systems Engineering, received the Frederic W. Lanchester Prize by the Institute for Operations Research and the Management Sciences for a recent book he co-authored titled The Traveling Salesman Problem: A Computational Study.

Kirk Englehardt, Georgia Tech Research Institute director of communications, and John Toon, manager of the Georgia Tech Research News & Publications Office, won a Council for the Advancement and Support of Education District III grand award in the media relations projects category for a news release entitled “Nano-Manhattan: 3-D Solar Cells.” Englehardt also won a special merit award for GTRInews, the GTRI employee newsletter.

The Association for Computing Machinery’s Special Interest Group on Computer-Human Interaction awarded College of Computing professor Jim Foley its Lifetime Achievement Award and College of Computing professor Gregory Abowd its Social Impact Award.

Tom Fuller, director of the Georgia Tech Research Institute’s Center for Innovative Fuel Cell and Battery Technologies and a professor in the School of Chemical and Biomolecular Engineering, received the Research Award from the Energy Technology Division of The Electrochemical Society.

Ken Gall, professor in the School of Materials Science and Engineering and the School of Mechanical Engineering, received The Minerals, Metals & Materials Society’s (TMS) Robert Lansing Hardy Award.

Assistant professors Wendy Kelly and Christine Payne from the School of Chemistry and Biochemistry were awarded American Chemical Society PROGRESS/Dreyfus Lectureships.

Professor William Koros, the Robert C. Goizueta Chair and Georgia Research Alliance Eminent Scholar in Membranes in the School of Chemical and Biomolecular Engineering, won the 2008 Alan S. Michaels Award for Innovation in Membrane Science and Technology from the North American Membrane Society.

Mindy Millard-Stafford, an associate chair in the School of Applied Physiology, is president-elect of the American College of Sports Medicine.

School of Chemistry professor Art Ragauskas was honored with the 2008 Fulbright Distinguished Chair in Alternative Energy Technology.

Assistant professor of Building Construction Kathy O. Roper was named a Fellow of The International Facility Management Association.

Preet Singh, an associate professor in the School of Materials Science and Engineering, was named a Fellow of the National Association of Corrosion Engineers.

Robert Snyder, chair of the School of Materials Science and Engineering, was selected as the recipient of The Minerals, Metals & Materials Society’s (TMS) 2008 Educator Award.

Terry Sturm, professor in the School of Civil and Environmental Engineering, was selected as the 2008 Engineer of the Year in Education during Georgia Engineers Week.

Naresh Thadhani, a professor in the School of Materials Science and Engineering, was named a Fellow of the American Physical Society.

The Society for Military History selected John Tone, associate dean for undergraduate studies and professor in the School of History, Technology and Society, for the 2008 Distinguished Book Award in non-American history for his book, War and Genocide in Cuba.

Assistant professor Bruce Walker of the School of Psychology was awarded the Helping Hands Service Award from the Center for the Visually Impaired.

Gleb Yushin, an assistant professor in the School of Materials Science and Engineering, received the Roland B. Snow Award from the American Ceramic Society.

Ellen Zegura, chair of the School of Computer Science, received the Alumni Achievement Award from the School of Engineering and Applied Sciences at Washington University in St. Louis.

- compiled by Abby Vogel
Disasters like the 9/11 attacks and Hurricane Katrina have underscored the importance of emergency communications in the United States. The survival of thousands can depend on flexible, robust networks that can quickly connect police and other first responders throughout an affected area.

In cooperation with the Department of Homeland Security (DHS), the Georgia Emergency Management Agency – Homeland Security (GEMA) is developing a statewide system that will connect existing radio communications systems in most Georgia counties and certain state agencies to an Internet protocol (IP)-based network. The resulting Interoperable Communications System will even reach into some neighboring states, and it already includes satellite-capable mobile communications units that can travel to stricken areas.

Engineers from the Georgia Tech Research Institute (GTRI) are participating in the far-reaching venture as part of a team that includes GEMA, the Georgia State Patrol, Motorola, the Georgia Technology Authority, AT&T and SpaceNet. GTRI engineers have been supplying organizational design and testing services to the undertaking – called the Georgia Interoperability Network (GIN) Project – since it began in 2005.

“Not surprisingly, this project has been challenging from both an organizational and a technical standpoint,” says Douglas Cobb, a GTRI principal research engineer. “By the time we finish Phase Four in mid-2009, our GTRI team will have met and worked with nearly all of Georgia’s 159 counties in one way or another.”

The Georgia Interoperability Network is not an upgrade to existing public safety wireless communications. Rather, it’s an add-on that connects existing radio equipment to an adaptable IP backbone statewide. Cobb, who leads the GTRI technical project team, explains that when the network is complete, Georgia public safety personnel will be able to contact colleagues in other counties almost instantly using their own native radio systems. The network will link the radios of different counties regardless of their technology, which could be VHF, UHF, 800 megahertz, iDEN or others.

While communication between neighboring locales is usually the most vital, Cobb explains, a major emergency could require extensive conferencing among field and headquarters personnel in various counties. The interoperability system can easily connect any number of officers and managers in wide-ranging departments with first responders in the field.

“During emergencies, many kinds of situations can come up, including some that no one even anticipated,” Cobb says. “Those are among the things for which the interoperability project is designed.”

There are many examples of emergency communication needs, he says. One that’s occurred in recent years involves hurricane evacuations. Police and fire/rescue personnel along an interstate evacuation route must be able to talk to their counterparts up and down the crowded corridor to check conditions, set up detours or call in aid.

In the past, mobile units like police vehicles could communicate when they moved out of their own system’s radio coverage. But the process was cumbersome, involving the need to switch to special “mutual aid” channels. Often, first responders aiding another county
had to borrow some of the host county’s radio equipment to enable communication.

By contrast, the new interoperability system can connect any elements in the system quickly, thanks to the reliability and flexibility of Internet technology. Using Microsoft Windows-based custom software, county and municipal dispatchers will employ a familiar drag-and-drop interface to seamlessly connect wired and/or wireless users to conference calls whenever needed.

The Georgia network is also expected to extend in varying degrees into neighboring states, including Alabama, Florida, South Carolina and Tennessee.

The Georgia Interoperability Network uses a radio gateway unit to connect a county’s radios to the statewide IP backbone. In some cases, engineers must design a custom interface to connect an existing radio setup to the backbone successfully.

On behalf of GEMA, GTRI is serving as the technical systems integrator and project manager for the Georgia Interoperability Network. The job includes major responsibilities in site, network and satellite design; simulation and testing; facilitating meetings and information exchange, and extensive trouble-shooting.

GTRI’s experience in designing communications for the U.S. Department of Defense, GEMA and others is allowing its engineers to develop individual county-specific interoperability solutions. One pervasive issue involves the fact that Georgia counties use a variety of mobile systems and radio frequencies.

In one instance, GTRI engineers assisted Motorola in its design of a custom two-wire / four-wire hybrid setup to bring certain local mobile-radio systems into the network. In another case, GTRI used its satellite-design expertise to develop requirements specifications, assist in satellite-vendor selection and test the GIN system’s mobile communications units.

When complete, the network should be a model of speed and transparency, Cobb says. Robust connectivity hardware and software and the use of Internet technology will give the state an excellent communications network.

“The first time I ever saw this system, someone was talking on a radio in Atlanta to a radio in Tel Aviv, Israel,” he recalls. “Distance just doesn’t make any difference with this technology.”

- Douglas Cobb, a GTRI principal research engineer
Researchers have discovered a peptide in scorpion venom that may hold the key to understanding and controlling cystic fibrosis and other secretory diseases.

