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Transdisciplinary research brings together passionate people from various fields of study to provide a comprehensive approach to a specific issue. In today’s academic setting, this collaborative method is breaking down silos of information and creating new fields of discovery. UT is embracing this concept, as you will learn in this edition of Quest.

One of the shining examples of this approach is the Institute of Biomedical Engineering (IBME). Investigators from diverse backgrounds in science, engineering, computing, and business are studying the clinical pathway within the health care ecosystem. By tackling the issue from several viewpoints, IBME is creating solutions that benefit both patients and facilities.

Another of our exciting transdisciplinary projects involves architecture, civil engineering, forestry, and environmental sciences. Students are collaborating to design an economically feasible structure from green oak—an inexpensive wood normally used to build shipping pallets. Their innovative work recently earned them distinguished recognition at the EPA P3 Student Design Competition for Sustainability as well as a $90,000 grant for further development.

Saving money—in this case, by reducing waste in manufacturing—is also the focus of UT–Oak Ridge National Laboratory Governor’s Chair Sudarsanam Suresh Babu. A pioneer in emerging 3D printing technologies, Babu and his team are joining forces with automotive experts at Local Motors to design and produce the world’s first 3D-printed car. But the automobile industry isn’t the only one to benefit from this research. Collaborative ventures involving human prosthetics and military applications are also under way.

As many of us know, sometimes working in teams can lead to anxiety or awkward social situations. That’s why undergraduate researcher Sahba Seddighi is exploring the causes of stress and possible ways to mitigate them. Her fascination with the human brain took hold at an early age and continues to drive her desire for discovery. Today, she follows a simple philosophy—“[Research] is the international language of science, a way for the passionately curious to make sense of the world.”

I hope you enjoy learning more about the intriguing research, scholarship, and creativity of our faculty and students at UT as we all work together to propel our understanding forward.

Taylor Eighmy
Vice Chancellor for Research and Engagement
Award-Winning Sustainability
The New Norris House, a sustainable home and landscape designed by UT students and faculty, recently earned a national Honor Award for Research from the American Society of Landscape Architects. The project was recognized for integrating sustainable water systems into the landscape design. The research involved the collection and treatment of rainwater for in-home and landscape use, infiltrating graywater on site, and managing 100 percent of the site’s stormwater. The results produced new conversations and revisions to policies governing residential rainwater and graywater uses.

Vols in Space
NASA astronaut Butch Wilmore, a graduate of the UT Space Institute, began a six-month stint in September 2014 as commander of the International Space Station. While in orbit, Wilmore and his crew of Russian cosmonauts are conducting numerous experiments. Their primary investigations relate to how the body deals with pain and headaches in a zero-gravity environment. Wilmore also piloted the space shuttle Atlantis on a supply mission to the International Space Station in 2009.

When Reptiles Attack
At the beginning of the age of dinosaurs, 220 million years ago, the Earth was ruled by gigantic reptiles. Some lived on land and others in water, and it was thought they had never interacted much—until now. Thanks to a recent discovery by Stephanie Drumheller, a lecturer in the Department of Earth and Planetary Sciences, evidence to the contrary has emerged. Drumheller and her colleagues recently found the tooth of a semiaquatic phytosaur lodged in the thighbone of a terrestrial rauisuchid, indicating that the smaller reptile eventually ate the larger one.

Diagnosis on the Spot
An innovative mobile disease detection technology developed by researchers in the College of Engineering and UT Institute of Agriculture is on its way to the marketplace. The device can quickly identify infectious diseases, pathogens, and physiological conditions in people and animals without the need to send samples to a lab for analysis. Health care professionals only need to place a droplet of blood or other bodily fluid on a specially treated microchip. Meridian Bioscience will develop, manufacture, and distribute the new product.

Publication Preservation
UT Libraries has received $345,000 to fund the third phase of the Tennessee Newspaper Digitization Project. The money, awarded by the National Endowment for the Humanities, will ensure the digital preservation of another 100,000 pages of Tennessee’s microfilmed newspapers dating from the late nineteenth century to 1922. Working in partnership with the Tennessee State Library and Archives, UT Libraries has already digitized 200,000 pages from Tennessee newspapers dating back to 1849. The project is part of the National Digital Newspaper Program, a partnership between NEH and the Library of Congress.

Thought Leaders
UT Professors of Engineering Matthew Mench and David Mandrus were named to the “World’s Most Influential Scientific Minds: 2014” list by Thomson Reuters news service. Mandrus, a professor of materials science and engineering, is known for breakthroughs that allow ever smaller and more efficient electronics. Mench, a professor of mechanical engineering, specializes in electrochemical energy storage and fuel cells. The list measures how many times other researchers cited the material in their own findings and which individual papers were cited the most.
BREAKING DOWN THE WALLS

Pushing different lab benches together to solve some of the nation’s most pressing health care challenges.

By Katie Elyce Jones. Photography by Nick Myers.

Unlike tissue samples and electrical circuits, you can’t put a hospital under a microscope and observe how it works.

That’s part of why UT’s Institute of Biomedical Engineering, known as IBME, was created. “We focus on patient care to the point that the patient and the health care professionals are part of our research team,” said Christopher Stephens, IBME research and outreach director.

Emerging technology is shrinking the gap between the laboratory and the clinic. Sensors are monitoring the body in greater detail, computer modeling is speeding up drug design, and data management tools are tracking patients as they progress through a string of physicians, nurses, and pharmacists.

The application of technology across medical and scientific fields means the gap between research disciplines is also shrinking. To meet the increasing need for interdisciplinary solutions, IBME has brought together staff and students from disparate backgrounds in science, engineering, computing, and business to tackle priority health care issues.

With UT Medical Center just across the river from campus, IBME investigators have a convenient hospital “ecosystem” where they can study patient treatment from beginning to end. The main objective is to find the ideal clinical pathway to maximize the quality of care and minimize the cost.

“Researchers are tracking information like how many procedures one patient undergoes, the doctors and nurses they interact with, and how their health information is entered in databases,” Stephens said. “These factors may be tied to why one patient is re-admitted several times and another is not re-admitted.”

The clinical pathway is the route a patient takes through diagnosis and treatment—such as from general practitioner to specialist to surgeon. Health care engineers seek to optimize this process by eliminating repetition and making sure a patient’s medical information is sent quickly and accurately down the pathway.

