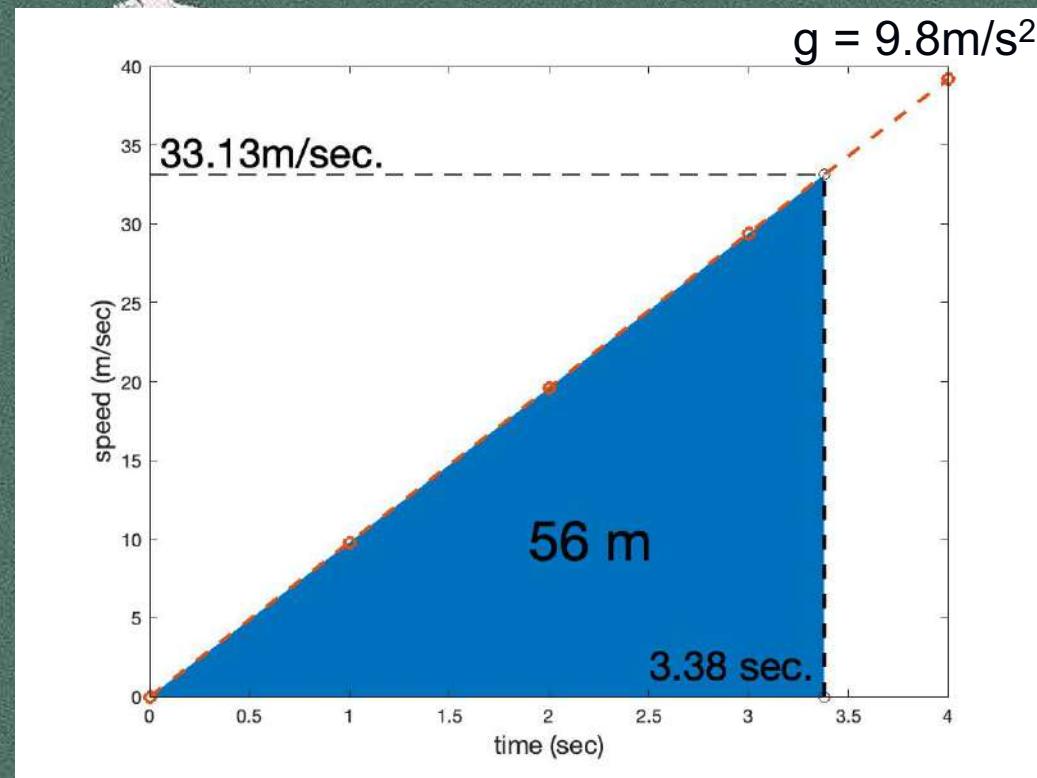
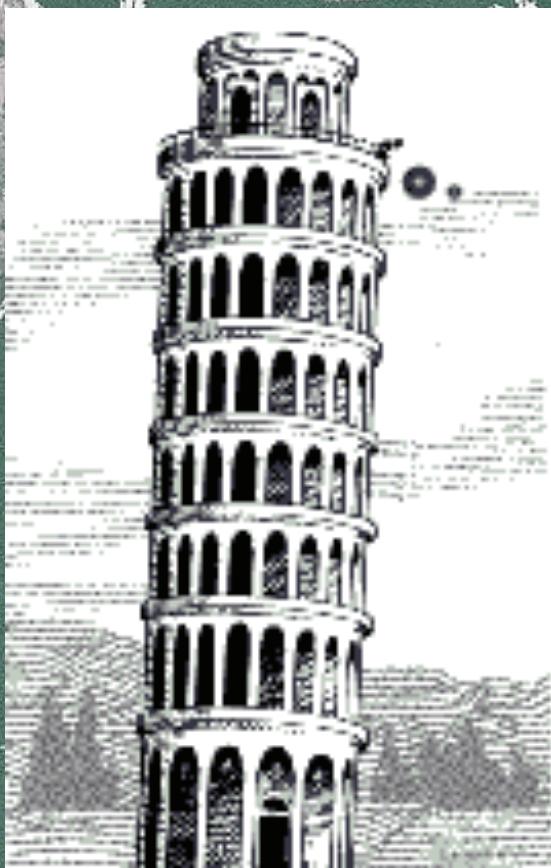


