THE TEXAS SCIENTIST

HOW MATH-DRIVEN MEDICINE CAN SAVE LIVES

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This otherworldly range of turquoise peaks is a close-up of fabric embroidered using algorithmic design and patterning. Created by Luisa Gil Fandino, a lecturer in The University of Texas at Austin’s Division of Textiles and Apparel, the process begins with programming a repetitive algorithm to create a recurring geometric motif. A pattern that will best hold the encoded structural shape is then designed and tested. Creation of the final product includes hand folding, industrial steaming and chemical treatment of the fabric to preserve the pattern. Fandino’s process can be applied to woven, knit or embroidered textiles.
A digest of the people and groundbreaking discoveries that make the College of Natural Sciences at The University of Texas at Austin one of the most creative and interesting places on Earth. #discoverystartshere
Dear Friends,

To perceive the world as a mathematician or scientist is to see possibilities and intricacies that others miss. Wonders are literally everywhere, from the inner workings of a cell to the mysterious black holes swirling in distant galaxies. A wealth of new knowledge remains to be discovered, and here in The Texas Scientist, we introduce you to people who contribute to those discoveries – in the lab, in the classroom, and in a society that needs science and math to help solve problems.

Many solutions to crucial problems we face involve mathematics and data science. If you’ve watched films like The Big Short or Moneyball, you have a sense for how acting on the recommendations of data experts and mathematicians can transform whole industries. In our cover story, we meet leading thinkers here in the College of Natural Sciences who are solving core problems in health care by applying novel mathematical and statistical insights.

We also highlight here our college’s 21st Century education initiatives and the ways UT Austin is leading in providing transformative experiences in STEM education. Our innovations here in CNS have already made an impact in the lives of students and the communities our students return to after graduation.

As always, what’s here provides only a glimpse of life in the college. For more, read our e-newsletter (sign up at cns.utexas.edu/alumni-friends). Subscribe to our Point of Discovery podcast. Engage with Texas Science on social media. And come to an event, like the annual Explore UT celebration the first Saturday in March.

I hope you enjoy the stories here and all that Texas Science has to offer.

Linda Hicke
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Peek at how Texas scientists are harnessing tomorrow's technology and ideas for new discoveries.
Traditionally, astrophysics has been a science of observations, not experiments. How in the world (literally) can researchers conduct tests involving celestial bodies hundreds of light years away, far hotter and denser than anything on our planet?

It sounds impossible, but researchers in The University of Texas at Austin’s Department of Astronomy conduct experiments that recreate the physical conditions of stars. To replicate the extreme temperatures and densities of plasma, the stuff inside stars, astronomers Don Winget and Mike Montgomery are leading a team that makes use of Sandia National Laboratories’ Z Machine, the world’s most powerful laboratory generator of X-rays.

Electricity charges massive capacitors, which store and then release charges in microseconds. The capacitors compress the electricity into tight pulses, flowing into containers holding gas.

The gas is ionized with lasers, further compressing pulses into finer spaces and shorter increments of time.

Finally, the electricity flows into a delicate array of tungsten wires clustered together in a central compartment the size of a spool of thread.

For just nanoseconds, the X-ray energy generated by the magnetically imploded plasma is far greater than all the energy released by all the power plants in the world.

The result is a tiny chunk of a star.

Go online for more on the team making star stuff and how they inspired one artist’s recent work: txsci.net/emulatingstars
QUANTUM COMPUTING

Take the principles of quantum mechanics. Add the imagination of computer scientists. What you get is a mind-bending technological advance called a quantum computer, with links, past and present, to the UT Austin campus.

Setting a Foundation: UT Austin physicist John A. Wheeler assembled a group of graduate students and postdocs who made seminal contributions in the 1970s and 80s. Former Longhorns include David Deutsch, who cofounded the field of quantum computation by describing mathematical principles for a universal quantum computer; Wojciech Zurek (PhD ’79), who cofounded the subfield of quantum-error correction; and Benjamin Schumacher (PhD ’90), who coined the term “qubit” for a component that processes and stores information in a quantum computer.