In the December 28, 2007, issue of the Journal of Biological Chemistry, an international team of researchers describes how this novel peptide, called GaTx1, can control chloride channels that regulate the flow of ions and water out of cells by interacting with a crucial chloride channel. This research was funded by the National Institutes of Health, National Science Foundation and Cystic Fibrosis Foundation.

“Peptide toxins from scorpions, snakes, snails and spiders paralyze prey by blocking nerve or muscle ion channels so the prey can’t get away,” explains Nael A. McCarty, formerly an associate professor in Georgia Tech’s School of Biology. “Those toxins have been enormously useful for studying the potassium, calcium and sodium channels that they interact with, but this is the first toxin discovered that potently binds to and selectively and reversibly inhibits a chloride channel of known molecular identity.”

Chloride channels are crucial for secretion in many epithelial tissues, but little has been known about their structures and mechanisms. Researchers do know that chloride channels open to allow millions of chloride ions to travel through them and out of epithelial cells. This movement creates an osmotic gradient that allows water to flow.

For the more than 70,000 people worldwide affected by cystic fibrosis, a lack of water flow in airway cells results in abnormally thick, sticky mucus that commonly causes blockages that obstruct airways and glands. The lack of water flow stems from a problem in a chloride channel called the cystic fibrosis trans-membrane conductance regulator (CFTR) protein.

In individuals with cystic fibrosis, the CFTR protein is mutated and consequently misfolded, often with one or more amino acids deleted. In the most common CFTR mutation leading to cystic fibrosis, the location of the deletion causes the chaperone proteins—which are responsible for quality assurance within cells—to bind to the misfolded proteins and discard them from the cell. Loss of CFTR proteins stops water from flowing into or out of the cells, thereby altering the conditions in the airway.

In other diseases, CFTR channels are overactive. This causes problems including secretory diarrhea, a worldwide health concern causing thousands of deaths per year; diarrhea-predominant inflammatory bowel disease; and autosomal-dominant polycystic kidney diseases, the fourth leading cause of end-stage renal disease in the United States.

With collaborators at the Hungarian Academy of Sciences, Emory University and the University of Calgary, the researchers used reversed-phase, high-performance liquid chromatography (HPLC) to extract the novel GaTx1 peptide from the complex venom of the giant Israeli scorpion, Leiurus quinquestriatus hebraeus.

“We chose this technique because each different peptide has slightly different water solubility and hydrophobicity properties, allowing them to be separated,” explains Julia Kubanek, an associate professor with joint appointments in the Georgia Tech School of Biology and School of Chemistry and Biochemistry.
Former Emory University graduate student Matthew Fuller and Georgia Tech graduate student Christopher Thompson collected individual peptides separated by the HPLC system and then applied each to chloride channels to see which peptide was responsible for the overall effects of the venom. They discovered a novel peptide that bound to the cytoplasmic side of the CFTR protein and weighed 3.7 kilodaltons. They named it GaTx1.

The researchers plan to use GaTx1 as a molecular probe to learn more about how chloride channels are structured and regulated. They also plan to study how this peptide can be useful in treating secretory diseases. For people with illnesses like secretory diarrhea, GaTx1 could potentially be used to inhibit the channels from opening, in turn decreasing production of the watery diarrhea that often leads to death in patients suffering from cholera and other diarrheal diseases, said McCarty.

To treat patients with cystic fibrosis, GaTx1 could possibly be used to increase water production by binding to the chaperone binding sites on the chloride channel. By blocking chaperones from binding, CFTR proteins would not be discarded and thus ions and water would flow from the cells to thin the mucus in the airway, according to McCarty.

“Even though the channels would be misfolded and probably only function at 50 percent capacity, chloride ions and water would still be transported through the cell,” says McCarty. “This is better than the alternative of allowing the chaperones to discard all of the CFTR proteins.”

McCarty has been studying CFTR for his entire research career, and, as he moves to a new position as associate professor in pediatrics and senior cystic fibrosis scientist at Emory University, he will continue this work in collaboration with researchers at Georgia Tech.

“GaTx1 has the potential to be used as a drug to help patients with cystic fibrosis and these other secretory diseases,” adds McCarty. “My new role at Emory will allow me to conduct pre-clinical studies to explore experimental drug treatment options based on this toxin.”

“Even though the channels would be misfolded and probably only function at 50 percent capacity, chloride ions and water would still be transported through the cell. This is better than the alternative of allowing the chaperones to discard all of the CFTR proteins.”

- Nael A. McCarty, formerly an associate professor in the School of Biology

Photo: Gary Meek

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Julia Kubanek and Nael McCarty, left to right standing, and Christopher Thompson observe the chromatogram showing the ultraviolet absorption of each peptide in the scorpion venom.
Researchers have developed a new, low-cost material for capturing carbon dioxide (CO₂) from the smokestacks of coal-fired power plants and other generators of the key greenhouse gas. Produced with a simple one-step chemical process, the new material has a high capacity for adsorbing carbon dioxide and can be reused many times.

Combined with improved heat management techniques, the new material could provide a cost-effective way to capture large quantities of carbon dioxide from coal-burning facilities. Existing CO₂ capture techniques involve the use of solid materials that lack sufficient stability for repeated use – or liquid adsorbents that are expensive and require significant amounts of energy in operation.

“Given the volumes involved, you must be able to recycle the adsorbent material for the process to be cost-effective,” says Jones. “Otherwise, you would be creating large and expensive waste streams of adsorbent.”

Details of the new material, known as hyperbranched aminosilica (HAS), appeared in the March 19, 2008, issue of the Journal of the American Chemical Society. The research was supported by the U.S. Department of Energy’s National Energy Technology Laboratory.

Growing concern over increased levels of atmospheric carbon dioxide has prompted new interest in techniques for removing the gas from the smokestacks of such large-scale sources as coal-fired electric power plants. But to limit economic impact, the cost of adding such controls must be minimized.

Once removed from the stack gases, the CO₂ might be sequestered in the deep ocean, in mined-out coal seams or in depleted petroleum reservoirs. If the CO₂ capture and sequestration process can be made practical, America’s large resources of coal could be used with less impact on global climate change.

Working with U.S. Department of Energy scientists Daniel Fauth and McMahan Gray, Jones and graduate students Jason Hicks and Jeffrey Drese developed a way to add CO₂-adsorbing amine polymer groups to a solid silica substrate using covalent bonding. The strong chemical bonds make the material robust enough to be reused many times.

“Given the volumes involved, you must be able to recycle the adsorbent material for the process to be cost-effective,” says Jones. “Otherwise, you would be creating large and expensive waste streams of adsorbent.”

Production of the HAS material is relatively simple, and requires only the mixing of the silica substrate with a precursor of the amine polymer in solution. The amine polymer is initiated on the silica surface, producing a solid material that can be filtered out and dried.

To test the effectiveness of their new material, the Georgia Tech researchers passed simulated flue gases through tubes containing a mixture of sand and HAS. The CO₂ was adsorbed at temperatures ranging from 50 to 75 degrees Celsius. Then the HAS was heated to between 100 and 120 degrees...
Celsius to drive off the gas so the material could be used again.

The researchers tested the material across 12 cycles of adsorption and desorption, and did not measure a significant loss of capacity. The HAS material can adsorb up to five times as much carbon dioxide as some of the best existing reusable materials.

The HAS material works in the presence of moisture, an unavoidable by-product of the combustion process.

Adsorption of the CO$_2$ generates considerable amounts of heat, which must be managed and thermally recycled. Removal of the carbon dioxide requires heating the adsorbent.

