Inside Black Holes and Beyond, Defying Gravity
A center first established three years ago has just been renamed for an alumnus whose public health legacy spans from vaccine development to reducing the spread of malaria. The John Ring LaMontagne Center for Infectious Disease hosts faculty from the College of Natural Sciences and other colleges on campus, supporting research and programs that predict the spread of disease and advance prevention and treatment. Each year the Center hosts an annual lecture on campus to which the public is invited. This year’s LaMontagne Lecture on March 29 will feature Dr. Penny Heaton, director of Vaccine Development with the Global Health Program at the Bill & Melinda Gates Foundation. To attend and learn more, visit: cid.utexas.edu/events.

Dr. Marvin Whiteley, director of the LaMontagne Center for Infectious Disease, pioneered a way of researching Pseudomonas aeruginosa bacteria like these, whose spread can be life-threatening for children with cystic fibrosis. See more at: txsci.net/TZlsEgd
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,

On one of my first visits to campus, I witnessed how the College of Natural Sciences harnesses the potential of an unexpected resource: college freshmen. Students here, who are just a few months out of high school, build robots, seek never-detected stars and make energy out of prairie grass. They use cutting-edge research equipment in faculty-led labs and join scientists in investigating new treatments for cancer. This program, the Freshman Research Initiative (FRI) is enough to make me wish I could time-travel and come back as one of these UT Austin freshmen.

Today, more than half of our first-year students do real-world research in FRI. They are members of the country’s largest program of its kind, a model other campuses in Texas and around the nation are now replicating. As contributors to the process of science, our freshmen work alongside mentors, exploring questions no expert has answered, experiencing the excitement of scientific discovery firsthand. And being bitten early by the research bug makes a difference in their lives. Our freshmen researchers outperform peers on multiple measures, including staying in a STEM field after graduation.

This year, as the FRI celebrates its tenth anniversary, our magazine takes you behind the scenes to see what these students experience. We also transport you around the world with our scientists—be they physicists exploring Mayan ruins in the jungles of Belize, marine biologists studying seals in the Arctic Ocean or astronomers probing the outer edges of our universe in the dark West Texas skies.

This edition highlights many emerging trends, amazing breakthroughs and incredible people of our Texas Science community. We’re proud to count you as a member of that community and to reacquaint you here with those first, awe-inspiring experiences of educational and research discovery.

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The Texas Scientist is a publication of the College of Natural Sciences at The University of Texas at Austin.
See how scientists are solving enduring questions, using new tools and techniques.
Is there an undiscovered tomb hidden in this ancient Mayan pyramid? Roy Schwitters, a professor of physics, and his team are using naturally occurring particles to scan a 20-meter tall mound of dirt and rock—the overgrown ruins of a Mayan pyramid in Belize. They are searching for stairs, chambers or artifacts without digging.

Combining data from two or more detectors yields a 3D image of the internal structure, much like a medical CT scan.

Muons—high-energy particles created by collisions between cosmic rays and our atmosphere—rain down on Earth continuously. Muons lose energy as they pass through rock, but not when they pass through a void like a pyramid chamber.

Detectors measure the angles and energies of incoming muons, indicating how the mound’s density varies in different directions.

Combining data from two or more detectors yields a 3D image of the internal structure, much like a medical CT scan.

Ultimately, any Mayan artifacts the researchers find might help answer an even bigger question: why did such an advanced civilization collapse?

Go online to hear more about the Maya Muon project: txsci.net/10cFBjZ
ERASING BIRTH DEFECTS

UT Austin is at the forefront of research linked to the causes and prevention of birth defects called neural tube defects (NTDs).

1941: Discovery of Folic Acid
75 years ago in the original Welch Hall, UT biochemist Esmond Snell discovered folic acid (Vitamin B9), which was later shown to prevent NTDs like spina bifida. It took four tons of spinach to isolate enough folic acid for Snell’s analysis.

1990s: Public Health Victory
The U.S. and other countries started fortifying foods with folic acid, prompted in part by research from teams that included UT Austin’s Dean Appling and Richard Finnell. (Appling calls Snell an “academic grandfather”: Snell’s former graduate student was Appling’s postdoctoral adviser.) A dramatic drop in neural tube defects followed, preventing thousands of child deaths and disabilities.

2013: A Genetic Link
Scientists aren’t sure why folic acid reduces birth defects, but Appling’s team made a discovery that provides important clues. They found a gene that, when functioning improperly in mice, causes all of the embryos to have NTDs.

Next Steps: Grants from the National Institutes of Health (NIH) will allow UT researchers to determine whether folic acid prevents NTDs by reducing the rate of spontaneous mutations in our genomes, as well as whether a different dietary supplement could prevent some of the 30 percent of cases where folic acid supplements do not prevent NTDs. Appling, Finnell and molecular biologists John Wallingford and Seema Agarwala are all participating in research that holds promise for prevention and for therapy.

Hear from a scientist investigating the cause of one child’s NTD: txsci.net/1KYSqsj
Weddell seals spend 95 percent of their time swimming under Antarctic sea ice. They can dive to great depths and hold their breath for stretches as long as an hour at a time, even while pursuing their prey at rapid speeds. Despite this physical prowess, the seals are just as vulnerable as humans to drowning if they can’t find a breathing hole in the underwater darkness.