Years: 37,8854356459

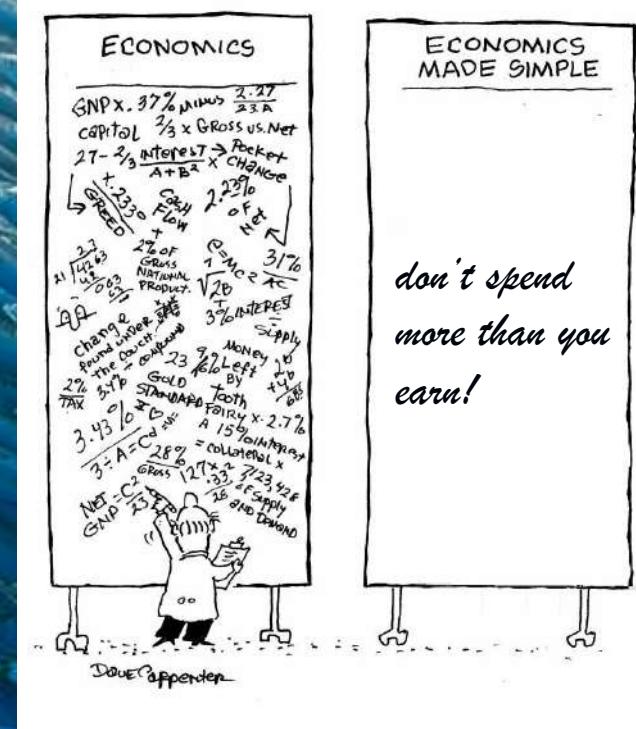
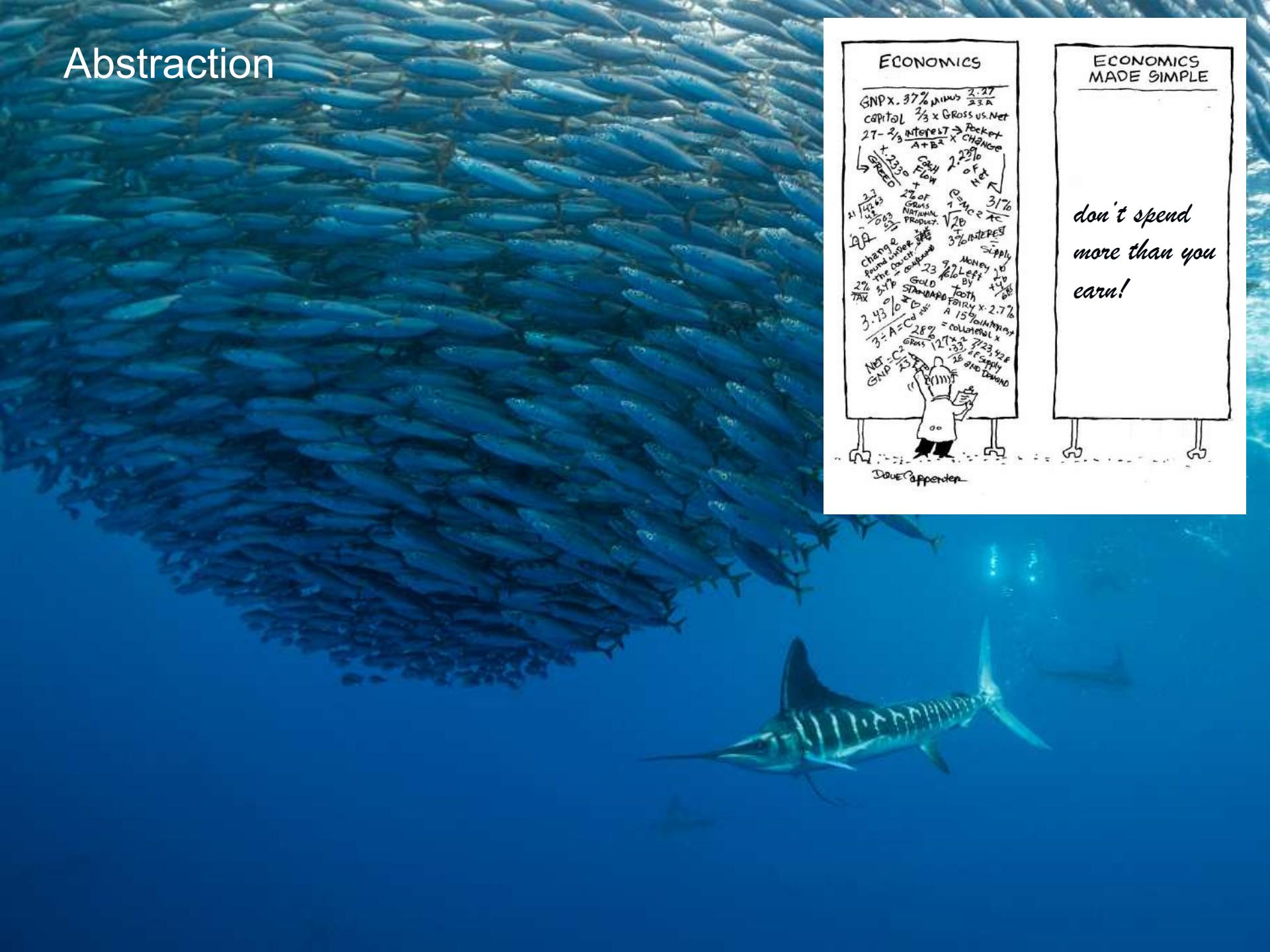
Modellazione
della vita
dai virus
ai coralli
Ozan
Kahramanoğulları