“How to manage this heat is one of the most critical issues controlling the economics of a potential large-scale process,” Jones adds. “You must control the production of heat by the adsorption step, and you don’t want to put any more energy into the desorption process than necessary.”

Beyond the material, other components of the separation and sequestration process must also be improved and optimized before it can become a practical technique for removing CO$_2$ from flue gases. The best way to expose the flue gases to the adsorbent material is also key issue.

“There are many pieces that must fit together to make the overall economics of carbon dioxide capture and sequestration work,” Jones explains. “The biggest challenge for this whole field of research right now is to do this as inexpensively as possible. We think that our class of materials – a hyperbranched amine polymer bound to a solid support – is potentially ideal because it is simple to make, reusable and has a high capacity.”

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“This is something that you could imagine scaling up for commercial use. Our material has the combination of high capacity, easy synthesis, low cost and a robust ability to be recycled.”

- Christopher Jones, a professor in the School of Chemical and Biomolecular Engineering
The Georgia Tech Research Institute (GTRI) is celebrating 30 years of service to the U.S. Army's Redstone Arsenal in Huntsville, Ala. GTRI supports missile and aviation technology, software and systems engineering, and other activities there.

Supporting the Army:

GTRI's Huntsville Research Laboratory Celebrates
30 Years of Service

By Rick Robinson

The Georgia Tech Research Institute's (GTRI) Huntsville Research Laboratory (HRL) is observing a major anniversary: 30 years of service at the Redstone Arsenal in Huntsville, Ala., supporting U.S. Army missile technology.

Since its modest beginning as “Huntsville Operations,” the laboratory’s impact has grown, branching out into a variety of defense fields. Moreover, its location on a key Army installation has helped enhance communication between its parent organization, GTRI, and its military stakeholders.

“Our Huntsville Research Laboratory is an extremely important part of our overall strategy,” says Stephen E. Cross, GTRI’s director and a Georgia Institute of Technology vice president. “It has delivered outstanding technical assistance and real innovation on a consistent basis, which is reflected in the positive feedback we get from our stakeholders.”

HRL’s milestone was celebrated at a Feb. 26 Huntsville event that drew some 200 attendees, including Georgia Tech officials, researchers and alumni, and representatives from the Army and other U.S. military branches.

Georgia Tech President Wayne Clough presented a GTRI award to William McCorkle, executive director of the Army Aviation and Missile Research, Development, and Engineering Center (AMRDEC) and an early proponent of a permanent GTRI presence in Huntsville. McCorkle is the first recipient of the GTRI Award for Exceptional Innovation and Leadership.

In making the award, Clough remarked on McCorkle’s many achievements in Army rocket and missile technology and praised him for his vision. “What we are celebrating today is Dr. McCorkle’s bold solution – to bring in Georgia Tech to Huntsville and establish the permanent presence of GTRI engineers at Redstone Arsenal,” Clough said.

Today, HRL focuses on software engineering and systems engineering for a variety of U.S. Department of Defense programs, said Barry Bullard, the lab’s director. HRL’s biggest customers include the Army Aviation and Missile Research, Development, and Engineering Center (AMRDEC); the Army Aviation and Missile Command (AMCOM); the Security Assistance Management Directorate (SAMD); the Army Space and Missile Defense Command (SMDC); the Army Program Executive Office Missle and Space; the Army Program Executive Office Aviation; and the Department of Defense Missile Defense Agency.

These agencies keep HRL busy with research that covers air defense systems modeling, software testing and evaluation, war-game simulations and analysis, and weapons system modernization. The lab’s current work includes hardware/software-in-the-loop (H/SWIL) systems engineering and analysis of the Patriot air and missile defense system, as well as ongoing modernization of the Hawk air defense system, a legacy system still used by numerous U.S. allies.

“In our 30 years here, we’ve had the opportunity to work with the Army on its missile defense mission as well as grow our sponsor relationships into other areas,” says Bullard, HRL director since 1998. “Our expansion into the aviation mission area and several forms of systems engineering is keeping our staff of 33 very busy.”

William Craig leads AMRDEC's...
Software Engineering Directorate, HRL’s biggest customer. Craig calls GTRI’s Huntsville lab “certainly one of the better contractors that we have…. You have unique expertise and very capable people, and you have given us valuable expertise in a number of areas.”

AMRDEC executive director McCorkle has been at Redstone Arsenal for nearly 50 years. He, too, expresses long-term satisfaction with the Huntsville lab’s work.

“It’s certainly true that we’re happy with GTRI’s work,” McCorkle says. “Over the years, it’s been a very good thing for both us and for Georgia Tech…. You have done important technical work on the Hawk system and assisted us in the air-defense arena, and that’s been a good arrangement.”

Richard Stanley, HRL’s first full-time director (1984-1998) and now director emeritus, recalls that McCorkle was indeed a major factor in bringing Georgia Tech to Huntsville.

“In the 1970s when GTRI was still known as the Engineering Experiment Station (EES), its personnel would often travel from the main campus in Atlanta to Huntsville to support Army technology,” Stanley relates. “During that period, World War II-era Army engineers were retiring in large numbers, and Redstone Arsenal needed additional technical support. McCorkle considered the issue and came up with the idea of a permanent Georgia Tech presence in Huntsville.”

HRL has also worked closely with other GTRI labs and has helped establish new research collaborations for them. In this way, HRL has acted as a kind of GTRI liaison in Huntsville, as well as a research facility in its own right.

“Huntsville Research Laboratory was a factor in GTRI’s becoming a University Affiliated Research Center (UARC) in 1995,” Stanley recalls. “GTRI’s accomplishments at Redstone Arsenal added to Georgia Tech’s reputation within the Department of Defense.” Adds Bullard: “The first 30 years, productive as they have been, may be only the beginning, and we look forward to growing in Huntsville and assisting the nation with its future science and technology defense needs.”

Barry Bullard, director of GTRI’s Huntsville Research Laboratory

“ In our 30 years here, we’ve had the opportunity to work with the Army on its missile defense mission as well as grow our sponsor relationships into other areas. Our expansion into the aviation mission area and several forms of systems engineering is keeping our staff of 33 very busy. ”

- Barry Bullard, director of GTRI’s Huntsville Research Laboratory
Researchers now have a possible solution for the one in three adults who fail to take their medicines as prescribed, as well as for everyone else who occasionally forgets: a sensor necklace that records the exact time and date when specially designed pills are swallowed, and reminds the user if any doses are being missed.

“Forgetfulness is a huge problem, especially among the elderly, but so is taking the medication at the wrong time, stopping too early or taking the wrong dose,” says Maysam Ghovanloo, an assistant professor in Georgia Tech’s School of Electrical and Computer Engineering. “Studies show that drug noncompliance costs the country billions of dollars each year as a result of re-hospitalization, complications, disease progression and even death.”

Ghovanloo and graduate student Xueliang Huo have designed a sensor necklace that records the date and time a pill is swallowed, which they hope will increase drug compliance and decrease unnecessary health care costs. The device could also be used to ensure that subjects in clinical drug trials take the study medications as directed by the research team. The details of the proof-of-concept device were published in the December 2007 issue of IEEE Sensors Journal.

The necklace, called MagneTrace, contains an array of magnetic sensors that detects when specially designed medication containing a tiny magnet passes through a person’s esophagus. And for persons who may not want to wear a necklace, MagneTrace sensors can be incorporated into a patch attached to the chest.

The date and time the user swallowed the pill can be recorded on a wireless device carried on the user’s body. The information can then be sent to the patient’s doctor, caregiver or family member over the Internet. The device can notify both the patient and the patient’s doctor if the prescribed dosage is not taken at the proper time.