How do they find their way? Lee Fuiman, a marine science professor, has hypothesized that a natural compass based on Earth’s magnetic field guides seals, helping them return to breathing holes in the ice. Terrestrial animals like homing pigeons use this trick, but no other marine mammals are known to.

Fuiman struck on the idea after noticing the accuracy with which Weddell seals return to their breathing holes from a distance of a kilometer or more. Now he and a research team are using innovative sensors attached to the seals to test the hypothesis. The researchers will return to Antarctica later this year to complete a three-year project tracking seals with support from a National Science Foundation grant. The data they collect will allow the researchers to recreate the seals’ path through the water in three different locations in McMurdo Sound, each with a different magnetic field. By comparing how the seals navigate each site, the scientists hope to understand the relationship between the seals’ dive paths and their ability to sense Earth’s magnetic field.
How is it that someone can navigate a dark room with little effort? Ila Fiete, an associate professor of neuroscience, researches the codes and computational rules embedded in the brain that make this possible. Neurons called grid cells are at the heart of her research.

Applications of this research:

- **Grappling with disease:** Problems with navigation occur early on in brain disorders like Alzheimer’s, so understanding grid cells may prove key in understanding neurological disorders.

- **Deciphering brain codes:** Fiete’s mathematical modeling predicts how firing patterns in grid cells change as we move through a space to represent that we are in a different location than before.

- **Engineering solutions:** Some of the coding principles that have been found hidden within the grid cells are being explored for new types of codes for digital communication.

- **Eliminating interference:** Fiete, Ngoc Tran, a recent addition to the UT Austin math faculty, and Sriram Vishwanath, professor of electrical and computer engineering, work to understand how grid cells transfer signals with high fidelity and perform error correction.

"I’m optimistic that within five to ten years neuroscientists will have a better handle on the grid cell circuit than on any cognitive circuit in the brain," Fiete says.
At age 12, you started Comfort and Joy, a nonprofit that helps the needy. What’s happened with that since then and since you came to UT?
We started out providing coats to the homeless and have had feeding programs, done home rehabs and offered scholarships. Now we are going national. We have our first national chapter starting in New York City this fall, to be followed by a chapter in Atlanta. The idea is for other kids all over the country to be able to give back, like I did.

What do you see yourself doing in the future?
I do plan to continue Comfort and Joy. Also, I interned at Google last summer and was offered the software engineering internship to come again next summer. I’m interested in game development because I find it to be a good creative medium. You hear all these negative things about video games, but really there are positives, too. Games increase reaction time and can help with problem solving, reasoning, rationality. These are all things that we’ll need in the future to solve the world’s greatest problems. Games got me interested in STEM, and I figure they can get other children interested in STEM, too.

How does your work in the community tie in with your studies?
Technology is an important part of the organization. I have to keep a website running, and I plan to provide other kids with technological advice as they run their own sections of Comfort and Joy.

Where else have your interests taken you?
UT is awesome. I am a second-generation Longhorn: my father, Reginald Cobb, got his MBA at McCombs in 1994. I am having the time of my life. I am an ambassador for the College of Natural Sciences and on the Council for Diversity Engagement. I also got to go the Tapia Conference in Boston, which brings together computer scientists: undergraduate and graduate students, faculty, researchers, etc. You can meet people from the industry, get advice and get your name out there. I was one of only a few freshmen to get to go.

See more from Nicholas and his fellow ambassadors for the College at: txsci.net/1REbKn5

The founder of charitable organization Comfort and Joy, Nicholas has won many accolades, including getting to meet the president and a Motorola Endowed Scholarship to UT Austin.
Their aim in simulating mass extinctions was to see whether destruction events could help computerized intelligence evolve more quickly and adopt better features and abilities.

The virtual mass extinctions were modeled after real-life disasters like what killed off the dinosaurs; so, at random, 90 percent of the team’s robots got wiped out. After a few cycles of destruction, the team discovered the surviving robotic lineages had advantages. They were more evolvable and better at producing new behaviors and features that helped them with the task at hand, learning to walk. Compared to robots in simulations with no mass extinctions, these extinction-event survivors had more creative solutions to help them walk.

“Focused destruction can lead to surprising outcomes,” says Miikkulainen. “Sometimes you have to develop something that seems objectively worse in order to develop the tools you need to get better.”
HUMANIZING YEAST

A billion years of evolution separate humans from the baker’s yeast in their refrigerators. But that didn’t stop a team led by Edward Marcotte, a professor in the Department of Molecular Biosciences, from demonstrating just how related the two distant cousins still are.

Marcotte’s team learned that hundreds of genes from a common ancestor of humans and yeast have remained nearly unchanged over the millenia. His experiment genetically engineering hundreds of strains of yeast with human genes demonstrated consistencies over time between the two.

Each strain received a single human gene swapped in for its yeast-gene counterpart. If the genes were too different, the yeast strain would die. Surprisingly, many gene groups were so stable over evolutionary time that becoming a little bit human with that single gene change made no difference. The yeast reproduced and thrived. Researchers found the yeast essentially couldn’t tell the difference between the two species’ genes with roughly half of the swaps.

