Back From the Brink

They are called vegetables, but many still have thoughts, feelings, and memories flickering in and out of consciousness. Can neuroscience rescue these lost brains?

By Kat McGowan Illustrations by Jean-François Podevin

THE WOMAN IN THE WHEELCHAIR WEARING BURGUNDY SCRUBS is lovely, with full eyebrows arching over her closed eyes. Joseph Giacino, director of rehabilitation neuropsychology at Spaulding Rehabilitation Hospital in Boston, squats beside her, looking into her face. “Hi, Kellie, it’s Dr. Giacino. How are you? Can you open your eyes?”

No response.

Two and a half months ago, during what was supposed to be a simple nasal operation for sinusitis, Kellie’s left carotid artery was accidentally sliced open, starving half her brain of blood and oxygen. Since that day, she has not spoken or clearly responded in any way. She opens her eyes, and sometimes she groans or gropes toward people nearby. Most of the time she seems to be asleep.

Is Kellie still in there? Giacino, 52, an expert in disorders of consciousness, will establish her condition more precisely with this exam. First, though, he needs Kellie to be more alert. He rubs her arm and her leg firmly, applying deep-muscle pressure, and her dark eyes pop open. She begins to breathe heavily and to shake. Giacino soothes her. “I’m just waking you up,” he says gently. “You had some bleeding in your brain, and we’re trying to help you get better.” The expression on her face is intense and hard to read. It mixes fear with annoyance, as if she has just woken from a nightmare. “Every kid has a dad and a…” he prompts. She moans, or is she trying to say “mom”? It is difficult to tell whether she is oblivious or struggling to respond. When she makes eye contact and holds it, she seems just as aware as anyone else in the room. By her fierce expression, she looks as if she is about to tell Giacino to buzz off. Yet she does not speak. That is why this exam, calibrated to distinguish between reflexes and real cognition, is so important. When Giacino hands her a toy ball, she grabs it, smoothly and naturally. It is a good sign.

Just a few years ago, a patient like Kellie would have been written off. Anyone who did not regain consciousness within a few weeks after a stroke or head injury was said to have no hope for meaningful improvement. But in the past decade, a series of increasingly spectacular experiments conducted by Giacino and Weill Cornell Medical Center neurologist Nicholas Schiff has proved that this bleak verdict is often wrong. The semiconscious brain is not a useless sack of neural goo, they have shown, and not all damaged brains are the same. Disorders of consciousness come in shades of gray, from severely impaired “vegetative states” to the perplexing “minimally conscious state” in which people slip into and out of awareness. By studying patients who emerge into consciousness after years in limbo, Schiff and Giacino have shown that the brain can sometimes fix itself even decades after damage. They have discovered apparently vegetative people whose minds can still imagine, still recognize, still respond. In turn, these profoundly disabled people have opened the door to one of the last great mysteries of science: the nature of consciousness.

Schiff, Giacino, and the handful of other scientists doing this work worldwide hope to help more brain-injured people make the leap back into consciousness. In the meantime, the implications of their work are haunting. It suggests that many of the estimated 250,000 to 300,000 or more people in this country languishing in bedrooms and nursing homes with disorders of consciousness are probably still “in there”—still have some capacity to think and to feel and might, in a limited way, be able to rejoin the world. “These are human beings who seem to have lost their humanity,” Giacino says. “The question is, is that really the case?”

The old verdict was harsh but clear-cut: Mourn your loved one, because he or she is gone. Now people like Kellie’s husband, Mark, are tormented by hope and uncertainty. Giacino’s exam establishes that Kellie is in the no-man’s-land of the minimally

The first vegetative patient Schiff saw, the victim of a stroke, had no sign of consciousness. But when he ran into her three years later at a rehab center, he was shocked to find her awake and capable of talking to him.

conscious state. Whether she will return is anyone's guess. "The very hard part for me is looking into her deep brown eyes and not knowing what she is thinking," Mark wrote on his Web site in late August. "Is she mad at me? Is she in pain? Is this process torturing her? We don't know. These are the questions that keep me up, pretty much every night."

