SUPER-SIZED knots

BY KATHERINE PENNAVARIA

MOST PEOPLE TIE AND UNTIE KNOTS THROUGHOUT THEIR LIVES WITHOUT GIVING THEM A SECOND THOUGHT. CLAUS ERNST AND UTA ZIEGLER, HOWEVER, HAVE GIVEN KNOTS A GREAT DEAL OF THOUGHT. IN FACT, THESE TWO WKU PROFESSORS SPEND MANY OF THEIR WORKING HOURS CONTEMPLATING THE MATHEMATICAL AND COMPUTATIONAL PROPERTIES OF KNOTS.

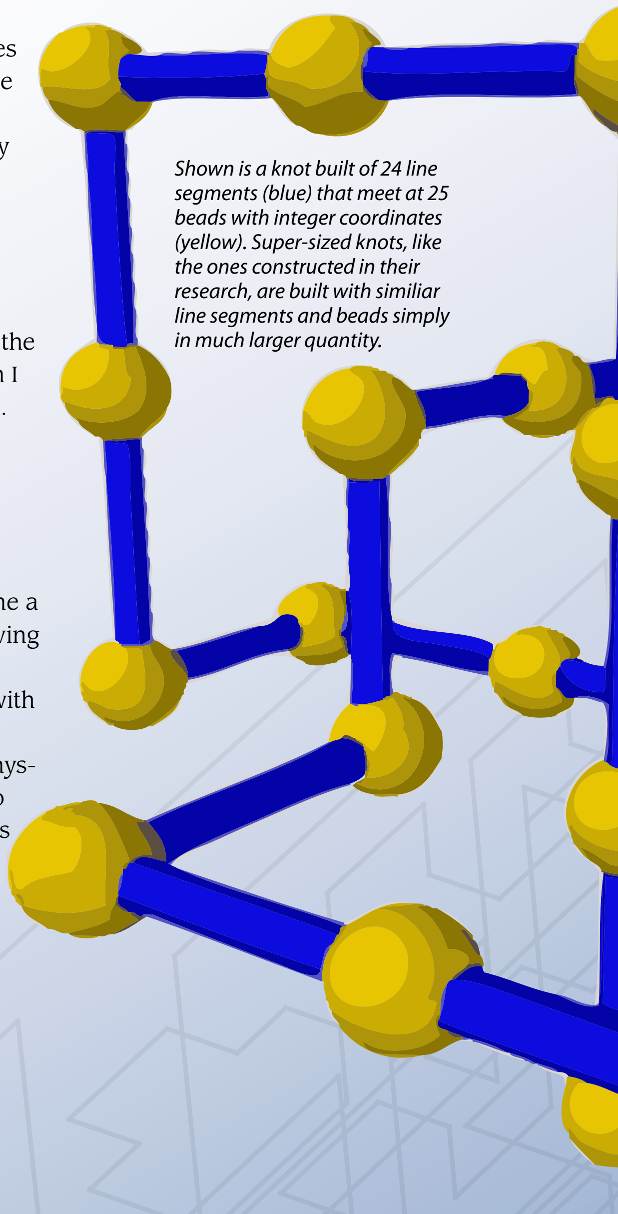
This husband and wife team has broken new ground in the theoretical modeling of physical knots — knots that exist in certain polymer chains and some DNA molecules. Dr. Ernst, a member of the Mathematics and Computer Science Department, is currently a leader in the field of knot theory, and oversees a grant-supported research project. Dr. Ziegler, also from the Mathematics and Computer Science Department, has created software which can deal with three-dimensional models of long, knotted entities, those with tens of thousands of crossing points (the simplest knot has only three crossing points). In other words, these researchers deal with really, really big knots — the kind that do not exist in the visible world.

The mathematical field that deals with physical shapes and surfaces is called *topology*. Topologists like Dr. Ernst deal almost exclusively with theoretical models, although he has a box full of intertwined plastic pieces, some of them children's toys, which he uses to demonstrate the principles of knot theory to his students. For her part, Dr. Ziegler has her own toy models. In her artificial intelligence (AI) class, her students use Lego pieces to build working robots and vehicles that move. "We have an artificial intelligence lab here, and even though I'm not doing research in AI right now, I like to stay involved with it," she said.

Both Ernst and Ziegler are natives of Germany who met after they came to the United States for what they each assumed would be a temporary stay while studying at Florida State University. "I just wanted a year abroad," said Ernst. Ziegler arrived in the country as part of a program sponsored by a German-American friendship club. "One of the schools the club worked with was FSU, to which I applied and was accepted," she said. "It was only supposed to be for nine months."

They both ended up working on Ph.D.s, Ernst in mathematics and Ziegler in computer science. After taking a topology class, Ernst became a research assistant in a project involving knot theory. "It was more or less a chance event, my getting involved with knots," he said. "But then I became really interested in biological and physical knot structures, which led me to knotted molecules." (Most molecules are *not* knotted.)

Ziegler's involvement with knots came later. "I started in artificial intelligence," she said. "But I had a microbiology minor when I was studying in Germany, which involved looking at DNA." Shortly after they took the jobs at WKU, Ernst, Ziegler, and a colleague at the University of North Carolina at Charlotte got the idea to develop and encode an algorithm to explore complicated physical knots. They were awarded a National Science



Shown is a knot built of 24 line segments (blue) that meet at 25 beads with integer coordinates (yellow). Super-sized knots, like the ones constructed in their research, are built with similiar line segments and beads simply in much larger quantity.