Showing Supremacy: Scott Aaronson, professor of computer science and founder of a new UT Austin center dedicated to quantum information, develops tests that quantum computers have to pass to prove they’ve reached a key milestone called “quantum supremacy” – performing a task that would take astronomical amounts of time for a traditional computer.

Taking a Test Drive: In a new research stream of the Freshman Research Initiative, undergraduates explore all aspects of quantum computing, from implementing algorithms to performing quantum-error corrections. They work with scientists doing experimental and theoretical work in quantum computing, quantum cryptography and quantum emulation (meaning using analog electronics to mimic the behavior of a quantum computer).

Exploring Information: The Departments of Physics and Computer Science are currently recruiting additional faculty members who research quantum information. In addition to continuing his current work, Scott Aaronson plans to study the properties of machine learning algorithms designed specifically for quantum computers and to apply tools from quantum information theory to answer questions such as, What happens to information in a black hole?

Listen to the podcast interview with our quantum computing expert: txsci.net/quantum-aaronson
A complex community of thousands of microbes live inside the digestive tracts of humans and other animals. To truly understand our health, behavior and even our ability to learn, we must first understand this gut microbiome inside our bodies.

Nancy Moran, an integrative biology professor, and her team have been studying the interactions of honeybees and their gut microbiome in the hopes of both protecting the future of the bees and applying this knowledge to better understand the role of the microbiome in human health and behavior. Recently her team has joined efforts with other UT labs, including that of molecular biosciences professor, Jeffrey Barrick, to develop tools that allow them to genetically engineer the gut microbes in bees.

In one project, the team infected bees with bacteria that produced L-DOPA, which promotes dopamine, a chemical in the brain that can affect memory, emotions and movement. Afterwards, the bees were tested to see how fast they could associate a random smell with an experience, or duration of the association. Scientists could measure both based on observations of when the bees extended their stingers in experiments and what prompted them to do so. Moran and her team found that the bees with the L-DOPA-producing gut bacteria were faster and better at picking up associations and retaining memories.

“We’ve been able to improve their learning with the dopamine-promoting gut bacteria,” Moran said.

While Moran doesn’t expect any direct applications to humans, this finding highlights the dramatic impact that microbiomes have on a host’s health and performance. In addition, she said these new tools for genetic engineering of microbes might be used to protect honeybees from common pathogens, such as the deformed wing virus, that have contributed to the decline in bee populations in recent years.
MANIPULATING NEURONS

With a flash of light, neuroscientists can now turn individual brain cells on or off. They do so using a set of tools, pioneered in part by UT Austin neuroscientist Boris Zemelman, called optogenetics. For the first time, scientists can see how sets of neurons work together in a healthy brain during learning and memory recall, as well as in disorders, such as Alzheimer's, Parkinson's, traumatic brain injury and addiction. Optogenetics is producing insights that could uncork a flood of new therapies.

It’s been 15 years since Zemelman and neuroscientist Gero Miesenböck at Memorial Sloan-Kettering first discovered a way to genetically modify nerve cells so they would respond to light. Zemelman’s lab now uses optogenetics to both perturb and track neuronal activity.

In a first-of-its-kind study coauthored with Eyal Seidemann, another UT Austin neuroscientist, researchers have even analyzed neurons’ activity in primates engaged in a cognitive task. Experiments like these bring scientists closer to understanding the human brain.

For more on how Zemelman and a team are working to map the brain’s activities, visit: txsci.net/neuronmapping

Optogenetics in practice

Scientists use viruses to express foreign proteins in neurons of a living animal, so that the brain cells either sense or emit light. Light-sensing relies on proteins called opsins.

The opsins are inserted into specific brain cells in the animal.

Now when a certain color light illuminates these neurons, the opsins respond to the light and activate the neurons – turning them on like a light switch.

Zemelman’s team is using this technology to map brain circuits, identifying sets of neurons that carry out tasks, such as seeing or hearing, or experiences, like learning or addiction.
How do you see the department growing or changing in the next few years?
One big area of growth is structural biology, particularly cryo-electron microscopy, which is revolutionizing biology. We are just finishing construction on a new state-of-the-art cryo-EM facility, which will enhance many of our research programs. We will also start to collaborate with UT Austin’s new Dell Medical School. This will enrich our work by allowing us to go from model systems into disease systems, by giving us access to clinical samples and by exposing us to ideas and problems that may benefit from our basic-science perspective.

