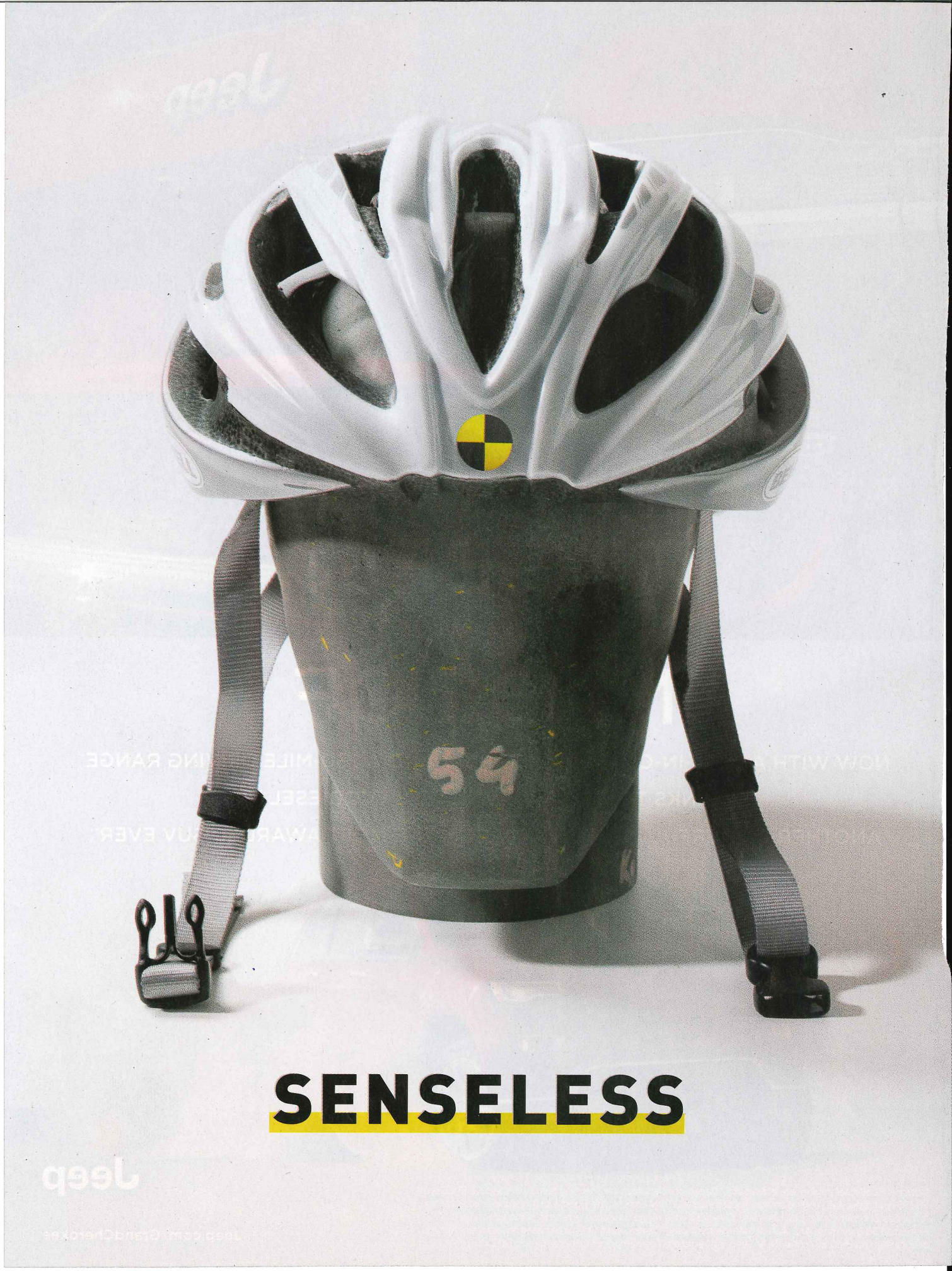

SENSELESS

BY BRUCE BARCOTT
PHOTOGRAPHY BY JONATHAN SPRAGUE

BICYCLE HELMETS DO AN OUTSTANDING JOB OF KEEPING OUR SKULLS INTACT IN A MAJOR CRASH. BUT THEY DO ALMOST NOTHING TO PREVENT CONCUSSIONS AND OTHER SIGNIFICANT BRAIN INJURIES—AND THE VERY GOVERNMENT AGENCY CREATED TO PROTECT US IS PART OF THE PROBLEM. THE TIME HAS COME TO DEMAND SOMETHING SAFER.

About a year ago my 14-year-old daughter needed a new bicycle helmet. Her skull and level of sophistication had both outgrown her old pink flowery one. We paid a visit to the local bike shop. On a far wall our options were stacked five high and 10 wide: multivented Specialized models, slick red and black designs by Giro, brightly colored versions manufactured by Bell. There seemed to be little rhyme or reason to the prices, which ranged from $40 to $120.

"Do any of these provide better protection than the others?" I asked the guy working the floor. "Does price reflect safety?"

I trust the guy working the floor. Over the years he's sold me tubes, tires, lube, shoes, gloves. He knows his merchandise.

"Not really," he said. "They all pass the same certification test." The difference, he told us, is in style, fit, comfort, and ventilation.

That struck me as odd. We live in an age of near-comical product differentiation. You can buy cough syrup in 14 formulas, coffee in dozens of permutations. Yet when it comes to bike helmets, I later learned, we're all wearing decorative versions of the same Model T: a thick foam liner (actually expanded polystyrene, or EPS) attached to a thin plastic outer shell. The basic setup hasn't changed much since the first one was sold in 1975.

That classic design deserves serious plaudits. The $40 helmet is one of the great success stories of the past half-century. Like seat belts, air bags, and smoke detectors, bike helmets save countless lives every year. They do a stellar job of preventing catastrophic skull fractures, plus dings and scrapes from low-hanging tree branches and other common nuisances.

But what about concussions? A friend of mine, Sheilagh Griffin, commutes on her bike and races cyclocross on weekends. During a recent race she had lost control and flown over the bar. Though she'd been wearing a helmet, headaches plagued her for the next few days. Her doctor diagnosed a concussion. Twenty years ago that wasn't such a big deal. It was a shake-it-off injury. You popped two aspirin and saddled up again the next day.

That has changed. Sheilagh's doctor told her to stop racing until the headaches subsided. And then sit out for one or two more weeks, to decrease the odds of a vastly more problematic second concussion.

This is because recent studies of football and hockey players have raised alarming questions about the disabling short- and long-term effects of concussions. President Barack Obama said that if he had a son, he might not let him play football; even some former NFL athletes agree. Cycling isn't immune from that conversation, at any level. Riders fall. Sometimes they hit their heads. In 2011, Belgian star Tom Boonen abandoned the Tour de France after suffering a crash-related concussion in the fifth stage. A few days later a concussion ended the race of Chris Horner, then the reigning Tour of California champion. More than a year after the crash Horner says he retained no memory of the incident.

Standing in the shop, my thoughts turned to my daughter's precious brain. Most of us reflexively strap on helmets assuming they'll protect us. But how well do they actually do the job? I wanted to know if the technology and design of the headwear had kept up with our growing understanding of what goes on inside our skulls. I started asking questions.

Over the past year I toured helmet labs, interviewed brain researchers and government regulators, and pored over dusty volumes in medical archives. What I found was troubling.

STATISTICS DON'T TELL the whole story, but they're a good place to start.

Stat #1: More people are riding. Between 1995 and 2009, the annual number of bike trips in the United States grew by 30 percent, and the number of daily bike commuters grew by 60 percent.

Stat #2: Despite that growth, until recently bicycle-traffic deaths were declining. From 1995 to 1997, an average of 804 cyclists in the United States died every year in motor-vehicle crashes. During an equivalent three-year period from 2008 to 2010, that average fell to 655. The number went up in 2011, but there's evidence that cycling is becoming safer. That's partly a result of more bike lanes and other infrastructure, and partly

OVER THE PAST YEAR I TOURED HELMET LABS, INTERVIEWED BRAIN RESEARCHERS AND GOVERNMENT REGULATORS, AND PORED OVER DUSTY VOLUMES IN MEDICAL ARCHIVES. WHAT I FOUND WAS TROUBLING.

