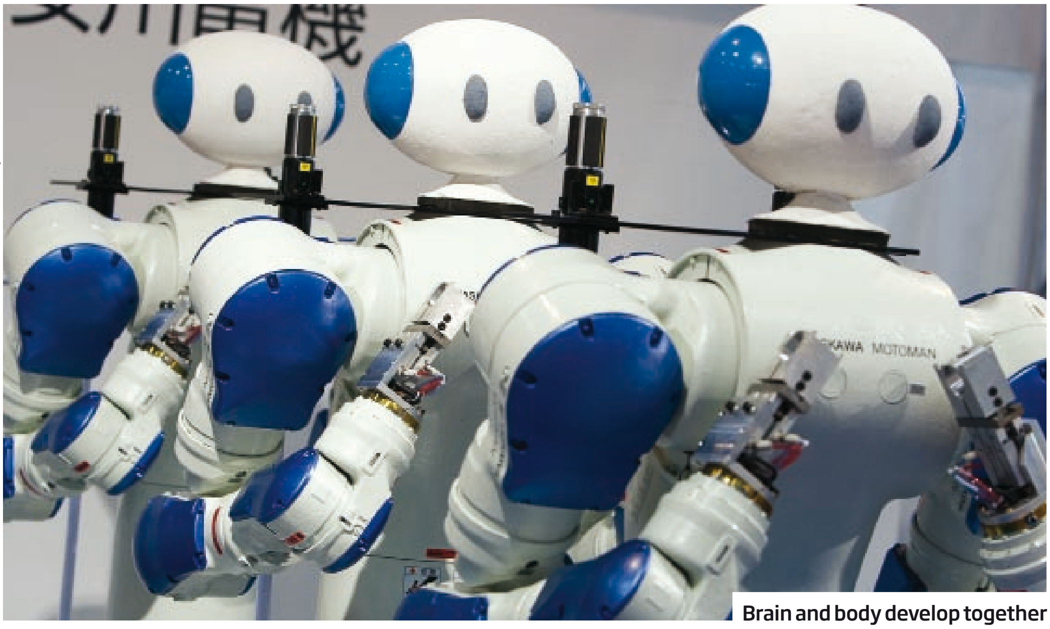

JEREMY SUTTON HIBBERT/REX

Brain and body develop together

Darwin's robots

A holistic, evolutionary approach means that robots could learn to design themselves

Lakshmi Sandhana

WHAT if a robot – brain, body and all – could be born and then develop in a similar way to a human baby?

Instead of a mother, the robot would come out of a printer, in its entirety. "The end game is to evolve robots in simulation, hit print, and watch them walk out of a 3D printer," says Jeffrey Clune, who heads the HyperNEAT project at Cornell University's Creative Machines Lab in Ithaca, New York.

Before he can do that, though, Clune needs the right design. His team had already evolved digital brains using neural networks that mimic biological evolutionary processes, and the researchers are now connecting these brains to a body, to find ones that can make the body walk right away.

The neural networks, essentially a series of algorithms, enable the brain to learn how to control physical robotic bodies, either simulated or physical. The brains receive sensory inputs from the body telling them what to learn to control – whether it has two legs or four, for example – then evolve the neural patterns needed to control it.

Each brain was given control of a physical body for a period of time. Some were abject failures, and could only muster enough control to flail about, fall over or twitch.

The best-performing brains were allowed to reproduce to create the next generation and the entire process was then repeated until the team obtained a brain that could control the robot and walk around the lab. So far, Clune's team has evolved a brain that is able to make a four-legged robot walk within a few hours of the brain being plugged into the body. The results were presented last month at the European Conference on Artificial Life in Paris, France.

"From an observer's perspective, it looks like a robot that 'wakes up', tries out a new gait, and then 'thinks about it' for a few seconds, before waking up again and trying a new gait," says

"The end game is to evolve robots in simulation, hit print, and watch them walk out of a 3D printer"

Clune. "Over time you see that the robot learns how to walk better and better."

As the robot brains can adapt according to the information given them from the body, they can learn continually and transfer acquired skills from one task to another. For example, a robotic brain evolved to control a four-legged robot would still function if hooked up to a six-legged robot. A small amount of damage shouldn't cripple these robots as they would be able to adapt.

Clune's team is now evolving simulated bodies and brains with their EndlessForms website, also developed at Cornell. This uses evolutionary algorithms to gradually modify designs before bringing them into the real world with 3D printing. Clune hopes to use EndlessForms to design soft-bodied robots using printable materials that act as muscles, bones, batteries, wires and even computers.

The lab has 3D-printed many of these components already, including wires and artificial muscles, which move when a current is passed through them. However, they have yet to find a way to print structural material with different levels of stiffness – harder materials for bone, for instance – as well as some of the softer, more flexible tissues. "Eventually, the entire thing will be printed, brains and all," says Clune.

