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Exzellente Forschung für Hessens Zukunft

Bacterial chemotaxis: from understanding to application

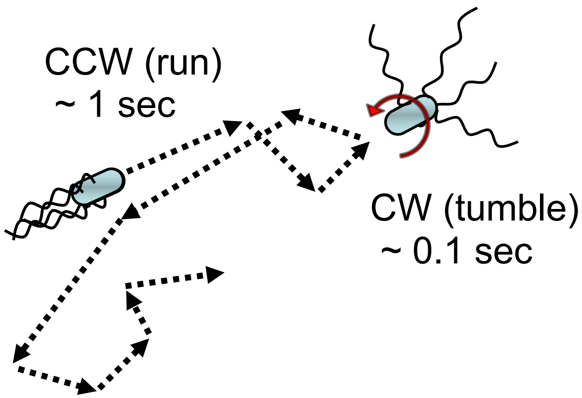
Victor Sourjik

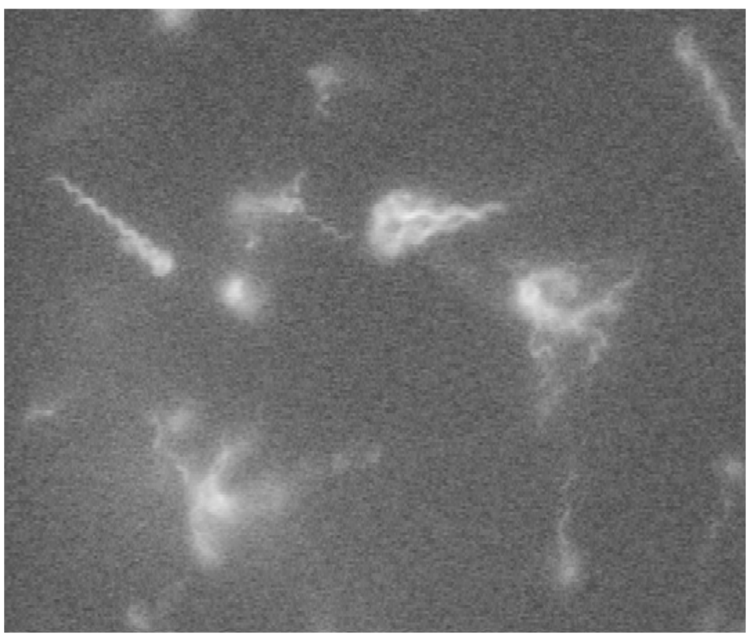
Max Planck Institute for Terrestrial Microbiology

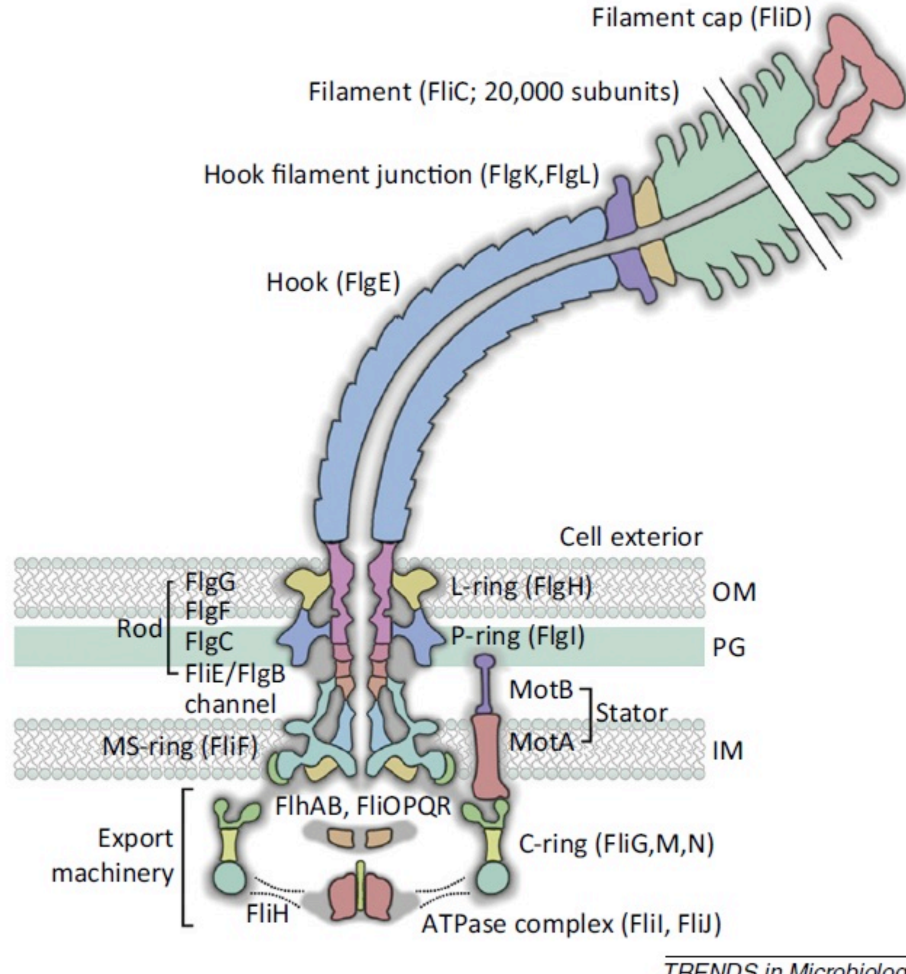
& LOEWE Center for Synthetic Microbiology (SYNMIKRO)

