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BY SALLY HELGESEN

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HUGH HERR WANTS TO BUILD A MORE PERFECT HUMAN

AT MIT'S MEDIA LAB, AN ENGINEER AND BIOPHYSICIST – AND DOUBLE AMPUTEE – IS DESIGNING PROSTHETICS THAT CONNECT BODY AND BRAIN

BY SALLY HELGESEN

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Hugh Herr sits at a table in his austere glass office in the famous Media Lab at the Massachusetts Institute of Technology, scrolling through images of a striking fashion model born without a right forearm. As head of biomechatronics research at MIT and one of the world's leading developers of wearable robotics, Herr is making a point about how disability is becoming obsolete as the boundary between humans and robots vanishes.

The model, Rebekah Marine, strikes a pose on the runway. She wears a black-and-gold braided asymmetrical dress, a forearm of woven mesh that fits like a long evening glove, and a large metal and polymer hand; her outsized finger joints resemble those in a cartoon drawing of a robot. Next up, there's Marine in a bathing suit, tossing a mane of silvery hair that coordinates with a silvery sleeve and hand. Then Marine in a black bodysuit and thigh-high black boots paired with a glistening all-black arm. In each photo, the model's eye-catching costumes are upstaged by her i-limb quantum prosthetic, which features advanced gesture control that mimics human function.

"What you see here is extreme bionics," says Herr. "By that I mean designed constructs that attach to or integrate with neural networks in order to normalize capability." Just as the functional use of advanced augmentations blurs the boundaries between human and machine, disability and function, so the materials and devices Herr and his colleagues design erode the barrier between the natural and the human-made. "We can use living muscle tissue and grown cells, or fabrics like aluminum and polymer. Or we can blend synthetics with biologics," he says. Herr's team at the Media Lab recently made a mechanical fish that swims using living muscle taken from frogs. "The kind of question we have to ask ourselves now is: *What would be more useful here, skin or polymer?* Fit, function, comfort, and aesthetics will dictate our decisions."

A computer scientist, mechanical engineer, and biophysicist, Herr is himself a double amputee. And his immersion in robotics was initially driven by a personal quest to develop superior prosthetics. By analyzing human motion, studying how electronic devices interface with the nervous system, and using live muscles to activate these devices, Herr and his biomechatronics team have created augmentations that respond to ever more subtle neural commands, with vastly improved functionality and fit. Innovations include an artificial knee that adapts to the individual's gait and an ankle–foot exoskeleton for patients suffering from drop foot, a pathology caused by stroke, cerebral palsy, and multiple sclerosis.

Known outside scientific circles for his powerful TED talks and appearances at high-visibility confabs such as SXSW in Austin, Herr, 52, compels attention. Tall and slender, with an athletic build and a quiet demeanor, he strides about the stage on robotic-looking legs of his own design. The system uses a bionic foot and calf system known commercially as the BiOM, which Herr developed and patented. It is the only prosthetic with powered push-off; that is, the calf function in normal walking is replicated because an algorithm in the ankle calculates every step. This push-off gives the wearer the sensation of actually moving his or her leg. The BiOM is sold through BionX, the company Herr spun off from MIT to manufacture and sell his products.

Far from viewing the loss of his own legs below the knee 34 years ago as a tragedy, Herr considers it a kind of fortunate wound that imbued him with an overriding

Photographs by Matthew Septimus

BionX at a Glance

- For-profit corporation spun off from MIT in 2007 as iWalk
- Manufacturing and product development site at company headquarters in Bedford, Mass.
- 49 employees
- 1,300 customers for BiOM prosthetics in U.S., Europe, and Canada
- Product approved for coverage in U.S. by Department of Veterans Affairs, Department of Defense, workers' compensation insurance; pending for Medicare coverage in 2017
- Working to develop a product that will draw information directly from the nerves in the upper leg

sense of purpose: It spurred him to create the foundational science that he hopes will eliminate disability as humanity has known it. In addition to focusing his attention on this goal, the damage sustained by his body has proven useful for testing iterations of what he designs. "I am one of those individuals with unusual bodies and minds who are exploring interventions that will give the gift of augmentation to all humanity," he says.