For example, after embedding himself in a stroke unit team and shadowing a patient, IBME researcher Emam Abdel Fatah developed a new computer application for tracking patient care.

“Making the system more efficient should not negatively affect quality of care. Ideally, payment should be tied to a successful clinical outcome. Our job is to analyze this process and ask what would really be best for the patient,” said Mohamed Mahfouz, IBME director.

To attract funding, IBME is organized into specialty areas that address national scientific and health priorities: biomechanics, biomaterials and regenerative medicine, health care engineering and bioinformatics, and medical sensors and devices.

To find the most innovative and efficient ways to approach these problems, IBME’s administrators stress the importance of a cross-disciplinary environment, especially for graduate students.

“People were doing biomedical research in silos,” Mahfouz explained. “We wanted to think of the problem a little differently. The institute allows people interested in biomedical research to come together from other departments under a common vision.”

By bridging these silos, researchers are designing devices for delivering medications and monitoring patient conditions. They are also using advanced computer models to engineer better joint replacements, and developing software to sync patients with their health care services through mobile devices to avoid missed appointments and unfilled prescriptions.

The institute’s research projects are designed to answer specific questions or solve specific problems that can be the main drivers of cost in the health care system. Its Healthy Aging Initiative develops technologies to help seniors—who consume about three-fourths of the federal health budget—manage chronic disease and the loss of physical and mental ability. Likewise, the Health Care Engineering Initiative tracks events following discharge from inpatient care. It analyzes incidents like negative drug reactions, which result in one in every five patients being readmitted to the hospital within thirty days, according to the US Centers for Medicare and Medicaid Services.

“We’re very driven to actually see our research impact the patient bedside,” Stephens said.

The institute has recruited forty-eight core and fifty affiliate faculty members. It was established by the College of Engineering and the Office of Research and Engagement in collaboration with the Graduate School of Medicine and the College of Veterinary Medicine.

Now in its second year, IBME is working to issue more graduate degrees and lay a strong foundation of peer-reviewed publications, research funding, and technology patents. However, the ultimate measure of the institute’s success will be the impact on its research partners—the patients who will receive better health care at lower cost.
The Green Oak Project took seed a few years ago when a forestry department Associate Professor Adam Taylor was showing some architecture students around a lumber mill. “Do you see this stack of beautiful oak wood? They cut it up and make it into shipping pallets,” Taylor explained to the group. “Wouldn’t it be interesting if there was some way to use it structurally?”

But as is often the case with great ideas, there were solid reasons why it wasn’t being used for buildings. This particular wood is from the heart of the tree—what’s left after the rest is milled away. The problem lies in the large amount of water the living tree was storing there; hence the term “green oak.”

Drying wood before use helps stabilize it, but these large sections—four by six inches and up to sixteen feet long—could take either years to dry outdoors or expend a lot of energy to dry in a drying kiln. On top of that, the process causes cracks, warps, and twists. “It’s low-grade, low-quality wood,” Taylor said. “The number of knots and warping get much worse toward the center of the tree. On the other hand, it’s local, relatively low-cost, and has a very low impact to the environment, which I think is a big plus.”

Recently Taylor and Ted Shelton, associate professor in the School of Architecture, were able to pursue their idea. They assembled a team of four professors and nine students to secure a $15,000 phase 1 grant from the Environmental Protection Agency’s People, Prosperity, and the Planet (P3) Student Design Competition for Sustainability. The team expanded to include about twenty students, mostly architectural but also from civil engineering, forestry, and environmental sciences.

During the fall of 2013, the students researched building ideas for green oak. Although somewhat similar work was being done in Europe, no one was using quite this product. “It was pure trial and error,” said architecture student Miranda Wright. “There were lots of times when we decided to look into, say, five different construction types. After research, we’d realize they were useless.”

“One of the technical challenges is building a structure that allows the wood to dry over the first two years,” Shelton said. “Often we put these structural members inside of walls, but we want to have some surfaces exposed to the air, which is not a typical way of detailing a building.”

“We were a little naïve at first because we thought we might be able to overpower the movement and force of the drying wood,” Shelton chuckled. “An important point in the process was realizing that we needed to accept what was going to happen and work with the nature of the material.”

The team finally decided to use a building method deeply rooted in the past. Four green oak timbers are joined into structural cross sections that take advantage of the wood’s longitudinal stability even as it dries. These preassembled “bents” are then lifted into place at the building site. “It’s how barn raisings worked. They’d build a bent, which was basically an entire section of the barn, and push it up and connect it to the other ones that were already up. So we took a very traditional way of working and then adapted it for our purposes,” Shelton said.

One modification is in the joints. “In a barn we might have members that are twelve by twelve inches in diameter or even bigger, so there’s room for four or five of them to come together in the same joint,” Shelton said. “Our green oak is only four by six inches, so we had to simplify the idea so only two or three members come together at one joint.”

Typically the physical defects of white oak—including knots, checks, and splits—occur more frequently at the heart of the tree.
Once the team nailed down their basic concept, the architecture school’s third-year design students joined in. “They created concepts and buildings, which gave us the artistic side showing how beautiful this new construction can be,” Wright said. The resulting four-room house with a shed roof has a broad front porch and ample windows.

In the spring of 2014, the students began building a full-scale mockup of part of the house frame for their presentation in Washington, DC. “There were some scary points,” Wright said. “We had to build it at our fabrications laboratory, but later we would disassemble it, ship it to the competition, and build it once again. There were times when we stripped a screw, or tightened something that might not come un tightened.” As the deadline neared, nights in the lab ran into the wee hours of the morning.

In April, two vans loaded with the mockup and other presentation materials headed to DC to compete against teams from thirty-four other universities for the next round of EPA P3 funding. After three days of reconstructing the mockup, setting up models and drawings, and explaining their work, the team faced judgment day.

First, the project won the Student’s Choice award. Next came verdicts from the judges, a panel of experts from the American Association for the Advancement of Science. The hard work and late nights paid off when the Green Oak Project was named one of seven winners and awarded $90,000 in grant funding for further development.

Although Shelton is the project leader, he credits the students with the win. “The students really took this on and made it happen. It was a joy working with them because of their level of investment.”