Marburg, Germany

Swimming motility of *Escherichia coli*



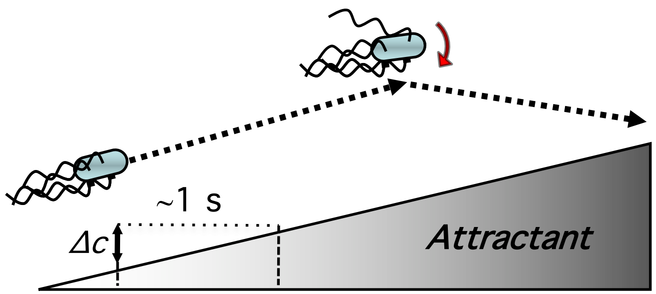




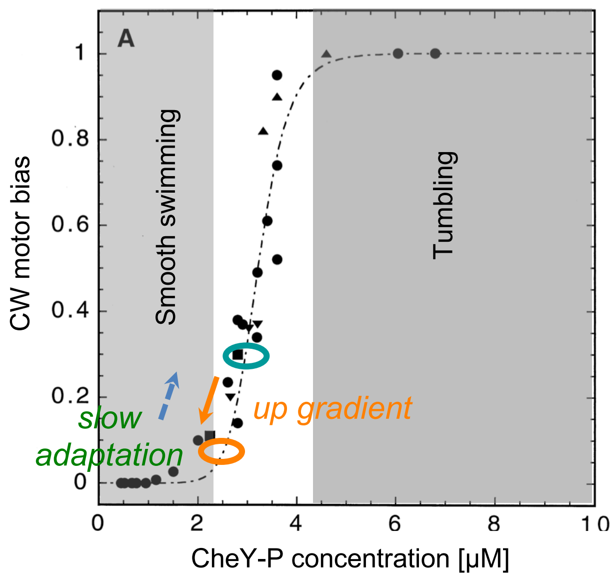
Turner & Berg, J Bacteriol, 2000

Evans et al., Trends Microbiol, 2014

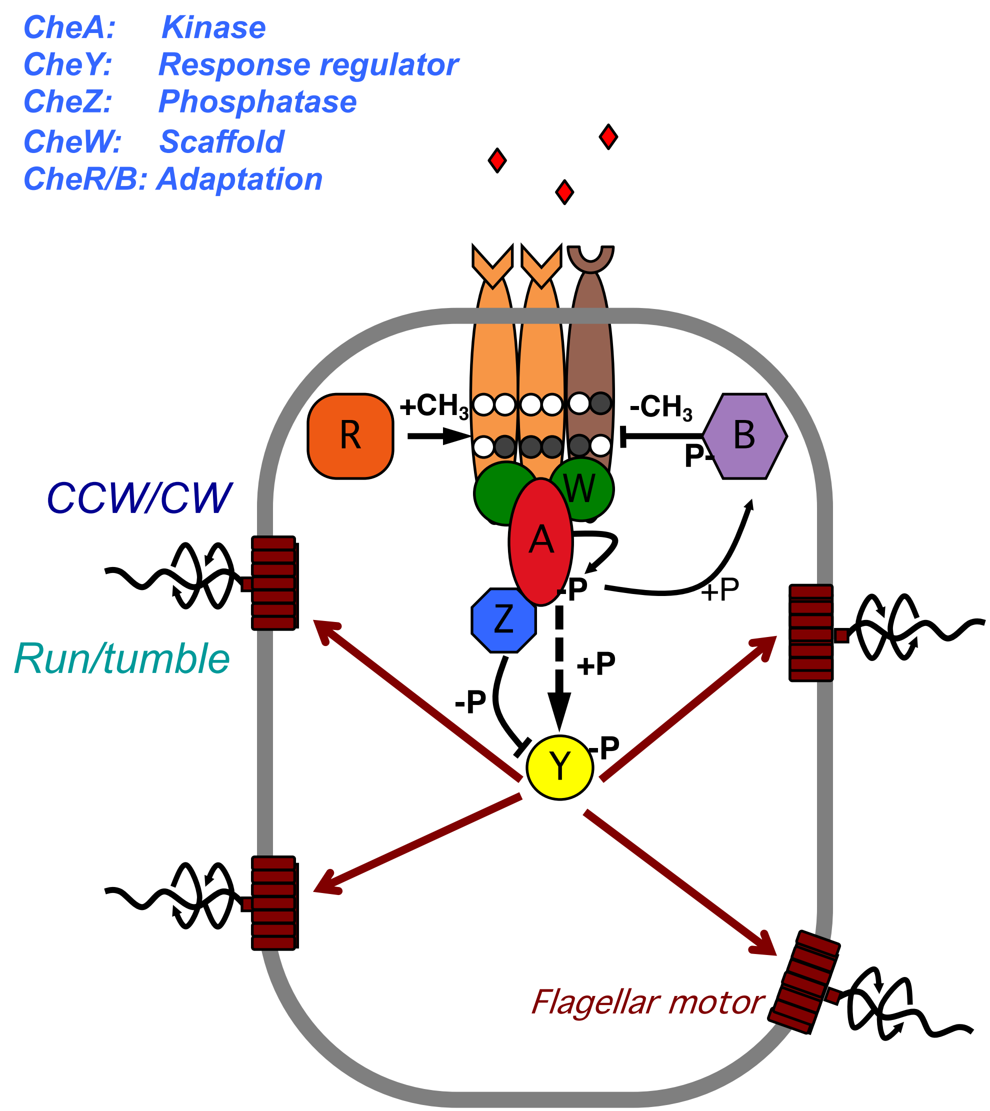
Strategy and signaling in *E. coli* chemotaxis



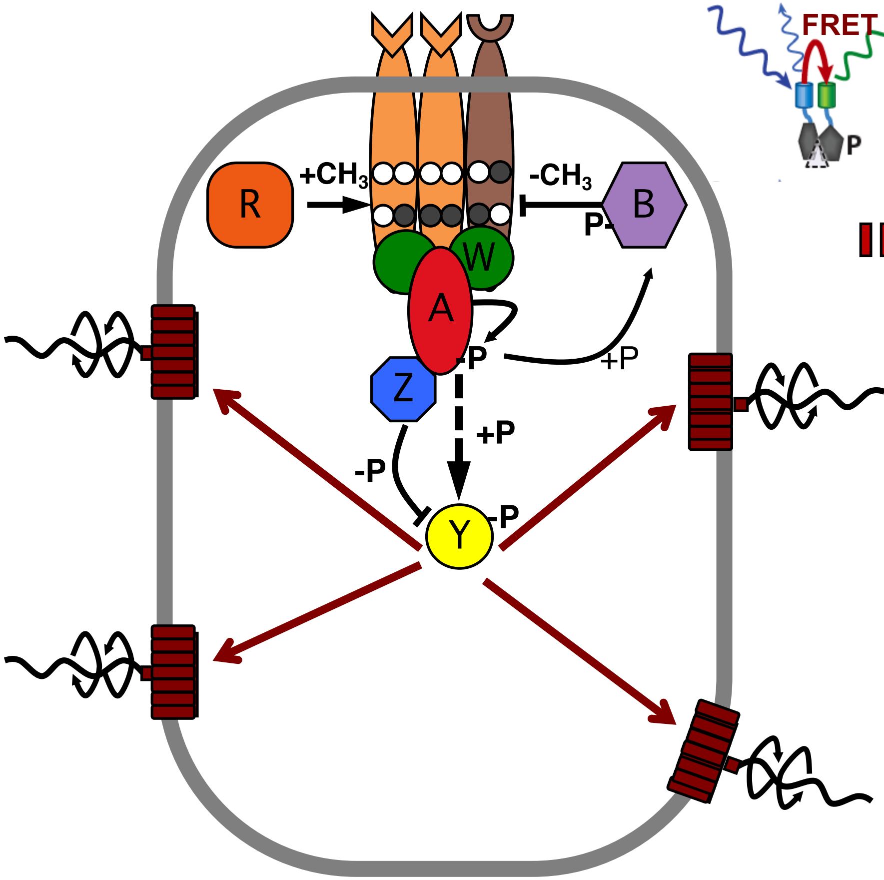
Sourjik & Wingreen, Curr Opin Cell Biol, 2012

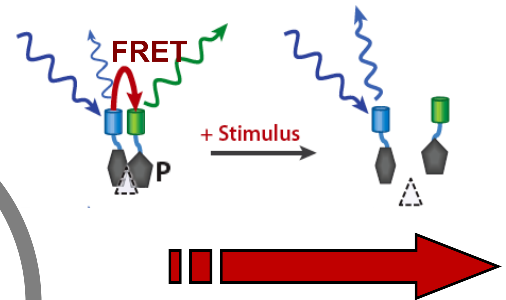


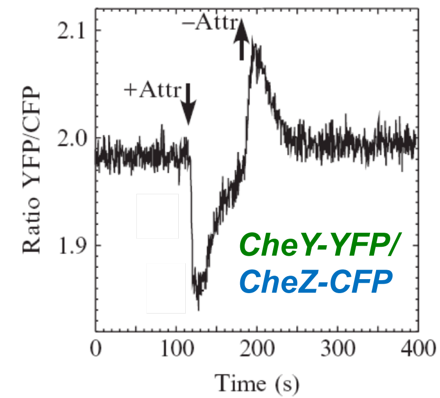
Cluzel et al., Science, 2000



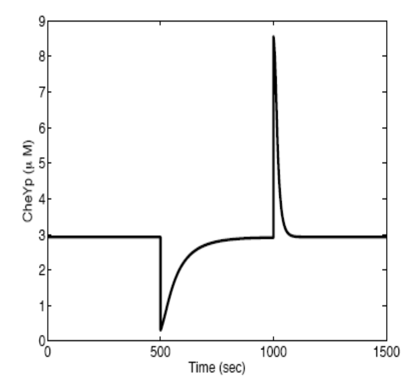
Closing the systems biology loop for *E. coli* chemotaxis network