Herr's sincerity, bolstered by decades of unceasing effort, makes this lofty observation sound thoughtful rather than pompous. And there is precedent for this type of activity: Louis Braille, who as a child was blinded in an accident, developed the eponymous enabling language in the early 19th century. Herr acknowledges that the enhancements he builds raise the kinds of questions — particularly regarding the potential consequences of scientists messing with the natural order — that have haunted humanity since Mary Shelley published *Frankenstein* in 1818. Herr comes down strongly on the side of scientific innovation because he views disability as an insult to nature. In his view, it's an evil, like poverty; humans are called upon to use their God-given intelligence to eradicate it.

In line with this sweeping vision, Herr anticipates that biomechatronics (integrating biology, mechanics, and electronics) and related disciplines will create interventions that counter not only physical but also mental and cognitive disabilities. Innovations will diminish pain without opioids and even address the routine effects of aging, such as the loss of balance. To him, the incorporation of enhanced capability into the human body is the next frontier in scientific discovery, one that builds directly on our growing understanding of how artificial intelligence works.

But the scope of Herr's interests and ambitions takes him beyond the desire to simply redress lost function. He's become an evangelist for the notion that augmentation can also be used to expand capacity for those with intact bodies and functioning minds: wearables that enable human eyes to see infrared waves; tools that permit individuals to design and sculpt their own bodies, either for aesthetic reasons or to enhance athletic or professional performance.

For example, soldiers clunk into battle carrying more than 100 pounds of special equipment, including night vision systems, auditory enhancements, and cumbersome body armor. Directly embedding enhanced function into soldiers' bodies and equipment would make them quicker on their feet and less vulnerable to attack. This is why the U.S. Department of Defense's research arm, the Defense Advanced Research Projects Agency (DARPA), has been aggressively funding further research on wearable robotics that give soldiers an edge in battle as well as addressing the physical and mental debilities that plague so many of those who have served in combat. "This spending creates the competitive environment for extremely rapid advancement," Herr says. "The money is pouring in. As a result, scientists are already doing things that nonscientists still believe are impossible."

Cesar Hidalgo, an MIT and Media Lab colleague, describes Herr's work as "translating what used to be science fiction into tangible products that transform how people experience the world." A physicist known for his work in economic complexity and the author of *Why Information Grows: The Evolution of Order, from Atoms to Economics* (Basic Books, 2015), Hidalgo cites wearable robotics as a prime example of what he calls "crystallized imagination" — packets of information transformed by human knowledge and human know-how into objects that remake industries and shape economic growth. "Hugh's work teaches me that constraints we see as intrinsic are not static and do not define reality," he says. "They can be changed if someone with the imagination to see beyond them is given access to the right team and the right resources."

In fact, Herr does not accept constraints or regard limitations as intrinsic: "When it comes to the human capacity to adapt, I literally do not see boundaries." Not surprisingly, his work is influential among so-called body hackers — the loosely organized grassroots activists who implant electronics (tracking devices, headphones, USB drives, Bluetooth-enabled artificial ears) into their own bodies. It doesn't bother Herr that body hackers' motivation is less rehabilitative than aspirational and transgressive. As the program notes for his SXSW talk on extreme bionics and the future of human identity make clear, Herr sees his own work as "extinguishing the conceptual and social divide between man and machine." But he adds that in doing so, he is less interested in making humans more machine-like than in making machines more human.

Nicholas Negroponte, the architect who cofounded the Media Lab with the humanist engineer Jerome Wiesner and who now serves as chair emeritus, concurs. "Hugh blends the artificial with the natural in ways that blur the crisp line between biological and mechanical," Negroponte says. As a result of this blurring, the work in labs like Herr's easily lends itself to high-flown rhetoric about the definition of *human* in an age of great technological advancement. "We're looking at the death of normalcy — the expansion of what it means to be human into something far more diverse," Herr puts it. He is as much of a technological optimist as Ray Kurzweil, the artificial intelligence pioneer and author of *The Singularity Is Near: When Humans Transcend Biology* (Viking, 2005), who believes that computers will possess human-level intelligence by 2029. But unlike Kurzweil, Herr says his work is inspired by the desire to repair damaged bodies rather than to build conscious machines or to live forever.