Photo credits: Lorenzo Bramanti



Abstraction



Lotka – Volterra



→



→ 2 x



+



→ 2 x



$$\frac{dX}{dt} = r_3 * X * Y - r_1 * X;$$

$$\frac{dY}{dt} = r_2 * Y - r_3 * X * Y;$$

Lotka – Volterra



→



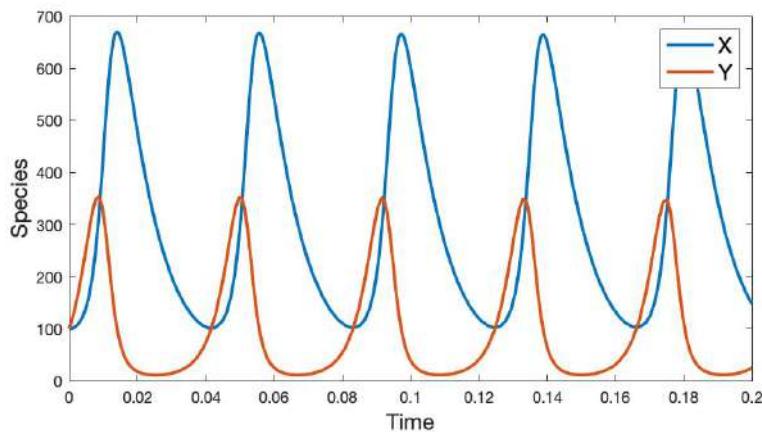
→ 2 x



+



→ 2 x



Lotka – Volterra



→



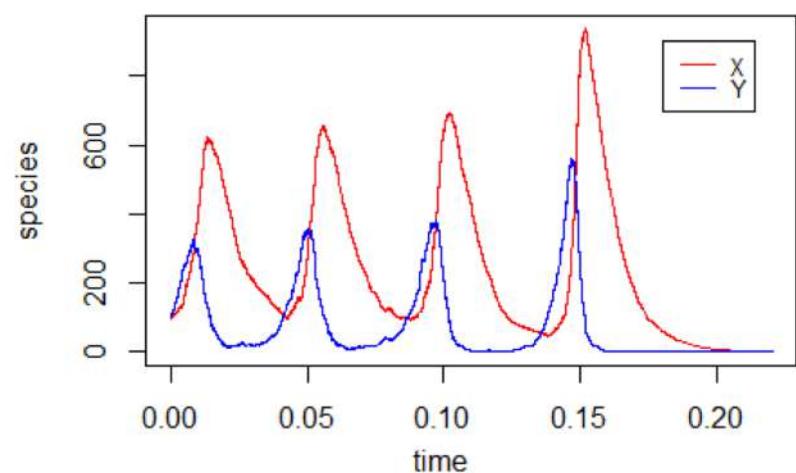
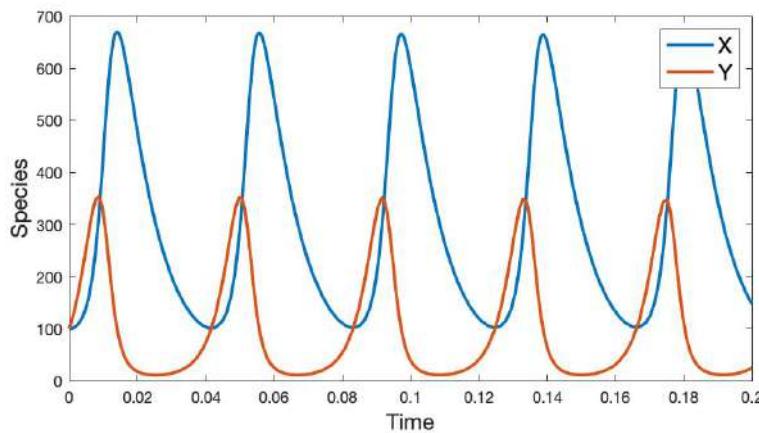
→ 2 x