A helmet torture device inside the Dome, testing lab for Easton-Bell.

because more riders make roads safer for cyclists. But at least some of the decline can be attributed to helmet use. By 1999 half of all riders were wearing them—up from just 18 percent eight years earlier—and that figure almost certainly increased as many cities passed mandatory-helmet laws. (No reliable survey on helmet use has been published since 1999.)

Here's the trouble. Stat #3: As more people buckled on helmets, brain injuries also increased. Between 1997 and 2011 the number of bike-related concussions suffered annually by American riders increased by 67 percent, from 9,327 to 15,546, according to the National Electronic Injury Surveillance System, a yearly sampling of hospital emergency rooms conducted by the U.S. Consumer Product Safety Commission (CPSC).

Of course, concussions are more readily diagnosed now than they were 15 years ago. That likely accounts for some of the increase. It's also possible that some of the 149 fewer riders killed every year survived to get lumped into the brain-injury category. But that still leaves thousands unaccounted for. We're left with this stark statistical fact: The concussion rate among bicycle riders has grown faster than the sport.

TO UNDERSTAND THE present-day art and science of head protection, I visited the global epicenter of helmet design. It's tucked away in an office building in Scotts Valley, California. The engineers and designers who work there call it the Dome because that's what they're paid to protect: the head, the skull, the cranium. The dome.

The facility was the brainchild of executives at Easton-Bell Sports. A few years ago the athletic-equipment company brought engineers, designers, lab technicians, and product managers from its helmet brands—Giro (bicycle and snow sports), Bell (bike, snow sports, and motorcycle), Riddell (football), and Easton (baseball, hockey, lacrosse)—together under one roof. The result was a Wonka factory of head protection.

Eric Horton, creative director with Giro, guided me through the Dome. We walked past a dozen industrial designers working out new prototypes in low-walled cubicles. Over here, a cycling time-trial shell. There, an engineer digitally sketched an idea for a new BMX lid.

Horton soon led me into a mechanical symphony: The *whump-whump* pump of pistons stress-testing handlebars, the snap and crack of helmets shattering. I watched a lab technician strap a snowboard helmet onto a metal headform, raise it 6 feet, and drop it onto a steel plate. The smack of impact had a surprising effect on me. Even with no human attached, it was a sickening thud.

FROM PITH TO POC

THE GRADUAL EVOLUTION OF PROTECTIVE HEADGEAR

1880S: PITH HELMET
Meant to cushion the head during a fall from a high-wheeler-style bicycle, the pith offers little protection.

1900 (APPROXIMATE): HAIRNET
Comprised of strips of leather-covered padding, this version shields the head only from some cuts and scrapes.

1939: FOOTBALL HELMET
The Riddell Company designs the first plastic-shelled helmet for football players. The material is brittle but improves on leather models used previously.

1975: BELL BIKER
The company then known for automotive helmets unveils the first head protection for cyclists using the basic design still in use today. MSR releases a similar helmet.

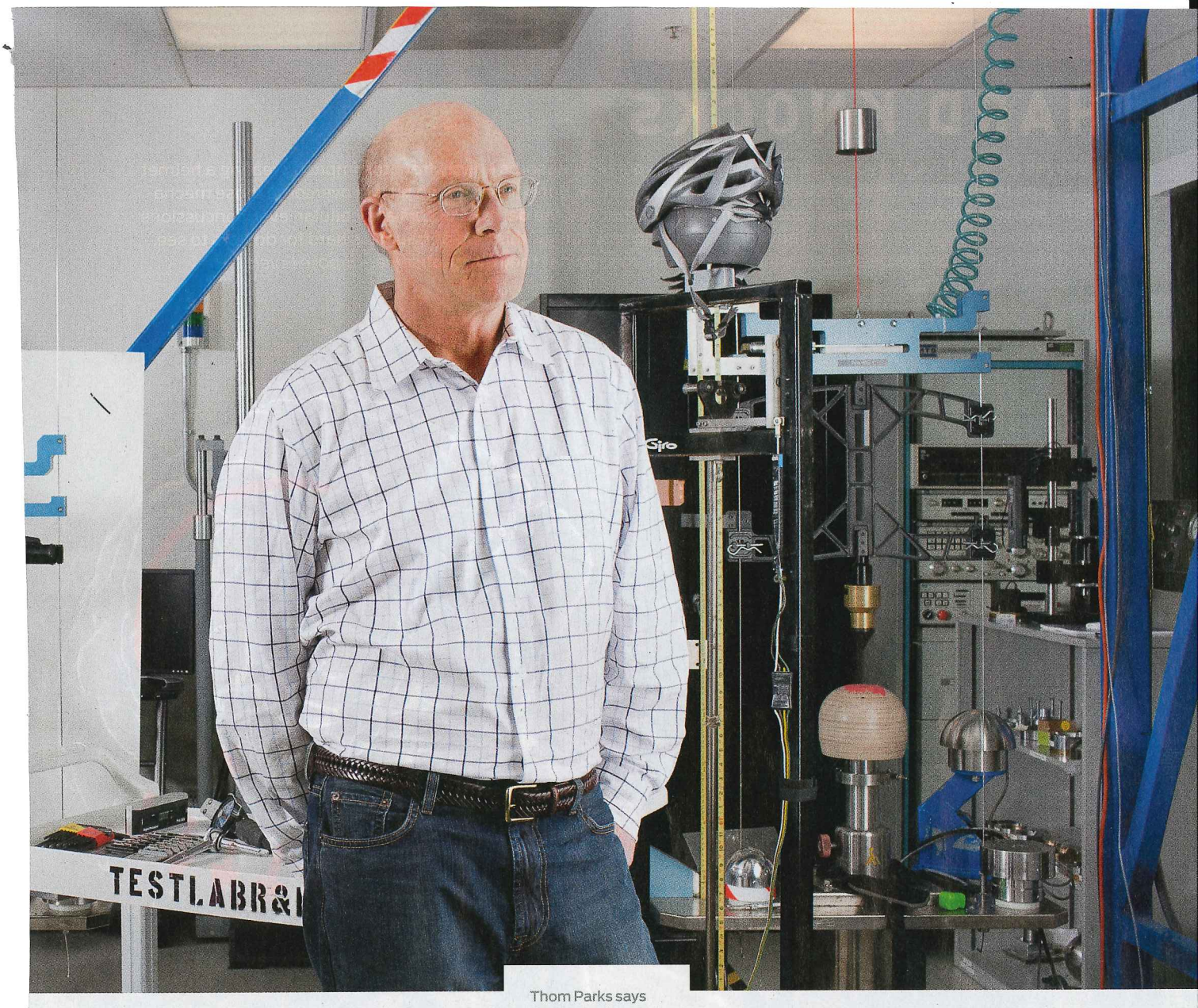
1985: GIRO PROLIGHT
The Prolight is the first helmet to prioritize ventilation while still meeting safety standards. It drives the industry toward lighter headgear with better venting.

1989: BELL MICROSHELL
Bell puts a thin plastic shell over molded EPS to allow the wearer's head to slide over pavement, counteracting foam's tendency to catch on the ground.

2012: POC TRABEC RACE
Swedish company POC is the first manufacturer to include the MIPS system (see p. 64) in a bike helmet—in this case, for mountain biking—in order to reduce concussion risk.

2013: SCOTT LIN
Scott becomes the first U.S. brand to introduce MIPS technology, which adds no size or heft: The Lin actually weighs 29.6 grams less than the similar Grove II.—*Andrew J. Bernstein*

OCEAN/CORBIS; AFP/GETTY IMAGES; COURTESY (X5); THOMAS MACDONALD



Thom Parks says Easton-Bell is pursuing a helmet that reduces the odds of concussion.