In THE 1970S, WHEN INTENSIVE CARE DRAMATICALLY improved the survival of brain-injured patients, doctors found that if the body can be kept alive, the brain usually shakes off a coma—a totally unresponsive, eyes-closed state—within two to four weeks. At that point some people simply wake up, although they may be delirious and impaired. Others graduate to an in-between zone that New York Hospital–Cornell Medical Center neurologist Fred Plum labeled the "persistent vegetative state" in 1972. At the time, among these patients, it seemed as if only "vegetative" brain functions like breathing, waking, and blinking were working. The higher functions commonly associated with consciousness seemed to be lost.

The patients, doctors found, usually had widespread brain damage, but two injured areas were especially noteworthy: the thin outer rind, called the cortex, and the thalamus, a pair of walnut-size lumps in the brain's central core, along with the neural fibers that connect these regions. The two areas are normally in constant cross talk, filtering and analyzing sensory data and making continual adjustments to attention and alertness. Lacking this chatter, someone in a vegetative state seems to be awake but not aware. They might moan and shift around, but they do not look toward a loud hand clap or pull away from a pinch. Given a feeding tube and basic medical care, someone might stay in this condition from days to decades, potentially until death.

Until recently, few neurologists besides Plum were interested in learning more. The consensus was that semiconscious brains do not heal, especially not months or years after an injury, so research and aggressive treatment were futile. But the very first vegetative patient Schiff ever saw, during his first month as a resident at New York Hospital in 1993, told a different story.

This woman had had a stroke more than six months earlier. When Schiff examined her, he found no sign of consciousness, just as expected. Three years later, on a visit to a local rehabilitation center, he ran into his former patient again. Not only was she awake, but she spoke to him. "I was shocked," he says now. "I remember the visceral feeling of having seen somebody come back from the dead. It seemed truly surreal."

Around the same time, Schiff heard about a female patient who had been in a vegetative state for nearly 20 years but sometimes blurted out a word, usually obscene. His first thought was that she could not possibly be vegetative. He and Plum, who had become his mentor, arranged for her to be part of a study using positron emission tomography, better known as a PET scan. This technique uses radioactive markers to map the brain's sugar metabolism—and, by implication, the speed at which neurons are firing.

When Schiff and Plum got this patient's scans back, they were confused. The PET scan looked blank. Her injured brain was functioning at such a low level that the normal rich glow of activity was barely a glimmer. When the researchers recalibrated the display screen, though, they could see tiny blobs of neural action in brain regions specialized for speech. Consciousness requires connectivity, and her vegetative brain was mostly disconnected. Nevertheless, this one isolated loop remained hooked up and active. Amid her scorched neural landscape, it spat out an occasional word, without meaning or conscious will.

The following year, 1997, another patient brought Schiff to the JFK Johnson Rehabilitation Institute in Edison, New Jersey, where he met Giacino. They made a good team. Schiff was a neuroscientist, probing the nuts and bolts of the brain; Giacino was a diagnostic master, devising better ways to evaluate semiconscious patients. With the support of Joseph Fins, chief of the department of medical ethics at Weill Cornell, who articulated the ethical arguments for why these patients must be studied and treated, they used PET to look at four more people in vegetative states. Metabolically, all the brains were limping along, underactive and underaroused. Yet each patient's pattern was idiosyncratic, showing unique clusters of remnant neural activity. "People look at these patients and say, 'They're all the same; they don't respond; their brain doesn't work,'" Giacino says. "This was a beautiful illustration of how dramatic the differences are."

FOR THEIR NEXT ACT, THE TWO RESEARCHERS TURNED TO another mystery, the much larger number of semiconscious brain-injured patients who are severely disabled but not truly

vegetative. (In the United States, these are estimated at 280,000 cases versus 35,000 patients in the vegetative state.) These people are not merely awake but also partly aware. In them, consciousness is neither on nor off; it is unstable, emerging and fading "like the smile on the Cheshire cat," Schiff says. On good days they might follow people or objects with their eyes, nod, laugh, even say a word. On bad days they do not react at all.

