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## Seeking that extra edge Trek finds it in carbon fiber

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Lance Armstrong is pitting strength, endurance and will-power against rival Jan Ullrich in a bid for a fifth consecutive win in the Tour de France. But beneath the battle of the cyclists is the battle of bike-frame technology.

Armstrong rides a carbon-fiber bike designed and built by Waterloo-based Trek Bicycle Corp. Ullrich is banking on Bianchi's Italian-made aluminum alloy frame. Both materials are super light, but that's about all they have in common.

Weight is the driving force behind bike design, which led to high-end carbon fiber and new aluminum alloys.

"They're all very similar frame weights," said Glenn Daehn, professor of materials science and engineering at Ohio State University, but each has its own unique response.

"In a bike frame you need something that's pretty stiff," said Bruce Pletka, professor of materials science and engineering at **Michigan Technological University** in Houghton. But what really matters is toughness, strength and how many times a material can withstand small stresses before failing, he said.

Aluminum has a reputation for being stiff, which can be hard on the rider over long distances because it doesn't absorb shock very well, Daehn said. But too much springiness in a frame makes the bike less efficient for the rider.

A carbon-fiber frame is stiffer than aluminum but can better absorb the vibrations of the road, said Steve Swenson, a technician at Trek. "It transmits vibration less harshly than aluminum," which translates into a more comfortable ride.

More riders are choosing to enter the Tour de France with carbon-fiber bikes than ever before, said Jim Colegrove, a manufacturing engineer of composites at Trek. Aluminum, though, still remains a popular favorite.

For non-professional riders, evaluating a bike frame involves many factors. Some are technical, and some purely subjective, such as ride quality and feel.

And some are purely financial. A carbon-fiber bike can cost almost 1 1/2 times as much as an aluminum bike with the same components, Swenson said.

For elite cyclists, however, it's all about weight and performance – as well as personal preference.

Armstrong has turned out to be the perfect experimenter

for Trek. When he wants a new bike or has an idea about a new bike, Trek ends up building one the public can buy at the store, Swenson said.

### Long road to composites

Bikes have come a long way from the wooden "bone shakers" of the mid-nineteenth century. In 1870, new metallurgy made possible the first all-metal bicycle, known as the high wheel, which tipped riders headfirst when the bike's large front wheel stopped unexpectedly. Developments a couple of decades later produced the familiar parts that endure today, such as chains and gears.

Tour de France bikes have changed radically in the race's 100 years. In the early 1980s, the era of light bikes began, starting with aluminum models. Aluminum is a handy material of choice, being the most abundant metal in the Earth's crust.

At first glance, carbon fibers – about five times thinner than a human hair – seem unlikely candidates to withstand the grueling demands of the world's best cyclists. "For its weight, it's about the strongest material you can find," said George Sines, professor of materials science and engineering at the University of California-Los Angeles.

"Carbon fiber comes to us in a sheet-like form," said Trek's Colegrove, so areas of the bike that need more strength can be given more layers, for example. "That is some of the beauty of carbon fiber," he said.

Aluminum bikes can be strengthened by a combination of the right alloys and shape, with wide tubes for stiffness that are thicker near joints and thinner in the middle where stresses are weaker.

"Pure aluminum you can bend in your hand," Pletka said, so zinc or magnesium often is mixed in.

Ullrich, the 1997 Tour de France champion, is probably not worrying about the strength of his Bianchi frame as he plans his race strategy, nor should he.

One square millimeter of aluminum wire can suspend 40 kilograms, said Stefano Locatelli, an engineer with

Dedacciai in Italy, which supplies Bianchi. That's like supporting a 12-year-old boy on a wire as thick as the tip of a ballpoint pen. "It means that this aluminum is better than some steel."

What materials will go in to the future Tour de France bikes? No one really knows. "It's constantly evolving," said Marc Muller, design engineer for Waterford Precision Cycles in Wisconsin. "That's what's fun."