In the fall of 2014, civil engineering students working with lecturer Jenny Retherford will tackle Green Oak as their senior design project. In the spring of 2015, Green Oak will return to the architecture students, and the goal is to have a finished house by the summer of 2016.

Turning their concept into a building holds many challenges, including negotiating through codes and regulations to get permits for a new kind of building material. “But if we can walk down that path first and say yes, there’s a way—we’ve monitored it, we’ve measured it, we’ve shown that it’s viable, here it is—then we can pave the way for professionals to build with the same materials later,” Shelton said.

An inspiring precedent is UT’s New Norris House, which won the EPA contest in 2008 and went on to become one of the most sustainable houses in Tennessee while prompting changes in state building policies and applications. “For us in the architecture school, any time we get to build is exciting,” Shelton said. “We get to go out there and translate our ideas into the physical world.”

Will the students be able to rescue stockpiles of this beautiful wood from the mundane fate of being crafted into shipping pallets? “We honestly don’t know,” Taylor said. “It’s a new idea and it’s local and sustainable. A progressive university and motivated young people are the right combination to explore whether or not this can work.”

The hands-on experience of building with the green oak provided students a better understanding of how the material can be implemented in standard building construction.
See-Through Subjects

Compared with mice and other rodents, which also share much of the human genome and disease states, zebrafish are inexpensive, easily housed, and capable of reproducing rapidly. They also mature quickly, reaching the larval stage in only five days. But perhaps the most distinctive and useful zebrafish characteristic is its transparent organs and skin during the early phases of life, allowing for direct observation of chemical and biological processes taking place inside the fish.

Unfortunately, the zebrafish's window of transparency closes rather quickly—within three to four weeks—leaving researchers to wonder what's happening beneath opaque skin. That is why CEB has devised a new process to allow scientists to observe disease processes, including the spread and remission of cancers, occurring in the fish's major organs and other body systems. Based on synthetic biology, the technique genetically induces glowing cells within the zebrafish to change their light signals as therapies attack specific diseases.

Innovative Illumination

Ever wonder what causes fireflies to create yellow-green flashes of light on a warm summer night? The answer is an enzyme called luciferase. Previous experiments have successfully transferred the firefly luciferase gene to a range of microorganisms. Unfortunately, that process requires the addition of a second substance to trigger the glow, making it impractical for drug testing.

CEB's latest innovation is a method that will cause target cells to illuminate throughout the fish's life-time without the need for an additional substance. According to Ripp, this genetically introduced trait may even be transferred to zebrafish offspring, creating a self-perpetuating population of glowing test subjects.

To use this novel platform to test a drug to treat liver cancer, for instance, zebrafish will be injected with CEB's bacteria-based luciferase via a genetic sequence. Because the luciferase is programmed to follow the genetic pathway that promotes the growth of cancerous liver tumors, the diseased liver will begin to glow, or bioluminesce. The intensity of the light will increase as the cancer progresses.

Then the tiny fish will be placed into the individual wells of a standard test plate (about the size of an iPhone, with ninety-six individual wells). Various formulations of the candidate anticancer drug will be added to the water for the zebrafish to ingest.

The test plate will then be placed in a photomultiplier to continuously measure the intensity of the light emitted by the cancerous liver cells in each zebrafish. If a candidate drug is working, the light will steadily ebb as the cancerous cells die. If the well gets dark, the promising new therapy could advance to the next stage in the FDA's approval process.

Industrial Revolution

CEB's pioneering approach comes at an opportune time and may help pharmaceutical companies reverse decades of industry stagnation. “Since the 1990s, drug discovery has significantly slowed, with only about thirty new drug approvals per year despite R&D investments that have more than doubled during that period, from $48 billion to $106 billion,” Ripp said. The problem, in large part, results from an industry-wide reliance on test methods that are rapid but ineffective.

Two decades ago, in the interest of speed and economy, drug makers began to abandon early in vivo testing on whole living animals. Instead they moved to clinical trials where they can assist in treating or curing human disease.

And then there are the big national pet shop chains. Ripp has heard from them, too. It seems that there just might be a booming consumer market for glow-in-the-dark fish.
Kimberly Wolbers was close to getting a degree in accounting when she took time off to work with disabled individuals at Camp Courageous. There she encountered a three-year-old deaf boy who didn’t know any sign language. And neither did she. Wolbers was at a loss. “He had no language through which to communicate,” she said. “The first sign we learned together was spaghetti.”

Her experience at Camp Courageous set Wolbers on a path that would eventually lead her to UT’s College of Education, Health, and Human Sciences as an associate professor of education for the deaf and hard of hearing. While working on her dissertation in graduate school, Wolbers developed the Strategic and Interactive Writing Instruction (SIWI) concept, which promotes language and writing skills among deaf and hard-of-hearing (DHH) children.

“Learning to read and write is more difficult for deaf and hard-of-hearing children,” Wolbers said. Most tend to show little literacy progress throughout their school years. According to Wolbers, previous research indicates that the median DHH student reads at a fourth-grade level upon graduation from high school, and 30 percent are functionally illiterate.

Researchers are studying a unique framework for teaching deaf and hard-of-hearing students to read and write more effectively.


THE METHOD
Wolbers developed SIWI to give teachers the tools and instructional approaches they need to improve the development of language and literacy in their DHH students. Three key components work together to drive the process. The first element emphasizes strategic instruction for writing, where students learn the tactics used by expert writers.

“Novice writers may not have good strategies for planning and organizing when writing,” Wolbers said. “We explicitly teach students to think about their audience and purpose while brainstorming ideas.” Teachers are encouraged to use graphic organizers, or scaffolds, to serve as visual representations of the writing processes, strategies, or skills. “We guide them in the process of continually rereading what they have written to spur necessary revisions or edits,” Wolbers said.

The second element, known as interactive instruction, promotes engagement while working as a group to write for a real audience with real purpose. “For example, if students and teachers are working on persuasive writing and the students have an interest in going on a field trip that requires administrative approval, they might choose that field trip as a topic and the principal as an audience,” Wolbers explained.