What kinds of research will the new cryo-EM facility enable?
Virtually any biochemical process – from copying DNA to building proteins to turning light into metabolism through photosynthesis – involves molecules behaving and moving. And we want to see how those processes work. That can help us design better drugs, understand the causes of diseases and make better crops. It’s not a guarantee, but the more you understand at a molecular level, the more insight you can have to use biology to make human lives better.

Why is it useful to see molecules in detail?
In structural biology, seeing is believing. A picture of a molecule helps us figure out how it works and how it interacts with other molecules to create living cells and tissues. It’s like taking apart a clock and studying all of the pieces to understand how it works.

What will you be studying with cryo-EM?
I study epidermal growth factor, an important receptor on cell surfaces involved in development and in healing skin after a wound. Tickle this receptor and the cells grow and divide, so mutated versions of the receptors are often involved in cancer. Consequently, many cancer drugs target these receptors. In my work, I try to see how the receptors and the drugs that target them work.

You played a role in getting a new breast cancer treatment into clinical use. Can you tell me about that?
A particularly aggressive form of breast cancer is caused by overexpression of a receptor called HER2. There was already a drug on the market called Herceptin that targeted HER2, but it didn’t work in some people, and in others, tumors often evolved resistance. Genentech had discovered another drug called Pertuzumab that also targeted HER2. We could see that the two drugs bound to different parts of HER2 and would inhibit its function in different ways. On the basis of this and other observations, Genentech decided to push Pertuzumab through clinical trials and received approval to market it. Now these two drugs are used together and, just as we suspected, they are more effective than Herceptin alone. By the way, Gail Lewis, a UT alumna and scientist at Genentech, played key roles in the development of Herceptin and Pertuzumab.
CONJURING TIME CRYSTALS

A new era in physics has arrived with the creation of time crystals, an exotic new form of matter. Unlike normal crystals, in which atoms are arranged in repeating 3-D patterns, the atoms in these new crystals move in a pattern that repeats in time rather than space. The atoms also never reach thermal equilibrium, a state in which they all have the same amount of heat.

Time crystals are the first examples of a new phase of matter called nonequilibrium phases and have the potential to be game-changers for quantum computing because of their unique properties.

Andrew Potter, assistant professor of physics at the University of Texas at Austin, was on the team that created the first time crystals from ions, or electrically charged atoms, of the element ytterbium. An electric field was applied to levitate 10 of the ions above a surface, and the atoms were repeatedly hit with a laser pulse, causing them to flip head over heels in a pattern that repeated in time.

Most importantly, the researchers found that the group of atoms flips only half as fast as the laser pulses, similar to tapping a piano key twice and hearing only one note. Although certainly weird, this quantum behavior had been predicted and helped confirm that the result was indeed a time crystal.

“This opens the door to a whole new world of nonequilibrium phases,” Potter said. “We’ve taken these theoretical ideas that we’ve been poking around for the last couple of years and actually built it in the laboratory. Hopefully, this is just the first example of these, with many more to come.”

Time crystals are the first examples of a new phase of matter called nonequilibrium phases.
When Gulf corvina, a commercially valuable fish in the Gulf of California, gather to spawn, they make sounds louder than an underwater rock concert, enough to damage your eardrums were it on land. Because corvina also are at risk of being overfished, marine scientists from the University of Texas Marine Science Institute (UTMSI) are part of a team trying to use these deafening mating calls to help protect the fish.

The researchers developed an inexpensive yet accurate method for estimating how many corvina are in a spawning aggregation based on their mating calls. Accurate data on when and where fish spawn, as well as how many there are, would help fisheries managers design effective management practices, such as setting sustainable harvest levels. Monitoring wild fish populations isn’t easy, but anecdotal evidence and a trend toward smaller fish getting caught suggest overfishing poses a serious threat.

“It can be extremely challenging to get a complete picture of fish spawning events because they can happen over very short to very long times and are often in difficult environments such as murky water,” said Brad Erisman, assistant professor at UTMSI. “Our work opens an acoustic window into these exciting spawning events.”