“Cells use a common set of parts and those parts, even after a billion years of independent evolution, are swappable,” says Marcotte, who holds the Corbin J. Robertson, Sr. Regents Chair in Molecular Biology. “It’s a beautiful demonstration of the common heritage of all living things—to be able to take DNA from a human and replace the matching DNA in a yeast cell and have it successfully support the life of the cell.”

The work has practical applications, as well. Partly humanized yeast could play a role in medical testing related to several genetic mutations and diseases.

Go online to hear Prof. Marcotte describe this discovery: txsci.net/1OWb8dE
Everyone knows that brain food isn’t usually handed out at drive-through windows, but could pizza and burgers be especially detrimental to growing minds? A study by Elizabeth Gershoff, associate professor of human development and family sciences, examined the culinary habits of fifth-graders and their subsequent academic performance as eighth-graders to find out.

The more often fifth-graders ate fast food, the worse the improvement rate in their reading, math and science test scores were by eighth grade. Students who didn’t eat fast food had 20 percent higher test score gains than those who ate the most fast food.

“The most detrimental findings were in kids who ate fast food every day,” said Gershoff. “Any effort parents can make to scale down from that is great.”

Many factors can influence test scores—bedtime, exercise, screen use and socioeconomic status, to name a few—so the authors carefully controlled for these. They even controlled for other differences in diet, such as the amount of vegetables, milk and soda children consumed.

“We tried to rule out all possible explanations, but the link was still there,” says Gershoff.

The study didn’t pinpoint the exact mechanisms behind reduced test scores, but other studies have shown that fast food lacks certain nutrients, especially iron, that aid cognitive development. Also, diets high in fat and sugar have been shown to hurt memory and learning.
Kepler-452b is the first Earth-like planet to be found revolving around a star that resembles the Sun.

EARTH’S COUSIN FOUND

It’s a good deal bigger and 1,400 light years away, but the newly discovered planet Kepler-452b is close enough to Earth in other ways that astronomers are calling it Earth’s long lost relative. Found by a team including UT Austin astronomers Bill Cochran and Michael Endl, Kepler-452b is the first planet orbiting a star like our Sun and within the “goldilocks” zone, meaning it’s not too hot and not too cold for liquid water to pool on the surface, potentially forming life.

A planet had been discovered earlier in a similarly habitable zone around a red dwarf, but Kepler-452b is the first Earth-like planet to be found revolving around a star that resembles the Sun. A dozen smaller candidates for habitable-zone planets, many around Sun-like stars, were also found by the research team, making the discoveries announced this summer a milestone in the journey to understand our place in the cosmos.

“Kepler has recently shown that virtually all of the stars that we see in the sky probably host planetary systems,” Cochran says. “Now we are discovering that a significant number of those systems are very much like our own and may have the capability of being habitable.”

Kepler-452b, in the constellation Cygnus, is bigger and older than Earth: it’s 60 percent wider than our planet and about 6 billion years old. The planet takes 385 days to orbit around its own star, which itself is 1.5 billion years older than our Sun.

Visit the McDonald Observatory online for more on the search for new planets: mcdonaldobservatory.org
RONNY HADANI
Associate professor of mathematics and co-founder of Cohere Technologies. Interviewed by Marc Airthart.

Your company improves wireless communications. What problem does your technology help solve?
Wireless communication often happens in a very complicated environment. Your cell phone signals reflect off of buildings and other objects. If you’re moving, the frequency of the signals shifts. These effects limit how much information you can reliably transfer in a given amount of time.

How effective is your solution?
With this technology you can transmit twice as much information as current systems. Maybe, eventually, even five or ten times as much.

How do you hope your work will impact everyday people?
People are talking about all kinds of applications for this boosted capacity. For example, doctors might be able to do robotic surgery from a distance. It’s impossible to do that today because wireless communication is not fast enough or reliable enough. You can’t send an instruction to make a cut and then have a delay before it actually happens. Advancements like these will change our lives, but they will require a much bigger digital highway. So you could say I am in the highway business.

What do you love the most about being a mathematician?
First of all, I love the beauty and the simplicity.

"Mathematics is a hammer that, in the right hands, can break big walls. It's powerful knowledge that allows you to solve non-trivial problems."

A lot of people think of mathematics as a complicated subject, but it’s not true. It’s the simplest. It becomes simpler as your understanding gets deeper. As you mature into mathematics, you remember less and less because you can develop all the tools you need from scratch. And at the same time, you become stronger because you know how to solve more things.

Secondly, I was attracted by its raw power. Mathematics is a hammer that, in the right hands, can break big walls. It’s powerful knowledge that allows you to solve non-trivial problems. I felt it as a young man and it always fascinated me.

To learn more about Hadani’s novel technology, read our extended interview: txsci.net/1ZeUVja
Beautiful images from University of Texas at Austin labs
Genomes for most of the ocean’s microbial life have yet to be sequenced, but this map, from Brett Baker, an assistant professor of marine science, shows DNA fragments sequenced from the Gulf of Mexico dead zone, an area of low oxygen. Each square is a different DNA fragment from the water.