Teachers and students will then share their ideas and decide together what actions they will take once the writing process begins.
**PROOF OF CONCEPT**

Wolbers and her research partner, Hannah Dostal, of the University of Connecticut, are conducting a controlled SIWI trial in fifteen classrooms from twelve educational programs in eight different states, which is undertaken with the help of a $1.16 million, three-year grant from the Institute of Education Science. The goal is to determine if their innovative approach leads to significant improvements in DHH students in grades three through five. The small and scattered DHH population was one of the problems the researchers faced when putting the trial together. Because the disability is not a common occurrence, study sites were geographically far apart. The Technology helped bridge the gap for classroom observations, which are completed with two-camera systems that capture the teacher as well as the students. Teachers use the SIWI instructional materials, including visual organization tools and student cue cards. They also have access to a SIWI website for additional resources and video clips.

Wolbers feels one of SIWI’s biggest strengths is that it is a framework for instruction, not a fixed curriculum. This allows teachers of different grades and content areas to work toward objectives. Results from prior studies show the participating students make gains in language, reading, and writing assessments. Wolbers recently hosted a group of teachers from around the country for a weekend SIWI workshop. They visited the Tennessee School for the Deaf in Knoxville to practice guided writing instruction with deaf junior campers. Together, they wrote a newsletter about their camp experiences to share with family and friends.

"In SIWI, we reread the English text often and find that students begin to pick up on English grammatical patterns that we have not explicitly taught."

Kimberly Wolbers

Those teachers have already begun to implement SIWI in their respective classrooms. They will collect language and literacy data from their students throughout the school year as part of the randomized control trial. In the future, Wolbers hopes to replicate her study in grades three to five to see if SIWI can be successful when broadly implemented. She would also like to expand the program to include more levels and other content areas.

Thinking back to her time with the young boy at Camp Courageous, Wolbers doesn’t know if there was much else she could have done to help him at the time. “But that camp experience has certainly impacted my work,” Wolbers said. And that work has already begun making an impact on deaf and hard-of-hearing children nationwide.

Scientists and researchers address many interesting and difficult challenges on a daily basis. Some look for solutions by applying simple observation techniques. Others engage in laboratory science. However, some problems are so complex that they require more data than observation or experiments can provide. That’s when they turn to the power of scientific computing. “Scientific computing offers another way of getting answers to these problems,” said Steven Wise, associate professor of mathematics at UT. “Many problems in science and technology are continuous in nature,” he explained. “But in order to solve a problem with scientific computing, we have to change something that is continuous in nature to something that is discrete in nature.”

Because computers can deal only with things that are discrete (or finite), the continuous (or infinite) variables and equations must be translated into discrete counterparts to make them suitable for numerical evaluation. The transformation process, known as discretization, is not 100 percent accurate and leaves room for errors, which Wise tries to determine using numerical analysis. “When you discretize a problem, you always change it and create error,” Wise said. “When we approximate a solution using computer simulation, we’re not getting reality. We are actually a couple of layers away from reality.” Figuring out how to quantify the error is where his expertise comes into play.

One of Wise’s research areas is simulating cancer growth. When a patient presents with symptoms, the medical team has a limited amount of time to diagnose and treat the patient before the tumor takes over. Researching how best to treat the growth is possible with observation and laboratory experiments, but that can be a waste of time and resources.

"Computer simulation is like a black box," Wise said. "We have to use real data to train our computer model to assign the parameters needed to run the simulation, GENERATES MORE REALISTIC SIMULATIONS.

By Amanda Womac

That’s why Wise and his collaborators work with medical professionals who supply data from their cancer patients using MRIs and other tests. The data include information such as the shape of the mass and where it is in the body. Is it near major organs or blood vessels? What kind of cancer is it and how fast does it grow?

Once the data points are entered and the computer understands the model, researchers can start running simulations that represent various treatments or medications to stop or slow the cancer’s growth.

Armed with real-world data, Wise and his collaborators were one of the first groups to successfully simulate the process of growth and neovascularization—an action very similar to how blood vessels grow new vascular tissue to seal a cut on your arm.

Neovascularization occurs when genetically mutated cancer cells send out a chemical signal called tumor angiogenic factor (TAF) to awaken blood vessels near the tumor. The cell walls then begin to break down and grow new vascular tissue. The tissue grows toward the cancer cells in order to replenish their nutrients. “These cancer cells are hungry,” Wise said. “They are subdividing and doing whatever they can to stay alive.” After the neovascularization process, cells without the genetic mutation might die. The remaining cells lump together and launch more TAF, which starts the process all over again. When the tumor gets its own blood supply, it has the ability to break off cells and send them all over the body via the bloodstream.

With this puzzle in place, Wise and his colleagues can run simulations with a variety of treatment options and medications to try and stop, or at least slow down, the cancer’s growth.

Wise’s group is working on a project with clinical experience on this process, but we’re trying,” Wise said. As the technology advances, researchers will be able to simulate more complicated activities and move even closer to reality.

A junior camper works on his writing during the SIWI workshop.

ELIMINATING ERRORS FROM COMPUTER CALCULATIONS ELIMINATING ERRORS FROM COMPUTER CALCULATIONS ELIMINATING ERRORS FROM COMPUTER CALCULATIONS
The year is 1502. Italian Renaissance artist Michelangelo is chipping away at a massive slab of marble, carving and shaping what will eventually become the iconic statue of David. In one respect, he is creating a masterpiece for the ages. But as he whittles away millions of tiny pieces fall to the ground, making a gigantic pile of useless rubble. This highly inefficient production process has been around since the Bronze Age.

“We end up with a lot of waste, paying for a lot of material that isn’t needed,” said Sudarsanam Suresh Babu, the UT–Oak Ridge National Laboratory Governor’s Chair for Advanced Manufacturing.

That’s all about to change. Welcome to the new age of additive manufacturing—more commonly known as 3D printing. “Now we are able to build things using only the exact amount of material we need,” he said.

How does it work? These highly modified printers use metallic powders, carbon fibers, or plastic pellets instead of ink to produce tangible objects, not just words or images on a page.

The advent of additive manufacturing is poised to change the world in ways we have yet to imagine.

By David Goddard. Photography by Dustin Brown.

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With just a set of geometric dimensions, it is possible to create an object with computer-aided design software or a scanner. “Our machine maps the layers of an object. That information is then fed to the printer, which assembles a replica of that object—layer by layer—using only the materials needed to make it,” Babu explained.