Schiff and Giacino, working with Columbia University neuroimaging expert Joy Hirsch and graduate student Diana Rodriguez-Moreno, started probing these unpredictable brains in 2001 using functional magnetic resonance imaging (fMRI), which tracks the minute changes in blood oxygenation that correspond to neural activity. They reasoned that some regulatory mechanism of the brain must be oscillating up and down, creating these wide swings in awareness, and fMRI might clarify what it was. In 2002 a group of neurologists led by Giacino formally chose the term "minimally conscious" to describe these patients.

One subject who fell into this category was a man who had been beaten and kicked in the head during a robbery several years back. About 30 percent of the time, he was able to follow instructions, indicating "yes" or "no" by looking at a card, but he only rarely spoke a word or two. Most of the time, he kept his eyes closed. While he was undergoing fMRI, the team played a recording of his mother's voice. They expected to see isolated flares of activity in simple language-processing regions. Instead, the whole network of cortical regions specialized for hearing and language comprehension fired up, just as in a healthy brain. "It was stunning," Giacino says. The patient's visual cortex was buzzing too, as if the sound of his mother's voice had conjured up her face. A second subject responded in much the same way.

In some types of brain injury, people eventually regain full consciousness, with normal awareness and intellect, but are trapped in an unresponsive body; they are said to be "locked in." But the two patients in this study clearly did not rise to that level. As part of the experiment, the team played recordings of speech that had been reversed. In healthy subjects, language-processing regions become more active when they hear such backward speech, working hard to interpret strange-sounding words. These patients' brains reached only the earliest stages of response, as if they could not engage enough to ask, "Hey, what's that?" The difference between a vegetative and a minimally conscious brain was looking like a question of how much brain wiring remained intact and, more important, still able to pass along a signal. Neurologist Steven Laureys of the University of Liège in Belgium, who would later collaborate with Schiff and Giacino, showed that same year, 2002, that in vegetative patients, mild electric shocks activated basic sense-perception regions but not the higher-level information processing networks that the minimally conscious patients could access.

The brain scans of the robbery victim had revealed enough connectivity and enough bandwidth to register and process a human voice. What the patient could not do was maintain his awareness. Since medical school, Schiff had believed that a technique called deep brain stimulation might help patients who have viable, net-

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worked cortical tissue but inconsistent awareness. In deep brain stimulation, electrodes are permanently installed in the brain, like a neural pacemaker. (It is most often used to help people with Parkinson's disease regain control over their limbs.) Such stimulation had not worked very well in a trial conducted on vegetative patients in the 1980s by the medical device company Medtronic. But Schiff, who had been mapping the pathways of consciousness, was convinced that Medtronic had picked the wrong patients—those who were catastrophically injured and beyond help—and had put the electrodes in the wrong place.

He had his eye on a distinctive part of the central thalamus, a circumscribed region within a group of neurons known as the intralaminar nuclei. In a normal brain, the neurons of the central thalamus crackle with electrical activity when we struggle to pay attention to the world around us, and they accelerate their action as we emerge from sleep. Anatomically, these neurons have widespread connections to the brain stem, a primitive region that controls waking and sleep; to nearby basal ganglia involved in movement; and to the medial frontal lobes, which are involved in motivation. Because of this architecture, the cells of the thalamus can buzz many regions at once to redirect attention, synchronize information processing, or kick-start activity. Long, thin fibers called axons extend from neural cells, and the particular geometry of the thalamus, with its many connections, makes it particularly vulnerable to injury. A shock wave from a blast or blow to the head, rippling through soft neural flesh, can sever the axons. The neurons then stop working or die, and the signal from the thalamus weakens, Schiff believes. The brain gets stuck in idle.