The colored groupings—based on similar DNA sequence composition—represent genomes of newly discovered species that are important to the ecosystem.

Go online for more winning UT science and math images: txsci.net/1ZVqb97
In November 1915, Albert Einstein unveiled before the Prussian Academy of Sciences a set of elegant equations that would forever change the way we see the universe. The Theory of General Relativity, Einstein's description of gravity, explained all motion in the cosmos.

So far, general relativity has held up well to various tests scientists have thrown at it. But there are signs that it's incomplete. Physicists say that in areas of extreme mass or energy density, the mathematical equations that explain so much of the universe blow up. And in some cases, relativity clashes with the other great pillar of 20th-century physics: quantum mechanics, which describes subatomic particles and how they interact.

Scientists now are drawn to a question: what happens in the places in the universe where theories collide?

“In 100 years, general relativity has never been shown to be wrong,” says Willy Fischler, a professor of physics. “Neither has quantum mechanics. But when we put the two together, we have problems in certain contexts such as black holes. This clash means there's something missing in our understanding, and we have the chance to make a big leap in understanding, to change paradigms.”

As scientists at The University of Texas
at Austin work to answer some of the biggest questions in astrophysics—about black holes, the beginning of the universe and dark energy—some say finding the answers might require overhauling general relativity.

Inside Black Holes
When a very large star runs out of nuclear fuel and breathes its dying breath, it collapses into a black hole, an object so dense that not even light can escape it. A star ten times as massive as our sun would squeeze down into a ball about the width of Austin.

In 1962, UT Austin mathematician Roy Kerr provided an exact solution to Einstein's equations of general relativity, a breakthrough that also described the physics of rotating black holes. At that point, it became clear how beautifully general relativity describes black holes—at least up to a point.

At the very heart of a black hole, things get trickier. According to general relativity, mass and energy become infinitely dense, and space and time become infinitely curved. At such a point, called a singularity, the steps involved in solving Einstein's equations become infinite.

That isn't the only problem. According to general relativity, if you fell into a black hole, you would first cross something called...
the event horizon, the outer edge of the black hole. Then as you continued falling, the black hole would shred you apart, atom from atom, like some cosmic garbage disposal apparently deleting information about you forever.

Yet according to quantum mechanics, information can never be truly lost. This is called the information paradox.

“Something has to give here,” Fischler says. “What is it in the description of either one or both of these theories that has to be amended?”

Fischler thinks part of the answer might be that, when an object crosses the event horizon, it leaves behind a two-dimensional imprint on the surface of the horizon with all the information about its state, similar to a hologram. So from the point of view of quantum mechanics, the object could fall in, but information about it would not be lost.

Ultimately, resolving the information paradox and making sense of what happens in a singularity might require a different theory that reconciles general relativity and quantum mechanics. Steven Weinberg, a Nobel laureate and professor at UT Austin, and others have long sought a theory of everything that would do just that.

“String theory is probably the most promising way to unify the two theories,” says Weinberg.

How Did our Universe Start?
String theory is the conjecture that all matter and its interactions can be described as vibrations of unimaginably tiny strings of energy. It might explain extreme cases like black holes, as well as another singularity—the birth of our universe as a hot, dense plasma in the Big Bang.

Raphael Flauger, a new assistant professor of physics, is trying to piece together a sort of home movie for our universe from back in its fast-growing infancy. The earliest frame we have in this film comes from about 380,000 years after the Big Bang. Taken by satellites, it shows the oldest light in the universe, called the cosmic microwave background. This ancient glow has tiny variations in brightness, or clumps of energy, that would eventually become the seeds of stars and galaxies.

Flauger uses string theory to build models of how the early universe might have evolved.

“You try one version of the film, then see if it fits with the snapshot of the cosmic microwave background,” says Flauger. “If it doesn’t

Testing Einstein
Einstein’s century-old description of gravity presented physicists with some pretty bizarre predictions. To test them, scientists from the University of Texas at Austin have traveled to the Sahara Desert to observe a rare eclipse. They launched into orbit around Earth an object that’s the densest known thing floating in our solar system. And they used computers to model ripples in space and time unleashed by the mergers of black holes.

Read more about these tests of general relativity in a companion web article at: txsci.net/1mP1Gfa
agree, you throw it out and make another version of the film and see how well it fits.”

Flauger is part of a team proposing a new satellite mission that will look for a distinct signature in the cosmic microwave background that could help rule out one or more of the competing models.

**What is Dark Energy?**

In the 1990s, astronomers observed that the expansion of the universe is speeding up, as if some mysterious force is pushing everything apart faster and faster. Nearly 20 years later, one of the biggest unanswered questions in science is: what is this dark energy? Not only was dark energy not predicted by general relativity, but its mere existence might mean that the theory needs to be tweaked or even replaced.

“Dark energy is the name we apply to our misunderstanding of how the universe is expanding,” says Karl Gebhardt, a professor of astronomy who holds the Herman and Joan Suit Professorship in Astrophysics.

According to Gebhardt, among astronomers there are two leading ideas for what dark energy might be.

One is that empty space itself pushes matter apart, sort of like anti-gravity. In this view, space is filled with something called vacuum energy. To account for it, scientists would have to add an extra term to the equations of gravity called the cosmological constant.