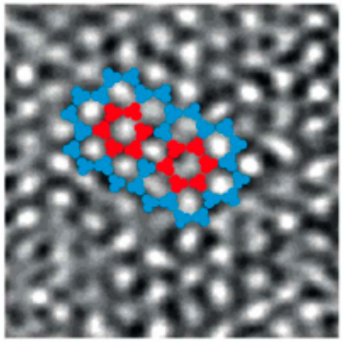


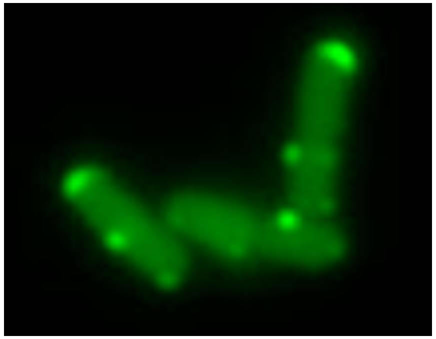
$$
\begin{aligned}
\partial_t T_m &= k_R R \frac{T_{m-1}}{K_R + T^T} + k_B\, Bp \frac{T^A_{m+1}}{K_B + T_A} \\
&\quad - k_R R \frac{T_m}{K_R + T^T} - k_B\, Bp \frac{T^A_m}{K_B + T_A} \\
\partial_t Ap &= k_A \left(A^T - Ap\right) T_A - k_Y Ap \left(Y^T - Yp\right) \\
&\quad - k'_B Ap \left(B^T - Bp\right) \\
\partial_t Yp &= k_Y Ap \left(Y^T - Yp\right) - k_Z Yp\, Z - \gamma_Y Yp \\
\partial_t Bp &= k'_B Ap \left(B^T - Bp\right) - \gamma_B Bp
\end{aligned}
$$



Colin & Sourjik, Curr Opin Microbiol, 2017

Function of spatial organization in chemotaxis

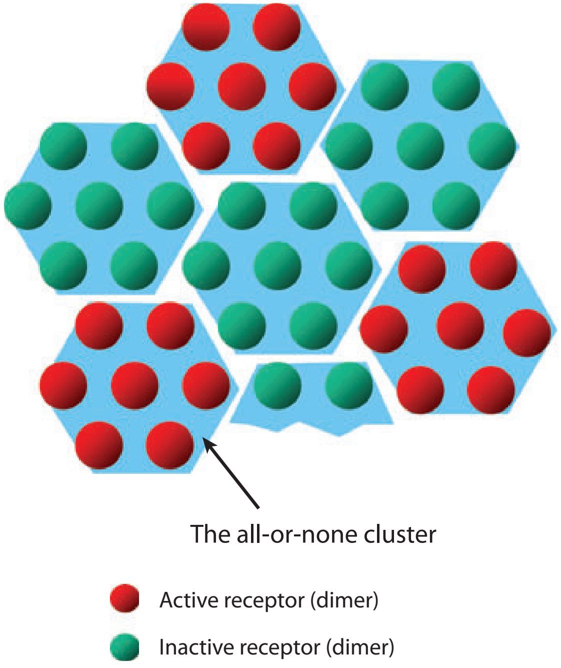




Sourjik & Berg, Mol Microbiol, 2000
Briegel et al., Mol Microbiol, 2009

Allosteric signal amplification by receptor clusters (10- to 30-fold)

Monod-Wyman-Changeaux (MWC) model
(Monod et al., 1965)



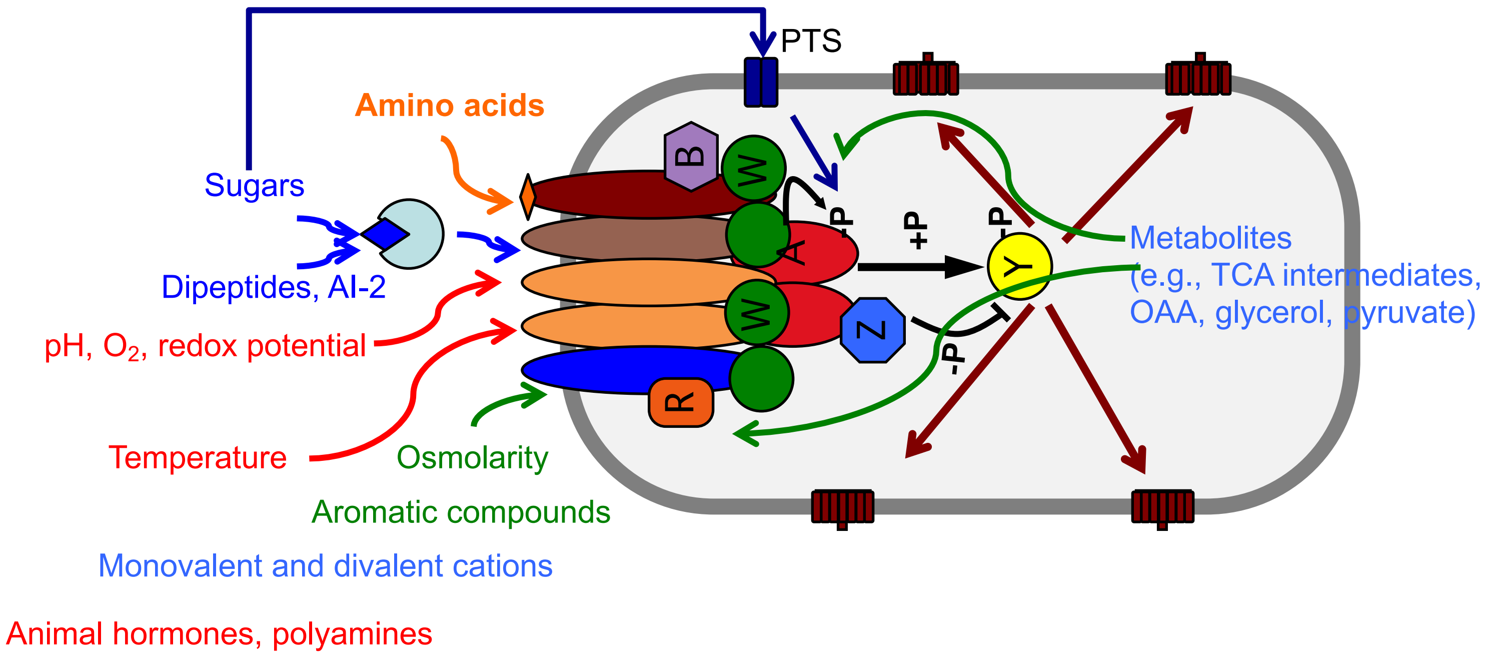
$$\langle a \rangle = p_{on} = \frac{1}{1+e^{-N\Delta f}} = \frac{e^{-Nf_m(m)}(1+[L]/K_a)^N}{e^{-Nf_m(m)}(1+[L]/K_a)^N + (1+[L]/K_i)^N}$$

$$H(\vec{s}) = -\sum_{\langle ij \rangle} J s_i s_j - \sum_i h s_i$$

Sourjik & Berg, Nature, 2004
Tu, Annu Rev Biophys, 2013

Open question:
Sensory diversity of chemotaxis

Spectrum of chemotactic stimuli for *E. coli*



Sensing in *E. coli* chemotaxis

Bi & Sourjik, Curr Opin Microbiol, 2018

Attractants:

