Shocking the spine back to life

Despite suffering a severe spinal fracture that left him paralyzed below the neck, Rob Summers can stand on his own two feet. The secret is a revolutionary electrical therapy that stimulates his legs, even without input from his brain.

Rob Summers, now 26, has taken remarkable steps — literally — toward a life without a wheelchair.
ROB SUMMERS/FRAZIER REHAB INSTITUTE

On July 12, 2006, as Rob Summers was taking his baseball gear out of the trunk of his car, he was struck by a hit-and-run driver. During a moment of consciousness, he reached for his cell phone to call for help, but his body wouldn't obey. When he arrived at the hospital, the doctors discovered why: His C6 vertebra had been fractured. He was paralyzed below the neck.

But Summers believed that he would walk again. He dedicated himself to an intensive regimen of physical therapy that helped him regain function in his upper body and increased some of the mild sensation he had retained in his legs. Then, in 2007, he was accepted to an ambitious study at the Frazier Rehab Institute in Louisville, Kentucky. It was based on experiments in which paralyzed cats were able to walk after having their spines stimulated with electrical impulses. After 80 sessions of therapy with the device, Rob Summers stood up.

Most of us master walking as toddlers, so it seems like a simple act. In fact, it requires the instantaneous cooperation of specialized parts of the brain, muscles and nerves. As best we understand it, as the brain orders muscles in the leg and foot to take a step, dedicated sensory cells in those muscles instantly relay back information concerning the positioning of the leg and foot. At the same time, pressure-sensitive sensory cells on the soles of the foot signal when it touches the ground. The brain fine-tunes the movements, adjusting the gait to the surface. However, if something disrupts this communication network, walking becomes difficult or, as in Summers' case, impossible.

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It would be much more efficient if our legs could walk on their own, only needing the brain to start and stop movement, regulate speed and adjust direction. In 1998, V. Reggie Edgerton, a neurobiologist at the University of California, Los Angeles (and a co-author of the journal article on Summers' case), and colleagues showed that this process could work in cats. After paralyzing the animals by severing their spinal cords, they used electrical stimulation to train the cats' bodies to walk again. The spine sent the necessary signals directly to the muscles, without engaging the brain.

The researchers found that the spine can learn to instruct the body to stand in conjunction with the motor nerves that stimulate the leg muscles and the sensory nerves that receive information about leg position, load and pressure from the surface. With assistance from the spine, the legs also may know how to walk and perform the movements on their own. Edgerton theorized that the same process could work in humans.