Today’s printers can be used to make almost anything imaginable, from prosthetic limbs to car parts to doorknobs. And yes, even statues. “Some students used one of the processes to make a Statue of Liberty,” he said. “It looked perfect, too,” even though the reproduction wasn’t quite the same scale as the original monument.

By using mere fractions of the material required in the past, the payoff is threefold, according to Babu. “When you reduce materials, you save money. When you reduce processing steps, you save energy. When you do both of those things, you’re helping yourself and the environment at the same time.”

Driving the Future

Although 3D printing technology has been around since the mid-1980s, the past five years have seen its capabilities take some giant leaps forward. Gone are the days when researchers got excited about replicating palm-sized objects. They now have their sights set on some more substantial things—like cars.

Babu is a technical team member at ORNL’s Manufacturing Demonstration Facility (MDF), where a massive 3D printer has been modified to produce a car frame in one go.

In 2007, a company called Local Motors set out to produce the world’s first drivable vehicles created with additive manufacturing technology. In 2014, in collaboration with MDF and researchers from UT and ORNL, an experimental version of the Strati 3D was printed on site at the International Manufacturing Technology Show in Chicago.

The size of the printer and the investment involved highlight the fruitful relationship that UT and ORNL share. “There is a lot of cost involved with doing projects like this, like some of the others we are working on that ORNL has invested in,” Babu said. “On the other hand, there’s a lot of large-scale design involved, a lot of testing, and a lot of data evaluation. That brainpower is what UT brings to the table.”

Perhaps one of the most exciting breakthroughs in additive manufacturing was unveiled at the 2014 International Manufacturing Technology Show in Chicago, when a drivable car was printed for the first time.

This historic achievement was made possible by a quartet of students from UT’s Department of Electrical Engineering and Computer Science. Alex Roschli and Andrew Messing operated the printer during the forty-four-hour process. Kyle Goodrick and Aaron Young contributed to the software that directed the printing process.

“None of the other slicing programs we tried were able to slice an object as large and complex as the car model,” Young said. “We also had various other problems to solve due to such large-scale printing.”

Messing joined Goodrick and Young to develop the program that could load in a part, adjust and align it on the print bed, slice it, and generate the code to print it. The code then defines the tool paths—literally the layer-by-layer movement of the printing tool. The software and hardware are continually evolving as 3D printing technology becomes more accessible.

Local Motors CEO Jay Rogers takes the Strati for a spin.

PRINT MY RIDE
Another project UT researchers are working on involves giving limb functionality back to those who have faced amputation. Similar to the technology featured in the popular 1970s science fiction TV series *The Six Million Dollar Man*, Babu and his team are investigating the ability to print replacement body parts such as hands, limbs, and joints.

“Are they reliable? How long will they last? How much do they cost? Those are some of the things we are still trying to figure out,” Babu said. In addition to improving the functionality of the devices, they hope to make them as human as possible. “We’re working on installing sensors and hardware to make them more usable,” he said. “We print them out with areas for hardware and electronics to pass through so they can be customized as needed.”

**Unlocking the Potential**

Even though parts for cars, airplanes, or even humans can already be printed, Babu believes we are only scratching the surface of what additive manufacturing can do. Future developments in the field will be limited only by the amount of time and money being invested.

“We’re in a stage where things are moving from the theoretical to the practical, but there’s still a lot of testing and studying to be done,” Babu said. “One of our big things right now is looking at different ways of understanding the properties of what we use.”

“For instance, instead of aligning the printed layers the same direction, will it make it stronger if we alternate directions, or is there a certain pattern that would make the best way to go about printing things?”

Those questions and more will undoubtedly be addressed by UT’s involvement in the $140 million American Lightweight Materials Manufacturing Innovation Institute. The White House–backed initiative aims to provide a way for companies, labs, and universities to tackle some of the technological issues surrounding advanced manufacturing.

With new developments under discussion, there is no telling what the next breakthrough will be. Things are progressing so rapidly that even experts like Babu have a hard time believing the advancements made in the past two decades. Imagine what Michelangelo would think.
Glenn Reynolds is a big thinker with a big audience, thanks to his highly influential political blog Instapundit. His first appearance in the blogosphere occurred in August 2001 when Reynolds, the Beaucamp Brogan Distinguished Professor of Law, was teaching a class on Internet law. As an experiment, he created a personal web page and started posting links to stories of the day along with his own personal take on them. At the time, the concept of blogging was new and uncharted. But Instapundit caught on quickly due to Reynolds’s witty, conversational style, his ability to summarize stories in plain talk, and his remarkable breadth of insight into a wide variety of topics. “I have a lot of interests,” he explains. “Scholars are often divided into ‘hedgehogs,’ who know one big thing, and ‘foxes,’ who know many things. I’m more of a fox.”

At the foundation of Instapundit’s appeal is an unpredictable libertarian perspective. Says Reynolds, “I like to joke that I’d like to live in a world in which you, whether you are innocent or not, you face strong pressure to accept a plea bargain. As a practical matter, the only decision that matters in the judicial process is the prosecutor’s decision to bring charges.”

Reynolds admits it isn’t practical to ask grand juries to be stinger in handing down indictments. Rather, he would like to give prosecutors a personal stake by penalizing those whose frivolous indictments create the revolving door of plea bargaining while rewarding those who bring only indictments worth prosecuting.

In his book The New School: How the Information Age Will Save American Education from Itself, Reynolds tackles the problems of education in an era of changing systems and technologies. “In our K–12 schools,” Reynolds says, “traditional models are collapsing. In a century of rapid change, our schools have stayed the same, except by becoming much less rigorous and vastly more expensive. It’s as if we were still writing about ships the way we did when the steam engine was being developed.”

The most obvious solutions involve embracing new technologies, like the free online lessons provided by the Khan Academy. The peskier conversation, which Reynolds admits he’s just opening up, is over replacing the public school system with something else. “My book is more of a conversation starter than a conversation ender, but it starts with entertaining the idea of throwing out old paradigms and starting over.”

Ever the libertarian, Reynolds connects his ideas about higher education to its ever-skyrocketing price tag. “Most of what we hear about the value of a college degree is crap,” he opines. “We’re spending vastly more but we are not getting more out, with the students knowing less.”