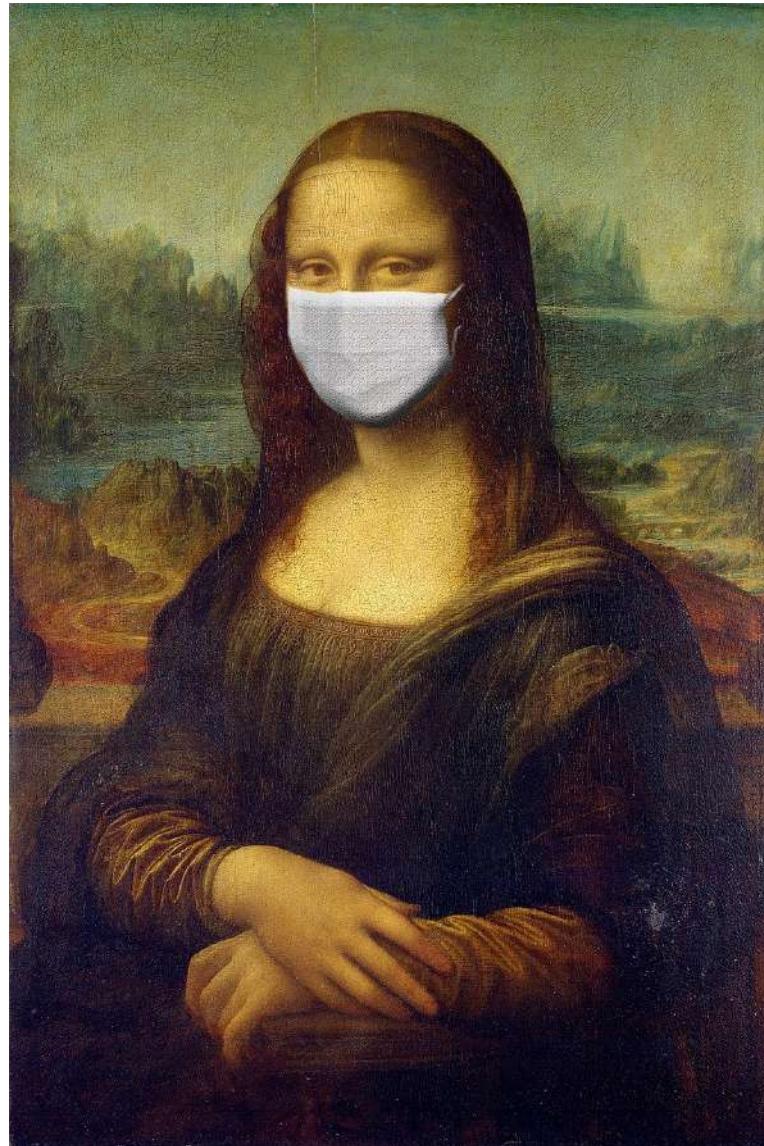
+



→ 2 x



Infectious Disease - SIR models



Infectious Disease - SIR models

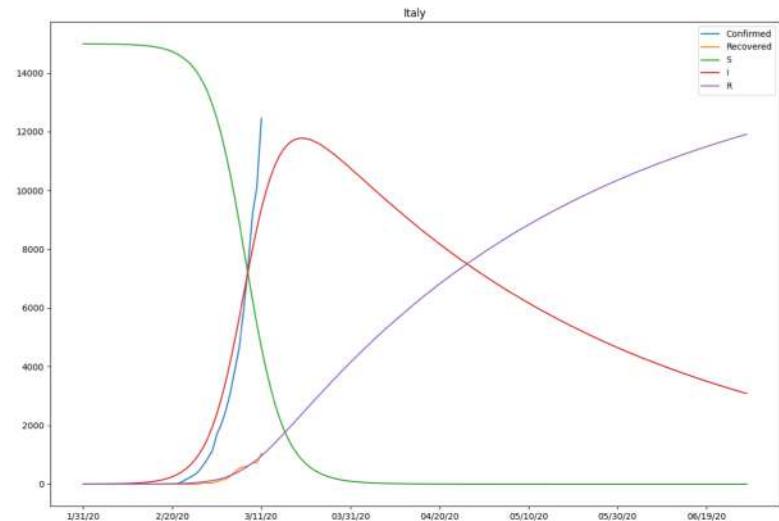
Susceptible + Infectious → 2 x Infectious

