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Out of the digital ooze, robotic life

Designs that evolve without human aid

By Charles W. Petit

Maybe Jordan Pollack, computer scientist and robot maker, should call his workplace at Brandeis University near Boston something other than a laboratory. Nest or hive seems closer to the mark. In it, he and mechanical engineer Hod Lipson run the Golem Project, a colony of machines that evolve and give birth to other machines without human guidance. Last week, in the journal *Nature*, the pair described their work as "Automatic design and manufacture of robotic life-forms."

Life-forms? That is something that Lieutenant Commander Data might say on the *Starship Enterprise*: "Captain, a scan of the planet reveals robotic life-forms!"

So far the life-forms—bundles of white tubes resembling crazily linked sausages that lurch, slither, and hunch their way across lab bench tops—aren't very advanced; their only talent is movement. But neither were the first creatures to appear in Earth's primordial ooze.

Massachusetts Institute of Technology artificial-intelligence expert Rodney Brooks calls these machine-bred robots a step toward the "ultimate dream of self-evolving machines." They conjure up a tomorrow in which machines breed among themselves, whelping devices whose abilities surpass human invention—a vision at once hopeful and unnerving.



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[GOLEM Project.](#) Access the text of the *Nature* article "[Automatic Design and Manufacture of Robotic Lifeforms](#)" (in PDF format) and get answers to [frequently asked questions](#) about the project.

To get machines to design other machines, Pollack and Lipson borrowed a strategy from nature: Darwinian evolution, played out not in a warm pond but in the software of a computer. The computer was programmed with a set of designs that were no more than disordered collections of struts, ball joints, and electric motors, plus electronic circuit parts for a nervous system. It randomly altered, or mutated, the initially useless designs. Next, the computer chose the "fittest" mutants—those that showed hints of locomotion—while killing off the others, in a digital version of natural selection. It further mutated these chosen few and then repeated the process over hundreds of generations, gradually evolving more capable robots.

The designs that eventually emerged might never have sprung from the human mind—but they do move. Some work by hunching forward like inchworms, others drag themselves along by walking on elbowlike protrusions, and still others creep sideways, crablike. In some cases, the evolutionary process stumbled onto the symmetrical body form common in living things, which makes movement in a straight line simpler.

Putting natural selection to work in a computer isn't new. Half a century ago, the pioneering Hungarian-American mathematician John von Neumann imagined self-reproducing computer programs called "cellular automata." Since then, artificial-life programmers have watched digital organisms evolve as they compete for survival in software ecosystems. But until now, the offspring have lived in cyberuniverses akin to video games. Even when engineers used such methods to produce novel designs for real objects—some jet engines, for instance, have features that evolved in computers—their actual manufacture was under human control.

Newborn robots. The Golem Project, however, automatically hatches the winners into the real world. An off-the-shelf, industrial "rapid prototyping" machine builds the kitten-size robots from plastic, following the evolved instructions rather than a blueprint penned by a flesh-and-blood engineer. Watching the embryonic devices spontaneously emerge and begin creeping about (after people click electric motors into place where the computer tells them to) "is a little scary," concedes Pollack.

The whole process takes just hours or days, compared with the million-year time scale of evolution in nature. But other researchers say the machine-bred robots are a case study in the power of natural selection as a design tool in the lab and in the natural world. "It is clear that evolution can do things that people cannot possibly do on their own," says David Fogel, chief scientist at Natural Selection Inc., a company in La Jolla, Calif., that evolves

[Lego MindStorms](#). If you're into robots, you'll want to check out the projects these Legos have inspired.

[Ars Robotica](#). While this site claims to cover "robotics for the masses," only real enthusiasts will understand all that is discussed here.



solutions to problems in business and other fields. He even thinks the Golem Project and other evolution-based technology could persuade people who are skeptical about evolution to accept Darwin's ideas. "The more people accept evolution as a design tool, the easier it is to see that it has been used by nature."

Whether or not the embryonic robots are plausible apostles for natural selection, they are likely to get still more lifelike before the project is over. So far, the evolution stops as soon as the robots step from the software into the real world. But Stanford University consulting professor John Koza, a breeder of computer programs, would like to see the actual plastic robots evolve generation by generation into more adept forms. John Holland, a University of Michigan pioneer in an artificial-evolution method called genetic algorithms, wants the project to add cybersex, allowing robot parents to pool their best features in their offspring, rather than using mutation alone for improvement.

Inevitably, the work resonates with fears of robots running amok. Most notably, Sun Microsystems chief scientist Bill Joy warned early this year that a triple whammy of genetics, nanotechnology, and robotics could unleash a "gray goo" of tiny, voracious, self-reproducing microbots marauding over the world—a fear also stoked by recent work showing that robots can collaborate in antlike swarms (box).

Pollack dismisses such fears. "We're far, far from that," he says. "[These] are small plastic gizmos that look like toys." Yet the project's name plays on the unease such work stirs. A golem, in ancient Jewish legend, is a lump of clay sculpted to human form and animated through cabalistic magic. Some variants are tireless servants that work without pay. Others make mischief and must be killed to protect the community—a centuries-old foreshadowing of Joy's warning.

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