With calibrations, the method Erisman developed can be applied to other threatened fish around the world.

“The idea is we try to bring all the stakeholders, different groups that have a vested interest in the fishery and the environment, together to try to work it out,” says Erisman. “It’s nice that science is playing a role in that.”
Supermassive black holes have been thought to lie at the heart of most galaxies, but some theorists have suggested that something else exists there instead—an even stranger supermassive object that has somehow managed to avoid gravitational collapse to a singularity, or a mysterious pinpoint where the laws of physics no longer operate.

UT Austin astronomers recently devised a test to determine which idea was correct. If a singularity has no surface area, the non-collapsed object would have a hard surface. If the hard-surface theory were true, an object being pulled in would hit the surface and be destroyed. Otherwise, the object should disappear past an event horizon, an invisible boundary past which no matter or energy can escape.

“Our motive is not so much to establish that there is a hard surface, but to push the boundary of knowledge and find concrete evidence that there is an event horizon around black holes,” said Pawan Kumar, a professor of astronomy who worked with a team on the project.

The team determined that if a star hit a hard surface of a supermassive object, its gas would envelop the object, shining for months or even years. Given the rate of stars falling onto black holes, they estimated more than ten of these events should be able to be detected over a period of 3.5 years. After searching recent archives of telescope observations, the team found none. The discovery suggests that, as predicted by Albert Einstein’s General Theory of Relativity, matter completely vanishes when pulled into black holes.
“Our technology could vastly improve the odds that surgeons really do remove every last trace of cancer.”
Brownian trees are fractal structures that form in a process called Diffusion Limited Aggregation (DLA). This depiction—submitted to the College’s annual Visualizing Science contest by physics graduate student Lukas Gradl—resulted from a computer simulation of the DLA process, where particles are dropped in the center of a circle and then move randomly about until they meet another particle to which they stick. The particles accumulate, growing into these trees.

To see all our most recent winners of Visualizing Science, visit: txsci.net/VizSci2017
LETICIA NOGUEIRA, PhD, CELL & MOLECULAR BIOLOGY, ’10
Director of Health Services, American Cancer Society. Interviewed by Annie Zhang.

Earlier this year, you became the Director of Health Services for the American Cancer Society. What do you hope to accomplish through your work?
A lot of my research and work is looking at disparities between various cancer treatments and accessibility to these treatments. One of the projects we’re currently working on is analyzing the early mortality rate in cancer, or death within 30 days of receiving surgery, across different types of facilities. We’ve found that people treated at NCI [National Cancer Institute]-designated cancer centers have a lower chance of dying within 30 days of receiving treatment compared to those receiving treatment at a community hospital. This project has huge implications for where people decide to get their cancer care and can work as an incentive for hospitals to improve their approach to surgery and treatment.

How did you first become interested in cancer research?
I believe everyone has had a personal encounter with cancer. When I came to UT for my PhD, my focus was actually on genetics. For the first practical, we had to choose a topic that was not related to our research, and I chose the relationship between obesity and cancer, and that got me more interested in other determinants of health. I learned that a person’s zip code can have a bigger impact on their health than their genetic code. So, halfway through my PhD, I switched from the molecular biology side to population science, focusing specifically on the link between obesity and cancer.

What motivates you to continue your work with cancer research?
A lot can be done, from prevention to treatment to addressing health disparities. There are so many different types of cancer, and each type is pretty much a completely different disease. There’s a lot of potential for our work to have an impact, and of course, it’s one of the trickiest and most pervasive diseases out there. Even if you have a terrible day at work, at the end of the day, you’re doing cancer research, and that motivates me to continue to do work that has a positive impact on the world.
From baseball to financial investing, from elections to oil drilling, analyzing data quickly to predict future outcomes is transforming industries and activities around the world. Take, for example, car-racing. Each time a Formula 1 driver lunges into first place, part of the credit goes to a crew not of mechanics but mathematicians, who continuously monitor and crunch data, on everything from air pressure across the hood to brake temperatures, using that data for sophisticated models to forecast how things will unfold and to inform a driver’s moment-by-moment strategy.

