

[Click to Print](#)
[Close](#)

A Doctor, a Pig, and a Magical Pixie Dust That Could Regrow Fingers

Once upon a time (last month), in a distant land (Pittsburgh), there was a medical breakthrough that could regrow fingers. Happily, this was no fairy tale.

By: Michael Rosenwald



The Cincinnati branch of HobbyTown USA is located in an old strip mall on the outskirts of the city, in between a Payless shoe store and an H&R Block. One recent Sunday morning, the assistant manager, Lee Spievack, stood behind the cash register licking his fingers, having just devoured a Krispy Kreme chocolate doughnut. Spievack is sixty-nine, and the accumulation of years has made him less imposing than he was thirty-five years ago, when he won a Silver Star during the Vietnam war. He was wearing his HobbyTown USA uniform: a crisp yellow button-down shirt with his name stitched in red letters that was tucked tightly into khaki pants pulled well higher than his waist. Model airplanes hung from the ceiling, and on the shelves around him were trains, railroad tracks, remote-control cars, rockets, and kites.

Spievack has been building and flying remote-control airplanes since he was ten years old. If someone in or near Cincinnati has a problem with an aircraft smaller than anything regulated by the FAA, they go see him. Not long ago, on a Friday evening, a customer who bought a remote-control plane on eBay dropped by because its propeller was spinning the wrong way. On his own planes, Spievack uses wooden propellers; if the plane falls out of the sky and lands on someone, which happens more than you'd think, wooden propellers are less likely to slice anything off. But this plane had a plastic propeller more than a foot long. Spievack and the customer took his plane behind the store for testing, and sure enough, after gassing up the engine, the whirling blades spun the wrong way. Spievack had never seen a plane act this way. He got down on his knees for a closer look, and just as

he said, "You've got to get rid of this thing," he pointed at the engine, inserting his middle finger directly into the propeller's path. "And that's how I cut my finger off," he says.

Over the years, Dr. Stephen Badylak has had problems explaining what he does for a living. He used to say, "I do biomedical engineering." But then he'd have to explain biomedical engineering. After a while, as a default response, Badylak would simply say, "Well, I'm in medical research." He hoped that would be enough, but it often prompted, "What are you researching?" Badylak says, "I got tired of struggling with it. So now I just tell them I make body parts." Badylak has regrown sizable portions of esophagi, tendons, ligaments, bladders, urethras, abdominal walls, blood vessels, and hearts within animals and humans.

Badylak, fifty-four, has sharp blue eyes and is tall and fit. He walks on the balls of his feet, probably owing to his obsession with running, which he does for three miles every morning at 4:30. Endurance is a trademark. Badylak has trained and worked as a veterinarian, a pathologist, and a general practitioner, and he spent several years as team doctor for Purdue University's football team. He now works at the University of Pittsburgh's McGowan Institute for Regenerative Medicine, which is located on the site of an old steel mill near the banks of the Monongahela River.

Badylak is the son of an Indiana steelworker, and his office window has a view of the Hot Metal Bridge, but steel is now mostly a memory in Pittsburgh. Badylak works in one of the city's more modern successful industries — organs. The city boasts one of the busiest and most well-known transplant centers in the world. From his office, Badylak can hear helicopters buzzing by, hauling coolers containing chilled livers, hearts, and kidneys.

The flight path of the choppers reminds Badylak almost hourly of the need for body parts and the fundamental problem with our system of procuring them. If someone needs a new heart, he often has to wait for someone else to die. And even if that new heart is a match, the patient must take powerful immunosuppressant drugs for the rest of his life, which can make a person sicker than he was before the surgery. Many people live happily ever after with transplanted organs, but many more

die waiting for them, or because of them.