Infectious → Recovered

$$dS/dt = - \beta * I * S;$$

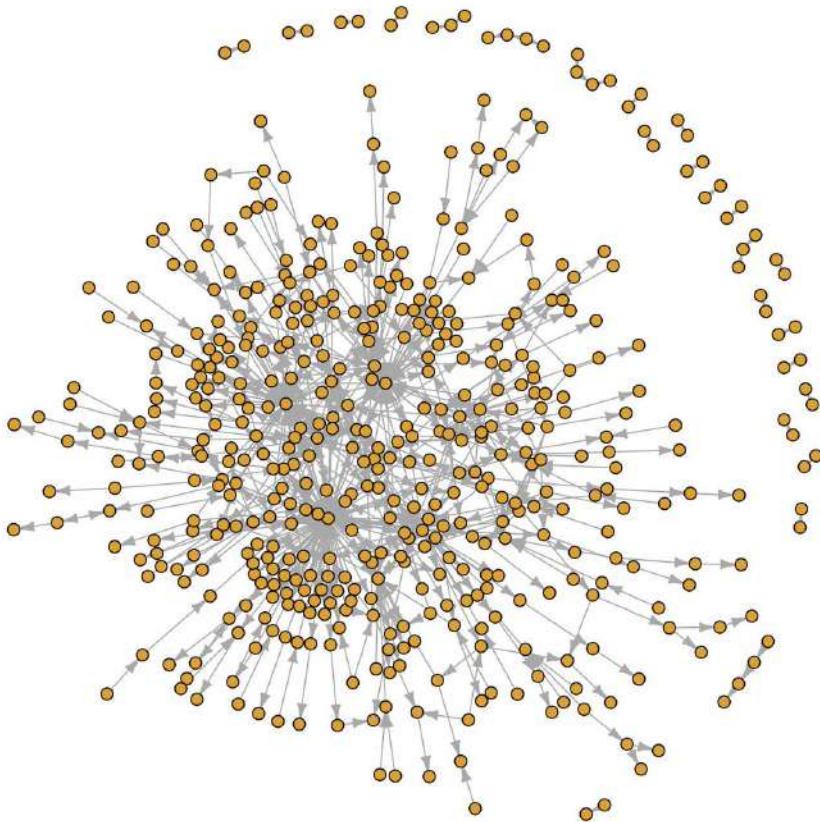
$$dI/dt = \beta * I * S - \gamma * I;$$

$$dR/dt = \gamma * I$$

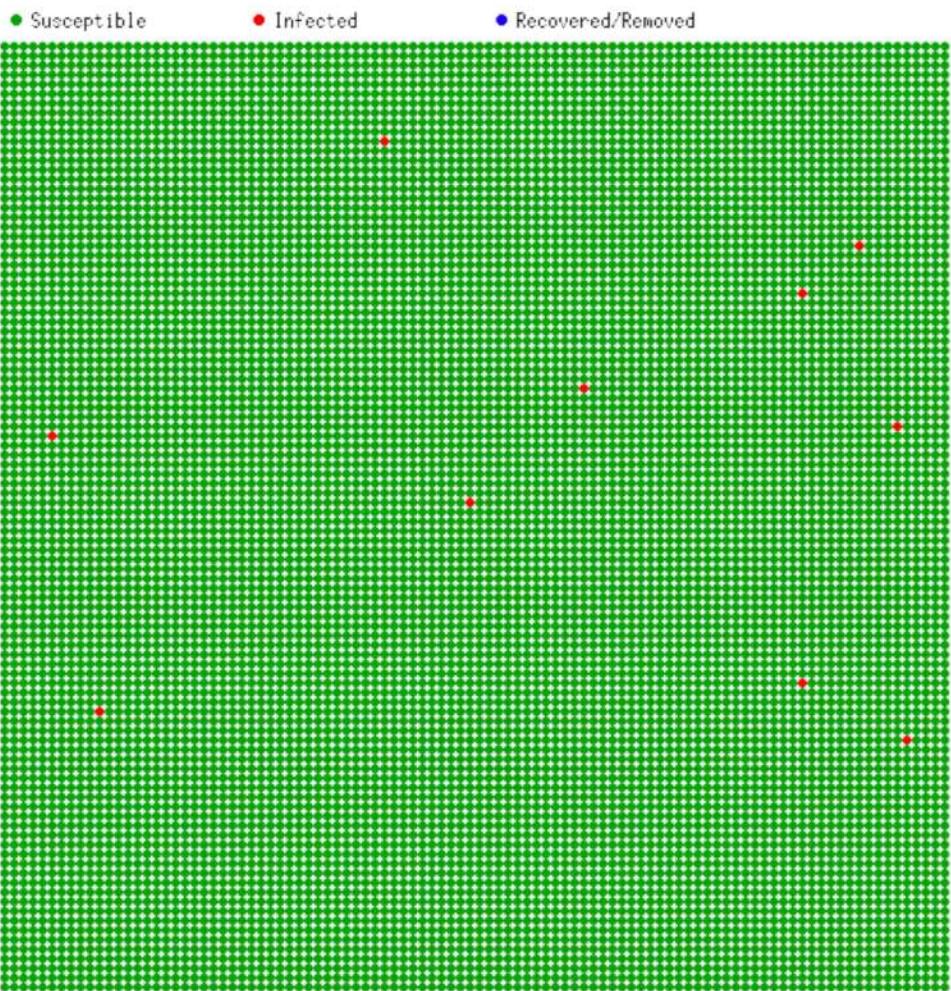
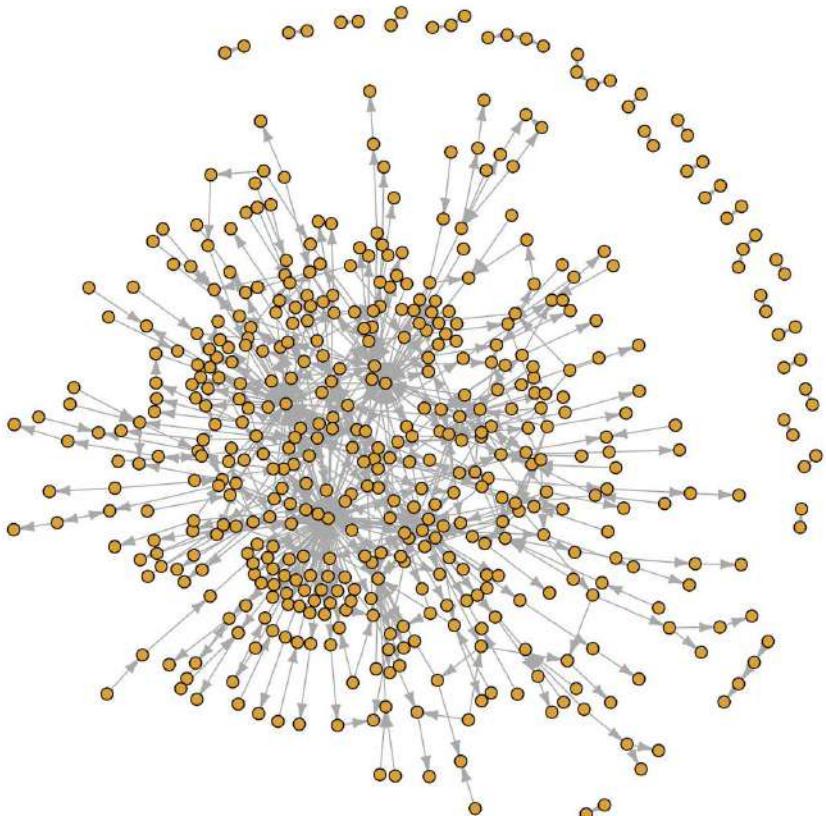


<https://www.lewuathe.com/covid-19-dynamics-with-sir-model.html>

Infectious Disease - SIR models – scale-free networks



Infectious Disease - SIR models – scale-free networks



degree distributions of the nodes decrease from the center outwards.

Coralli:
*Corallium
rubrum*

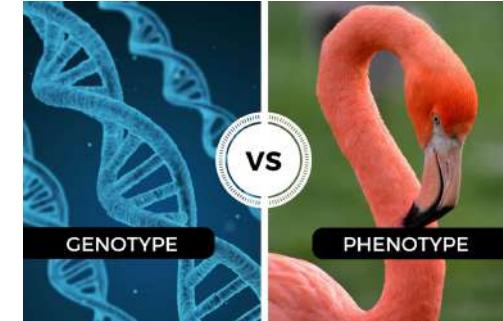
Photo credits: Lorenzo Bramanti



Phenotype = Genotype + Physical Environment

A fundamental question in biology:

What are the mechanisms that govern the phenotype?