It's a sound Thom Parks has heard thousands of times. Parks is vice president for corporate affairs; he's considered one of the wise old heads around the Dome. He's been in the bike industry since 1973. He began working on lids at Specialized in the late '80s and ran the company's helmet division prior to joining Easton-Bell. He walked me through Helmets 101—how they're designed, constructed, tested, and sold. I asked him why the industry still worked with EPS and plastic liners, which have been around for decades.

"We're always looking" for something new, he replied. "That's the holy grail, to find that miracle material. We have projects going right now. Different materials, different blends."

Helmet companies have found it tough to top the reliability of EPS, which molds easily and provides the same impact response, helmet after helmet. Other substances can vary from batch to batch. "We get a lot of people coming to us with great ideas," said Parks. "Sometimes we'll spend crazy amounts of money pursuing new materials. We had a project that came out of Europe a few years ago. We spent hundreds of thousands of dollars trying to make it work. It was close. But it didn't work. In the end it's got to have an actual real-world advantage. And it has to work in the testing lab."

Standards set by the CPSC demand that helmets perform—that is, hold up through the 6-foot drop test—at room temperature and in a variety of extreme conditions. Lids are tested at temperatures as high as 127 degrees Fahrenheit and as low as 1, and after being immersed in water for at least four hours. As years passed, liner materials came along that might have protected the brain better than EPS, especially in common, everyday-type weather. But none could survive the CPSC's extreme environments.

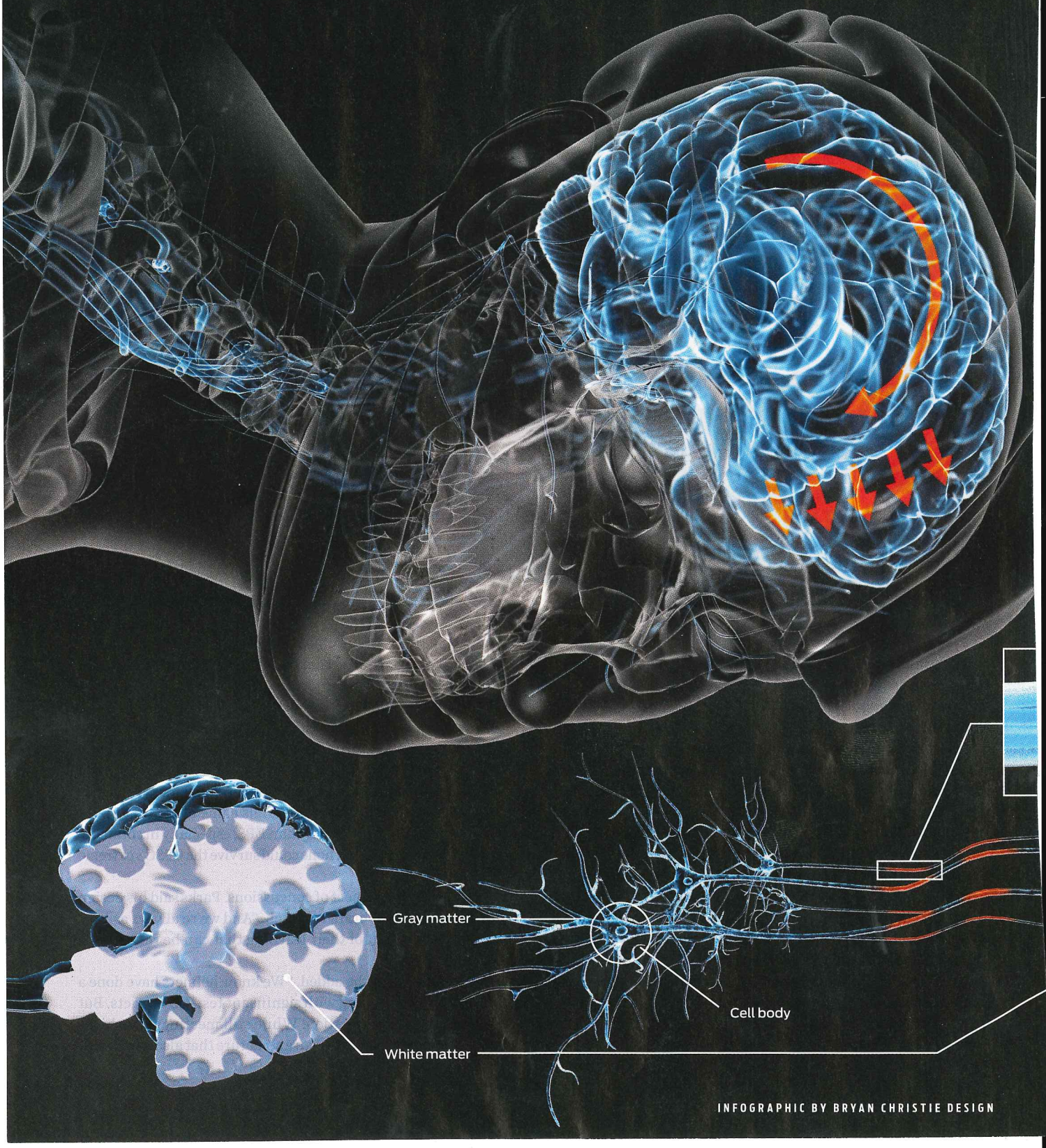
We turned to the subject of concussions. Parks said his design team follows current brain research. "And we're always asking, 'Is there some aspect of their learning that can be reflected in the headgear?'

"The issue is huge," he added. "We know helmets have done a pretty good job of dealing with significant test-lab impacts. But we're also asking the question: While still meeting those high-impact standards, can we design a structure that also works well with low-energy impacts?"

HARD KNOCKS

THE ANATOMY OF A CONCUSSION

If you fall off your bike and your head hits the ground, your skull absorbs energy from the impact. Wearing a helmet helps, and the brain's built-in shock absorbers soften the blow. But a hard enough hit will overcome those mechanisms, causing an injury such as a concussion. Because much of the damage occurs at a cellular level, concussions can be tricky to diagnose; even with advanced scanning technology, this kind of trauma is hard for doctors to see. But if they could peer inside a recently injured cranium, this is what they might observe.—*Brooke Borel*



INFOGRAPHIC BY BRYAN CHRISTIE DESIGN

TAKING A SPIN

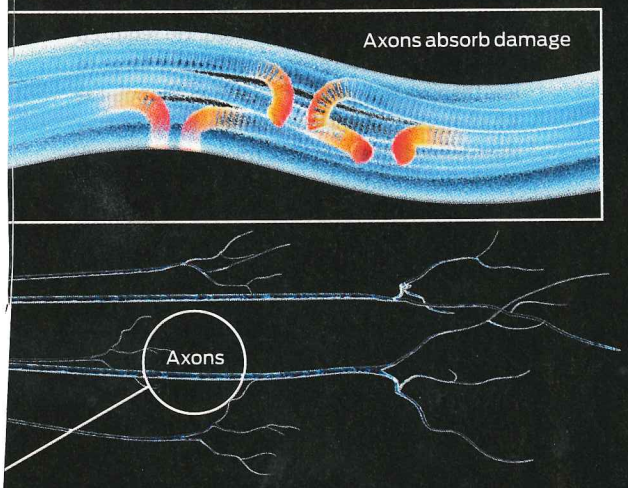
The head doesn't sustain injury from just the direct collision with the road. The brain also has to contend with **rotational acceleration** (indicated by the long orange arrow at left), the shifting action that occurs as the head whips back on the neck. It can result in what's known as shear strain, in which the brain tissue bends or twists. Imagine jerking a plate of Jell-O quickly so it separates, says Liying Zhang, research professor in the biomedical engineering department at Wayne State University who studies head trauma in the NFL.

WHAT'S THE MATTER

The brain is made up of tens of billions of neurons—the cells that process information and send the messages that allow us think and react to the world. The organ has long been described as being composed of "gray matter," but in fact, there is a second kind of tissue: white matter, comprised mostly of axons, the stringy messengers that connect the neurons, allowing the cells to "talk." Because they have different characteristics and consistencies, the two types of tissue react differently to the forces that come into play when a head hits the ground.