Amino acids

Monovalent cations

Bi et al., Nat Comm, 2018

Attractants:

Sugars

Dipeptides

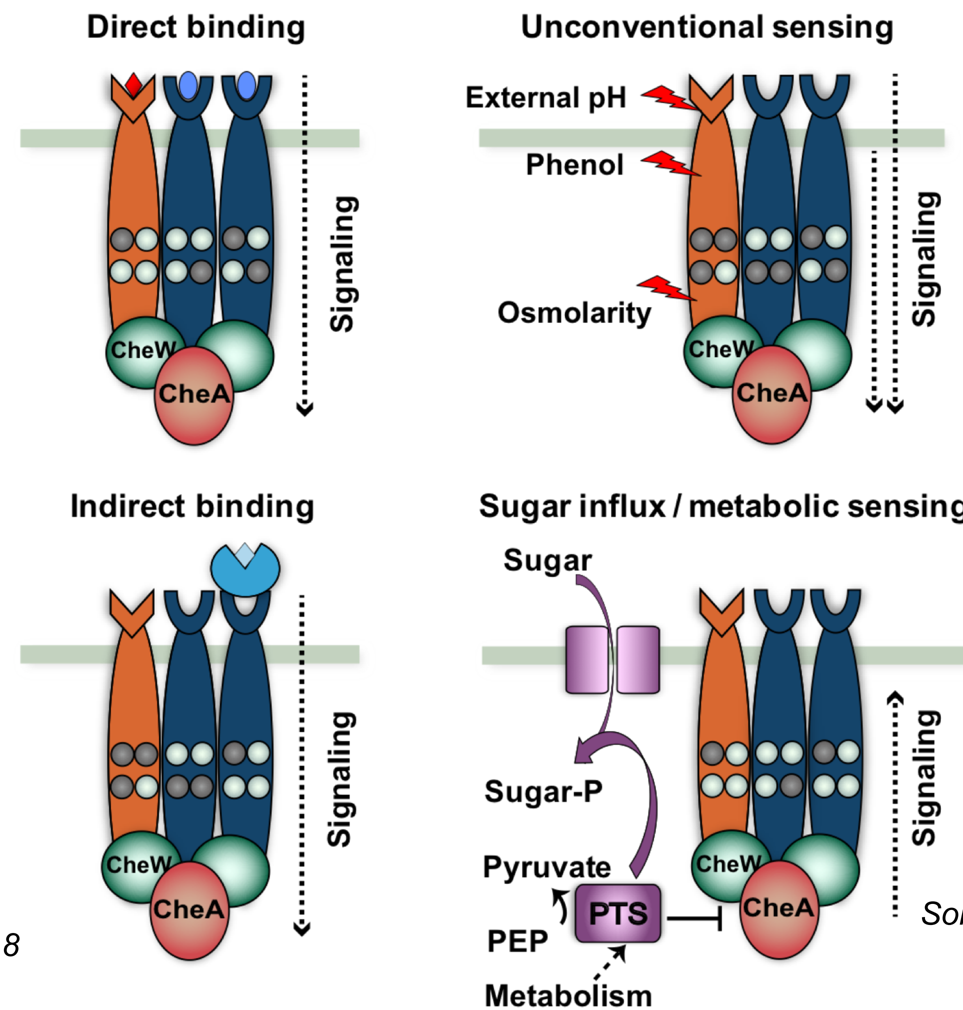
Autoinducer 2

Repellents:

Spermidine

Insulin

Lopes & Sourjik, ISME J, 2018



Attractants/Repellents

Temperature

Hormones (e.g., dopamine)

Aromatic compounds

Divalent cations

Osmolarity

pH

…

Bi et al., Nat Comm, 2018
Paulick et al., eLife, 2017
Lopes & Sourjik, ISME J, 2018

Attractants:

PTS Sugars

TCA intermediates

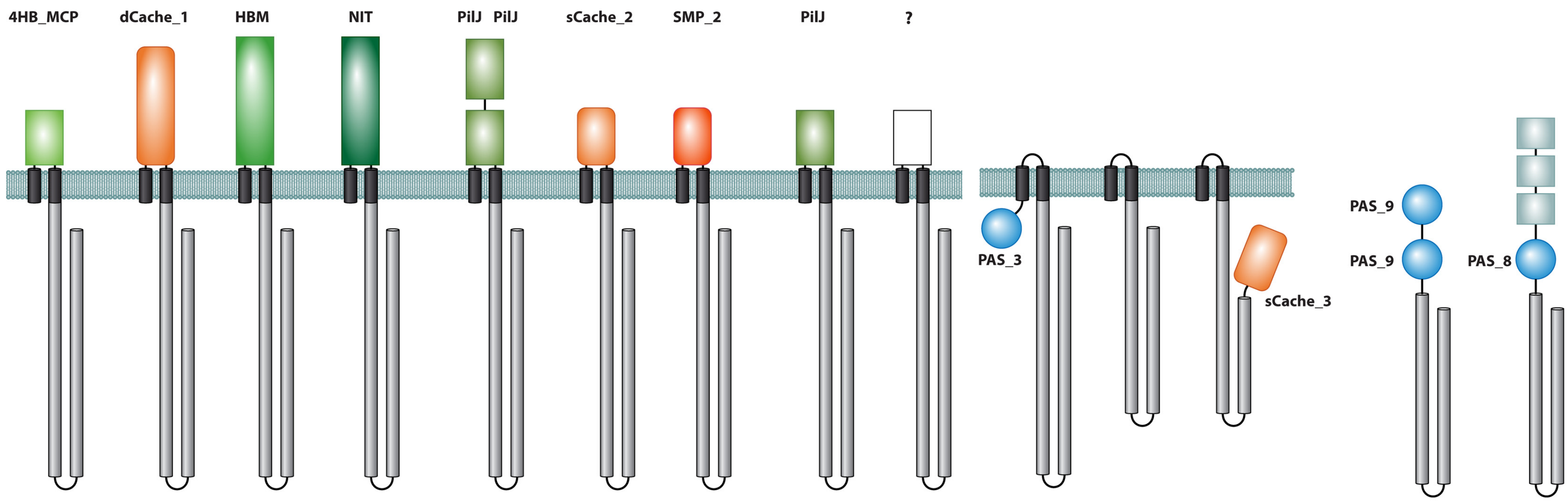
Glycerol

Serine

Pyruvate

Somavanshi et al., PLoS Biol, 2016

Sensory diversity of chemoreceptors



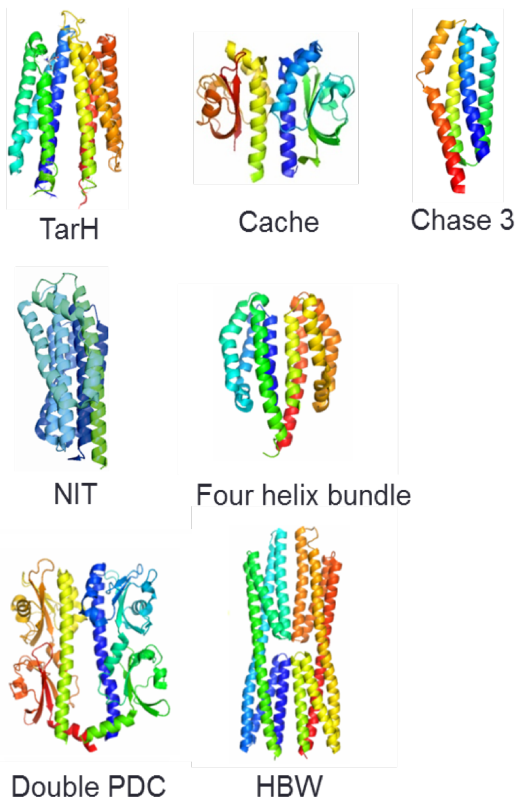
Example: Different classes of chemoreceptors in *Pseudomonas* species

