NEW PARTS AVAILABLE

Amazing advances in bioengineering are changing the lives of millions.

BY ANITA BARTHOLOMEW

This prosthetic allows individuals to feel and manipulate objects.

In the blockbuster movie "Robocop", scientists reconstruct a police officer into a cyborg—part human, part "bionic"—after an attack leaves him terminally injured. Could it happen?

Although we haven't begun producing super-humans, the concept of rebuilding grievously damaged bodies to be better than before has moved from the science fiction shelf to one marked simply, science. Today's doctors are replacing lost limbs with robotic prosthetics, swapping failed organs with functioning ones, restoring some hearing to the deaf and limited sight to the blind.

Tomorrow's doctors may be able to end blindness altogether, make paralysis a thing of the past—and if an organ wears out? No problem. They'll grow you a new one from scratch in a lab.

Here are some of the amazing advances changing lives for the better right now — and what else might be coming in the not very distant future.

A New Face

The suturing of myriad tiny blood vessels, nerves, and muscles to a surface they were never intended to fit, along with the need for a cosmetically pleasing end result, make face transplants among the most difficult and complex of surgeries.

In mid-2013, a young man known only as Grzegorz (his surname was never released) left doctors little time to prepare. In an industrial accident, Grzegorz's entire face—along with parts of his neck, jawbone and cheekbones—got torn off by stone-cutting machinery. Unable to eat or breathe on his own, he was deteriorating. Dr. Adam Maciejewski, head of transplantation at Poland's Maria Sklodowska-Curie Memorial Cancer Center and Institute of Oncology, led the team of surgeons that gave Grzegorz a new face and saved his life.

In a marathon 27-hour operation, surgeons first retrieved the parts to be transplanted from a deceased donor, then began the process of fitting and attaching bone, muscle, oral and nasal cavities, nerve and blood vessels, skin and underlying fat to their waiting patient.

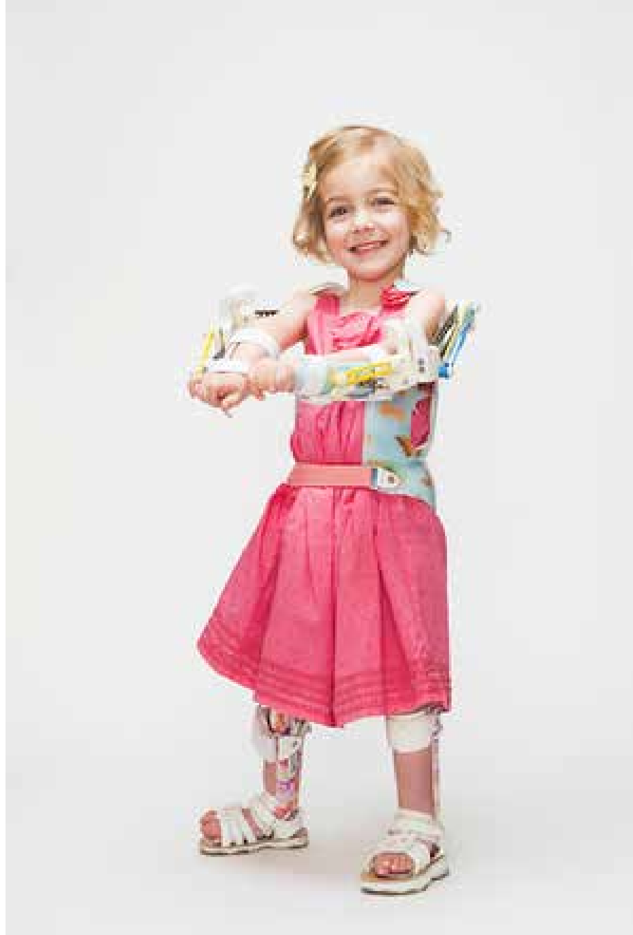
Full recovery from the exquisitely delicate surgery is a long process, but a year later Dr. Maciejewski reported that Grzegorz was doing well. "He can eat everything; he can drink and speak normally."

Since the first successful face transplant was completed in France less than ten years ago, only about another two dozen such operations have been performed worldwide. But in coming years Dr. Maciejewski believes face transplantation will become a "routine, normal procedure, everywhere in the world."