And then there are people like Lee Spievack, who severely damage or lose a limb. The answer for them is either a prosthesis or a nub. That's because the adult human body has evolved to scar, avoiding infection and moving on with life. But that life would be a lot better for a lot of people if their bodies could be manipulated into fixing and replacing lost or damaged body parts — similar to what happens to fetuses the first few months in the womb. If a fetus loses an arm or a leg, it grows back. "Humans can grow an *entire* human being in nine months. That's pretty remarkable," says Badylak. "If you think about it that way, you can say we just want an arm, you know, or we want a leg. Just give us enough information that we can do that."

Badylak happened upon this quest twenty years ago, early in his research career, while working on Rocky. Rocky was a dog, a mixed breed, and Badylak was conducting an experiment that required replacing a segment of the aorta around Rocky's heart. Sitting around having lunch one day, Badylak wondered, What in the body has the same shape and size as an aorta? What's tubular? He settled on the small intestine, and replaced part of the dog's aorta with part of his small intestine. "When we came in the next morning," says Badylak, "he was just standing, wagging his tail, and wanting breakfast." That was surprising, but not nearly as shocking as what happened next. Over the next weeks and months, as Badylak examined the new part of the aorta, he discovered that the intestine had not become simply a tube to pass blood through but had literally morphed into an aorta. And no scar tissue had formed. This defied what he previously knew about healing. Badylak had accidentally performed the biological equivalent of a magician turning a handkerchief into a dove. But this was no illusion.

Lee Spievack's finger didn't hurt, but the amount of blood squirting from it was worrisome. He raced inside the store and grabbed a roll of paper towels, furiously wrapping up what was left of his finger. His coworkers dialed 911. Spievack didn't get a chance to examine the damage until paramedics unwrapped the paper towels in the ambulance. He looked down and saw that it wasn't as catastrophic as he feared, but the tip — about half an inch — was gone. "It was a clean cut," he says. "There were no jagged edges. It was like you took a knife and cut it off." If he looked closely, he could see bone. Back at the store, his coworkers shined flashlights around outside hoping to locate the missing chunk of his finger, but they came up empty. "It probably landed on the roof and a bird had lunch," he says.

Seeing that there was nothing left to reattach, the doctors at the hospital bandaged his wound and told him to follow up with a hand surgeon, which he did a couple of days later. The surgeon was matter-of-fact: In a few days, he would take skin from Spievack's forearm or thigh, then paste it over the finger, leaving a nub. Spievack made an appointment for the procedure, then went outside and called his older brother, Alan, a retired Harvard Medical School surgeon. He told Alan they wanted to do a skin graft. "That's crazy," he said. "Instead of having one wound, you will have two. I want you to go back in there and cancel that appointment." Lee Spievack did what his brother advised, and the nurse told him he was going to get an infection. "She was just madder than shit," he says. "But I knew what my brother was up to."

When they were teenagers, the Spievack brothers raised salamanders. Alan Spievack was introduced to the creatures during his freshman year at Kenyon College, after acing a biology exam. Nobody had ever aced this professor's exam before, and so he asked to see Alan after class. "Instead of congratulating me, he began to ask questions — suggesting maybe I had cheated, or the test was too easy, or maybe the course was," Spievack says. "He was worried about his reputation as a tough guy teaching a tough course. I almost promised him I would never do it again." A week later, the professor called Alan in again and said he had a project for him. He took him down to the nearby Kokosing River and told him to roll up his pants, get in the water, and catch what appeared to be tiny black insects, which were salamander larvae. Spievack's job: raise them, then snip off their arms, legs, and tails, taking notes about how long it took for the limbs to grow back. Salamanders can regenerate almost any part of their bodies. Cut off an arm, it grows back. Gouge out an eye, same thing.

When the semester ended, Spievack took the salamanders back to his family's home in Cincinnati, where he nurtured them in his mother's pie pans. (He made his younger brother Lee feed them once a week with tweezers loaded with hamburger meat and fish food.) Alan eventually leveraged his interest in salamander regeneration into a Fulbright scholarship, then medical school at Harvard, and then a lengthy career in surgery.