In the organisms with bilateral symmetry:

morphology ~ genome



physical environment >>> growth process >>> variety of structural forms.

Corallium rubrum

Octocoral species, endemic to Mediterranean and neighboring habitats.

- Found on rocky bottoms,
between 10m and 800m depth.
- Slow growing: ~ 100 years.
- High economic value:
extensively harvested.
- The three-dimensional structuring
of coralligenous assemblages.
- Local extirpation influences the habitat and biodiversity.



Credits: Lorenzo Bramanti

Corallium rubrum

- The colony skeleton has a branching form.
- Calcium carbonate deposited by polyps.
- The colonies exhibit wide variability in growth forms.



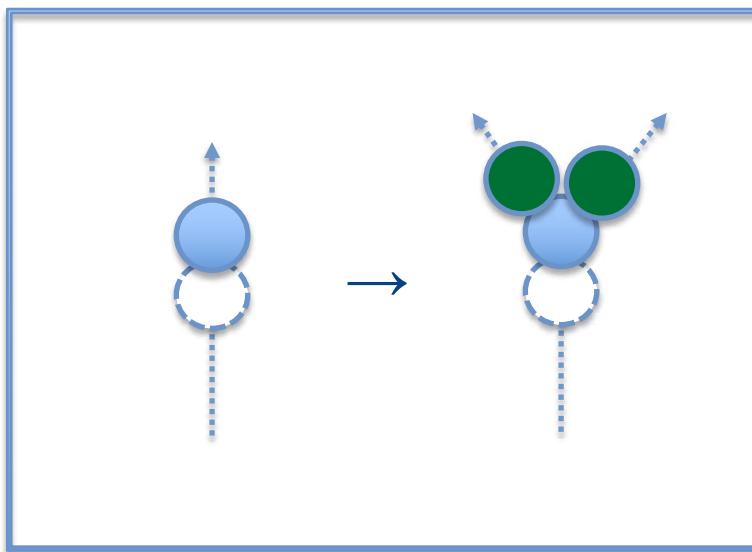
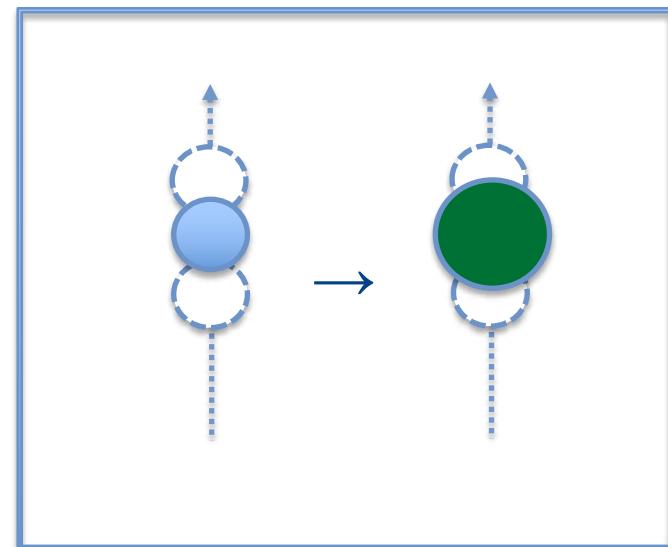
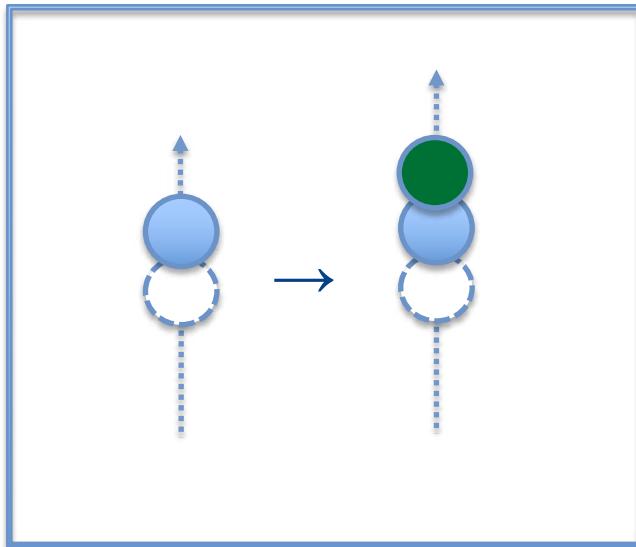
Credits: Lorenzo Bramanti