If deep brain stimulation could dial a patient's thalamus back up, Schiff expected that it would activate the rest of the brain as well. In February 2005, six years after his injury, the robbery victim was taken to the Cleveland Clinic, where a surgeon installed millimeter-thick platinum-iridium wires that could transmit electricity or receive neural signals. When fed through an amplifier, the signals from healthy neurons sound like Velcro being unhooked. But as the electrodes poked into this man's thalamus, Schiff and Giacino heard only silence, the eerie calm of a stalled-out brain.

As soon as the researchers switched the stimulator on, Giacino says, the man's eyes opened. The doctors were not yet sure that it worked; they waited two months for the patient to completely heal from surgery before beginning their cognitive tests. For Schiff, the real moment of drama came during one of those first sessions, when the patient had the electrodes fully switched on for several hours. Schiff and Giacino showed him a picture of a red Radio Flyer, and before Schiff even remembered what the toy was called, the patient said, "Wagon."

As months passed his repertoire increased; with the stimulator switched on, he could swallow, hold a cup, name objects, speak short sentences, and smile. The real impact of the stimulation is best described by his mother, who had been told the night of his beating that he would never be more than a vegetable. "My son can now eat, speak, and watch a movie without falling asleep," she said through tears at a press conference announcing the results of the study. "He can express pain. He can cry and he can laugh. The most important part is, he can say 'Mommy' and 'Pa.' He can say, 'I love you, Mommy.'"

What had it been like in limbo? The patient cannot say; like others who have emerged from disorders of consciousness, he does not remember anything about the experience. "Is it like waking up from surgery? Is it like being very groggy after you've been concussed? Who knows?" Schiff says. Maybe it is like waking up with jet lag in a dark hotel room far from home, speculates Caltech biologist Christof Koch, who also studies consciousness. At that moment, you have no idea where you are or how you got there. You simply know that you exist.

The IMPOSSIBILITY OF KNOWING GETS TO A core problem of consciousness: There is no way to measure it objectively. Normally we use people's behavior as a proxy for their internal state. But you cannot trust what your eyes and your ears tell you about someone with a disorder of consciousness.

In 2005, just as the deep brain stimulation patient was making his first forays into awareness, the fate of Terri Schiavo, a Florida woman who had been in a vegetative state since 1990, sparked an ideological war. Her husband wanted her feeding tube removed, believing that she would not have wanted to live that way; her parents disagreed. Eventually, everyone from the governor of Florida to the U.S. Congress took sides. The arguments hinged on different impressions of how much awareness Schiavo still retained. A clip of Schiavo smiling was shown over and over again on TV. Senate majority leader Bill Frist (a Harvard Medical School graduate) insisted that the video meant she was still conscious, a gut intuition that was as powerful as it was wrong. Eventually her feeding tube was removed and she died, and an autopsy proved that she

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could never have recovered. Her brain had shriveled to less than half the weight it should have been.

More often, brain-injured patients are more conscious than they appear because physical problems limit their responses. Their muscles often become permanently clenched in contracture so they cannot move their arms and legs. They may be deaf or blind, unaware of a neurologist's questions. They may be in too much pain to pay attention. Just staying awake with an under-aroused brain is difficult, and many patients receive muscle-relaxing drugs that make them even sleepier.

And sometimes doctors just fail to catch a patient's subtle or rare fluctuations in awareness. These people are like a Rorschach test, Schiff says; where families see signs of cognition, doctors may see only wishful thinking. "There's a kind of complacency about it—'What you see is what you get,'" he adds. "Some people don't have the intellectual curiosity or imagination to anticipate some of the things you might find when you start looking." Three separate studies, the most recent in 2009, indicate that up to 43 percent of people diagnosed as being in a vegetative state are, when more carefully examined, found to be at least partly aware.

Underestimating consciousness can have tragic consequences. Vegetative patients probably do not feel pain, but imaging experiments indicate that minimally conscious patients do, even if they cannot always react to it. In a European survey, 66 percent of health-care professionals said they thought it was permissible to remove a feeding tube from someone who had been in a vegetative state for more than a year, but only 28 percent felt that way for patients who were minimally conscious. When Schiff gave a grand rounds talk to a group of medical students, residents, and doctors last spring, a young neurologist brought up the elephant in the room. "We're asked early on, when the patient is still in the intensive care unit, what the prognosis is for meaningful recovery for a patient who seems vegetative," he said. "The family often withdraws care when we say there's no chance. Have we been killing people?"