Alan Spievack, now seventy-four, bears a striking resemblance to his younger brother, though he talks a lot more. One of the striking characteristics of his speech is that he ends every third sentence with the words *et cetera*. When asked if he had any children, he explained that he has a daughter who is thirty-two and another daughter who is fifteen and "a typical teenager, et cetera." He has so much going on in his head that there are things he would just as soon skip over to get to the important stuff.

Throughout his career, Alan Spievack continued his regeneration research, and several years before the propeller sliced off his brother's finger, he attended an orthopedic surgeons' conference in Atlanta, where he saw a speech given by Stephen Badylak. By that time, Badylak had been chasing answers about Rocky the dog for some time, becoming an expert on the biological components of the intestine — like the fact that the inner lining of the intestine regenerates itself every six days. Badylak honed in on the layer of the intestine that supported the tissue replacement, called the submucosa. He put the submucosa into other wounded organs in dogs, and the same thing happened. Achilles tendons grew back. Urinary bladders grew back. The implications of the discovery were profound: The submucosa stopped the scarring process and promoted regrowth.

Badylak determined that the intestinal material was an extracellular matrix — the part of the tissue in the body that connects cells to one another, like a scaffold. Only this extracellular matrix from the small intestine — he'd later use a similar lining from the bladder — tricks the body's cells into rebuilding instead of scarring. It's like the cells are in the womb again, and the extracellular matrix alerts them that the Achilles tendons are not yet done. The cells kick into gear and go to work. And they are joined by stem cells, those all-powerful building blocks of life capable of growing into any tissue in the body. Only the stem cells that show up haven't been harvested from human embryos. They come from the body's own reserve in the bone marrow and other places, and although these adult stem cells are not as flexible as embryonic stem cells, they may have more potential than previously thought to aid in the regeneration of multiple tissues.

As his research progressed, Badylak concluded that if there was any shot of this strategy going prime time in humans, he would not be able to use intestines or bladders from domesticated animals like dogs or cats (which have the strongest intestinal lining of any animals). Using human parts was also out of the question. Badylak tried zebras, groundhogs, prairie dogs, sheep, and cows before settling on pigs: They are plentiful, they are similar enough to humans in genetic makeup, and from a regulatory perspective, the FDA is friendly toward them because they have for years been the source of heart valves and dermatological research. And the extracellular matrix is not rejected by the human body, because all the pig cells are thoroughly removed. The material can be ground into a powder or made into a sheet like waxed paper or modeled into a shape, like that of an esophagus.

Throughout the 1990s, Badylak published one paper after another reporting his discoveries, but the collective response of the scientific community was basically to ignore him. In 1996, he spoke about his research at the conference in Atlanta that Alan Spievack was attending. Spievack recalls sitting through Badylak's presentation with his mouth agape: *When this guy gets done talking, everyone in the room is gonna raise their hands with questions. When Badylak was done talking, Spievack was just about the only person with his hand up. Well, people are just being coy. When he leaves the stage, he will be swarmed.* But only Spievack approached Badylak. At that moment, the two men began a friendship and casual working relationship, with Badylak advising a company Spievack eventually started to use extracellular matrix scaffolds in injured animals. Spievack still vividly remembers asking Badylak why nobody else seemed interested in his speech. Badylak answered, "Because they don't believe it."

A few days after Lee Spievack canceled his appointment with the hand surgeon, he received a package from his older brother containing a vial of powder that looked like Kraft Parmesan cheese. His brother instructed him to sprinkle it on his finger every other day until the powder was gone.

Lee Spievack is not a man who asks a lot of questions. So in the case of the vial, Spievack didn't much care what it contained (ground-up pig bladder) or where it came from (a little farm in Albion, Indiana).

Albion is a speck of a town about a forty-minute drive from Fort Wayne on some of the flattest land in America. The Whiteshire Hamroc farm is located a few miles off the main road and its prim little houses, around the corner from an abandoned nineteenth-century schoolhouse, and down past some cornfields.