Reynolds believes higher education is in a classic economic bubble, like real estate before 2008, dot-coms before 2001, and even the Dutch tulip mania of the 1630s. Prices inflate beyond reason and then, inevitably, the bubble bursts.

Citing a principle coined by economist Herbert Stein, Reynolds says, “Something that can’t go on forever won’t. The higher education bubble may have already burst. With the tough economic times, law school applications plummeted.” For their undergraduate degrees, today’s students are looking for less expensive options, including community colleges, and figuring out ways to avoid the onerous student loans that recent graduates are struggling to pay off in a tepid job market.

In line with the traditional libertarian dislike of bureaucracies, Reynolds sees a major source of escalating costs in the ever-swelling number of administrative positions in colleges and universities. His possible solution: “Along with rewarding schools with great teacher-to-student ratios in its all-important rankings, it might be a good idea for US News & World Report to penalize schools with too many administrators.”

In the history books, Reynolds’s influence on the public debate will be measured by the enduring legacy of his blog, even if the world doesn’t become a libertarian utopia.
One of the first things people do when moving into a new office is unpack their things. Hang a degree on the wall. Find a spot for their favorite coffee mug. For Thanos Papanicolaou it was no different, but his accouterments required more space than a normal office. Much more space.

As a professor studying the effects of moving water, Papanicolaou needed room for pumps, gauges, a boat, and a brand new water flume the length of a tractor-trailer.

“The flume really is the centerpiece,” Papanicolaou said. “It can run scenarios ranging from soil erosion simulations to structural tests.”

Resembling a long blue trough, the flume channels water from a continuous recycling pump fed by a tank the size of a small pool, giving it the ability to maintain a flow of up to twelve feet per second. It employs hydraulic lifts to vary the slope up to six degrees and a flow-dampening system to ensure the pump doesn’t affect the testing area.

Civil engineers use the flume to observe how shapes or angles of bridge pilings affect downstream flow. Papanicolaou also operates two smaller flumes and nearly seventy-five other pieces of equipment, including a rainfall simulator for bank erosion testing. Agricultural researchers use them to study better ways to prevent soil erosion by pinpointing where erosion and runoff originate along stream and riverbanks. The simulation results benefit farmers by demonstrating the amount of soil they are losing downstream and providing ideas to help protect their soil and the environment at the same time.

“These are things that we can show people conclusively,” Papanicolaou said. “It’s one thing to tell them a theory about what might happen to their structure or their farm, but it’s another to physically be able to show them what will happen.”

A recognized leader in hydraulic engineering research, Papanicolaou holds UT’s Henry Goodrich Chair of Excellence. He has served as editor of various journals and earned funding from NASA, the US Department of Agriculture, and other agencies.

His group has previously tested everything from sediment flow to the effect of rivers on cutting both shorelines and bridge pilings. But bringing the new equipment online opens the door to even greater knowledge.

“With this flume, we can raise the amount of research exponentially,” Papanicolaou said. “By having such a large flume that still has the ability to change flow, volume, and even the slope of the water, we’ll be able to take on projects and research that we haven’t been able to do in the past.”

The facility is open for use by other faculty interested in fostering large-scale multidisciplinary efforts in the broader area of water resources. It also is available to researchers at peer institutions.

“There’s no question other schools will want to take advantage of our advanced resources,” Papanicolaou said. With his “office” now complete, the real work begins.

Go with the Flow


Postdoctoral Associate Achilleas Tsakiris and Thanos Papanicolaou inject dye into the flume water to visualize the flow around objects.

The custom-built flume is about as long and wide as a tractor-trailer.

“It’s one thing to tell them a theory about what might happen to their structure or their farm, but it’s another to physically be able to show them what will happen.”

Thanos Papanicolaou
After some early drama, a unique theater project gets rave reviews.

By Angie Vicars.
Photography by Shawn Poynter.

At just under one foot tall, Barbie represents a five-foot-nine-inch woman on the Yeager Lab stage.

Cultural icons Barbie and Ken have been entertaining children for over fifty years. But recently the ultimate power couple of the toy world has stolen the spotlight in a new role on a stage built just for them.

The stage is the brainchild of Kenton Yeager, an associate professor of theatre at UT. Known as the Yeager Lab, it is a fully functional 1:6 scale portable model theater that can be outfitted with equipment for lighting, audio, projection, several types of draperies, and rigging.

Yeager created the lab so he could use “light to teach light instead of words to teach light.” Prior to his invention, the two most common ways to teach theater lighting design were using regular equipment in a large light lab or not using lights at all in a classroom. Neither of those options was particularly practical.

With a little ingenuity, Yeager was able to recreate a theater experience within a standard classroom and take advantage of the similarly scaled Barbie and Ken dolls to represent the actors. “Barbie is such a universal image that when you put her on the stage, everybody understands the 1:6 scale,” Yeager said.

Act I—Learning Curve

Although he had more than two decades of lighting design experience, Yeager had no idea how to create a mini lighting lab—something he imagined would work like an erector set. “There were a lot of trips to Home Depot,” he recalled. “I would cut pipe in my basement, then assemble the prototypes on the back porch to find out how to fit it together.”

In 2006, Yeager completed a 1:4 scale prototype. However, he says, that dimension “never quite fit the right size with people.” From there he decided to start over at a slightly reduced scale.

As he progressed, UT saw the potential and awarded him a $30,000 research grant in 2009. It provided a three-year funding line to buy material and miniature equipment to continue developing the lab.

During the design process, Yeager quickly realized the lab could be more than just a lighting setup. He was inspired to take it to the next level and model an entire theater. The current version can be configured to emulate different types such as proscenium, black box, thrust, or theater in the round.
Act III—Reluctant Entrepreneur

Yeager always saw the lab as a teaching tool, so he originally created a website with directions for building one. He envisioned other schools taking advantage of the fruits of his labor and making their own. Instead, he got calls from schools that wanted to buy one.

To maintain his focus on teaching, Yeager struck an agreement with a lighting sales company to handle the marketing and sales aspects of the project. However, Yeager does offer potential customers help with pursuing grants to cover the purchase price, which can range from $10,000 to $40,000, depending on the equipment they select. A majority of the grant-seeking attempts have been successful.