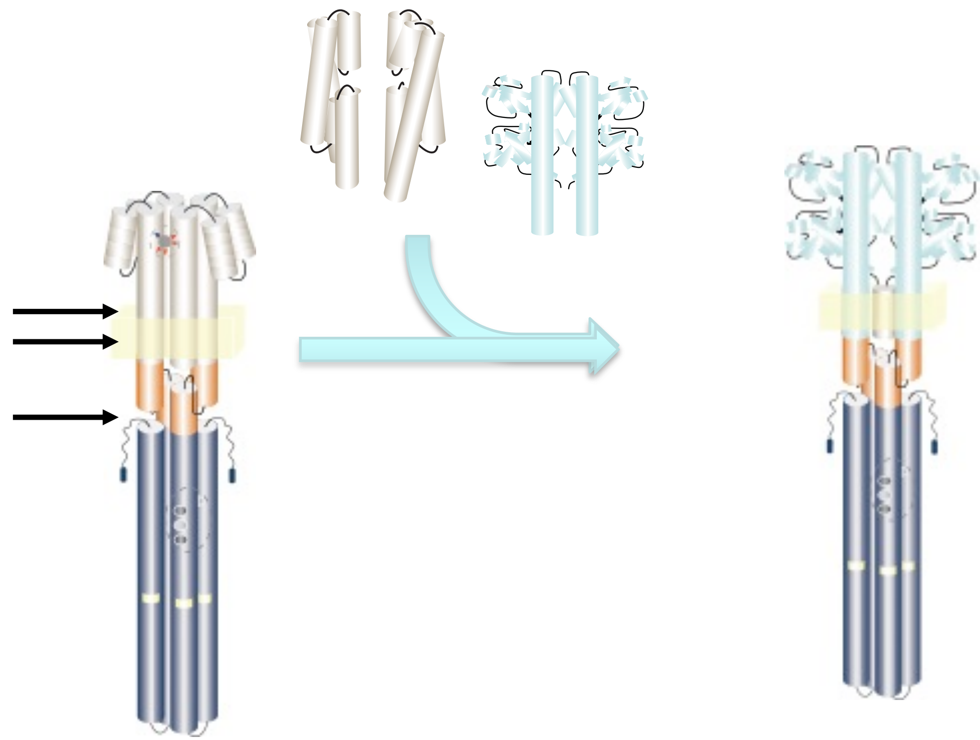
Ortega, Zhulin & Krell, MMBR, 2017

Using hybrid receptors to map specificity of sensory domains

Various sensory domains

(chemoreceptors, two-component histidine kinases)



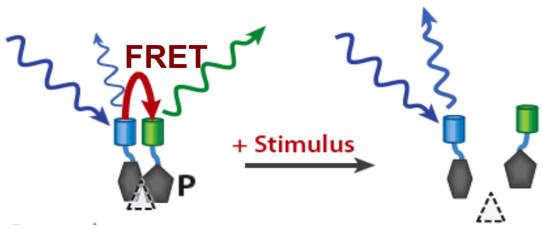


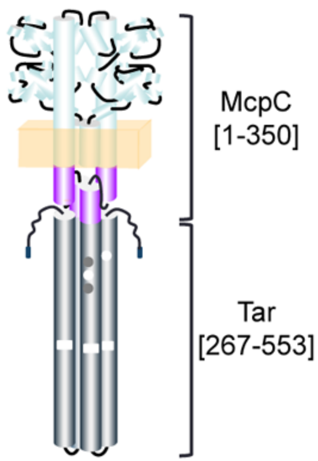
E. coli receptor Tar

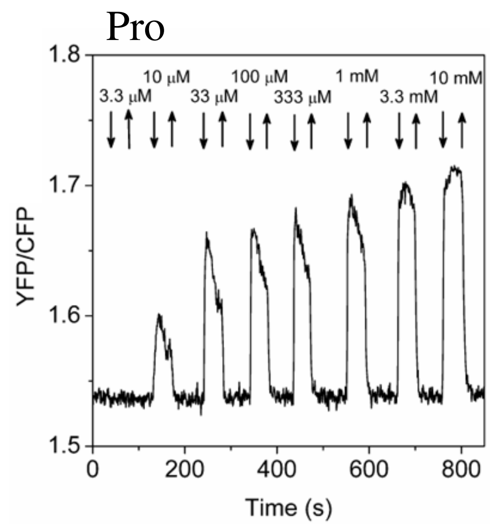
Hybrid receptor

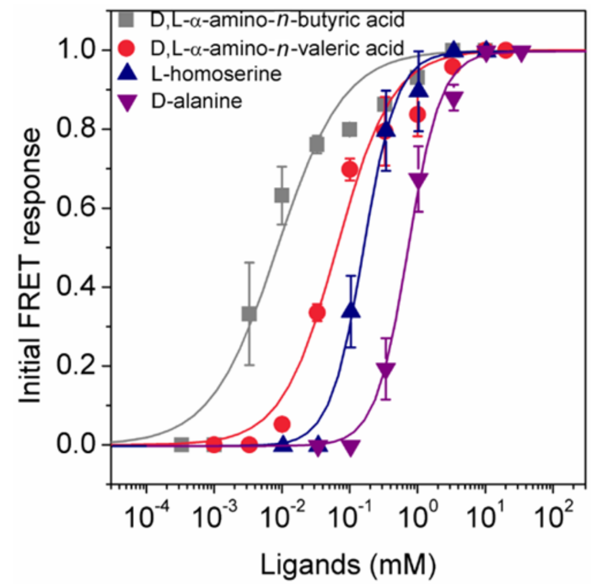
Bi et al, ACS Synth Biol, 2016

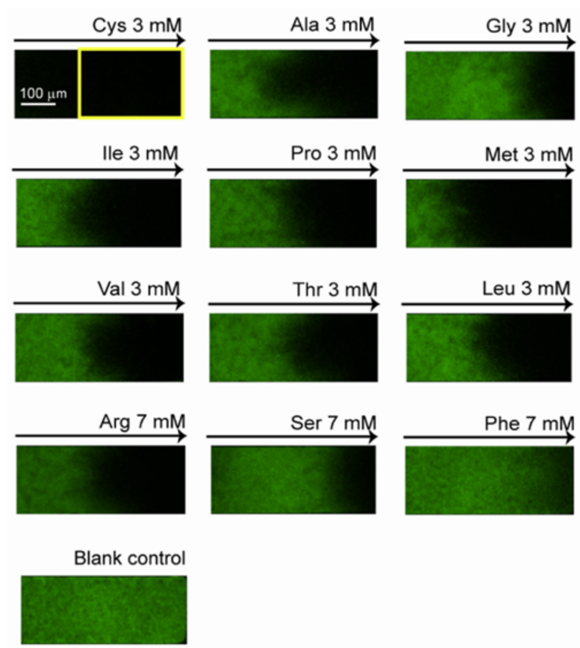
Characterization of response specificity

