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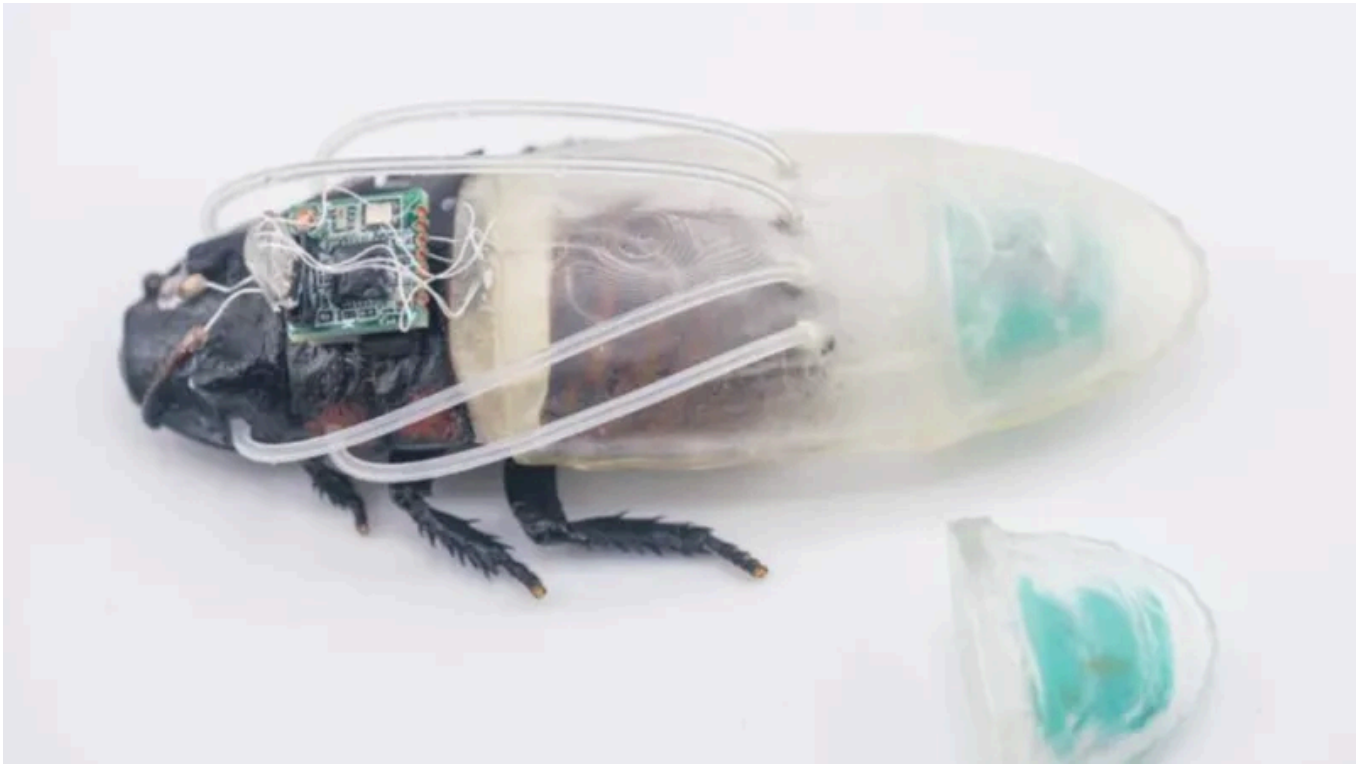
Diving suit for cyborg cockroach enables underwater rescue

News

Scientists have developed a flexible 'diving suit' for cyborg cockroaches that enables them to survive and move in underwater or low-oxygen environments.



Close-up of the cyborg insect and the new diving suit, which has tubes that connect to the breathing holes of the insect and an oxygen generator mounted at the rear of the suit - *NTU Singapore*

The study from NTU Singapore and Japan's Waseda University could expand the use of cyborg insects in search-and-rescue missions, particularly in disaster zones where flooded rubble, puddles or partially submerged spaces can block access for conventional robots. The work is detailed in *Nature Communications*.

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Cyborg insects are living insects fitted with electronic controllers that guide their movement. Because they use the insect's own muscles to move, they require far less power than small artificial robots, which need high-power onboard batteries to drive motors and other parts.

However, cyborg insects still depend on spiracles in their respiratory system that allow air to enter the tracheal system for gas exchange. When submerged, they cannot take in oxygen from water, thereby making underwater operation a fundamental limitation.

In tests, the scientists built plastic tubes that simulated various environments, such as flooded tunnels filled with carbon dioxide to replicate a low-oxygen environment.

With the new suit, the cyborg insects could remain active and move underwater for up to three hours.

In a statement, project lead Professor Hirotaka Sato, from the School of Mechanical and Aerospace Engineering, NTU Singapore, said: "Our new insect diving suit works like the oxygen tank used by human divers. It generates oxygen and delivers it directly to the insect's breathing holes.

"This is important because real disaster sites can be challenging after heavy rain or flooding, blocking access routes in the rubble, drains and narrow gaps. By expanding the operating parameters of our cyborg insects to include underwater travel, we believe that they can enhance search and rescue efforts."

Professor Shinjiro Umezu, School of Creative Science and Engineering, Waseda University, said: "The key engineering challenge was to build a system that was small, light and flexible enough for the insect to wear, while still producing enough oxygen for long-duration underwater movement.

"Our approach combines a soft waterproof shell with a simple yet reliable chemical oxygen generator. This allows the insect to retain its natural mobility while being protected from an environment that it cannot normally survive in."

How it works

The underwater suit consists of an oxygen-generation tank, a flexible shell, and four silicone oxygen-supply tubes. Together, they form a compact, self-contained system that excludes water while delivering oxygen to the cockroach's spiracles.

The oxygen-generation tank, 3D-printed using a transparent PMMA-type resin, contains a manganese dioxide-coated sponge that acts as a catalyst. To start the oxygen supply, the team injected a small amount of diluted hydrogen peroxide into the tank. The opening was then sealed with ultraviolet adhesive to prevent liquid leakage.

Inside the tank, the manganese dioxide slowly breaks down the hydrogen peroxide and releases oxygen. The oxygen is then channelled through the flexible shell and silicone tubes to the cockroach's spiracles, allowing it to breathe underwater.

The tubes are attached to the insect's thoracic spiracles and can be removed later without pain or harm, the researchers claim.

The researchers then tested their suit on a flightless Madagascar hissing cockroach, a species commonly used in cyborg insect research because of its size and robustness.

The work builds on more than a decade of cyborg insect research at NTU, where Prof Sato has developed cyborg insects for applications across land, sea and air.

His cyborg insects have been deployed in search and rescue operations, such as Operation Lionheart for the 7.7 magnitude earthquake in Myanmar on March 28, 2025 and are now being further developed for public infrastructure inspection.

Further work is underway to test the cyborg insect diving suit in simulated disaster environments, improve its durability, and to integrate sensors and navigation systems for field use.

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