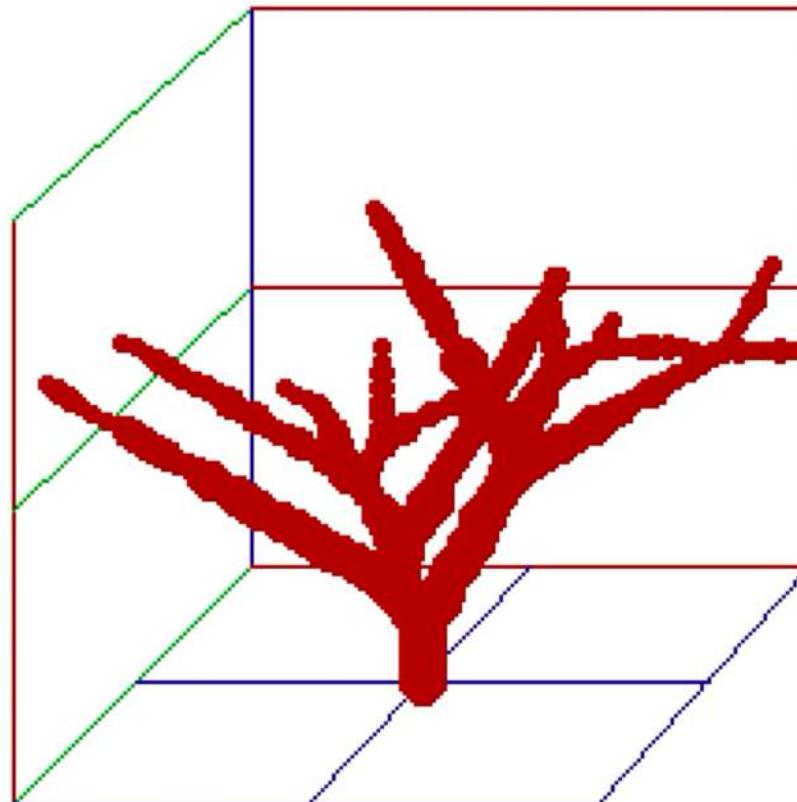
Credits: Lorenzo Bramanti

The variations are linked to local environmental conditions.