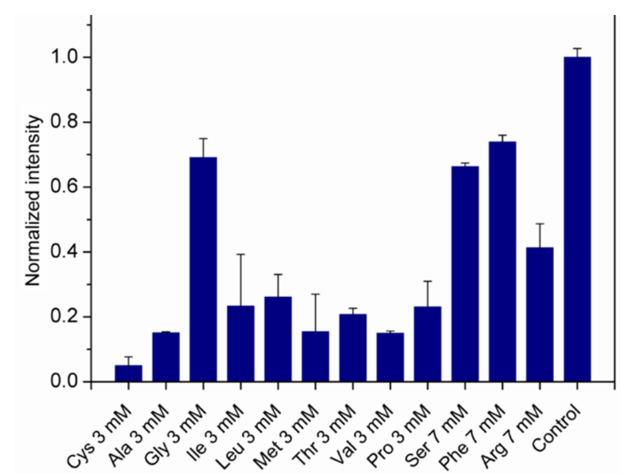




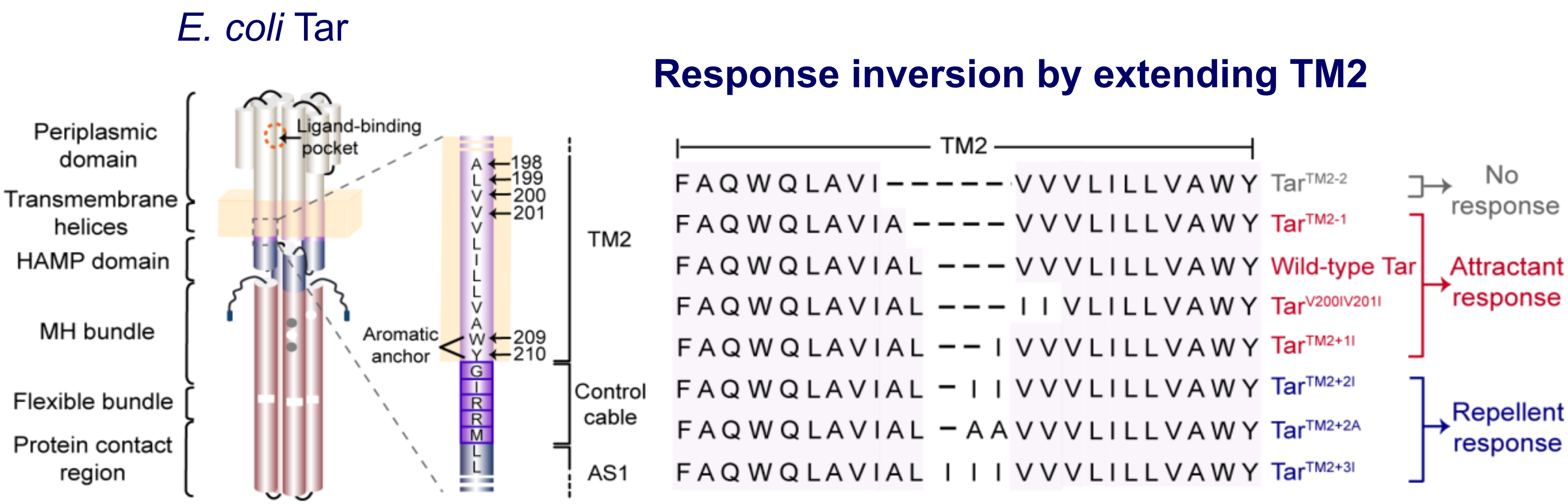




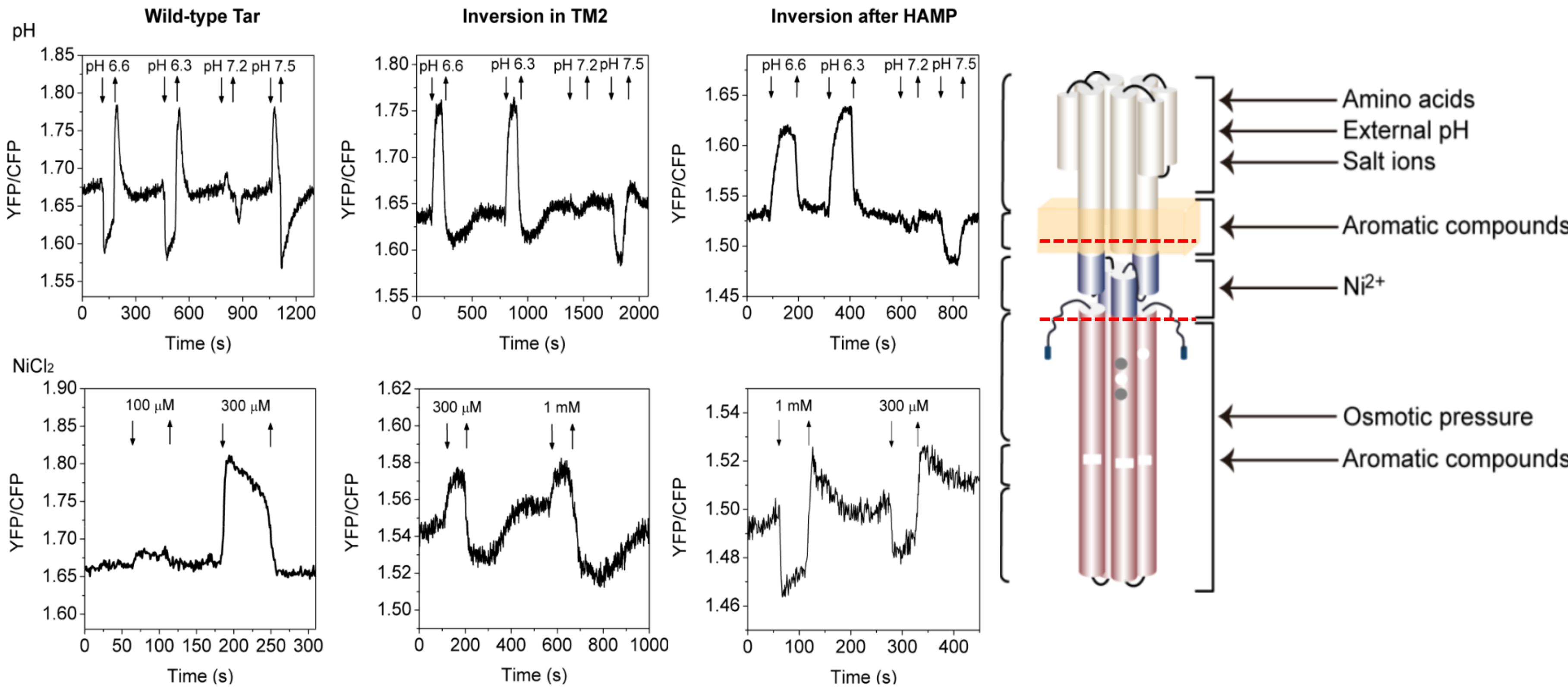




Using sign inversion of receptor response to map sensory regions



Using sign inversion of response to map sensory regions of receptors

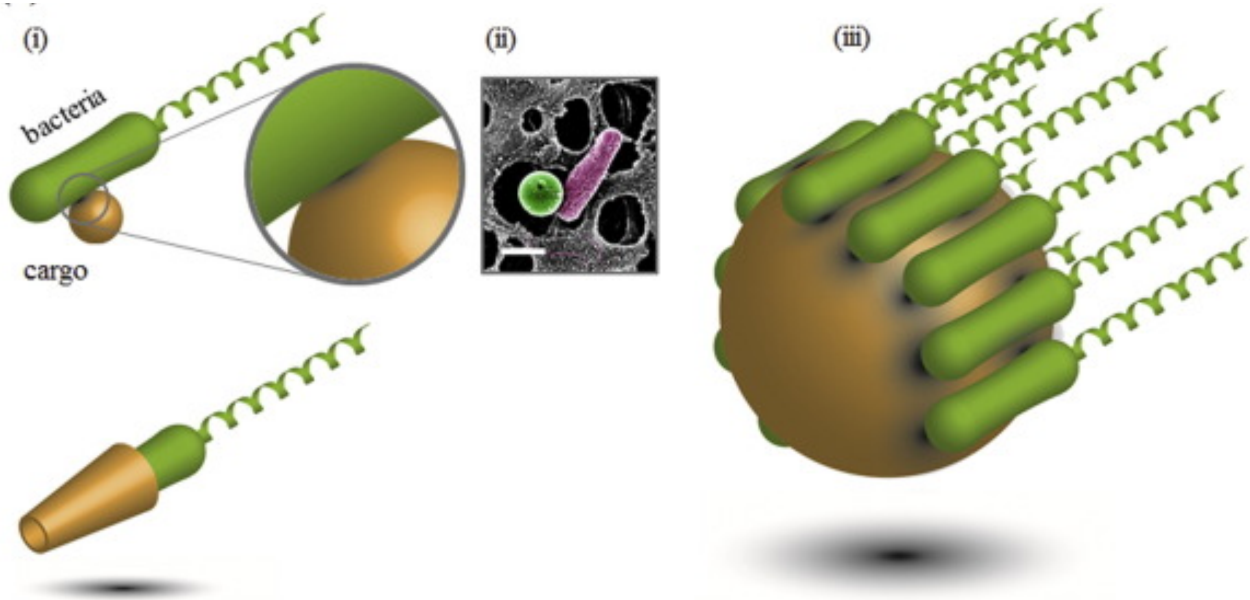


Inversion depends on the sensory site:

- *Periplasmic sensing: inverted in both mutants*