Now imagine applying similar data-monitoring and forecasting to our physiology and health instead of to cars. Experts say joining the mathematical and computational revolution has the potential to transform healthcare, one of our nation’s largest and most critical industries.

“This idea of real-time monitoring and making decisions on the basis of models, it’s really changed the way engineering works and large sectors of the economy,” said James Scott, an associate professor in the Department of Statistics and Data Sciences (SDS), “but it hasn’t changed healthcare yet.”

Scott and other researchers at UT Austin are leading the way in applying mathematical tools to make the next big breakthroughs in medicine and healthcare, with data-enriched imaging techniques, clinical drug trials built on sophisticated formulas and new statistical tools that help doctors make better decisions.
Medical math could forecast how a tumor would grow in a particular patient’s body.

Targeted Drug Trials

In one ambitious project, researchers are applying data science to predict trajectories for cancer patients. Right now, so-called targeted therapies – those designed to go after specific gene mutations or proteins found only in a disease like cancer – are largely failing to live up to their promise as a more effective, less toxic alternative to existing therapies. One reason is that cancers are so complex that, for many patients, these therapies either work only temporarily or not at all.

But what if medical math could forecast how a tumor would grow in a particular patient’s body?

“We’re moving away from the paradigm of treating all patients the same,” said Peter Mueller, a professor in the Departments of Mathematics and Statistics and Data Sciences. “Each cancer is different.”

One reason targeted therapies fail is that tumors evolve. New genetic mutations can arise in some cells but not in others; over time, the cancer becomes a soup of many different subpopulations, called subclones. Mueller is developing mathematical models to help explain how tumors evolve into this heterogeneous mix. Using genome-sequencing data from tumor biopsies, he applies methods from Bayesian statistics to cluster and analyze these subclones: identifying groupings, characteristics, and particular genetic mutations. It’s the ultimate in “know thy enemy.”

One of the ways Mueller is most excited to see the approach applied is in a clinical drug
Experts see the potential for mathematical precision to help correct for human biases and blind spots.

Making Tough Choices
Developing models to help doctors arrive at the best decisions for their specific patients based on large data sets isn’t meant to replace doctors, Scott explained.

“It’s about empowering them,” he said, “with the information they need to make a decision wisely.”

For example, obstetricians have a hard time estimating the risk of two significant dangers for developing babies: stillbirth – meaning deaths in utero after the 20th week of pregnancy – and neonatal deaths, those in the first month after birth. Each year in the U.S., about 40,000 pregnancies end with one of these two devastating outcomes.

A dizzying range of factors in a mother’s health history help determine which risk is higher. What is a doctor to do when inducing delivery can prevent a stillbirth in one case and lead to a baby being born dangerously prematurely in another? Scott envisions an app that would plot, for each patient and her risk factors, one risk curve for stillbirth as a function of gestational age and another curve for neonatal death as a function of time since delivery.

“If the stillbirth curve goes above the neonatal death risk curve, in principle there’s a higher risk of leaving the baby in utero than of early delivery,” Scott said. “Based on that, a doctor might decide to induce delivery at 38 or 39 weeks.”

He’s already working with a team including collaborators at UT’s Dell Medical School to begin to draw these sophisticated curves as accurately as possible, based on millions of patient records from national vital statistics datasets.

David Paydarfar, chair of neurology at Dell Medical School, is one doctor working on a similar decision-making tool for physicians who treat preterm babies. It’s an innovation he said has the potential to complement a physician’s own experience and help correct possible biases: “It allows you to take the wisdom gained from thousands of infants, instead of the 10 or 20 you’ve personally seen that seem similar, and choose how best to treat an individual.”
**Hidden in Plain Sight**

Just as experts see the potential for mathematical precision to help correct for human biases and blind spots, similar methods may be able to address performance gaps in our current medical technologies. Chandrajit Bajaj, a professor of computer science, for example, is developing a new way to use mathematics and light to analyze biological tissue more effectively than today’s pathology tests allow.

For some types of cancer, cells are misidentified – as either malignant or benign – after a biopsy in up to 20 percent of cases. Bajaj’s method would remove much of the guesswork and enable earlier cancer detection by identifying the chemical make-up of individual cells, so doctors would have a much more sensitive readout for differentiating cancer cells from healthy cells in a biopsy.

