Many energy issues are truly multidisciplinary and can't be addressed by one faculty member. The Strategic Energy Institute has been broadly engaging companies to define projects that many faculty members at Georgia Tech can pursue in a collaborative effort.

– Roger Webb, interim director of Georgia Tech’s Strategic Energy Institute

Our goal is to harvest every last photon that is available to our cells. By capturing more of the light in our 3-D structures, we can use much smaller photovoltaic arrays.

– Jud Ready, senior research engineer in the Electro-Optical Systems Laboratory at the Georgia Tech Research Institute (GTRI)

Digital media lets you describe the world in ways that older media couldn’t. Technology allows us to create imaginary worlds that people can act in. In contrast to a traditional board game, like Monopoly, which can only do one thing, the computer is tireless.

– Janet Murray, a professor and director of graduate studies at Georgia Tech’s School of Literature, Communication and Culture

“There has been a lot of interest in making nanodevices, but we have tended not to think about how to power them. Our nanogenerator allows us to harvest or recycle energy from many sources to power these devices.”

– Zhong Lin Wang, Regents’ Professor in the Georgia Tech School of Materials Science and Engineering
Georgia Tech is defining its own path through the biosciences. The path we are defining comes from our tradition of being quantitative and analytical, and this results in a style of approaching life sciences that allows us to step back and apply our strengths.

– Gary Schuster, Georgia Tech provost and vice president for academic affairs

The old method took four hours for each type of radium you needed to test – totaling eight hours for radium-226 and radium-228. Our method does the two tests simultaneously and it takes about half an hour of actual technician time.

– Robert Rosson, senior research scientist in the Georgia Tech Research Institute (GTRI)

One of the goals of lean health care is to awaken a new level of thinking and introduce manufacturing approaches that have been proven to produce excellent efficiency and profitability.

– Alan Kent, CEO and president of Meadows Regional Medical Center in Vidalia, Ga.

Now, because of our research, regulators know these microbes exist, that they are native to certain environments and that natural degradation processes are at work. Maybe this will influence decision-making processes, and bioremediation will be implemented.

– Frank Loeffler, associate professor, Georgia Tech School of Civil and Environmental Engineering

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Cover: Professor William Koros and postdoctoral fellow Wulin Qiu examine a hollow fiber membrane used to separate water from ethanol.

Photo by Gary Meek
Unique three-dimensional solar cells that capture nearly all of the light that strikes them could boost the efficiency of photovoltaic (PV) systems while reducing their size, weight and mechanical complexity.

The new 3-D solar cells capture photons from sunlight using an array of miniature “tower” structures that resemble high-rise buildings in a city street grid. The cells could find near-term applications for powering spacecraft, and by enabling efficiency improvements in photovoltaic coating materials, could also change the way solar cells are designed for a broad range of applications.

“Our goal is to harvest every last photon that is available to our cells,” says Jud Ready, a senior research engineer in the Electro-Optical Systems Laboratory at the Georgia Tech Research Institute (GTRI). “By capturing more of the light in our 3-D structures, we can use much smaller photovoltaic arrays. On a satellite or other spacecraft, that would mean less weight and less space taken up with the PV system.”

The 3-D design was described in the March 2007 issue of the journal JOM, published by The Minerals, Metals and Materials Society. The research has been sponsored by the Air Force Office of Scientific Research, the Air Force Research Laboratory, NewCyte, Inc., and Intellectual Property Partners, LLC. A global patent application has been filed for the technology.

The GTRI photovoltaic cells trap light between their tower structures, which are about 100 microns tall, 40 microns by 40 microns square, 10 microns apart – and grown from arrays containing millions of vertically aligned carbon nanotubes. Conventional flat solar cells reflect a significant portion of the light that strikes them, reducing the amount of energy they absorb.

Because the tower structures can trap and absorb light received from many different angles, the new cells remain efficient even when the sun is not directly overhead. That could allow them to be used on spacecraft without the mechanical aiming systems that maintain a constant orientation to the sun, reducing weight and complexity – and improving reliability.

“The efficiency of our cells increases as the sunlight goes away from perpendicular, so we may not need mechanical arrays to rotate our cells,” Ready notes.

The ability of the 3-D cells to absorb virtually all of the light that strikes them could also enable improvements in the efficiency with which the cells convert the photons they absorb into electrical current.

In conventional flat solar cells, the photovoltaic coatings must be thick enough to capture the photons, whose energy then liberates electrons from the photovoltaic materials to create electrical current. However, each mobile electron leaves behind a “hole” in the atomic matrix of the coating. The longer it takes electrons to exit the PV material, the more likely it is that they will recombine with a hole – reducing the electrical current.

Because the 3-D cells absorb more of the photons than do conventional cells, their coatings can be made thinner, allowing the electrons to exit more quickly, reducing the likelihood that recombination will take place. That boosts the “quantum efficiency” – the rate at which absorbed photons are converted to electrons – of the 3-D cells.

Fabrication of the cells begins with a silicon wafer,
which can also serve as the solar cell’s bottom junction. The researchers first coat the wafer with a thin layer of iron using a photolithography process that can create a wide variety of patterns. The patterned wafer is then placed into a furnace heated to 780 degrees Celsius. Hydrocarbon gases are then flowed into the furnace, where the carbon and hydrogen separate. In a process known as chemical vapor deposition, the carbon grows arrays of multi-walled carbon nanotubes atop the iron patterns.

Once the carbon nanotube towers have been grown, the researchers use a process known as molecular beam epitaxy to coat them with cadmium telluride (CdTe) and cadmium sulfide (CdS), which serve as the p-type and n-type photovoltaic layers. Atopt that, a thin coating of indium tin oxide, a clear conducting material, is added to serve as the cell’s top electrode.

In the finished cells, the carbon nanotube arrays serve both as support for the 3-D arrays and as a conductor connecting the photovoltaic materials to the silicon wafer.

The researchers chose to make their prototype cells from the cadmium materials because they were familiar with them from other research. However, a broad range of other photovoltaic materials could also be used, and selecting the best material for specific applications will be a goal of future research.

Ready also wants to study the optimal height and spacing for the towers, and to determine the trade-offs between spacing and the angle at which the light hits the structures.

The new cells face several hurdles before they can be commercially produced. Testing must verify their ability to survive launch and operation in space, for instance. And production techniques will have to be scaled up from the current two-inch laboratory prototypes.

“We have demonstrated that we can extract electrons using this approach,” Ready says. “Now we need to get a good baseline to see where we compare to existing materials, how to optimize this and what’s needed to advance this technology.”

Intellectual Property Partners of Atlanta holds the rights to the 3-D solar cell design and is seeking partners to commercialize the technology.

Another commercialization path is being followed by an Ohio company, NewCyte, which is partnering with GTRI to use the 3-D approach for terrestrial solar cells. The Air Force Office of Scientific Research has awarded the company a Small Business Technology Transfer (STTR) grant to develop the technology.

“NewCyte has patent pending, low-cost technology for depositing semiconductor layers directly on individual fullerenes,” explains Dennis J. Flood, NewCyte’s president and chief technology officer. “We are using our technology to grow the same semiconductor layers on the carbon nanotube towers that GTRI has already demonstrated. Our goal is to achieve performance and cost levels that will make solar cells using the GTRI 3-D cell structure competitive in the broader terrestrial solar cell market.”

In addition to Ready, other Georgia Tech researchers contributing to the work include R.E. Camacho, A.R. Morgan, M.C. Flores, T.A. McLeod, V.S. Kumsomboone, B.J. Mordecai, R. Bhattacharjeya, W. Tong, B.K. Wagner, J.D. Flicker and S.P. Turano.
We feel it at the pump. Fuel prices are at record highs and so is the demand for alternative fuels. But major scientific and technological advances are still required before economically viable alternative fuels become a significant part of the U.S. energy supply.

Researchers across the Georgia Institute of Technology campus are focusing their attention on biofuels. And while most experts agree that biofuels are not the silver bullet to solve the world’s long-term fuel needs, they see biofuels as a necessary complement to conventional oil and gas.

Georgia Tech is taking a comprehensive and interdisciplinary approach toward developing the technologies needed to economically produce bioethanol from forest products. In addition to addressing all five steps in the biofuel production process, researchers are also looking broadly at the entire production system.

Changing Energy

Georgia Tech takes interdisciplinary approach to developing biofuels from forestry products.

By Abby Vogel

Each year, the state of Georgia alone produces more than five million tons of trees beyond what its pulp and sawmill operations need. A research group (right) headed by Christopher Jones is pre-treating pine with catalysts used in the petroleum industry.
Biofuel research at Georgia Tech intensified in 2004 with the launch of the Strategic Energy Institute (SEI), created to enable, facilitate and coordinate programs related to energy research and education.

"Many energy issues are truly multi-disciplinary and can’t be addressed by one faculty member," says Roger Webb, interim director of the SEI. "The Strategic Energy Institute has been broadly engaging companies to define projects that many faculty members at Georgia Tech can pursue in a collaborative effort."

This interdisciplinary approach was a major reason why Chevron Corporation chose Georgia Tech as its first strategic research alliance partner, according to Rick Zalesky, vice president of the biofuels and hydrogen unit of Chevron Technology Ventures.

"Georgia Tech has the infrastructure so that researchers from various departments work together in the same building to solve complex problems, and we think that’s terrific," says Zalesky.

With funding from Chevron, Atlanta startup C2 Biofuels, the Georgia Research Alliance and one of the U.S. Department of Energy’s new BioEnergy Research Centers, Georgia Tech researchers are exploring advanced technologies aimed at making transportation fuels from forestry products.

Georgia Tech researchers are examining and optimizing the five major steps required to produce bioethanol, or ethanol obtained from the carbohydrates in many agricultural crops. These steps include selecting the best plant material, preparing the plants for conversion, breaking down the carbohydrates into simple sugars, fermenting the sugars into alcohol and separating the ethanol from water.

**Choosing a Plant Source and Preparing It for Conversion**

Bioethanol produced from corn is being manufactured at a rate of more than five billion gallons per year in the United States, but concerns exist about the future price and availability of corn as a food crop if it’s being used to help meet energy needs.

Because forest products are a more efficient source of ethanol and more than five million tons of trees are available for harvest each year in Georgia, Georgia Tech researchers are turning to Southern pine trees.

Switchgrass, a fast-growing tallgrass, is another attractive source of plant material because of its ability to grow in poor soil and adverse climate conditions, its rapid growth and its low fertilization and herbicide requirements.

Art Ragauskas, a professor in the School of Chemistry and Biochemistry, studies the chemistry and structure of the starting plant material, known as biomass, to determine which varieties and characteristics of switchgrass and pine trees improve conversion to ethanol.

He also examines how different acids react with the wood chips to make accessible the complex interior mixture of carbohydrate polymers, including cellulose, hemicellulose and lignin.

"Pre-treatment is performed under severe chemical conditions and very high temperatures. Understanding the chemistry should allow us to make pre-treatments more efficient, less costly and more effective," says Ragauskas.

After the acid pre-treatment, the wood is placed in a reactor and exposed to high-pressure steam.

John Muzzy, a professor in the School of Chemical and Biomolecular Engineering, and Kristina Knutson, a postdoctoral fellow in the School of Chemistry and Biochemistry, are working with Ragauskas to develop a continuous reactor that will employ mechanical energy and/or boiling water instead of acid and high temperatures to break up the wood. That would greatly reduce processing and chemical costs while increasing the life expectancy of the reactors, Ragauskas notes.

