FEBRUARY 2007 Volume 32, Number 2

ASCE | The newspaper for members of the American Society of Civil Engineers

news

Collagen Research Could Shed Light on Bone Integrity

By Mark Fitzgerald

Roberto Ballarini, Ph.D., a civil engineering professor at the University of Minnesota, has been applying his experience in structural engineering and the mechanics of solids to an interdisciplinary research project that involves measuring the mechanical properties of nanoscale structures. According to Ballarini, understanding how collagen fibrils—the basic elements of bone, cartilage, tendon, skin, and other connective tissues—relate to the overall properties of bone structures could help improve scientific techniques for assessing a person's susceptibility to bone fracture.

"If you look closely at bone, you see that it has a very large number of sizes of features within it," Ballarini explains. "The bone itself may be on the order of centimeters and, for some of the smaller constituents, millimeters; some are down to microns and some nanometers. So it's a very complicated architecture within the structure, and it's a living structure, so it changes its properties throughout its life. This research is important because we currently lack mathematical models to predict the reliability of these types of structures. The process involves developing models and analyzing the behavior of each of the constituents before putting everything together and predicting the behavior of a given piece of bone as a whole."

Ballarini began working on small-scale structures about 10 years ago, developing methods for testing the fatigue and strength behavior of microelectromechanical systems

(MEMS)—chip-size devices that are typically carved from semiconductor wafers and include moving parts that, though microscopic, act as sensors or actuators. “The traditional civil engineer might view this as a strange field of work,” he notes. “But why would it be more natural for a mechanical engineer to look at a piece of bone than a civil engineer? They look at machines; we look at buildings. Well, a machine is a structure and a building is a structure, right? So why shouldn’t I apply my knowledge to better understand how a mems device and a structure of collagen work?”

Funded with grants from the National Institutes of Health and the National Science Foundation’s Nanoscale Interdisciplinary Research Team, the interdisciplinary project has brought together experts from the fields of engineering, structural mechanics, biology, and chemistry. “No one person is going to be able to make much headway through this without working with others,” adds Ballarini, who has collaborated closely with Steve Eppell, a biomedical engineer at Case Western Reserve University, where Ballarini taught before moving to the University of Minnesota. “The other big factor,” he notes, “is today’s funding landscape, which really encourages multidisciplinary teamwork.”

Although research into the mechanical properties of nanoscale structures is still in its early stages, Ballarini and Eppell have also been investigating the possibility of developing replacements for damaged or broken bone. “Maybe you could insert something near a broken or damaged bone that could act as a temporary repair,” Ballarini explains. “This could take some of the load off the bone as it heals, or create what’s called a scaffold. The idea is that what’s put in there will work as a replacement bone and may even eventually dissolve back into the body after the bone is repaired. So you are actually temporarily replacing bone with something that has similar mechanical properties.”

Ballarini believes that a deeper understanding of how biological structures have adapted to the forces and demands of nature could be of great benefit to structural engineers. “If you look at the data for biological structures, you find that many of them are solutions to problems associated with loads,” he points out. “If you look at a palm tree and how its microstructure has developed, you find that it is a really good solution for a structure that has to bend significantly under heavy winds and hurricanes. If you look at the properties of skin and its fracture toughness, you learn that skin cartilage could be a great model for an elastic hinge. In other words, nature, through evolution, has found architectural solutions that are good responses to certain criteria it has to face every day. And so bone has evolved in this way too. Its structure has developed to tolerate, as best it can, all the things that it encounters day to day."