The old adage isn’t always right: Build a better mousetrap, and the world might not beat a path to your door. “It requires significant work to move early stage research into the marketplace,” explains Alan Thomas, director of the Office of Technology and Intellectual Property, the University department that deals with all aspects of technology transfer. As a first step in the process, Thomas’s office, better known as UChicagoTech, works with researchers to assess a discovery’s commercial potential. When appropriate, the
department obtains patents; in many indus-
tries, exclusive rights to intellectual property are
needed to attract venture capital. UChicagoTech
then works to find commercial partners or
form a start-up company to develop the discovery.
Navigating the world of patent law, licensing,
and commercialization can be a distraction to
someone who spends most of their time in the
classroom or the lab. UChicagoTech strives to
facilitate the process, with the goal of maximizing
and increasing the University’s impact in the
world.

For example, consider the Everyday Mathemat-
ics textbook developed by the University of Chicago
School Mathematics Project. Major textbook pub-
lishe...
Faculty Q&A with
Amie Wilkinson

Amie Wilkinson is professor of mathematics. She received her bachelor’s degree in mathematics from the University of California, Berkeley, in 1995.

Your research focuses on dynamical systems. Why are those of interest to a mathematician?

It goes back to Henri Poincaré and the three-body problem. There was a competition sponsored by King Oscar of Sweden to solve exactly a system of equations describing the dynamics of a solar system that had at least three bodies—say, one huge like a sun, one moderate, and one miniscule. Poincaré won the competition, and his final solution was extremely influential in math. It was not a solution of the differential equations, but a qualitative analysis of the problem. What he showed was that there were configurations that were definitely not stable in any sense we think of—configurations that oscillate wildly over time.

Another important precursor to the modern study of dynamical systems was the ergodic hypothesis, which states that, over time, a system of molecules will assume all conceivable microstates that are compatible with the conservation of energy. This very unrigorous hypothesis placed on certain physical systems was made pretty rigorous in the ’30s by John von Neumann and George Birkhoff. A system is ergodic if any of its initial configurations will evolve into almost all other states of the system with probability one. If you randomly pick a starting configuration and let it evolve, it’s going to have very randomly. You’re not going to see any structure in the long run. This is the property that I study.

So, you have the notion of a dynamical system, and you have the notion of a configuration in that system, and you have a good notion of a random configuration. You also have a notion of a typical random dynamical system. What I want to understand are typical dynamical phenomena that occur in a typical dynamical system.

Much of your work revolves around foliations. Can you explain what those are?

A foliation is a special way of decomposing a space into smaller dimensional spaces. For example, take a square, which is two-dimensional, and imagine ruling it by horizontal line segments, which are one-dimensional. Do this with infinitely many parallel segments, one through each point in the square. This is a foliation of the square, and the line segments are called leaves of the foliation.

Now you can generalize this idea quite a bit. For example, take a bunch of these squares and glue them together so that the horizontal lines of neighboring squares match up (though the squares themselves don’t). With some care, you can construct the surface of a torus out of these squares, and with some more care, you can do this in such a way that the leaves of the foliations that you glue together join up to form infinitely many circles. Now you have a two-dimensional torus foliated by one-dimensional circles.

You can do this with higher dimensional spaces and higher dimensional leaves. A two-dimensional foliation of a three-dimensional space (like the one you live in) is built out of horizontal squares filling out a three-dimensional cube, kind of like a stack of square pancakes. You can do this with higher dimensional spaces and higher dimensional leaves. A two-dimensional foliation of a three-dimensional space (like the one we live in) is built out of horizontal squares filling out a three-dimensional cube, kind of like a stack of square pancakes.

Your stack of pancakes and glue it to another stack of pancakes, and pretty soon you’ve filled a room with stacks of pancakes that might not be lined up precisely. Next, imagine going all around the Earth, coming back, and gluing your stack of pancakes to the pancakes you started out with. This global decomposition of your space into two dimensions can wind around in rather complicated ways. Depending on the three-dimensional space you start with and the way you glue things together, you could end up with a foliations where some leaves look like tori, or spheres, or planes, etc.etera. If you look at them closely, however, it’s just a very straightforward decompositions into lower dimensional spaces. These types of decompositions arise in dynamical systems very naturally.

How do foliations relate to your work on dynamical systems?

