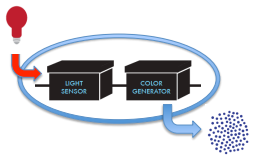
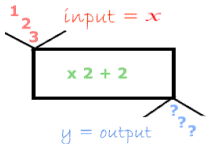
System Engineering

20.109(F14)
M2D2 lecture
10.09.14

Abstracted View of Bacterial Photography





Photons	Color
1	0
0	1

Input x	Output y
1	4
2	6

The 2CS paradigm: in words

Name	Two-component system
Description	Two-component signal transduction systems enable bacteria to sense, respond, and adapt to changes in their environment or in their intracellular state. Each two-component system consists of a sensor protein-histidine kinase (HK) and a response regulator (RR). In the prototypical two-component pathway, the sensor HK phosphorylates its own conserved His residue in response to a signal(s) in the environment. Subsequently, the phosphoryl group of HK is transferred onto a specific Asp residue on the RR. The activated RR can then effect changes in cellular physiology, often by regulating gene expression. Two-component pathways thus often enable cells to sense and respond to stimuli by inducing changes in transcription.

KEGG: Kyoto Encyclopedia of Genes and Genomes

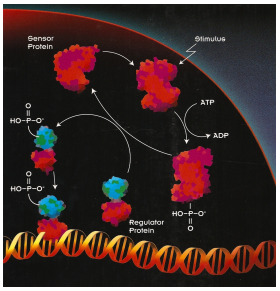
KEGG is a database resource for understanding high-level functions and utilities of the biological system, such as the cell, the organism and the ecosystem, from molecular-level information, especially large-scale molecular datasets generated by genome sequencing and other high-throughput experimental technologies (See Release notes for new and updated features).

http://www.genome.jp/kegg/

BRENDA
The Comprehensive Enzyme Information System

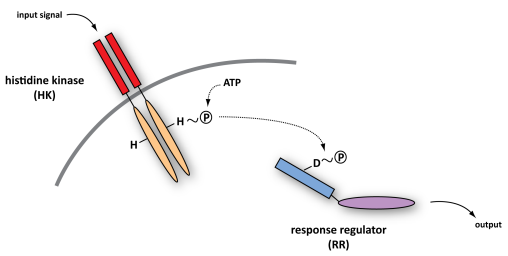
http://www.brenda-enzymes.info/index.php4

The 2CS paradigm: cartoon 1 (information flow)



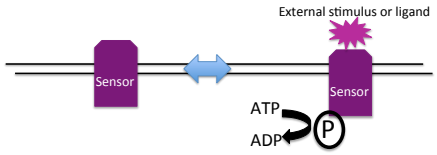
Stimulus
↓
Sensor protein (HK)
↓ ±Ⓟ
Response regulator (RR)
↓
Output

The 2CS paradigm: cartoon 2 (His, Asp)



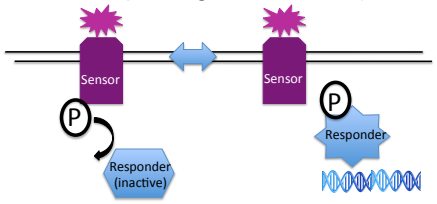
Slide from Mike Laub

The 2CS paradigm: cartoon 3 (reactions)



RXN 1: Autophosphorylation in response to stimuli

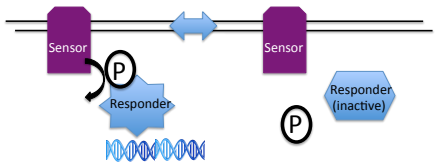
The 2CS paradigm: cartoon 3 (reactions)



RXN 1: Autophosphorylation in response to stimuli

RXN 2: Phosphotransferase from Sensor to Response Regulator

The 2CS paradigm: cartoon 3 (reactions)

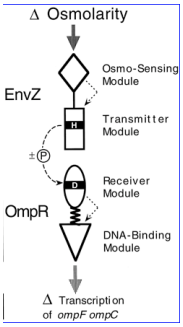


RXN 1: Autophosphorylation in response to stimuli

RXN 2: Phosphotransferase from Sensor to Response Regulator

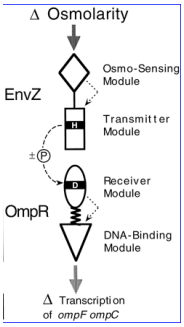
RXN 3: Phosphatase inactivates Response Regulator, resets system

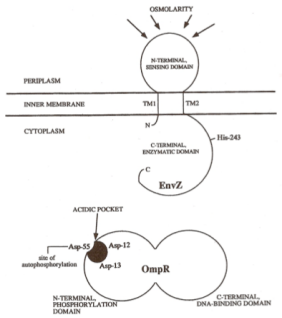
2CS examples: classic (osmoregulation)



http://www.plantphysiol.org/cgi/content-nw/full/117/3/723/F1

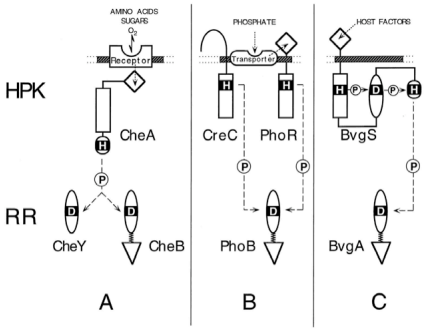
2CS examples: classic (osmoregulation)