**CONTINUED ON PAGE 09**
Researchers at Georgia Tech, Imperial College London and the Oak Ridge National Laboratory formed the AtlantIC Alliance for BioPower, BioFuels and Biomaterials in 2003. Researchers including Georgia Tech’s Art Ragauskas developed a roadmap that contained a series of comprehensive research and policy plans to increase the practicality of using biofuels and biomaterials as a supplement to petroleum. A condensed version of the roadmap was summarized as a review article, called “The Path Forward for Biofuels and Biomaterials,” which appeared in the January 27, 2006 issue of Science. For a summary, see gtresearchnews.gatech.edu/reshor/rh-ss06/ragauskas.html.
Breaking Down the Sugars and Converting Them to Ethanol

After the pre-treatment, the cellulose and hemicellulose are further broken down to free the sugar for fermentation to alcohol. Commercially available enzymes can do this, but they are too expensive to use in biofuel production, according to Andreas (Andy) Bommarius, a professor in the School of Chemical and Biomolecular Engineering and the School of Chemistry and Biochemistry. As an alternative, he is identifying novel enzymes and engineering them to be longer-lasting and more effective at breaking down cellulose polymers to sugars than those commercially available.

“We want to produce enzymes more efficiently and make them more active and stable, at the same time improving bioethanol production at a lower cost,” explains Bommarius.

In conventional ethanol production, the sugars obtained are then fermented with yeast to produce alcohol. Rachel Ruizhen Chen, an associate professor in the School of Chemical and Biomolecular Engineering, is working to increase the ethanol production rate by using the bacteria Zymomonas mobilis instead of yeast in the fermentation process because it has a three- to five-fold higher productivity than yeast when making bioethanol. Chen plans to manipulate the enzymatic, transport and regulatory functions of the bacterial cell to improve the bioethanol fermentation process.

The lignin portion of the biomass must be extracted from the mixture prior to fermentation. Unfortunately, current pre-treatments break down some of the lignin, which enables it to be carried over to the fermentation process where it acts as a fermentation inhibitor.

RISING DEMAND FOR IMPORTED OIL

Annual U.S. oil imports increased from approximately two billion barrels in 1981 to more than five billion barrels in 2005. With domestic oil production declining, the U.S. is becoming more dependent on other countries for its energy supplies. In 2005, the top five countries from which the U.S. imported oil were Canada, Mexico, Saudi Arabia, Venezuela and Nigeria. At $70 per barrel, these expanding oil imports are adding significantly to the nation’s balance of payments deficit. “A near term solution to our growing transportation oil demand is urgently needed,” says Roger Webb, interim director of Georgia Tech’s Strategic Energy Institute. Webb testified before the U.S. Senate Committee on Agriculture, Nutrition and Forestry in January 2007.
William Koros, the Roberto C. Goizueta Chair in the School of Chemical and Biomolecular Engineering, is investigating efficient ways to separate the lignin from the cellulose and hemicellulose portions of the biomass. Koros, a Georgia Research Alliance (GRA) eminent scholar in membranes, plans to extract the lignin byproducts by pulling the hydrolyzed biomass mixture through a selective membrane with a vacuum using a process called pervaporation.

Lignin is an important by-product of the enzymatic process and has many potential uses. Ragauskas is examining the possibility of converting lignin to a biofuel precursor or using lignin as a building block chemical to make new polymers or chemicals. Professors Christopher Jones and Pradeep Agrawal, both of the School of Chemical and Biomolecular Engineering, are exploring ways to chemically fractionate pine and convert suitable portions to true gasoline fuels.

To produce a biofuel with a similar energy density to gasoline from renewable feedstocks, they plan to convert pre-treated pine to fuel using chemical catalysts traditionally used by the petroleum industry, rather than enzymes. These biofuels could yield higher miles-per-gallon than traditional ethanol-rich fuels such as E-85, according to Jones.

**Separating Ethanol from Water**

For bioethanol, once the sugars are fermented into alcohol, a significant amount of water must be separated out. This separation primarily occurs in a distillation column, which involves heating the mixture and separating the components by the differences in their boiling points.

“Distillation is very energy intensive and expensive, and it might defeat the purpose when you’re trying to produce biofuel economically,” says Sankar Nair, an assistant professor in the School of Chemical and Biomolecular Engineering, who is collaborating with Koros on two separation projects aimed at improving the energy efficiency of the biofuel process.

A membrane-based approach would avoid the need to supply heat energy, and instead rely on differences in the transport rates of the components through a membrane to achieve separation. The challenge is in producing selective membrane systems that can produce pure ethanol. Polymer materials have been widely investigated and have the advantage of high throughput, but such membranes can’t yet produce pure ethanol from a dilute ethanol-water mixture, notes Nair.

Instead, Koros and Nair are exploring membranes that contain nanoparticles of porous inorganic materials called zeolites that are so small they can be dispersed efficiently into a polymer matrix. The very specific porosity of the zeolite should allow separation of ethanol from water. By using two membranes in series – the first hydrophobic to remove ethanol from a large mass of water and the second hydrophilic to remove any trace water in the ethanol product from the first membrane – it may be possible to design an economical membrane process for biofuel separation from water.

**Taking a Systems Approach**

Producing ethanol from biomass involves more than these process steps. Researchers must also decide how to ship the biomass to the processing plant, how large the processing plant should be, where it should be located, and how to ship the ethanol to fueling stations.

Bill Bulpitt, an SEI senior research engineer who returned to Georgia Tech in 2004 after working 17 years for Southern Company, is working with students who are running computer simulation models that represent what a full-scale production plant
Professor John Muzzy in the School of Chemical and Biomolecular Engineering (CHBE) is evaluating a process called pyrolysis. Biomass is heated with catalysts to form a synthetic natural gas and create volatile compounds that can be condensed for blending with oil. Since current pyrolysis techniques require very high temperatures, Muzzy aims to perform catalytic pyrolysis at lower temperatures and create a stable bio-oil with reduced oxygen content.

Professor W. J. (Jim) Frederick, Jr. and principal research engineer Kristiina Isa, also of CHBE, study a similar process called gasification. They add oxygen or steam to the biomass mixture to create a gaseous mixture of carbon monoxide and hydrogen. Their research focuses on both gasification and removing contaminants from the product gas so that it can be converted into ethanol, synthetic diesel and other fuels through catalytic processes. Using a large-scale reactor on the Georgia Tech campus, they can study the high pressure, high temperature conditions the gas encounters in the catalytic reactors.
might look like. The models analyze the costs for the various components of the system, which helps to determine the optimal biorefinery size.

"When building a biorefinery, there is a certain size that's economically viable. That's what we are trying to determine," Bulpitt explains.

To evaluate a biofuel system, the project team must consider the energy balance – that is, how much energy goes in versus how much comes out. A biofuel system must take into account positive or negative energy balances, positive or negative net greenhouse gas emissions, and positive or negative environmental and ecosystem impacts.

Ethanol biorefineries could get a significant economic boost from the sale of high-value chemicals that could be generated from the same feedstock. Charles Eckert, a professor in the School of Chemical and Biomolecular Engineering and collaborator Charles Liotta and Art Ragauskas are exploring the use of environmentally friendly solvent and separation systems to produce specialty chemicals, pharmaceutical precursors and flavorings from a small portion of the ethanol feedstock.

Matthew Realff, an associate professor in the School of Chemical and Biomolecular Engineering, is developing optimization models to determine the best structure for a biofuel processing system. Realff’s model integrates information from crop production through processing to fuel distribution. It includes information on the location and number of crop acres available, the current economic value of the crop, distances and ability to ship the crop, the economic scaling of the cost of the processing equipment with size and the location of the distribution terminals.

These optimization models are valuable to companies like C2 Biofuels that plan to build biorefineries. And they complete the comprehensive research approach Georgia Tech has taken toward optimizing bioethanol production process.

“Researchers at Georgia Tech have different strengths and take different approaches toward solving the problem of developing biofuels,” says Christopher Jones. “If you assemble all of the pieces together, you will come up with the best solution.”

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CONTINUED FROM PAGE 10

Georgia Tech is one member of a new $125 million U.S. Department of Energy (DOE) Bioenergy Research Center, intended to accelerate basic research in the development of cellulosic ethanol and other biofuels. The Center aims to advance President Bush's Twenty in Ten Initiative, which seeks to reduce U.S. gasoline consumption by 20 percent within ten years through increased efficiency and diversification of clean energy sources. Georgia Tech's primary role in the center will focus on biomass characterization and the fundamental chemistry of plant cell walls. The goal will be to study the chemical bonds of poplar and switchgrass to help create more efficient methods of breaking the plants down into the sugar needed to make ethanol.
With support from a broad range of organizations, Georgia Tech researchers are exploring advanced technologies aimed at making transportation fuels from forestry products.

**Chevron Corporation**

In June 2006, Chevron Corporation and Georgia Tech formed a five-year, $12 million strategic research alliance to pursue advanced technology aimed at making cellulosic biofuels and hydrogen viable transportation fuels.

The alliance focuses its research on four areas:

- Producing cellulosic biofuels
- Understanding the characteristics of biofuel feedstocks
- Developing regenerative sorbents (porous materials used to remove gases such as carbon monoxide, carbon dioxide and nitrogen)
- Improving sorbents used to produce high-purity hydrogen

A portion of the money will be used to set up a bioethanol laboratory on the Georgia Tech campus to support ongoing and future biofuel research. The laboratory will contain new equipment, including analytical equipment to study how much ethanol is being produced, how long it takes to ferment and the quality of the ethanol being produced.

**C2 Biofuels**

C2 Biofuels is a Georgia Tech VentureLab startup that seeks to develop fuel-ethanol production from biomass material available in large quantities in the Southeast, including Southern yellow pine. Led by Roger Reisert, a Georgia Tech alumnus, C2 Biofuels obtained two $100,000 grants from The Agriculture Innovation Center in Tifton to match the initial investment from Georgia Tech alumnus Glen Robinson Jr.

Reisert has provided grants to Georgia Tech and University of Georgia researchers to evaluate and develop processes and technologies. Since the target ethanol yield has been met by the researchers, Reisert's efforts are now focused on building a pilot bioethanol plant in Georgia.

**Georgia Research Alliance (GRA)**

Founded in 1990, the Georgia Research Alliance (GRA) helps build Georgia’s technology-rich economy by bringing business and state government together to invest in the innovative research at six affiliated Georgia research universities, including Georgia Tech.

With the support of Governor Sonny Perdue and the Georgia Legislature, the GRA added an energy initiative last year, the Energy Research Seed Grant Program (ERSGP), to spark university-based research into the development of new approaches to producing and conserving energy resources.

With Georgia’s abundant resources and potential of cellulosic biomass, this program sought contributions to the growth and efficient harvest of improved cellulosic crops (including forest resources) and the conversion of cellulosic crops to higher value energy and/or chemical co-products. Four Georgia Tech researchers were awarded seed grants under the ERSGP for funding from July 1, 2006 to June 30, 2007. – Abby Vogel
The first video game debuted in 1958, but it wasn't until the early 1970s that this new diversion began to catch on, emerging first in bowling-alley and bar arcades and then spreading to consumers' homes via personal computers.

