When Michael Reddick (chemical engineering ’13) arrived at Northwestern, he had a hunch that he wanted to study chemical engineering—he’d aced high school chemistry, after all. Then he found himself gravitating toward medicine as well, but he wasn’t sure how to meld the two. “I liked the idea of being a doctor, but I didn’t just want to be the person administering the drugs,” he says. “I wanted to be the person discovering the drugs. The idea of discovery, application, and technology all in one was very exciting to me.”

Reddick didn’t have to wait until graduate school to learn that he was interested in research—and to learn what research would be like. By landing a spot in a McCormick research lab that seeks to reprogram yeast cells to serve as inexpensive diagnostic tests for diseases, Reddick has gained invaluable insight into what conducting research means: hard work, trial and error, and hours upon hours of learning about other researchers’ work.

Real research doesn’t much resemble the research described in high school textbooks—but that doesn’t deter undergraduates like Reddick. Whether they take on the work for course credit, as a paid position, or just for the experience, undergrads play an increasingly vital role in McCormick research laboratories; since 2005 the percentage of undergraduates engaged in research at the school has more than tripled to 40 percent.

“Having undergraduate students in our labs is a critical part of the research experience at McCormick, not just for the undergraduates who do it but for the graduate students, postdoctoral researchers, and professors who work with them,” says Julio M. Ottino, dean of the McCormick School, Distinguished Robert R. McCormick Institute Professor, and Walter P. Murphy Professor of Chemical and Biological Engineering. “Our undergraduate research program fosters learning for the students, while our labs benefit from our students’ curiosity, work ethic, and perspective.”
From yeast, a career path rises

When Reddick sought a spot in a lab during his sophomore year, his timing couldn’t have been better for his interests: McCormick had just hired several faculty members whose research in synthetic biology blurred the lines between medicine, biology, and engineering. Among them was Keith Tyo (above, left), assistant professor of chemical and biological engineering, who studies cells’ metabolic networks to synthesize new materials and engineer new kinds of sensors. “I emailed Professor Tyo before he even arrived on campus,” Reddick says. “I was that eager for a spot in his lab.”

Reddick landed a spot and has spent the past two years in the Tyo lab studying the intracellular communication of yeast cells to determine how they respond to stimuli. Reengineering the cells so that researchers could control their growth was just the beginning. By rewiring the cells’ sensing mechanisms, Tyo’s team seeks to reprogram them to do useful things for humankind, such as providing an inexpensive and transportable diagnostic tool for the developing world.

The lone undergraduate in a newly established lab, Reddick was part of an all-hands-on-deck mentality. “It’s been such a cool process to see someone start a lab,” he says. “Most times when you join a lab it’s already established, but I was there for everything—from ordering equipment to setting up the space to getting projects under way. In the process I was fortunate to interact with Professor Tyo a lot.”

Five more undergraduates have since followed Reddick to the Tyo lab. “Undergraduate researchers, especially the fantastic students we have at Northwestern, are a great asset,” Tyo says. “Their enthusiasm and willingness to try new things can be an example to graduate students and even to me. In my lab they get the opportunity to start making a real impact and to see how their work fits into a larger plan to solve some really important problems. And the older researchers get to develop their mentoring skills.”

Reddick’s work in the Tyo lab has shaped his career plans as much as he’d hoped. The experience led to a lab stint last summer at the University of Wisconsin. Reddick plans to enroll in a doctoral program after graduating this spring and to join a lab there working on similar synthetic biology research. “Professor Tyo’s lab was how I learned what’s out there,” he says. “It has showed me what I want to do with my career.”

Connecting to coursework

Not all research opportunities involve wearing a lab coat—and that’s perfectly fine with Maya Stuhlbarg (civil engineering ’13). For the past two years Stuhlbarg has worked on structural health monitoring research at Northwestern’s Infrastructure Technology Institute, and her “lab” sites have ranged from a Wisconsin freeway overpass to the base of a deteriorating California bridge.

“I don’t think I would have liked research as much if I had been confined to a lab. I think I would have gotten bored with it,” Stuhlbarg says. “At ITI I get an understanding of the bigger picture.”

Stuhlbarg helps ITI develop and maintain electronic sensor systems that monitor the structural performance of bridges and other structures throughout the United States. The systems—metal boxes that affix to the structures and collect data about deflections, temperature changes, and shrinkage—transmit information wirelessly to computers at ITI, where researchers crunch the numbers and turn them over to transportation officials to aid in infrastructure-related decision making.

Students at ITI travel across the country to install and maintain equipment. The summer before her junior year Stuhlbarg flew to Malibu, California, where she spent a week installing sensor systems on a scour-critical bridge. The condition occurs when a bridge, usually with its...
foundations in a body of water, experiences a loss of support as rocks and soil are washed away.

Stuhlbarg was able to contribute meaningfully on the job site after just a year at ITI, applying many of the topics she’d learned about in her coursework, such as stress and strain and behavior of beams and columns. “It was a really great experience,” she says. “It allowed me to see the decisions that are necessary with structural health monitoring, such as where to place the sensors or where to find a power source, and it gave me first-hand experience working in real conditions.”

“ITI has worked with many undergrads over the past several years, and we have a good system in place to bring them in, get them up to speed, and get them contributing quickly,” says David Corr (pictured with Stuhlbarg on page 29), clinical associate professor of civil and environmental engineering and Stuhlbarg’s research adviser. “The type of research we do connects directly to the topics they are learning in their courses.”