The Turning Point

The journey that set Herr into motion began 34 years ago on Mount Washington in the White Mountains of New Hampshire. The tallest peak in the Northeast, Mount Washington is known for extremely cold temperatures and is beset by hurricane-force winds for more than 100 days a year. In January 1982, Herr, a fearless 17-year-old climbing prodigy, was hiking with a 20-year-old friend when they became lost in a wasteland known as the Great Gulf during an extended whiteout. For two nights and three days, they cradled each other in the snow, trying to keep their bodies' temperature up. A rescue team finally managed to find them in the middle of the third night. Airlifted to a local hospital, both hikers had suffered extensive frostbite and would end up losing limbs. Mentally reconstructing the accident later, he remembered he had fallen in the snow when his brain stopped delivering signals to his feet, which had grown completely numb.

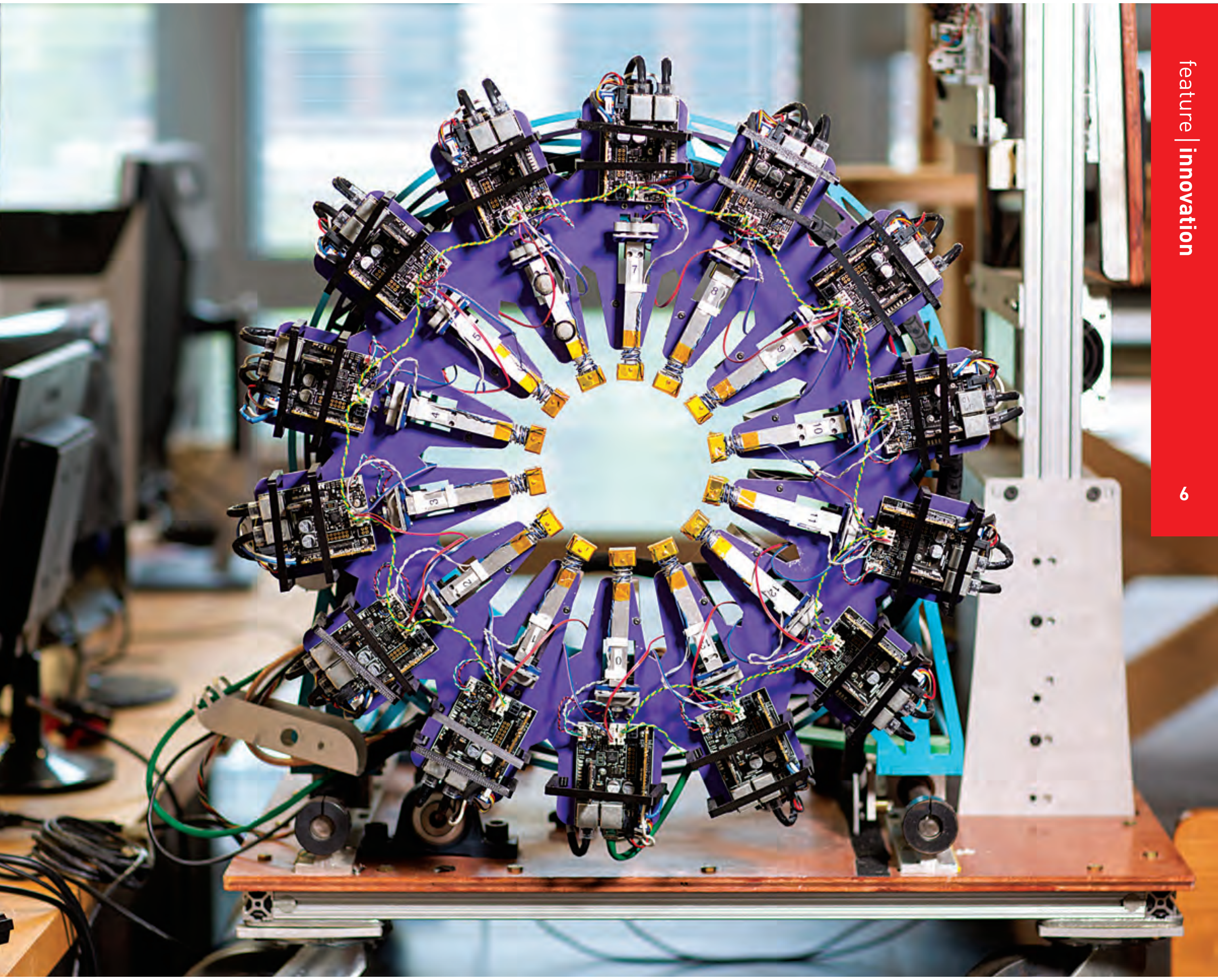
Herr's biographer, Alison Osius, recounts in detail the aftermath of the accident in *Second Ascent: The Story of Hugh Herr* (Stackpole Books, 1991). First in New Hampshire and then in a hospital near his family's home in Lancaster, Pa., Herr endured excruciating pain, multiple surgeries, and successive infections that caused spiking temperatures and system-wide trauma. At one point, he developed an addiction to morphine; when his brother pointed it out, he locked himself in his room and went cold turkey. Still, he was determined to avoid amputation for the simple reason that his primary goal from the moment he regained consciousness was to climb again. To visitors, he spoke of little else.