- *HAMP-mediated sensing: inverted in one but not the other mutant*
- *Sensing below HAMP: no inversion*

Getting bacteria to work: particle transport

Hosseinidoust et al. (2016)




Oliver Schauer

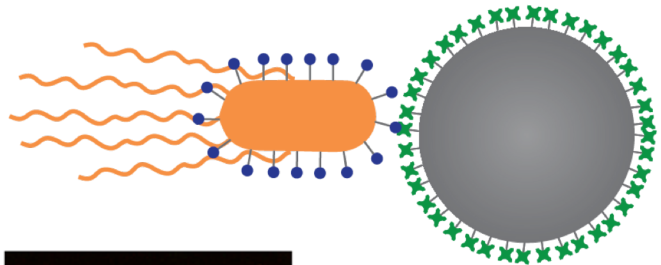

Metin Sitti

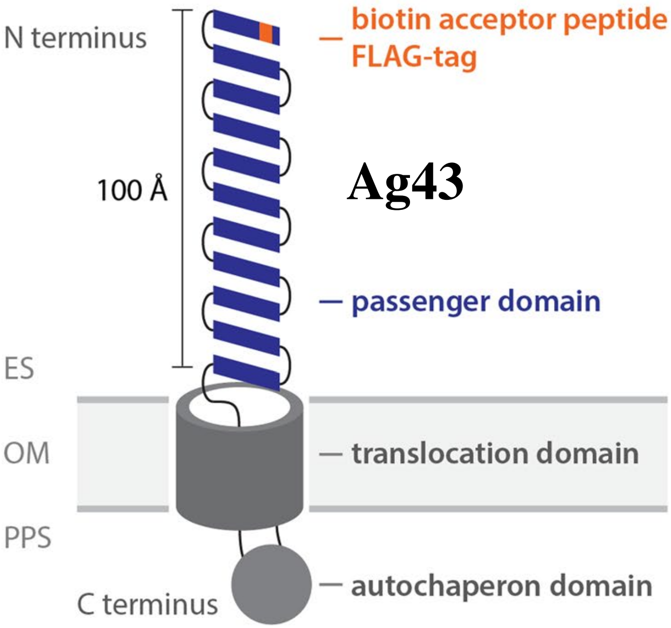

Babak Mostaghaci

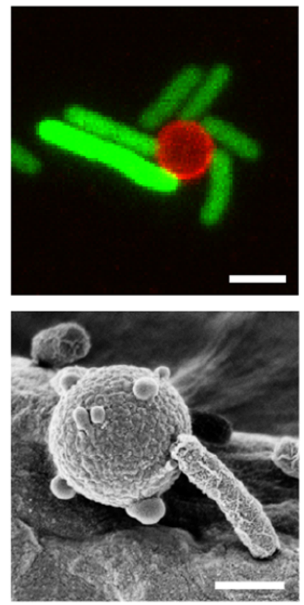
MAX PLANCK INSTITUTE FOR INTELLIGENT SYSTEMS