According to a 2005 Wall Street Journal Online/Harris Interactive Health Care Poll, one in three U.S. adults who had been prescribed drugs to take on a regular basis reported that they did not follow the doctor-recommended course of treatment, with two-thirds reporting that they simply forgot to take their medication.

This technology can also help researchers and pharmaceutical companies conduct more accurate clinical trials of new drugs. Currently, compliance is determined by medication diaries kept by the patients. Inaccurate data from clinical trials can affect decisions made about new drugs, potentially impacting millions of people.

“If each drug trial volunteer had to wear a MagneTrace necklace, the exact date, time and dose would be recorded, rather than relying on the patient’s memory and honesty,” says Ghovanloo.

This technology also has the potential to reduce the size of clinical trials and reduce the need to repeat them.

“A patient cannot cheat the system by passing the pill past the necklace sensors on the outside of the neck because the signal processing algorithm is smart enough to only look for the pill’s

By Abby Vogel
magnetic signature while it passes through the esophagus," says Ghovanloo, who started working on this project about two years ago at North Carolina State University.

To test their system, the researchers have designed an artificial neck built from a PVC pipe filled with plastic straws. They place a necklace containing an array of sensitive magneto-inductive sensors around the artificial neck to study detection of a pill passing through it.

The magnetic sensors are distributed in different orientations, allowing the pill to be detected regardless of its orientation when it passes through the patient’s esophagus. The sensors are driven by a control unit on the necklace that consists of a battery, power management circuitry, low-power microcontroller and radio-frequency wireless transceiver. The prototype MagneTrace necklace with six sensors weighs less than one ounce.

“Preliminary results testing the artificial neck have shown 94.4 percent correct detections when the magnetic tracer passed through the esophagus detection zone and about 6 percent false positives when it passed through areas not in the detection zone,” says Ghovanloo.

Multiple strong magnets in the gastrointestinal tract can potentially result in a blockage. However, the magnet used in the pill or capsule is very small – three millimeters in diameter and about one millimeter thick – and coated with a thick indigestible, insoluble polymer coating that prevents absorption of the magnet and prevents magnets from aggregating.

“The magnet should simply pass through a patient’s gastrointestinal tract with no interactions and be excreted from the body in about 24 hours without any effects,” notes Ghovanloo.

Assistant professor Maysam Ghovanloo, left, and graduate student Xueliang Huo, both of Georgia Tech’s School of Electrical and Computer Engineering, test their drug compliance monitoring system on an artificial neck.

“Forgetfulness is a huge problem, especially among the elderly, but so is taking the medication at the wrong time, stopping too early or taking the wrong dose.”

- Maysam Ghovanloo, an assistant professor in the School of Electrical and Computer Engineering
The air traffic control radios that help guide U.S. military aircraft tend to be a venerable breed – thousands are based on a design that went into service in 1968. Engineers at the Georgia Tech Research Institute (GTRI) are helping keep these workhorses on the job until newer designs replace them.

That task can be a challenge, says Russell S. McCrory, a GTRI senior research engineer. Some 7,500 of these veteran ground communications radios – known as AN/GRT-21 and AN/GRT-22 transmitters and AN/GRR-23 and AN/GRR-24 receivers – are still in service. And when they break down, they often require parts that are no longer available.

“This system has been in the field almost 40 years now,” says McCrory, who is project director. “Many parts now unavailable were originally manufactured by hand, and would be very expensive to reproduce today just because of the manual labor involved.”

Even more challenging are semiconductor components such as transistors and diodes that are no longer manufactured. In some cases the original makers are no longer in business; in other cases the products are so old there are no replacements for them.

Eventually, all U.S. Department of Defense radios are due to be replaced by a reprogrammable software-based technology known as the Joint Tactical Radio System (JTRS), McCrory explains. Though the first JTRS systems could begin replacing high-priority radios as early as 2011, ground radios like the GRT/GRR systems are scheduled for replacement much later – probably not until 2020-2025. That means GRT/GRR radios could require maintenance for another 18 years.

In 1999, engineering responsibility for these radios was moved to the Warner Robins Air Logistics Center at Robins Air Force Base in Georgia. In 2005, engineers from GTRI were called in to produce documentation for the radios, and to create a support roadmap that laid out how to sustain the radios until they are retired. This analysis showed that major components of the radios would need to be replaced to meet this goal.

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Currently, the GTRI team has a contract to redesign five major assemblies within the GRT/GRR, which is a complex system comprised of receivers and transmitters for both the VHF and UHF radio bands. The team has received $750,000 to redesign the system’s dual-band-power amplifier unit, which has the unusual capability to broadcast a 10-watt radio signal in either the VHF or UHF bands.

Instead of trying to reproduce the original technology, GTRI engineers are designing replacement units that use only modern off-the-shelf parts. The aim is to give the customer a replacement module that is plug-compatible with the original unit and does the same job.

“We throw away the original design, and we make a unit with the same size and the same function,” McCrory says. “If the old unit had a certain meter reading to show a certain condition, the new one should work identically.”

In replacing the radio’s original analog components, GTRI engineers are crafting a system that is still all-analog but uses new technology that is widely available. This approach allows the Air Force to ask for competitive bids from numerous manufacturers rather than relying on a sole source.
The savings can be substantial, McCrory notes. He cites a competing approach that would have cost the government about $500,000 for drawings of one obsolete transistor in the GRT system, and then at least another $500,000 for the first transistor reproduced from those drawings.

“Our approach will result in major savings for the military versus trying to remanufacture the original components,” he says.

In many cases, McCrory says, his team’s redesigns may allow radios to not only keep working but also to operate more effectively. For example, a redesigned synthesizer unit could dramatically reduce the complexity of tuning the GRT/GRR radios, which currently can be re-tuned only through laborious settings changes.

In addition, the new dual-band-power amplifier is expected to replace three older models, easing parts inventory tasks.

One of GTRI’s top goals is to make it cheaper for the Air Force to simply plug in a new module than to repair an old one. The difference could save not only money and time, but also bring broken units back online faster.

“The Air Force, in conjunction with Tobyhanna Army Depot which does the maintenance, has done just a wonderful job keeping the system in the field,” McCrory adds. “We’re trying to help them continue to do that, while keeping costs under control and even improving the technology.”

Russell McCrory, GTRI senior research engineer

“This system has been in the field almost 40 years now. Many parts now unavailable were originally manufactured by hand, and would be very expensive to reproduce today just because of the manual labor involved.”

- Russell McCrory, GTRI senior research engineer
Georgia Tech and Saint Joseph’s Health System to Collaborate

Officials of Georgia Tech, Saint Joseph’s Health System and Saint Joseph’s Translational Research Institute (SJTRI) — a division of Saint Joseph’s Health System — have signed agreements designed to more rapidly move new treatments, therapies and products into clinical use with patients.

The agreements call for the $18.5 million relocation and expansion of the SJTRI research facilities to Technology Enterprise Park (TEP), a new bio-business park located adjacent to the Georgia Tech campus, and collaboration between physicians and researchers at Saint Joseph’s Hospital and Georgia Tech faculty and students.

“The greatest roadblock to getting new therapies or devices from the research lab to patients has been the silo approach to research,” says Nicolas Chronos, M.D., president of the Saint Joseph’s Translational Research Institute. “This relationship between Saint Joseph’s and Georgia Tech brings all the forces together — clinicians, patient care, biotechnology, bioengineering, bioscience and entrepreneurial business — for cross collaboration and innovation that will move the process ahead much faster for the benefit of patient care.”