Climbing had been Herr's obsession since the age of 6. He had fallen in love with it when his family, Mennonites who had lived in eastern Pennsylvania for many generations, drove to Alaska and Canada for a hiking, fishing, and canoeing vacation. Mountains represented challenge, wildness, and adventure while also manifesting what he had been taught in church about the power and majesty of God.

The youngest of five children, Herr idolized his athletic older brothers, who began tearing up summits

HERR DOES NOT ACCEPT CONSTRAINTS AS INTRINSIC: "WHEN IT COMES TO THE HUMAN CAPACITY TO ADAPT, I LITERALLY DO NOT SEE BOUNDARIES."

The MIT FitSocket robot is a critical tool for developing comfortable ways to attach a prosthesis to a specific biological limb. Its 14 actuators gather data about the limb and how it reacts to different forces.



In a corner of Hugh Herr's MIT office, a model shows the mechanics of how a human leg works during running.

and competing to bag ever-higher peaks. Hugh was determined to keep up with them, and his parents, who ran a farm as well as a family contracting business, did not discourage his adventures. "I had great freedom as a child, along with profound discipline," he recalls. "Behaviors and rules were set down but in nature we were free. It was idyllic, like that Robert Redford movie *A River Runs Through It*."

Returning home from their Northwest idyll at the end of summer, the Herr children read mountaineering books; collected gear; and studied mountain safety, weather, and avalanches. They began traveling on weekends to the Shawangunk Mountains, a rock-climbing mecca a few hours away in southern New York state. From the start, Hugh excelled at bouldering, scrambling up massive rocks or sheer cliff faces by finding footholds and handholds among crevices and irregularities. By age 11, he was leading climbs in the region. At 14, he ranked as one of the top amateurs in the world.

Herr loved the mental aspect of climbing, the meticulous problem solving required to figure out exactly where to put each hand and foot and to envision the entire sequence of moves a particular situation would require. His intensity was such that he almost never spoke during trips. "I practiced my concentration, thinking through every one of my moves and memorizing the configurations," he recalls. "I took risks, but was always calculating and analytical."

The catastrophe on Mount Washington did not cool his ardor for climbing. Once he faced the inevitable amputation of both legs below the kneecap, he switched from thinking about how soon his legs would permit him to climb to considering how he might climb despite the loss of his legs. In the rehab facility, he pulled himself from side to side on the window ledge, figuring out how to use his arms in the absence of legs. At home, he did pull-ups on the refrigerator and spent hours scrambling up the side of the family's stone barn, seeking to build upper-body strength. On weekends, Herr's brother Tony carried him piggyback along hiking paths to stony outcrops where he would clamber around using his hands and his stumps. Through it all, he continued and even deepened the habits of thought he had cultivated since he started climbing, bringing his full focus to envisioning every move and to *feeling* each sequence as it ran through his mind — a practice that would prove useful when he later began designing prosthetics.

A few months out of the hospital, Herr was fitted with his first pair of artificial legs, plaster of paris castings that attached with straps to the stumps. When the prosthetist showed him a variety of feet and asked him to choose, Herr said he wanted whatever would fit with climbing shoes. The doctor told him that although he might be able to walk again with canes, he would never be able to climb. But Herr had already decided that the problem lay with the technology, not with him. He just needed to find the right kind of prosthetic. "I am not handicapped; the technology is," he told himself then, as he tells students and colleagues today. "I am dependent on technology, but technology itself is limitless."

