Life Redesigned: The Emergence of Synthetic Biology

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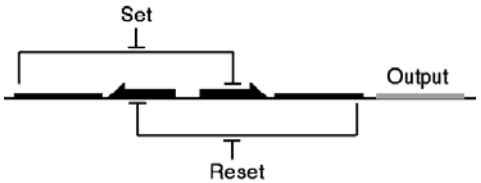
Synthetic Biology: Engineered Gene Networks

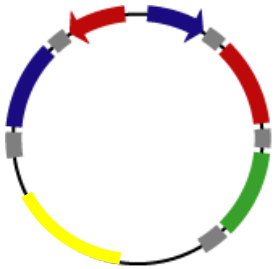
Design & model network



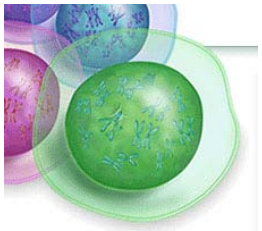
$$\frac{du}{d\tau} = \frac{\alpha_1}{1+v^\beta} - u$$

$$\frac{dv}{d\tau} = \frac{\alpha_2}{1+u^\gamma} - v$$

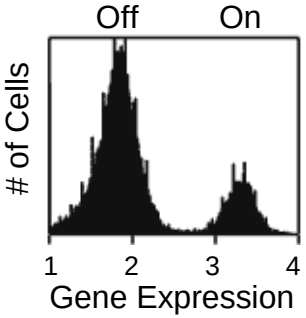
Encode into DNA plasmid