When you have a dynamical system, this transformation of a space over time, you can look for structures in the space that don’t change over time. Or maybe they’ve moved around but we still see them. Imagine taking a stack of pancakes and flipping them around, but in the end you come back to a stack of pancakes, rearranged. That’s an example of an invariant foliation. In dynamics, we look for invariant structures because they tell us something about the dynamical system. They tell us we can understand the dynamical system, which could be in a huge, high-dimensional space, like 20 dimensions. You can reduce the dimensionality of the problem—it’s a way to break down the problem and understand it. Dynamical foliations and invariant foliations occur all over the place, so it’s interesting to study their properties as a way to understand the dynamical system itself.

Some people study foliations just for the sake of studying foliations. But I do it in the context of my dynamical studies, and as a tool really. It’s funny—sometimes dynamical systems will generate foliations with very strange properties that you couldn’t imagine producing with your bare hands, but the dynamical system produces them.

How does your work fit in with the other faculty members in the department?

There are some first-rate people who do work in dynamical systems and other areas. Dynamical systems is a field that takes a lot from many subfields. It’s specialized, but it also connects with other areas of mathematics in an essential way. The field wouldn’t exist without its connections to algebra, geometry, topology, measure theory, and so on. Chicago is very strong in these fields.

Your husband, Benson Farb, is also a professor of mathematics at UChicago. Was that a plus or a minus when deciding to join the Chicago faculty?

I wouldn’t have accepted if that wasn’t a plus! But it’s certainly a question for any couple working in the same field. Happily, it’s worked out very well. We’re actually working together on a project now, which we’ve never done in our fifteen years of marriage.
"Proteins are blobby things," says L. Ridgway Scott, the Louis Block professor of computer science and mathematics. "They don’t look like they would interact in a discrete way, but at the molecular level, they do." This realization has led Scott to a new way to simulate biological processes: a protein-by-protein approach called digital biology.

The first step to understanding to digital biology is grasping the concept, dubbed wrapping, by Scott and his collaborator Ariel Fernandez, a former visiting faculty member at the University’s Institute for Biophysical Dynamics and the Department of Computer Science, and R. Stephen Berry, the James Franck distinguished service professor emeritus of chemistry. The hydrogen bonds that hold a protein together are susceptible to disruption by water, a polar molecule. But water can be deflected from the bond by a hydrophobic structure nearby, such as a CH₂ or CH₃ group. A wrapped bond is one that is vulnerable to it.

Scott believes that dehydron analysis could be used to improve drugs in other ways as well. Scientists could design inhibitor drugs that attach to specific proteins and prevent them from affecting the body, or drugs that target and disable proteins that spread diseases by tackling them at their dehydrons. By crafting a drug to attack one problem specifically, the chances that it will cause unwanted side effects diminish.

The technique’s use isn’t limited to pharmaceutical processes: a protein-by-protein approach called WRAPPA and improved methods of data analysis (www.wrappa.org) for analysis and get the locations of dehydrons and poorly wrapped bonds. Up to now, Scott says, advances in biology have existed in science since Euclid. I think it’s one of the great and inspiring stories in the history of science, and it hasn’t been appreciated.

What is the Five Most Consequential Ideas in the History of Statistics?

The five most consequential ideas in the history of statistics are much more effective methods—we call them nonparametric tests and modern statistics, especially modern multivariate analysis. The process of taking measure - ments is not that simple. It can involve deep statistical ideas; it can involve serious conceptual problems; and if handled poorly, it can involve major errors. Even modern scientists are often unaware of some of these nuances and problems. One of the things I look for when I’m studying old materials is not just what people did but how they did it and whether they did it well. In particular, I keep my eyes open for blunders. And I find them, in old works and in modern works. It’s not unusual to pick up a current issue of Nature or Science and be able to locate some significant blunder that has been propagated by a noted and excellent scientist who was ignorant of the sober science of statistics.

Much of your work has to do with not just the history of statistics, but also the history of the way people understand and use statistics. History can be a dry recitation of facts or can be an exploration of intellectual history, by which I mean the way ideas have developed and changed. Ideas change as they migrate between different fields of application. Methods that were based on a framework of Newtonian gravitational theory in astronomy, like the method of least squares and the use of probability to deal with errors, became the means of creating the objects of modern social science.

What concept in statistics, or perhaps in the scientific method in general, do you think is most misunderstood?

It is often accepted as the naive history of science that one conceives of a theory and then one takes measurements. The process of taking measurements is not that simple. It can involve deep statistical ideas; it can involve serious conceptual problems; and if handled poorly, it can involve major errors. Even modern scientists are often unaware of some of these nuances and problems. One of the things I look for when I’m studying old materials is not just what people did but how they did it and whether they did it well. In particular, I keep my eyes open for blunders. And I find them, in old works and in modern works. It’s not unusual to pick up a current issue of Nature or Science and be able to locate some significant blunder that has been propagated by a noted and excellent scientist who was ignorant of the sober science of statistics.