Once the stumps stabilized, Herr dispensed with the straps and was fitted with artificial leg sockets. Immediately he began experimenting, gluing bits of rubber and leather into the sockets as padding, trying to make the prosthetics more functional and less painful. Preoccupied with climbing, he also began trying to fashion feet that would suit various climbing situations,

TRUE FUNCTIONALITY REQUIRED PROSTHETICS CAPABLE OF INTERPRETING BRAIN SIGNALS AND INCORPORATING THEM INTO A RANGE OF MOVEMENT.

for example, sculpting a blade that would enable him to secure a foothold on a ledge — a functional improvement on an ordinary human foot.

In high school, Herr had pursued the vocational track in order to devote as much time as possible to climbing. Returning to school in the autumn following his accident, he found a new purpose in these studies. The school shop gave him access to tools and materials he could use to customize his prosthetics and experiment with different kinds of designs.

Herr constantly experienced pain in his nonexistent lower legs and feet. In his dreams, he was always running, but then pain from the effort would awaken him and it would take a few minutes before he realized his legs and feet were missing. Herr soon understood that he was feeling more than phantom pain, a phenomenon that had been well documented long before neural connections between brain and body were understood. No, he was also still able to perceive vibrations through his legs and feet when he mentally shifted them into different positions. In other words, he had phantom *awareness*.

He put this recognition to work in the shop. When crafting a blade foot, he thought through exactly how it would feel set in a climbing hold. When he tried the foot out on an actual rock, he wanted to be able to sense where and how it was placed even when he couldn't see it, so he could position his prosthetics where they belonged by using his brain.

The power and accuracy of his sensations made him realize that the neural connections to his vanished lower legs were still operating — an insight that would prove crucial in his early efforts to design prosthetics and that would shape his distinctive contribution to the field. The acuity of his phantom awareness, intensified by a nearly lifelong practice of mentally deconstructing and feeling through even his most subtle movements, suggested that the thought processes that had made him exceptional remained intact. All he needed was a device capable of connecting his physical responses with what his mind could conceive of doing.

Single-Minded Pursuit

True functionality required prosthetics capable of interpreting brain signals and incorporating them into a range of movement — bionic limbs that used mechanics to support the biology of the human neural system. This insight spurred Herr to two simultaneous realizations. First, shop classes were inadequate for his ambition. Second, he couldn't solve his physical problems if he continued to focus primarily on climbing because it claimed too much of his time and attention. So in 1984, he entered Millersville University, near his hometown, where he studied math and computer science before switching to physics. Although he felt underprepared among students who had a more conventional academic background, he soon found that the obsessiveness he had developed in thinking through his climbs gave him a level of concentration and commitment that most other students lacked.

Meanwhile, as Osius relates, Herr was working with a new prosthetist, Barry Gosthnian in Mechanicsburg, Pa., to address kneecap and tendon problems his prosthetics caused. Together they came up with the idea of developing a cushioning socket that used hydraulics. Drawing on the dynamics of how aircraft use shock-absorbing struts to soften the blow of landing, they worked in Gosthnian's lab to adapt the technique to artificial joints. At a machine shop in New Jersey owned by the father of a girlfriend, Herr also experimented with materials that he thought might improve prosthetic function. He tested polyurethanes and various adhesives and developed an inflatable bladder. He and Gosthnian then incorporated these elements into their prosthetic designs, making constant adjustments as they observed how different levels of pressure caused

THE CYBORG FUTURE IS WHERE ADVANCES IN ARTIFICIAL INTELLIGENCE ARE LEADING, AND WORK LIKE HERR'S IS THE ENTRY POINT.

different reactions. The creative aspect of this work fired his imagination. "In climbing, you're only creating your sequence," he notes, "but when you're building something like this, you're basically creating everything."

Gosthnian viewed Herr's capacity to do field research on himself as invaluable for their efforts. "You needed someone with heightened analytical skills, who could feel through the various iterations," Gosthnian told Herr's biographer. What's more, such finely calibrated experimental work required "someone willing to take constant risks." Herr took time off from school at various points to refine the prototype of their socket, on which he and Gosthnian would secure a patent in 1990.

Shortly before the patent was attained, Herr asked an engineer what would happen when the new socket appeared on the market. "When that happens," he was told, "thousands of people will start wearing it and giving input. New problems will come up, and then other people will start trying to do it better." Thus began Herr's education in the commerce of science.