Fast-forward to today: Video gaming has become one of the fastest-growing forms of entertainment. According to a recent study sponsored by the Entertainment Software Association (ESA):

• Sales of video-game software in the United States totaled $8.2 billion in 2004 — not far behind the music industry, which generated $11.4 billion the same year.
• By 2010, U.S. sales of video games are expected to grow to $15 billion.
• Video gaming is expected to generate more than 250,000 jobs by 2009, a 75 percent increase over the industry's 144,000 full-time positions in 2004.

The New Golf
What's caused video games to evolve from a boutique market to a bona fide industry? Experts point to a myriad of reasons, including more powerful central processing units (CPUs) and advanced technology for sound, video, 3-D art and motion in game play.

“Digital media lets you describe the world in ways that older media couldn’t,” observes Janet Murray, a professor and director of graduate studies at Georgia Tech’s School of Literature, Communication and Culture (LCC). “Technology allows us to create imaginary worlds that people can act in. We can set up games that are more challenging and have more variety because they are procedurally created by making up rules in the computer. In contrast to a traditional board game, like Monopoly, which can only do one thing, the computer is tireless.”

Michael Nitsche, an assistant professor at LCC, points out that Hollywood films and related video games are often released at the same time. “This blurring of boundaries between media is putting video games more into the limelight,” says Nitsche. "Plus, we have a longer history of video gaming now, which means a bigger, older and some-
Stereotypes suggest that video gaming is primarily for adolescents, but ESA statistics show the market is much broader. According to the organization, 69 percent of American heads of household played video games in 2005. The average age of gamers was 33 years, and 25 percent of players were older than 50.

Celia Pearce, an LCC assistant professor who heads up the Experimental Game Lab, studies both female and older players. “There’s a popular misconception that older gamers, especially women, are only playing casual games,” she says. “It turns out that Baby Boomer gamers are hard core players, though they have very different practices and preferences than the groups for which the industry typically develops and markets games. Plus, they are spending a lot more money.”

Pearce sees a demographic shift as gamers get older, and older people get into gaming. The Nintendo Wii machine is leading this shift with aggressive marketing to Baby Boomers and women. “They even had a booth at the American Association for Retired Persons (AARP) National Event and Expo, which is an all-time first for a game company,” Pearce notes.

Video games, it seems, have gone beyond mainstream and captured audiences early developers never imagined.

“In many ways, video gaming is becoming the new golf,” says Christopher Klaus, founder and CEO of Kaneva, an Atlanta startup focused on building a 3-D virtual entertainment world. (Klaus also founded Internet Security Systems, which IBM purchased recently for $1.3 billion.)

“While players are on a game quest, they’re also building friendships and bonds with other people – similar to golf,” explains Klaus. In addition to developing an innovative virtual entertainment world, Kaneva also plans to let subscribers use its platform to engineer their own virtual world or video games.
The term “video games” comes with a lot of baggage, Klaus continues: “Most people think video games are just for kids. Yet this technology is becoming part of our social fabric and culture. It goes beyond being just a game; it becomes part of your identity.”

Beyond Entertainment

What’s more, gaming technology has transferred to other industries, ranging from health care to defense, where it is used for educational and training simulations.

Take Persuasive Games, an Atlanta startup launched by Ian Bogost, an assistant professor at Georgia Tech’s LCC. Among its products, Persuasive Games has developed a game for Cold Stone Creamery that teaches employees about portion sizes and how they affect profitability. Another game helps grade-school students learn about the science behind telecommunications technologies.

Bogost, who is interested in how games can argue position and attempt to convince people of a particular belief, has also created a number of public-policy games, such as “Take Back Illinois.” Sponsored by the Illinois Republican Party, this game challenges players to explore four issues tied to the 2004 state elections.

Sparking innovation in hardware, SimCraft – a member company of Georgia Tech’s Advanced Technology Development Center (ATDC) – is introducing a low-cost, military-grade, full-motion simulator that provides a simulated G-force for SimRacing and FlightSim at home.

SimCraft’s system features a patent-pending chassis that rotates around three degrees of freedom. At its most advanced setup, the system allows the cockpit’s occupant to yaw up to 50 degrees to the left and right, pitch up to 30 degrees fore and aft, and roll up to 50 degrees port and starboard.

“Some experts believe that the physical, tactile element is the most significant factor affecting the realism of any vehicle simulation,” says Sean MacDonald, SimCraft’s CEO. “A sense of realism is particularly important if you’re using a simulator for training, because it makes learning more intuitive and fun – and consequently more efficient.”

Initially, the company is focusing on simulations for amateur race car drivers and general aviation pilots because they receive dual benefits in both training and entertainment at home.

“Since racing and flying are so expensive, a simulator allows enthusiasts in these hobbies to subsidize actual racing or flying with realistic simulation,” says MacDonald. “It is a safe, convenient and cost-effective way for them to enjoy their hobby and get better at it in the comfort of their home.”

SimCraft’s technology also has broad applications that include more generalized video gaming entertainment and military defense training.

On the Upswing

Georgia’s video-gaming industry is relatively small but poised for growth, say observers.

“The overall gaming industry is experiencing tremendous growth and we believe that Georgia has the ingredients to be a hub of activity,” says Tony Antoniades, general manager of the ATDC. “From the design industry in Savannah to the computing and visualization expertise in Atlanta, we expect to see more great gaming technologies over the next few years.”

Kaneva’s Klaus is also upbeat. “If there’s one industry that Atlanta could jump into, it’s video games. We can leverage the high-tech foundation that already exists here,” he says, noting that ISS alone employs some 300 engineers in the metro area. “If you look at where entertainment is going, it’s all about high tech. Today, entertainment is being driven by how good the technology is.”

For the Atlanta region, video gaming is a comeback story of sorts. For in the early 1990s, there were a number of game studios here, including divisions at IBM and Turner Broadcasting. “But then the market shifted from PCs to console gaming, and both IBM and Turner shut down their gaming groups,” says Marcus Matthews, CEO and co-founder of Blue Heat Games, an up-and-coming developer of wireless video games.

Matthews, a graduate of Georgia Tech's
A n experimental approach is one of the hallmarks of Georgia Tech’s digital media programs. “We not only do paper designs, but when we get an idea, we develop it and get a prototype up and running,” says Michael Nitsche, an assistant professor in Georgia Tech’s School of Literature, Communication and Culture (LCC). “Very few universities do that.”

A sampling of current projects includes:

**Interactive TV** – Students in Janet Murray’s Experimental TV Lab (www.etv.gatech.edu) have recently created a prototype for a game based on a broadband version of the Cartoon Network’s Ben 10 show, meant for broadband delivery through a game console like the Sony PS3. Players can select an episode and watch it with an active game controller targeting items in the video stream – such as a hat or a sword – and saving them to play in their own play space. This allows them to play a matching game, which intensifies their immersion in the show rather than distracting them from it.

**Characters and procedural game spaces** – Nitsche is developing an experimental video game called Charbitat (www.egl.gatech.edu/charbitat/) where the 3-D world changes based on the player’s actions in the game. The project, funded by Turner Broadcasting, focuses on the idea of procedural space. “You create the world as you play in it, which is unique,” Nitsche explains. “The game world is player dependent and constantly changing.”

**Multiplayer gaming** – Georgia Tech’s Emergent Game Group (EGG), headed by Celia Pearce, focuses on “designing for social emergence” in massively multi-player online games (MMOGs). The group is developing *Mermaids*, a multi-player game set in an underwater mermaid world. The first prototype has been shown at the Game Developers Conference, the Indie MMOG Conference, SIGGRAPH and the Austin Game Developers Conference.

**Moving beyond the joystick** – Graduate students Brian Schrank and Jeremy Rogers are designing software that would react with a standard keyboard in new ways. “For example, if players bang the keyboard, they could get a different result as opposed to just typing,” says Ian Bogost, an assistant professor at LCC who is the project’s adviser.

**Augmented reality** – Researchers are working on an augmented-reality version of Façade, a video game in which players visit a quarreling couple’s apartment. In the augmented-reality version, players can physically walk through the couple’s apartment and carry on conversations with the computer-animated characters, which are superimposed on the real world via a see-through head-worn display.

“Our experiment compares whether walking around in the space is more engaging and enjoyable than sitting at a desktop,” says Blair MacIntyre, an associate professor in Georgia Tech’s College of Computing (CoC). “Interestingly, we found that being immersed in the emotionally charged environment was too intense for some people and interfered with their ability to enjoy the experience as a game.”

In addition to MacIntyre, the project’s team includes Steven Dow and Manish Mehta, two CoC graduate students, and Michael Mateas, an assistant professor at the University of California-Santa Cruz who created the original Façade video game.

Video-game development is a multidisciplinary endeavor. “One of the great things about Georgia Tech is that interdisciplinary work is much easier here than other places,” says Murray. “Granted, collaboration is always easier in an institute of technology because the engineering model is one of making things together. Yet at Georgia Tech, there’s a particular climate of cooperation and mutuality of interests among the faculty in digital media which makes it much easier to collaborate.”
Stewart School of Industrial and Systems Engineering, was working for Turner at the time of the downturn. He relocated to San Francisco where he joined Sega of America and eventually ran its sports group, which generated about $100 million in revenue.

Yet Matthews had an entrepreneurial itch that led him back to Georgia to launch Blue Heat in 2001. “I felt there was a lot of untapped talent in Atlanta – plus the cost of living was lower here,” he explains. Blue Heat, which counts 16 employees, has shipped more than 30 mobile games during the past four years including one on Jimmy Neutron, a movie and TV character that Nickelodeon is distributing.

Blue Heat is one of some 60 companies working in Georgia’s video-game arena, says Clinton Lowe, founder of the Georgia Game Developers Association, Inc. (www.ggda.org), a nonprofit trade organization focused on growing the state’s gaming industry.

“I see video games as a new market for Georgia – one that, if we make some fundamental investments, will explode,” says Lowe. Among positive signs, the Georgia General Assembly recently passed tax credits aimed at game developers and film companies that base production activities, such as editing, animation and coding, in the state.

Why care about video gaming? For one thing, the industry provides high-paying jobs that could help ease the economic sting of Georgia’s eroding manufacturing base. According to ESA statistics, entry-level game developers earn $67,000 per year.

Video-game development is high science, providing white-collar, intellectual jobs, Lowe notes. Today’s game development teams must have expertise in a wide range of skill sets, including 3-D graphics, architectural engineering, artificial intelligence, computer networking, databases, mathematics, physics, digital sound and more.

**Educating the Next Generation**

Education is one advantage that the state already has in its favor, for Georgia Tech is a magnet school for video gaming.

“When game companies hire employees, Georgia Tech is one of three schools that they turn to,” says LCC’s Murray, noting the other two schools are Carnegie Mellon and the University of Southern California. “We’re supplying the next generation of game designers and we’re training them in a way that employers can’t get elsewhere.”

Georgia Tech has offered a master’s degree in digital media since 1993. In 2004, the school expanded its offerings by launching both a Ph.D. program in digital media and an undergraduate degree in computational media, the latter being a joint program between the College of Computing and

“Digital media lets you describe the world in ways that older media couldn’t. Technology allows us to create imaginary worlds that people can act in. In contrast to a traditional board game, like Monopoly, which can only do one thing, the computer is tireless.”

