Living Structural Materials to reduce emissions in cities and build self growing & self repairable military bases

The cities of today are built with concrete and steel between they are responsible for as much as a tenth of worldwide carbon emissions. Before they ever reach a construction site, both steel and concrete must be processed at very high temperatures – which take a lot of energy. And yet, our cities are completely dependent on these two unsustainable materials.

Researchers have now turned to biology for design of next generation smart materials for structures to support an ever-expanding population, while keeping carbon emissions under control. Bioengineer Dr Michelle Oyen of Cambridge's Department of Engineering is working in the field of biomimetics and with funding support from the US Army Corps of Engineers, is constructing small samples of artificial bone and eggshell, which could be used as medical implants, or even be scaled up and used as low-carbon building materials.

A team of interdisciplinary researchers at UCLA has been working on developing a new building material made by capturing carbon from power plant smokestacks and fabricating them using 3D printers. "This technology could change the economic incentives associated with these power plants in their operations and turn the smokestack flue gas into a resource countries can use, to build up their cities, extend their road systems," DeShazo said. "It takes what was a problem and turns it into a benefit in products and services that are going to be very much needed and valued in places like India and China."

DOD and the military services own and operate hundreds of thousands of buildings and other structures across more than 5,000 locations in support of their various defense-related missions. Those installations are located throughout the United States and the world and are subject to a wide range of geographic and climatic conditions. The structural materials that are currently used to construct homes, buildings, and infrastructure are expensive to produce and transport, wear out due to age and damage, and have limited ability to respond to changes in their immediate surroundings. As a result, the energy and financial costs of building and infrastructure construction and repair, to both the DoD and the nation, are enormous.

Now, Darpa is looking to new methods inspired from Living biological materials, such as bone, skin, bark, and coral, for example that have attributes that provide advantages over the non-living materials people build with, in that they can be grown where needed, self-repair when damaged, and respond to changes in their surroundings. The inclusion of living materials in human-built environments could offer significant benefits; however, today scientists and engineers are unable to easily control the size and shape of living materials in ways that would make them useful for construction.

DARPA is launching the Engineered Living Materials (ELM) program with a goal of creating a new class of materials that combines the structural properties of traditional building materials with attributes of living systems.

UCLA researchers turn carbon dioxide into sustainable concrete

The production of cement, which when mixed with water forms the binding agent in concrete, is also one of the biggest contributors to greenhouse gas emissions. In fact, about 5 percent of the planet's greenhouse gas emissions comes from concrete.

An even larger source of carbon dioxide emissions is flue gas emitted from smokestacks at power plants around the world. Carbon emissions from those plants are the largest source of harmful global greenhouse gas in the world.

A team of interdisciplinary researchers at UCLA has been working on a unique solution that may help eliminate these sources of greenhouse gases. "What this technology does is take something that we have viewed as a nuisance — carbon dioxide that's emitted from smokestacks — and to use it to create a new kind of building material that will replace cement," said J.R. DeShazo, professor of public policy at the UCLA Luskin School of Public Affairs and director of the UCLA Luskin Center for Innovation.

Thus far, the new construction material has been produced only at a lab scale, using 3-D printers to shape it into tiny cones. "We have proof of concept that we can do this," DeShazo said. "But we need to begin the process of increasing the volume of material and then think about how to pilot it commercially. It's one thing to prove these technologies in the laboratory. It's another to take them out into the field and see how they work under real-world conditions."

"We can demonstrate a process where we take lime and combine it with carbon dioxide to produce a cement-like material," Sant said. "The big challenge we foresee with this is we're not just trying to develop a building material. We're trying to develop a process solution, an integrated technology which goes right from CO2 to a finished product.

"3-D printing has been done for some time in the biomedical world," Sant said, "but when you do it in a biomedical setting, you're interested in resolution. You're interested in precision. In construction, all of these things are important but not at the same scale. There is a scale challenge, because rather than print something that's 5 centimeters long, we want to be able to print a beam that's 5 meters long. The size scalability is a really important part."

DeShazo has provided the public policy and economic guidance for this research. The scientific contributions have been led by Gaurav Sant, associate professor and Henry Samueli Fellow in Civil and Environmental Engineering; Richard Kaner, distinguished professor in chemistry and biochemistry, and materials science and engineering; Laurent Pilon, professor in mechanical and aerospace engineering and bioengineering; and Matthieu Bauchy, assistant professor in civil and environmental engineering.

The researchers are excited about the possibility of reducing greenhouse gas in the U.S., especially in regions where coal-fired power plants are abundant. "But even more so is the promise to reduce the emissions in China and India," DeShazo said. "China is currently the largest greenhouse gas producer in the world, and India will soon be number two, surpassing us."

DARPA's Engineered Living Materials (ELM) program

Living materials represent a new opportunity to leverage engineered biology to solve existing problems associated with the construction and maintenance of built environments, and to create new capabilities to craft smart infrastructure that dynamically responds to its surroundings.

"The vision of the ELM program is to grow materials on demand where they are needed," said ELM program manager Justin Gallivan. "Imagine that instead of shipping finished materials, we can ship precursors and rapidly grow them on site using local resources. And, since the materials will be alive, they will be able to respond to changes in their environment and heal themselves in response to damage."