COMMUNICATION BREAKDOWN

Zhang and other scientists are still trying to unravel which of the brain deformations that occur in a crash cause which injuries. It's possible that during a concussion some of the long axons may get sheared like a yanked strand of cooked spaghetti breaking in two, disrupting their signals (below). Or cell membranes may rupture as the axons are stretched apart, causing chemicals that are important to neural communication to leak. This cellular damage may cascade across the brain, continuing for days after the injury occurs, and may cause the common and often gradually morphing symptoms of concussion.



IF YOUR RIDING PARTNER FALLS AND TAKES A BLOW TO THE HEAD, HOW DO YOU KNOW IF THERE'S A CONCUSSION? SEE BICYCLING.COM/HELMETS FOR A RUNDOWN OF COMMON SYMPTOMS, AND TO LEARN WHAT YOU SHOULD DO.

THE CONDITION OF HER HELMET ILLUSTRATED THE PROBLEM. THE LINER WAS INTACT—WHICH MEANS THE IMPACT ENERGY WAS ABSORBED BY HER BRAIN.

In other words, helmets are great at softening rare catastrophic blows. But what about more common crashes, the ones that happen at slower speeds but can still result in concussion? Testing those lesser blows, Parks and Horton said, might be as simple as dropping the headform from 3 feet instead of 6. Engineers in the Dome already do a fair amount of that, though it's not required, and Parks is among those pushing to make a low-drop-height test mandatory for bike helmets. Designing a helmet to offer both kinds of protection, however, isn't as easy as you might think.

A bike helmet is designed to spread the energy of an impact over space and time. The hard outer shell works like a shield for the skull and distributes the blow across a larger surface area. By crushing and cracking, the inner EPS liner attenuates impact energy—that is, it extends the hit over a longer period of time. Six milliseconds, say, instead of two. Helmet experts call it "slowing the blow," and it can turn a lethal fall into a survivable one.

The problem is that EPS doesn't absorb much energy unless the impact is forceful enough to make it start to disintegrate. "Think of it like a drinking glass," Parks said. "If you hit it lightly it won't deform at all. But if you hit it hard enough it will shatter. It's not really attenuating any impact energy until it starts deforming and cracking."

Making a helmet that deforms more easily might better protect the brain against smaller falls. But that could undermine the helmet's catastrophic-impact protection.

The post-crash state of my friend Sheilagh's helmet illustrated the problem. "The helmet doesn't appear to be damaged at all," she said. "There's a little dent in the front of the shell, and another one on the back right side."

Those marks indicate that the helmet protected her skull. But the liner remained intact. That means a significant portion of the impact energy was absorbed not by the helmet, but by her brain.

DURING OUR CONVERSATION the Giro designers rolled out their pride and joy, a radical new helmet called the Air Attack. In a departure from today's vent-crazy designs, the model features

closed-cap construction—only four small slit vents.

Mark Cavendish helped to cement the design idea. At the UCI Road World Championships in September 2011, he clapped a rain shield over his vented helmet and beat the field. Whether he actually gained an aero advantage over his competitors—the day was dry—is arguable. But Cavendish's brash move affirmed Giro's plans for a ventless aerodynamic helmet already underway. Months of sketches, wind-tunnel work, and safety testing went into the design.

Rabobank and Garmin-Sharp riders adopted the Air Attack during last year's Tour de France. By late summer, road-bike websites had lit up with gearheads lusting after the helmet, which didn't hit shelves until this spring. The Air Attack perfectly illustrates what drives most helmet innovation: performance. For decades, major helmet manufacturers have competed on styling, comfort, and aerodynamics. Not safety.

After my visit to the Dome I spoke with numerous current and former helmet designers. Many said the same thing. "A lot of the innovation in helmets has been focused on making them lighter, more ventilated, and fit better," said John Thompson, bike helmet product manager for Scott Sports. "The customers leave it to the certifying authority to assure safety."

The certifying authority. That would be the Consumer Product Safety Commission. The federal agency sets out minimum standards to protect consumers against shoddy helmets.

But those testing standards aren't handed down by God on stone tablets. They come from somewhere. Surely someone was keeping track of whether bike helmets were keeping up with medical science.

I decided to find out.

BICYCLE-HELMET STANDARDS were first developed in the 1950s by the Snell Memorial Foundation in Sacramento, California. In August 1956, an amateur auto racer named Pete Snell died in a rollover crash. To honor his memory Snell's friends created a nonprofit dedicated to helmet research. (Snell's leather helmet did not protect his head.) The foundation funded the work of George Snively, MD, a Sacramento physician. Snively tested 16 helmets then on the market and found that all but two were useless.

The key to Snively's method was a test in which he dropped helmets straight down onto a flat anvil and other metal shapes. A metal headform inside the helmet registered the impact. Snively estimated that a naked head struck the surface with a force more than 1,000 times greater than gravity, or 1,000g, which is lethal. He required that a helmet protect the skull by decreasing the impact force to less than 300g, a number well below the point at which researchers believed critical head injury—then defined mainly as skull fracture—occurred.

Thus a standard was born. A helmet that passed Snively's tests could be sold with a Snell Certified sticker, which quickly became the auto-racing and motorcycle-helmet industry's version of the Good Housekeeping seal of approval. In 1972 the foundation issued a standard for "Bicyclist Helmets" that was essentially a one-page modification of the motorcycle and auto-racing benchmarks. The problem was that Snively set the bar too high.

"It would take a motorcycle helmet to pass it, so it was largely ignored," recalls David Thom, a senior forensic consultant at Collision and Injury Dynamics, a forensic engineering firm based in Los Angeles that does independent

MEDICAL RESEARCH ADVANCED. CONCERNS OVER CONCUSSIONS GREW. BUT THE GOVERNMENT SAFETY STANDARD HASN'T BUDGED. SINCE 1999, NOT A SINGLE WORD HAS CHANGED.

HEADWAY

HOW TWO NEW HELMET DESIGNS TAKE AIM AT THE CONCUSSION PROBLEM

SPIN CONTROL *(fig. 1)* A thin layer of viscous liquid separates your brain from your skull, dissipating some of the energy from a fall during impact. Two new helmet systems try to diminish concussion-causing forces by imitating that naturally occurring defense mechanism. The Multidirectional Impact Protection System (MIPS), from Sweden, and the Angular Impact Mitigation (AIM) design, created by Legacy Biomechanics Laboratory in Portland, Oregon, both incorporate an inner and outer shell; in a crash, the outer layer rotates away from the impact, which may reduce the odds of concussion.

EASING THE BLOW *(fig. 2)* Rather than hard-foam liners, which don't offer much protection from slower-speed crashes, an AIM helmet will be made from sliver-thin aluminum strips arranged in a lightweight honeycomb structure. On impact, individual cells compress against one another, like an accordion, to reduce the blow's intensity. On the hardest hits, the structure collapses like a crumple zone in an automobile. Legacy Biomechanics engineers have tested prototypes, and company officials say they hope to sell models priced between $100 and $200 within a year or two.

biomechanical analysis. In 1984, the American National Standards Institute (ANSI) issued a benchmark that bike helmets could actually pass, relying on a variation of the drop test. The Snell Foundation followed with a revised code, as did the American Society for Testing and Materials (ASTM).

Though the standards were voluntary, most major helmet companies adhered to at least one set. And the standards were dynamic. ASTM, ANSI, and Snell officials kept up with biomechanical research and technologies. They continually revised their criteria and forced helmet makers to keep pace.

As helmet use increased in the 1980s, doctors began noting that in cases involving serious crashes, helmeted riders arrived at emergency rooms in better shape than those without helmets. In 1989, *The New England Journal of Medicine* published a study that looked at hundreds of cyclists treated at Seattle-area hospitals. The research team concluded that helmets "reduce the risk of head injury by 85 percent and of brain injury by 88 percent."