Schiff does not directly respond, but the answer is almost certainly yes. In the immediate aftermath of a massive brain injury, doctors tend to paint a grim picture of the future. Many feel that a good doctor is obligated to help a family let go of unrealistic hope. "One has to help people just face the facts," says William Landau, who for two decades was head of neurology at the school of medicine at Washington University in St. Louis. "Otherwise their hope goes on forever, and the tragedy and human cost go on forever, while the ability to live autonomously never comes."

The PROBLEM, SCHIFF, FINS, AND GIACINO SAY, IS that it is increasingly hard to predict early on who will linger for years in limbo and who will make significant strides. People who regain consciousness a year or more after injury rarely return to normal; many remain bedridden, incontinent, confused, or agitated. But as lifesaving interventions grow steadily more sophisticated, the course of recovery from severe brain injury is often much better than it used to be. If a patient escapes outright brain death, some improvement can be expected, especially among those who survive trauma rather than oxygen-deprivation injuries, such as a stroke or heart attack. In a recent small study, 16 out of 18 minimally conscious trauma patients recovered consciousness within five years. Four still needed 24-hour care, but another five were working or studying part-time. "To paint a dire picture about somebody with an uncertain diagnosis, early in the course, is to misrepresent reality and misunderstand one's obligation as a doctor," Fins says. "It's wholly wrong and unethical to obscure those facts."

Some injuries are obviously catastrophic, but for many patients, it takes weeks or months to know who will wind up where. When Giacino examined Kellie in late summer, the diagnosis of "minimally conscious" seemed promising. In the fall, however, after struggling with infections and other complications, she stopped moving the left side of her body. She died in mid-December. Just as unpredictably, other patients get better. One research subject was a 58-year-old woman who was in a minimally conscious state after a stroke. Her age and her injury suggested a dire outcome, but three years later she was awake and talking.

Schiff, Fins, and Giacino still struggle to convince their colleagues that their findings are not flukes, that they are not attributing meaning to mere reflexes. "I went to a well-regarded major medical center to speak to the trauma team, and I did my whole spiel, an hour-long lecture with everybody there: residents, attending physicians, the head of trauma," Giacino says. "I explained how we go through the assessment process, the importance of differential diagnosis, distinguishing between vegetative state and minimally conscious state. The head of trauma thanks me and in a very jovial manner says, 'In my day, the term for these patients was *jellyfish*.' And he laughs and moves on. What do you do with that?"

One way to convince the skeptics is with better biological evidence. Indications that a person can be cognizant and yet show absolutely no outward sign keep getting stronger. In 2006 a group led by neuroscientist Adrian Owen of the Medical Research Council in Cambridge, England, used neuroimaging to pick up the thoughts of a woman who had been in a vegetative state for five months after a traffic accident. He asked her to imagine one of two scenes—playing tennis or walking around her house—for 30-second intervals while having an fMRI. In a normal brain, imagining tennis activates the supplementary motor area of the cortex, and picturing one's home prompts activity in regions involved in spatial perception, such as the posterior parietal cortex. This patient's brain responded exactly the same way.

Some neurologists said these responses could be largely unconscious, so Owen, in collaboration with Laureys, pressed on. They found that of 54 patients with disorders of consciousness, five were able to make tennis/house responses. Then, in 2009, Owen's postdoctoral student Martin Monti asked one of them, a 22-year-old who had been in a vegetative state for five years, to answer simple questions with his thoughts, using the output of the scans to communicate. "Do you have any siblings?" Monti asked, telling him to concentrate on tennis for yes or walking around his house for no. Using this crude binary system, the man answered five out of six questions correctly.

