SCIENCE

Answers when the questions hide in plain sight

His unfettered curiosity leads a scientist into odd corners of the natural world

BY JAMES GORMAN

David Hu was changing his infant son's diaper when he got the idea for a study that eventually won him the Ig Nobel Prize. No, not the Nobel Prize — the Ig Nobel Prize, which bills itself as a reward for "achievements that make people laugh, then think."

As male infants will do, his son urinated all over the front of Dr. Hu's shirt, for a full 21 seconds. Yes, he counted off the time, because for him curiosity trumps irritation.

That was a long time for a small baby, he thought. How long did it take an adult to empty his bladder? He timed himself. Twenty-three seconds: "Wow, I thought, my son urinates like a real man already."

He recounts all of this without a trace of embarrassment, in person and in "How to Walk on Water and Climb Up Walls: Animal Movements and the Robotics of the Future," just published, in which he describes both the silliness and profundity of his brand of research.

No one who knows Dr. Hu, 39, would be surprised by this story. His family, friends, the animals around him — all inspire research questions.

His wife, Jia Fan, is a marketing researcher and senior data scientist at UPS, the shipping company. When they met, she had a dog, and he became intrigued by how it shook itself dry. So he set out to understand that process.

Now, he and his son and daughter sometimes bring home some sort of dead animal from a walk or a run. The roadkill goes into the freezer, where Dr. Hu used to keep frozen rats for his several snakes. "My first reaction is not, oh, it's gross," Dr. Fan said. "It's 'Do we have space in our freezer?'"

Dr. Hu also saves earwax and teeth from his children, and lice and lice eggs from the inevitable schoolchild hair infestations.

"I would describe him as an iconoclast," Dr. Fan said, laughing. "He doesn't follow the social norms."

Dr. Hu's curiosity has led him to investigations of eyelashes and fire ants, water striders and horse tails, frog tongues and snakes.

He is a mathematician who studies animals at the engineering department of Georgia Tech in Atlanta. His seemingly oddball work has drawn both the ire of grandstanding senators and the full-throated support of at least one person in charge of awarding grants from that bastion of frivolity, the United States Army.

"VAGARIES OF THE REAL WORLD"

Long before his role in the Brett Kavanaugh confirmation hearing, Senator Jeff Flake, Republican of Arizona, put three of Dr. Hu's research projects on a list of the 20 most wasteful federally funded scientific studies. The television show "Fox and Friends" featured Senator Flake's critique.

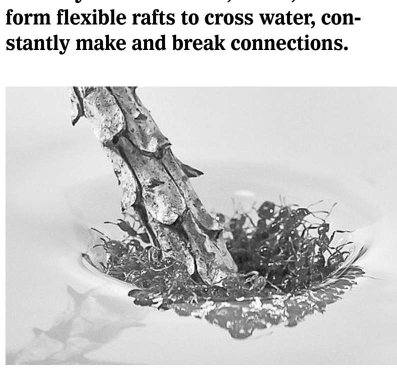
Naturally, Dr. Hu made the attack on his work the basis for a TEDx talk at Emory University, also in Atlanta, in which he took a bow for being "the country's most wasteful scientist" and went on to argue that Senator Flake completely misunderstood the nature of basic science.

Dr. Hu was tickled to think that one scientist could be responsible for such supposed squandering of the public's money. Neither he nor his supporters were deterred.

Among those supporters is Samuel C. Stanton, a program manager at the Army Research Office, which funded Dr. Hu's research on whether fire ants are a fluid or a solid. (More on that and the urination findings later.)

MELISSA GOLDEN FOR THE NEW YORK TIMES

David Hu's research in mechanical engineering tests the boundary between the silly and the profound — How does a frog flick its tongue? Among his findings: The ideal length for eyelashes of a mammal like a sheep, right, is one-third the width of the eyeball. Fire ants, below, which form flexible rafts to cross water, constantly make and break connections.



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Dr. Stanton does not share Dr. Hu's flippant irreverence.

He speaks earnestly of the areas of science to which he directs Army money, including "nonequilibrium information physics, embodied learning and control, and nonlinear waves and lattices."

So he is completely serious when he describes Dr. Hu as a scientist of "profound courage and integrity" who "goes where his curiosity leads him."

Dr. Hu has "an uncanny ability to identify and follow through on scientific questions that are hidden in plain sight," Dr. Stanton said.