Successful completion of ELM program objectives will require innovations in the ability to functionally unite living components with inert structural materials, to program structural features into living systems, and to extend the scale of synthetic biology building blocks from the molecular to the cellular. The deliverables from this program will comprise a suite of technologies that enable the production of living structural materials tailored to design specifications, such as those provided by architects and builders.

A major inspiration for the ELM program is the recent development of biologically-sourced structural materials that are grown to specified size and shape from inexpensive feedstocks. For example, mycelia can be grown on agricultural byproducts to produce materials that are drop-in replacements for polystyrene. Similarly, bacteria can be used to bind sand to produce drop-in replacements for bricks. That factory-scale production of grown materials can be economically competitive with materials as common as polystyrene and brick, demonstrates the feasibility of using biological approaches to reduce the energy and waste associated with the manufacture of structural materials.

However, these products are rendered inert during the manufacturing process, so they exhibit few of their components' original biological advantages. Scientists are making progress with three-dimensional printing of living tissues and organs, using scaffolding materials that sustain the long-term viability of the living cells. These cells are derived from existing natural tissues, however, and are not engineered to perform synthetic functions. And current cell-printing methods are too expensive to produce building materials at necessary scales.

ELM looks to merge the best features of these existing technologies and build on them to create hybrid materials composed of non-living scaffolds that give structure to and support the long-term viability of engineered living cells. DARPA intends to develop platform technologies that are scalable and generalizable to facilitate a quick transition from laboratory to commercial applications.

The long-term objective of the ELM program is to develop an ability to engineer structural properties directly into the genomes of biological systems so that neither scaffolds nor external development cues are needed for an organism to realize the desired shape and properties. Achieving this goal will require significant breakthroughs in scientists' understanding of developmental pathways and how those pathways direct the three-dimensional development of multicellular systems.

Examples DARPA suggests are roofs that control airflow in a structure by breathing; chimneys that heal after smoke damage; and driveways, roads, or runways that literally eat oil spills. Work on ELM will be fundamental research carried out in controlled laboratory settings. DARPA does not anticipate environmental release during the program.

Ecovative gets $9.1M DARPA contract for living materials

Ecovative Design has been awarded a contract valued at up to $9.1 million from the Defense Advanced Research Projects Agency (DARPA) to develop next generation building materials: living materials that are more versatile, more efficient, and more cost effective in rapidly creating structures, by literally growing those structures in places where they are needed. Ecovative, the pioneer and world leader in the design and manufacturing of mycelium-based biomaterials, will work in collaboration with leading researchers in synthetic biology, biochemistry, and systems biology from Columbia University, New York University (NYU), and the Massachusetts Institute of Technology (MIT). This four-year project aims to create these living systems, and to demonstrate that the materials can be manufactured at scale

Columbia University Helena Rubenstein Professor, Departments of Chemistry and Systems Biology, Dr. Virginia Cornish said, “We are excited to bring our expertise in chemical and synthetic biology to this collaboration with Ecovative Design. Our team seeks to functionalize the surface of Ecovative Design’s fungal material with an engineered yeast skin that can sense (and respond to) the environment, and enables the material to heal after damage. Like this, we are developing an adaptable living material that challenges the paradigm of traditional building materials.”

MIT Synthetic Biology Center (SBC) co-director, and Professor of Biological Engineering, Christopher A. Voigt, Ph.D. said: “Living cells can function as atomic architects in the construct of functional nanomaterials with a precision impossible using chemistry and materials science. The marriage of synthetic biology and grown materials provides a means to harness this precision engineering at the bulk scale.”

We have used biology to grow materials with exceptional properties that are simply unattainable through conventional chemistry. We have clearly demonstrated these products can be manufactured at scale. This project will demonstrate what is possible when we start taking advantage of biomaterials most powerful property: life itself,” says Bayer. “These same techniques can be used to develop new housing solutions in conventional architecture, as well as support rapidly deployable relief structures in area’s struck by natural disasters”

“During the last ten years we created a new materials science by demonstrating the versatility of mycelium, in combination with agriculture waste, to create sustainable products with a range of properties and functions," Ecovative's Chief Scientist Gavin McIntyre, said. "This next logical step is to determine how to tap the power and potential of a consortia of organisms to create the next generation of advanced, biomaterials. Microbial communities power our bodies and ecosystems, and Ecovative is uniquely positioned to exploit a novel microbiome to propel material science into new frontiers."

The U.S. Department of Defense, of which DARPA is a part, must at times establish shelters or other structures for military or civilian purposes in unfamiliar or under-resourced environments. Imagine a U.S. military unit arriving in a conflict zone, or a humanitarian disaster site, and creating its base of operations by literally growing building materials or the required structures themselves – shelter, barriers, furniture and more.

Ecovative envisions a day when U.S. forces will arrive at a location and be able to do just that. Ecovative Design says the contract with the Defense Advanced Research Projects Agency, or DARPA, is to develop living building materials. An idea being explored would be to literally grow shelters or other structures in places where they are needed.

References and Resources also include:

https://www.darpa.mil/news-events/2016-08-05 http://newsroom.ucla.edu/releases/ucla-researchers-turn-carbon-dioxide-into-sustainable-concrete

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