Another possibility is that at great distances, gravity becomes weaker than the equations of general relativity say it should. So the accelerating rate of expansion of the universe wouldn’t be due to a mysterious new force, but instead would be due to gravity’s loosening grip on a universe already expanding from the Big Bang.

Gebhardt is part of a team that could be close to discovering which, if either, of these two explanations for dark energy—each with big implications for the future of general relativity—is correct. The project, based at the University’s McDonald Observatory, is a key piece of the newly upgraded Hobby-Eberly Telescope, now the world’s third-largest telescope.

The Hobby-Eberly Telescope Dark Energy Experiment will help measure the rate of expansion of the universe at different times in its history, which will help theorists constrain their models of dark energy. Researchers plan to start collecting data in 2016.

Although the immediate quest is to explain dark energy, their findings might end up taking scientists one step closer to a “theory of everything” that would write the next chapter for general relativity.

Listen to UT scientists describe the search for dark energy on the CNS podcast, Point of Discovery: txsci.net/1REctEz

Locked in a cosmic tug of war, dark energy (purple) pushes the universe apart, while gravity (green) pulls it together. At the moment, dark energy is winning.
Landmarks, the university’s public art program, grew out of a 2005 UT System policy to set aside a small percentage of capital improvement project funding for the acquisition of public art. Throughout the College of Natural Sciences and UT, Landmarks’ growing collection is transforming campus spaces with public art that’s free and accessible to all.

1. **Circle with Towers** by Sol LeWitt
   A pioneer of Minimal and Conceptual art, LeWitt is fascinated with simple geometric forms. This structure outside the Gates Dell Complex consists of eight towers of concrete cubes. The towers are four cubes wide and spaced eight cubes apart atop a low circular wall.

2. **Monochrome for Austin** by Nancy Rubins
   This imposing cluster of 70 aluminum canoes has become a new focal point at the heart of campus, 24th and Speedway. Tethered by slender steel cables and seeming to be delicately balanced over passersby, the canoes form a sculpture that the artist explains as “exposing math.”

3. **Pedogna** by Walter Dusenbery
   Careful geometric calculations went into carving a sculpture on loan from the Metropolitan Museum of Art in New York that today resides in the Life Science Library, located in the UT Tower. A limestone called travertine contains mineral and biological impurities within the white stone, imbuing the piece with a rainbow of hues. It celebrates the wonders of nature over time.
HAYLEY GILLESPIE, PhD, 2011

Talk about how you got started as a scientist interested in art.
As an undergraduate, I was a biology major with an art minor, and a lot of the art I did was inspired by use of natural resources. I spent a year teaching middle school science in Dallas—everything from physics to chemistry to biology—then came to UT for the graduate program in Ecology, Evolution and Behavior. My dissertation needed visualizations, so I started sketching and I teamed up with an artist. It made me remember why I liked doing art and science.

What was your research about?
I studied the ecology and conservation of the Barton Springs salamander. At that time, we hardly knew anything about their ecology. I found out that one thing that seems to be really important to population dynamics is the amount of winter rainfall we get: it’s much better for amphibian larval development when rain falls when it’s cold out. If you don’t get these periodic episodes of winter rainfall, there’s no opportunity for the little salamanders to survive and become adults, which also has some scary implications with climate change.

How did Art.Science.Gallery. come about?
After graduation, I started writing about art and science on my blog, Biocreativity. I was interviewing ecologists who do artwork and learning how they use art to communicate science and tell a story. It started to snowball, and people started to email me all the time about showing their work on the blog and then asking if I could show it in a gallery. I eventually got enough of these requests that I thought, “I guess nobody is really doing this, and these artists are making really neat work.” I think it’s important to show everyone what they’re doing, because it communicates science, it contributes to a more science-literate society, we can nurture more science enthusiasts, and maybe it can be a tool to get other scientists to learn how to communicate better.

The gallery supports other science communications efforts, too, right?
Art is one way to get a lot of people who may not be into the sciences engaged, but it’s not all we do. We do science communications boot camps and trainings, teaching scientists to communicate. Our mission at the gallery is to engage the public in the sciences through visual arts, to support the careers of science artists and to help scientists become better communicators. That can take many different guises. Our exhibits and programs make people walk away with a nugget or two of science. I think every time we get a visitor we may be generating science enthusiasts.

Go online for an extended interview with more on salamanders, science communications, and the science-art continuum: txsci.net/22UeHF7
FRESH STARTS IN SCIENCE

By Steve Franklin. Photos by Marsha Miller.

A student’s hand hovers over a computer, skewing left, then right, then forward, constantly in motion. A few feet away a robotic flying machine called a quadcopter mimics the motions of his hand. A crowd of students stares in rapt attention as, with deft flicks of his wrist, sophomore Robert Lynch guides the craft through a hoop held by his partner-in-programming Matt Broussard.

The students are good at showing off programming skills they developed during their time in the Freshman Research Initiative (FRI), a unique approach to science education created at The University of Texas at Austin and now the nation’s largest initiative of its kind. In FRI, students like Broussard, Lynch and thousands of others throughout the College of Natural Sciences emerge from their first year of college with captivating real-world experience.