— Janet Murray, a professor and director of graduate studies at Georgia Tech’s School of Literature, Communication and Culture (LCC).
LCC. Currently there are about 40 graduate students and 200 undergraduate students in the three degree programs.

“More than half of the undergraduate students in computational media are interested in the video-game industry, which is difficult to get into,” says Blair MacIntyre, an associate professor in Georgia Tech’s School of Interactive Computing, which is part of the College of Computing.

“Our program sets students apart from other people,” he adds. “The degree puts them in a position to bridge the gap between art and technology and get them into production management as opposed to being down in the trenches.”

Strengthening Georgia’s video-gaming industry would not only improve the state’s economy, but also prevent brain drain. “If graduates are getting into video games, they’re more than likely relocating to the West Coast,” says GGDA’s Lowe. “That’s a tremendous loss of human capital for the state of Georgia. We’re spending tax dollars to educate students and then letting them go.”

To bolster gaming, Lowe would like to see more venture capital flowing toward video-game startups. That’s because the average cost of developing a video game today has soared from about $40,000 to $10 million during the last decade. “One of the things GGDA is doing is to help companies learn to speak the language of capital sources and learn how to approach venture capitalists,” says Lowe.

Attracting a major video publishing company would also be a plus, Lowe adds. Publishers have muscle in managing intellectual property – an area where small design studios typically are weak.

On Matthews’ wish list: recruiting more senior-level talent to Georgia. “We have a good pipeline school, but we also need seasoned people who can avoid making mistakes – and that’s something that only comes from years of experience in an industry,” he explains.

Still, Matthews remains optimistic. “We’re starting to get a nucleus of companies and talent that are doing things,” he says. “Georgia has the right pieces in place – state incentives, business and technical talent, the right cost structure – it’s just a matter of time.”
Powering Nanodevices

Nanogenerator provides continuous power by harvesting energy from the environment.

By John Toon

Researchers have demonstrated a prototype nanometer-scale generator that produces continuous direct-current electricity by harvesting mechanical energy from such environmental sources as ultrasonic waves, mechanical vibration or blood flow.

Based on arrays of vertically aligned zinc oxide nanowires that move inside a novel “zigzag” plate electrode, the nanogenerators could provide a new way to power nanoscale devices without batteries or other external power sources.

“This is a major step toward a portable, adaptable and cost-effective technology for powering nanoscale devices,” says Zhong Lin Wang, Regents’ Professor in the Georgia Tech School of Materials Science and Engineering. “There has been a lot of interest in making nanodevices, but we have tended not to think about how to power them. Our nanogenerator allows us to harvest or recycle energy from many sources to power these devices.”

Details of the nanogenerator were reported in the journal Science in April 2007. The research was sponsored by the Defense Advanced Research Projects Agency (DARPA), the National Science Foundation (NSF), and the Emory-Georgia Tech Center of Cancer Nanotechnology Excellence.

The nanogenerators take advantage of the unique coupled piezoelectric and semiconducting properties of zinc oxide nanostructures, which produce small electrical charges when they are flexed.

Fabrication begins with growing an array of vertically aligned nanowires approximately a half-micron apart on gallium arsenide, sapphire or a flexible polymer substrate. A layer of zinc oxide is grown on top of the substrate to collect the current. The researchers also fabricate silicon zigzag electrodes, which contain thousands of nanometer-scale tips made conductive by a platinum coating.

The electrode is then lowered on top of the nanowire array, leaving just enough space so that a significant number of the nanowires are free to flex within the gaps created by the tips. Moved by mechanical energy such as waves or vibration, the nanowires periodically contact the electrode, transferring their electrical charges. By capturing the tiny amounts of current produced by hundreds of nanowires kept in motion, the generators produce a direct current output in the nano-Ampere range.

Wang and his group members – Xudong Wang, Jinhui Song and Jin Liu – expect that with optimization, their nanogenerator could produce as much as four watts per cubic centimeter – based on a calculation for a single nanowire. That would be enough to power a broad range of nanometer-scale defense, environmental and biomedical applications – including biosensors implanted in the body, environmental monitors – and even nanoscale robots.

With its multiple conducting tips similar to those of an atomic force microscope, the new zigzag electrode serves as a Schottky barrier that accumulates and preserves electrical charge from hundreds or thousands of wires simultaneously.

“We can now see the steps
involved in moving forward to a device that can power real nanometer-scale applications," Wang says.

Before that happens, additional development will be needed to optimize current production. For instance, though nanowires in the arrays can be grown to approximately the same length – about 1 micron – there is some variation. Wires that are too short cannot touch the electrode to produce current, while wires that are too long cannot flex to produce electrical charge.

“We need to be able to better control the growth, density and uniformity of the wires," Wang adds. “We believe we can make as many as millions or even billions of nanowires produce current simultaneously.”

In their lab, the researchers aimed an ultrasonic source at their nanogenerator to measure current output for as long as five days. Though there was some fluctuation in output, the current flow was continuous as long as the ultrasonic generator was operating, Wang says.

Providing power for nanometer-scale devices has long been a challenge. Batteries and other traditional sources are too large, and tend to negate the size advantages of nanodevices. And since batteries contain toxic materials such as lithium and cadmium, they cannot be implanted into the body as part of biomedical applications.

Because zinc oxide is non-toxic and compatible with the body, the new nanogenerators could be integrated into implantable biomedical devices to wirelessly measure blood flow and blood pressure within the body. And they could also find more ordinary applications. 

“If you had a device like this in your shoes when you walked, you would be able to generate your own small current to power small electronics," Wang notes. "Anything that makes the nanowires move within the generator can be used for generating power. Very little force is required to move them."
Research Horizons

Georgia Tech researchers’ work is covered in the news media.

Publishing in the journal Science, Georgia Tech researchers reported on a prototype nanometer-scale generator that produces continuous direct-current electricity by harvesting mechanical energy from such environmental sources as ultrasonic waves, mechanical vibration or blood flow. The New York Times, New Scientist, Electronic Engineering Times, Nature Nanotechnology, Military & Aerospace Electronics, Advanced Materials & Processes, Technology Horizons, The Dallas Morning News, Technology Review, The Atlanta Journal-Constitution, Scientific-American.com, LiveScience.com and more than 40 other news outlets reported on the work, which was led by Regents’ Professor Zhong Lin Wang in the School of Materials Science & Engineering. (See the article on page 20 of this issue of Research Horizons).

More than 80 news outlets reported on the Georgia Tech Research Institute’s development of unique 3-D solar cells that capture nearly all of the light that strikes them. BusinessWeek, The Boston Globe, Electronic Engineering Times, Newsday, InfoWorld, Materials World, USA Today, The Washington Post and Technology Review were among the outlets reporting on the work. Based on tiny “towers” fabricated from carbon nanotubes, the cells could boost the efficiency of photovoltaic (PV) systems while reducing their size, weight and mechanical complexity. Jud Ready of GTRI’s Electro-Optical Systems Lab is the principal researcher. (See the article on page 4 of this issue of Research Horizons).

Producing 3-D polymer line structures as small as 65 nanometers wide became easier with Georgia Tech’s development of new two-photon absorbing molecules that are sensitive to laser light at short wavelengths, allowing researchers to create them without highly sophisticated fabrication methods. Key technical media, including Semiconductor International, Solid State Technology, Laser Focus World and Electronic Engineering Times reported on the development, which was led by Professor Joe Perry in the School of Chemistry and Biochemistry and the Center for Organic Photonics and Electronics. (See the article on page 37 of this issue of Research Horizons).

Chemical & Engineering News, Chemical Processing, Chemistry World, New Scientist, Electronic Products and Technology Review were among more than two dozen news outlets reporting on development of a new form of the industrially important metal platinum: 24-facet nanocrystals whose catalytic activity per unit area can be as much as four times higher than existing commercial platinum catalysts. The work, reported in the journal Science, was done by a team of researchers from Georgia Tech and Xiamen University in China. Regents’ Professor Zhong Lin Wang from the School of Materials Science and Engineering was the Georgia Tech project leader. (See the article on page 34 of this issue of Research Horizons).

International news media, including Reuters, the Australian Broadcasting Corp., the Sydney Morning Herald, and ANTARA – the Indonesian National News Agency – reported on a Georgia Tech study of the July 2006 Java tsunami that killed more than 600 persons. The study, led by Hermann Fritz from the School of Civil and Environmental Engineering, found that beachgoers did not feel the earthquake that caused the tsunami and even trained lifeguards missed signs of the approaching waves. (See the article at gtresearchnews.gatech.edu/newsrelease/java-tsunami.htm).

A patent received by the Georgia Tech Research Institute (GTRI) for a key improvement to the circuitry of military radar warning receivers attracted attention from Defense News, Electronic Design, Machine Design, Military & Aerospace Electronics and other key technical media. The improvement, developed by GTRI researchers Michael L. Willis and Michael L. McGuire with Air Force scientist Charlie W. Clark, is for a digital crystal video receiver that allows a troublesome analog process to be shifted to the digital domain. The change is expected to improve reliability and reduce cost for the radar warning receivers. (See the article at gtresearchnews.gatech.edu/newsrelease/digital-video.htm).

Regents Professor C.P. Wong was quoted in an Associated Press article on a new superhydrophobic – water-repelling – surface coating developed by the General Electric Co. Wong, a researcher in the School of Materials Science and Engineering who is pursuing water-repelling coatings for other applications, described the technical challenges involved in the research. News articles were picked up by dozens of print and online news outlets, including BusinessWeek, Forbes, the Los Angeles Times, MSN Money, Newsday, the Washington Post and the Miami Herald. (See the article on Wong’s research at gtresearchnews.gatech.edu/newsrelease/lotus.htm).

Hermann Fritz interviews a tsunami survivor, while the map (below) shows heights of the tsunami waves.
Georgia Tech faculty and staff receive recognition.

In recognition of his outstanding achievements in the areas of volume holography and photonic crystals, Associate Professor Ali Adibi in the School of Electrical and Computer Engineering has received the Technology Achievement Award, given annually by the International Society for Optical Engineering.

Four faculty members have been named Fellows of the American Institute for Medical and Biological Engineering. They are: Associate Professor Paul J. Benkeser, Professor Gang Bao and Professor Shuming Nie – all from the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University – and Associate Professors Andres J. Garcia and Robert E. Guldberg, both from the Woodruff School of Mechanical Engineering.

Fred L. Cook, professor in the School of Polymer, Textile and Fiber Engineering, is president-elect of the American Association of Textile Chemists and Colorists (AATCC).

John Cressler, Byers Professor in the School of Electrical and Computer Engineering, and his recently graduated Ph.D. students, Ram Krithivasan and Yuan Lu, were named the recipients of the Institute of Electrical and Electronic Engineers (IEEE) Electron Devices Society 2007 George E. Smith Award.

Russell D. Dupuis, the Steve W. Chaddick Endowed Chair in Electro-Optics in the School of Electrical and Computer Engineering, received the 2007 Institute of Electrical and Electronic Engineers (IEEE) Edison Medal for "pioneering contributions to metal organic chemical vapor deposition technology and continuous-wave room-temperature quantum-well lasers."