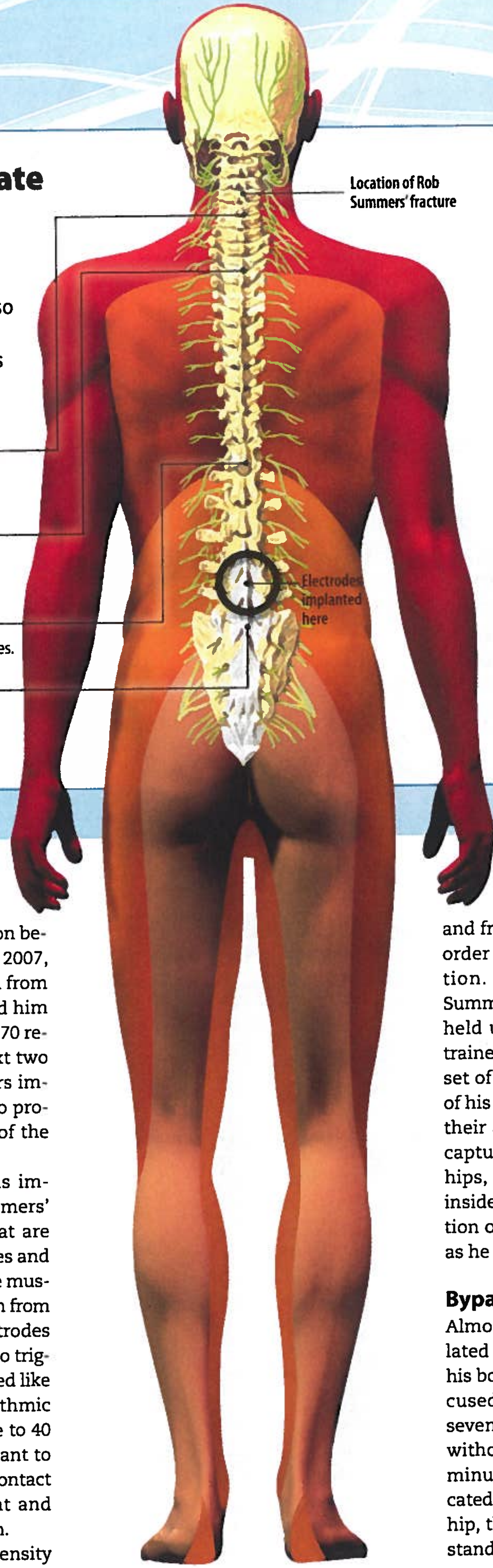
Reviving dormant muscles

Summers was a good subject to test the theory — he had already undergone extensive locomotor training and had

Electrodes stimulate isolated nerves

Rob Summers' spine was fractured fairly high in the spinal column, paralyzing his legs, torso and much of his arms. But a device in his lower back stimulates the nerves and muscles in his legs, enabling him to stand.

HENNING DALHOFF



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A device with 16 electrodes was implanted in Summers' spine to send electrical impulses to the nerve circuit in his legs.

been in excellent physical condition before the accident. So in October 2007, researchers led by Susan Harkema from the University of Louisville started him on a program that would include 170 rehabilitation sessions over the next two years. In late 2009, the researchers implanted the epidural stimulator to provide weak electrical stimulation of the spine to further revive his body.

An array of 16 electrodes was implanted in the lower part of Summers' spine near bundles of nerves that are connected to the hips, knees, ankles and toes. These nerves, which order the muscles to contract, receive information from sensory cells in the legs. The electrodes did not deliver enough electricity to trigger a nerve response, but functioned like a pacemaker, emitting weak, rhythmic shocks of up to 10 volts some five to 40 times per second. These were meant to tickle the nerves, which had lost contact with the brain after the accident and were no longer used to stimulation.