Transfer to cell

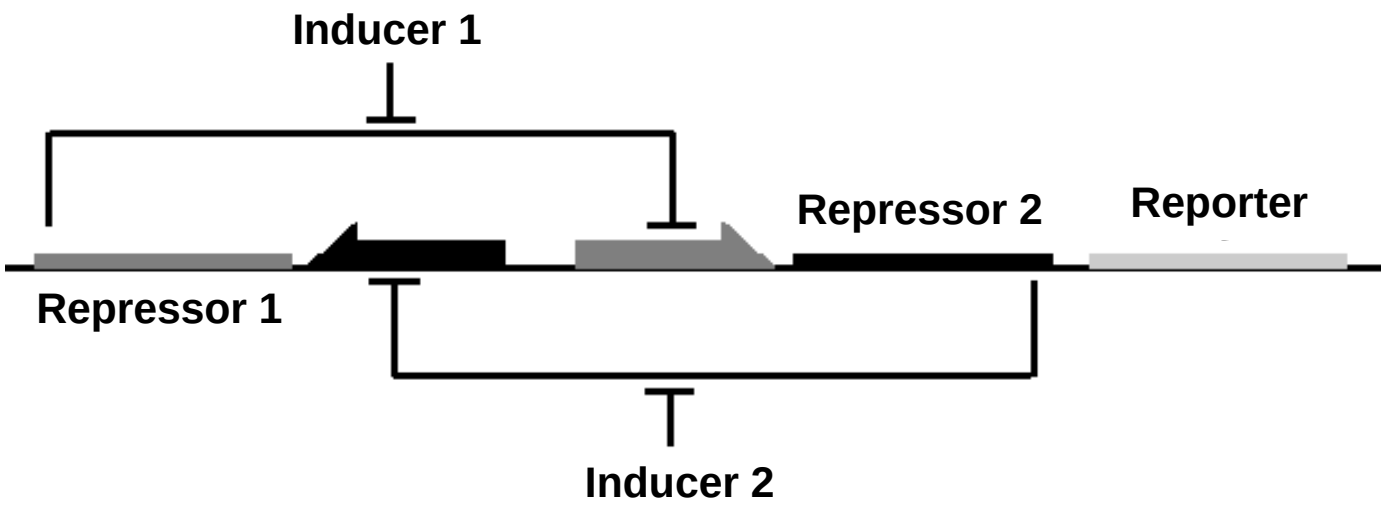


Test network dynamics



TS Gardner et al., Nature, 2000

Schematic Design of Genetic Toggle Switch

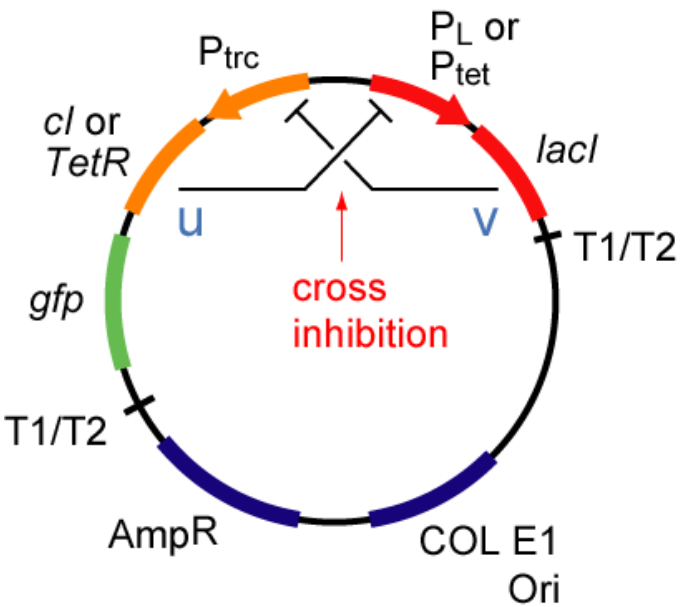


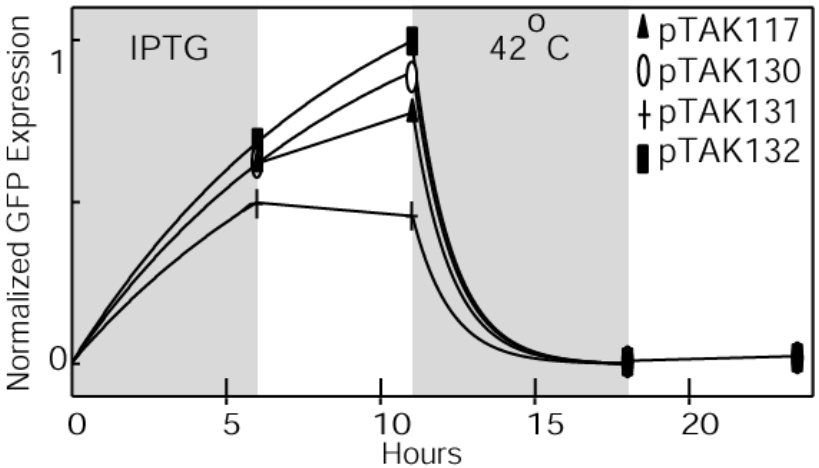
TS Gardner et al., Nature, 2000

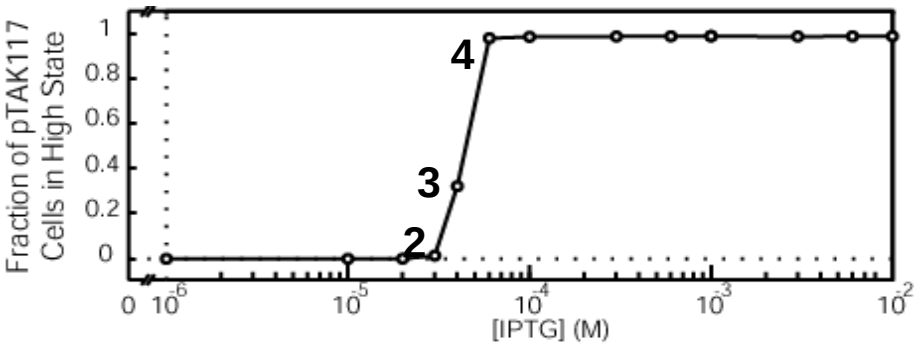
Genetic Toggle Switch: Results

$$\dot{u} = \frac{\alpha_1}{1 + v^{\beta}} - u$$

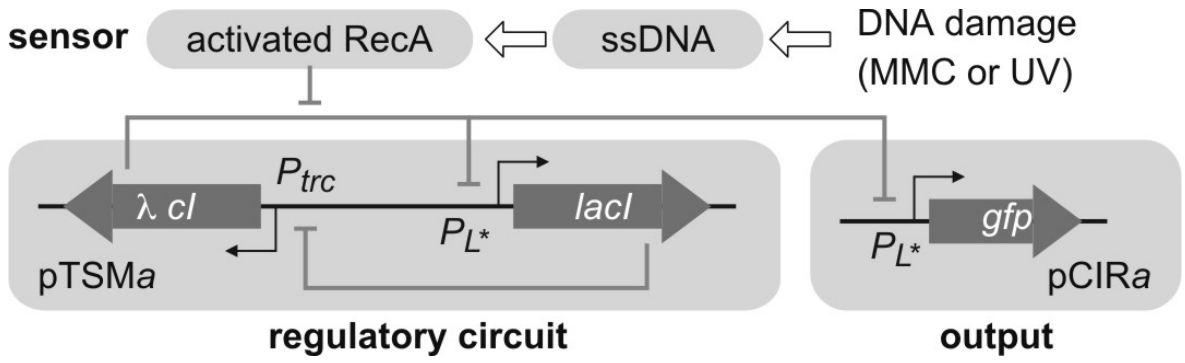
$$\dot{v} = \frac{\alpha_2}{1 + u^{\gamma}} - v$$