Stewart School of Industrial and Systems Engineering Professor Augustine Esogbue was honored with NASA’s Space Flight Team Awareness Award and its Public Service Medal in 2007 for his service and leadership on the Aerospace Safety Advisory Panel.

The American Society of Mechanical Engineers has named Professor Jerry Ginsberg in the Woodruff School of Mechanical Engineering as recipient of its 2007 Per Brue Gold Medal for Noise Control and Acoustics.

The Manufacturing Extension Partnership in the U.S. Department of Commerce’s National Institute of Standards and Technology has named Principal Research Associate Ed Hardison of the Enterprise Innovation Institute as a “Practitioner of the Year,” one of only five to be chosen nationwide in recognition of individuals whose leadership and contributions have made a significant impact on small and medium-sized manufacturers.

Professor of Computing Mary Jean Harrold was named as the number one software engineering scholar in the world in the June 2007 issue of Communications of the ACM.

For his contributions to organic nonlinear optical materials and optoelectronic devices, Professor Bernard Kippelen of the School of Electrical and Computer Engineering has been elected as a Fellow of the Optical Society of America.

Chin-Hui Lee, a professor in the School of Electrical and Computer Engineering, received the Signal Processing 2006 Technical Achievement Award by the Institute of Electrical and Electronic Engineers’ Signal Processing Society Board of Governors.

Stewart School of Industrial and Systems Engineering Professor Jye-Chyi (J.C.) Lu was inducted as a Fellow of the American Statistical Association, a scientific and educational society promoting excellence in the application of statistical science across the wealth of human endeavor.

Tom McDermott, director of the Electronic Systems Laboratory in the Georgia Tech Research Institute, was selected as a senior member of the Institute of Electrical and Electronic Engineers.

Assistant Professor Chris Paredis from the Woodruff School of Mechanical Engineering was recently recognized with the Ralph R. Teetor Education Award from the Society of Automotive Engineers.

Meisha Shofner, assistant professor in the School of Polymer, Textile and Fiber Engineering, has been selected to receive one of the Ralph E. powe Junior Faculty Enhancement Awards, an award that provides seed money for research by junior faculty at Oak Ridge Associated Universities member institutions.

Mohan Srinivasarao, professor in the School of Polymer, Textile and Fiber Engineering, was elected a Fellow of the American Physical Society for “for his creative contributions to the fields of microstructured polymers and polymer-disperse liquid crystals.”

Rao Tummala, the Joseph M. Pettit Chair in Electronics Packaging in the School of Electrical and Computer Engineering, received the 2007 David Feldman Outstanding Contributions Award, given by the Institute of Electrical and Electronic Engineers (IEEE) Components, Packaging, and Manufacturing Technology Society for outstanding contributions in executive or managerial directions.

The Georgia Society of CPAs recently selected Deborah Turner, associate professor of accounting in the College of Management, as the recipient of the 2007 Accounting Educator of the Year Award.

— compiled by Nancy Fullbright
When materials scientist Ken Sandhage needs to consult with a chemist, biologist or even an electrical engineer, he need only step up or down a few flights of stairs in Georgia Tech’s new Molecular Science & Engineering Building (MS&E).

“It’s much easier to have productive conversations in the hallways if you are clustered in a building with people who have similar research interests, even if they aren’t in the same department,” he says. “I don’t have to walk across campus to find someone to talk with about an issue outside of my own discipline.”

Easy collaboration across disciplines and departments provided the design goal for the five-story, 275,000-square-foot structure that opened in August 2006. Everything about it – including the location of faculty offices, design of interior open spaces and orientation to other buildings in the complex – encourages faculty from a broad cross-section of Georgia Tech to work together.

Even Sandhage’s lab is interdisciplinary, a necessity to support his interest: creating tiny electronic devices from the unique 3-D micro-shells of diatoms. His lab includes a cell culture room for growing the brownish-red phytoplankton, traditional ceramic engineering furnaces, an electronic test station – and a biochemistry lab for studying peptides that induce the formation of functional inorganic materials.

MS&E can house 41 principal investigators, 50 support staff and more than 400 research staff and graduate students. Research done in the building includes materials and polymer characterization, biomanufacturing, membrane fabrication, nanochemistry, molecular biophysics and computational chemistry. Five schools from Georgia Tech’s College of Sciences and College of Engineering are represented.

That suits Joe Perry’s work well. A faculty member in the School of Chemistry and Biochemistry, he’s part of the Center for Organic Photonics and Electronics – which already includes researchers from different schools.

“We have built our new buildings so they are interactive and flexible, with a lot of open meeting space,” he says. “We have tried to provide a social, interactive environment that allows easy collaboration and cooperation.”

But there’s much more to it than that.

“Building ‘Research Neighborhoods’”

Universities traditionally organize themselves around disciplines, part of a “reductionist” approach that solves difficult problems by breaking them down into pieces small enough to understand. That approach has worked well, and is necessary to gain the depth need-
ed to make progress within disciplines, Schuster says.

But that approach won’t work against complex and interrelated problems, such as understanding the social aspects of biological systems. Take ant colonies, for example.

“If your objective is to understand ant colonies, you can’t study just one ant,” Schuster explains. “All of the interactions of ant colonies, which are very complex structures, emerge from interactions among ants. A lot of the problems that the world now faces are of the character of ant colonies.”

For instance, he notes, solutions to the world’s energy problems must consider not only such issues as British thermal units (Btu) and electrical efficiency, but also environmental impact and sustainability. Those are “emergent” problems, and they must be

“We have built our new buildings so they are interactive and flexible, with a lot of open meeting space. We have tried to provide a social, interactive environment that allows easy collaboration and cooperation.”

– Gary Schuster, Georgia Tech provost and vice president for academic affairs
solved holistically – and at the intersection of different disciplines.

Hence the organization of the Molecular Science & Engineering building into “research neighborhoods” housing faculty members from different disciplines who are working on similar issues – but from different perspectives. The concept was also applied in the Ford Environmental Science & Technology Building (ES&T), which is also part of Georgia Tech’s four-building Biotechnology Complex.

“What we have done is try to build a physical infrastructure that supports the reductionist approach, but has an emergent overarching view,” Schuster explains. “We didn’t build a chemistry building or chemical engineering building. We built the Environmental Science & Technology Building, and we built the Molecular Science & Engineering Building. We still have departments that have the disciplinary expertise, but we’ve put people together to solve the emergent problems.”

Within the new building, which completes the four-building complex, faculty offices are clustered in a “wedge” to encourage casual conversations. The traditional approach would have put faculty together with their laboratories and space for graduate students.

“That puts the faculty into interaction with people, regardless of what their degrees happen to be, who are thinking about similar things, but from different perspectives,” Schuster explains. “An electrical engineering faculty member is likely to have his or her office next to a chemistry faculty member.”

The faculty members still interact with their graduate students, of course, and the students also benefit from neighbors who may approach issues from a different perspective.

The Impact of Life Sciences

The Environmental Science & Technology Building is the largest research facility on the Georgia Tech campus. The new Molecular Science & Engineering Building is the second-largest. That both are part of the new Biotechnology Complex demonstrates the importance of the life sciences to Georgia Tech, which emerged on the national scene through its strengths in industrial, mechanical, civil, aerospace and other traditional engineering areas.

But that traditional focus is changing rapidly.

“Georgia Tech is defining its own path through the biosciences,” Schuster continues. “The path we are defining comes from our tradition of being quantitative and analytical, and this results in a style of approaching life sciences that allows us to step back and apply our strengths. We are able to combine the quantitative engineering and scientific challenges of Georgia Tech with a strong medical school in Emory University.”

That collaboration, for example, led to
Issues of sustainability also affected the design of the Molecular Science & Engineering Building, which will be part of the planned Eco-Commons on the Georgia Tech campus.
The Biotechnology Complex carries entrepreneurship to an unusual level with the ATDC Biosciences Center. Located in the ES&T Building, the Center is a satellite facility of Georgia Tech’s science and technology incubator, the Advanced Technology Development Center. The ATDC facility allows researchers with offices and labs in the Complex to tend their companies while maintaining their regular Georgia Tech duties.

A recent graduate of the facility is CardioMEMS, a maker of implantable medical sensing devices that has raised more than $50 million in venture funding since 2001. The incubator currently houses three companies focused on life-science markets.

Beyond entrepreneurship, the self-assembly of chemists, biochemists, materials engineers, biomedical engineers, electrical engineers, mechanical engineers and other specialists has already begun to pay off, says Thomas Orlando, chair of Georgia Tech’s School of Chemistry and Biochemistry – Joe Perry’s home department.

“We have had new faculty join us due to our ability to work together, and this has helped in recruiting some of the best talent in the world,” he reports. “We have also noticed that the interdisciplinary nature of our school has been attractive to graduate students and has helped increase the number and quality of students.”

Connecting to Green Space

Located in booming midtown Atlanta, Georgia Tech could easily become a concrete wasteland. But creating an attractive environment was important to the school’s administration. So the new MS&E Building connects the Biotechnology Complex to an attractive bit of forest in the city – the President’s Glade, located behind the campus home of President Wayne Clough.

The facility will also be part of the planned Eco-Commons, which will restore creeks and green space destroyed by development during the last century.

Issues of sustainability also drove the building’s design, which was done by the architectural firm CUH2A, Inc. To reduce storm water runoff from the building, for instance, the architects incorporated cisterns that store rainwater and use it for landscape irrigation. Condensation from the building’s HVAC system is also used for irrigation – instead of being dumped into the city’s sewerage system.

“We also got rid of a lot of concrete that had been in the area and restored permeable soil that allows water to percolate into the ground,” notes Fred Dolder, senior capital projects manager in the Georgia Tech Facilities Department. “Terracing of a new quad within the four-building complex provides a great space for the community to sit and enjoy the sun.”

The $77 million facility also features an energy recovery system designed to reduce utility costs and cut the building’s impact on the environment. A dramatic glass wall faces north – away from the sun – while south-facing windows were designed to admit light while keeping out direct sunlight during the hot Georgia summers. More than three-quarters of the building’s space has access to natural light.

Laboratory spaces were designed to be modular, easily reconfigurable to meet changing needs – and hold down construction and renovation costs. Service hallways ensure that supply deliveries are kept separate from pedestrian traffic. Beyond the research laboratories, the MS&E building provides four 40-seat classrooms and a 150-seat lecture hall.

The building replaced facilities that had been the headquarters for Georgia Tech’s Facilities Department. Many of the maintenance activities associated with that unit were integrated into the MS&E Building – but few students and faculty will ever see them because they were separated from public spaces by an access tunnel.

In addition to classroom, office and laboratory spaces, the building also features a two-level 8,000 square-foot “Quad Café” – a restaurant and coffee shop that Dolder describes as the “little jewel” of the project. To be operated by Georgia Tech’s Auxiliary

Reconsidering the Physical Environment

Georgia Tech’s growth created an opportunity to reconsider how the physical environment affects research, teaching and service. Over the past decade, it has invested nearly $1 billion in new and remodeled facilities, including the Biotechnology Complex.

“This allowed us to think about what a major research university of the 21st century should look like, and it gave us enough flexibility in the construction projects to think seriously about what we wanted to be,” Schuster explains. “We were able to think strategically.”

But in encouraging collaboration, administrators can do only so much. They can create a supportive environment, but the organization of projects will be done by faculty members who form natural alliances based on mutual benefit.