The Monti study could not determine how conscious this man is or whether his awareness is normal. Furthermore, there is no simple way to find out how many patients there are like him. Functional MRI is expensive and awkward, and transporting a brain-injured person for scanning is logistically daunting. Even Monti's star patient has not yet been able to return for further evaluation. And some brain-injured people who are indisputably conscious do not look that way in neuroimaging. Schiff's group has a subject, formerly vegetative, who can carry on a conversation and crack jokes but still cannot produce an intelligible signal in the fMRI.

Schiff's group now hopes to clarify this mess by finding a way to gauge the brain's status directly rather than through the filter of a scan. Schiff, 45, is intense; he speaks quickly in long, dense sentences jammed with subclauses and punctuated with wry laughter. Although he is now a professor of neurology and neuroscience at Weill Cornell and gets invitations to talk about his work all over the world, he is down-to-earth, as are the rest of his small team. The patients and their heartbreaking, humbling brains keep them that way.

Some subjects have unbelievable Rip Van Winkle stories. An Arkansas man named Terry Wallis spent 19 years in a minimally conscious state after a car accident and then abruptly woke up in 2003. "Mom," he said, then "Pepsi," and within days he was speaking fluently. Later, when Schiff and neuroimaging specialist Henning Voss brought Wallis to Weill Cornell, they caught his brain in the act of rewiring itself. Using diffusion tensor imaging (DTI), which can depict axonal fibers, they found a thick cable of what looked like new axons sprouting at the back of the patient's brain. This study was "incredibly important," Owen says; nobody would have believed that a brain could reconnect itself decades after it was injured—until it actually did.

There is also the case of George Melendez, a Texas man who, after nearly drowning, fell into a minimally conscious state and remained there for two years. He did not speak, but because he often groaned loudly at night, his mother got him a prescription for the sleeping aid Ambien. Hours after giving him the first pill, he seemed more alert than usual. "George?" she said, and he turned to her and asked, "What?" Now, nine years later, as long as he keeps taking the drug, he can feed himself and answer questions, even demonstrate baseball grips (he used to be a minor-league pitcher). Without it his hand shakes, he cannot eat, and he has trouble speaking. The sedative paradoxically keeps his brain awake: PET scans show that on Ambien, his brain uses twice as much fuel.

Schiff brings subjects one at a time to New York–Presbyterian Hospital to be scanned, measured, and probed for several days. PET/CT scans reveal how much energy their brains are using, and MRI shows which parts are damaged. While the team peppers a subject with questions, audiotapes, pictures, and other sensory prods, an fMRI machine tracks brain activity to look for evidence of awareness and the possibility of establishing communication. At other times, dozens of tiny electrodes are glued to the patient's scalp to pick up electrical signals through electroencephalography (EEG). Schiff repeats the clinical exam over and over, looking for fluctuations in awareness.

The scientists have now profiled more than 30 subjects, with some coming back as many as four times over the years. From these studies Schiff is developing a circuit diagram of the recovery of consciousness, a schematic that offers tentative explanations for some of the surprises he has seen. In this blueprint there is no single consciousness center of the brain. Instead, consciousness appears as a type of collective agreement among different brain regions, a dynamic state made possible by an active coalition of parts. "If somebody asked me 10 years ago, 'So, what's the circuit for consciousness?' I wouldn't have had a clue," Giacino says. "We can start to maybe answer that question now."

The circuit diagram focuses on the links among the central thalamus, the cortex, and regions (such as the globus pallidus and the striatum) that closely regulate the level of stimulation between cortex and thalamus. Schiff thinks that some of these regulatory mechanisms may actually prevent the damaged brain from restarting itself, and that pharmaceutical or electrical assistance can sometimes get it over that hurdle. That could explain Melendez and others like him who improve on Ambien: The drug might boost thalamic activity by blocking activity in the globus pallidus, which normally keeps the thalamus in check. Amantadine, a Parkinson's drug that simulates the natural brain chemical dopamine and activates the striatum, has also helped some people with disorders of consciousness, probably because it increases the striatum's inhibition of the globus pallidus, which in turn stops smothering the thalamus.

