WORLD CHANGING IDEAS

10 innovations that are radical enough to alter our lives

Illustrations by The Heads of State

Scientists and engineers dream about big advances that could change the world, and then they try to create them. On the following pages, *Scientific American* reveals 10 innovations that could be game changers: an artificial alternative to DNA, oil that cleans water, pacemakers powered by our blood, and more. These are not pie-in-the-sky notions but practical breakthroughs that have been proved or prototyped and are poised to scale up greatly. Each has the potential to make what may now seem impossible possible. *—The Editors*

Drones at Home

Tiny, unmanned aircraft are ready to warn you about traffic or spy on you in your backyard

Airborne eyes that peer down from the sky are already changing how science gets done and how wars are fought, and a commercial fleet of them is destined to radically change how we live our lives.

Scientists such as Lian Pin Koh of the Swiss Federal Institute of Technology and Serge Wich of Liverpool John Moores University in England are helping to create that intriguing and possibly unnerving future. After spending two and a half years and $250,000 tracking orangutans in Sumatra on foot, Koh and Wich devised a quicker, cheaper method. They bought a battery-powered model airplane and added an inexpensive open-source autopilot and high-resolution camera. For less than $2,000, they created a Conservation Drone—an autonomous plane with a 4.5-foot wingspan that uses GPS signals to fly preprogrammed routes and bring back remarkably detailed pictures and data about orangutan nests and new areas of deforestation. "We're still surprised how easy it was to assemble from off-the-shelf components," Koh says.

The first tests in early 2012 were so successful that other conservationists have been clamoring for their own planes. Working with a Swiss startup company, Koh and Wich have now built more than 20 drones.

The military already depends on big drones such as the Predator to fight enemies and on small autonomous planes and helicopters to scout paths for convoys or ferret out ambushes. Officers use them to find illegal activity along the U.S.–Mexico border. But civilian enthusiasts are getting into the act, too; they have customized drones to nab polluters, inspect drilling rigs, and take stunning pictures for movies and real estate listings. "Drones are going to change the world in profound ways," says Matthew Waite, a journalist-turned-professor at the University of Nebraska–Lincoln who is exploring the use of drones for journalism.

This revolution is being propelled by rapid advances in technology. With powerful smartphone chips and open-source hardware platforms such as Arduino, do-it-yourselfers and communities such as DIY Drones have begun to build inexpensive but sophisticated autopilots that transform radio-controlled aircraft into autonomous ones. Companies that build drones for the military are pitching their wares to police departments and government agencies. The U.S. Department of the Interior has already obtained 60 Raven planes, weighing 4.8 pounds apiece, from aviation pioneer AeroVironment, to observe roosting sandhill cranes and measure stream temperatures and sediment flows, among other tasks. Future possibilities seem endless: with sophisticated cameras and sensors, small drones could tell when crops need water, chart oil spills and report on traffic jams. "We're just at the tip of the iceberg of what's possible," says Mike Hutt, manager of the U.S. Geological Survey's National Unmanned Aircraft Systems Project Office.

The full iceberg will not come into view for several years, however, because the Federal Aviation Administration has banned commercial uses of drones, fearing the confusion and accidents that could occur if thousands of unmanned craft take to already crowded skies. The FAA basically allows flying by hobbyists, government agencies and researchers and usually limits the altitude to a few hundred feet. But the FAA Modernization and Reform Act of 2012, signed by President Barack Obama in February, requires the agency to develop rules permitting more civilian uses. The FAA is working with companies on the key technology: systems that allow drones to sense and avoid other flying objects. Final rules are expected by 2015, opening the door to an explosion of commercial applications.

The current pause before that explosion is a boon, Waite suggests. "Drones raise humongous questions about safety and ethics and law and privacy," he says. "But now we have a rare opportunity to think about how we are going to use a technology before we actually use it."

—John Carey

Electronic Tattoos

Ultrathin, flexible sensors could adorn packaging, accessories, even our bodies

Engineers have built circuitry on flexible plastics, but electronics may soon reach a far more pliable realm: circuits that we can wear on our bodies, like tattoos, to monitor our vital signs. The circuits could also be woven into clothing to power our smartphones and into food packaging to alert us about contamination.

Rather than looking for flexible substances that can conduct electricity, John Rogers, a materials scientist at the University of Illinois at Urbana-Champaign, got the idea to take common silicon circuitry and make it bendable. He and engineers at mc10, a firm in Cambridge, Mass., sanded silicon microchips, usually millimeters thick, down to 10 or 20 microns using well-established manufacturing processes. They also devised ultrathin wires to connect those chips to one another and to traditional input-output ports—wires that can bend, fold and stretch up to twice their original dimension.

Kevin Dowling, vice president of research and development at mc10, likens this configuration to "islands [the chips] that are anchored and oceans of interconnects" between them that can stretch or bend. "If you take a Slinky made of spring steel, that steel itself doesn't stretch very much," Dowling explains. "But a Slinky can stretch 40 to 50 times its original length without exceeding the plastic limits of the steel. In the same way, we can create metal or silicon interconnects."

Rogers, who co-founded mc10 and whose laboratory is the company's de facto R&D operation, says that in the next five to 10 years stretchable electronics will show up in forms no thicker than a Band-Aid. These sensors could monitor a person's body and transmit the results wirelessly. Already mc10 has a contract with Reebok for an apparel-based health monitor. The company also has a contract with the U.S. Army to determine whether it can produce flexible solar cells that can be integrated into soldiers' clothing and backpacks. In April, NASCAR driver Paulie Harraka tested a transparent skin patch during a race. The patch measured Harraka's level of hydration, an important consideration in a cockpit that can roast drivers for hours. Other engineers are also pursuing flexible biomedical tattoos, including Nanshu Lu of the University of Texas at Austin and a team at Korea University in Seoul.

Band-Aid-like sensors could stay on the body for up to a week, acting as "biostamps" or medical tattoos that could measure heart rate and perspiration. The circuitry is so thin and transparent that it looks like a small, see-through film on the skin.

The circuitry could one day be embedded inside the heart or the brain. Rogers imagines that hearts with arrhythmias could be sheathed in an artificial sac that would electronically sense and correct the organ's flawed rhythm. Such a sheath could deliver variable electrical stimulation to any location on the heart, thereby creating a much more nuanced shaping of the heart's beating than a pacemaker. Rogers also envisions "artificial skin over a burn site to provide artificial vasculature and, at the same time, drug delivery and stimulation to accelerate healing of that wound."

If mc10's technology scales up, one product could be a roll of stickers, each one a sensor. A person could bug a room with tiny stickers designed to pick up sound. Anything that a silicon chip can sense—strain, vibration, electric fields—could be measured by little paper-thin sensors. Worn on the body or in clothing, such devices could be powered by weak electromagnetic fields and could then use those same fields to report back via people's smartphones.

Wide application will depend on manufacturing innovations from electronics makers that license mc10's technology. As with other transformative electronics innovations—think of the LEDs that now light up everything from household bulbs to grocery stores—it is ultimately up to the thousands of consumer device makers to figure out how best to apply this foundational technology.

—Christopher Mims

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