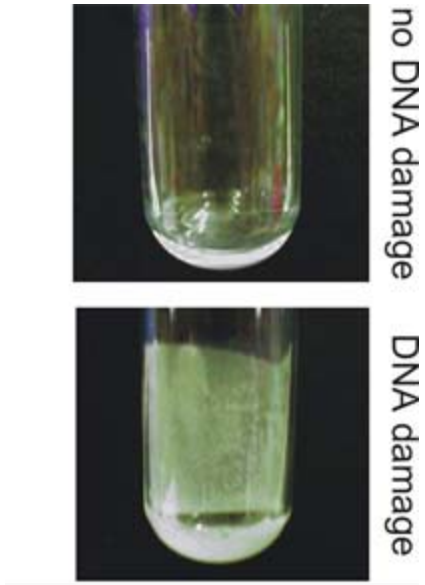


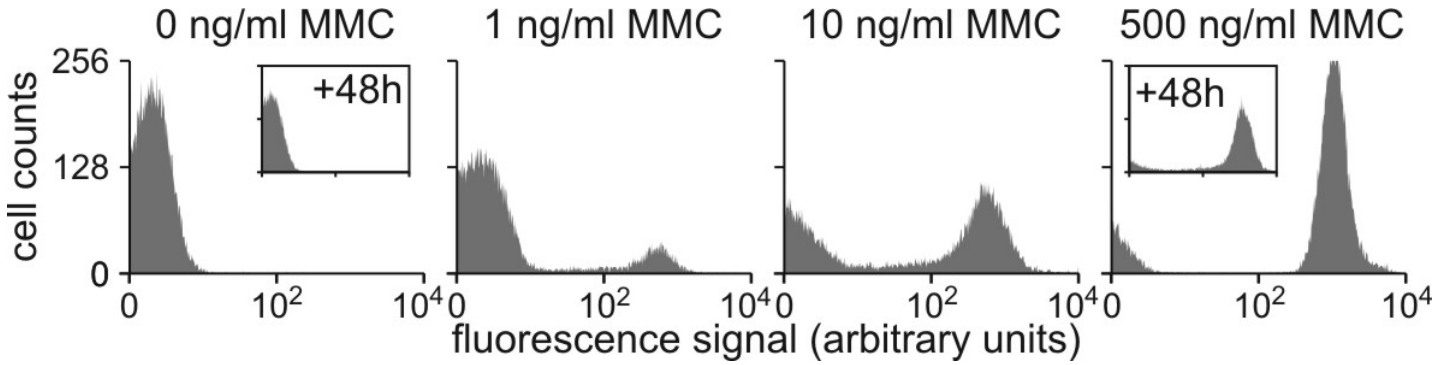




Programmable Cells: Whole-Cell Biosensors

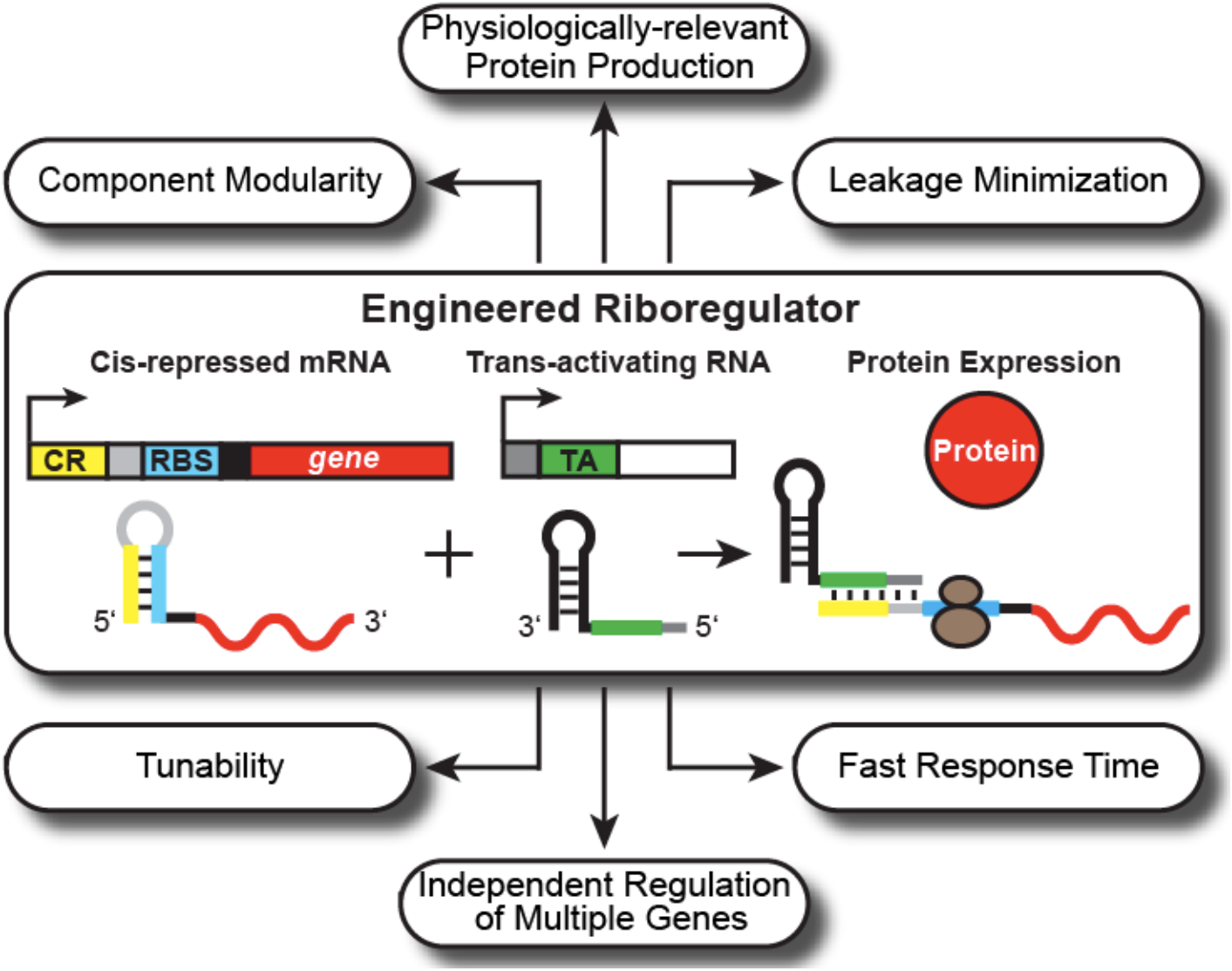






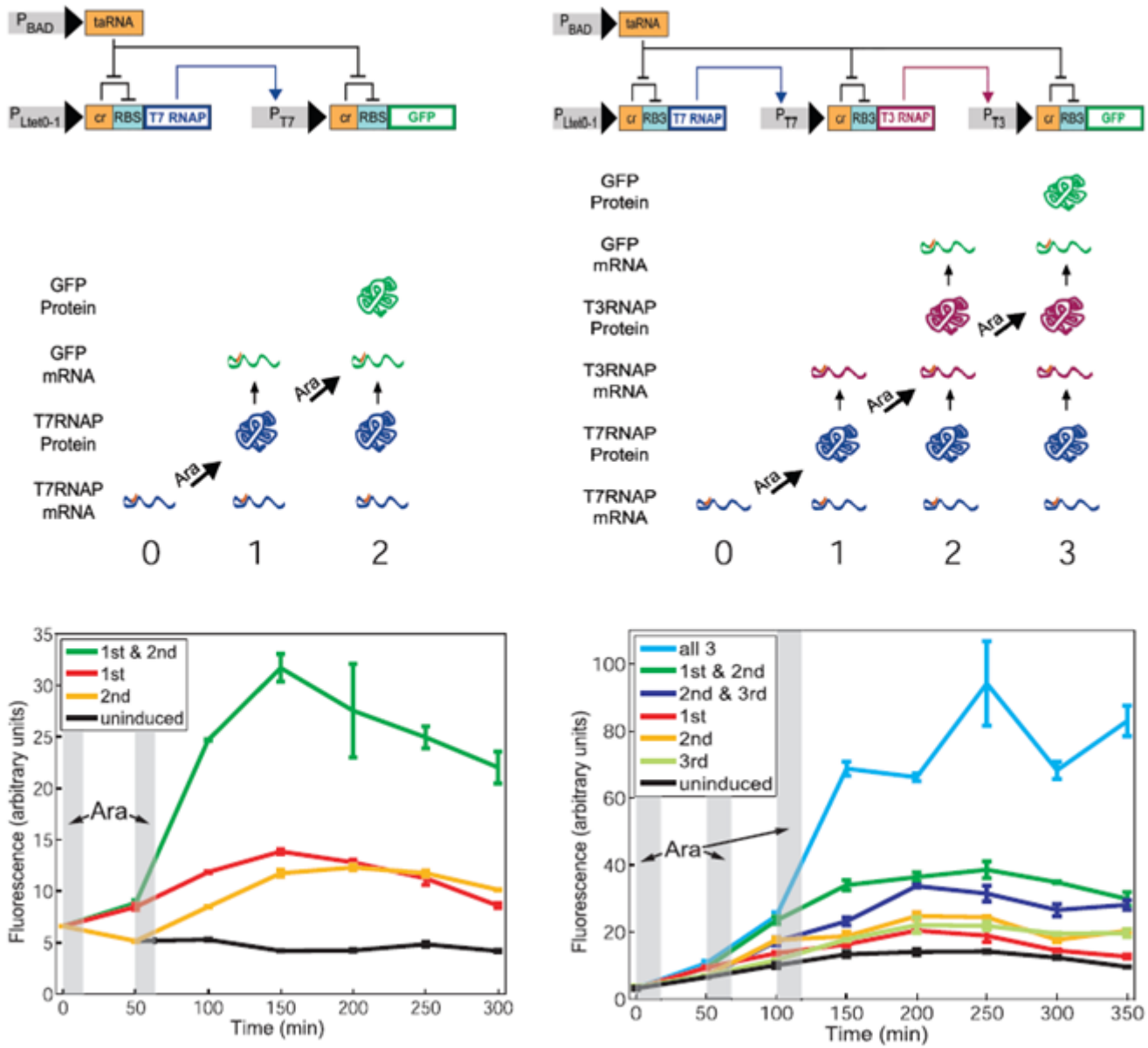
