the LANGUAGE OF LIGHT
A biological analog for the optocoupler

Penn iGEM 2015
The Dilemma

Chemical based communication systems in biology are limited by diffusion.

How can synthetic biologists overcome this design constraint?
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Chemical based communication systems in biology are limited by diffusion.

How can synthetic biologists overcome this design constraint?
Electrical Optocoupler

Electrical signals between two isolated circuits are transferred via light.
The Biological Optocoupler

Circuit A

Light-Emitting Diode

Circuit B

Phototransistor

Sender Cell

Receiver Cell
Characterization of the **Sender Cell**
The Sender

The Lux Operon

- **a)**
  - $P_{\text{inducible}}$
  - **LUX OPERON**

- **b)**
  - Luciferase
  - $P_{\text{inducible}}$
  - $P_{\text{on}}$
  - Enzymes involved in co-factor synthesis

The Sender Strains

- **c)**
  - NEB10
  - HNS
  - SY1047
Luminescence Output Over Time

Error bars represent standard deviation, $n=3$
TWO-STEP CALIBRATION

PROBLEM:
Major sensitivity difference between devices measuring the sender and receiver

Luminometer Conversion

Relative Luminescence Unit (RLU)
Measured by a luminometer or a plate reader

Irradiance
Measured by a powermeter
TWO-STEP CALIBRATION

PROBLEM:
Major sensitivity difference between devices measuring the sender and receiver
PROBLEM:
Major sensitivity difference between devices measuring the sender and receiver
Two-Step Calibration

\[ f(x) = 2 \times 10^{-8} \left( 2515.9 \times x^{0.8403} \right)^{0.8298} \]
Characterization of the 

Receiver Cell
Receiver Characterization as Compared to Publication Characterization

The graph shows the fold change in RFP expression plotted against illumination intensity (uW/cm²). The data points represent experimental data (red diamonds) and published data (blue line). The graph indicates a significant increase in expression with increasing illumination intensity.
OPTICAL COUPLING OF BIOLOGICAL CIRCUITS
Cell communication via light
Signal persists across...

- **Incompatible growth conditions**
  - pH, temperature, % oxygen, antibiotic resistances

- **Different strains and species**
  - possibility for talk between yeast + bacterial species

- **Physical boundaries**
  - light signal persists through glass & plastic
Close Range System Design

- 50 ml centrifuge tube
- Cuvette with light-sensitive receiver
- Luminescent sender surrounding cuvette
Predicted Fold Change in RFP Expression in Response to Sender Luminescence

Fold change in RFP expression vs. Illumination Intensity (uW/cm²)

- Experimental data
- Published data
- Illumination intensity produced by the senders
Predicted Fold Change in RFP Expression in Response to Sender Luminescence

- SY104
- NEB10
- HNS

- Experimental data
- Published data
- Illumination intensity produced by the senders
Luminescence Output Over Time

Error bars represent standard deviation, n=3
Analysis of Predicted Fold Change in RFP Expressions vs. Experimental Communication Results

Error bars represent standard deviation, n=3
Successful communication between sender and receiver with SY104 yielding the highest receiver activation.

Error bars represent standard error, n=3, curves generated to guide the eye.
Takeaways

Used an engineering approach to quantitatively characterize the sender and receiver cells and apply this information to present a predictable system of light-based communication.

Future Directions

- Alter promoter strength to increase yield of luminescence from sender
- Tune the photoreceptor to increase sensitivity of receiver
- Establish a light-based communication system that extends across different species (i.e. bacteria and yeast)
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THANKS!

Any questions?

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