“I’m a big fan of self-organizing systems,” Schuster adds. “It’s the responsibility of the administration to be strategic in its thinking and to set the boundary conditions and goals. We have to provide the facilities to allow the faculty members and students to operate. That encourages a spirit of entrepreneurship among our faculty, and leads to collaborations not only within Georgia Tech, but also with government and industry.”

The Biotechnology Complex carries entrepreneurship to an unusual level with the ATDC Biosciences Center. Located in the ES&T Building, the Center is a satellite
Services, the café will also support the goals of interdisciplinary collaboration.

The project’s construction manager was Turner Construction Company, and project management was handled by the Staubach Company. Though portions of the building remain to be built out, Dolder considers the project an overwhelming success.

“It was an excellent project not only from the design perspective, but also for the quality of the construction and the teamwork in pulling it off,” he adds. “We wanted to create a pleasant environment that would encourage collaboration and interdisciplinary research. When you take these four buildings together with the type of work that is done here, it’s a very powerful site by any measure.”

Robert Snyder, chair of Georgia Tech’s School of Materials Science and Engineering – Ken Sandhage’s home department – has his own measure for judging the project a success.

“The Molecular Science & Engineering Building has many of our bio- and bio-enabled faculty working next to nanomaterials faculty who have an interest in cancer, who are next to biomedical engineering faculty and students,” he points out. “We have succeeded in knocking down the old traditional walls between engineering and science disciplines. The synergy can be felt in the air.”

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“It’s much easier to have productive conversations in the hallways if you are clustered in a building with people who have similar research interests, even if they aren’t in the same department.”

– Ken Sandhage, professor in the School of Materials Science and Engineering
The U.S. Environmental Protection Agency (EPA) has approved the use of a new technique that reduces the time and cost required to test public drinking water samples for the presence of the radioactive element radium.

The technique – developed by Bernd Kahn, director of the Georgia Tech Research Institute’s (GTRI) Environmental Radiation Center (ERC), and GTRI senior research scientist Robert Rosson – became advantageous when the EPA established new radionuclide drinking water standards in 2000.

While radium is found at low concentrations in soil, water, plants and food, the greatest potential for human exposure to radium is through drinking water. Research shows that inhalation, injection, ingestion or body exposure to relatively large amounts of radium can cause cancer and other disorders. Since radium is chemically similar to calcium, it has the potential to cause harm by replacing calcium in bones.

As a result, drinking water systems are now required to sample and report on the amounts of two isotopes, radium-226 and radium-228, found in drinking water supplies.

“The Georgia Department of Natural Resources recognized the applicability and benefits of our method because of the new rules and proposed it to the EPA in 2002,” Kahn notes.

The new method developed at GTRI requires only two steps. First, hydrochloric acid and barium chloride are added to a sample of water and heated to boiling. Then concentrated sulfuric acid is added and the radium precipitate is collected, dried and weighed. The samples are then counted with a gamma-ray spectrometry system to determine the content of radium-226 and radium-228.

A gamma-ray spectrometer determines the energy and the count rate of gamma rays emitted by radioactive substances. When these emissions are collected and analyzed, an energy spectrum can be produced. A detailed analysis of this spectrum is used to determine the identity and quantity of radioisotopes present in the source.

“The old method took four hours for each type of radium you needed to test – totaling eight hours for radium-226 and radium-228,” explains Rosson. “Our method does the two tests simultaneously and it takes about half an hour of actual technician time.”

Previously approved EPA methods for measuring radium required several isolation and purification steps involving sequential precipitations from large sample volumes and sometimes liquid-liquid extractions. They all ended with a complicated final preparation step before measurement with an alpha scintillation detection system. The scintillation detector detects and counts the flashes of light that are produced when a radioactive substance interacts with a special coating on the inside of the detection container.

The EPA’s December 2007 deadline requiring every water supply be tested for radium-228 and gross alpha radioactivity greatly increased the number of radium-228 measurements required, as well as the likelihood both radium-226 and radium-228 must be measured in the same sample, also increasing the number of measurements required.

If the total radium concentration measured is above five picograms per liter, the sample must be reanalyzed to determine the exact concentration.

By Abby Vogel
curies per liter, then the water supply is out of compliance and radium-226 and radium-228 must be measured quarterly. This may require the water source to be replaced or treated to reduce the radium concentration. If the amount of radioactivity measured is less than five picocuries per liter, samples may be collected at three-, six- or nine-year intervals.

Since the EPA approved this new testing procedure in July 2006, GTRI’s ERC has been able to use the testing method they developed to analyze water samples from Georgia’s Department of Natural Resources.

“We analyze about 1,200 samples per year for them. With 3,000 to 6,000 water supply entry points in Georgia, we’re not done yet,” notes Rosson.

Since the new rules were published on March 12 in the Federal Register, the official publication of rules from U.S. government agencies, Rosson and Kahn have received dozens of requests for the testing procedure. Departments of natural resources around the country are interested in saving time and money by using GTRI’s procedure that tests for radium-226 and radium-228, according to Rosson.

“The old method took four hours for each type of radium you needed to test – totaling eight hours for radium-226 and radium-228. Our method does the two tests simultaneously and it takes about half an hour of actual technician time.”

– Robert Rosson, senior research scientist in the Georgia Tech Research Institute.
Getting Lean

Rural Georgia hospital increases efficiency and serves more patients by adopting principles developed for manufacturing.

By Nancy Fullbright

The emergency department at Meadows Regional Medical Center in rural Vidalia, Ga., has achieved what would make most hospitals across the nation envious: a 44 percent reduction in average length of stay per patient, a 10 percent boost in patients served and a 92 percent patient satisfaction rate.

The secret? With assistance from the Georgia Institute of Technology, the hospital implemented lean manufacturing principles, a process management philosophy derived mostly from the Toyota Production System and known for reducing wasted time and effort in manufacturing.

At one point, the average length of stay for Meadows’ emergency department patients exceeded 200 minutes, well below the national average of 3.3 hours, but sill unacceptable to the hospital’s management. “We had issues with bottlenecking, turnaround times, decreased satisfaction and overworked nurses,” recalls Peggy Fountain, director of the emergency department at Meadows.

With funding from the Georgia Rural Economic Development Center (GREDC), lean specialists with Georgia Tech’s Enterprise Innovation Institute began the hospital’s transformation in June 2005. They conducted a three-day lean overview workshop and value-stream mapping event with Meadows’ emergency department. In addition to Fountain and CEO Alan Kent, workshop participants included the emergency room nursing staff, an emergency room physician, the radiology director, laboratory manager and business office staff.

The lean team at Meadows developed 44 action items for reducing the time needed to admit, treat and discharge non-critical ER patients. Forty-one percent of the items were determined to be low-cost and high-impact. The ideas fell into one of seven categories: 5S and visual controls, cross-training, equipment, hospital procedures, patient information, general procedures and staffing.

5S – which stands for sort, straighten, shine, systemize and sustain – is a way of organizing and managing the workspace to improve morale and efficiency.

Changes made by the hospital included standardizing mobile supply stations; labeling racks, trays and drawers; installing a color-coded flag system outside patient rooms; issuing patients red allergy armbands to alert medical staff; and adding a holding area for patients who need to see a doctor but who don’t need a room.

The hospital also implemented the T System®, a software program that shows staff who is in the waiting room, who needs an X-ray and who can be put into a room or a wheelchair. The T System also documents length of stay, lab tests ordered, physician and nurse assigned to the patient and discharge disposition, as well as patient name, room number and prior ER visits, if applicable.

Beyond the more visible improvements, Fountain says emergency room employees are now more empowered to take initiative and make changes that could positively impact their work process – a hallmark of the lean system.
“Staff members realize that it’s not just the ER’s problem – it’s everyone’s problem. Whatever we can do to improve the process makes everyone’s job easier,” she says. Meadows’ management plans on utilizing lean health care principles when it builds a new, state-of-the-art hospital. The original facility, built in 1963, employs 600 people and operates 87 beds, as well as a 35-bed nursing home, an eight-bed outpatient facility, and one part-time and two full-time operating rooms.

“We want to design the new facility using lean processes before architects draw up the building,” says Kent, who also plans to incorporate online patient registration, self-check-in kiosks and bar-coding into the new hospital. “We want to optimize the process before we draw the first line. We want form to follow function.”

Kent says that Meadows’ approach could be successful in other hospitals, but notes that change is often difficult, especially in health care.

“If you don’t change and innovate, it will kill you,” Kent says. “One of the goals of lean health care is to awaken a new level of thinking and introduce manufacturing approaches that have been proven to produce excellent efficiency and profitability.”

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Alan Kent, CEO and president of Meadows Regional Medical Center, and Peggy Fountain, director of the Center’s emergency department, played key roles in the lean implementation.

“Staff members realize that it’s not just the ER’s problem – it’s everyone’s problem. Whatever we can do to improve the process makes everyone’s job easier.”

– Peggy Fountain, director of the emergency department at Meadows Regional Medical Center in Vidalia, Ga.
Vacuum Evaporator Purchased in 1957 Still Going Strong

A 1957 classic sits in the Georgia Tech Research Institute (GTRI) clean room. It’s not a Chevy, but a Veeco vacuum evaporator more than six feet tall and five feet wide. The evaporator, still in use today, deposits thin films necessary for microfabrication processes. Applications include creating the reflective or anti-reflective coatings on optics and building up layers of insulators, semiconductors and conductors to form integrated electronic circuits.

“It’s a very rugged machine and it’s gotten better with age,” says Mike Harris, a GTRI principal research engineer who first used the Model 775 evaporator in 1972 as a student.

The system operates by evaporating a source material, such as a metal, in a high vacuum, allowing vapor particles to travel directly to a target object, such as a semiconductor, where they condense back to a solid state and form a thin film of the source material.

Harris attributes the machine’s longevity to its design and documentation — and to the skills of GTRI technicians and engineers. “The operator and maintenance manuals are excellent, with exploded views of the various piece parts, making it very easy for our technicians and engineers to repair it when we have problems,” he explains.

In addition to repairing the system, GTRI engineers have upgraded and modified the evaporator several times since it was purchased.

First, they changed the high vacuum pump from a diffusion pump to a more modern cryogenic pump in 2002. The diffusion pump generated a high speed jet of vapor by boiling fluid and directing the vapor in the pump throat down into the bottom of the pump and out the exhaust. The newer cryogenic pump traps gases and vapors by condensing them on a cold surface.

To increase the uniformity of results, GTRI researchers added a planetary substrate fixture that rotates inside the evaporation chamber.

In addition, the original system was designed with a tungsten filament that was heated to a high enough temperature so that the source material placed in a crucible on the filament evaporated. GTRI engineers changed this to an electron beam evaporator that fires a high-energy beam from an electron gun to boil a small spot of material, allowing lower vapor pressure materials to be deposited.

Since the 1957 system still runs and remains optimal for numerous applications, Harris sees no reason to buy a new one. “New systems like this probably cost between $700,000 and $1 million;” he adds. “And the new systems are designed primarily for throughput and that’s not necessarily best for a research environment.”

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Platinum Nanocrystals Boost Catalytic Activity

A research team from two continents has produced a new form of the industrially important metal platinum: 24-facet nanocrystals whose catalytic activity per unit area can be as much as four times higher than existing commercial platinum catalysts.

