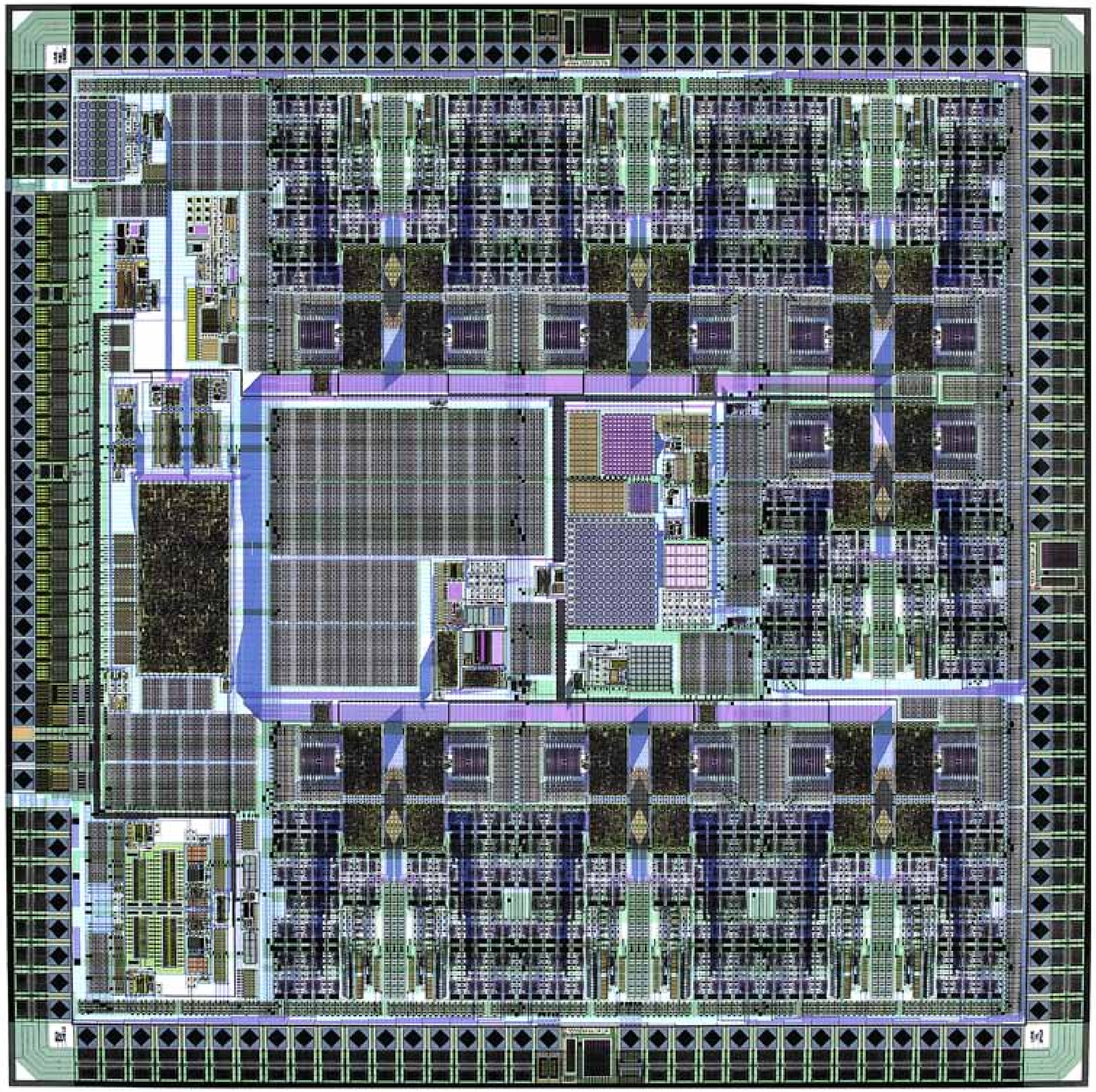
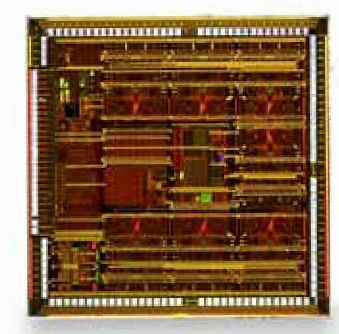


