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PROJECT ABSTRACT (300 WORDS)

Living cells are natural architects in building intricate chemical and material structures with atomic precision. Accessing this capacity will require pushing genetic engineering to the scale of genomes to enable precise control over multi-gene cellular processes. In this proposal, we will develop the foundational tools required to obtain a leap in the sophistication of materials that we obtain from biology. Objectives 1, 2, and 3 expand the scale of genetic programming (synthetic regulatory control of gene expression), enable the controlled differentiation of a population, and expand the number of genes that can be simultaneously controlled, respectively. While focused on foundational advances, each objective is built around a specific need in building functional composite materials. In Objective 1, we will develop a platform that enables the complex structures from DNA nanotechnology to be built in living cells. A genetic programming language (Cello) will be expanded to enable temporal control of structural and processing genes. Objective 2 focuses on a differentiation device that couples sensors, logic gates, memory, and resource allocation to stably divide a population of cells to perform different tasks. This requires assembling synthetic regulation on the scale of natural regulatory programs. In Objective 3, we will build living functional materials by hacking a 3D printer to be able to print embedded bacteria that have been engineered to produce multiple protein-based biomaterials. The printer will be modified to enable to projection of different colors of light in order to differentiate cells as they are being printed. Collectively, these objectives will provide the knowledge and technology base to enable precision genetic engineering to manufacture designed materials from mixed components (metals, polymers, lipids, and silica) with atomic resolution.