Moving With Robotics

Prosthetic legs, at their simplest, merely fill the void left by the loss of a natural leg. But today's specialized prosthetic legs are anything but simple, allowing users who can afford them to hike, swim, ski, climb mountains and more.

Magnus Oddsson, an engineer with Ossur of Iceland, which developed the carbon fibre "Cheetah" legs used by Paralympic athletes, says the next phase in lower limb prosthetics is bioelectronics—bionics, for short—robotic prosthetics with built-in sensors and microprocessors.



Emma (who has the use of her legs) suffers from neuromuscular weakness. The Wilmington Robotic Exocskeleton (WREX) allows her to lift her arms to play and feed herself.

That phase is already well on its way in upper limb prosthetics. Trauma surgeon Albert Chi, medical director of John Hopkins Targeted Muscle Reinnervation Program, believes that in the not very far-off future, robotic limbs will be indistinguishable in every way from natural ones. His focus is on giving amputees greater function by re-routing nerves that once were attached to their missing hands into new areas of muscle where these nerves can communicate, via tiny electrodes on the surface of the skin, to robotic prosthetics. When this is done, the result is a thought-controlled bionic arm. It uses the same brain signals that once led to the missing hand and arm with instructions to flex, grasp and rotate. The user feels almost like the prosthetic is his own limb.

Our nerves do more than transmit the brain signals that allow us to move, though. They also feel, reacting to external stimuli such as heat and cold. Could a bionic limb feel?

Dr. Chi's patient, Johnny Matheny, 59, lost his much of his left arm to cancer. But when using the thought-controlled bionic arm developed in Johns Hopkins' University Applied Physics lab, Matheny can sense touches to each individual bionic finger. He can feel whether he's grasping hard or soft objects. It's even possible for his bionic hand to distinguish hot from cold. For Matheny, perhaps the most wondrous moment was when his wife reached out and held his bionic hand. Her touch felt almost as it had when his natural hand last held hers, five years before.

It's not just those who have lost limbs who are benefiting from robotics. People who are paralyzed or weakened by spinal cord injuries or neurological disorders can be fitted with wearable robots, known as exoskeletons, that are like "an Iron Man suit, which you strap on," explains Arun Jayaraman, who studies and researches these devices at the Rehabilitation Institute of Chicago. The robotic exoskeleton propels the wearer along.

Several models are already commercially available in certain countries. They use different mechanisms to get you where you want to go, but all have multiple sensors meant to detect the user's intended movement. So, for example, leaning forward on your left might trigger the left exoskeleton leg to move you a step forward. A computer and battery in a backpack provide the brains and power for many models but a newer, lighter exoskeleton developed by Honda can be controlled by an app from your smartphone or tablet.

A Bionic Eye

As a young man, Dr Mark Humayun could do little to help as his grandmother lost her sight and struggled with the simple things most of us take for granted. Since then, the professor of biomedical engineering at the University of Southern California has devoted much of his career to developing an artificial retina, a.k.a. "bionic eye. "

A small camera, mounted on wraparound eyeglasses, captures a scene, which is then wirelessly communicated to a minuscule device that is surgically implanted on the retina. The implant "takes the information from the camera, and converts it into tiny electrical impulses that jumpstart the otherwise blind eye," explains Dr. Humayun. The resulting images resemble blurry, low-resolution video.

Initially, the bionic eye was able to transmit only gray-scale visuals, but a tweak to the software has allowed those with the implant to distinguish up to nine colors. "Every time we've pushed this technology, " says Dr. Humayun, "patients continue to see better and better."

Approved for use in Europe in 2011, the bionic eye only works for those whose blindness is due to a loss of the cells that process light, which happens in retinitis pigmentosa, macular degeneration and some other diseases. But it might be possible one day to connect such a device directly to the part of the brain that processes vision, so that people with other types of blindness, or even with an eye missing, might again be able to see.

Tomorrow's Organ "Donor"

There simply aren't enough organ donors to save the lives of all 56,000 people on transplant waiting lists throughout Europe. But what if they could be saved despite the scarcity of donors?

