bi-on-ics

Etymology: from bi (as in “life”) + onics (as in “electronics”); the study of mechanical systems that function like living organisms or parts of living organisms



**By Josh Fischman**

Amanda Kitts is mobbed by four- and five-year-olds as she enters the classroom at the Kiddie Kottage Learning Center near Knoxville, Tennessee. “Hey kids, how’re my babies today?” she says, patting shoulders and ruffling hair. Slender and energetic, she has operated this day-care center and two others for almost 20 years. She crouches down to talk to a small girl, putting her hands on her knees.

“The robot arm!” several kids cry.

“You remember this, huh?” says Kitts, holding out her left arm. She turns her hand palm up. There is a soft whirring sound. If you weren’t paying close attention, you’d miss it. She bends her elbow, accompanied by more whirring.

“Make it do something silly!” one girl says.

“Silly? Remember how I can shake your hand?” Kitts says, extending her arm and rotating her wrist. A boy reaches out, hesitantly, to touch her fingers. What he brushes against is flesh-colored plastic, fingers curved slightly inward. Underneath are three motors, a metal frame, and a network of sophisticated electronics. The assembly is topped by a white plastic cup midway up Kitts’s biceps, encircling a stump that is almost all that remains from the arm she lost in a car accident in 2006.

Almost all, but not quite. Within her brain, below the level of consciousness, lives an intact image of that arm, a phantom. When Kitts thinks about flexing her elbow, the phantom moves. Impulses racing down from her brain are picked up by electrode sensors in the white cup and converted into signals that turn motors, and the artificial elbow bends.

“I don’t really think about it. I just move it,” says the 40-year-old, who uses both this standard model and a more experimental arm with even more control. “After my accident I felt lost, and I didn’t understand why God would do such a terrible thing to me. These days I’m just excited all the time, because they keep on improving the arm. One day I’ll be able to feel things with it and clap my hands together in time to the songs my kids are singing.”

Kitts is living proof that, even though the flesh and bone may be damaged or gone, the nerves and parts of the brain that once controlled it live on. In many patients, they sit there waiting to communicate—dangling telephone wires, severed from a handset. With microscopic electrodes and surgical wizardry, doctors have begun to connect these parts in other patients to devices such as cameras and microphones and motors. As a result, the blind can see, the deaf can hear, and Amanda Kitts can fold her shirts.

Kitts is one of “tomorrow’s people,” a group whose missing or ruined body parts are being replaced by devices embedded in their nervous systems that respond to commands from their brains. The machines they use are called neural prostheses or bionics.

The work is extremely delicate, a series of trials filled with many errors. As scientists have learned that it’s possible to link machine and mind, they have also learned how difficult it is to maintain that connection. If the cup atop Kitts’s arm shifts just slightly, for instance, she might not be able to close her fingers. Still, bionics represents a big leap forward, enabling researchers to give people back much more of what they’ve lost than was ever possible before. “That’s really what this work is about: restoration,” says Joseph Pancrazio.

There are other types of prosthesis that can begin to help more than current prosthesis. This is the kind of prosthesis Amanda Kitts has volunteered to test—one controlled by the brain, not by body parts that normally have nothing to do with moving the hand. A technique called targeted muscle reinnervation uses nerves remaining after an amputation to control an artificial limb. It was first tried in a patient in 2002. Four years later Tommy Kitts, Amanda’s husband, read about it on the Internet as his wife lay in a hospital bed after her accident. The truck that had crushed her car had also crushed her arm, from just above the elbow down.

“I was angry, sad, depressed. I just couldn’t accept it,” she says. But what Tommy told her about the Chicago arm sounded hopeful. “It seemed like the best option out there, a lot better than motors and switches,” Tommy says. “Amanda actually got excited about it.” Soon they were on a plane to Illinois.

Todd Kuiken was the person responsible for what the institute had begun calling the “bionic arm.” He knew that nerves in an amputee’s stump could still carry signals from the brain. And he knew that a computer in a prosthesis could direct electric motors to move the limb. The problem was making the connection. Nerves conduct electricity, but they can't be spliced together with a computer cable. (Nerve fibers and metal wires don’t get along well. And an open wound where a wire enters the body would be a dangerous avenue for infections.)

Kuiken needed an amplifier to boost the signals from the nerves, avoiding the need for a direct splice. He found one in muscles. When muscles contract, they give off an electrical burst strong enough to be detected by an electrode placed on the skin. He developed a technique to reroute severed nerves from their old, damaged spots to other muscles that could give their signals the proper boost.