Phase one involves the expanded SJTRI facility in Technology Enterprise Park (TEP), a 32,000-square-foot facility that will include catheterization labs, expanded vascular physiology lab, surgical suites and additional research capabilities. Georgia Tech researchers will have access to the research facility for clinical trial activities.

“Collaboration between the engineer/scientist and clinician is key to new discoveries, so we welcome this opportunity to collaborate with Saint Joseph’s to help accelerate the development and application of advances being made across a broad range of medical specialities,” said Mark Allen, Georgia Tech’s senior vice provost for research and innovation. “Working with the physicians and researchers of Saint Joseph’s will give our faculty and students new opportunities to combine what they learn in our classrooms and research laboratories with clinical experience.”

Phase one of the new facility is expected to be completed by early 2009.

The collaborative agreements include reciprocal faculty and research appointments for Saint Joseph’s clinicians and Georgia Tech academic faculty. Initial areas of scientific collaboration include:

- Orthopedics
- Bioengineering
- Cardiovascular surgery and cardiology
- Genomics
- Systems biology and informatics
- Advanced diagnostic and therapeutic technologies
- Robotics and surgical education
- Facilities design and process improvement.

— Lynn Peterson
Saint Joseph’s Hospital

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Sensor-based Vest Helps Understand Causes of Asthma

Scientists at the Georgia Tech Research Institute (GTRI) have developed a sensor system that continuously monitors the air around persons prone to asthma attacks. Worn in the pockets of a vest, the new system could help researchers understand the causes of asthma attacks.

“We are investigating whether we can go back after an asthma attack and see what was going on environmentally when the attack started,” says Charlene Bayer, a GTRI principal research scientist. The research was supported by the U.S. Department of Housing and Urban Development with initial funding from the GTRI Independent Research and Development (IRAD) program.

Although no one fully understands why certain people get asthma, doctors know that once a person has it, his or her lungs can overreact to environmental stimuli, causing chest tightness or breathlessness known as an asthma attack.

The new sensor system measures airborne exposure to formaldehyde, carbon dioxide, ozone, nitrogen dioxide, temperature, relative humidity and total volatile organic compounds (VOCs). VOCs are emitted as gases from products such as paints, cleaning supplies, pesticide formulations, building materials and furnishings, office equipment and craft materials.

In addition to detecting these seven environmental stimuli, a special mesh filter in the system collects particles. A pump pulls air through the filter so the quantity of particles can be measured at the end of the sampling period. The composition of the collected particulate can also be analyzed in the laboratory.

The battery-powered
system fits into the pocket of a vest and contains commercially available sensors that were integrated into a single system by Mark Jones, chief executive officer of Keehi Technologies.

"The device weighs less than one pound including batteries, and it takes a measurement of air every two minutes, stores the data in onboard memory and then sleeps to conserve battery power," Jones explains.

Bayer and GTRI research scientist Robert Hendry calibrated and tested the sensors in a room-sized chamber that simulates real-world environmental conditions inside buildings. Coupled with sensitive mass spectrometers, the chamber allows indoor air chemistry to be studied in detail.

The sensor system is designed to be comfortably worn in the pockets of a vest throughout the day and kept at the bedside while sleeping at night. Another vest pocket contains an electronic peak-flow meter to periodically measure pulmonary function. When experiencing an asthma attack, the vest wearer notes what time it occurred, allowing Bayer to examine the levels of the chemical compounds at that time.

Six adult volunteers have tested the vest for comfort and the effectiveness of the sensor system under actual use conditions. That has already brought benefits for one volunteer, whose vest detected higher volatile organic exposures in his home than anywhere else. The readings led researchers to discover a pollutant pathway from the volunteer's basement garage into the living areas that was allowing automobile exhaust and gasoline fumes to invade the house.

With future funding, Bayer hopes to develop a smaller and more sensitive sensor system, test the current vest in population studies of asthmatic children and develop software to process the population studies data as it is collected.

"With this system we can determine what children are exposed to at home, at school and outside where they play," says Bayer. "Chances are there are some overreaching compounds that seem to trigger asthma attacks more in children."

- Abby Vogel

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Mapping Tool Visually Tracks Emergency Resources

Tracking the location and availability of resources such as hospitals, transportation equipment and water during an emergency situation can be life-saving.

A collaborative mapping tool developed by the Georgia Tech Research Institute (GTRI) is helping emergency management officials better coordinate event and incident planning — and real-time response.

GTRI has teamed with Atlanta-based company Emergency Visions to provide mapping capabilities for a resource database the firm developed to identify, activate, track and coordinate response assets. The GTRI and Emergency Visions applications were selected by the Florida Division of Emergency Management in June 2007 as part of a solution that combines these comprehensive technology tools with the training and management expertise of a team led by the International City/County Management Association (ICMA).

"A lot of mapping systems are very complex to operate. Our system was deliberately designed to be easy to use for people who are not mapping experts," says Kirk Pennywitt, a GTRI senior research engineer.

Researchers began developing the Geographic Tool for Visualization and Collaboration (GTVC) in 2000 for military applications, but it has since been tailored to the needs of the emergency management community and first responders.

GTVC can track chemical or smoke plumes and help management personnel plan evacuation routes for emergencies such as hurricanes, fires or flooding. To do this, the system tracks resources including the locations of hospitals, fire stations, schools, nursing homes, sand bags, dump trucks, water, personnel and supplies in an affected region. The map can also indicate the status of those assets, such as the number of beds available in a specific hospital.

Emergency planners can immediately get a snapshot of what is going on without relying solely on traditional voice communications. During an event, electronic feeds can alert users to new incidents and display the location of the events live on the map.

The combined mapping and database system provides Florida with a robust networked emergency management system that it plans to implement in all 67 of the state's counties.

The Georgia Emergency Management Agency has been using the system since 2005 to track forest fires and hurricanes. Hillsborough County, Florida and Dakota County, Minnesota have also licensed the emergency management software for their incident preparedness plans.

"We've also had interest from more than 100 other cities, counties and local agencies," adds Pennywitt.

- Abby Vogel

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Scientists at the Georgia Tech Research Institute (GTRI) are laying the foundation for techniques that could do for ground-based imaging what the Hubble Space Telescope did for astronomy.

Optical turbulence is the distortion of light caused by its passage through the atmosphere. The phenomenon causes stars to twinkle and a desert horizon to shimmer – and makes accurate, detailed ground-based observation of distant objects all but impossible.

With a laser radar (lidar) developed at GTRI, “We can point that system in any direction in the sky and measure the strength of the turbulence effect,” says Gary G. Gimmestad, GTRI’s Glen Robinson Chair in Electro-Optics and senior faculty leader in remote sensing technology. “That has never been accomplished before.”

The three-year Department of Defense-sponsored project represents a crucial step toward controlling the effects of optical turbulence, itself a separate, fast-growing field called adaptive optics. But first, turbulence “must be measured and characterized and monitored,” Gimmestad notes.

The eventual development of algorithms or other techniques to compensate for optical turbulence could provide Earth-based telescopes with improved clarity and dramatically boost the quality of all kinds of long-distance imaging.

“Any kind of imaging you do on the ground is going to be affected by it,” says Gimmestad. “With surveillance imaging, you tend to get waviness in the images. Certainly looking at space objects – stars, planets or whatever – your image quality is really degraded by turbulence.”

Optical turbulence also inhibits long-range “free-space” laser applications; that is, laser light moving through the air rather than through a medium such as fiber optic cable.

One potential free-space laser application would facilitate high data-rate communication between a ground station and aircraft, particularly the unmanned aerial vehicles used for reconnaissance in military and natural disaster situations.