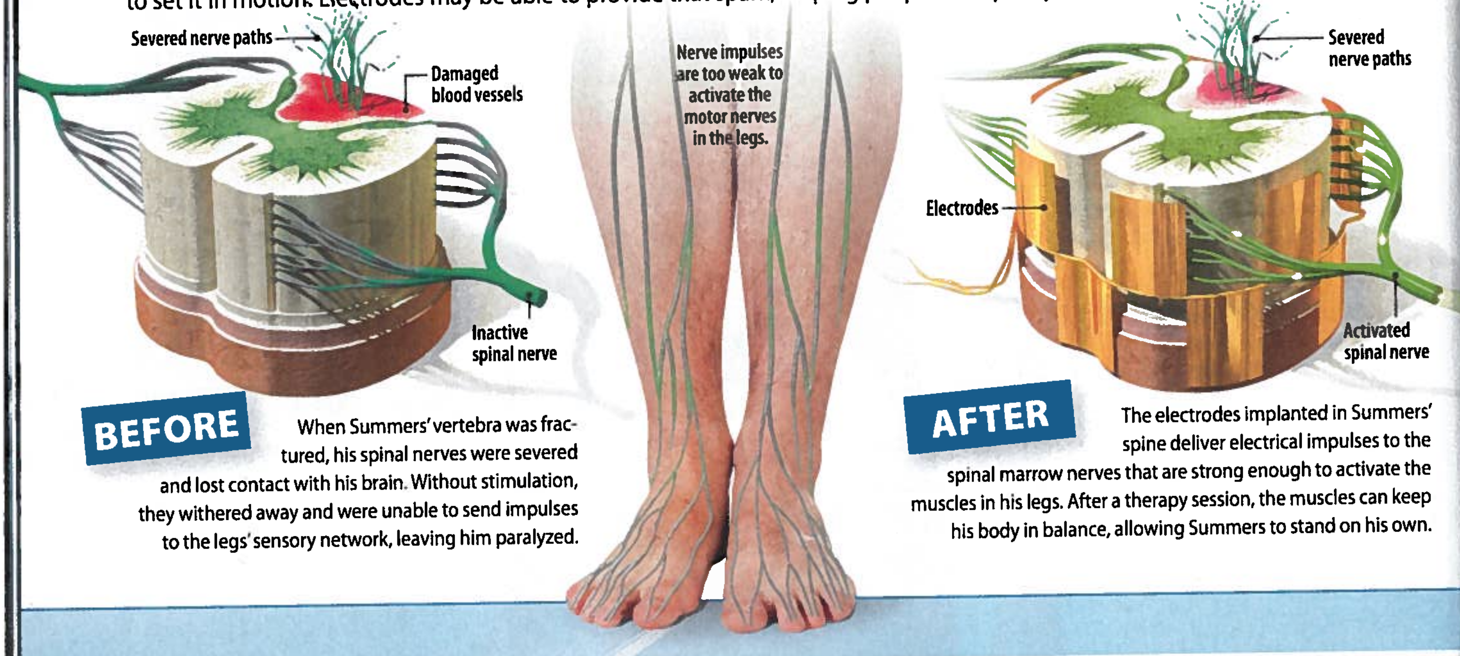
The researchers varied the intensity and frequency of the electrical signal in order to determine the best combination. For part of the experiment, Summers walked on a treadmill and was held upright by a harness, with three trainers helping him when necessary. A set of electrodes on the major muscles of his legs helped the scientists monitor their activity, and high-speed cameras captured the angles and motion of his hips, knees and ankles, while sensors inside his shoes measured the distribution of force across the soles of his feet as he attempted to stand and to walk.

Bypassing the brain

Almost immediately, Summers' stimulated muscles could carry 65 percent of his body weight. After 80 sessions of focused rehabilitation over a period of seven months, he was able to stand — without support — for more than four minutes. The measuring devices indicated that the muscle movements in his hip, thigh, knee and calf that kept him standing were active and coordinated. ▶

Walking without help from the brain

Scientists have discovered that walking doesn't actually require brainpower. The spine has a nerve circuit that can monitor information about the position of the legs and order the muscles to move; it just needs a spark to set it in motion. Electrodes may be able to provide that spark, helping people with paralysis to walk.



When Summers' vertebra was fractured, his spinal nerves were severed and lost contact with his brain. Without stimulation, they withered away and were unable to send impulses to the legs' sensory network, leaving him paralyzed.

The electrodes implanted in Summers' spine deliver electrical impulses to the spinal marrow nerves that are strong enough to activate the muscles in his legs. After a therapy session, the muscles can keep his body in balance, allowing Summers to stand on his own.

The muscle activity constantly adjusted in an effort to help him maintain his balance and stand still. If he leaned slightly forward and offset his balance — which happens when we walk — the leg muscles reacted and tried to put one leg in front of the other, taking a step to recover the body's balance. Summers' muscles were unable to carry out the walking movements independently, but if assistants helped Summers move his legs, the muscles worked in a coordinated fashion and attempted to make his legs walk.

The experiments showed that when the muscles were stimulated, they worked in a rhythmic, coordinated way, even if Summers was walking with assistance. They were also activated when he was simply standing up, but were almost completely relaxed when he was sitting down. And all of this happened with the nerves' communication line to the brain having been cut as a result of the spinal cord injury, indicating that direct contact between the brain and legs isn't always necessary for locomotion — perhaps muscle activity is not regulated by the brain, but by the influence of sensory nerves in the skin and muscles, which detect the pressure of the surface against the feet and the position and weight distribution of the legs.

The researchers think that these biological sensors relay information directly to the nerves that originate from the same part of the spine and are responsible for activating the leg muscles. The sensory and motor nerves thus form part of a closed circuit independent of the brain, which compels the legs to move in the most appropriate way.