I will say that we don’t make quite as many elementary errors as we used to, but that’s not to say that you can’t find some really elementary errors in modern scientific literature as well. I’m not studying it just because of perversity, but because it sheds some light on how understanding spreads and develops and how precarious that understanding can be.
Up, up, and away

“Scientists have always been field explorers,” says John Grunsfeld, SM’84, PhD’88. It’s a statement of fact, but it might also be Grunsfeld’s own personal manifesto. Attempting science in the field has taken him from launching cosmic ray detectors on balloons in Australia to becoming “the Hubble repairman” in low Earth orbit. In January, Grunsfeld embarked on a new mission: overseeing NASA’s satellites and probes that take scientists’ experiments to the edge of the solar system and beyond.

A five-time space shuttle astronaut, Grunsfeld visited the Hubble Space Telescope three times. (He holds the distinction of being perhaps the only person to have observed with the telescope on the ground as well as having maintained it in orbit.) Before the space shuttle program ended in 2011, NASA declared there would be no more servicing missions to the telescope, so Grunsfeld decided to retire from the astronaut corps and “get back to being a practicing scientist.” He took on the position of deputy director of the Space Telescope Science Institute (STScI), the organization that manages the operations of the Hubble and its eventual successor, the James Webb Space Telescope.

But in 2011, when NASA Administrator Charles Bolden asked Grunsfeld to become associate administrator for the Science Mission Directorate—in effect, overseeing all of NASA’s scientific projects outside of aeronautics and manned spaceflight—he couldn’t resist. “I’ve spent my entire career, starting in 1976 with NASA,” he says, “My heart is still very much with the agency.” Today, Grunsfeld is in charge of an armada of 98 spacecraft, in operation or planned, representing 86 space science missions. With a budget of almost $5 billion, it is “the largest science investment any country makes in science, period.”

That investment spans the solar system, from Mercury to Pluto, and Grunsfeld enthusiastically carries out the mission. “I’m interested in finding the synergies between robotic and human spaceflight and the science enterprise,” he says, and he’s confident that human scientists will eventually take their research stations to the moon and Mars.

“Robots don’t discover anything—people do, using robots.” He sees part of his mission as breaking down the barriers between the two communities. “I’m interested in finding the synergies between human spaceflight and the science enterprise,” he says, “and one of the largest investments our country makes in science is carrying out. There’s Earth science: “We have spacecraft orbiting Earth that are able to watch sea level rise at a rate of 3.2 millimeters a year, while measuring the ice thickness over Greenland and Antarctica.” Mars: “We have this incredible Mars Science Laboratory heading for the surface of Mars for landing on August 6th, that’s going to be the Hubble Space Telescope of Mars exploration,” Extraterrestrial planets: “We have the capability in the next generation James Webb Space Telescope and beyond to answer some really fundamental questions, like are we alone in the universe?”

Although NASA’s internal politics is sometimes depicted as a struggle between human and robotic space exploration, Grunsfeld, familiar with both sides, sees a unified picture. “There’s no such thing as robotic science,” he says. “Robots don’t discover anything—people do, using robots.” He says part of his mission is to take on some of the research stations to the moon and Mars and break down the barriers between the two communities.

John Grunsfeld keeps NASA’s space science missions flying.
Kids are into either dinosaurs or trilobites,” says Mark Webster. “Shell game—Teasing the mysteries of trilobites from rocks.

INQUIRY photo by Dan Dry

Trilobites inhabited the seas of Earth for 270 million years ago. Even Proetida died 89 million years later for unknown reasons during a mass extinction. Organisms they shared the oceans with; in rocks dating from their heyday, the Cambrian period, Webster hopes to clear up.

Webster analyses the sizes and shapes of hundreds of different species of trilobites, a process called morphometric analysis. He uses the data he compiles to determine what kind of variations could be expected in individuals of the same species over time. To free his trilobites from the rock they were preserved in, he relies on the fact that their shells were often turned to silica by the process of fossilization and placed the rock in a bath of acid. “The rock dissolves away,” he says, “and sitting in the bottom of the bucket are all these little trilobite fossils.”

Whereas dinosaur species are sometimes known from just a single specimen, trilobite fossils are common enough to allow him to perform a statistically valid analysis on data from his photographs and measurements. (“Sample size is not an issue,” Webster says.) From that, he and his researchers can build an evolutionary tree for trilobites.