Another possibility attracting interest in scientific circles is the use of lasers to transfer power. Specifically, powerful ground-based lasers could recharge satellite batteries when their beams are trained upon a photovoltaic panel installed on the side of an orbiting satellite.

“高大云天”年问题”是导致自旋光强度下降的主要原因。光强下降使得观测距离的图像质量显著下降。

光学湍流也抑制了长距离“自由空间”激光应用；即，激光光束在空中传播而不是通过诸如光纤这样的介质。

一个潜在的自由空间激光应用是促进高数据速率通信。在空中站和飞机之间，特别是无人机可以进行高数据速率通信。这些无人机在军事和自然灾害中被用于侦察。

另一个吸引科学界兴趣的可能性是使用激光传输电能。尤其是，强大的地面激光器可以为卫星上的电池充电。当它们的光束对准安装在轨道飞行器上的光伏面板时，就可以做到这一点。

Using a laser radar (lidar) developed at GTRI, "We can point that system in any direction in the sky and measure the strength of the turbulence effect," says Gary G. Gimmestad, GTRI’s Glen Robinson Chair in Electro-Optics and senior faculty leader in remote sensing technology. "That has never been accomplished before."

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Another possibility attracting interest in scientific circles is the use of lasers to transfer power. Specifically, powerful ground-based lasers could recharge satellite batteries when their beams are trained upon a photovoltaic panel installed on the side of an orbiting satellite.

“高大云天”年问题”是导致自旋光强度下降的主要原因。光强下降使得观测距离的图像质量显著下降。

光学湍流也抑制了长距离“自由空间”激光应用；即，激光光束在空中传播而不是通过诸如光纤这样的介质。

一个潜在的自由空间激光应用是促进高数据速率通信。在空中站和飞机之间，特别是无人机可以进行高数据速率通信。这些无人机在军事和自然灾害中被用于侦察。

另一个吸引科学界兴趣的可能性是使用激光传输电能。尤其是，强大的地面激光器可以为卫星上的电池充电。当它们的光束对准安装在轨道飞行器上的光伏面板时，就可以做到这一点。

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Research Horizons

Laser Radar Measures Optical Turbulence

GTRI researcher Dave Roberts examines output from a lidar system being used to measure atmospheric turbulence.

Photo: Sheree Colestock

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GTRI Helps a Small Company Bring New Products to Market

When a local company’s rolling walker couldn’t be sold in Wal-Mart stores because the box wouldn’t fit on the shelves, the company came to the Georgia Tech Research Institute (GTRI) for help. A group led by GTRI senior research scientist Brad Fain solved the problem, reducing the volume of the cardboard box by 51 percent.

“The carton became much smaller than we thought it could get,” says Phil Willis, president of the durable medical division for Access Product Marketing (APM) in Alpharetta, Ga. “We were very impressed with the way GTRI researchers aggressively and professionally attacked the problem.”

According to Fain, finding a new way of folding the walker to fit inside a smaller box was an engineering challenge.

“We added a few hinges to the frame that allowed the rear wheel assembly to be folded, and designed a new way of attaching the front wheels,” explains Fain. “Then we suggested they move a few support structures to allow the walker to be folded more efficiently.”

GTRI also kept the cost low with the changes, allowing APM to sell the rolling walker at discount chain Wal-Mart.

GTRI’s assistance was instrumental in helping APM market its Hugo® rolling walker to seniors around the country.

When APM took the next step in elderly mobility devices from rolling walker to cane, it returned to GTRI for assistance. This time, APM asked Fain and his team to design a sturdy folding cane from scratch. Because many older persons perceive folding canes to be weak and unsafe, according to consumer research conducted by Willis, the new cane design needed to address these issues.

Fain pooled a group that included Tedd Toler, a mechanical engineer with GTRI, and Michelle Berryman, an industrial engineer with local design company Echo Visualization.

The group first focused on what material to use. They also studied what the inner and outer diameters of the cane shaft should be. Next, the group designed the tip of the cane, making sure it could bear heavy loads and be highly resistive to slipping.

The Hugo folding cane was successfully tested with 550 pounds of weight applied, while competitors broke at around 250 pounds, according to Willis.

Once the basic structure of the cane shaft was designed, Fain’s team moved its attention to the handle. Cane users feel a handle is the most personal and most intimate part of the cane, according to Willis. “It’s the one part of cane that’s unique to the user,” he says.

For this reason, the Hugo folding cane was designed with a removable handle so that each user’s personality could be on display, whether with a hook handle, a pink handle or a cushioned handle.

The personalized handle feature came to the attention of the producers of the FOX television show, House, M.D. The main character, Dr. Gregory House, used a Hugo folding cane with a customized handle in more than eight episodes last season.

“With all of GTRI’s work for very large government agencies, we were concerned that our project would be so far under the radar that GTRI might not be able to pay attention to it,” says Willis. “However, GTRI has been very welcoming to my small company. We received a tremendous amount of attention and some very deep thinking around our project, and we appreciated it.”

– Abby Vogel

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Study Shows Microneedles Enhance Drug Delivery in Humans

In what is believed to be the first peer-reviewed study of its kind involving human subjects, researchers at Georgia Tech and the University of Kentucky demonstrated that patches coated on one side with microscopic needles can facilitate transdermal delivery of clinically relevant doses of a drug that normally cannot pass through the skin.

Reported in the journal Proceedings of the National Academy of Sciences, the study could help advance the use of microneedles as a painless method for delivering drugs, proteins, DNA and vaccines into the body. The research also found other advantages for the microneedles, including an ability to produce therapeutic drug levels with lower doses, and reduced production of drug metabolites that may cause side effects.

“This study represents an important landmark in the development of microneedles into drug delivery devices suitable for use in clinical medicine,” says Mark Prausnitz, a professor in the Georgia Tech School of Chemical and Biomolecular Engineering. “This method may be useful for a broad range of drugs that cannot normally be delivered without a hypodermic needle.”

The research was supported by the National Institutes of Health and the University of Kentucky Research Foundation.

Transdermal drug delivery has proven successful in a number of applications, including pain management, congestive heart failure and hormone replacement. Transdermal administration offers advantages over other delivery techniques, but existing systems can only be used for a narrow range of compounds that easily pass through the skin.

By painlessly punching a series of microscopic holes in the outer layer of skin, microneedles promise to expand the range of drugs and vaccines that can be delivered transdermally. Until this study, however, the only published research demonstrating drug delivery using microneedles had involved studies in animals and on human cadaver skin.

Collaborating with Prausnitz and his Georgia Tech research team, University of Kentucky associate professor of pharmacology Daniel Wermeling and colleagues Stan Banks, David Hudson and Audra Stinchcomb set out to determine whether microneedle patches could indeed help deliver useful amounts of drug compounds that otherwise couldn’t pass through the skin.
As a test compound, they chose the drug naltrexone, a skin-impermeable compound used to treat opiate and alcohol addiction.

Working with a small group of nonaddicted human test subjects, they first prepared a section of skin on each subject’s arm by pressing and removing thumb-sized patches that contained 50 stainless steel microneedles each about 620 microns — about 1/40th of an inch — in length. Next, gel containing naltrexone was applied to the prepared area, which was then covered by a protective dressing. The concentration of the drug in each subject’s bloodstream was monitored for 72 hours. The researchers quickly saw levels of the drug reach pharmacologically active concentrations, and those levels remained steady for at least 48 hours in the six test subjects. None of the control subjects had detectable levels of the drug in his or her bloodstreams.