When it comes to physics, the Army and Dr. Hu have a deep affinity. They both operate at human scale in the world outside the lab, where conditions are often wet, muddy or otherwise difficult.

In understanding how physics operates in such conditions, Dr. Stanton explained, "the vagaries of the real world really come to play in an interesting way."

Besides, Dr. Stanton said, the Army is not, as some people might imagine, always "looking for a widget or something to go on a tank." It is interested in fundamental insights and original thinkers. And the strictures of the hunt for grants and tenure in science can act against creativity.

Sometimes, Dr. Stanton said, part of his job is persuading academic scientists "to lower their inhibitions."

Needless to say, with Dr. Hu that has not really been an issue.

AN ASPIRING DOCTOR IS LED ASTRAY

"Applied mathematicians have always been kind of playful," Dr. Hu said recently while talking about his academic background — although most of them are not quite as playful as he can be.

A few years ago he did gymnastic flips onto the stage of a Chinese game show that sometimes showcases scientists.

He grew up in Bethesda, Md., a suburb of Washington, and while he was still in high school he did his first published work on the strength of metals that had been made porous. He was a semifinalist for the Westinghouse Science Prize (the forerunner of the Intel Science Prize) and won several other awards.

That work helped him get into the Massachusetts Institute of Technology, which he entered as a pre-med student planning to get an M.D./Ph.D.

He was soon led astray.

Dr. Hu's undergraduate adviser at M.I.T. was Lakshminarayanan Mahadevan, a mathematician who works to describe real-life processes in rigorous mathematical terms.

Dr. Mahadevan, known to students and colleagues as Maha, investigated wrinkling, for example. Naturally he won an Ig Nobel for that work.

"Maha lit the fire," Dr. Hu said. Before he encountered his adviser's research, he said, "It didn't really make sense that you could make a living just playing with things."

But he came to see the possibilities.

He stayed at M.I.T. for graduate work in the lab of his adviser, John Bush, a geophysicist. Dr. Bush remembers him as very enthusiastic.

Asked by email about some of Dr. Hu's wilder forays into the physics of everyday life, he said, "A sense of playfulness is certainly a good thing in science, especially for reaching a broader audience." But, he said, "targeting silly problems is not a good strategy, and I know that David has taken considerable flak for it."

Dr. Hu may be the first third-generation (in terms of scientific pedigree) Ig Nobel winner, because Dr. Mahadevan studied under Joseph Keller, a mathematician at Stanford University. Dr. Keller won two Ig Nobels. One was for studying why ponytails swing from side-to-side, rather than up and down, when the ponytail owner is jogging. The other was an examination of why teapots dribble.

FROM ANTS TO ROBOTS

Dr. Hu's research may seem like pure fun, but much of it is built on the idea that how animals move and function can provide inspiration for engineers designing objects or systems.

The title of Dr. Hu's book refers to the "robots of the future," and he emphasizes the way animal motion offers insights that can be applied to engineering — bio-inspired design.

When the Pantanal wetlands of Brazil flood, for instance, fire ants form rafts so tightly interlaced that water doesn't penetrate their mass.

When he picked up such a mass in the lab, Dr. Hu writes, it felt like a pile of salad greens.

"The raft was springy, and if I squeezed it down to a fraction of its height, it recoiled back to its original shape. If I pulled it apart, it stretched like cheese on a pizza."

He found out that the ants were constantly moving even though the shape of the mass stayed more or less the same. They were breaking and making connections all the time, and they became, in essence, a "self-healing" material.

The idea is appealing for many engineering applications, including concrete that mends itself and robots that self-assemble into large, complex structures. Depending on the force applied to them, a mass of a hundred thousand ants or so can form a ball or a tower, or flow like a liquid.

He and students in his lab also showed that the reason mosquitoes don't get bombed out of the air by water droplets in a rainstorm is that they are so light that the air disturbed by a falling drop of water blows the mosquitoes aside.

The finding could have applications for tiny drones.

They also showed that the ideal length for a row of mammalian eyelashes is one-third the width of an eyeball. That gives just the right windbreak to keep blowing air from drying out the surface of the eye.

Artificial membranes could use some kind of artificial eyelashes.

And what about urination? It didn't make sense to Dr. Hu that a grown man and an infant would have roughly the same urination time.

He and students in his lab showed that mosquitoes are so light that the air disturbed by a drop of rain blows them aside.

