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A Synthetic Approach to bioconversion of carbon dioxide to formic acid

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In order to tackle climate change it is important that everyone on the planet does their best to limit the amount of CO2 that is released into the atmosphere. In order to reduce CO2 emissions, especially those very significant amounts generated by heavy industry, a whole raft of different and complementary technologies will be required. One way scientists skilled in biology can help is by harnessing and applying the mechanisms that living organisms naturally use to process gases and other simple, single-carbon, compounds. CO2 is produced naturally by living things all the time, especially when sugars are being processed for energy. A few organisms – plants and some microbes – can take up CO2 and process it into more complicated (and useful) molecules. The common, and generally harmless, gut bacterium Escherichia coli contains a special enzyme that can perform a very simple conversion of CO2 into formic acid – a one-carbon acid – using hydrogen gas (H2) to drive the reaction. Generating formic acid from CO2 would have huge benefits. First, formic acid is a liquid at ambient temperature. This makes it much easier to store and transport than gaseous CO2. Second, formic acid can be used in fuel cells to liberate energy as electricity, and thus it is a useful energy store and energy carrier. The challenge comes in convincing E. coli to carry out this reaction as a priority and with high efficiency. E. coli has evolved to perform the opposite reaction – that it is the production of CO2 and H2 from formic acid as a substrate. Thus all natural biological processes, from gene regulation to enzyme assembly, are focused on using formic acid as a substrate rather than CO2. The beauty of taking a synthetic biology approach is that it enables the use of modern genetic modification tools to completely repurpose E. coli enzymology for the conversion of CO2 to formic acid. The regulation of the main enzyme required can be put directly under the scientists control; the amounts of the enzymes and proteins required for the process can be dramatically increased in the cell; and the efficiency of the conversion of gaseous CO2 to formic acid can be optimized. Biologists working in the laboratory will be supported and advised by mathematical modellers, who will analyse the biochemical processes for bottlenecks and other problems. Finally, by including enzymes from other bacteria that are not normally found in E. coli, it may be possible to further process the formic acid to other one-carbon compounds or even into more complicated molecules. This short project will enable the concept to be proven that engineered E. coli may contribute to the basket of solutions required to re-cycle and capture industrially produced CO2.