Topic: Transforming Cells into Automata

Paper reference

Engineering *Escherichia coli* to see light. Anselm Levskaya, Aaron A. Chevalier, Jeffrey J. Tabor, Zachary Booth Simpson, Laura A. Lavery, Matthew Levy, Eric A. Davidson, Alexander Scouras, Andrew D. Ellington, Edward M. Marcotte and Christopher A. Voigt. Nature 438, 441-442, 2005.

Abstract

In this paper, the authors show how they modified *E. coli* to control the presence of a visible readout in response to light. A lawn of *E. coli* was therefore engineered to function as a high-definition photographic biofilm. The device that was engineered in *E. coli* consists of several components. The first component is a membrane-bound extra-cellular photosensor (Cph1) that responds to red light. The second component is a histidine kinase (EnvZ) fused to Cph1 that gets dephosphorylated as Cph1 senses light. The third component is a response regulator (OmpR) that receives the phosphate group from Cph1 and binds to the promoter region of the reporter gene lacZ. The fourth component is LacZ, which catalyzes the formation of a black precipitate from S-gal. Therefore, each bacterium in this biofilm can either be set to dark or light, depending on the amount of light that it receives. Without light, the modified bacteria turn black. By holding a stencil between a Petri dish and a light source, the researchers could impose a light image onto the bacteria.

Discussion

The film of genetically engineered bacteria described in the paper was reported to record images up to 100 mega-pixels per square inch. Using a dense bed of genetically modified living bacteria might not sound like a plausible alternative for replacing high-end digital cameras. Instead, the photosensitive switch reported in this paper could be employed to temporally and spatially control millions of cells in producing certain substances at locations precisely defined by light beams. This might help cells spatially differentiate in an organized way and might be useful as a methods to guide cellular self-assembly.

This article also presents a remarkable example of how genetic engineering and modern molecular biology are enabling us to hook up biological components, found in very different organisms, to construct a new device that performs a desired function. Phytochromes help some species to control processes such as phototaxis, photosynthesis, and the production of protective pigments, but these photoreceptors are not found in enterobacteria such as E. coli. Therefore this light-sensing gene had to be extracted from *Synechocystis*, a blue-green algae, and then inserted into *E. coli* to allow it to "see" light on the first place. Secondly, most of the response regulators for phytochromes found in *Synechocystis* don't have DNA binding sites, so the photosensor domain of the phytochrome (Cph1) was fused to a the histide kinase of a very well characterized two-component system in *E. coli* (EnvZ-OmpR). This shows how an extra-cellular sensor can be hooked up to the intercellular signaling pathway of a completely different species which performs a completely different function. Third, the reporter gene (LacZ) was chromosomally fused to the OmpR-dependent promoter of ompC. OmpR normally regulates OmpC expression in response to osmotic shock. This time, ompC was replaced by lacZ in order to produce the precipitate that turns cells black. Nice. The increasing amount of off-the-shelf biological components (or "Bio-bricks") that are becoming available to the community will continue inspiring a new generation of scientists and engineers to characterize these new components and to combine them to perform high-level design. Engineering biology is still a big challenge, but the first steps towards this ambitious goal have already been successfully achieved.