After he sent out undergraduates, under the guidance of Patricia Yang, a graduate student, to time urination in all the animals at the Atlanta Zoo, the situation became even more puzzling. Most mammals took 10 to 30 seconds, with an average of 21 seconds. (Small animals do things differently.)

The key was the urethra, essentially a pipe out of the bladder, which enhances the effect of gravity. Even a small amount of fluid in a narrow pipe can develop high pressure, with astonishing effects.

Water poured through a narrow pipe into a large wooden barrel can split the barrel.

Dr. Hu said the experiment, known as Pascal's barrel, can be replicated nowadays with Tupperware.

What is interesting about the urethra biologically is that its proportions, length to diameter, stay roughly the same no matter the size of the animal, as long as it weighs more than about six and a half pounds.

The 21-second average urination time must be evolutionarily important. Perhaps any longer would attract predators? But then predators are subject to the same rule. In any case, the principle of how to effectively drain a container of fluid could be useful, Dr. Hu wrote in the original studies, to designers of "water towers, water backpacks and storage containers."

As usual, in his book Dr. Hu does not neglect the human side of his work or treat it too seriously. He refers to the urethra as a pee-pee pipe. And he corrects his son when he brags that only he, not his sister, has a pee-pee pipe.

Not so, Dr. Hu insists. The urethra is present in males and females.

Once older, his children may never forgive him for this book. But middle school science teachers and nerds everywhere will thank him.

Electric implant helps 3 partly paralyzed men walk again

BY BENEDICT CAREY

David Mzee broke his neck in 2010. He was a college student in Zurich at the time, an athlete who enjoyed risk and contact, and he flipped off a trampoline and onto a foam pad. "The foam pad — it didn't do its job," he said.

Mr. Mzee, now 33, is one of three men who lost the use of their legs years ago after severe spinal injuries, but who now are able to walk without support, if briefly and awkwardly, with the help of a pacemaker-like implant, scientists reported last week.

The breakthrough is the latest achievement in the scientific effort to understand and treat such life-changing injuries. Several recent programs have restored motion to paralyzed or partially paralyzed patients by applying continuous electrical stimulation to the spinal cord.

The new report, described in the journal Nature, is the first demonstration of so-called patterned stimulation: An implant sends bursts of targeted stimulation to the muscles that are intended to move. In effect, the stimulation is given on an as-needed basis, roughly mimicking the body's signaling mechanism.

The treatment is still experimental, and its effectiveness for others with complete or partial paralysis is yet to be worked out. The three men had some sensation in their legs before the trial began, and they needed months of intensive training to achieve their first awkward steps. They still rely on wheelchairs; two can walk out in the community, using walkers.

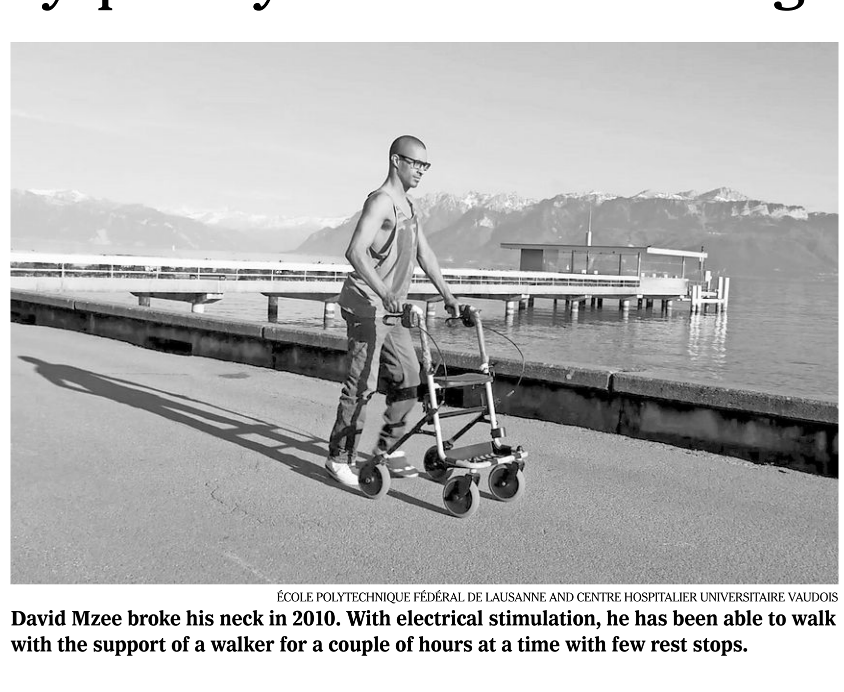
Each of them has learned to move previously limp muscles without help from the implant — an indication that the electrical stimulation has prompted nerves to regrow.