"What if?" may be a reality sooner than we imagine, thanks to a novel technique for bioengineering new body parts using 3-D printing technology.

"We modified ink-jet printers so they'd print one layer at a time, layer after layer after layer," says Anthony Atala, MD, director at the Wake Forest Institute for Regenerative Medicine in North Carolina. The "inks" used by 3-D printers in bioengineering can be cells or other organic materials, miner-

WORLD "FIRSTS"

What, When, Where and approximate performed today

Corneal transplant
1905
in today's Czech Republic. An estimated 120,000 globally.

Kidney transplant
1954
in the US. Today some 69,400 transplants annually.

Hip replacement
1962
in the UK. Approximately 1.4 million a year globally.

Liver transplant
1967
in the US. Now about 20,00 annually.

Lung transplant
1963
in the US. Some 3,400 per year worldwide.

Titanium dental implant
1965
in Swede. Now commonplace worldwide.

Pancreas transplant
1968
in the US. About 2,500 each year.

LOOKING AHEAD - BUILDING A BETTER YOU

3-D Printing
Doctors have already transplanted synthetic substitutes of skulls and bone grafts, 3-D printed to fit, to replace damaged skull and other bone. In the future they could replace lost bone by 3-D printing with cells cultured from your body.

Burn victims could be positioned under a 3-D printer which will then "print" new skin cells, previously cultured from them, directly over the injury.

And, Instead of off-the-shelf replacement joints, tomorrow's surgeons will use a scan to produce a 3-D printed model of your natural hip. From this a customized joint replacement is manufactured, greatly increasing the chances of long-term success.

And, one day, scientists hope to 3-D print an ear that incorporates everything you need for hearing, without requiring external processors. Some believe such a device could make it possible to hear well beyond current human capabilities.

Grow-your-own
In a small study, heart failure patients had their own healthy heart stem cells extracted during coronary bypass, cultured and infused back into their hearts. These multiplied, and in most patients, damaged heart muscle healed. Such infusions might become an alternative to heart transplants.

New organs from old
Many organs are unsuitable for transplant but their structure might in the future form the "scaffold" for generating new, transplantable organs. Doctors are already experimenting with discarded livers.

als, synthetics, or a combination.

For example, using collagen as "ink," Dr. Atala's team has produced hollow objects the shape and size of human bladders. These form the scaffolds onto which patients' own cells are seeded.

To get the cells, "We take a very small piece of [healthy bladder] tissue from the patient," says Dr. Atala. Those cells are cultured until there are enough to coat the scaffold. The whole bioengineered bladder is then incubated in a device that mirrors the conditions of the human body. The cells proliferate for six to eight weeks, until the scientists have a fully functioning transplantable organ.

Several young people whose bladders failed are now living with Dr. Atala's lab-grown organs, and his team has successfully transplanted other 3-D printed hollow, flat and cylindrical body parts.

Solid organs, printed in the lab, are years away from being viable due to their complexity. But sometime in the future, should you need a heart, kidney, lung, liver, or pancreas, your new organ might be generated this way. Your immune system is then less likely to attempt to reject it, eliminating perhaps the greatest challenge facing recipients of donated body parts.

BIO-ELECTRONICS AND bio-engineering are still in their infancy. But as medicine becomes more and more intermingled with technology, it resembles what, only recently, we might have dismissed as science fiction.

And tomorrow? Somewhere, a scientist is dreaming of a breakthrough solution to one of medicine's most intractable problems. And, sooner than we think, that dream will be part of our everyday reality.

Heart transplants
1967
in South Africa. Today about 5,400 annually around the world.

Knee replacement
1968
in the U.K. About 1.1 million knee replacements each year.

Cochlear implants
1972
in the US. Now approximately 219,000 worldwide.

Intestine (small bowel) transplant
1992
in the U.S. About 250 annually worldwide.

Prosthetic legs.
1990s
From 1990s advanced models designed for specific activities.

Face transplants
2005
(full or partial) in France. About 25 a year.

First robotic hand developed
2007
in Scotland. About 500 a year sold to clients.

Hand/arm transplants
2000
in Malaysia. Only about 85 transplants have been performed globally.