Stuhlbarg’s recent focus has been a highway overpass in Hurley, Wisconsin, near the Michigan border. Logging is an important industry there, so large trucks frequently travel the area’s freeways. The two states have vastly different weight regulations for trucks, however, making for an interesting case. Stuhlbarg is working on a paper about the Wisconsin project that she hopes to see published before graduation.

Stuhlbarg is planning a career in infrastructure design, for which her ITI experience will be invaluable. “If you want to design new things,” she says, “you have to understand maintenance—and now I do.”

Tangible results
Some undergraduates have so much on their plates that carving out time for research is a challenge in itself. Dedicated student-athlete Patrick Ward (mechanical engineering ’13), a Wildcats left tackle and two-time NCAA Academic All-America honoree, couldn’t squeeze in lab time during the school year, when he was busy attending football practice, working out, maintaining a 3.94 GPA, and preparing to graduate early. So, Ward did research over the summer.

He was offered a spot in Northwestern’s Neuroscience and Robotics Lab with Kevin Lynch (above, right), professor of mechanical engineering. “I had Patrick in my Introduction to Mechatronics class, and when I saw his discipline, work ethic, and native ability, I started recruiting him immediately,” says Lynch. “We are fortunate to have had many outstanding undergraduates work in our lab, and Patrick was one of the best.”

In the lab Ward participated in National Science Foundation–sponsored research aimed at helping a woman who had suffered a spinal cord injury regain voluntary control of her right arm. The Northwestern lab, in collaboration with the Rehabilitation Institute of Chicago and Case Western Reserve University, is developing a system based on surgically implanted electrodes to stimulate the woman’s arm, shoulder, chest, and back muscles to animate her arm. Coupled with a system that senses what task she would like to perform, the goal is to restore her ability to perform basic functions such as eating and drinking.

A missing step in creating a working system was to develop an optical tracking system that could track the arm’s precise location in space. That’s where Ward came in. Ward spent his afternoons researching, evaluating, and implementing high-speed, vision-based methods to provide feedback for the electrical stimulation controller. “Even in the best-designed controller, there’s going to be some error between where the subject wants to move her arm and where the computer moves it,” Ward says. “Using a feedback controller, we can detect the error in the position and make a correction, then adjust the electrical stimulations as needed.”
After spending weeks learning about methods for tracking rigid bodies, Ward got to work writing code in MATLAB—a technical computing language and interactive environment for algorithm development—that would interpret vision data from a three-camera system. In one of his favorite activities of the summer, he went to work in McCormick’s prototyping shop to create a stand-in for the human arm to test his work. “I built a really crude, three-degrees-of-freedom model of a human arm out of two-by-fours, door hinges, and screws, and I attached some reflectors to it,” he says. “As I moved the test arm around, the computer reconstructed the three-dimensional motion of the arm from the vision data. It was really gratifying to see my efforts pay off.”

All new terrain
Coauthoring a journal paper is an exciting opportunity for an undergraduate. Being the lead author of a paper that lands on a journal cover—with coauthors who include Dean Ottino and Richard Lueptow (above, right), senior associate dean—is knocking the ball out of the park.

But Marissa Krotter (mechanical engineering ’13) is no ordinary student. As a scholar in the Murphy Institute, a program that invites select McCormick undergraduates to engage in self-directed activities, Krotter had funding for a long-term research project. When it came time to choose a sophomore-year project, she followed her interest: fluid dynamics.

Krotter had become acquainted with Lueptow the previous year, when a course required her to design an umbrella that could withstand Chicago’s high winds. “There are a lot of forces at work, such as how the velocity of the winds and shape of the umbrella can impact forces,” she says. “Dean Lueptow is an expert in fluid dynamics, so I emailed him and asked if we could talk.”

Lueptow welcomed her into his lab. Early on in her research there, Krotter performed easy tasks, like organizing supplies and keeping chemical lists up to date. “It was a good way to become familiar with the lab,” she recalls. As her comfort level grew, so did her responsibilities. By her senior year Krotter was entrenched in the cut-and-shuffle method, a new way of mixing solid materials that resembles a deck of cards being cut and shuffled. Explored over the last few years by Ottino, Lueptow, and their research team, the method might find applications in geophysics and materials processing.

These days Krotter spends most of her time writing code in MATLAB. In her research, she has also collaborated with a doctoral student in the Department of Engineering Sciences and Applied Mathematics who is applying theorems related to a relatively new area of mathematics called “piecewise isometries” to the cut-and-shuffle approach. She interacts frequently with Lueptow and participates in meetings every few weeks with Ottino and the rest of their team. “Working with Deans Ottino and Lueptow has been great, especially hearing their insights into research,” Krotter says. “I’m always amazed at how willing and happy they are to meet with me and make sure I’m getting what I need out of this process.”

The experience reached its pinnacle in December, when Krotter’s paper about the cut-and-shuffle method appeared on the cover of the International Journal of Bifurcation and Chaos. “The whole process of writing a paper, putting all the figures together, and getting it published has been so eye-opening,” she says.

Working in a lab has given Krotter a keen insight into how the research process works. “Shifting from the classroom to research is like night and day,” she says. “In class, if you’re working on a project or doing homework, you have an answer set so you know if you’re on the right track. Research is completely open-ended. It’s all new terrain.”

Sarah Ostman