This schematic is a first step, a set of testable hypotheses about how an injured brain might climb back into awareness. It turns consciousness from a metaphysical question into a scientific one.

Remarkably, consciousness itself seems to heal the brain. Wallis,

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Melendez, and the deep brain stimulation patient all continued to recover after their awakenings, perhaps because the fundamental mechanisms by which the brain remolds itself—through learning, memory, and normal sleep cycles—were put back online. Schiff thinks that once a brain reengages with the world, it will often restart processes of repair and renewal. "There is some aspect of recovery that requires the brain to be active in the process," he says.

IN HIS SEARCH FOR A BIOLOGICAL FINGERprint of the recovering brain, Schiff has identified a few brain-wave patterns common to Wallis, Melendez, and a handful of others who have made notable, though less spectacular, recoveries. In the transition to awareness, the squiggly EEG signals —electrical patterns generated by the collective activity of the neurons in the cortex —make a distinctive shift. Someone with a disorder of consciousness generates big, slow-rolling EEG waves that resemble those of a sleeping or anesthetized brain. With greater awareness, the slow swell gives way to faster, higher-frequency waves as more electrically active neurons kick in. These faster rhythms, between 25 and 40 hertz (cycles per second), typically signal concentration and normal alert thought. Many neuroscientists think they coordinate regions of the cortex to jointly analyze information. Schiff's team is now looking at the details of the shift, seeking signature patterns that could be detected with EEG. Cheap, portable, noninvasive, and relatively easy to use, EEG could be deployed in nursing homes and long-term care facilities to search for consciousness hidden from view. Depending on the pattern, signals might indicate which treatment to try for which patient and offer a means of evaluating the therapies. EEG could also be used to identify patients who need more careful inspection with neuroimaging.

In the future, more patients may benefit from deep brain stimulation, although the team is moving forward slowly with this project to be sure to pick the best subjects. As for those patients whose brains are trapped in inanimate bodies, implants that pick up electrical impulses can already translate neural signals to control a cursor, move a wheelchair, or say hello, although they are not now suitable for people with severe brain injuries. Owen predicts that within five years at least one patient who appears fully vegetative will, with the aid of some kind of brain–computer interface, be able to communicate routinely with the world.

Some patients' families have requested that fMRI be used now to ask them how they want to live or whether they might prefer to die. The answers provided by neuroimaging can be confounding. Recently, Schiff's grad student Jonathan Bardin tried to establish fMRI communication with a young woman who had been in what seemed to be a minimally conscious state for two years. A stroke had wiped out most of her brain stem and damaged her thalamus, but her cortex looked almost untouched on CT scans, and her brain metabolism was close to normal. Everything pointed to her being able to communicate if given the chance. Because she had been a competitive swimmer, Bardin asked her to imagine swimming to signal "yes" when shown the right answer to a multiple-choice question. The patient had responded correctly in a test of her ability to identify cards via eye movement, but when Schiff asked her to do the same thing via fMRI, she answered consistently, but consistently wrong. Did she misunderstand? Is she delirious? Nobody knows.

But sometimes the successes are unambiguous. One of the Schiff group's recent subjects was 23 years old when he sustained a severe head injury in a car crash. CT scans showed that his brain was ravaged, with a huge shadow of fluid where neural flesh should be. He spent three months in a vegetative state. A year after the accident, a physical therapist realized the patient could voluntarily move his head. The therapist trained him to use a letter board, in which a helper points to letters until the patient reacts, spelling out a message one letter at a time. His IQ turned out to be normal, and apparently his personality survived too; after several hours of being queried and quizzed by Schiff's team, he used the board to spell G-E-T O-U-T.

Schiff's team helped him acquire a head mouse, which allows him to use a computer by moving his head to control the cursor. He slowly continued to improve. Last winter, this man—who not long ago might have been abandoned as hopeless—sent Schiff's group an e-mail. Hi, it said; I'm doing well. It was a telegram from a future world.