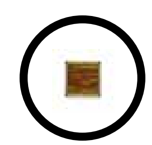
// A magnified computer-generated image of a bionic eye's integrated circuit //



MAN AND MACHINE: HOW BIONIC ENGINEERING IS CHANGING THE WAY WE LIVE

WORDS **SHANE CONROY** PHOTOGRAPHY **RICHARD MORTIMER**

From giving vision to the blind to potentially curing Parkinson's disease with electronic brain implants, bionic science is melding man and machine with astonishing results.



// The actual size of a bionic eye's integrated circuit //

There's a good reason why most sci-fi fans don't have girlfriends. While catalogue couples are off comparing pinots, shopping for antiques and rolling around on picnic blankets, we're busy speculating about the love lives of superheroes, folding our collection of ironic T-shirts and polishing our vintage Han Solo figurines.

But the quality that really keeps the girls away is the propensity to launch into heated diatribes about the swiftly advancing evolution of bionics.

Let me begin by explaining that there are two strictly divided schools of thought on the subject. There are those of us who believe that our laptops and smartphones are mere nanoseconds away from sprouting consciousness and releasing a storm of angry Schwarzenegger-like cyborgs on humanity. On the other, much more reasonable hand, there are those of us who saw Luke Skywalker's robotic arm or Steve Austin's laser-equipped bionic eye, and immediately thought, 'Damn, I gotta get me one of those.'

Scoff all you like, but it's the sci-fi fan community which will have the last laugh as modern bionic science catches up with — and eventually leapfrogs — their wildest dreams of machine-assisted human awesomeness. The bionic arm is already a functioning reality; the bionic eye (minus the laser death ray) is expected to go to human trials in 2013; and the brave new world of neurobionics is promising to cure a range of neurological disorders.

That means in the not-too-distant future, with the help of bionics, the blind will see, the paralysed will walk and debilitating neurological disorders will simply be switched off.

So what exactly is this scientific wizardry that is making such large promises? The word bionics is an etymology of biology and electronics, and refers to the study of mechanical systems that function as part of living organisms.

The fundamental premise of bionics, says professor Robert Shepherd, director of the Melbourne-based Bionics Institute, is the use of an implanted electronic device that stimulates nerve or muscle tissues to either operate prosthetic limbs or bridge broken nerve pathways.