Bajaj’s method, called chemical imaging, analyzes the colors of light reflected by human tissue under a microscope to create chemical profiles for each pixel in the image. Unlike human eyes that can see combinations of three primary colors, the sensor is able to detect thousands of colors, or frequencies, of light, including infrared frequencies that we can’t see. Satellites use something like chemical imaging to distinguish details like grass, rocks and concrete on Earth from vantage points in space or to identify different chemical elements produced by stars.

Bajaj built a mathematical model to simulate how a chemical imaging system would work, allowing him to tune the design virtually until it gathers the clearest, most accurate images – information that’s now allowing colleagues to build the ideal chemical imaging instrument itself.

Another mathematical model Bajaj is constructing translates the varying intensities of thousands of colors of light that the instrument collects into chemical components. This, the equivalent of distinguishing trees from rocks in satellite data, is known in mathematics as inverse un-mixing analysis. This will allow doctors to distinguish a wider range of cell types in a biopsy, which can mean earlier cancer detection and better characterization of cancer subtypes. It might even shed light on changes in the microenvironment around cells, which could potentially signal a shift towards dangerous metastasis.

“Just in the last few years, computer scientists and mathematicians have developed methods for analyzing large data sets and solving optimization problems quickly,” said Bajaj, “and this lets us do our high-level data analysis in real time.”
The science of our campus spaces and places
From weekly star parties on the roof of one tall campus building to a search for antibiotics down in the soil near campus greenhouses, there is more to the physical places of The University of Texas at Austin than meets the eye. Find 360-degree photos of much-loved spots on campus, peek into natural and historic wonders hidden from the public eye and explore the science behind iconic campus places and spaces like the UT Tower, Gearing Hall and the turtle pond.

For the full online experience, visit fortyacres.cns.utexas.edu
KAYLA EBOREIME
Public health junior and Women in Natural Sciences (WINS) outreach coordinator. Interviewed by Vivian Abagiu.

What have you gotten involved with here at UT?
I was a WINS student when I came to the University. It was one of the best things that happened in my UT experience. WINS is this really supportive female science community that is so unique. We cried together, laughed together, studied together and built such community. They always say that women don’t support each other, but that’s what we do in WINS. We’re a diverse group, studying diverse fields of science, and we’re all trying to win and help each other win.

Why major in public health?
Public health is rooted in advocacy, in lessening health disparity and noticing trends in different demographics. I’m passionate about that. It’s interdisciplinary, too. Right now, I’m taking an international advertising class towards my major. … I want to live my life in a way where I’m helping people who got the short end of the stick, who don’t have access or opportunity. I want there to be more equity.

What are some other passions of yours?
I’m one of those people who wants to do many things. I want to be a doctor, but I also want to be in policy, educate others, have a talk show — maybe, like, Doctor Oz and Oprah together. I’m passionate about STEM education and about representation. I think we need to see people in every corner telling different stories, so that people see that scientists, doctors, can be a black woman with big hair. If you don’t see yourself somewhere and don’t see people who look like you doing things you might want to do, then it is hard to imagine the future.

What were some early science experiences?
When I was around 5 or 6 years old, I did Mad Science, an after school science program. It’s hands-on, interactive science. It was something I looked forward to every Friday. If I was sick and had to miss a Friday at school, I would say, “Mom, at 3:00 when school gets out, I’ll be better.” I loved how they made science fun and playful. Later on, I worked there as a science educator. My boss was my instructor from when I was five. It was a great experience. I loved being high-energy — especially for third-graders who you want to keep engaged in Newtonian physics.

Any advice for new students?
Practice self-care. Taking care of yourself is important. … All these really hard classes, we just do it. We don’t make it look easy, because it isn’t. But we do it.

Catch Kayla’s interview of the three STEM deans at UT Austin, including Natural Sciences Dean Linda Hicke, Jackson School of Geosciences Dean Sharon Mosher and Cockrell School of Engineering Dean Sharon Wood: txsci.net/threedeeans

"We need to see people in every corner telling their stories... If you don’t see people who look like you doing things you might want to do, then it is hard to imagine."
A FRESH TAKE ON RESEARCH

Eric Yu and Jinseok Yeom, students in UT Austin’s award-winning Freshman Research Initiative (FRI), set out to solve a problem with one of the most popular and affordable types of 3-D printers.