The education would continue at MIT's Department of Mechanical Engineering. While he was considering graduate schools, Herr was given a personal tour of the Newman Laboratory for Biomechanics and Human Rehabilitation at MIT by Woodie Flowers, now professor emeritus. Flowers was a pioneer in using digital technologies to improve prosthetics as well as a robotics enthusiast who ran a competition (carried on public television for many years) to build robots capable of accomplishing specific tasks.

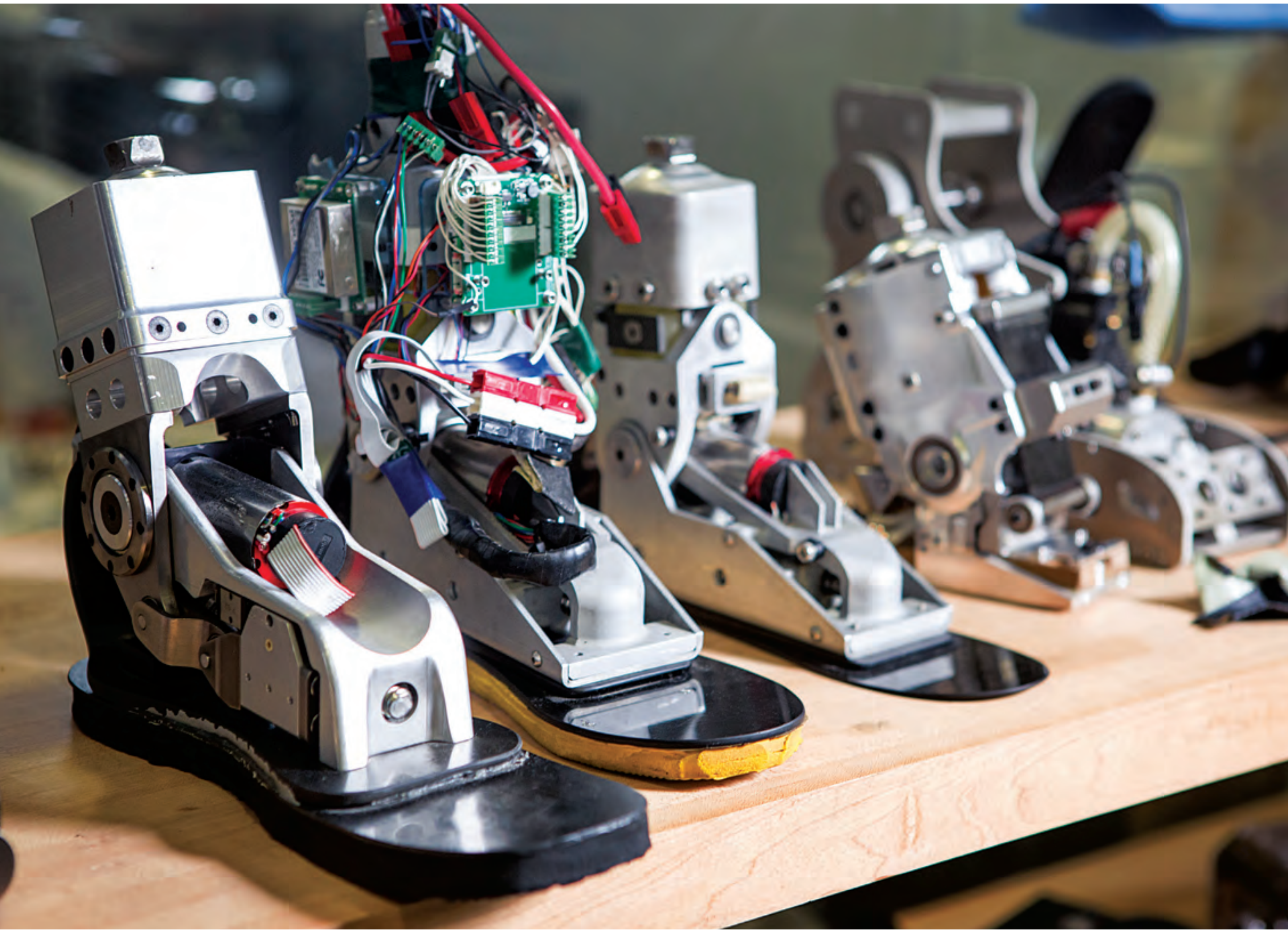
Cambridge, Mass., which is anchored by two poles in the pursuit of different types of knowledge — the physical world at MIT and the metaphysical world at Harvard University — proved a congenial home for Herr, who earned a master's degree in mechanical engineering at MIT and a Ph.D. in biophysics from Harvard. In 1990, he married Patricia Ellis, a writer studying anthropology at Harvard. They have two young daughters, with whom Ellis is committed to hiking New Hampshire's 48 tallest peaks, which would of course include Mount Washington. Herr, who continues to climb, rarely joins them on the trail, but says he is delighted his daughters have come to love the mountains and is gratified they can experience the freedom in nature he knew as a child.