Beyond maintaining a steady level of the naltrexone, microneedle delivery may offer another advantage over oral administration: a reduction in the presence of compounds metabolized from the drug. The primary metabolite, known as naltrexol, is rapidly produced by the liver and intestines when the drug is administered orally, creating blood levels as much as 10 times that of the parent drug — which can cause undesirable side effects.

Microneedle administration also reduced the amount of drug required to produce therapeutic levels, replacing a 50-milligram tablet with 10 to 12 milligrams of drug in the gel.

The study represents a first step in demonstrating the broad range of potential uses for microneedles, says Prausnitz, who has been developing the devices for more than 10 years. In addition to Prausnitz, the Georgia Tech research team included Harvinder Gill and Jyoti Gupta.

“Microneedle administration is here, and we have shown that it can be done efficiently, safely and successfully,” says Prausnitz. “This is just the beginning of what we can do with this technology.”

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Developing a Washable Robot for Poultry Processing

Even a hard-working robot needs a good bath at the end of the day. That was the issue facing researchers at the Georgia Tech Research Institute (GTRI) as they delved into one of the big challenges in food-processing automation.

Robots have begun to be deployed in many areas of food production, but their use for handling fresh meat has been hampered because such machines would also have to withstand cleaning with high-pressure water spray and corrosive sanitizing chemicals.

At GTRI’s Food Processing Technology Division, research engineer Jonathan Holmes led a project to develop a robot that would pack fresh meat into trays, but with a design and construction able to withstand the harsh conditions created by routine washing in a way more consistent with how other equipment is cleaned.

Georgia Tech researchers have teamed with CAMotion, Inc. of Atlanta and are working in collaboration with Cargill Meat Solutions of Newnan, Ga. The robot’s job is to grasp raw meat products from a conveyor and place them onto foam packaging trays. The task requires considerable dexterity to pick up the products without causing damage, place them within the boundaries of the trays in an aesthetically pleasing manner, and provide one more visual inspection. And it has to be done fast — one per second.

But that was the easy part, relatively speaking.

“We’re used to building automated machines, so the automation side was something we’ve accustomed to,” Holmes explains. “The wash-down side of it was brand new for us — it’s new for most people — and that was very challenging. We had to go through a lot of component testing initially just to find components we could use.”

The current prototype uses special protective coatings and plating on its metal parts, shaft seals on its motors and other moving parts, and special watertight bearings that are little affected by the wash-down process.

The tray-filling stage of the poultry processing line may require up to a half-dozen human workers and often results in a bottleneck to the process. The hope is that automation of this type would result in increased throughput and lower costs for the industry. In addition, the wash-down technologies devised in this project could find their way into other areas untouched by automation because of cleaning requirements.

This project was funded in part by Georgia’s Traditional Industries Program for Food Processing.

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“Developing a Washable Robot for Poultry Processing” by Gary Goettling

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Georgia Tech researchers are developing unique polymers that change shape upon heating to open blocked arteries, probe neurons in the brain and engineer a tougher spine. These so-called shape-memory polymers can be temporarily stretched or compressed into forms several times smaller than their final shape. Then heat, light or the local chemical environment triggers a transformation into their permanent shape.

“My focus has been to optimize these polymers for many different biomedical applications,” says Ken Gall, a professor in Georgia Tech’s George W. Woodruff School of Mechanical Engineering and School of Materials Science and Engineering. “My lab studies how altering the chemistry and structure of the polymers affects their chemical, biological and mechanical properties.”

The mechanical properties of these polymers make them attractive for many biomedical applications, according to Gall, who described his research in this area during two presentations at the Materials Research Society’s fall meeting in November 2007.

Finding materials that display unconventional properties able to satisfy requirements for implantation in the body is a constant challenge for biomedical engineers. Particular attention must be paid to the biofunctional- ity, biostability and biocompatibility of these materials, which come into contact with the body’s tissue and fluids.

With funding from the National Institute of Biomedical Imaging and Bioengineering of the National Institutes of Health (NIH), Gall proposed replacing metallic cardiovascular stents with plastic ones because polymers more closely resemble soft biological tissue. Plus, polymers can be designed to gradually dissolve in the body.

“Metal stents are frequently covered in plastic anyway, so we set out to remove the metal and leave just a polymer sheath,” explains Gall. “Also, polymers are more flexible and do not stress the artery walls like the metals.”

Gall’s research group has designed a shape-memory polymer stent that can be compressed and fed through a tiny hole in the body into a blocked artery, just like a conventional stent. Then, the warmth of the body triggers the polymer’s expansion into its permanent shape, resulting in natural deployment without auxiliary devices. This work was published in the journal Biomaterials earlier this year.

For another project, Gall and graduate student David Safranski have been investigating how altering a polymer’s chemistry changes its properties, such as its ability to stretch. This project was funded by MedShape Solutions, an Atlanta company that Gall co-founded to develop medical devices primarily for use in minimally invasive surgery.

The researchers found that by changing the chemistry of the polymer backbone to include special side groups, they could increase the amount of strain the polymer could withstand before failing — without sacrificing stiffness. Gall and graduate student Scott Kasprzak are exploring how these polymers might be used as a deployable neuronal probe, with funding from the National Institute of Neurological Disorders and Stroke of the NIH.

“We’re looking for smart materials that can be synthesized in the size range of 100 microns — similar to the size of a strand of hair — and then be inserted into brain tissue,” explains Gall. “This type of probe would need to slowly change shape inside the brain as to not disturb any surrounding tissue.”

Another project in Gall’s laboratory is examining the use of these polymers for the spine. Most spinal surgeries are currently not performed arthroscopically, so Gall sees benefits in using these shape-memory materials to enable minimally invasive spinal surgery.

- Abby Vogel

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Shape-memory Polymers Developed for Biomedical Applications

Copper Improves Interconnects in Computer Systems

As computers become more complex, the demand increases for more connections between computer chips and external circuitry such as a motherboard or wireless card. And as the integrated circuits become more advanced, maximizing their performance requires better connections that operate at higher frequencies with less loss.

Improving these two types of connections will increase the amount and speed of information that can be sent throughout a computer, according to Paul Kohl, Thomas L. Gossage chair and Regents’ professor in Georgia Tech’s School of Chemical and Biomolecular Engineering. Kohl presented his work in these areas at the Materials Research Society fall meeting in November 2007.

The vertical connections between chips and boards are currently formed by melting tin solder between the two pieces. Research conducted by Kohl and graduate student Tyler Osborn shows that replacing the solder ball connections with copper pillars creates stronger connections and the ability to create more connections.

“Circuitry and computer chips are made with copper lines on them, so we thought we should make the connection between the two with copper also,” Kohl says.

Solder and copper can both tolerate misalignment between two pieces being connected, according to Kohl, but copper is more conductive and creates a stronger bond.

With funding from the Semiconductor Research Corporation (SRC), the researchers developed a novel fabrication method to create all-copper connections between computer chips and external circuitry.

The researchers first electroplate a bump of copper onto the surface of both pieces, a process that uses electrical current to coat an electrically conductive...
object with metal. Then, a solid copper connection between the two bumps is formed by electroless plating, which involves several simultaneous reactions that occur in an aqueous solution without the use of external electrical current.

Because the pillar, which is the same thickness as a dollar bill, is fragile at room temperature, the researchers anneal it, heating it in an oven to remove defects and create a strong solid-copper structure. Osborn found that strong bonds were formed at an annealing temperature of 180 degrees Celsius. He has also been investigating how misalignments between the two copper bumps affect pillar strength.