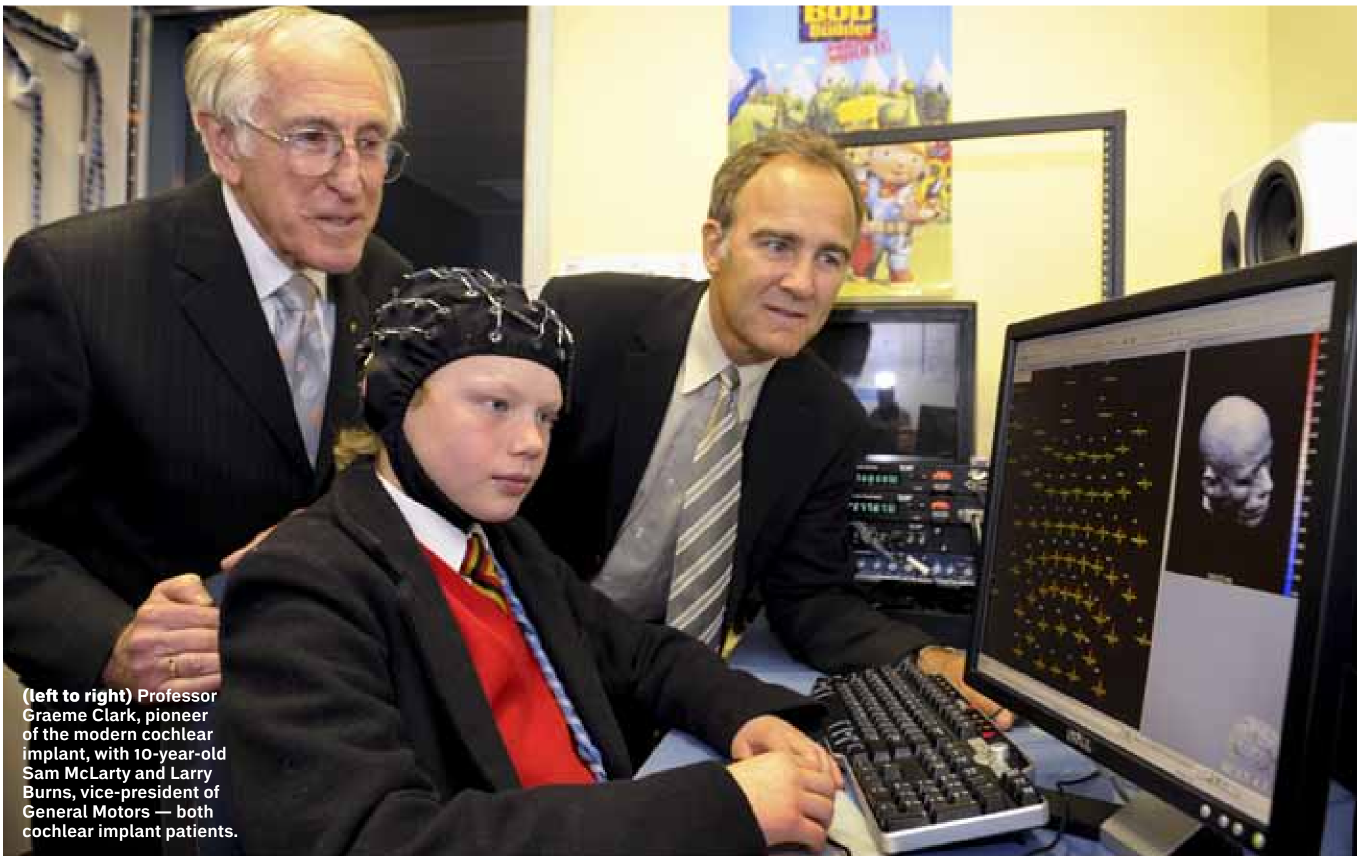
He traces the evolution of bionics back to the early cardiac pacemakers developed in the 1950s and 1960s. The first pacemakers were the size of television sets and needed to be plugged into a wall outlet. However, advancements in integrated circuitry and lithium-ion batteries allowed scientists to develop small, self-powered, implantable cardiac pacemakers.

"Australia was certainly at the forefront of that research," says Shepherd. "In fact, the cochlear implant was borne out of that work." Developed in 1978 by Australian professor Graeme Clark, the multi-channel cochlear implant — or bionic ear — was a monumental leap in bionic science and is still informing modern-day bionics.

THE BIONIC EYES HAVE IT

Shepherd and his team are part of the Australian government-funded Bionic Vision Australia program, taking their knowledge from more than 30 years of experience and applying it to a new range of projects — chiefly, the bionic eye.

Just as the cochlear implant stimulates the auditory nerve, the bionic eye stimulates the optic nerve. A camera is attached to a pair of glasses, which transmits high-frequency radio signals to a microchip implanted in the retina. These signals convert into electrical ►



(left to right) Professor Graeme Clark, pioneer of the modern cochlear implant, with 10-year-old Sam McLarty and Larry Burns, vice-president of General Motors — both cochlear implant patients.

Researchers at the Bionics Institute discuss the placement of an electrode on a model of a bionic eye.

impulses and are passed along the optic nerve to the brain, where they are interpreted as an image. For the devices to be effective, patients do need to have an operating optic nerve and some retinal cells in tact. The first human trails are expected to take place as early as 2013. However, Shepherd is quick to point out that test patients won't experience sight as we understand it.