“Research is where discovery begins, and it is also the basis of our educational mission,” declared UT Austin President Greg Fenves in his inaugural State of the University address. He held up the Freshman Research Initiative as an example of the university’s “major leaps in undergraduate education.”

The evolution of the FRI has occurred against a backdrop of uncertainty for students in science, technology, engineering and mathematics (STEM) fields in the U.S. The President’s Council of Advisors on Science and Technology released a report in 2012 that found 60 percent of undergraduates who begin college in a STEM field do not finish with a STEM degree. The loss increases to 80 percent for students in underrepresented minority groups, according to the Howard Hughes Medical Institute.

Most students lose interest in or become
overwhelmed or alienated by science studies in their first two years of college, when taking introductory science courses. According to the President’s Council report, students often switch majors because they find these early courses to be uninteresting, unwelcoming or indecipherable.

Enter the Freshman Research Initiative.

A Decade of Results
The FRI began ten years ago with a pilot class of 43 students working on faculty-led research projects soon after the students arrived on campus. FRI has grown into the nation’s largest research program for first-year students, immersing hundreds each year in cutting-edge scientific discovery. Today, roughly 900 first-year and transfer students participate in the program. Half are women and half come from economically disadvantaged backgrounds, are first in their families to go to college or have racial or ethnic backgrounds that are underrepresented in the sciences.

The program’s results are impressive and have won it many fans. Over the last decade, the Howard Hughes Medical Institute alone has invested more than $4 million to support FRI at UT Austin and given millions more to replicate the program at other universities because of its strong outcomes. Compared to their peers, FRI students are significantly more likely to graduate in four years and graduate with a degree in math or science. Their cumulative GPAs at graduation are higher, and they are much more likely to pursue an advanced degree.

The FRI accomplishes these results by making early-college science real and engaging. Students actually conduct research
and experience the victories and failures common to scientific experimentation, but in a safe environment, all while earning course credit for participating in research.

“FRI allows students who really want to do research to do research from their very first days on campus, and it allows students who don’t know if they want to do research to try it out,” says Andy Ellington, a professor of molecular biosciences. Ellington helped start the program and is a faculty lead on three FRI research projects, which are called “streams.”

Students begin the three-semester program in the fall learning what scientific inquiry is about. In a special course, they study how to design experiments, use scientific literature and carry out basic research techniques. They design and conduct their own experiments and build and evaluate scientific arguments about their results.

“It gets around this problem that in a research lab, to take in a brand new student who’s never done anything is really rough, and the FRI is a way of getting them inoculated,” says Nancy Moran, a professor of integrative biology who leads a new research stream, Microorganisms in Bees and Other Insects.

The first semester is also when participating labs hold open houses where students can learn about the options for them to do research. Students apply to their top five choices among 28 different research streams, where they can not only learn to program robotics like the quadcopter or investigate big problems like bee health but they can search for new antibiotics, create nanomaterials, study white dwarf stars and more.

Students begin their research stream their second semester. At first they learn necessary techniques and lab protocols unique to their subject of research, while lectures, discussions and readings help them get up to speed on the background and importance of their research area.

The Real Fun Begins
Next, students assist faculty with research and devise unique research projects to pursue, while being mentored by their faculty member and their research educator, often a postdoctoral researcher or graduate student within the lab. Just like the senior scientists, the new undergraduates conduct original research and seek answers to questions science has not yet answered.

In some cases, students even get published in peer-reviewed scientific journals. More than 140 papers authored in whole or part by FRI students have been published. This includes a high-profile paper in late 2014 that FRI students coauthored for a top journal, Nature Genetics. FRI alumna Lee Elam helped write that paper and now attends medical school at The University of Texas Medical Branch at Galveston.

“I ended up really liking research a lot more than I thought I would, so I wanted to do something where I could continue doing research,” she says. “The work got me a lot
more interested in genetics because I got hands-on experience with it.”

In the final semester students continue their research, often with greater independence and responsibility. Many have gotten a head start during the summer, either as volunteers or on a fellowship.

Students bring a lot of creativity to the labs in which they work, often expanding the scope of research by pursuing avenues that lab leaders had not considered before.

“I’m looking forward to this year seeing what the students come up with,” Moran says. “Having all these young minds coming up with new things or new ways of looking at things can be interesting.”

**Life Beyond FRI**

At the end of the program, students can continue in the world of research. They can join a lab as a student researcher, participate in summer research programs around the country or intern abroad or in the industry. Sometimes they continue with their original research stream as peer mentors, helping guide new first-year students.

“FRI granted me the opportunity to not only cultivate research skills, but to learn to be self-motivated and learn to mentor others,” says Adriana Carillo, a former peer mentor who is now an analyst for the UT Southwestern Medical Center at Dallas. “FRI allowed me to develop analytical skills. Asking ‘Why?’ is a big part of being an analyst in the healthcare field. Had I not participated in the FRI, I would not have come to recognize one of my strongest skills and would have perhaps ended up on a different career path.”

Simon Hiebert, another alumnus of the program, realized that, although doing bench science was not for him, the FRI could still be a source for inspiration. Hiebert created a company called CottonGen to license modified crop plants developed in the lab of Stanley Roux, a molecular biosciences professor. Hiebert, who first conducted research in that lab as an FRI student, hopes that these transgenic plants will use resources more efficiently while producing higher yields.

