Phantom limb pain (PLP) affects nearly 80 percent of the amputee population worldwide. Various theories have been proposed to explain why and how PLP occurs, but they all acknowledge that the sensation of PLP involves various sensory inputs from the body and nerve impulses that are sent to the missing limb's location and return to the central nervous system and the brain.

One expert familiar with the theories of PLP is Jack Tsao, MD, D. Phil., of the Uniformed Services University of the Health Sciences, the military's medical school. He explains that sensing where a limb is in space involves one’s visual sense, the nerves within the limb, and the sense of proprioception (the unconscious perception of movement and spatial orientation arising from stimuli within the body itself). Tsao believes that signals from these different senses are fed into a region of the brain that allows a person to smoothly coordinate limb movement. Amputation removes both the proprioceptive and the visual inputs, but the neurons (nerve cells) leading to the limb are still intact. They continue to send signals, but lacking the other sensory inputs, the nerve impulses may get misinterpreted.
“They interpret the signals as the hand is being fixed in some odd posture, with the resulting sensation being that the hand is experiencing pain,” explains Tsao. “Another theory is that the neurons keep sending out signals but don’t get an answer, so they keep sending stronger signals to the missing limb. The end result is that the brain interprets the lack of signals coming back as a mismatch of signals. So it creates a phantom sensation that an amputee can feel as vividly as if it was coming from an intact hand.”

Memory may also play a role. “I treated a soldier who lost his hand in combat,” says Tsao. “The phantom sensation he experienced for six weeks was that his finger was stuck in a pulling position on the rifle trigger, which is what he was doing when he was hit by a grenade. My interpretation, based upon his description of events, is that, even with short periods of action, you can create a memory of a certain hand position and the accompanying sensation, and it is this sensation that the brain continues to experience after the amputation.”

Whatever the cause of PLP, the result is the same. The path to treating PLP lies in the nervous system and the brain, which is the focus of several recent studies. U.S. Army Col. Jeff Gambel, MD, chief of the Walter Reed Army Medical Center (WRAMC) Physical Medicine and Rehabilitation Ambulatory Patient Care Clinic, is involved in some of this research. “Many of the proposed treatments for PLP are either ways of blocking the incoming signals of pain or to alter the consciousness of it,” says Gambel. “Also, other interventions are to lay down new memory to cover over painful memories with new memories that are not painful.”

By the Pricking of My Ears

Acupuncture is a traditional form of medical treatment that has been practiced for thousands of years in China. It involves the placement of needles at strategic points on the body. The Air Force Surgeon General’s Consultant for Complementary and Alternative Medicine, Col. Richard Niemtzow, MD, is chief of Andrews Air Force Base’s Acupuncture Clinic and has extensive experience in acupuncture. He and Dr. Gambel are part of a tri-service cooperative effort to help service members dealing with pain, not just PLP, through acupuncture.

“The acupuncture we are doing for the most part is the placement of needles in the ear; the other part is the placement of needles in the scalp,” says Niemtzow. “The needles used in the ear are extremely small because they must remain in place for a number of days. And their placement must be precise.

“The locations that we have found in the ear are the key to making the process work,” explains Niemtzow. “With almost two years of experience, we’re achieving pain attenuation in at least 50 percent of the amputee patients. We haven’t seen elsewhere in the literature that, even with short periods of action, you can create a memory of a certain hand position and the accompanying sensation, and it is this sensation that the brain continues to experience after the amputation.”

Because most patients who request acupuncture treatment are already on pain medication, Niemtzow refers to acupuncture as a “clinical force multiplier.” “In some patients the pain may go away, in some patients the pain may drop down, in some patients they may have the pain but feel better,” he says. “I don’t want to say it’s a cure-all. It helps reduce pain and because of its nontoxicity, it doesn’t add to the discomfort of the patient by making them groggy or nauseous. We don’t see any side effects associated with it.”

Col. Gambel notes that other acupuncturists in the U.S. and around the world can treat phantom limb pain. But he cautions that the amputee population at WRAMC isn’t representative of the general amputee population, so the acupuncture techniques Col. Niemtzow uses and teaches may not work elsewhere.

“Our patient population right now is primarily young adult, otherwise healthy, with blast injuries,” he says. “The vast majority of the 1.8 million amputees with major limb loss in the U.S. have diabetes, peripheral vascular disease, other comorbidities. They are also older, and typically have different functional goals.”

Nonetheless, Niemtzow shares his techniques with civilian medical personnel. “Dr. Gambel has been gracious enough to allow visitors to come here to learn,” he says. Niemtzow says sharing the acupuncture technique is just one example of the positive spin-offs from military medicine. “We investigate complementary and alternative medicine to see whether it’s useful to our patients, because we want to deliver to them the best care possible because of the sacrifices they have made for our country,” he says.