"At the moment [all patients will see are] a number of black-and-white dots, which represent the number of electrodes we have implanted behind the eye," Shepherd says. "We are developing a device that will have approximately 100 electrodes, which we believe will allow people to distinguish between light and dark, and make out rough shapes."

While that may not sound revolutionary, Vision Australia chairman Dr Kevin Murfitt says the new technology will have a major impact on how blind and low-vision people interact with the world.

"It will help in terms of a person's independent mobility," says Murfitt, who lost his eyesight in a car accident more than two decades ago. "If you could see the outlines of buildings or the outlines of people walking towards you, or objects on the footpath, you have rich information about manoeuvring around safely."

"Further into the future, there is the potential for the [bionic eye] to achieve facial recognition."

And this is just the beginning. According to Shepherd, a second bionic eye prototype containing 1000 electrodes should be ready for test patients by 2014.

"Once we are up to 1000 electrodes, we believe a patient could read large print," he says. "Further into the future, there is the potential for the devices to achieve facial recognition."

A CALL TO ARMS

That's Steve Austin's bionic eye signed, sealed and (almost) delivered; what about Luke Skywalker's bionic arm?

There's no need to travel to a galaxy far, far away. Rather, the Rehabilitation Institute of Chicago (RIC) is as far as you need to go. Engineers there have pioneered the bionic — or myoelectric — arm, that uses a process called targeted muscle reinnervation, which allows amputees to control an artificial limb using their remaining nerves.

Think of it like this: when an arm is amputated, the nerves that once connected the brain to the muscles in the elbow, wrist and hand often survive in the patient's limb. Much like severed telephone cables, the nerves are still capable of carrying messages from the brain but are no longer connected to the muscles that moved their amputated limb. Put simply, myoelectrics uses surface electrodes placed at the site of the patient's surviving nerves to pick up messages from the brain. These messages can then be relayed to electric motors that are used to drive the new artificial limb.

Bionic legs, says Dr Jon Sensinger, director of the Prosthesis Design & Control Laboratory at RIC, are more problematic ►

than bionic arms. Passive, or non-mechanical leg prostheses already do an excellent job, and at this point myoelectric control is not stable enough to achieve reliable walking.

What we are seeing, however, is the emergence of the use of bionic leg braces as rehabilitation tools for people with spinal injuries and mobility problems. At the University of California Medical Centre, bionic leg braces are being used with great success, helping to gently retrain the brain and muscles in patients, improving their balance and mobility.

While the device is currently not used as a long-term prosthesis, engineers envisage future simplified versions of the bionic leg that will help improve the mobility of stroke victims and people with arthritis.

According to Sensinger, the next five to 10 years will also bring big advancements to myoelectric prostheses. He predicts evolving technologies that will allow for the simultaneous control of joints, intramuscular electrodes for improved reading of nerve signals, and direct skeletal attachment.

"I think the greatest change we'll see decades in the future is the level of individualisation," he says. "As rapid prototyping technology becomes less expensive and uses more durable materials, I think we'll see a greater level of clinicians designing custom devices for particular activities that are interchangeable with their standard hand." However, the most significant advancements are more likely to be of an environmental nature: "It's been said that in *Star Wars* the focus is on the technology — that is, the hand that restores function to the individual. Whereas in *Star Trek* the focus is on the environment, or accommodating the needs of the person," Sensinger explains. "It may very well be that as our environments become sufficiently sophisticated, they more than compensate for the lack of an arm." Trust a Trekkie to spoil the party.

IT'S ALL IN THE MIND

Back in Melbourne at the Bionics Institute, neuroscientists are working on new technology that not even the most wild-eyed of sci-fi writers saw coming.

Admittedly, the research is still in its early days, but neuroscientists at the institute believe they have cracked the bionic code to curing a range of neurological and psychiatric disorders. Neurobionics takes the idea behind the cochlear implant and bionic eye one step further, by applying it directly to brain function. Australian neuroscientists, including Bionics Institute deputy director of research, professor Hugh McDermott, are attempting to develop tiny bionic implants that are capable of detecting abnormal neural activity and then automatically delivering correctional electronic stimulation.