"At first, everything was new and, of course, exciting, but it took so much work to see any difference," Mr. Mzee said. "I would go home after rehab, eat, then go straight to bed. Then it got easier to get the movement I wanted, and the biggest step for me was when I could move — hands free — for the first time, on the treadmill. I wasn't able to do that for so many years; it was a really cool feeling."

Chet Moritz, a brain scientist at the University of Washington, who was not involved in the study, was impressed by the results.

"The exciting thing about these findings is that they hold out the promise that spinal cord injuries can be cured to an extent that restores walking and that many movements persist, even when stimulation is turned off," he said.

Other researchers cautioned that the study was small and that the patients had been only partially paralyzed. "We're still a long way from people being able to access this as standard medical care," said Dr. Kimberly Anderson, professor of physical medicine and rehabilitation at Case Western Reserve University School of Medicine in Cleveland, although she added that the approach had great potential.



ÉCOLE POLYTECHNIQUE FÉDÉRAL DE LAUSANNE AND CENTRE HOSPITALIER UNIVERSITAIRE VAUDOIS

David Mzee broke his neck in 2010. With electrical stimulation, he has been able to walk with the support of a walker for a couple of hours at a time with few rest stops.

In recent years, researchers have used brain implants — electrode chips placed below the skull on the motor area of the cortex — to decode neural signals and restore movement in people and nonhuman primates who have lost the use of limbs. Other scientists are investigating nerve growth factors: chemical compounds that are injected at the site of an injury to promote repair.

The authors of the new report, who are based at the Swiss Federal Institute of Technology in Lausanne, previously demonstrated that rats that had lost the use of their hind legs could be trained to run again when continuous current was applied through the spinal cord to the muscles. Other research teams have reported that continuous stimulation could also restore some movement in human patients.

But in people, continuous stimulation seems to send mixed signals to the muscles, activating some and confusing others, the authors of the new study argued in a companion paper in the current issue of Nature Neuroscience.

The three men in the new trial showed more rapid improvements than most subjects had in previous trials, but their injuries were also less severe.

"The key now will be to optimize this technology and the positions for the nerve connections," said Grégoire Courtine, the senior author of the new report in Nature. "When you haven't walked for many years, you have to learn to walk again."

The treatment of the men began with surgery. Doctors implanted a small patch of electrodes on the surface of the spinal cord in the lower back, below where each injury had occurred. The patch was connected to a pacemaker device, which was placed in the abdomen.

The implanted device, when turned on, delivered bursts of stimulation to individual muscles as they were called into use. The intention to lift a knee generated a certain pattern of nerve firing; stepping forward generated a different one. In effect, the device provided the pattern of stimulation that the body had delivered before the injury. Over time — with intensive physical therapy, on a treadmill with hand supports — the stimulation appeared to engage the brain's motor cortex through nerves that had been spared from injury, Dr. Courtine said.

"In the animal studies, the reorganization in the brain was really massive," Dr. Courtine said. "There were a lot of new connections from the motor cortex to brain stem."

The same would be expected in humans, he said.

After his injury, Mr. Mzee began playing wheelchair rugby and soon made the national team. The injury also plunged him into research of his own; through a doctor, he learned of the program in Lausanne and the animal experiments. When he heard that a human trial was in the works, he quickly enlisted.

"It's really hard to say what's coming next for me," Mr. Mzee said. "I think the next step will have to be a huge one, and one of the problems is that I have to have some trunk control. My trunk is not well balanced. I'm trying to set up a body support system at home to do more rehab, but, you know, it's expensive. I'm still not steady without those supports."

Even so, rehab — the hard work, sweat and discipline that have proved so helpful for many patients — will be essential to the recovery process. "We've known for years that people" with partial paralysis can respond to rehabilitation, Dr. Anderson said. "The problem comes down to access; long-term rehabilitation in the chronic setting is not paid for by very many insurers. As a result, most people with motor incomplete injuries do not recover to their fullest potential."