building materials and embedded sensors that can identify damage. “What we’re trying to do is make concrete a bit like a biological system, so it can detect damage and then heal itself,” says Susanne Gebhard, a microbiologist at the University of Bath, UK, who leads part of the project.

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Most of RM4Ls work is focused on chemistry and materials science, but Gebhard is probing the interactions between **bacteria, nutrients and concrete** to find combinations that can outshine existing self-healing systems. “We’re taking a step back to find out how it works, and where it could work better,” she says. For example, her team has encapsulated *B. cohnii* spores in aerated concrete granules and covered them in a waterproof shell of polyvinyl alcohol. This encapsulation ensures the bacteria are not activated until a growing crack breaks through the shell, allowing water to reach the spore inside. When the researchers added a growth medium containing yeast extract and calcium nitrate into the granules, it enhanced the crack-healing effect of the bacteria.

RM4L researchers are also engineering the spore-forming bacterium *Bacillus subtilis* to better understand the biochemical pathways involved in making calcium carbonate. These pathways involve, for example, cell surface structures, ureolysis and the production of extracellular materials. Although European Union regulations on genetically modified organisms mean that these bacteria would not be used in construction, Gebhard says they can offer clues about which genes and properties researchers should look for in wild-type bacteria when seeking better strains.

Others are moving beyond concrete repair, employing bacteria to craft entirely new building materials. Biotech company bioMASON, based in Durham, North Carolina, uses a wild-type *Bacillus* strain that can stick grains of rock and sand together into sturdy tiles. The bacteria hydrolyze a urea feedstock to form CO₂, which combines with calcium ions to form calcium carbonate. This binds the surrounding aggregate particles into a solid matrix within a tile mold. After three days, these bioLITH tiles can hold their shape like wet sandcastles, and only need ambient drying before they are ready to use on walls

or floors. The company can already produce about 10,000 square meters of the tiles per year at its pilot plant.

Urea is mostly used as a fertilizer in agriculture, and it is produced at industrial scale by combining ammonia and CO₂. Ammonia is made in the Haber–Bosch process, which reacts nitrogen and hydrogen over an iron catalyst at a high temperature and pressure. The hydrogen that feeds this reaction is made in a process called steam methane reforming, which generates **about 3% of our global CO₂ emissions** and also supplies the CO₂ for urea synthesis.

Turning urea’s carbon into calcium carbonate within bioLITH tiles means that “we are effectively sequestering the carbon from urea,” says Michael Dosier, the company’s chief technology officer. As a result, the tiles have a carbon footprint that is less than 1% that of conventional cement-based materials. The tiles look like natural stone, and have a cost similar to that of conventional stone and high-end concrete products, he says. The company’s first big commission was to supply pavers for the San Francisco headquarters of technology company Dropbox in 2016.

The company has also received an undisclosed amount of funding from the \$47-million **Engineered Living Materials** (ELM) program, run by the US Defense Advanced Research Projects Agency (DARPA). As part of this program, bioMASON developed a form of marine cement that uses a community of different wild-type bacteria to lay down calcium carbonate, as a way to slowly **maintain underwater concrete structures**. Some of the bacteria produce urea, while others feed on the urea and absorb calcium from seawater to produce the required calcium carbonate.

In another demonstration for DARPA, dubbed Project Medusa, the company showed that its industrious bacteria could build a 230-square-meter helicopter landing pad using local soil. Delivering construction materials into conflict zones can be dangerous, complicated and expensive, so “if we can start to utilize biology to build materials on site, then we may have the opportunity to reduce that logistical burden,” explains Blake Bextine, ELM program manager.

DARPA has also funded University of Colorado Srubar’s research into cyanobacteria that can form living building bricks. The team adds cyanobacteria to a hydrogel matrix, where they absorb CO₂ through photosynthesis, which increases the pH at the cells’ surface. This triggers calcium carbonate precipitation, which binds the hydrogel into solid blocks that are about as

First NGS-based COVID-19 diagnostic

In June, the US Food and Drug Administration granted Emergency Use Authorization (EUA) for Illumina’s next-generation sequencing (NGS) test for COVID-19, the first such authorization for a NGS diagnostic. The COVIDSeq test can be scaled up for high-volume screening, anticipating increasing demand as countries and municipalities reopen. It is a modified version of the tests developed by the ARTIC Network, a Wellcome Trust collaborative set up to speed surveillance during outbreaks. It employs 98 DNA fragments, or amplicons, to cover the roughly 30 kilobases in the SARS-CoV-2 genome. By multiplexing the reaction, upwards of 3,000 tests of nasopharyngeal or oropharyngeal samples can be run in one go with a 24-hour turnaround. Company literature states that the test requires at least 1,000 copies of the viral genome per milliliter and displays 98% sensitivity and 97% specificity. Although the test has EUA, it has yet to receive approval from the FDA.

Presently only a few sites are equipped to run the test; in addition to Clinical Laboratory Improvement Amendments (CLIA) certification, labs must be trained on Illumina’s NovaSeq6000 sequencing platform. However, the company plans in the coming months to increase the number of sites. Investing in the Ginkgo Bioworks, a synthetic biology foundry company, could facilitate this expansion. In May, Illumina led a \$70 million series E funding round that Ginkgo will use to create the infrastructure for large-scale testing at its Boston lab.

Rapid and large-scale testing is considered key to safely opening schools and workplaces, as well as surveilling for new hotspots. Furthermore, having sequence information will inform public health officials on the route of transmission and mutation rate of the virus. Although rapid, large-scale diagnostics are also in the works, they will mainly be used for detecting and managing COVID-19 clinically.

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