“I’ve also studied the optimal shape for the connections so that they’re flexible and mechanically reliable, yet still have good electrical properties so that we can transmit these high-frequency signals without noise,” says Osborn.

The researchers have been working with Texas Instruments, Intel and Applied Materials to perfect and test their technology. Jim Meindl, director of Georgia Tech’s Microelectronics Research Center and Sue Ann Allen, a professor in the School of Chemical and Biomolecular Engineering, have also collaborated on the work.

In addition to this new method for making vertical connections between chips and external circuitry, Kohl is also developing an improved signal transmission line with the help of graduate student Todd Spencer.

“Several very long communication pathways exist inside a computer that require a very high performance electrical line that can transmit at higher frequencies over long distances,” explains Spencer.

This is especially important in high-performance servers and routers where inter-chip distances can be large and signal strength may be significantly degraded. Kohl and Spencer have developed a new way to link high-speed signals between chips using an organic substrate, with funding from the Interconnect Focus Center, one of the Semiconductor Research Corporation/Defense Advanced Research Projects Agency (DARPA) Focus Center Research Programs.

- Abby Vogel

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Researchers Jonathan Holmes and Sergio Grullon demonstrate operation of the Ergonomic Work Assessment System.

Taking Aim at Preventing Worker Injuries

New technology is positioning an old injury-prevention program at the cutting edge of the poultry industry.

Nearly 10 years ago, scientists from the Georgia Tech Research Institute (GTRI) collaborated with Georgia Tech’s School of Applied Physiology to create the Ergonomic Work Assessment System (EWAS) to track the positioning and arm movements of workers as they deboned poultry. The idea was to identify and then avoid the factors leading to repetitive-stress injuries.

The improved EWAS, developed in cooperation with the poultry industry, provides a more accurate and detailed assessment by taking advantage of technology that wasn’t available in the ‘90s — namely position-tracking technology typically used to create computer animation.

“It measures arm position in three dimensions,” says GTRI research engineer Jonathan Holmes. “You strap the system onto your arm and move your arm around, and you can watch it moving on a screen beside you.”

The system measures forearm and wrist orientation as well as upper arm and shoulder activity. Separate modules provide a global reference for the position sensors. Muscle response is monitored through electromyography, a procedure for determining the level of electrical activity in muscles. Grip force on the knife is calculated by a technique developed by Liberty Mutual Research Institute for Safety, which is teaming up with the Georgia Tech design team for that part of the system development.

The aggregate data of shoulder and arm position, muscle response and grip force of a worker cutting poultry are transmitted wirelessly to a computer for analysis. EWAS will be used in field studies to assess the dynamics of muscle group interactions in job rotation schemes designed to reduce repetitive-motion disorders such as carpal tunnel syndrome.

“By monitoring these forces and positions, you can put numbers to physical motions and get a better idea of what is good and what is risky,” says Holmes. “You can hopefully determine if someone is using certain muscles too often, or if they are bending their wrists too far. This opens the door for studies that can eventually help us determine which risk factors are more likely to lead to injuries.”

The group is also investigating the development of a second system to monitor the back. They ultimately hope to pursue studies that can help reduce back injuries resulting from back-instability conditions.

- Gary Goettling

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In October 2001, letters containing anthrax spores were mailed to several news media offices and two U.S. senators, killing five people and infecting 17 others. Clearing the Senate Office Building of the spores with chlorine dioxide gas cost $27 million, while cleaning the Brentwood postal facility outside Washington, D.C. cost $130 million and took 26 months.

Researchers at the Georgia Tech Research Institute (GTRI), in collaboration with Austin-based Stellar Micro Devices, Inc. (SMD), have developed prototypes of a rapid, non-disruptive and less expensive method that could be used to decontaminate future bioterrorism hazards.

Using flat panel modules that produce X-rays and ultraviolet-C (UV-C) light simultaneously, the researchers can kill anthrax spores in two to three hours without any lingering effects. The system also has the ability to kill anthrax spores hidden in places like computer keyboards without causing damage.

“This is certainly an improvement over previous techniques,” says Brent Wagner, GTRI principal research scientist and director of its Phosphor Technology Center of Excellence (PTCOE). “The UV-C attacks spores on surfaces and the X-rays penetrate through materials and kill spores in cracks and crevices.”

The current decontamination standard – chlorine dioxide gas – cannot reach hidden spores. Hard surfaces must be cleaned independently with harsh liquid chlorine dioxide. In addition, people cannot re-enter a room fumigated with chlorine dioxide until the gas is neutralized with sodium bisulfite vapor and vented from the building.

The new decontamination system resembles a coat rack with radiation modules arranged on rings at various heights that face outward to broadcast radiation throughout a room.

UV-C light in the modules is produced using the optical and electrical phenomenon of cathodoluminescence. Numerous electron beams are generated by arrays of cold cathodes, each acting like the electron gun in a cathode ray tube.

“When an electron beam hits a powder phosphor, it luminesces and emits visible and/or non-visible light,” explains Hisham Menkara, a GTRI senior research scientist.

GTRI became involved in SMD’s project, which was funded by the Air Force Research Laboratory’s Small Business Innovation Research program, because the PTCOE housed UV-C phosphors created and patented by Sarnoff Corporation in the mid-1970s.

“We knew that Georgia Tech had experts in powder phosphors with regard to flat panel displays and we approached them to develop new phosphors for our decontamination purpose,” says Mark Eaton, president and CEO of SMD. “We were fortunate that they had UV-C phosphors available from decades earlier.”

With the Sarnoff phosphors, Wagner and Menkara set off to determine the best UV-C emitting phosphor and optimize its properties for use with X-rays in SMD’s small flat panel display.

To find the best phosphor that emitted light in the UV-C region of the spectrum – wavelengths below 280 nanometers – the emission spectrum of each phosphor was measured against the DNA absorption curve. This curve shows the optimal wavelengths to destroy an organism’s DNA.

After investigating many different phosphors, the researchers chose lanthanum phosphate:praseodymium (LaPO$_4$:Pr or LAP:Pr) as the most efficient phosphor. In the laboratory, Menkara created the phosphor by mixing precursors lanthanum oxide, hydrogen phosphate and praseodymium fluoride (La$_2$O$_3$, H$_3$PO$_4$, and PrF$_3$, respectively) in a glass beaker with methanol (CH$_3$OH) and ammonium chloride (NH$_4$Cl).

After evaporating the methanol, the resultant cake was crushed into a fine powder, heated in a furnace to a temperature as high as 1,250 degrees Celsius. Wagner and Menkara also found that adding lithium fluoride (LiF) and reducing the praseodymium concentration increased the cathodoluminescent properties of the LAP:Pr phosphor.

With the improved phosphor, laboratory tests conducted by SMD showed that the combined X-ray and UV-C decontamination system could kill anthrax spores. Beyond bioccontamination, UV-C panels could be used for sterilizing medical equipment or purification applications.

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MICRO NEEDLES DELIVER DRUGS THROUGH THE SKIN

In what is believed to be the first peer-reviewed study of its kind involving human subjects, researchers at Georgia Tech and the University of Kentucky demonstrated that patches coated on one side with microscopic needles can facilitate transdermal delivery of clinically-relevant doses of a drug that normally cannot pass through the skin.

Reported in the journal *Proceedings of the National Academy of Sciences*, the study could help advance the use of microneedles as a painless method for delivering drugs, proteins, DNA and vaccines into the body. The research also found other advantages for the microneedles, including an ability to produce therapeutic drug levels with lower doses, and reduced production of drug metabolites that may cause side effects.

Shown is an array of stainless steel microneedles.

See story on page 43.