From his main work on trilobites, Webster branches out into related projects. Paleontologists, he explains, “are having a lot of problems correlating rocks from the Cambrian of say, North America, to [those of] the Cambrian in China or Australia or Siberia,” because those landmasses have few fossils in common. However, some trilobite species were almost globally distributed, identifying those species and placing them in their proper chronological sequence can help paleontologists accurately match up rock strata from the Cambrian period on different continents and construct a timescale for more precisely calibrating evolutionary rates.

Webster is also attempting to use his trilobite data to understand how limited trilobites were in their ability to evolve. While Webster cautions that his area of expertise is the early diversification of trilobites, not their end, his work may yet give a clue to their extinction. Organisms can adapt to their environment—sometimes radically—but how fast a lineage can adapt under pressure to evolve is still imperfectly known. All but one trilobite order, Proetida, died out at the end of the Devonian period, 359 million years ago. Even Proetida died 89 million years later for unknown reasons during a mass extinction called “the Great Dying” that wiped out 96 percent of all marine species.

One theory (which Webster is beginning to test) holds that some lineages, perhaps including Proetida, were developmentally incapable of evolving quickly enough to adapt to sudden environmental change. He hopes his work will provide a better understanding of how constrained evolutionary lineages are in what they can and can’t do, which might help us understand what kind of organisms today will adapt when faced with climate change from global warming—and which won’t.

Most of Webster’s fieldwork (about two months a year) takes place in the American Southwest, where the desert climate makes it easy to find exposed rock from the Cambrian period and, with it, fossils. However, the search for trilobites has also taken Webster to the Appalachian Mountains, the Canadian Arctic, Spain, and China. “I go where the trilobites are,” he says. “And they are everywhere.”

Making Plans
If you are interested in supporting the physical sciences but don’t have the resources to make an outright gift, you may consider including a provision in your will for the benefit of the Physical Sciences Division. Your bequest of a specific dollar amount, a percentage of your estate, or a piece of property can:

» fund student aid;
» sponsor faculty positions;
» support groundbreaking research; and
» provide unrestricted funds.

Bequests are simple to arrange, reduce your taxable estate, and allow you to retain your assets during your lifetime. Providing for the physical sciences in your will is a simple way for you to help support the future of science at Chicago.

For more information on the many ways you can give to the PSD, please contact Heather R. McClain in the Office of Gift Planning at 773.834.217 or hmcclean@uchicago.edu.

Faculty additions
Nicolas Brunel, professor of statistics and neurobiology (effective July 1, 2012)
Jian Ding, assistant professor of statistics (effective July 1, 2012)
Rina Foygel, SM’09, assistant professor of statistics (effective January 1, 2014)

Madhur Tulsiani, assistant professor of computer science (part time, joint appointment with Toyota Technological Institute at Chicago)
Amie Wilkinson, professor of mathematics

Faculty retirements
James Pichler, professor of physics in the Enrico Fermi Institute

News from the University of Chicago Physical Sciences Division
The alma mater of invention

As you can read on the cover of this issue, the division is encouraging the efforts of our faculty to commercialize the discoveries they make in the course of their research. Faculty and students alike at the University of Chicago take perverse pride in being at an institution that reveres theory and knowledge for its own sake—yes, even the experimentalists. But we don’t have to sacrifice our mission of advancing knowledge via basic research and education if we want to make an impact beyond our ivy walls.

If you fear that this means the division will reorient itself and its resources toward the projects seen as the most profitable instead of the most worthy, then you can put your mind at ease: this is not a commercial laboratory and never will be. Still, there’s a huge overlap between fundamental science and changing the world. Think of the computer scientists investigating systems design or quantum computing. Think of the statisticians trying to understand the human genome, or the collaborations between chemists and biologists as they try to defeat drug-resistant infections. (I’ve often thought that I would know my tenure as dean was a success if our scientists came up with the cure for a major disease on my watch.) I could go on, but I only have half a page.

There are many other reasons to foster innovation on campus. Supporting a researcher’s interest in commercializing their discoveries also helps us to retain them when other institutions try to lure them away. And we’re certainly happy when a successful product like Everyday Mathematics returns money to the division’s coffers, since those funds get reinvested in aid for our students and faculty. But to my mind, at least, the best reason to support innovation and commercialization is that our discoveries can be a great force for good in our world.

With warm regards,

Robert A. Fefferman, Dean