Now hold on. If bike helmets reduced the risk of brain injury by 88 percent in 1989, what's the problem, right? Well, they didn't—at least not in the way that sentence indicates. The study's authors conducted more rigorous follow-up research seven years later. They looked at patients who arrived at ERs in seven Seattle-area hospitals after bicycle-related accidents. In that second study, 63 percent of all head-injured cyclists over the age of 39 wore helmets at the time of the crash. More than half of all brain-injured riders (a subset of head-injured riders; think of them as concussed but without a skull fracture) over age 19 wore helmets. And 42 percent of severely brain-injured riders over age 19 wore helmets. So it may be true that helmets *reduced* brain trauma in nearly 90 percent of riders, as that first study contended. But most people read that sentence to mean that helmets *eliminated* it.

That original 1989 study lit a fire under consumer- and child-safety advocates, who launched campaigns to increase helmet use. They lobbied Congress to pass a law requiring manufacturers to heed minimum standards—because it didn't do any good to increase helmet use if the helmets were shoddy. And some were. "Back then you could make anything that would fit on your head and sell it as a bike helmet," says David Thom, the testing expert.

That ended in 1994 when Congress mandated that all bike helmets sold in the United States meet minimum safety standards set by the CPSC. For several years the CPSC held public meetings, read hundreds of comments, investigated the materials and technology involved, and ultimately enacted a rule that was essentially a hybrid of the existing ANSI, Snell, and ASTM standards. The drop test invented in George Snively's garage became federal law.

fig. 1

SPIN CONTROL

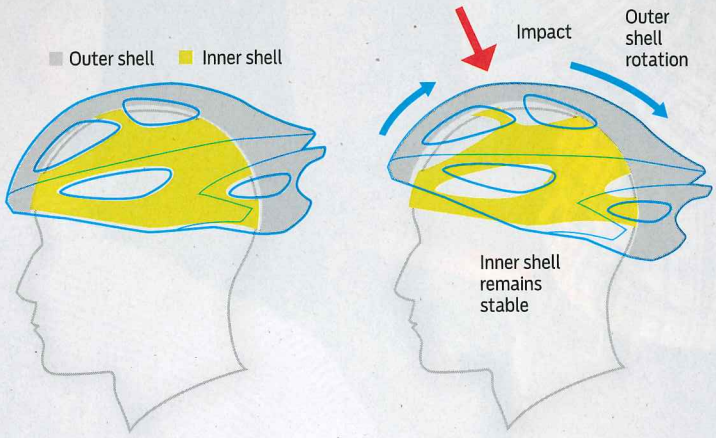
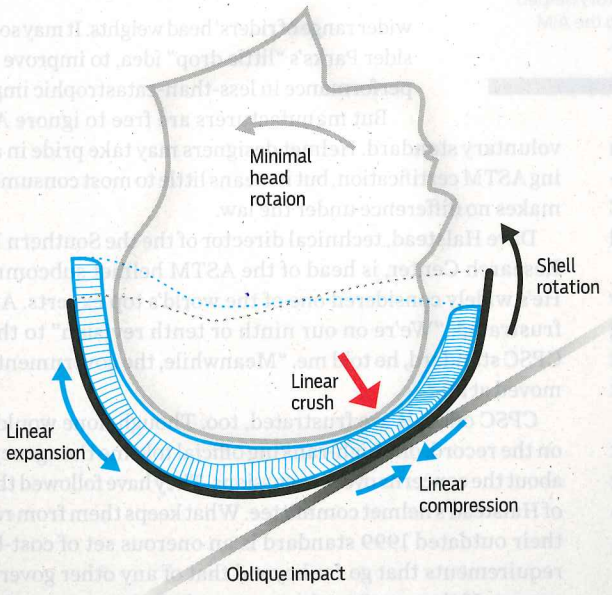
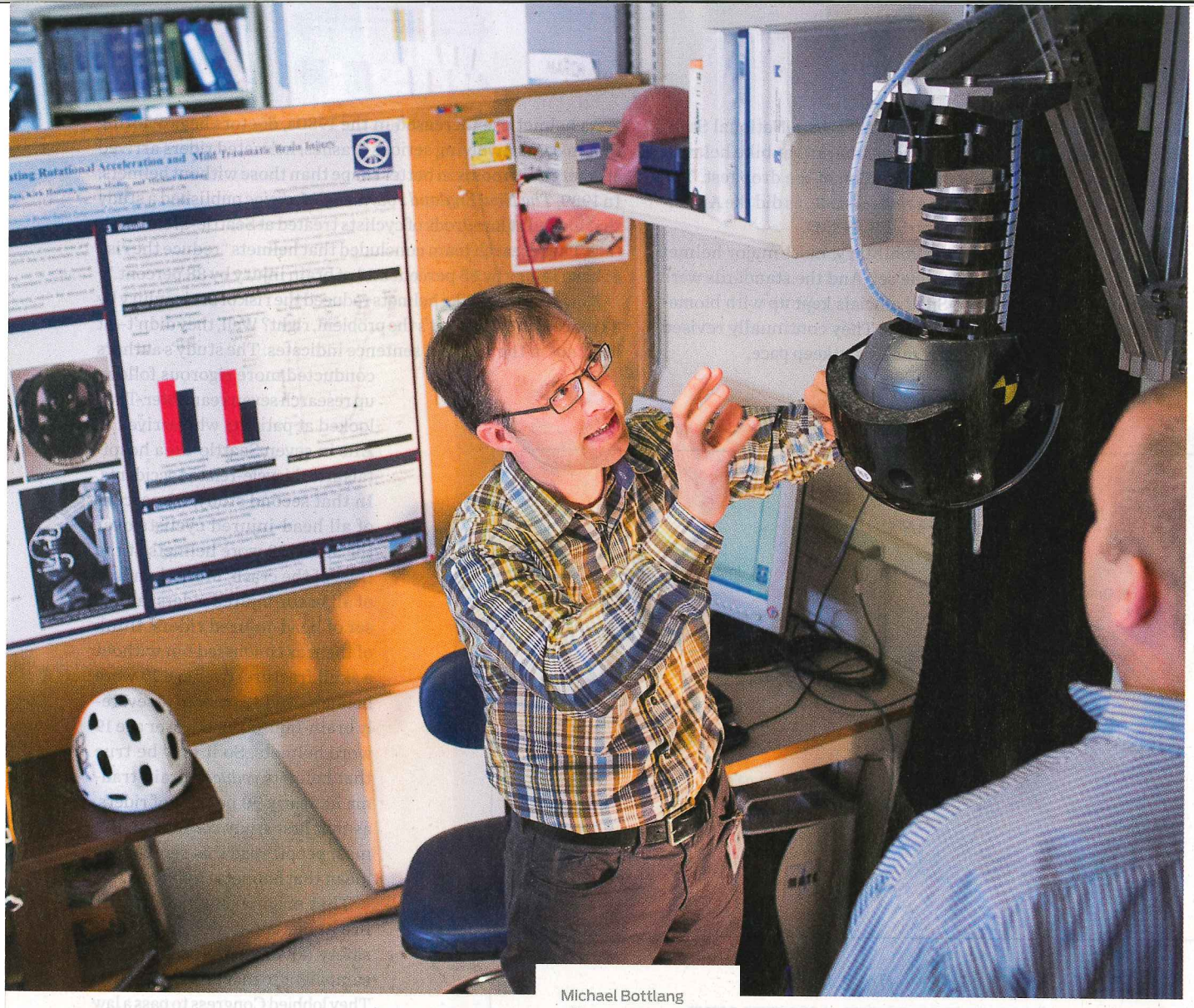


fig. 2

EASING THE BLOW: AIM HELMET



INFOGRAPHIC BY CHARLIE LAYTON



Michael Bottlang of Legacy Biometrics Laboratory helped develop the AIM system.

The CPSC standard took effect in 1999. It swept the garbage off the shelves. For the past 14 years it has been illegal to sell a helmet that hasn't passed the government-mandated drop test.