These printers, which cost just a few hundred dollars, use a technology called fused deposition modeling (FDM), in which objects are built up layer by layer by heating plastic filaments. This allows you to build almost any small object you can imagine, including a rabbit like this one. But these printers have a big drawback: any part of the object that hangs out away from the rest, say a bunny’s ears, tends to sag before the plastic cools and stiffens. Yu and Yeom spent a year designing software that, for a given 3-D shape, generates many different ways to divide up the object for printing and arrive at the most efficient one.

FRI offers first- and second-year students the opportunity to engage in authentic research experiences. Students work to solve real-world problems, while being supported and mentored by scientists and graduate students. FRI students have written more than 200 peer-reviewed scientific papers and presented at conferences. The paper Yu and Yeom wrote about improving efficiency in 3-D printing took first place at the 2017 Genetic and Evolutionary Computation Conference. Coauthors on the paper were UT Austin computer scientists Cem Tutum, Etienne Vouga and Risto Miikkulainen.
ACCOLADES
What made you want to move from a career in biotech to brewing?
I was doing DNA sequencing, then automated DNA sequencing came around, and the owner shut down the molecular biology service department in the small biotech company where I worked. So, I started a brewery. We started raising money and rented an old sausage plant, renovating it ourselves. We sold our first beer in April 1997. People liked it. We were making beers you could drink in the hot weather of Texas.

Before that, I also was running the first beer festivals in Texas, the Texas Brewers Festivals, with a couple other guys who were also UT grads.

How did studying biochemistry and chemistry help you in the brewing business?
I understand chemistry, I understand enzymology and fermentation – and that is what brewing is. Brewing is not a loose recipe, you know: a little of this, a little of that; never mind the details, it’ll come out good. Instead, it is meticulously controlled art and science. I understand the details and a lot of what is happening on a molecular level.

We make a couple of German sour beers, for example. They’re soured with the bacterium Lactobacillus, which, coincidentally, takes me back to my graduate school days. In Jon Robertus’ lab – he was an X-ray crystallographer – we did molecular biology in support of the crystallographic efforts. My research made mutants of histidine decarboxylase from Lactobacillus. Well, Lactobacillus eats glucose and makes lactic acid, and that gives the beer a lemony sour taste.

I never knew there was so much science going on in beer.
There’s piles of it. Brewers were the first practical microbiologists. Domesticated brewers’ yeast have been selected over hundreds of years for desirable characteristics [related to their chemistry]. The yeast in our Hefeweizen is a unique type that puts out fruity esters ...like the banana ester, isoamyl acetate. This is the molecule that gives bananas their flavor. It also makes a class of chemicals called phenolics. The most predominant one is this clove-flavor molecule, but they also make molecules similar to vanilla, cinnamon and nutmeg.

Most people have heard of skunky beer. It’s a result of a UV-catalyzed reaction between hop constituents and a sulfur-containing molecule in the beer. It creates one of two similar molecules made by skunks. Take a beer, put it in a glass and stick it in direct sunlight for about five minutes, and you’ll smell it. That’s why most beer doesn’t come in clear bottles.
START WITH THE STUDENT

By Christine Sinatra
In the twentieth century, education revolved around ideas and facts students learned. Lectures and readings, well-worn methods for transferring knowledge, preceded opportunities for students to parrot back what they knew on tests. Yes, some students who achieved mastery in a subject received chances to apply lessons on a job, in research or by entering a PhD program on their way to their own academic career. Still, many students left school feeling ill-prepared for what came next.

A recent Gallup poll found that 15 percent of U.S. college graduates thought their undergraduate years prepared them poorly for life and work. University of Texas at Austin alumni are much more likely to indicate that their university prepared them well, according to Gallup, but room for improvement still exists.

All university-goers learn skills, but not everyone manages to pick up those that research has found to sometimes matter most for success later in life—things like a person’s process for decision-making, ease in working with others and approach to problem-solving or setbacks. Employers demand candidates with abilities in these areas as much as content knowledge in the people they hire.