Mirror, Mirror

Mirror-box therapy was first tried with considerable success by Dr. Vilayanur S. Ramachandran in the early 1990s. The mirror box has two mirrors in the center, one facing each way. The residual limb is inserted into a covered half of the box and the intact limb in the uncovered half facing the mirror, making it appear that the subject has two whole limbs. Then the subject does symmetrical exercises, imagining the missing limb is making the motion shown in the mirror. Because they see the image of the intact limb in place of the missing limb, subjects feel that their missing limb is moving, which theoretically helps reduce PLP.

Dr. Tsao is studying mirror-box therapy at WRAMC. He notes that Ramachandran was able to relieve PLP in about 60 percent of his subjects. “Since that time, nobody has done a controlled study to demonstrate whether
mirrors truly are effective in PLP and whether the effect is as dramatic as Ramachandran reported,” says Tsao. “I talked to one other group using mirrors. They haven’t published their results yet, but they found about a 60 percent response as well.” So one goal of his study is to determine how effective mirror-box therapy actually is. If it is effective, Tsao’s group wants to “determine how we can accelerate the resolution of the phantom limb phase and see if we can effect a complete cure, because some of Ramachandran’s patients had total resolution of their phantom pain.”

Because mirror-box therapy also involves mental visualization, Tsao’s study is also aimed at ascertaining if only one component of the therapy is actually alleviating the pain. “What we’re trying to sort out is whether the mirror actually is better than either a covered mirror or mental visualization,” explains Tsao. “The second goal is to try to isolate whether vision is the most important component in PLP, or could it be that your other, intact foot is somehow affecting your phantom foot. It may be that mental visualization alone might be the trick.”

Tsao likens this process to athletes who mentally visualize the motions they use in their sport, such as making a free throw in basketball. “We know from MRI studies that if you imagine performing specific movements, the brain areas that light up are the same ones that light up when you’re physically doing those movements,” notes Tsao.

Currently working with lower-limb amputees only, Tsao plans to expand the research to include upper-extremity amputees and virtual reality applications. After that, he hopes to move on to identifying the parts of the brain that control PLP. Tsao says, “If one or more of these treatments is effective, there is the potential to benefit a lot of people, not just in Walter Reed, but also in the rest of the U.S. and the world.”

“Our goal is to try to treat one major aspect of the pain that people feel after amputation,” says Tsao. “So we’re hopeful we can come up with something. Down the road, another thing we are going to try to figure out, maybe with the Amputee Coalition of America, is what kinds of phantom pain do people experience, and is there possibly a genetic link, because some of our patients in Walter Reed never experience PLP whatsoever, whereas in others it’s only for a short period of time, while a third group seems to experience chronic pain lasting for months or years.”

Virtual Reality Treatment for Virtual Pain
Researchers from the United Kingdom’s University of Manchester recently published results from a study on using virtual reality to treat PLP. Drs. Stephen Pettifer and Craig Murray designed the virtual reality system to give patients the illusion of using their missing limb, on the theory that, if the brain can be fooled into perceiving that the missing limb is still intact and “see” that it can control the limb and that it is not in pain, the phantom pain may be reduced or eliminated.

They use a regular PC to generate a simple virtual environment. A head unit that covers each eye provides a stereo view of the environment “to give a sense of 3-D,” says Pettifer. Through specialized equipment, they track movements of the remaining limb. For upper limbs, they use a data glove that tracks finger movements to replicate the remaining arm’s movements. “We track the good arm, the anatomical arm, then we mirror that onto where the phantom arm would be,” explains Pettifer. The subjects are then given tasks to do with their virtual limbs.

“The main advantage to a virtual environment rather than using an actual mirror is that you have much greater freedom of movement because you’re not constrained by having a physical mirror on a table. Also you don’t have to have experiments that work in the real world. In our virtual world, there is an experiment where a ball hovers in front of the participant and they have to reach out and knock it in any direction they like.”

Four out of five subjects experienced significant PLP reduction, which Pettifer calls “quite a good hit rate.” But, he adds, “It’s complicated because there are different types of PLP, different degrees. This has been quite a small study so far, so we haven’t been able to isolate the different types of pain and correlate them against different types of effectiveness. So it’s promising, but it’s not something we know the details of why or how it works.” Pettifer hopes that the next stage of their study will involve many more subjects and will be able to more clearly distinguish types of PLP and the types of treatment that are helpful for those specific types of pain.

With so many studies underway, it seems inevitable that better therapies will be developed for PLP. However, prescriptive treatments may still be years away. The common thread running through these researchers’ work is the need for a more definitive understanding of how PLP occurs. Until the mechanisms that cause PLP can be identified, a full course of treatment is likely to remain elusive.