Yeager added that designers and students are “amazed when they start to play with the lab. In five minutes, they decide they want one. They bring their instructors to have a look. Sometimes they bring deans to see it and convince them they need funding.”

Since UT is home to this premier teaching tool, Yeager has the luxury of handpicking his graduate students while building one of the country’s top lighting design programs. But he’s not resting on his laurels. Yeager is currently working with a company to create a rigging system that will give the lab options for flying scenery.

Superstars like Barbie and Ken would expect nothing less.

For more information, visit yeagerlabs.com.
Sahba Seddighi didn’t know a word of English when she left Iran for the United States. But the precocious fourth-grader quickly learned the language and became fascinated with the potential of the human brain.

Now a junior in UT’s College Scholars Program, she is focusing on neuroplasticity—how the brain changes as a result of experience.

Working with Matthew Cooper, associate professor of psychology, Seddighi is putting stress, or specifically what causes it, under the microscope.

“StressTest
AN UNDERGRADUATE RESEARCHER_examines_the_behavior_and_biology_of_brain_strain.

By Whitney Heins

Sahba Seddighi with a “resident aggressor” hamster, known as RA99.

“We all respond to stress in different ways. Some get headaches. Some get heart disease. But the underlying mechanisms for the basis of this variation is not fully understood,” Seddighi said.

To help unlock the mystery, Seddighi is using an unusual tool—a community of 100 Syrian hamsters.

Her investigation centers on restricting the playtime of young hamsters to see if they experience any permanent changes to a part of their brain called the ventromedial prefrontal cortex (vmPFC). Such a modification could make them more vulnerable to stress later in life, becoming evident through submissive and defensive behavior.

At first, the young hamsters were divided into two groups. One group lived only with their mothers, while the other lived with peers and learned to socialize. Eventually, all hamsters were moved to cages with their peers.

In a rodent version of a reality TV show, the hamsters were then exposed to stressful social situations in which a smaller submissive hamster was put in a cage with a larger aggressive one. Seddighi recorded their activity and counted the frequency and duration of submissive, defensive, aggressive, social, and nonsocial behaviors.

“The hamsters literally fight each other,” Seddighi said. “This social and physical interaction is the basis of psychosocial defeat where a Syrian hamster, known for aggression, loses its aggressive tendency and becomes more stressed.”

In the second phase of the study, Seddighi will look at neurons in the hamsters’ brains under a microscope. She will use tracing software to quantify the structure of the neurons, looking at density, length, and junctions—all clues to the function and communication of the nerve cells.

“We expect that mother-housed animals will show reduced neural activity in the vmPFC compared to peer-housed animals because of lack of play and thus be more vulnerable to stress,” Seddighi said.

If Seddighi’s research supports a link between the vmPFC and stress, better treatment options for stress-related mental illnesses may follow.

“If our hypothesis is proven true, it could lead to novel treatments like using play therapy or drugs that target the underlying biological mechanisms to reduce stress,” she added.

Seddighi has already conducted neuroscience research at the National Institutes of Health and Stanford University. Upon graduation, she plans to enter a doctoral program to explore neurological diseases, with a focus on neuroplasticity as a therapeutic tool.

“We don’t know what causes so many of these often intractable neurological diseases like Alzheimer’s and multiple sclerosis,” she said. “I think there is a lot of potential for discoveries that will make a difference.”

While diligently working to uncover the brain’s hidden secrets, Seddighi has developed a profound thirst for research. “It is the international language of science, a way for the passionately curious to make sense of the world,” she said. “Just another language she continues to master on her journey for knowledge.”
Falling/Winter 2014

GOING FOR GOLD

Hosting an international sporting event can be a great source of pride but is unlikely to pay off financially.

By Robert S. Benchley

The 2014 World Cup put Brazil in the global media spotlight, with more than three billion viewers tuning in to watch the games. All that attention, however, came at an enormous financial cost to the country. The final bill for stadium construction, infrastructure improvements, and other related expenses is expected to total $14 billion—about triple what South Africa paid just four years ago—making it the most expensive World Cup yet.

Many Brazilians were upset by the high cost of hosting the 2014 World Cup. The actual cost was nearly three billion dollars, but the royal family of the time faced financial adversity—starting with the first Olympiad of the modern era, hosted by Athens in 1896. Greece was already bankrupt, but the royal family of the time thought hosting the games would increase their popularity. The actual cost was nearly six times the amount budgeted. Thus began a tradition of economic overspending to achieve noneconomic gains.

Olympics ever—costing about 25 percent more than the $40 billion spent on the much larger 2008 Summer Olympics in Beijing.

“Hosting the Olympic Games can be a great source of pride for a city, but it is unlikely to pay off financially,” says Holladay, who co-authored a 2010 study entitled “Should Cities Go for the Gold? The Long-Term Impacts of Hosting the Olympics.” His research compared the economic histories of cities selected as an Olympic host between 1950 and 2005 against nonwinning cities. For the most part, there wasn’t much difference in the eventual outcome.

“Host cities tend to grow quickly after the Olympics, but the games are awarded to fast-growing, well-organized cities,” Holladay said. “Other cities that bid and don’t win the games usually grow just as quickly. This suggests that hosting the games doesn’t have a big long-term impact on the local economy.”

Historically, Olympic cities have often faced financial adversity—starting with the first Olympiad of the modern era, hosted by Athens in 1896. Greece was already bankrupt, but the royal family of the time thought hosting the games would increase their popularity. The actual cost was nearly six times the amount budgeted. Thus began a tradition of economic overspending to achieve noneconomic gains.

Holladay notes a more recent boondoggle. The 1976 Montreal Winter Olympics lost $1 billion on a budget of $207 million. It took thirty years to pay off the debt, with the final total, counting interest, reaching $3 billion. “Cities that need to invest in building venues seem to do worse,” he explained. “Montreal was such a financial disaster that the number of cities bidding to host fell off dramatically. By contrast, cities that have a lot of the venues already in place tend to do relatively well. Los Angeles did well financially (a profit of $250 million), and the number of bid cities crept back up after the 1984 games.”

Holladay also cites Atlanta, which hosted the 1996 Summer Olympics, as an example of a city that made smart investments—improving the airport, expanding Interstate 75 and 85, and upgrading its MARTA railway system.