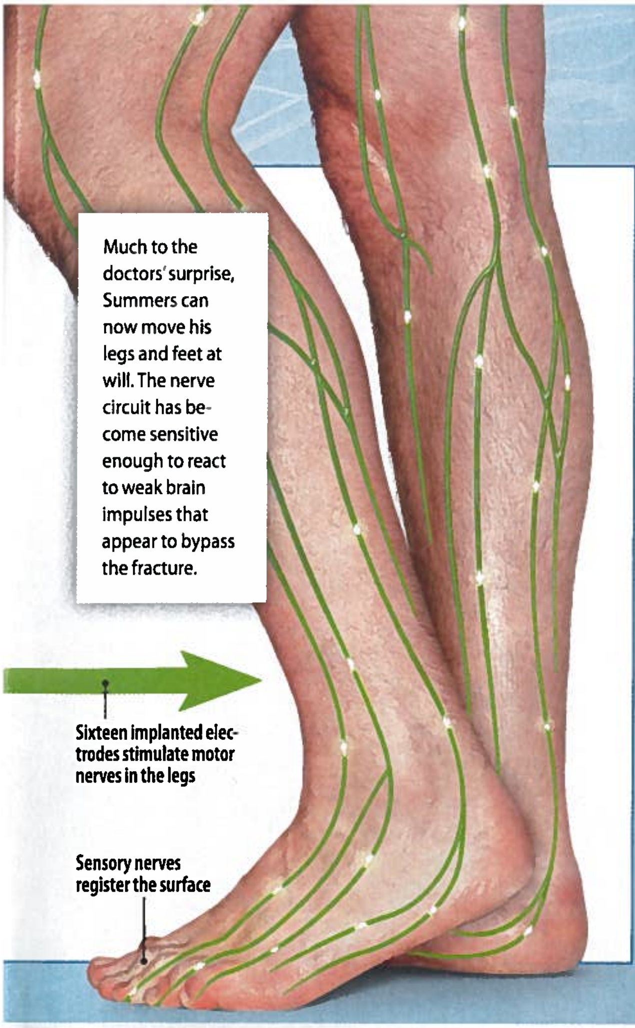
B. LANDRY/GETTY/ALL OVER

Chickens actually can run around with their heads cut off — their legs can move without instruction from the brain.

Although the epidural electrodes helped excite the circuit, despite the brain's lack of direct involvement, the circuit could only be activated through the weak electrical stimulation of the spine. No matter how much Summers practiced, his muscles were unresponsive when the electrodes were off.