The nanocrystals, whose “tetrahexahedral” structure had not previously been reported in the metal, could improve the efficiency of chemical processes such as those used to catalyze fuel oxidation and produce hydrogen for fuel cells.

“If we are going to have a hydrogen economy, we will need better catalysts,” says Zhong Lin Wang, a Regents’ Professor in the Georgia Tech School of Materials Science and Engineering. “This new shape for platinum catalyst nanoparticles greatly improves their activity. This work also demonstrates a new method for producing metallic nanocrystals with high-energy surfaces.”

The new nanocrystals, produced electrochemically from platinum nanospheres on a carbon substrate, remain stable at high temperatures. Their sizes can be

Carefully maintained and updated, a 50-year-old vacuum evaporator is still applying coatings in a Georgia Tech Research Institute clean room.

Platinum Nanocrystals Boost Catalytic Activity

(A) Low-magnification image shows a platinum tetrahexahedral (THH) nanocrystal and its geometrical model, while (B) a high-resolution image reveal surface atomic steps in the areas made of two different sub-facets.
controlled by varying the number of cycles of “square wave” electrical potential applied to them.

“This electrochemical technique is vital to producing such tetrahedral platinum nanocrystals,” explains Shi-Gang Sun, an Eminent Professor in the College of Chemistry and Chemical Engineering at the Xiamen University in China. “The technique used to produce the new platinum nanostructures may also have applications to other catalytic metals.”

The research was supported by the Natural Science Foundation of China, Special Funds for Major State Basic Research Project of China and the U.S. National Science Foundation. Details were reported in May 2007 in the journal Science.

Platinum serves as a catalyst in industrial chemical processing, motor vehicle catalytic converters, fuel cells and sensors. Commercially available platinum nanocrystals—which exist as cubes, tetrahedra and octahedra—have what are termed “low-index” facets. Because of their higher catalytic activity, “high-index” surfaces would be preferable—but until now, platinum nanocrystals with such surfaces had never been synthesized.

The nanocrystals produced by the U.S.-Chinese team have high energy surfaces that include numerous “dangling bonds” and “atomic steps” that facilitate chemical reactions. These structures remain stable at high temperatures—up to 800 degrees Celsius in testing done so far. That stability will allow them to be recycled and re-used in catalytic reactions, Wang said.

Though the process must still be fine-tuned, the researchers have learned to control the size of the particles by varying the processing conditions.

Depending on conditions, the new nanocrystals can be as much as four times more catalytically active per unit area than existing commercial catalysts. But since the new structures are more than 20 times larger than existing platinum catalysts, they require more of the metal—and hence are less active per unit weight.

“We need to find a way to make these nanocrystals smaller while preserving the shape,” Wang notes. “If we can reduce the size through better control of processing conditions, we will have a catalytic system that would allow production of hydrogen with greater efficiency.”

Production of the new crystals begins with polycrystalline platinum spheres about 750 nanometers in diameter that are electrodeposited onto a substrate of amorphous carbon. Placed in an electrochemical cell with ascorbic acid and sulfuric acid, the spheres are then subjected to “square wave” potential that alternates between positive and negative potentials at a rate of 10 to 20 Hertz.

The electrochemical oxidation-reduction reaction converts the spheres to smaller nanocrystals whose size averages 81 nanometers in diameter.

—John Toon

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Georgia High School Students Learn Job Safety Lessons

As part of an effort to increase job safety training and awareness among younger Americans, scientists from the Georgia Tech Research Institute (GTRI) have joined with the U.S. Occupational Safety and Health Administration (OSHA) and other groups to introduce health and safety training to Georgia high schools.

The aim: to try to ensure that young workers grasp job-safety basics before they ever reach the workplace.

GTRI instructors and others have already taught OSHA job-safety classes to three Georgia high schools, and more schools are scheduled to receive instruction. The effort stems from a 2006 agreement between OSHA, GTRI, Georgia schools and other groups to make safety and health training more available to the state’s students.

“Today, it’s an effort for many people in the workforce to remember safety basics—for example, to put their safety glasses on when working with chemicals,” says Michelle L. Dunham, a research scientist in the Occupational Safety and Health Division of GTRI’s Electronic Systems Laboratory (ELSYS). “We want to make it automatic for young people joining the workforce to take those kinds of precautions.”

Students attend a 10-hour course that’s team-taught by OSHA and Georgia Tech instructors as well as industry representatives. The modular course covers general safety and health information as well as instruction pertaining to students’ areas of work specialization.

“There are lots of different modules, and depending on the school, they’ll vary,” Dunham adds. “We’ve started out teaching students going into the construction trades, but the course could be helpful to students in other study areas such as automotive and medical services.”

Those graduating receive the OSHA 10-hour card, which can give them an advantage with employers wanting to comply with OSHA regulations.

Dunham, an industrial hygienist, explains that the Georgia Tech Safety and Health Program also works directly with industry. Georgia Tech staff perform on-campus training and consultation at the OSHA Training Institute Education Center, and also at job sites throughout Georgia and the Southeast.

Bringing the OSHA 10-hour course to high schools is one of the first results of the Georgia Youth Alliance, a 2006 outreach agreement between OSHA, GTRI, the Georgia Department of Education, the American Industrial Hygiene Association, the American Society of Safety Engineers and the Construction Education Foundation of Georgia.

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Students at Maxwell High School of Technology in Lawrenceville receive instruction in power-saw safety. Shown (l-r) are Ricky Child, GTRI’s Michelle Dunham, Marvin Hugging, Hunter Brandenburg, Brandon Reid and Justin Bennett.

—Rick Robinson

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A tiny single-celled organism that plays a key role in the carbon cycle of cold-water oceans may be a lot smarter than scientists had suspected.

In a paper published in June 2007 in *Proceedings of the National Academy of Sciences*, researchers report the first evidence that a common species of saltwater algae—a known as *Phaeocystis*—can change form to protect itself against attack by predators that have very different feeding habits. To boost its survival chances, *Phaeocystis globosa* enhances or suppresses the formation of colonies based on whether nearby grazers prefer eating large or small particles.

“Based on chemical signals from attacked neighbors, *Phaeocystis* enhances colony formation if that’s the best thing to do for survival, or it suppresses the formation of colonies in favor of growing as small solitary cells if that’s the best thing to do,” says Mark E. Hay, Georgia Tech’s Teasley Professor of Biology. “These changes in form made nearly a 100-fold difference in the alga’s susceptibility to being eaten. It’s certainly surprising that a single-celled organism can chemically sense the presence of nearby consumers, identify those consumers and change in opposing ways depending on which consumers are present.”

The behavior could have implications for global climate change because *Phaeocystis* blooms play a key role in the carbon cycle of cold oceans, accounting for up to 85 percent of local productivity during some time periods. This complex defensive behavior also shows how environmental factors can affect even simple organisms, Hay notes.

The research was sponsored by the U.S. National Science Foundation and the U.S. Environmental Protection Agency.

*Phaeocystis* has two primary predators: small grazers such as ciliates, which prefer to eat small solitary cells that are four to six microns in diameter, and the larger shrimp-like copepods, which prefer to eat large, ball-shaped colonies.

When copepods are attacking the phytoplankton, therefore, the best survival strategy of *Phaeocystis* is to form solitary cells. When ciliates are attacking, the best strategy is to form colonies that are too large for those predators to consume.

Lead author Jeremy D. Long, along with collaborators Gabriella W. Smalley, Todd Barsby, Jon T. Anderson and Mark Hay, found that’s exactly what *Phaeocystis* does. Chemicals that signaled attacks from copepods suppressed the formation of colonies by 60 to 90 percent, while signals from ciliates enhanced colony formation by more than 25 percent.

The transformations took place over periods of three to six days, and the overall size difference could be dramatic. “When one of these cells changes to the biggest colony form, although it takes a while, it’s like changing from a mosquito to 76 blue whales or 3,000 bull elephants,” Hay explains.

Defensive responses are often seen in higher plants, but this is believed to be the first report of such a complex and species-specific response in marine plankton. The response of *Phaeocystis* could be important to scientists studying climate change because the predator that ultimately consumes the phytoplankton determines the fate of the carbon it contains. If eaten by copepods, for example, the carbon becomes part of fecal packages that sink into the deep ocean where a portion of that carbon is sequestered—thereby reducing atmospheric carbon dioxide, a leading greenhouse gas. If consumed by smaller creatures like ciliates, less of the carbon sinks to the deep sea and more remains in the surface waters.

Experimentally, the researchers attempted to separate the chemical signals from the actual predators. They grew *Phaeocystis* in the presence of either ciliates or copepods. They then filtered out both the phytoplankton and predators, leaving only water containing the chemical signals of attack.

Water samples containing signals from the two predators were then separately introduced into *Phaeocystis* cultures that had not been attacked. The scientists then studied how the different chemical signals affected the percentage of *Phaeocystis* living in colonies or as solitary cells. Finally, they examined whether this response affected how much the predators ate to determine if the change conferred a survival advantage.

“We found that these organisms were making the right choice,” Hay adds. “They were shifting to the shape that made them largely immune to whichever predator was attacking, and this shift suppressed either the feeding or growth and reproduction of the consumer to which they were responding.”

—John Toon

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Two-Photon Absorbing Molecules Allow Polymer Features 65 Nanometers Wide

Producing three-dimensional polymer line structures as small as 65 nanometers wide just became easier with the development of new two-photon absorbing molecules that are sensitive to laser light at short wavelengths, allowing researchers to create them without highly sophisticated fabrication methods.

Fabricating such small features normally requires expensive electron beam or extreme ultraviolet lithography equipment. However, using a technique called 3-D multi-photon lithography simplifies the process and reduces the cost. The technique could compete with existing processes for fabricating nanoscale electronic, photonic and microfluidic devices.

"Being able to obtain line widths down to 65 nanometers, which is substantially below prior published work of 100 nanometers, opens up new applications for multi-photon lithography," says Joseph W. Perry, a professor in the Georgia Tech School of Chemistry and Biochemistry and the Center for Organic Photonics and Electronics.

The technique scans a laser beam across a substrate coated with a polymer resin containing a unique dye to create a hardened polymer structure. The laser writing process takes advantage of the fact that the chemical reaction of cross-linking occurs only where molecules have absorbed two photons of light. Since the rate of two-photon absorption drops off rapidly with distance from the laser's focal point, only molecules at the focal point receive enough light to absorb two photons.

The fabrication method and dye were described in the journal Optics Express in April 2007. The research was supported by the Office of Naval Research APEX Consortium and the National Science Foundation.

Seth Marder and Stephen Barlow, also researchers in the School of Chemistry and Biochemistry and the Center for Organic Photonics and Electronics, synthesized the unique molecule called DAPB, 4,4'-bis(di-n-butylamino) biphenyl, used to initiate the chemical reaction leading to the hardening of the polymers when exposed to laser light.

The molecule is about 10 times more efficient at absorbing light by two-photon absorption than commercial ultraviolet photoactive materials. That efficiency allowed Perry and graduate students Wojciech Haske and Vincent Chen, research scientist Joel Hales and postdoctoral associate Wenjing Dong to create 3-D patterns with nanoscale lines at light intensities low enough to avoid damaging the polymers.