"For example, standard procedure in treating severe epilepsy that is unresponsive to medication is for a neurosurgeon to remove the part of the brain that is affected," says McDermott. "That obviously comes with large risks and any side effects are irreversible. Our research is showing that if we can implant an electronic device into the affected area of the brain, it can detect abnormal activity and automatically prevent a seizure before it happens. A person with the implant would not be aware that anything has happened."

The same philosophy can be applied to a range of neurological disorders, says ►

Bionic arm recipients Jesse Sullivan and Claudia Mitchell display the functionality of their prosthetic arms at a press conference in Washington DC, 2006.

McDermott. Potentially, neurobionic devices could be implanted to stop tremors and movement disorders such as Parkinson's disease — "like flicking a light switch," according to McDermott — and treat debilitating psychiatric conditions such as obsessive-compulsive disorder and schizophrenia.

As neurobionics develops, McDermott also believes that the technology has the potential to drastically improve brain-computer interface technology. With a bionic device capable of reading brainwaves implanted into the brain of a quadriplegic, for example, the device could transmit the brain signals to chips implanted into machines, such as wheelchairs and computers. In theory, we would then be capable of controlling any appropriately microchipped machine with the power of our minds.

And it doesn't stop there. Early research has found that neurobionic devices may one day be able to heal people suffering from memory loss. "Early tests of electrical brain stimulation have begun on people with certain neurological disorders," McDermott explains. "As a side effect of the stimulation, it seemed that some patients reported improvements in memory."

For a tragic sci-fi fan or aspiring super-villain, such developments surely beg the obvious question: What will happen if we use this sort of technology on a perfectly healthy person?

McDermott says that while the technology may well prove safe to use on healthy people, it does pose the question of ethics. "There is the possibility that in the future, a neurobionic device could be developed that stimulates parts of the brain that we don't currently use," muses McDermott. "The device could possibly be harnessed to help increase our intelligence, but whether it is ethical to do that is a completely different story."

While we can't be sure how the ethical debate regarding computer-assisted human intelligence will resolve itself, we can be sure that our smartphones will not be orchestrating the cyborg revolution any time soon. Rather, man will continue to develop its mastery over machines to achieve a life increasingly unburdened by physical injury and neurological distress.

Engineers examine a prototype electronic device to treat epilepsy at the Bionics Institute.

ARTIFICIAL INTELLIGENCE

Bionic technology has certainly come a long way since its humble beginnings in the form of television-sized pacemakers.

1950

Canadian electrical engineer Dr John Hopps invents the first external cardiac pacemaker. It's about the size of a television set and must be plugged into a wall outlet.

1958

Swedish cardiac surgeon Dr Ake Senning and medical engineer Dr Rune Elmqvist develop the world's first implantable pacemaker (inset).

1964

The first commercial myoelectric arm is developed in Russia.

1978

Professor Graeme Clark implants a prototype cochlear implant in a patient. Developed in Melbourne, it becomes the world's leading clinically accepted device capable of restoring sensory function.

1998

The first myoelectric shoulder is successfully fitted to an amputee.

2007

Melbourne-based Bionics Institute, in partnership with the Centre for Eye Research Australia, begins research on the bionic eye.

2008

Prosthetic technology company, Touch Bionics, develops the world's first myoelectric hand with five individually powered digits. The i-LIMB Hand is also revolutionary in the fact that it is capable of replacing one to five missing fingers of a person with prosthetic digits.

In the future

2013

Human trials of the bionic eye will begin. Patients are expected to be able to see light from dark, and manoeuvre around large objects.

2013–2016

Improvements in bionic eye technology will likely allow patients to recognise faces and read large-print text.

2014–2026

Advances in neurobionics could prevent epilepsy and treat illnesses such as depression and Parkinson's disease.

Photography: Bionics Institute, Getty Images, Newspix, Marko Turina