H Kobayashi et al., PNAS, 2004

Engineered Riboregulator: RNA Switch



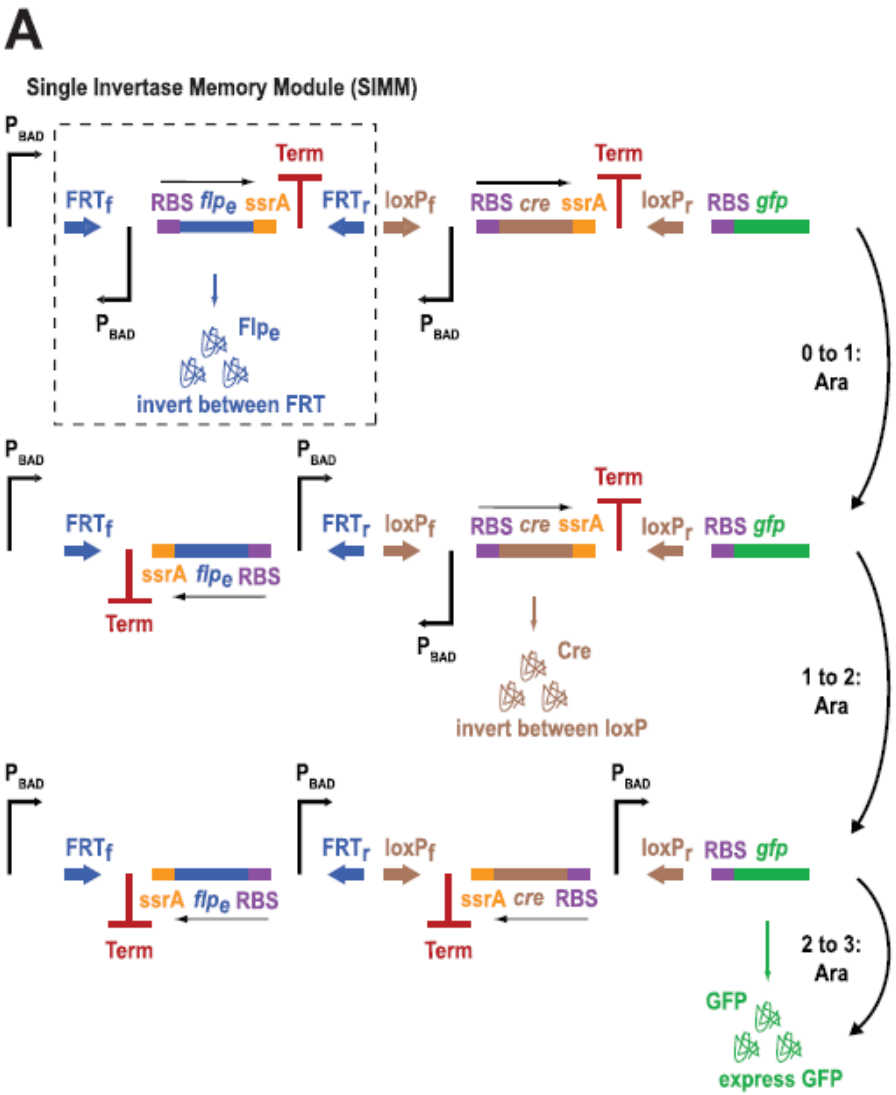
FJ Isaacs et al., Nature Biotechnology, 2004

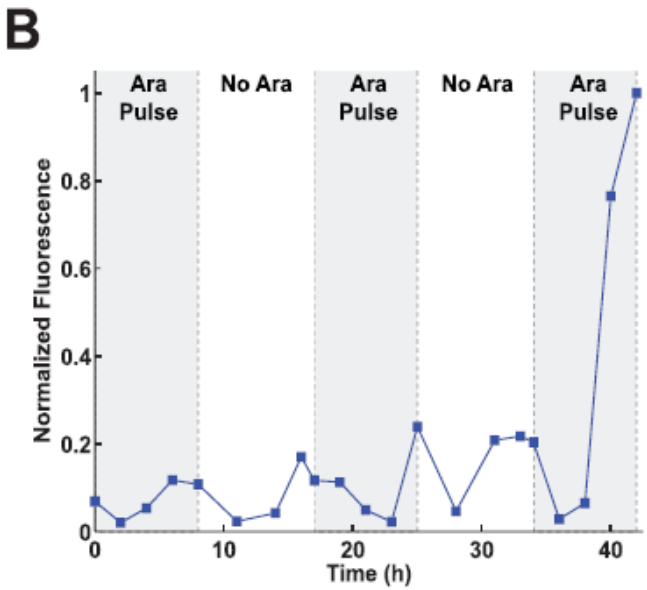
Synthetic Gene Networks that Count: RNA Switches