Meanwhile, technology is transforming how people learn. Neuroscience is making new discoveries about how the brain processes information. All of this has led higher education institutions to rethink the last century’s educational approach.

A new two-year planning process in the College of Natural Sciences, dubbed the 21st Century Education initiative, is implementing a number of student-centered changes and shifting the emphasis from what students learn about to also cover more of what they learn to be and do.

“This is about being intentional in designing curriculum that builds those core skills,” said David Vanden Bout, associate dean for undergraduate education, “versus hoping those skills emerge organically. You could think about education as mining and trying to surface gems, or you can do as we’re doing and take more of a farming approach. You cultivate growth in every student.”

Learning by Doing
In a typical introductory statistics class, most students are freshmen—and some, between 5 and 8 percent, will quit, drop or fail the notoriously tough class. Though students consider her statistics classes challenging, Kristin Harvey has managed to bring her students’ non-completion rate down to almost zero. Students learn by getting ample practice. A project-based final exam even has class participants gathering data, running analyses, making research posters and delivering presentations of their own.

“It’s splendid!” one student remarked in an anonymous course survey. “We take relevant data from the real world and apply different methods to extract a conclusion.”

The 21st Century Undergraduate Education Initiative is among those to benefit from experiential learning in the College.
The plan calls for curricular restructuring leading to more applied-learning experiences, like the one in Harvey’s class. The goal is for students to practice using reason and creative thinking the way a scientist or mathematician would. Team projects and self-directed learning also factor heavily into the strategy. This allows students, across disciplines, to gain skills in communicating, working with diverse groups, organizing tasks and operating independently and collaboratively.

“Today’s students are digital natives, accustomed to instant access to information online,” said Sarah Eichhorn, executive director of the College’s Texas Institute for Discovery Education in Science (TIDES). “This challenges us to rethink STEM curriculum and really focus in on concepts, skills and habits of mind that we want to impart to students.”

Eichhorn’s team includes new STEM instruction consultants who work with departments to implement changes within coursework and degree plans. TIDES also has a new evaluation expert who is helping measure the effectiveness and impact of the new curriculum implementations in the College.

Finally, the College envisions having every student receive an immersive experiential learning opportunity as part of the curriculum. The research by Gallup found that these opportunities—from credit-bearing internships to study abroad to involvement with the college’s award-winning Freshman Research Initiative (FRI)—can have a marked impact on the well-being of graduates.

“FRI definitely taught me time management and other life skills—especially collaboration, organization and the value of showing initiative,” said 2017 biology graduate Joe Angel Espinoza. “I also learned how to communicate complex scientific information effectively.”

Reimagining the PhD

Parallel to the undergraduate initiative, a 21st Century Graduate Education strategy also is underway. Nationwide, roughly 6 in 10 people who receive a science or math PhD will work outside of academia. But as an editorial in Science magazine explained: “Graduate training in science has followed the same basic format for almost 100 years, heavily focused on producing academic researchers.”

If that’s true, the College of Natural Sciences is bucking a century-long trend. Its latest innovations support PhD students in preparation for careers both inside and outside of higher learning. Paths to their degrees are being streamlined, with opportunities for added flexibility. Students also can delve into the learning more in select areas: from teaching to project management, from strategic leadership to science communications.

Across the College, graduate students will acquire interdisciplinary “big data” skills—programming and statistics—useful in numerous fields. The Office of Graduate Education is also developing mentoring programs, boot camps, electives, assessment and planning tools and career counseling strategies to support the overall plan.

“Graduate students are essential to our research and teaching mission in the college,” said Dan Knopf, associate dean for graduate education. “Our focus on modernizing graduate education means we are in the best possible position to compete for the top students and to prepare them to change the world.”
Dean’s Discovery Circle

We are grateful to our first class of Dean’s Discovery Circle members (through August 2017). These individuals’ annual unrestricted gifts to the college allow for nimble investments in the future of Texas Science. For more, visit txsci.net/deansdiscovery, or contact Marsha Reardon at mreardon@austin.utexas.edu or (512) 232-4470.

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– Su Yeong Kim, associate professor and mentor to PhD student Yang Hou

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