“FRI is the cornerstone of this project and my current vocation,” Hiebert says. “I’d say that’s a pretty big impact.”

The FRI reach goes beyond the more than 6,000 students who have participated the past ten years, extending also to faculty and the research mission of the College.

“This is a Texas-grown institution that has begun to have national impact, and I don’t think people understand just how good it is,” Ellington explains. “Texans should be proud of what they have and should continue to try and foster it wherever possible. I think that it’s a gem at UT, both for education and for research.”

See FRI streams in action in our video series: txsci.net/1Ol5YSG
What was your undergraduate research about when you were in the Freshman Research Initiative?
In the Supramolecular Sensors lab, we had a wine analysis team and a synthesis team. The goal of the analysis team was to differentiate wine varietals based on tannin composition. ...It's fascinating because there was also this huge lawsuit that's part of the reason the stream got funding. A French company had sold grapes under a different name, as better grapes than they actually were, and a wine distributor sold wine made from them. There was an investigation, and a court decision set aside money for science, including in this lab at UT. In the FRI Stream, we were analyzing a bunch of different wines and trying to classify them, but there was one that was an outlier. It was showing that it was not a pinot noir when it should have been. Because of the investigation, we know why it was an outlier.

Now as a mentor, how do you help students care about research?
I try to explain concepts in a way so that their meaning is obvious. I like to present cool case studies of scientists using techniques similar to ours to detect diseases. In the FRI class, students present a summary of research related to our field. We have to make it relevant. Otherwise, I'm just telling them what to do.

What motivates you to do what you do?
I get to collaborate with tons of different people. Right now we are working with UT biochemistry. My research could speed up reaction discovery, which ultimately could be applied to synthesizing a new pharmaceutical drug.

What are the most surprising things you've learned?
I've learned that it's completely up to me how much work I get done. No one else can change that. I can have bad days—maybe my reaction didn't work, or maybe I dropped a vial that had 15 milligrams of something I've been making for weeks. Those days happen, but ultimately everything is up to me. I'm responsible for how much I get done and how successful I am. It's okay to dream big, but if I don't work, the dreams are never going to come true.

Go online to learn more about the wine analysis research and to see an animation about this science in action. txsci.net/1mP26SF

BRENDEN HERRERA
Chemistry PhD student, alumnus of and mentor in the Freshman Research Initiative. Interviewed by Ellen Airhart.

"My research could speed up reaction discovery, which ultimately could be applied to synthesizing a new pharmaceutical drug."
5 TRENDS TO WATCH AT CNS

Science and higher education together have brought the world countless innovations. Just at the University of Texas at Austin, scientists found folic acid, which today prevents thousands of birth defects. They created the scanning electrochemical microscope, which led to countless medical and technological breakthroughs, and developed the first secure sockets layer, the basis for safe online transactions. They discovered X-rays can induce mutations in the genes of a living being, which revolutionized genetic research. And they solved thorny mathematical equations that brought about breakthroughs in medicine and the energy industry.

So, the world needs universities and their scientists. The health of the planet, medical progress, the next great devices and awe-inspiring discoveries all hang in the balance. Three years ago, faculty and friends of UT Austin’s College of Natural Sciences came together to talk about what the world needs most from one of the nation’s biggest colleges of science. The conclusion? Our Texas-sized college needed a map for maximizing its potential to be one of the very best. The strategic plan that grew out of that process is helping deliver what Texas, the nation and the world need from a leader in science and higher learning.
Transforming how students learn science and math.

Graduating more students with STEM degrees.

Facilitating discovery on campus.

Leading innovations at key crossroads.

Making the Texas Science impact known.
Transformations in how students learn science and math.

Tens of thousands of students each year take UT Austin science and math courses, and the aim of those classes is to produce better problem-solvers and thinkers.

In 2014, the college established the Texas Institute for Discovery Education in Science (TIDES) to help raise the profile of and expand on excellent science education in the College. TIDES promotes student engagement and exploration in science and mathematics. The Institute’s staff guide faculty in integrating more opportunities for students to solve problems, analyze data and think at a higher level in courses. TIDES has established a new series of courses for graduate students to improve their teaching and mentoring abilities. It’s also analyzing college-wide data to identify strategies faculty use that are especially effective and worthy of replication.

“TIDES is breaking new ground with a three-pronged approach to education innovation—large-scale experiential learning, teaching professional development for current and future faculty, and using data to drive educational decision making,” says TIDES director Erin Dolan.

The college is also investing new energy and support in the faculty whose focus is entirely on the vital work of teaching. This is giving these professionals, who are not on the tenure track, room to try new, data-driven approaches to teaching—both in the classroom and in the online platforms that supplement traditional classes.

Growth in STEM graduates.

With enrollment up 25 percent over the last decade and with nearly 2,000 graduates a year, Natural Sciences now is UT’s largest college.

Students face challenging course requirements across the sciences. Nationwide, many students who major in science, technology or math either take longer than four years to graduate—or they abandon their STEM degree plan altogether.