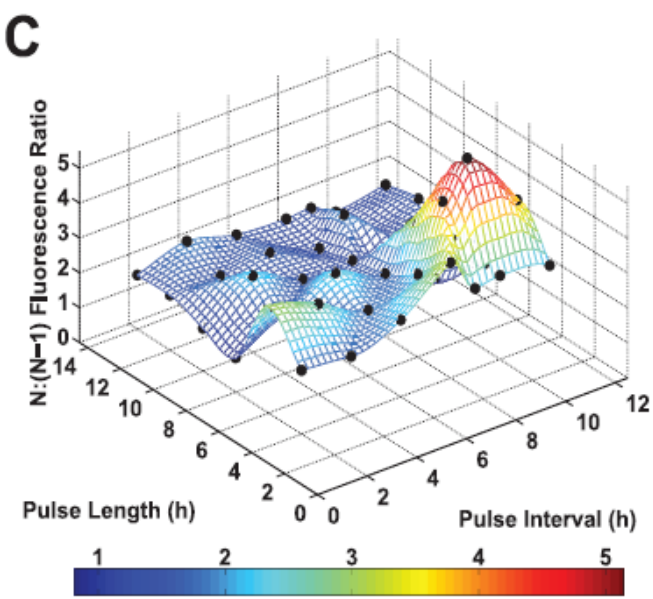


AE Friedland et al., Science, 2009

Genetic Counter: Recombinase-Based Cascade of Memory Elements







AE Friedland et al., Science, 2009

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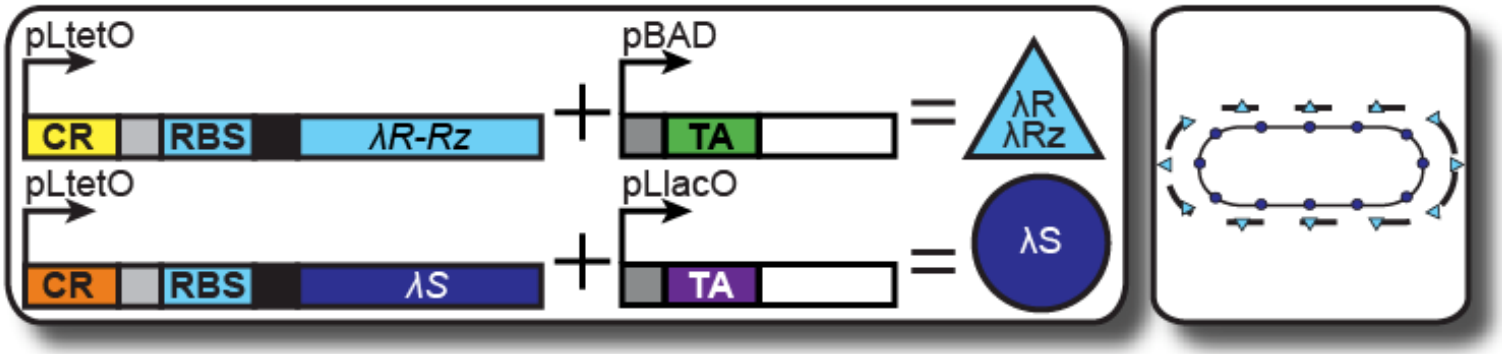
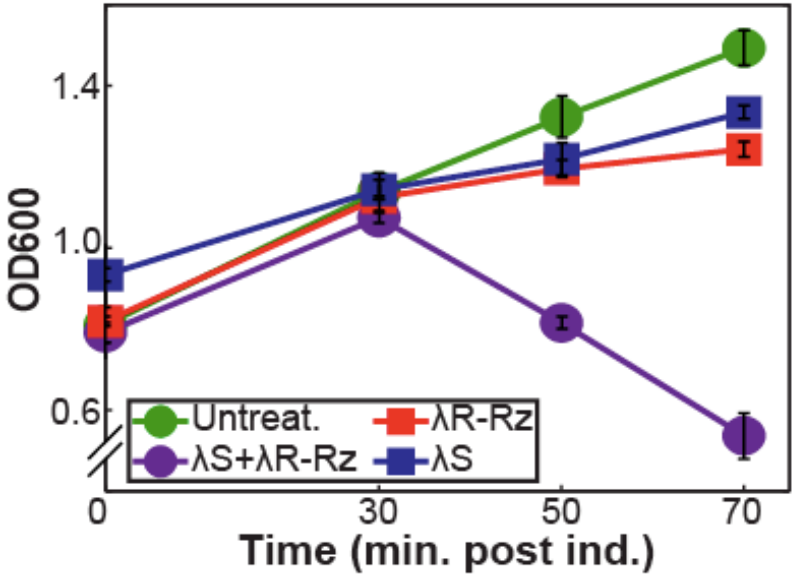
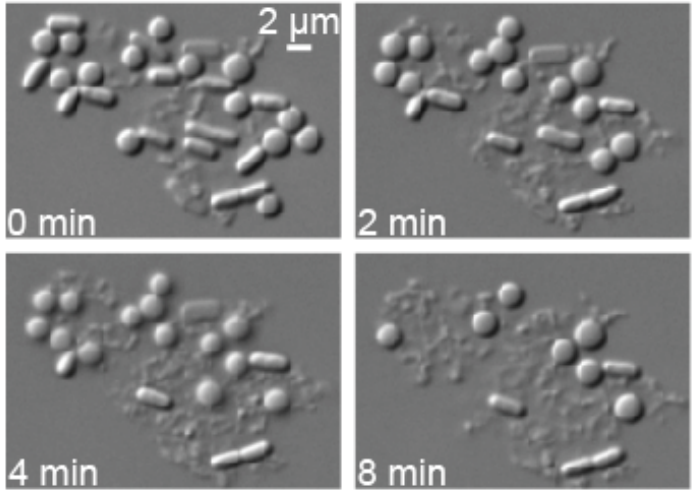
Programmable Kill Switch for Microbes