For the experiments, a film of the polymer resin containing DAPB was formed. When the film was exposed to the focused laser, DAPB was excited and triggered cross-linking, leaving the insoluble scanned structure on the surface of a substrate after it was placed in a developer solution.

Since Perry uses a computer program to control where the Ti: Sapphire-pulsed laser scans, the polymers can be cross-linked in any pattern — including 3-D stacks of straight lines that are connected. The laser beam is turned on to expose lines of polymer and off when no line should be drawn.

Conventional lithography involves creating a specific pattern on a mask for each new layer, exposing each layer to light and then developing it. "With this new technique, three-dimensional layered nanostructures can be created simply by having a computer program scan a different pattern for each layer. Mask templates become unnecessary — and the coating, exposing and developing processes only have to be conducted once.

"We can write very small lines and create stacked-up grids of lines called photonic crystals," explains Perry. "This work shows that we can fabricate functional photonic micro-devices with tailored transmission capabilities."

It takes only 10 minutes to create a 20-micron-by-20-micron structure with 30 layers, Perry adds. He envisions using this technology to create compact micro-spectrometers on a chip for use in telecommunications and sensors. It may also be used as a compact way to separate the multiple wavelengths traveling through a fiber optic cable.

This type of simple, table-top technology may also be useful to fabricate customized types of circuits with many layers, which would be extremely expensive with standard methods because each layer would require a special mask.

"With the combination of the right molecule and short wavelength light, we’ve demonstrated that we can obtain nanoscale features. We’re at 65 nanometers now and we’re still trying to go smaller," says Perry.

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Gene Thought to Assist Chemotherapy May Help Cancer Thrive

A gene thought to be essential in helping chemotherapy kill cancer cells may actually help them thrive.

In a new study of chemotherapy patients, scientists at the Georgia Institute of Technology and the Ovarian Cancer Institute found that 70 percent of subjects whose tumors had mutations in the gene p53 were still alive after five years. Patients with normal p53 displayed only a 30 percent survival rate.

The findings raise the possibility of a new strategy for fighting cancer — namely, developing drugs to disable the functioning of this gene in the tumors of patients undergoing chemotherapy. The results appeared in May 2007 in the journal PLoS ONE.

"p53 has long been recognized as a key player in directing chemotherapy-damaged cancer cells to self-annihilate, but less attention has been paid to p53’s role in repairing damaged cells," says John McDonald, chair of Georgia Tech’s School of Biology and chief research scientist at the Ovarian Cancer Institute.

When a cell is malfunctioning or injured, the gene p53 is called into action and tries to repair the cell. If the cell can’t be repaired, p53 starts a process known as
apoptosis that kills the cell. It is p53’s role as one of the genes involved in initiating cell death that has led cancer researchers to believe that the gene is essential to successful chemotherapy. The idea is that p53 assists in killing the cancerous cells that the chemotherapy treatment injures.

But in this latest trial, Georgia Tech researchers found that p53 may be a “double-edged sword.” Chemotherapy patients whose tumors had a mutated p53 gene that didn’t work had a much better survival rate than those who had normal p53.

In the study, researchers compared the gene expression profiles of malignant and benign ovarian tumors. Some of the cancer patients had been treated with chemotherapy prior to surgery, and some had not.

The researchers found that the gene expression profiles of the tumors clustered the chemotherapy-treated patients into two groups: those whose profiles were similar to cancer patients who had not been treated with chemo and those whose profiles were similar to patients with benign tumors.

As they continued their analysis, they found that the main difference between the groups’ genetic profiles was the gene p53. While both groups had roughly the same amount of the protein encoded by p53, the cancer group had mutations in their p53 that caused the gene’s corresponding protein not to function. The benign group’s p53 was normal.

Five years later, only 30 percent of the chemotherapy cancer patients clustering in the benign group were alive, while 70 percent of those clustering in the cancer group were still alive. The stage of cancer at the time of surgery had no correlation to who survived and who didn’t. What did seem to have an effect was whether p53 was working or not in the chemotherapy-treated tumors.

A standard belief in cancer research is that a working p53 is essential in helping chemotherapy patients because it turns on the killing mechanism for the cells that were damaged by chemo. But McDonald points out that p53 can also help repair damaged cells. If p53 is repairing cancer cells, that may lead to cancer recurrence.

“We think p53 may actually help some cancer cells make a comeback,” he says. “Based on our results, we propose that p53 may help repair some of the cancer cells damaged by chemotherapy — leading to tumor recurrence and explaining the higher mortality rate of patients whose tumors had a functioning p53. If we are correct, inhibiting p53 in tumors being treated with chemotherapy may substantially improve patients’ long-term survival.”

In addition to McDonald, the research team consisted of: Benedict Benigno, gynecologic oncologist and founder of the Ovarian Cancer Institute; Lilya Matyunina, Erin B. Dickerson, Nina Schubert and Nathan J. Bowen from Georgia Tech and the Ovarian Cancer Institute; Sanjay Logani from Emory University; and Carlos Moreno from Emory’s Winship Cancer Institute.

The research was supported by the Georgia Cancer Coalition, the Georgia Tech Research Foundation, the Robinson Family Foundation and the Larry and Beth Lawrence Foundation.

— David Terraso

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Companies from Science & Technology Incubator Attract $1 Billion

Companies associated with Georgia Tech’s science and technology incubator have raised more than $1 billion in venture capital since 1999 — and in 2006 accounted for 10 of the top 25 venture deals in Georgia, including the two largest.

The incubator, the Advanced Technology Development Center (ATDC), has turned out 112 science and technology companies since 1986 — including 31 that have been represented on the public markets through initial public offerings or acquisitions.

At a May 10 event held to showcase the incubator’s companies, ATDC “graduated” six early-stage firms — three Internet companies, two semiconductor firms and a developer of homeland security technology. Together, those six early-stage firms raised more than $50 million while in the incubator.

“ATDC is a source of exciting deal flow, and we have invested in many ATDC companies,” says Fred Sturgis, managing director of the $4-billion Miami-based venture capital firm H.I.G. Ventures. “ATDC attracts leading entrepreneurs in Georgia and increases the probability of success for its companies.”

The $1 billion raised by ATDC companies included 160 deals in 75 companies from 138 venture investors. The average deal size was $6.7 million, though funding amounts varied, with 32 companies raising less than $5 million and 10 raising more than $25 million. The $1 billion includes funds raised by companies throughout their growth, including their time in the incubator and after they graduated.

“ATDC is an invaluable resource to Georgia, as the leading organization for advancing business incubation and entrepreneurship,” says Susan O’Dwyer, national director of venture capital research for PricewaterhouseCoopers. “Over its 26-year history, ATDC’s staff has provided hundreds of entrepreneurs at early-stage companies with the right experience, business planning advice and networking resources needed to grow their companies.”

The incubator is an example of how universities are making an increasingly important contribution to local and state economies, notes Wayne Hodges, vice provost for Georgia Tech’s Enterprise Innovation Institute — ATDC’s parent organization.

“Through ATDC, Georgia Tech is helping build a strong com-
Beneficial Bacteria

Researchers identify naturally occurring bacteria that can detoxify PCB contamination.

By Jane M. Sanders

Researchers have identified a group of bacteria that can detoxify a common type of environmental contaminants, polychlorinated biphenyls (PCBs). These toxic chemicals have contaminated more than 250 sites in the United States, including river and lake sediments.

The discovery is a first step toward a new bioremediation strategy that would naturally detoxify the chemicals without risky removal of the sediments in which they persist. The research results were reported in April 2007 in the journal Applied and Environmental Microbiology.

Researchers have known for more than two decades that naturally occurring microorganisms could slowly dechlorinate PCBs, which were banned from production in the United States in 1977 because of their toxicity to wildlife.

In research funded by the National Science Foundation and General Electric, a PCB expert at Rensselaer Polytechnic Institute (RPI) collaborated with microbiologists at the Georgia Institute of Technology to study microbial degradation in Aroclor 1260, a common PCB mixture.

RPI Professor of Biology Donna Bedard collected PCB-contaminated sediment samples from the Housatonic River in Massachusetts. In microcosm studies in her lab, Bedard found that Aroclor 1260 was indeed being degraded by native sediment microbes, and she developed sediment-free enrichment cultures. She then worked with Georgia Tech researchers Frank Loeffler and Kirsti Ritalahti to further characterize these Aroclor 1260-dechlorinating enrichment cultures.

Through a series of experiments, the team was able to determine that bacteria in the Dehalococcoides (Dhc) group were responsible for the detoxification of Aroclor 1260. These microbes replace the chlorine atoms in Aroclor 1260 with hydrogen, which fuels their growth and initiates the PCB degradation process, explains Loeffler, an associate professor in the Georgia Tech School of Civil and Environmental Engineering and the School of Biology.

The research indicates that the Dhc bacteria active in the enrichment cultures also contribute to PCB dechlorination in situ. Once Dhc bacteria dechlorinate Aroclor 1260 to a specific level, other microbes will degrade it further and completely detoxify PCBs, Loeffler adds.

"Identifying the bacteria responsible for the initial reactions of Aroclor degradation represents a crucial step. Now we can start to design tools to look for these microbes in sediments and then develop engineering approaches to stimulate their growth and activity in river or lake sediments," Loeffler says.

"Then the decontamination will occur more rapidly. Instead of taking decades, the microbes might be able to degrade the PCBs in a few years."

Loeffler is optimistic about a bioremediation strategy for PCBs because of his lab’s earlier success in identifying microbes that degrade the common solvents tetrachloroethene (PCE) and trichloroethene (TCE). These toxic compounds, which contaminated subsurface environments and groundwater decades ago when their use was unregulated, were primarily used in dry-cleaning operations and degreasing of metal components.

Following Loeffler’s discovery, it took less than five years for scientists and engineers to develop and implement bioremediation strategies that use these microbes to detoxify PCE and TCE.

"The situation with PCBs is a little more complicated because they are in river and lake sediments instead of groundwater and subsurface environments, but in principle, the same sequence of events could occur," Loeffler notes. "We need industry, engineers and scientists to work together to develop a bioremediation approach for PCBs."

Development of bioremediation technologies for PCB cleanup would offer an alternative to sediment dredging and disposal in landfills, which is the most commonly used method for removing PCBs. Dredging is controversial because of the invasive nature of this technology and the risk of spreading contaminants.

"Now, because of our research, regulators know these microbes exist, that they are native to certain environments and that natural degradation processes are at work," Loeffler says. "Maybe this will influence decision-making processes, and bioremediation will be implemented. This could save millions of dollars spent on controversial dredging projects."

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POWERING NANODEVICES

Georgia Tech researchers have demonstrated a prototype nanometer-scale generator that produces continuous direct-current electricity by harvesting mechanical energy from such environmental sources as ultrasonic waves, mechanical vibration or blood flow.

Based on arrays of vertically-aligned zinc oxide nanowires that move inside a novel “zigzag” plate electrode, the nanogenerators could provide a new way to power nanoscale devices without batteries or other external power sources.

“This is a major step toward a portable, adaptable and cost-effective technology for powering nanoscale devices,” says Zhong Lin Wang, Regents’ Professor in the Georgia Tech School of Materials Science and Engineering. “There has been a lot of interest in making nanodevices, but we have tended not to think about how to power them. Our nanogenerator allows us to harvest or recycle energy from many sources to power these devices.”