The Whiteshire Hamroc farm raises a special line of genetically linked pigs that are reared indoors and sequestered from disease. The idea is that if pig parts are going in humans — and they have already been used, by the thousands — then the pigs need to be as clean as possible. The pigs at the Whiteshire Hamroc farm are some of the most pampered swine in the world. They inhale filtered air. When they are behaving, they are fed strawberry and vanilla ice cream. The handlers tried chocolate, but the pigs demurred.

Sherry Ziobro, an attractive former student-loan executive who now brokers pig bladders and other tissues, recently arranged a tour of the facilities. Before entering, visitors must shower and change into farm-approved clothing — Fruit of the Loom boxer shorts, blue flannel pajama pants, a gray T-shirt, tube socks, and black sneakers — all in an effort to prevent as much bacteria as possible from coming into contact with the pigs. A filtration mask that covers the mouth and nose is also required, though not for the visitors' benefit — even through a mask, specially raised pigs smell terrible.

Inside, the pigs seemed remarkably content. The barn housed litters that had been born the day before (the mothers resting on their sides while the piglets fed), adolescent pigs who tried to nip at their guests, and some older pigs, of an age and size that would soon have them embarking on the hour's drive to Tippecanoe, Indiana, to visit the Vin-Lee-Ron slaughterhouse (founded by Vin, Lee, and Ron).

About eleven hundred pigs meet their maker each day at Vin-Lee-Ron. They start in pens, then make their way forward on a conveyor belt, snorting and whining louder the farther they get. "Pigs are smart. They know," explained the slaughterhouse manager. The pigs ride up the belt until they eventually meet a man who shocks them with two hundred volts, killing them instantly, though they still convulse for a few seconds. Another man slits their throats, and they bleed out for seven minutes. The pigs are then conveyed to various cutting stations, where assembly-line workers slice out specific parts. It takes about two seconds to slice out a bladder, which looks like a water balloon. It is then stored in a cooler and taken to a lab, where it is processed and either turned into a sheet like waxed paper or ground into powder.

Spievack followed his brother's directions: Every other day for the next eight days, he sat down at his living-room coffee

table and sprinkled the powder on his finger. Whatever powder fell onto the table he scooped up with a piece of paper, then dropped back into the vial. He covered his finger with a Band-Aid. A few days went by, and Spievack could see something was happening. There was skin growing, and tissue on the inside, too. He insists that what happened after four weeks did not surprise him in the least, though it should have. Because his fingertip grew back.

The fingerprint took a couple more months. The tip is a little hard on the end, but he can feel things just fine. Spievack says he was particularly happy this past winter; while all of his fingers chapped in the cold weather, the new fingertip didn't. The only side effect during treatment was that his finger began to smell like a pig's quarters at the state fair. "It was a pretty offensive odor," Spievack says. He doesn't much think about his finger anymore, except when he clips his nails. He usually cuts them once a week, but the new nail has to be clipped every two days. "That fingernail grows like a son of a bitch," he says.

Asking Badylak what happened with Spievack's finger does not produce an exceptionally long answer: He doesn't really know. He can't fully explain why the scaffolds do what they do, and until he can explain that, he cannot manipulate the technology to grow back entire digits or organs. He's getting there, but he's not there yet.

Still, the scaffolds have already been used in more than a million patients to regrow cartilage in sports injuries, rebuild urethras, and repair hernias, and Badylak's lab will start testing the technology on human esophagi soon.

Meanwhile, Alan Spievack's company, ACell, has had tremendous success with veterinary applications. Not long ago, in his house near Boston, Spievack pulled up an image of a horse with a deep hole in his face as wide as a hand. "This is Classy," Spievack said. "Now, Classy is your typical unlucky horse, et cetera." The horse had run into a fence and gouged out his face, including a big chunk of bone. Surgeons at Colorado State University inserted the pig-bladder material into the hole during several surgeries over about a year. There were pictures of the operations, which were bloody. Then there was a picture of Classy, with his face completely healed. "I know that good things can happen with this as a matrix and that there are a lot of different applications," Badylak says. "I'm also just as sure that people will not regrow *whole* digits if you just put the powder on. There's missing pieces to the puzzle. The problem is I don't know how big the puzzle is."