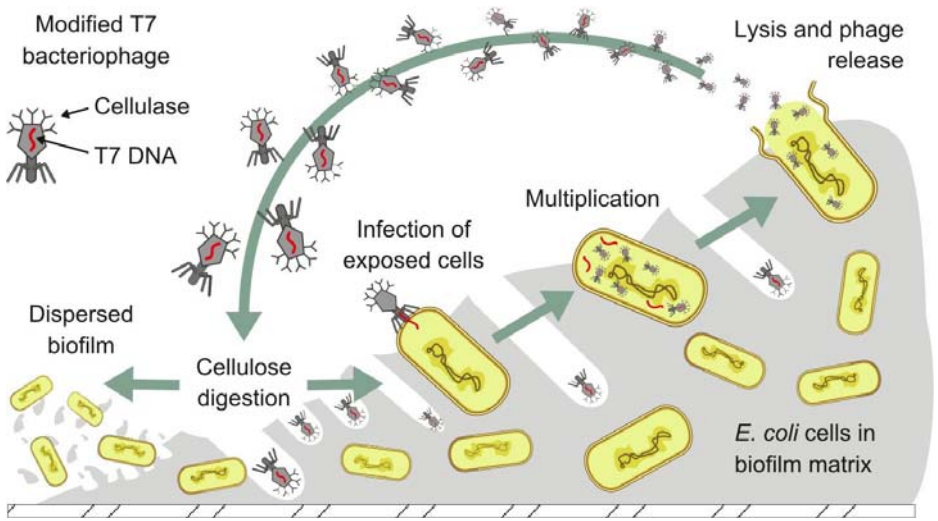


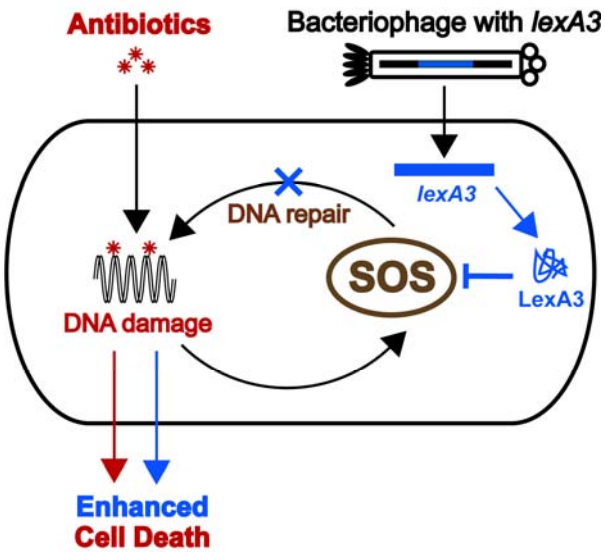


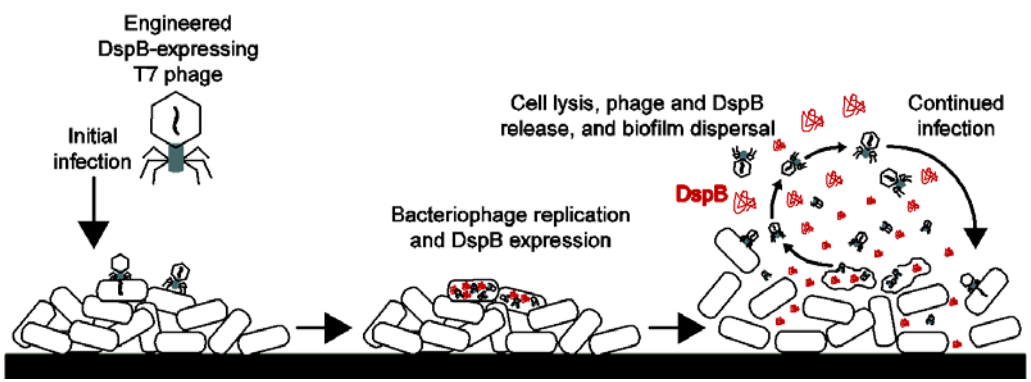


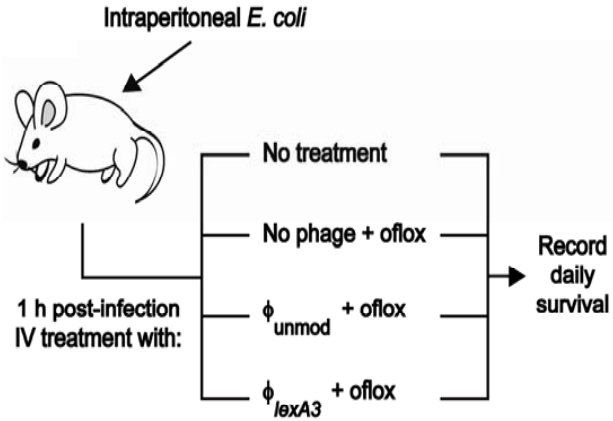
JM Callura et al., PNAS, 2010

Engineered Bacteriophage as Antibacterial Agents