In October 2006 Kuiken set about rewiring Amanda Kitts. The first step was to salvage major nerves that once went all the way down her arm. “These are the same nerves that work the arm and hand, but we had to create four different muscle areas to lead them to,” Kuiken says. The nerves started in Kitts’s brain, in the motor cortex, which holds a rough map of the body, but they stopped at the end of her stump—the disconnected telephone wires. In an intricate operation, a surgeon rerouted those nerves to different regions of Kitts’s upper-arm muscles. For months the nerves grew, millimeter by millimeter, moving deeper into their new homes.

“At three months I started feeling little tingles and twitches,” says Kitts. “By four months I could actually feel different parts of my hand when I touched my upper arm. I could touch it in different places and feel different fingers.” What she was feeling were parts of the phantom arm that were mapped into her brain, now reconnected to flesh. When Kitts thought about moving those phantom fingers, her real upper-arm muscles contracted.

A month later she was fitted with her first bionic arm, which had electrodes in the cup around the stump to pick up the signals from the muscles. Now the challenge was to convert those signals into commands to move the elbow and hand. A storm of electrical noise was coming from the small region on Kitts’s arm. Somewhere in there was the signal that meant “straighten the elbow” or “turn the wrist.” A microprocessor housed in the prosthesis had to be programmed to fish out the right signal and send it to the right motor.

Finding these signals has been possible because of Kitts’s phantom arm. In a lab at the RIC Blair Lock, a research engineer, fine-tunes the programming. He has Kitts slide off the artificial arm so that he can cover her stump with electrodes. She stands in front of a large flat-panel TV screen that displays a disembodied, flesh-colored arm floating in blue space—a visualization of her phantom. Lock’s electrodes pick up commands from Kitts’s brain radiating down to her stump, and the virtual arm moves.

In a hushed voice, so as not to break her concentration, Lock asks Kitts to turn her hand, palm in. On-screen, the hand turns, palm in. “Now extend your wrist, palm up,” he says. The screen hand moves. “Is that better than last time?” she asks. “Oh yeah. Strong signals.” Kitts laughs. Now Lock asks her to line up her thumb alongside her fingers. The screen hand obliges. Kitts opens her eyes wide. “Wow. I didn’t even know I could do that!” Once the muscle signals associated with a particular movement are identified, the computer in the arm is programmed to look for them and respond by activating the correct motor.

Kitts practiced using her arm one floor below Kuiken’s office in an apartment set up by occupational therapists with everything a newly equipped amputee might ordinarily use. It has a kitchen with a stove, silverware in a drawer, a bed, a closet with hangers, a bathroom, stairs—things people use every day without a second thought but that pose huge obstacles to someone missing a limb. Watching Kitts make a peanut butter sandwich in the kitchen is a startling experience. With her sleeve rolled back to reveal the plastic cup, her motion is fluid. Her live arm holds a slice of bread, her artificial fingers close on a knife, the elbow flexes, and she swipes peanut butter back and forth.

“It wasn’t easy at first,” she says. “I would try to move it, and it wouldn’t always go where I wanted.” But she worked at it, and the more she used the arm, the more lifelike the motions felt. What Kitts would really like now is sensation. That would be a big help in many actions, including one of her favorites—gulping coffee.

“The problem with a paper coffee cup is that my hand will close until it gets a solid grip. But with a paper cup you never get a solid grip,” she says. “That happened at Starbucks once. It kept squeezing until the cup went ‘pop.’”

There’s a good chance she’ll get that sensation, says Kuiken, again thanks to her phantom. RIC has been developing a new prototype for Kitts and other patients that not only has more flexibility—more motors and joints—but also has pressure-sensing pads on the fingertips. The pads are connected to small, piston-like rods that poke into Kitts’s stump. The harder the pressure, the stronger the sensation in her phantom fingers.

“I can feel how hard I’m grabbing,” she says. She can also tell the difference between rubbing something rough, like sandpaper, and smooth, like glass, by how fast the rods vibrate. “I go up to Chicago to experiment with it, and I love it,” she says. “I want them to give it to me already so I can take it home. But it’s a lot more complicated than my take-home arm, so they don’t have it completely reliable yet.”

 “It means I can do a lot more with the arm,” she says. “A new one up in Chicago lets me do lots of different hand grasps. I want that. I want to pick up pennies and hammers and toys with my kids.” These are reasonable hopes for a replacement part, Kuiken says. “We are giving people tools. They are better than what previously existed. But they are still crude, like a hammer, compared with the complexity of the human body. They can’t hold a candle to Mother Nature.”

Still, at least the people using the tools can grab the candle. And some can even see it flicker in the dark.