The computer chip that thinks it's a tiny human liver

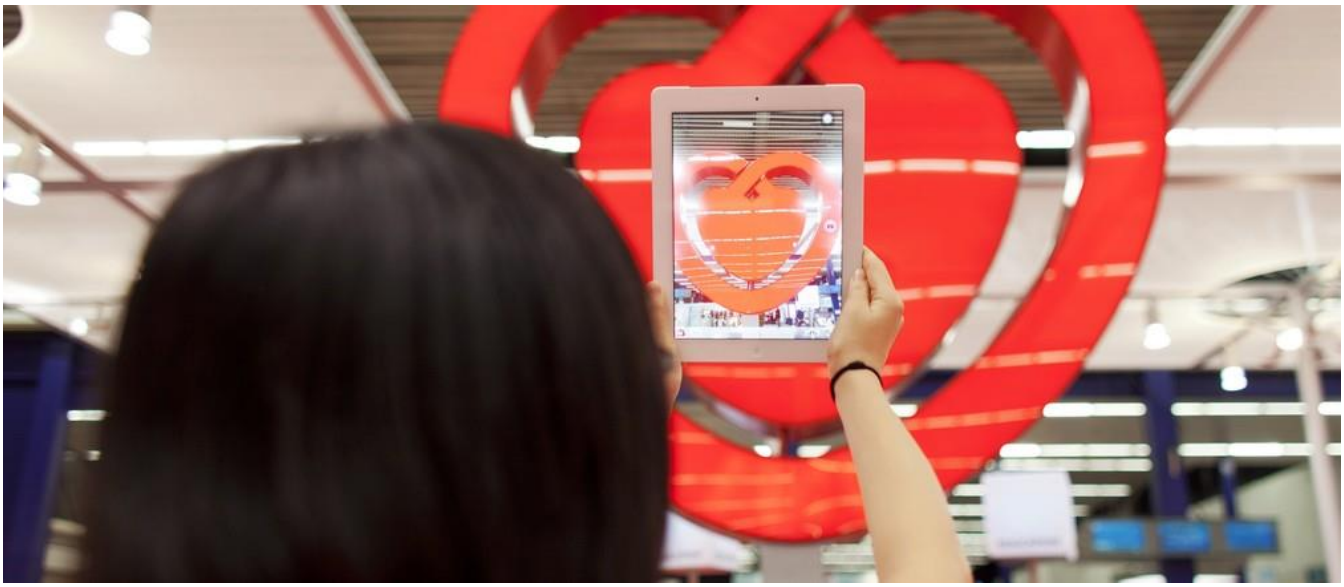

Image: REUTERS/Cris Toala Olivares

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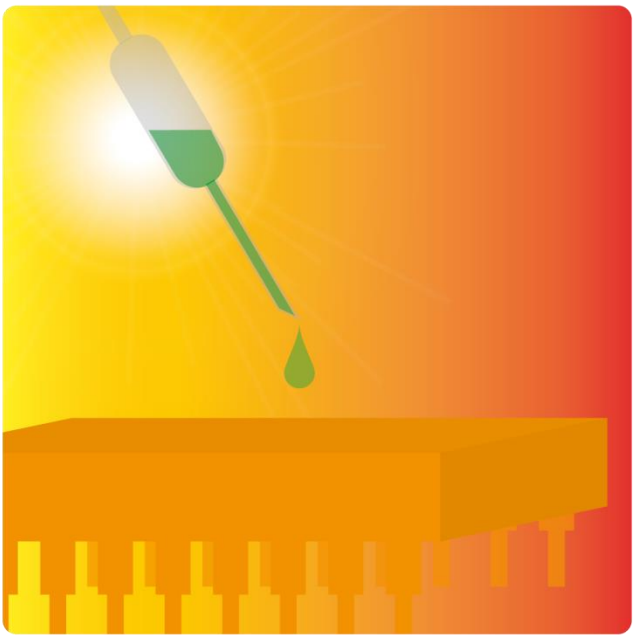
Brains—even relatively simple ones like those in mice—are daunting in their complexity. Neuroscientists and psychologists can observe how brains respond to various kinds of stimuli, and they have even mapped how genes are expressed throughout the brain. But with no way to control when individual neurons and other kinds of brain cells turn on and off, researchers found it very difficult to explain *how* brains do what they do, at least not in the detail needed to thoroughly understand—and eventually cure—conditions such as Parkinson's disease and major depression.

Scientists tried using electrodes to record neuronal activity, and that works to some extent. But it is a crude and imprecise method because electrodes stimulate every neuron nearby and cannot distinguish among different kinds of brain cells.

A breakthrough came in 2005, when neurogeneticists demonstrated a way to use genetic engineering to make neurons respond to particular colors of light. The technique, known as optogenetics, built on research done in the 1970s on pigment proteins, known collectively as rhodopsins and encoded by the opsin gene family. These proteins work like light-activated ion pumps. Microbes, lacking eyes, use rhodopsins to help extract energy and information from incoming light.



The chambers inside the chip can be arranged to simulate the particular structure of an organ tissue, such as a tiny air sac in a lung. Air running through a channel, for example, can then very accurately simulate human breathing. Meanwhile, blood laced with bacteria can be pumped through other tubes, and scientists can then observe how the cells respond to the infection, all without any risk to a person. The technology allows scientists to see biological mechanisms and physiological behaviors never before seen.

Organ microchips will also give a boost to companies developing new medicines. Their ability to emulate human organs allows for more realistic and accurate tests of drug candidates. Last year, for example, one group used a chip to mimic the way that endocrine cells secrete hormones into the blood stream and used this to perform crucial tests on a diabetes drug.

Other groups are exploring the use of organs-on-chips in personalized medicine. In principle, these microchips could be constructed using stems cells derived from the patients themselves, and then tests could be run to identify individualized therapies that are more likely to succeed.

There is reason to hope that miniature organs could greatly reduce the pharmaceutical industry's reliance on animal testing of experimental compounds. Millions of animals are sacrificed each year to such tests, and the practice provokes heated controversy. Ethical considerations aside, it has proven to be immensely wasteful—animal trials rarely provide reliable insights into how humans will react to the same drug. Tests done on miniaturized human organs might do better.

Military and biodefence researchers see the potential for organs-on-chips to save lives in a different way. The simulated lung, and other devices like it, could be the next big step in testing responses to biological, chemical or radiological weapons. It isn't possible to do this today, for obvious ethical reasons.

This is part of a series on the top 10 emerging technologies of 2016, developed in collaboration with Scientific American.