TK Lu and JJ Collins, PNAS, 2007, 2009

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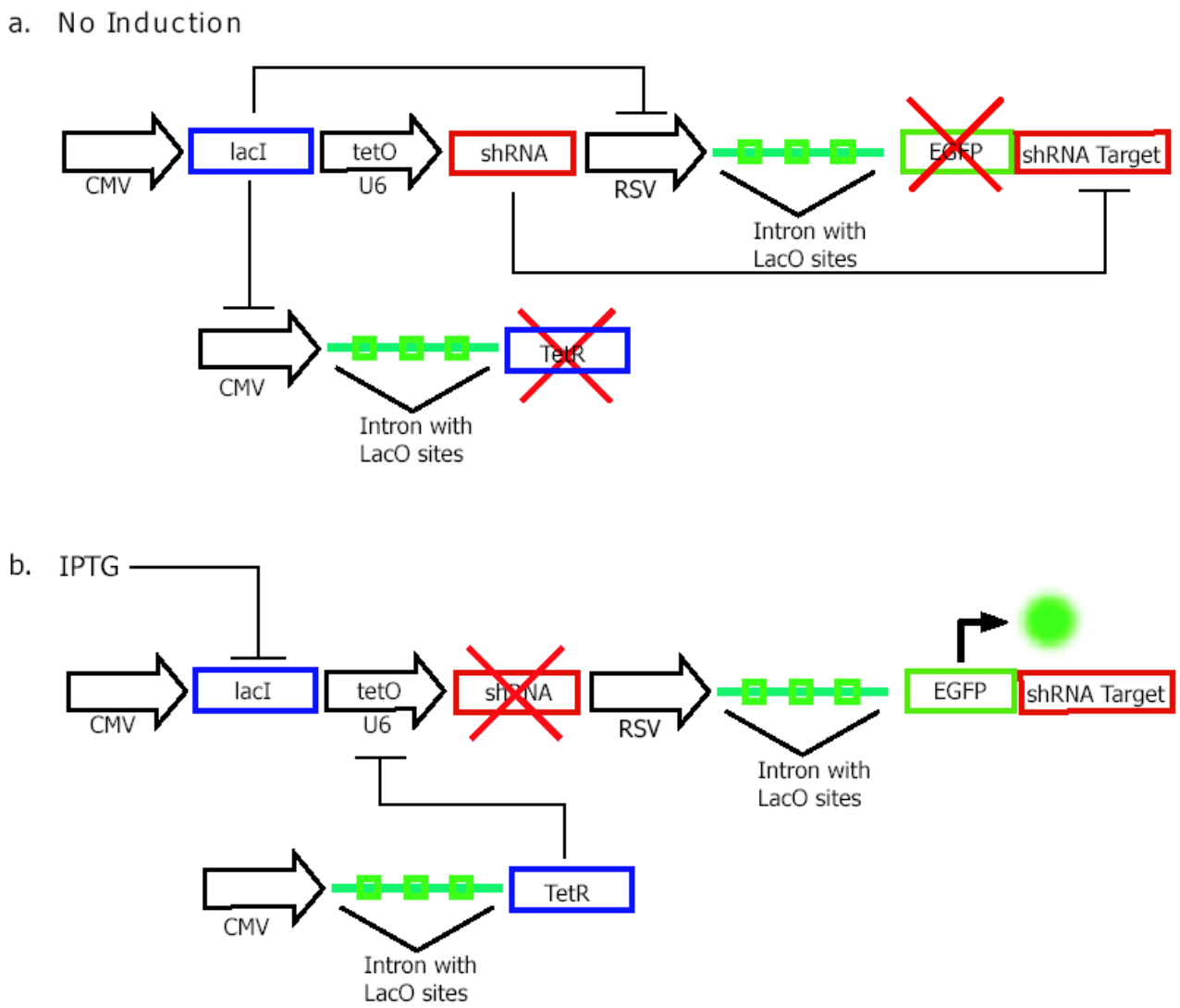
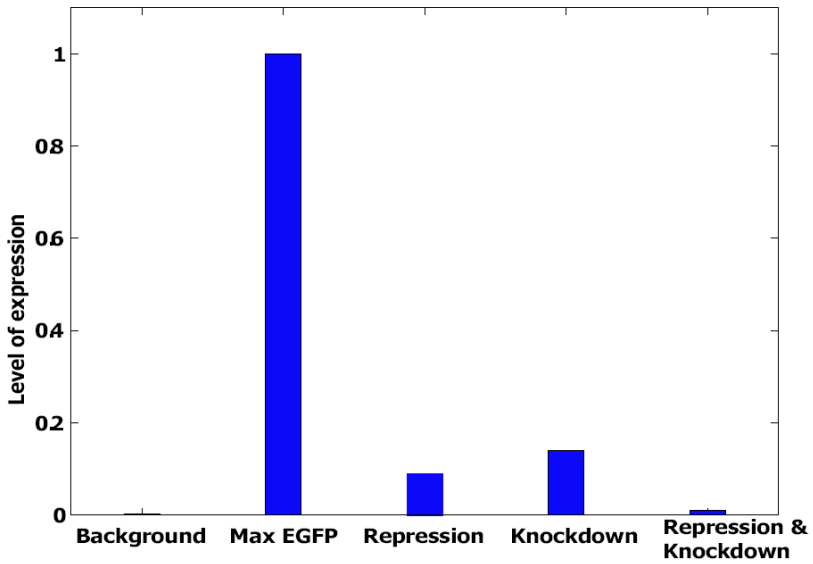
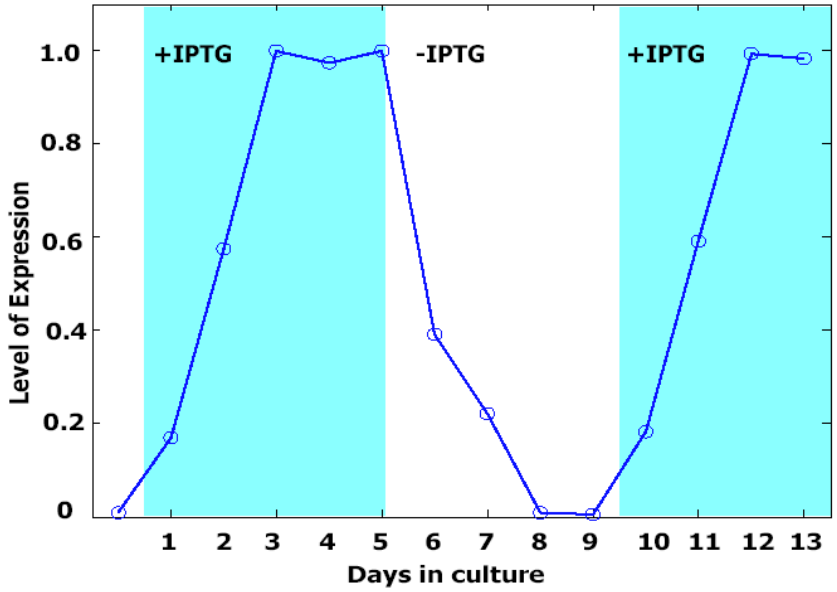
Engineered Mammalian Gene Switch: RNAi and Repressor Proteins