Then all forward progress halted at the CPSC. Medical research marched on, but helmet makers no longer had to meet the ever-improving ANSI, Snell, or ASTM standards—only the CPSC standard. But that hasn't budged. Since 1999, not a single word has changed.

When I asked helmet designers about safety innovation, they often circled back to the CPSC. "As long as those specific testing circumstances are in place," Travis Youman told me, "you're not going to get any real innovation." Youman managed Trek's helmet division from 2007 to 2009.

ANSI disbanded its helmet committee years ago; Snell hasn't updated its bicycle benchmarks since 1998. But ASTM's helmet subcommittee still meets twice a year. Its members include Easton-Bell's Thom Parks, testing expert David Thom, Snell Foundation executive director Ed Becker, Bicycle Helmet Safety Institute director Randy Swart, and most of the industry's other bold-faced names. That committee recently revised its testing standard to allow for variable-mass headforms, so helmets can better accommodate a wider range of riders' head weights. It may soon consider Parks's "little drop" idea, to improve helmet performance in less-than-catastrophic impacts.

But manufacturers are free to ignore ASTM's voluntary standard. Helmet designers may take pride in achieving ASTM certification, but it means little to most consumers and makes no difference under the law.

Dave Halstead, technical director of the the Southern Impact Research Center, is head of the ASTM helmet subcommittee. He's widely considered one of the world's top experts. And he's frustrated. "We're on our ninth or tenth revision" to the 1999 CPSC standard, he told me. "Meanwhile, the government hasn't moved at all."

CPSC officials are frustrated, too. Though none would speak on the record, one high-ranking official told me the agency knew about the concerns over concussions. They have followed the work of Halstead's helmet committee. What keeps them from revising their outdated 1999 standard is an onerous set of cost-benefit requirements that go far beyond that of any other government agency. If they can't make an overwhelming case to change a rule, it doesn't get touched. The requirement works like this: If an incremental safety improvement results in higher manufacturing

CHARLES GULLUNG

costs, the realized value of the improvement must outweigh those costs. Preventing a theoretical number of concussions—that's an extremely hard dollar value to prove.

In Congressional testimony last year, CPSC commissioner Robert S. Adler said the provisions make rule changes "almost impossible." In the 31 years since the CPSC became subject to those requirements, the agency has promulgated a total of nine new consumer-product-safety rules. Nine.

Congress in recent years has made it easier for the CPSC to swiftly change rules for children's products such as cribs. But nothing else. Table-saw accidents result in more than 4,000 amputations and 40,000 emergency treatments every year. CPSC officials have struggled for eight years to improve the table-saw safety standard, and Adler says his agency is still years away.

The government standard for bike helmets will in all likelihood never change. "With the CPSC, those standards are carved into stone," David Thom told me. "It may take an act of Congress to revise them."

EVEN IF THE CPSC required protective headgear to reduce concussions, could new helmets do the job? That depends on who you ask and which studies you cite.

When George Snively devised the drop test in the 1950s, the medical world thought the brain was a solid organ encased in a hard shell. Severe injuries, it was believed, were caused primarily by the brain rattling against its casing like dice in a box.

Research has since disproved that notion. The brain's gray matter of closely packed neurons (cells that transmit information through electrical and chemical signals) in fact more closely resembles tofu. Those cells communicate via nerve fibers called axons.

If you crash and hit your head, there are two types of impacts. One is known as linear acceleration. That's the impact of skull meeting pavement. Today's helmets do an excellent job of preventing catastrophic injury and death by attenuating that blow.

The second type is known as rotational acceleration. This is where things get tricky. Even if the skull isn't damaged, it still stops short. That causes the brain to rotate—the technical term is inertial spin—which creates shear strain. Imagine a plate of fruit gelatin being jarred so hard that little cuts open throughout the jiggly mass. That strain can damage the axons that carry information between neurons.

There are other factors involved, but research has consistently pointed to rotational acceleration as the biggest single factor in a concussion's severity. The CPSC helmet benchmark is based solely on linear acceleration. There's never been a standards test, required or voluntary, for rotational acceleration.

That disconnect made me wonder. Surely the link between rotational acceleration and concussions must be a recent discovery. To find out, I dug into the University of Washington's health-sciences library. Following a trail of footnotes, I traced the connection back as far as it would go.

It went a long way. In 1962, a team of Michigan State University researchers presented a study at the American College

CONTINUED ON PAGE 110

LOSE THE LID?

SOME ARGUE WE'RE BETTER OFF NOT WEARING HELMETS AT ALL

Laws mandating bicycle-helmet use have sparked a backlash of sorts over the past decade. A loosely connected band of outside-the-box thinkers have coalesced around the contrarian viewpoint that we'd be better served skipping the headgear entirely. Some think helmets are too limited as a safety device, while others just believe it's a bad idea to require people to wear them. Here's a look at some of their arguments.—*Julia Merz*

THEY MAKE MOTORISTS COMPLACENT In 2006, Ian Walker, a psychologist at England's University of Bath, used an ultrasonic sensor to measure the distance between his bike and 2,500 passing cars over the course of two months. Vehicles passed him on average 3.35 inches closer when he wore his helmet. Walker argued that drivers assume cyclists wearing helmets are more experienced and need less space.

THEY INCREASE RISKY RIDING Psychologists Aslak Fyhri and Ross O. Phillips from the Institute of Transport Economics in Oslo, Norway, published a study in January in which they tested the risk-compensation theory: If you trust your helmet to protect you, you'll engage in riskier behavior, like riding faster. The researchers found that cyclists accustomed to wearing helmets rode slower without them. (People unaccustomed to helmets didn't ride any differently after buckling one on.)

THEY SCARE AWAY RIDERS This one gets tricky: The Australia-based organization Helmet Freedom contends that helmets are good, but helmet *laws* are not. Requiring riders to wear helmets (as Australia does) discourages riding by making the sport seem dangerous, the argument goes. The organization cites a survey conducted by University of Sydney professor Chris Rissel in which 23 percent of Sydney adults said they would ride more if helmets were optional.

THEY DIMINISH BIKE-SHARE USAGE Similarly, public officials worry that tying a helmet requirement to a share program will tamp down participation—at a time when cities are expanding cycling initiatives. Mayor Michael Bloomberg recently rejected the idea of requiring lids for New York City's soon-to-launch Citi Bike program (though he still encourages individuals to wear a helmet).

SENSELESS

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of Sports Medicine's annual convention. "It is fairly well established that the extent of skull fracture and severity of concussion are not closely related," they said. Further research, they added, should focus on "developing headgear which would provide greater protection from brain concussion." A decade later, National Institutes of Health (NIH) scientists warned that "existing helmets are not protecting the brain adequately" because their design was based on a paradigm that ignored data on rotational forces. Revising the existing standards was deemed an "urgent task."

The most interesting studies involved, of all things, woodpeckers. In the 1970s, researchers at the University of California at Los Angeles wondered how the birds could *rat-a-tat* all day long without hurting their brains. Their beaks hit with a force of more than 150g. Why wasn't the forest littered with concussed woodpeckers?

Using high-speed film, the UCLA team discovered the woodpecker struck the tree on a perfectly linear trajectory. Between strikes, its glide path forward and back was dead level, which resulted in almost zero head rotation. Woodpeckers, the researchers theorized, sacrificed the greater power they'd get from swinging their beaks in an arc—the way we bang a nail with a hammer—for the brain-protecting value of a straight-line strike.

In light of previous studies, the data led the UCLA researchers to implore the medical community to "discard the magical notion that wearing a helmet on the head is sufficient to protect against impact brain damage."

During that same era, NIH researchers working with monkeys found it impossible to concuss the primates using straight linear acceleration. Meanwhile, every instance of rotational acceleration resulted in concussion. (There's no sugarcoating it: Head-trauma research in those days was gruesome and ethically questionable.)