Because academic and community support can keep students on track, the college is taking steps to help STEM majors stay engaged. New and redesigned degree plans built around a core science experience give students flexibility in their programs. And all incoming freshmen and transfers are placed in small learning communities to help them navigate UT.

“The rate of students who begin in the college and graduate with a STEM degree four years later is now at an all-time high, and the number of freshmen on academic probation is at an all-time low,” says Associate Dean for Undergraduate Education David Vanden Bout.

As the population becomes more diverse, the college also is working to ensure groups underrepresented in the sciences have opportunities at UT. New scholarships, outreach programs and invitation-only academic learning communities all play a role.

Finally, the college is prioritizing competitive fellowships to attract top graduate students. “Our educational effort would be incomplete without graduate students,” said Dan Knopf, Associate Dean for Graduate Education. “They do critical research for the college, make valuable contributions to teaching undergraduates and become the next generation of scientists and mathematicians.”
New drivers of discovery on campus.
“UT’s reputation for scientific advances, the campus’s innovative offerings and its location in Austin all play a part in recruiting top scientists,” explains Dean Appling, Associate Dean for Research and Facilities. Those scientists’ brilliance lies at the heart of the college’s many world-changing discoveries. To help faculty thrive and expand into new research areas, the College has started gathering its scientists and mathematicians together for lively discussion and exchange of ideas at themed Discovery Dinners each semester.

Having productive scientific researchers and mathematicians at the top of their fields requires having cutting-edge facilities. Appling helped the college develop a master space plan that aimed to make good use of existing campus buildings and plan for renovations in some of UT’s most beloved and well-used areas, like Welch Hall. Renovations to the largest academic building began in 2015, just after the Texas Legislature approved new construction bonds for Welch. Public and private investments soon will transform this heart of campus into a hub for learning and discovery.

Innovations at key crossroads.
With a mission “to provide research-enhanced education and promote educationally connected research,” the College of Natural Sciences does things that can happen only at a research university.

The Freshman Research Initiative is a good example. The nation’s largest effort to involve first-year students in scientific research, FRI opens doors for students to engage in the real work of their discipline. This helps them persist in science and math and makes a difference in discoveries. FRI alumni have coauthored more than 140 peer-reviewed scientific papers. Now campuses in Texas and around the country are working to replicate the program.

Another example: no other college of science at a top university has had the opportunity to work with a newly forming medical school in decades, but the College of Natural Sciences is doing just that with the new Dell Medical School. From reorganizing departments and research units to planning joint faculty appointments, the College is finding ways to collaborate with the medical school.

Finally, to promote interdisciplinary research, the college established a new Catalyst Grant Program that seeds ideas at the interface of existing and emerging fields. Already, these grants have resulted in scientific breakthroughs published in the nation’s top scientific journals.

A spotlight on the Texas Science impact.
Igniting people’s passion for science requires communicating the value of discovery. That’s why the college works to convey scientists’ sense of wonder and excitement to people everywhere.

For friends of the college, a series of Roadshow presentations provide a chance for college leaders to connect with alumni, parents and friends throughout the country. Social networks and digital communications reinforce connections, reaching more than 50,000 members of the broad Texas Science community.

Many others also have a stake in the college’s success: communities, patients, entrepreneurs, consumers and school children among them. New public outreach programs, an annual Visualizing Science gallery of beautiful images from campus labs and science-focused video and podcast series are among the ways the college is working to make its science accessible for people in Texas and around the world.
Mighty Larvae
Coral larvae like this can float hundreds of miles across the ocean—and it turns out that’s good news for their species. Mikhail Matz, an associate professor of integrative biology, found that some corals in the Great Barrier Reef tolerate heat better: the ones whose parent came from a distant, warmer part of the ocean. With reefs worldwide at risk, the discovery suggests corals can adapt to climate change. But it will require some match-making between the corals native to cool waters and those from warmer waters farther away.
Invest in Texas Science

The College of Natural Sciences is the largest college on campus and one of the best colleges of science in the nation. Our faculty and students perform cutting-edge research every day that is truly changing the world. You can make an impact by renewing your connections with the College in support of one of these three priorities:

GRADUATE STUDENT SUPPORT
More than 1,200 graduate students from around the world make possible the excellent research and educational advances in the College of Natural Sciences. In order for UT Austin to compete with peer research institutions for the best graduate students, we must increase our graduate fellowship offerings.

FRESHMAN RESEARCH INITIATIVE (FRI)
FRI offers first-year students the opportunity to engage in research experiences in chemistry, biochemistry, nanotechnology, molecular biology, physics, computer sciences, astronomy and more with support and mentorship from faculty and graduate students.

BUILDING RENOVATIONS
The College has begun renovations to key facilities, including Welch Hall. Welch renovations include new classrooms, teaching and research labs, dedicated FRI space and modernized community space. More information, including giving levels at: NewWelchHall.utexas.edu

Join us in our mission by renewing your investment in CNS. Whether you give through the annual fund, establish an endowment, or help update our facilities, you make a difference in the lives of our students and faculty.

To support the College or for more information, please call Kelsey Evans, Assistant Dean for External Relations, at 512-471-6151, or email Kelsey.Evans@mail.utexas.edu

cns.utexas.edu/giving