Our Future among the Robots

Across the hall from Herr's glass-walled office is the vast third-floor lounge where Media Lab students pound away on laptops amid banners printed with MIT's version of aspirational slogans, such as *Seamlessly coupling the worlds of bits and atoms by giving dynamic physical form to digital information and computation*. Course offerings advertised include the seminar Human 2.0, for which Herr delivers regular lectures. It's not surprising that a discipline such as biomechatronics should be housed at the Media Lab, which has been at the frontier of human–machine research since its establishment in 1985.

Negroponte, the cofounder, observes that the Media Lab's "mission has evolved over the years into being a global salon des refusés: a place to come when you are an academic misfit, polyglot, or anti-disciplinarian. Even an institute as fluid, collaborative, and interconnected as MIT has white spaces that fall outside the traditions of science, engineering, and the arts. If you inhabit such a space — and Hugh does — you belong at the Media Lab."

Synthetic ankle–foot machines fill laboratory shelves in an MIT workshop where the Biomechatronics Group designs, builds, and tests bionic appendages.



The Media Lab, Herr's base and creative home since the early 1990s, has given him the resources — the materials, the technology, the researchers, and above all the freedom — to pursue his overarching vision of a world in which disability no longer exists. That banner about bits and atoms sums up the essence of his quest: to incarnate digital information in order to enhance human capacity. Herr says, "What we are capable of imagining, we are capable of designing. As our brains evolve, our imaginations do too, expanding the possibilities. In my view, this pursuit is holy."

Herr projects intense engagement with his subject and minimal interest in that which does not touch the core of his work. *Messianic* is too strong a word to describe a man with his gentle presence. Yet his passion and energy make him an evangelist for a vision of the future that, although inspiring in its particulars, remains unsettling in what it might portend: a world in which robots do not simply perform tasks that were formerly done by humans, but also assume human functions via their incorporation into living human tissue and capacity to make use of neural networks.

This cyborg future is where advances in artificial intelligence are leading, and work like Herr's is the entry point — a kind of Trojan horse to some — whereby humans willingly collaborate in their own evolution. Many people, mostly non-scientists, remain queasy about such potential enhancements as gene editing, brain chip implants, and synthetic blood; in a 2016 Pew Research Center survey, between 65 and 70 percent described themselves as worried about such enhancements despite their potential for improving and even saving lives. Patrick Lin, a philosopher at California Polytechnic State University who consults on the ethics of robot development for the U.S. military and private companies, notes that implants raise serious ethical issues in part because technology is constantly evolving, but also because advanced implants could cause germ-line (cellular) change that could be passed onto offspring.

For Herr, this scenario is not frightening. "I'm turned on by the notion of human improvement," he says. "The attraction to what lies at the frontier is inherent in humans, inherent in our DNA.… That's how our brains evolve. This is just the next stage in our human evolution."

He insists that his enthusiasm for this future does not blind him to its potential dangers, saying, "The dangers emerge when individuals lose control, when they don't have the power to choose their own improvements. If an all-powerful interest — private or public, commercial or governmental — mandates interventions, that's when we get into a *Brave New World* scenario."

Herr believes that finding ways to avoid potential abuses will consume policymakers in the immediate future, and he advocates for global standards that favor biodiversity. Just as computer engineers helped set the protocols that made the evolution of the Internet possible and have kept it relatively benign, Herr foresees his fellow researchers taking the lead in advising the global institutions tasked with preventing abuses that could arise from augmentation and bionic design.

Herr's creative life reveals a fascination with superhuman function, but he views the very concept of being superhuman as provisional. "What we see as superhuman today will be normal 100 years from now, as technology catches up with our imaginations," he says. His own imagination, disciplined over a lifetime by fierce intention and total immersion in whatever has most engaged him, demonstrates a level of commitment that might also be called superhuman. "But when does creative achievement *not* involve superhuman effort?" he asks.