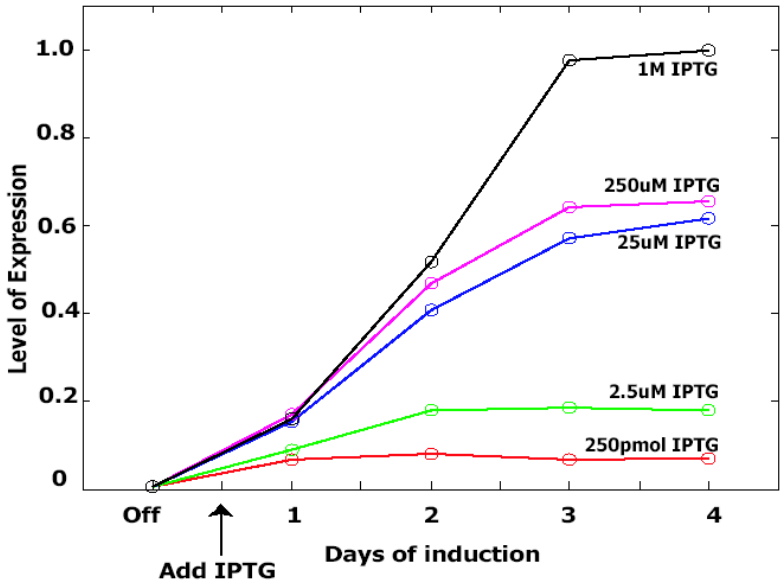


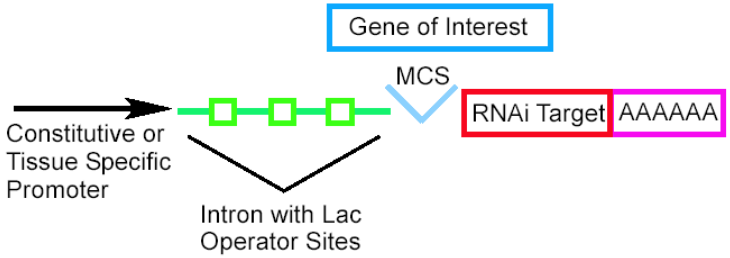
TL Deans et al., Cell, 2007

Engineered Mammalian Gene Switch: Performance Characteristics









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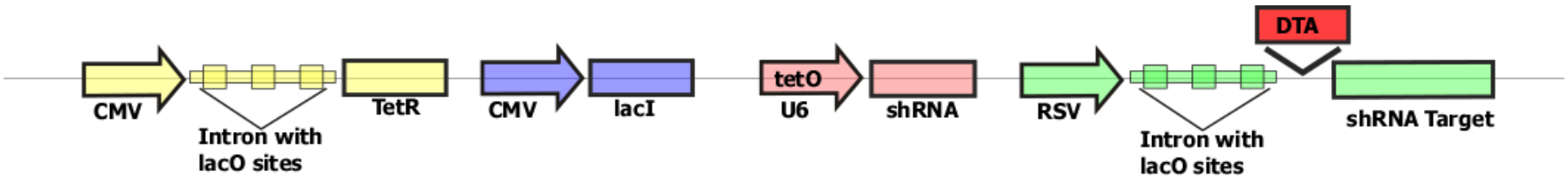
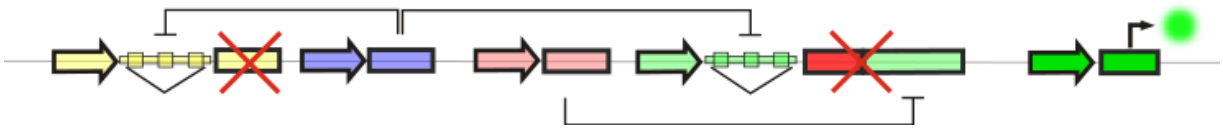
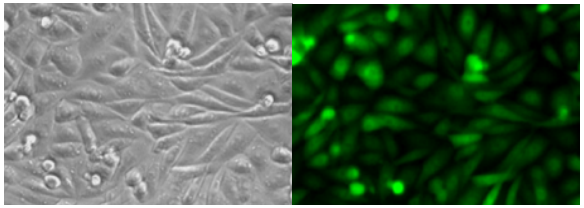
Using the Genetic Switch to Control the Expression of DTA

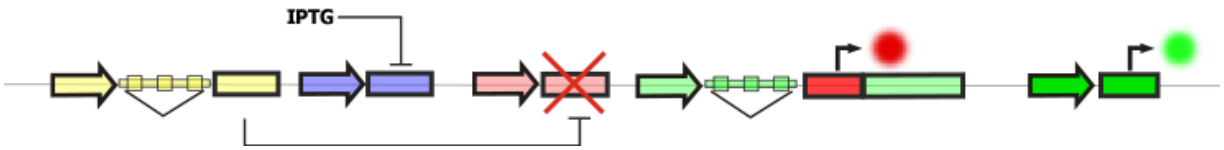


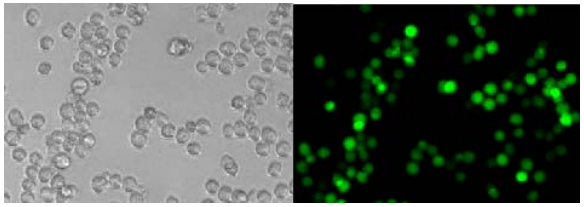
Switch Off (DTA off)





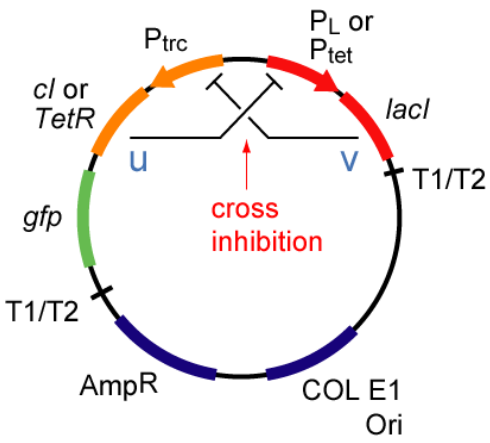
Switch On (DTA on)



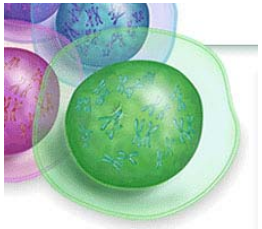


Synthetic Gene Networks: Applications Come of Age

Engineered gene circuits

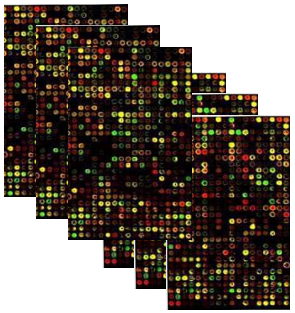


Cell therapy, stem cells



Biosensors, bioenergy, biomaterials

Functional genomics, microbiome



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