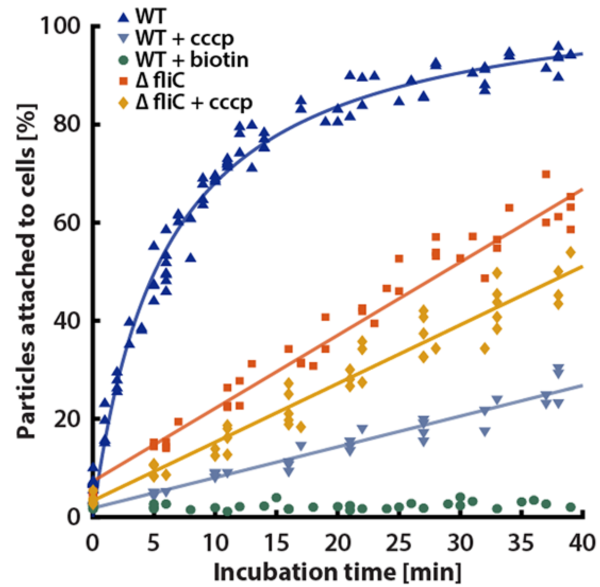
Physical Intelligence Department

Ag43-mediated particle attachment







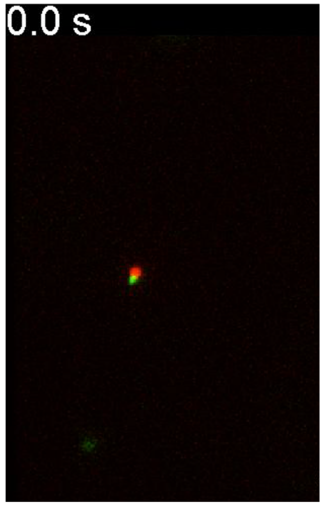


Attachment is strongly enhanced by motility

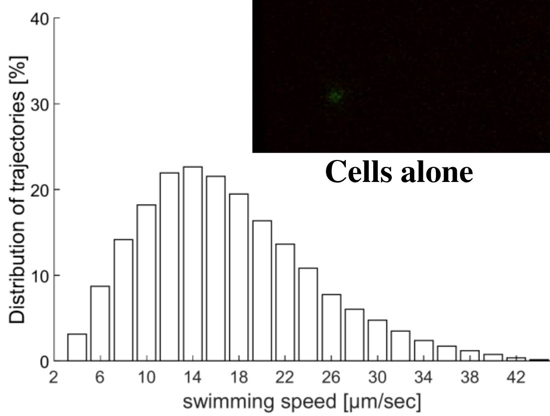
Schauer et al., Sci Rep, 2018

Dependence of motility on particle attachment

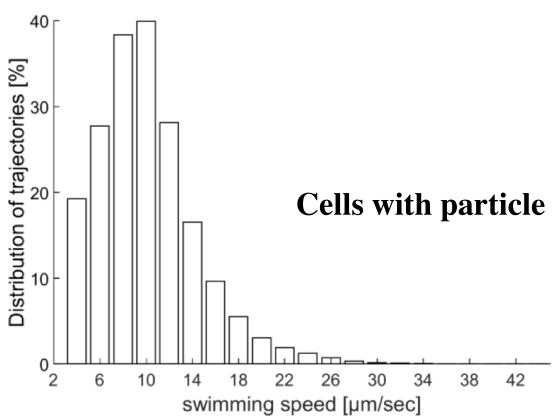
Bacteria with normal length (2-4 µm)



- *Move particles only by pulling*
- *Swimming speed is strongly affected by particle attachment*

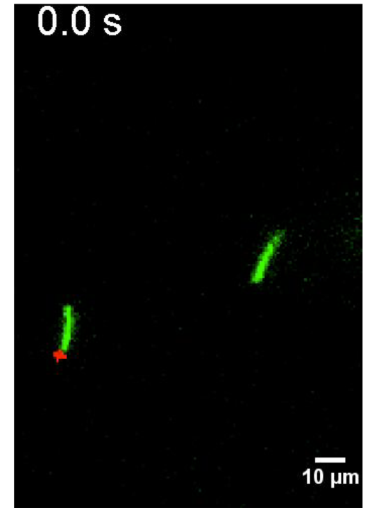


Cells alone

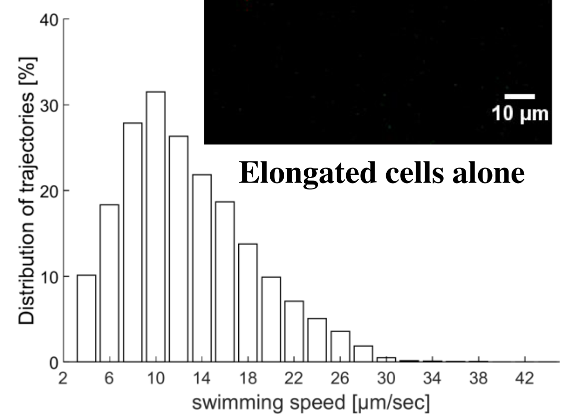


Cells with particle

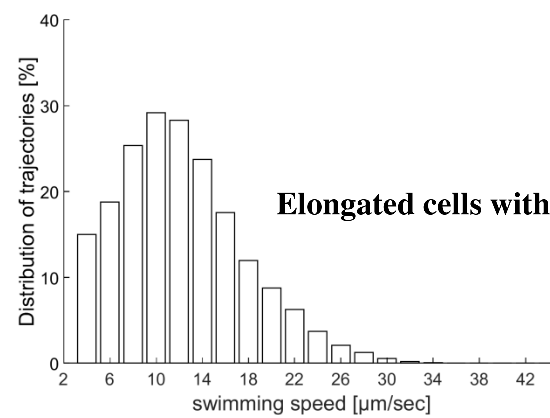
Elongated bacteria (~10 µm)



- *Move particles by pulling or pushing*
- *Swimming speed is little affected by particle attachment*



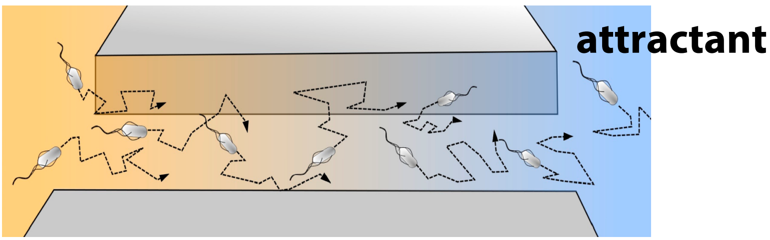
Elongated cells alone

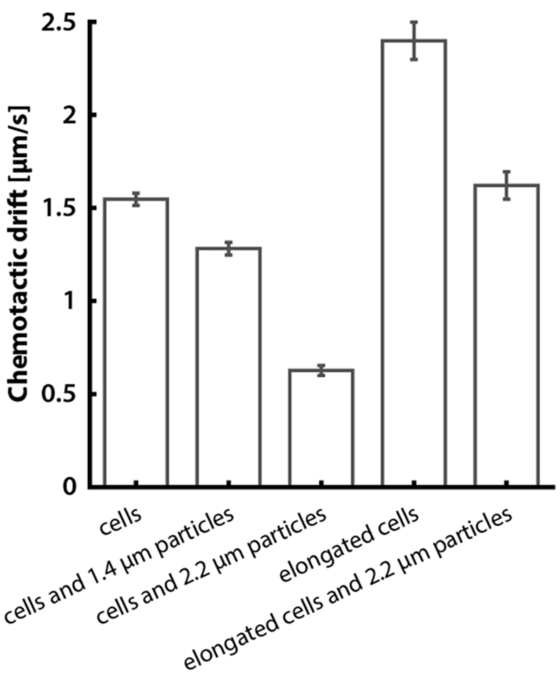


Elongated cells with particle

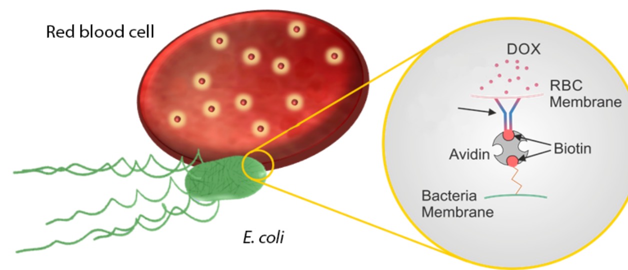
Using bacteriabots to directionally move attached particles

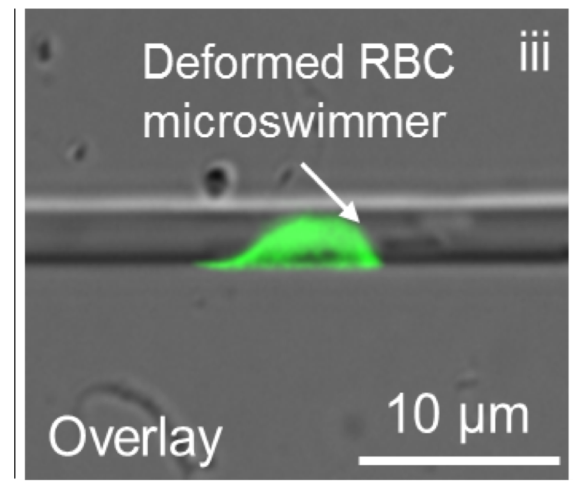
Movement in chemical gradients





Movement in capillaries





Schauer et al., Sci Rep, 2018

Alapan et al., Sci Robot, 2018