Reassessing Purity

Before his accident on Mount Washington, Herr had been a climbing purist. For him, the culture of climbing, the essence of its appeal, lay in the unmediated experience of a human being in nature testing his or her limits. *Real* climbers — like his idol Reinhold Messner, who ascended Mount Everest without supplemental oxygen and regarded the expeditionary style of ascent traditional in the Himalayas as disrespectful of the mountains and nature — disdained heavy equipment and all external help.

Herr's accident shattered this vision. He found it psychologically wounding to need a rescue, especially because it put the volunteer team at great risk (one of the rescuers died during the search). In addition, his return to climbing required complex technologies that he quickly began adapting to provide himself with advantages such as wedge feet and extended calves. The paradoxical aspect of this shift in perspective was not lost upon him. In particular, his passionate commitment to extending the gift of augmentation to those who want, as opposed to need, it has landed him on the other side of the spectrum from the purist ethic to which he once adhered.

Herr is at peace with the change. In his view, his personal evolution reflects a more general evolutionary push by humans to adapt technology to enhance their experience of the world. He anticipates that the work he is doing today will lead to a world in which "the designer will design herself," and views this as an advance for humanity. Researchers such as Herr are "enlarging the palette with which we will all create our own identities in the future."

Herr does in fact actively engage with some of the real-world dilemmas that his research creates. For example, he served on the team of experts who researched whether South African track prodigy Oscar Pistorius should be banned from running in able-bodied events because his prosthetics gave him an advantage. Herr

Mannequins wearing bionic appendages on display in the offices of the MIT Biomechatronics Group

and a colleague presented their findings in an international arbitration court, resulting in the reversal of a ban on disabled athletes competing in able-bodied Olympic events. (Pistorius's career was effectively ended in December 2015, when he was convicted of killing his girlfriend.) More recently, he headed a team that developed a prosthetic for Adrianne Haslet, a professional ballroom dancer who lost a leg in the 2013 Boston Marathon bombing. Not only has Haslet been able to continue to dance competitively, she also completed the Boston Marathon in 2016.

Herr has been a passionate advocate for soldiers with disabilities and has worked hard to ensure that advanced prosthetics are eligible for VA benefits. BionX, the company he founded, has a continuing relationship with SoldierStrong, a nonprofit that makes its BiOM available to amputee vets who may otherwise be ineligible for it; about 50 percent of all BiOMs are used by severely injured soldiers. Dr. Charles Carignan, CEO of BionX, says, "Hugh's work, both with the BiOM and with a powered orthotic we and his lab are developing, provides a standard of care on par with the fully enabled. BiOM gives people the ability to walk on their own, which restores independence. The psychological and emotional benefits of this autonomy are significant, especially for soldiers who have been traumatized."

The complexity and ubiquity of today's technology make the notions of purity that Herr once cherished ever harder to sustain. As tool-using animals, humans have continually reshaped their neural connections by performing repetitive actions required to employ the objects they have made. Humans' evolutionary path has thus been modified and continually reshaped by what they themselves create. "Artificial intelligence is always a product of distributed knowledge," MIT's Hidalgo notes. "It is another tool we are using to reshape ourselves, our potential, and our lives."

Herr does not view his own participation in this process as in any way profane, or a contradiction of the purity of the natural order. "The Bible tells us, 'blessed are those who believe without seeing.' People who believe without seeing create new ideas and mechanisms, so I believe creative action is blessed. We humans have been given this power. Our universe is not fixed and it is not inscrutable. It will become more comprehensible as we extend our knowledge. What people now consider mysterious, even magic, will be understood." +

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Resources

Cary Funk, Brian Kennedy, and Elizabeth Podrebarac Sciupac, "U.S. Public Wary of Biomedical Technologies to 'Enhance' Human Capabilities," Pew Research Center, 2016: A comprehensive study gauging people's views on issues such as gene editing and brain implants.

Patricia Ellis Herr, *Up: A Mother and Daughter's Peakbagging Adventure* (Broadway, 2012): A memoir by Hugh Herr's wife of her experiences hiking New Hampshire's 48 highest mountains with her young daughter, Alex.

Alison Osius, *Second Ascent: The Story of Hugh Herr* (Stackpole Books, 1991): The harrowing tale of Herr's injury and recovery, written by a former editor of *Climbing* magazine.

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