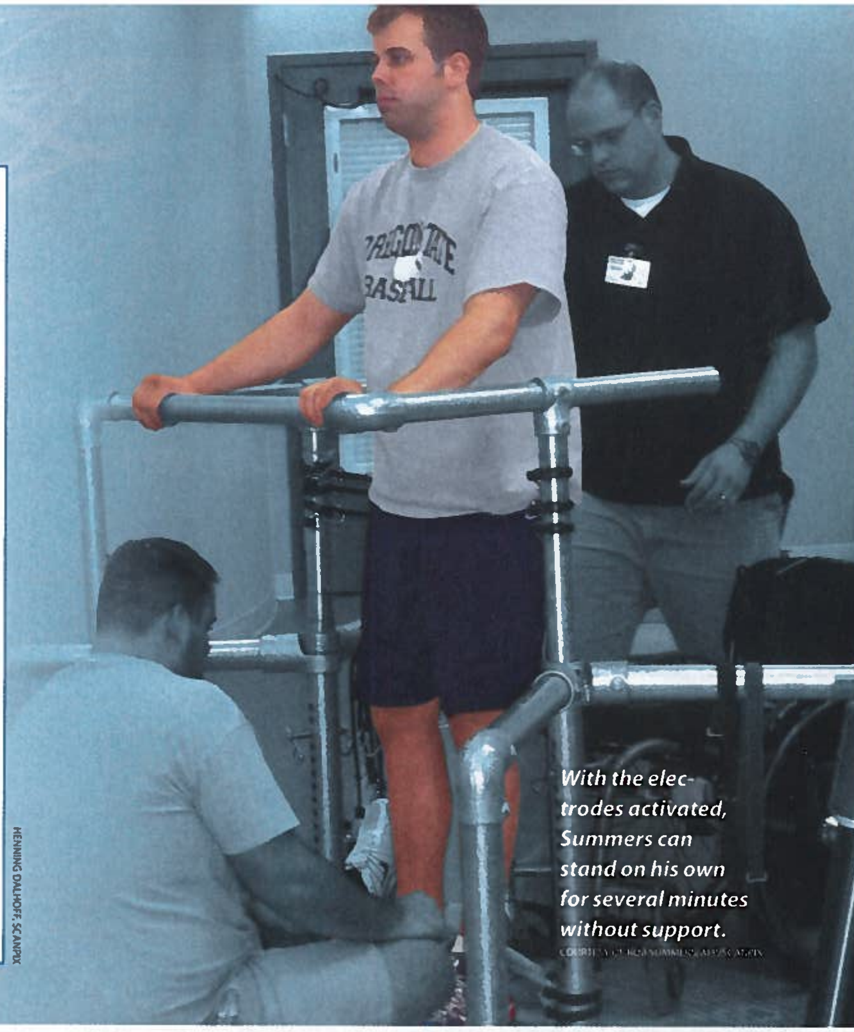
Restoring vital functions

Much to the researchers' surprise, Summers was able to stand on his own by the third day with the epidural electrodes on. By the end of the experiment, when the researchers had Summers lie on his back and bend his leg or move his big toe, as long as the electrodes were on he was able to do so. This was unprecedented: Such voluntary movement had



Much to the doctors' surprise, Summers can now move his legs and feet at will. The nerve circuit has become sensitive enough to react to weak brain impulses that appear to bypass the fracture.

HENNING DALHOFF, SCANPIX



With the electrodes activated, Summers can stand on his own for several minutes without support.

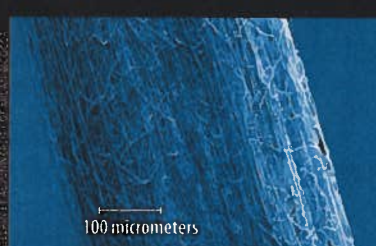
been thought impossible for someone with full paralysis. Even when the brain registers the need to move the leg, once there is a break in the pathway between the brain and the closed circuit in the lower part of the spine, the message cannot travel past the fracture.

The researchers can't yet explain how Summers is able to make these movements, but they think that either nerve activity spurred by the electrodes or their electrical effect has stimulated some of the spinal nerves into action, boosting the circuit's ability to function.

Despite his remarkable progress, Summers still can't walk on his own. Perhaps he never will. But the therapy has improved his quality of life in other ways, most notably in helping him regain some bladder control and sexual function. And he has restored muscle mass, which also helps him to stay active. So far, he is the only patient to see such impressive results, but his hard-won steps may lead to therapies that someday will help others with paralysis to stand on their own.

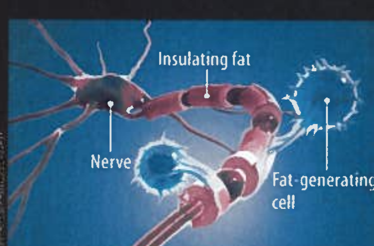
Tubes and stem cells may treat paralysis

Scientists are working on ways to repair injured spinal cords, from growing new nerves in tiny tubes to using stem cells to regenerate nerve tissue.



Tube-grown nerves can heal

Hair-thin nanotubes can be implanted in a damaged spot in the spinal column to function as tunnels in which new nerve cells can grow. This promising new treatment, invented by Italian scientists, can heal the severed spine nerve ends in rats and restore the connection.



Stem cells regenerate myelin

Paralysis partly results from nerves' loss of their insulating layer of myelin; this makes the passage of nerve signals difficult. U.S. scientists have shown that stem cells injected into the spine can generate special cells that create this insulating fat around nerve cells.