Further studies in the '80s, '90s, and 2000s linked rotational acceleration to concussions and other brain injuries. But without a standard addressing this phenomenon, helmet manufacturers haven't been forced to adapt their products. A report last year by the International Olympic Committee World Conference on Prevention of Injury and Illness in Sport summed up the state of the art in a sentence: "Little has changed in helmet-safety design during the past 30 years."

In their defense, manufacturers and researchers say they don't have enough information. "We don't know where to set the injury threshold," David Thom told me. In other words, there's no agreed-upon number above which concussion occurs. "That's an area of intense scientific interest right now," he said. "So far nobody's got a standard. We haven't even got agreed-upon test equipment."

That's true up to a point. Researchers have measured rotational acceleration in headforms for decades. The equipment exists. It's partially a chicken-and-egg problem: There's no agreed-upon test because the major manufacturers haven't yet developed a helmet that dampens rotational acceleration. If nobody invents a concussion-reducing helmet, there's no reason to agree upon the standard for testing it.

Legal forces are another significant factor. When athletes hurt their heads, helmet makers sometimes get sued. Sports-concussion lawsuits are so common that a monthly publication, *Concussion Litigation Reporter*, is devoted to the field. Some companies try to skirt the legal thicket by avoiding the C-word altogether. In autumn 2011 Cannondale introduced the Teramo, a bike helmet with dual-density EPS: a layer of softer foam to attenuate low-energy falls along with a tier of harder traditional foam for catastrophic impacts. The word *concussion* appears nowhere in the marketing material.

"There's no such thing as a concussion-proof helmet," Elliot Kaye, the CPSC's deputy chief of staff, told senator Jay Rockefeller during a hearing on concussions last year. Again, the word choice. Kaye said concussion-*proof*, not concussion-*reducing*. Safer doesn't mean safe. It's a fine line, but plenty of lawyers will go after any helmet maker whose marketers so much as mention the word concussion in describing what their product is engineered to do.

And some in the industry contend that helmets should not, or cannot, prevent concussions. Snell Foundation executive director Ed Becker, a respected member of the ASTM helmet subcommittee, told me that Snell helmet standards have always focused on catastrophic impacts. "We haven't really worried about concussion," he said. "We're mostly worried about the single impact that doesn't just concuss but leaves a rider with long-term disability,

or kills him outright."

"If a bicyclist is getting more than one or two concussions a year," he added, "he really needs to take up another activity."

Dave Halstead, ASTM helmet chairman, remains staunchly unconvinced that a new helmet design might significantly reduce concussion risk. "A lot of people think that because people sometimes suffer concussions while wearing helmets, that the helmet didn't do its job," he said.

He believes that, in fact, the problem lies in the way the head is attached to the body. When a rider falls, he said, "the head rotates like the end of a flyswatter, and the shear strain is high enough to break axons in the brain." The only solution, Halstead contended, would be to outfit cyclists with something like the HANS device in NASCAR vehicles, which uses straps to prevent whiplash. "The likelihood of preventing concussions with a better helmet," Halstead said, "is almost zero."

OTHERS DISAGREE. Over the past decade a handful of researchers and engineers have ardently worked on the issue of bike helmets and concussions. They range from a Veterans Administration biomedical engineer in Florida to a well-financed group of inventors associated with Sweden's Karolinska Institute, one of Europe's most prestigious medical universities. There's a striking commonality, though. With one exception, they all come at the problem from a medical perspective.

They believe a better helmet can help prevent concussions. Not all concussions. Some of them. And they believe they have the data to prove it.

In the late 1990s a Swedish neurosurgeon named Hans Von Holst grew weary of seeing helmet-wearing patients who'd suffered brain injuries in bicycle and equestrian accidents. In most cases, the damage had been caused by rotational acceleration. Working with Peter Halldin, a mechanical engineer at Stockholm's Royal Institute of Technology, Von Holst noted that the head has a built-in protection system of sorts—a low-friction layer of cerebrospinal fluid between the brain and the skull. The fluid allows the brain to move a bit; it acts as an energy-absorbing system. Von Holst and Halldin hatched an idea: What if they mimicked that action within a helmet?

That wasn't their only insight. Since the 1950s the drop test has been based on a straight 90-degree impact. But pile-driver drops occur only in professional wrestling and Warner Bros. cartoons. Studies have shown that most bike falls result in an impact angle between 30 and 45 degrees. The Swedish team invented a test rig that examined drops at those more realistic angles.

By 2008, after years of sketching, testing, and prototyping, they had a working model. Their MIPS (Multi-directional Impact Protection System) helmet contained a low-friction slip plate between the head and EPS liner. On impact, the helmet rotates independent of the MIPS liner, absorbing some rotational acceleration.

Their tests indicated this made a difference. Rotational acceleration is measured in radians per second squared, or rad/s^2. According to tests done by the independent lab Biokinetics and Associates, riders wearing conventional bike helmets suffered a 7,000 to 11,000 rad/s^2 brain spin during crashes. (The discrepancy was due to different head positions at impact.) The MIPS helmet brought those numbers down to 6,000 to 8,000 rad/s^2—which doesn't

eliminate concussion risk, but rather reduces it. The technology also reduced linear impact by 10 to 20 percent.

Those are significant numbers. Science doesn't have perfect information about concussions, but in 2004, Wayne State University researchers for the first time pegged risk of concussion to rad/s² data. By replicating the speed and angle of NFL collisions on video, and correlating each hit to the known medical outcome, the researchers found that players had an 80 percent probability of getting a concussion when the collision produced a 7,900 rad/s² spin. At 5,900 rad/s² the odds dropped to 50 percent, and 4,600 rad/s² resulted in a concussion only 25 percent of the time. So bringing rotational acceleration down by a couple thousand rad/s²—to where spin is below the threshold for an almost certain concussion—is a big deal.

As the MIPS engineers fine-tuned their system, a group of inventors in Portland, Oregon, also attacked the problem. Steven Madey is an orthopedic surgeon. Michael Bottlang is a biomedical engineer. Like Von Holst, they were concerned. "More helmet laws had come into effect, but head injuries didn't go down at all," Madey recalled.

Madey and Bottlang have collaborated for more than 15 years. Their Legacy Biomechanics Laboratory is the kind of place where saws, clamps, and chisels hang next to complete human skeletons. They have a proven track record in the field of medical innovation. First responders in 46 countries use their SAM Pelvic Sling to stabilize hip-fracture victims at accident scenes.

They brainstormed the problem. "The question became, What does a conventional helmet do to prevent acceleration of the brain?" Bottlang said.

To get a rough idea of the rotational forces that impact an unprotected head, Legacy Biomechanics biomedical engineer Nate Dau looked to a study done by Wayne State researchers. (The Detroit-area university is a leader in body- and head-impact research because of the field's importance to auto-safety design.) In 2007, scientists there dropped eight human cadaver heads at a speed of 7 miles per hour and measured each brain's rotational acceleration. They averaged about 10,600 rad/s². The standard helmet-drop test happens at twice that velocity. Those forces don't lend themselves to linear extrapolation, but it's safe to say the spin on the brain in a naked head would be well north of 11,000 rad/s².

Using a slightly different testing method than his Swedish counterparts, Dau found that conventional helmets lowered the spin to 9,400 rad/s². (The difference between the Portland and Stockholm data lends credence to David Thom's point about the lack of a uniform standard.) Bottlang and Madey figured they needed a helmet that was capable of absorbing both linear and rotational energy—something that might approximate a crumple zone in a car.

After years of experimenting with different materials, Bottlang and Madey hit upon a potential solution: They built an aluminum honeycomb liner with ultrathin cell walls that replaces the EPS liner. The liner isn't static; it floats slightly between the head and the helmet's hard outer shell. A thin polymer sheath rides between the aluminum liner and the head. During impact, the liner shifts to absorb some of the rotational energy; the honeycomb cells buckle individually to absorb impact energy.

When Dau strapped the prototype AIM (Angular Impact Mitigation) helmet onto a headform, the data came back strong. Spin ranged from 3,400 to 6,200 rad/s². Compared with a conventional helmet, the AIM design lowered the likelihood of concussion from greater than 80 percent to about 50 percent in the worst case, and lower in other crashes. Dau's data didn't predict a concussion-proof helmet—but the numbers indicated the AIM design might be a solid step forward.

