Biology by Design

Introduction

Let's think in general terms about what happens in the bacterial photography system (Lab 3). The absence of light stimulates a sensor molecule that activates (phosphorylates) a transcription factor that turns on expression of a gene that causes a black compound to accumulate in the media. On the other hand, the presence of light deactivates the transcription factor and inhibits expression of the gene. No gene expression, no black compound in the media. We can summarize these results using the following truth table:

Light	β-gal production
1	0
0	1

However, the system does not work with 100% inefficiency so some β-gal is produced even in the dark. Data measurements for that gene's expression might look more like:

Light	β-gal production
present	200 units
absent	1000 units

The biology text books contain many examples of genetic systems such as these in which cells respond to an environmental cue by altering gene expression. For example, the lac operon even includes the same lacZ gene that the photography system does. What makes the bacterial photography system special is that this specific group of molecules (the sensor, the regulator and the lacZ reporter gene) are not found together in any cell in nature. Instead, synthetic biologists imagined this system and then matched the parts to create it. In fact, the two parts of the sensor protein have actually been put together from two different sensor proteins (one that responds to light and one that phosporylates the OmpR molecule)!

Now you may wonder why anyone would want to take black and white photos with bacteria. Sure, the bacteria are smaller than any pixels currently made using conventional technology and can therefore produce sharper images. But, as small as these pixels are, the images are slow to develop and specialized training is required. Be assured, bacteria will not be replacing your camera. In building this system, however, we've learned more about the process of biological engineering. The engineers have demonstrated that they can link parts of proteins and control gene expression. So now it is on to greater challenges.
For instance, imagine that we could use this pattern, but replace some or all of the parts to design another system. For instance, you could substitute a gene that would lead to cell movement instead of producing β-gal. Would this produce bacteria that move toward light? What if you wanted bacteria that moved in the opposite direction? What changes would you have to make? What if you wanted bacteria that moved toward a toxin instead of light? And if it moved toward a toxin, what might you want the bacteria to do to it once it found it? An example of this type of use of bacteria can be found here.

BioBuilding: Synthetic Biology for Students: Design Assignment

Your Task

You will write a proposal to the NISB (The National Institute of Synthetic Biology) to convince them to fund the next three years of your research. Think about a problem or challenge that can be addressed through synthetic biology. Perhaps you want to do something to improve the environment, or address a human health issue, or build structures that will make our lives better. Think about a stimulus resulting from this situation. Think about how you would want cells to respond to this stimulus. Think about how that response will be better than any existing technology. Please use your imagination and think big but stay away from science fiction. You are designing an overall system so you do not have to worry about describing individual parts. However, you do need to describe 1) the problem, 2) stimulus and 3) cell output in enough detail to convince the proposal evaluators that you are a knowledgeable, creative, serious candidate for funding.

The Proposal

Your proposal should contain the following sections. Your explanations must address, but are not limited to, the following questions. Approximate length 5-7 pages total.
Before you write your proposal, be sure to look over the Design Assignment Rubrics and Scoresheets

I. Purpose

- Describe the problem or challenge you are trying to solve.
- Why is solving this problem or meeting this challenge important?
- What will your design do to address that problem (overview)?

II. Competing technologies

- What technologies are being used to address this problem at present?
- How effective are they?

III. The design

- Using both words and diagrams, describe your design.
- What input would the cell be responding to?
- How would genetic expression be affected?

IV. Expected results

- Using both words and a truth table, explain how you expect the cell to behave when the design system is working perfectly.
- Using both words and a data table, explain how you expect the cell to behave at a not perfect but acceptable level.
- How will these results bring about a successful solution to the problem?

V. Advantages

- How is your biological design an advantage over the existing technologies?
- Why is your design worth funding? (Be convincing!)

VI. Potential problems

- What are the potential problems with your system?
- What safety features would be required to protect your employees during development of your design?
- How would you protect the environment during development of your design?
- In what ways could evolution of the cells you've engineered negatively affect use of your design in the future?
- Are there inefficiencies or shortcomings of your design as compared to the existing technologies?
- Does your design pose dangers to the environment, lab safety, and the security of the public?
- In what ways are the potential rewards worth the risks?

VII. Testing

- How would you test the effectiveness of the system?
- (If your design has multiple components, you may select one component for testing.)
- How would testing help improve the system?
- How would testing help reveal greater potential for the system?