The team uses neural networks known as compositional pattern-producing networks (CPPNs) to mimic how natural organisms develop. This produces designs that share important properties ›

Understanding intelligence

The "brain plus body" approach to evolving robots (see main story) may also help researchers in other fields, allowing them to study the conditions under which intelligence evolves fastest. For instance, one theory says that intelligence evolved to keep track of life in complex social societies. This can be tested by studying robot evolution when they are alone and in groups. "These are dream experiments for evolutionary biologists and they become possible using evolution in computers, but only once we are able to evolve complex-enough brains," says creator Jeffrey Clune. "That's one reason our breakthrough is so important: it opens doors to many new types of science."

with natural organisms, such as symmetry and the repetition of modules.

Josh Bongard, who works on robot evolution at the University of Vermont in Burlington, says Clune's approach is exciting because it explores how a robot's body affects its behaviour and offers control over the evolution of every aspect of a robot – brain, body and behaviour.

"If CPPNs are used to evolve robot bodies along with brains, he may be able to evolve robots with complex bodies as well as complex brains," Bongard says.

Using evolutionary methods to build whole robotic entities opens up an even more intriguing possibility – that robots could evolve new and entirely different structures. "It may well be that the neural networks and bodies that we create for the system are not those that the system would develop for itself," says James Giordano, who directs the Center for Neurotechnology Studies in Arlington, Virginia.

Better robotic bodies that can handle the brain's demands are certainly needed: the test robot broke down because it was unable to cope with the running motions that the brain had evolved after a number of generations.

Eventually, the brain and body should work in concert, with the brain's evolution dependent upon what tasks the robot carries out during its lifetime, says Jean-Baptiste Mouret of the Intelligent Systems and Robotics Institute in Paris, France.

"The brain will depend on the body and on the 'life' of the robot, in the same way as birds' brains are different from rats' brains," says Mouret. Breeding robots that can do more than walk is the next big step. The software-based brains that are best at performing a desired behaviour in simulation, such as climbing a wall or getting close to a person, will be allowed to reproduce until the final generation has hard-wired instincts to perform the task. ■

Smart app scans brain on the fly

A portable EEG scanner could make life a lot easier for people with neurological problems

Jacob Aron

CLASSICSTOCK / ALAMY

YOU can now hold your brain in the palm of your hand. For the first time, a scanner powered by a smartphone will let you monitor your neural signals on the go.

By hooking up a commercially available EEG headset to a Nokia N900 smartphone, Jakob Eg Larsen and colleagues at the Technical University of Denmark in Kongens Lyngby have created a completely portable system.

This is the first time a phone has provided the power for an EEG headset, which monitors the electrical activity of the brain, says Larsen. The headset would normally connect wirelessly to a USB receiver plugged into a PC.

Wearing the headset and booting up an accompanying app designed by the researchers creates a simplified 3D model of the brain that lights up as brainwaves are detected, and can be rotated by swiping the screen. The app can also connect to a remote server for more intensive number-crunching, and then display the results on the cellphone.

"Traditionally, in order to do these kind of EEG measurements you have big lab set-ups that are really expensive," says Larsen. "You have to bring people in, isolate them and give them specific tasks." The smartphone EEG would let researchers study people's brain signals in more natural environments such as at home or in the workplace. Teams can also use the smartphone's other features to conduct

Wall-climbing, base-jumping, paragliding robot

ADRENALIN junkies, step aside: a new base-jumping robot can climb up buildings before deploying a paraglider to fly back down to earth. And it has its own on-board video camera to record the jump.

The remote-controlled robot, named Paraswift, is a collaboration between Disney Research and the Swiss Federal Institute of Technology (ETH) in Zurich, and was initially built to entertain visitors to theme parks. But as the first compact robot that can both climb and fly, it has practical uses too, such as gathering aerial footage for 3D modelling systems.

It uses an impeller – a rotor spinning in a tube – to create a vortex that sticks it to the wall as it climbs. "It's like a mini tornado within the robot," says ETH student Lukas Geissmann, who presented Paraswift last week at the Conference on Climbing and Walking Robots in Paris, France, with Paul Beardsley of Disney Research. The centre of this vortex is low pressure, just like the eye of a tornado, and the higher atmospheric pressure around it pushes the robot onto the wall.

"The big benefit is that you don't need a seal between the robot and the wall because the vortex forms its own seal around the low-pressure area," Beardsley says. That means only the robot's wheels need touch the wall, and it can navigate the often rough surfaces of buildings.

This is one of the major challenges in designing wall-climbing robots, says Metin Sitti of the Carnegie Mellon University Robotics Institute in Pittsburgh, Pennsylvania: "It is very difficult to have a robust attachment mechanism that could work on a wide range of smooth and slightly rough surfaces in real-world conditions," he says.

Mobile robots are increasingly used to inspect dangerous or hard-to-reach structures such as wind turbines, dams and tall buildings. Most commonly, they use magnetic adhesion, but that limits a robot to ferrous structures. Others use

"A mini tornado within the robot creates a vortex that sticks it to the wall as it climbs"