Those investments are still paying off because Atlanta residents are still using them,” Holladay said. “It’s the kind of investment strategy that benefits citizens more than sporting centers that will go unused after the games.”

Holladay suggests true hosting success comes down to having realistic expectations and realizing that the benefits, if any, will be long-term and relate to the city’s overall quality of life. “As long as everyone involved understands that, bidding for the Olympics can be a good idea,” he said.

For the 1996 Olympics, Atlanta made numerous investments in infrastructure that are still benefiting city residents and visitors.
Shedding light on how critical sleep patterns vary across our life span.

By Amanda Womac

It’s all about rhythm.

“Virtually everything your body does, from the timing of hormones being released to your blood pressure rate, is based on circadian rhythms,” said Theresa Lee, dean of the UT College of Arts and Sciences and professor of psychology.

A circadian rhythm is any biological process driven by the body’s internal daily “clock,” which makes it possible for most living organisms to coordinate their biology with the twenty-four-hour environment.

Lee first discovered the importance of circadian rhythms while studying ground squirrels in the late 1980s. Because the squirrels were in a laboratory, they could not go into deep hibernation. However, Lee observed changes in the timing and amount of daily activity.

“Therapy behavior got me interested in the circadian rhythms of humans,” Lee explained. “Turns out, there’s a corollary with humans.”

In the Beginning

The first mammals emerged during the time of the dinosaurs. They were primarily nocturnal, which allowed them to avoid predators during the day. Since they were active at night, the various light-sensing organs of their reptile relatives gradually disappeared through evolution—except their eyes.

Humans, like all other organisms, have biological clocks that are not exactly twenty-four hours long. We synchronize to our planet’s light-dark cycles. These cycles reset a “master clock” in the brain, which in turn synchronizes the rhythms of organs, skin, blood cells, etc.

At birth, our circadian rhythm is not yet functional. Newborns usually sleep and eat on continuous two- to four-hour cycles. As their internal clock matures, their daily sleeping patterns develop and they sleep through the night. However, sleep patterns change drastically when children reach adolescence.

“The working theory was that the internal circadian clock got longer than the twenty-four-hour circadian cycle during adolescence or that social behavior was driving late hours,” Lee said. “It turns out that neither is the case. What’s really going on is that the clock begins changing at the onset of puberty and never really stops.”

There is a stable period of circadian control and sleep time between ages four and twelve. “But during adolescence, just when more sleep is needed because of rapid growth, teens find it very difficult to get enough sleep,” Lee explained.

Are you a morning lark or a night owl? Do you struggle to get out of bed? Is your sleep cycle erratic? Why are teenagers so hard to wake up?

In the Teenage Years

Why do adolescents have trouble getting enough sleep?

One word: hormones. “Actually, it’s the interaction of the changes in the circadian system caused by hormones conflicting with societal expectations,” Lee said.

Anyone who interacts with a teenager knows that hormonal changes occur rapidly during those years of development. The complicated mechanism of synchronizing the master internal clock becomes even more complex when you throw hormones into the mix. The result is delayed rhythms.

Whether you are now a night owl or a morning person, your sleep cycle became delayed in your teen and early adult years. According to Lee, animal studies demonstrate that it’s not exclusively a human phenomenon. And it occurs in societies around the globe, even those without phones, TVs, or other modern entertainment that can make one want to stay awake.

Teenagers are most alert and learn best in the afternoon and function better when the rest of us are fading. “But because this circadian delay makes it hard to go to sleep at night, they need to sleep later into the morning to get enough sleep,” Lee said.

Sure, they can set alarms and make it to school and work on time, but teens are more likely to oversleep or be late. Some may even become sleep-deprived because of the schedule society requires (particularly early start times at school).

“The amount of sleep we need is pretty stable after we finish growing,” Lee said. “The notion of how much sleep we need and when we need it is probably correct from age twenty to twenty-four to about fifty-five to sixty.”

During that thirty-year span, the average person needs seven to nine hours of sleep at around the same time each night to remain mentally and physically healthy. However, the time of night we prefer to sleep is likely to shift gradually as we age. Everyone recognizes that grandparents typically get up much earlier than younger adults, for example.
Staying Alive
Sleep is an active, complex, and highly regulated process measured in five basic variations in brain activity: stages one and two (light sleep), stages three and four (deep sleep), and REM (sleep characterized by rapid eye movement and dreaming). While we sleep, the body is at its lowest temperature, the immune system is active, and melatonin and growth hormones are released. It is also when the brain removes the debris from a long day of activity, allowing us to awaken renewed.

“Data consistently suggests people who sleep less than seven hours a day on a regular basis will suffer negative consequences,” Lee said. “If someone says they are sleeping five to six hours a day and they are fine, they are not fine when tested.” The best amount and timing of sleep varies depending on the individual and is often similar between relatives.

Lee notes that people who get less than seven hours of sleep are usually the ones who are late or fall asleep at the movies. They take micronaps during the day to make up for lost sleep. They also tend to be moody and unmotivated, and their ability to learn is compromised. “There are lots of negative impacts when we deprive our bodies of sleep,” she added.

Our bodies start to break down, and many people with too little sleep or erratic sleep patterns become overweight or show signs of Type 2 diabetes.

“One of the fascinating things researchers report is that when you get older, you tend to lose the deep sleep,” Lee said. “There seems to be a very good correlation between the amount of deep sleep we get as we age and our health.” Growth hormones released during the deepest part of sleep are necessary for maintenance and repair of the body throughout life. As most folks with elderly parents or grandparents know, sometimes aches and pains can cause older people to wake more often during the night and disrupt deep sleep. “There’s really no way around the fact that we need a proper amount of sleep and we need to sleep at approximately the same time every day, whether we are young or old,” Lee said.

So if you find yourself having trouble focusing or keeping your eyes open throughout the day, think about your sleeping pattern. Do you get the recommended seven to nine hours a night? Do you go to bed at about the same time each night? If not, a little change could be the natural answer to regaining your rhythm.

Young or old, we need a proper amount of sleep at approximately the same time every day.
This unassuming tropical freshwater species is helping point the way to cures for cancer and other deadly diseases. Page 12