There are scientists who question whether the powder was really the catalyst for what happened to Spievack's finger. Ken Muneoka, a Tulane scientist who has been working on tissue regeneration for two decades, says his own research suggests that fingertips can grow back on their own, even in a man's Spievack's age. He cautions that Spievack's finger did not grow back in a controlled study — meaning the injury and the response to it were not compared with someone else's in the same circumstances who didn't undergo treatment. Badylak doesn't deny the controlled-study issue, but he disputes the notion that someone as old as Spievack could grow the tip back on his own.

Some of this back-and-forth is the scientific equivalent of playground trash talk. Both Muneoka and Badylak are at the center of a sort of Manhattan Project to regrow limbs. The Defense Department research-and-development agency DARPA, located not far from the Pentagon in northern Virginia, has been closely watching the progress of limb regeneration, given the thousands of soldiers coming home from Iraq after getting body parts blown off. The agency is now spending about \$8 million to fund two teams of researchers racing to regrow toes in mice. The upcoming year is make-or-break: They must show DARPA that they can successfully take the first step and grow a blastema — a collection of cells that can form a new body part. If they can do that, a toe is not far behind. One of the teams, led by Muneoka, is growing extra arms on salamanders to see how the process might eventually be stimulated in humans. Badylak leads the other team, which is trying to understand the role of the scaffolds. Meanwhile, Badylak is also advising surgeons at the Army Institute of Surgical Research in San Antonio on a project to use the extracellular matrix to help soldiers returning from the war who have lost digits. He says the project will be successful if the soldiers can grow back a little more than an inch of tissue. "There is some sense of competition," says Muneoka. "Because at the end of the day, as we move to the next level of this type of work, not everyone's gonna be sitting in the boat."

Badylak is confident about his method, but he also believes that his approach alone isn't going to fully unlock the body's regenerative potential. There are researchers trying other methods. Many are adamant that pig material doesn't need to be used at all — that artificial scaffolds can work better and faster. Other researchers are using the scaffolds in entirely different ways. Anthony Atala, a urologist at Wake Forest and editor of the definitive *Principles of Regenerative Medicine*, takes cells from his patient's bodies and grows them new bladders on large part-biological and part-artificial scaffolds in a lab. Seven weeks later, he implants the bladders in the body.

Badylak says he does not want to be known as "the guy who grows fingers," because he's not sure he can do it, at least not yet. But like it or not, pleas for his help reach him daily in the form of e-mails, letters, and phone calls. His face sinks as he describes one:

"I'm a mother from Bologna, Italy, my daughter was born with a defective hand. She's three years old now. She's being made fun of in school. We'd like her to have a normal life. She's a beautiful child. You know, we read about this, and we're willing to travel to the States. What can you do for us?"

Badylak pauses for a moment. "They're just heartbreaking. I got another last week from the family of a little girl that fell off a

wagon and into a meat grinder — it included a picture of her hand all chopped up."

For now, Badylak works at that potentially frustrating scientific junction of having achieved something remarkable but not being able to explain exactly how he did it. "It's a lot of fun," he says. "Much better than not being able to do it at all. If you know that it can happen, then it's easy to remain enthusiastic and motivated about looking for the reasons why. If you don't know for sure that it can happen, then you start to wonder if there is even an answer at all."


For Badylak, the wondering is over. The puzzle may be incomplete, but the answer, he knows, lives in Cincinnati, snapping together parts of model airplanes.



This story is part of our second annual register of emerging ideas, trends, discoveries, products, people, and obscene gestures you should know about before everyone else does.

[<< Read Previous](#) * [\[Back to Esquire 100\]](#) * [Read Next >>](#)

Find this article at: <http://www.esquire.com/features/esquire-100/pigfinger1007>

 [Click to Print](#)

[Close](#)