HOW DID THESE innovations go over within the establishment helmet industry? They made scarcely a ripple.

The MIPS team, thinking they had invented a revolutionary safety system, shopped their prototypes with the idea of licensing the technology. Few manufacturers were interested.

"Helmet companies had been programmed only to pass U.S. or EU certification," Niklas Steenberg, CEO of MIPS, told me. (The European Union has a helmet standard that is slightly different than the U.S. version.) "We'd created a situation where good protection was available but no one gave a damn about it because you didn't need it to pass certification."

The concern that helmets weren't protecting the brain against concussions, Steenberg said, "wasn't even on the agenda."

Back in 2008, most people were only

beginning to grasp the seriousness of concussions. And there's more nuance here than a frustrated Steenberg conveyed. Big helmet makers devoting enormous time and expense to their products can't easily adapt a radical new technology. Easton-Bell and most other big companies were starting to make preliminary R&D forays into the issue—but behind closed doors, away from the eyes of competitors and attorneys looking for their next class-action lawsuit.

Most helmet designers and marketers are avid cyclists. The entry hall at the Dome is jammed with staffers' bikes. They value their brains and those of their customers. But their customers—from top pros to weekenders—haven't been clamoring for safer helmets, and the unchanging CPSC standards helped to ensure they were never offered one. And the industry's independent safety experts have for years insisted that no helmet can reduce concussion risk. Repeated often enough, that becomes accepted wisdom.

When the MIPS system appeared, those experts dismissed it. "That's not doing anything except taking up space," Dave Halstead told me. "It's a wonderful solution for a problem that does not exist."

Randy Swart, the ASTM helmet subcommittee's co-vice chairman, said he found the MIPS data "just not compelling." He called MIPS "an unproven technology. I think it just adds complexity—and could add to the thickness of the helmets."

In some cases, these assumptions were not true. The MIPS system doesn't make helmets larger or heavier. The idea that the only safer helmet is a bigger helmet has been accepted for so long that it's become an ingrained assumption.

Swart continued his explanation. "You have testing methodologies [for rotational acceleration] that are not accepted by everybody," he said. Which is true. But reliable testing methods do exist. The helmet industry has the ability to strap MIPS and conventional helmets onto headforms and test for rotational forces. "Nobody is really sure what the actual effect in the field is," he said. "The tests we do in the lab today don't duplicate real-life crashes—they never have. But those tests produce helmets that work well in the field."

That's true—if you don't count all the concussions.

AS HE HOPSCOTCHED across Europe and the States, MIPS chief executive Niklas Steenberg found himself giving product pitches that sounded more like neurological seminars. Eventually his message began reaching receptive ears. An equestrian gear company introduced a MIPS-equipped helmet in 2009. The Swedish gear maker POC introduced the first MIPS mountain bike helmet in 2011. That same year, snow-sports equipment manufacturer Burton signed on as well.

It took Steenberg more than four years to convince Scott Sports to take a chance on the system. John Thompson, the company's bike-helmet product manager, started talking with the MIPS team about three years ago. "We noticed when it crept into the equestrian market," Thompson recalled. The more he looked into it, the more he believed all helmets need concussion-dampening systems. But it wasn't an easy call.

Thompson sees his challenge as story and price. He has to convince customers that a MIPS-equipped helmet is safer, despite the fact that all helmets pass the same safety test. "If the customer can't digest that message," he says, "you're adding a system that nobody

will care about."

In late 2012, a third team jumped in. 6D, a company co-created by bike designer Robert Reisinger, recently unveiled a rotation-dampening motorcycle helmet with what it calls "omnidirectional suspension." Reisinger is an engineer who helped develop suspension forks and disc brakes for mountain bikes. His data says that the 6D helmet brings rotational acceleration down to 6,000 rad/s^2, just on the threshold of concussion. "It's suspension for your brain," Reisinger told me. "We're making a helmet to protect riders long-term." The first 6D motorcycle helmet went on sale in February. A bicycle version may follow within a year or two.

The first generation of concussion-dampening bike helmets is now—finally—hitting the shelves. POC's $200 model, Trabec Race, received strong reviews from mountain bikers but sold few models here due to the company's limited U.S. distribution. Scott, a more familiar brand, brought the MIPS-equipped Lin to stores this spring. It costs $120, about $40 more than the company's Groove II helmet, a comparable model without MIPS. An AIM helmet is expected in the next year or so. And the German company Abus has announced plans to market British designer Anirudha Surabhi's Kranium helmet, which replaces the EPS liner with honeycombed cardboard. Surabhi's design has garnered tech-geek buzz, but there's no information about how it mitigates rotational acceleration. It also has yet to pass the CPSC's water-immersion test.

Back in the Dome, the quest for new designs has been a hot topic. Thom Parks and five Easton-Bell colleagues last year attended a symposium on concussions organized by the ASTM's helmet subcommittee. The company has intensified its research efforts in that area, assigning a team to focus specifically on innovative head protection.

As the market leader, Easton-Bell isn't as nimble as a smaller company, but it can marshal great resources. Cyclists can expect something big from the Dome within two to three years, Parks said, but he declined to offer specifics: "Our projects are proprietary, so we can't speak to what's in our innovation pipeline." But he reiterated that any new technology must confer a real-world advantage that's proven in a laboratory. Similar initiatives have already bubbled to the surface from the folks in the Dome. Giro recently unveiled the Combyn, a snow-sports helmet that contains three different densities of vinyl nitrile (VN), an impact-absorbing liner material more commonly found in football and hockey helmets. Giro engineer Rob Wesson indicated that the poly-density VN design "could someday prove useful for bicycling helmet liners," but company officials were leery of saying more. The helmet landscape is so riddled with legal landmines, in fact, that Giro can't even advertise that the Combyn's VN liner is designed and tested to withstand multiple impacts. It's a tough spot: Even when the Dome engineers advance the technology, legal constraints prevent the company from heralding their work as a safety innovation—reinforcing the idea that safety doesn't sell.

There may never be an improved government standard for bicycle helmets. Experts may never come to a consensus on a standard for testing the forces most closely associated with concussions. But one test can be administered now: the market test. After all, new technology costs more. "Adding that upcharge to a $50 helmet," Scott Sports designer John Thompson told me, "is a harder sell."

This is the bike-helmet industry's air-bag moment. The new rotation-dampening systems may not be perfect, but they are the biggest step forward in decades. The choices cyclists make with their money matter. You can pretend to protect your brain, or you can spend more money and get closer to actually doing it.

Back in my local bike shop, my daughter eventually found a pretty and perfectly fitting sky-blue helmet. She went home happy—and for that day, at least, I was content with her choice. Now? Not so much.

A year later, I've replaced all four of my family's snowboard helmets with MIPS-equipped models. The wait for something new we can wear during bike rides is frustrating. Every time I catch a glimpse of my daughter pedaling by, I think about her amazing, priceless brain, and I swear that her lovely blue lid will be the last one of its kind I'll ever buy. B

BICYCLING (ISSN 0006-2073) Vol. 54 No. 5 is published 11 times a year (monthly except bimonthly in January/February) by Rodale Inc., 400 S. 10th St., Emmaus, PA 18098. Periodicals postage paid at Emmaus, PA 18049, and at additional mailing offices. Postmaster: Send address changes to BICYCLING, P.O. Box 26299, Lehigh Valley, PA 18002-6299. In Canada: Postage paid at Gateway, Mississauga, Ontario; Canada Post Publication Mail Agreement Number 40063752. Return any address changes to BICYCLING, 2930 14th Ave., Markham, Ontario L3R 5Z8; GST #R122988611. Copyright by Rodale Inc., 2013. BICYCLING, incorporating *Cyclist* magazine, is published by Rodale Inc. Subscribers: If the postal authorities alert us that your magazine is undeliverable, we have no further obligation unless we receive a corrected address within 18 months.