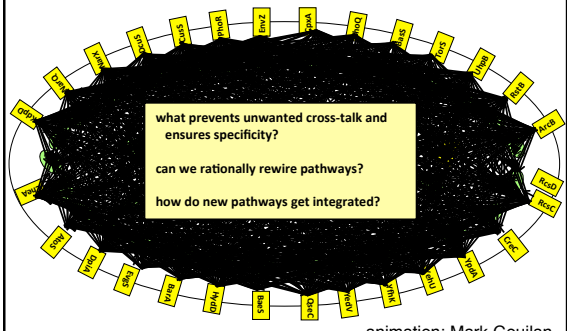
2CS transduction, Hoch and Silhavy

2CS examples: possible networks



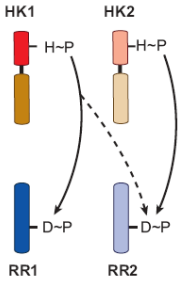
http://www.plantphysiol.org/content/vol117/issue3/images/large/pp0785128002.jpeg

Special consideration: crosstalk between paths



animation: Mark Gouilan
slide from Mike Laub

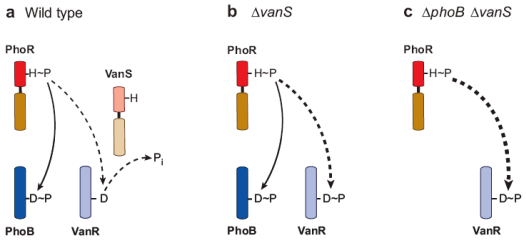
Preventing cross-talk



At least *in vitro* the answer seems to be a kinetic preference of sensor for its response regulator

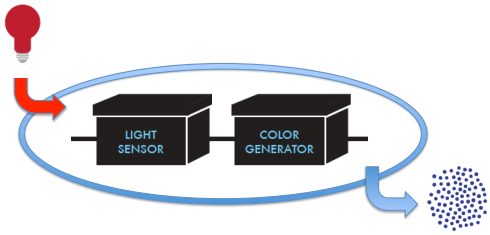
Ann Rev Genetics, 2007 Laub and Goulian

Preventing cross-talk: phosphatase activity



Ann Rev Genetics, 2007 Laub and Goulian

Abstracted View of Bacterial Photography



Input = photons	Output = color
1 (= cells are in the light)	0
0 (= cells are in the dark)	1

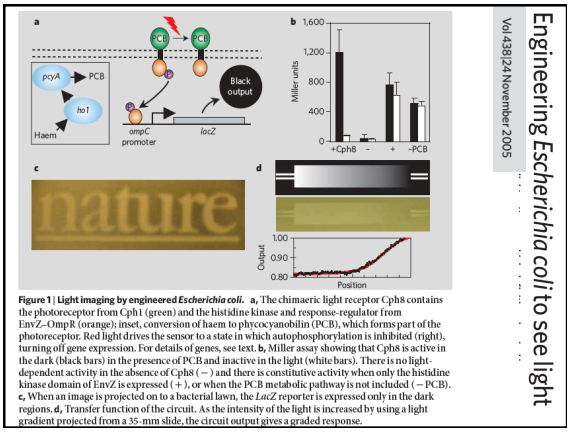
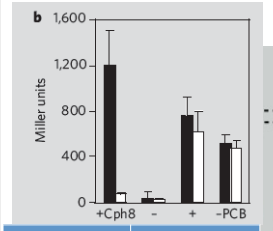
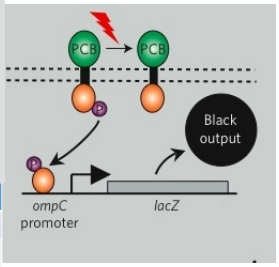


Figure 1 | Light imaging by engineered *Escherichia coli*. **a,** The chimaeric light receptor Cph8 contains the photoreceptor from Cph1 (green) and the histidine kinase and response-regulator from EnvZ–OmpR (orange); inset, conversion of haem to phycocyanobilin (PCB), which forms part of the photoreceptor. Red light drives the sensor to a state in which autophosphorylation is inhibited (right), turning off gene expression. For details of genes, see text. **b,** Miller assay showing that Cph8 is active in the dark (black bars) in the presence of PCB and inactive in the light (white bars). There is no light-dependent activity in the absence of Cph8 (−) and there is constitutive activity when only the histidine kinase domain of EnvZ is expressed (+), or when the PCB metabolic pathway is not included (−PCB). **c,** When an image is projected on to a bacterial lawn, the *LacZ* reporter is expressed only in the dark regions. **d,** Transfer function of the circuit. As the intensity of the light is increased by using a light gradient projected from a 35-mm slide, the circuit output gives a graded response.

Signaling in the bacterial photography system



Red light	β-gal
1	0
0	1



Nature (2005) **438**, 441-442

Summary

2CS paradigm
in words
in cartoons

Idea **S**torm for **R**esearch
Organisms game

Crosstalk considerations

Bacterial
Photography

UBER