Foundation (NSF) grant, which allowed them to hire seven student research assistants. So far, the project has generated numerous journal articles for Ernst and Ziegler, as well as several master's theses for their assistants.

It's a complicated project, and takes some patient explaining. "Knot theory comes from physics," explained Dr. Ernst. "What we are trying to do is take a large knot and track thousands of crossings. It's too big to look at on paper or in a physical model." The underlying question is, he said, "How much length do you need to make a complicated knot, one with thousands of crossings and a fixed thickness?"

Research-based data about knotted molecules such as polymers and DNA has many possible applications, but right now the team is just trying to establish the statistical properties of these structures. "This knot project is basic research," Ernst explained. "Science is full of examples where people have made discoveries which may or may not have an obvious payoff. This is about creating and manipulating data that might be used by later researchers."

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"That's right," Ziegler agreed. "The same concept applies in computer science: you often create tools for other researchers to use."

The NSF research grant they received is given on a peer-review basis, and is quite prestigious. It is the second NSF grant they were awarded for this topic. Dr. Ernst said, "This is one of the highlights of my career. It's not a lot of money, but it's an important recognition of the high quality of work I've already done in this field." In math and science, research progress is typically measured not in months or years, but in decades. "For people to do deep-level study," he added, "the investment is tremendous. I have been doing knot theory for my entire career."

When not working on the project, both professors teach a variety of classes at WKU. Dr. Ernst has recently taught graduate-level topology classes, computational problem-solving, and several general math courses. He also regularly teaches calculus for the Carol Martin Gatton Academy of Mathematics and Science in Kentucky Dr. Ziegler teaches program development, research methods for graduate students, mathematical foundations of computer science, advanced computer networking, and artificial intelligence, among other things.

But that's not all that these active professors do. Because of his established place in the field of topology, Dr. Ernst gets invited to attend conferences all around the world. "Last year I got to go to a wonderful conference in Venice," he said. "I hope to go to Japan for one on knots and macromolecules." And Dr. Ziegler has other research projects and interests. "I'm on a cyber-defense grant, and am working on a project that involves Internet security," she said. "We're aiming at testing software developed to detect when a network is under attack, and to give the software a standardized rating."

Like Ernst, Ziegler also teaches for the Gatton Academy. They both praise the program highly, and say they hope their own two children will someday participate in it. "I've been very happy to get involved in the Gatton Academy," said Dr. Ziegler. "Those are the best and brightest students I've ever taught." ■

About the Gatton Academy:

The mission of the Carol Martin Gatton Academy Of Mathematics and Science in Kentucky is to offer a residential program for bright, highly motivated Kentucky high school students who have demonstrated interest in pursuing careers in science, technology, engineering, and mathematics. The Gatton Academy also seeks to provide its students with the companionship of peers; to encourage students to develop the creativity, curiosity, reasoning ability, and self-discipline that lead to independent thought and action; and to aid students in developing integrity that will enable them to benefit society.

For more information, visit www.wku.edu/academy

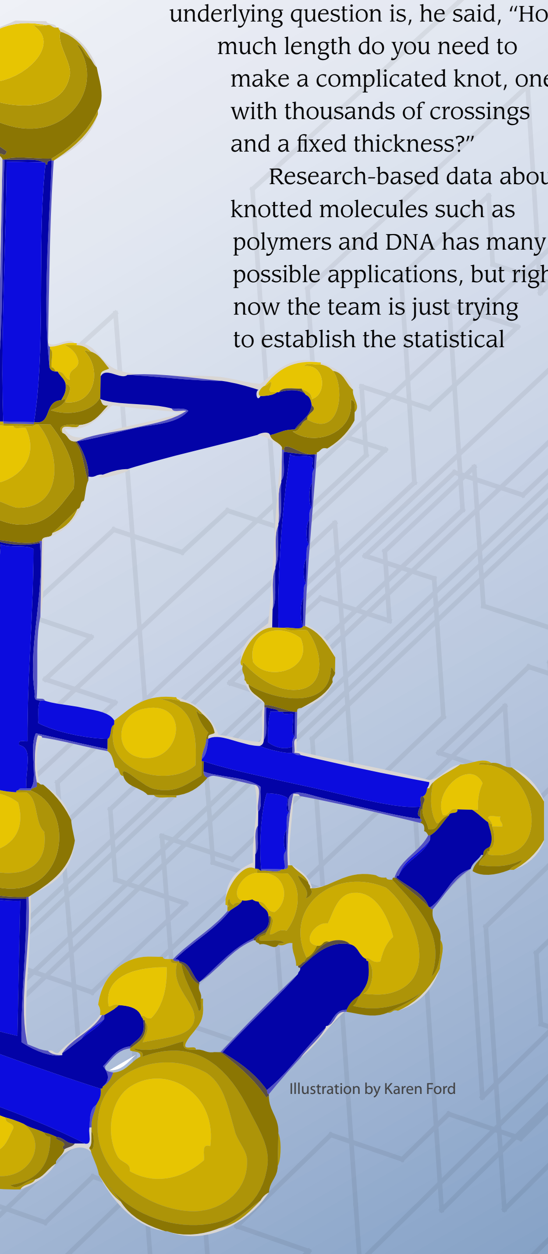

Illustration by Karen Ford