A SIMPLE MODAL OF GROWTH AND BRANCHING

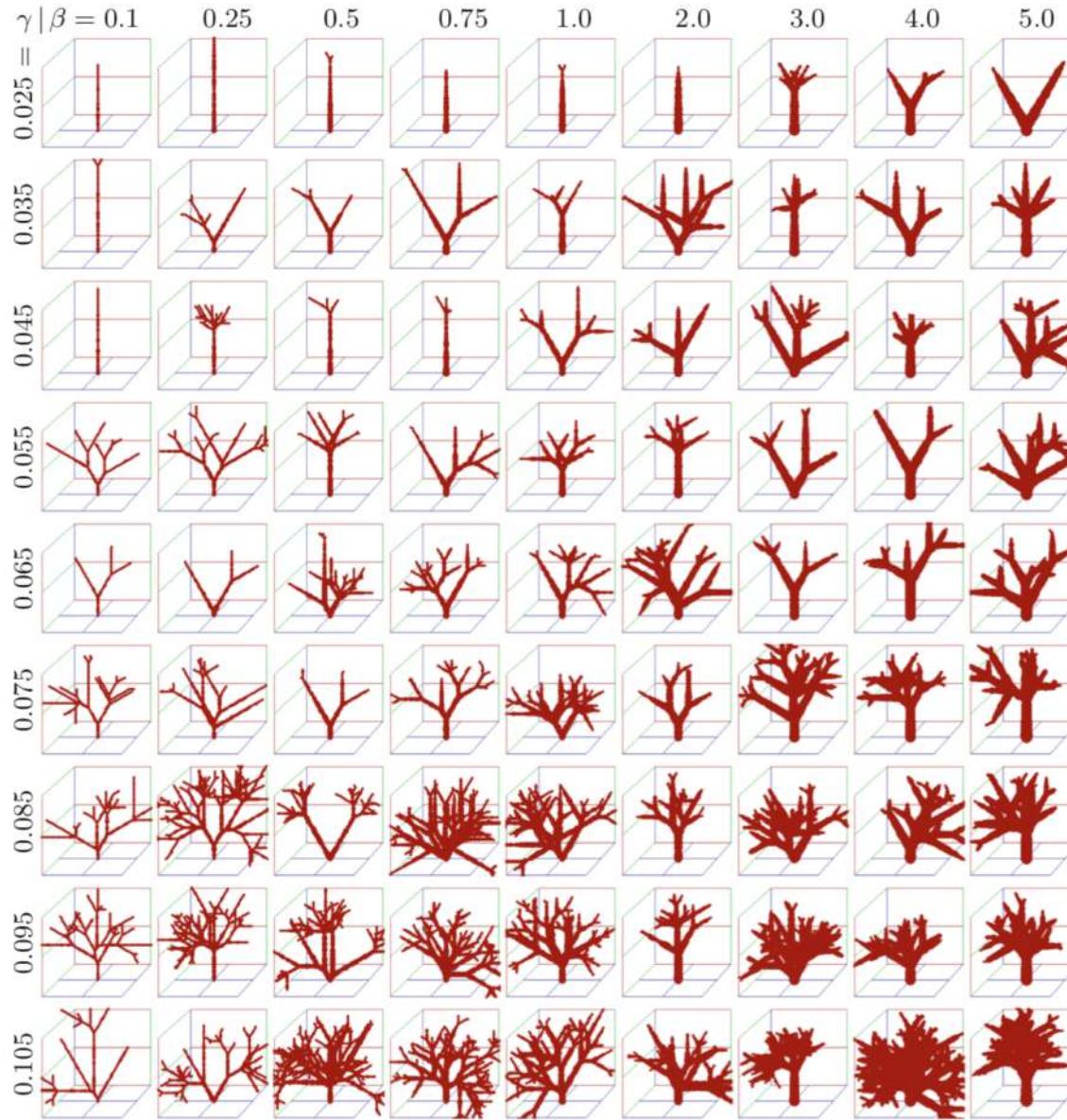


A SIMPLE MODEL OF GROWTH AND BRANCHING

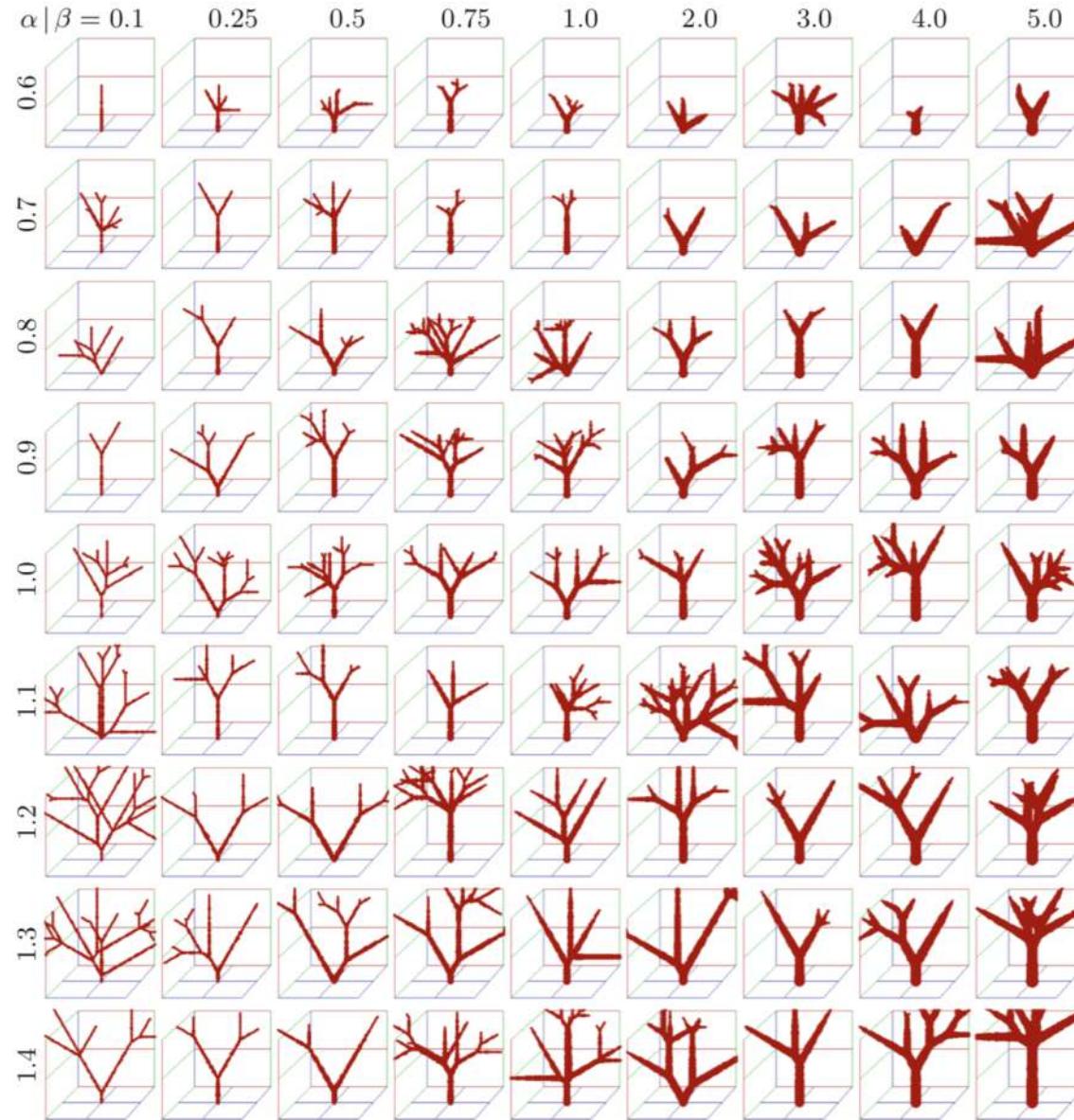


Years: 37,8854356459

STOCHASTIC SIMULATIONS

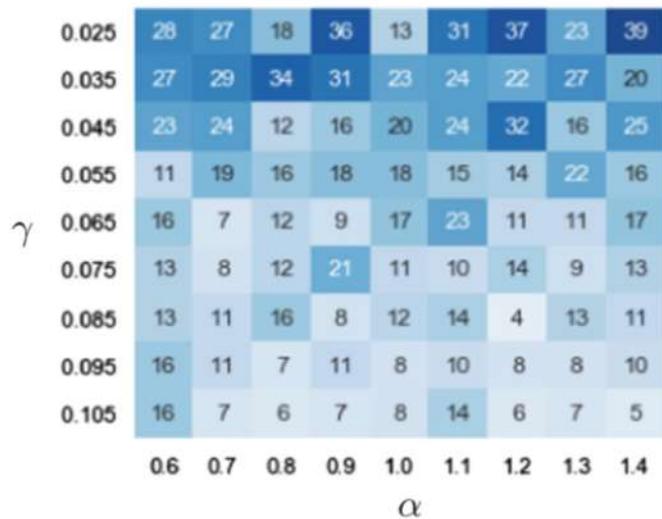


STOCHASTIC SIMULATIONS

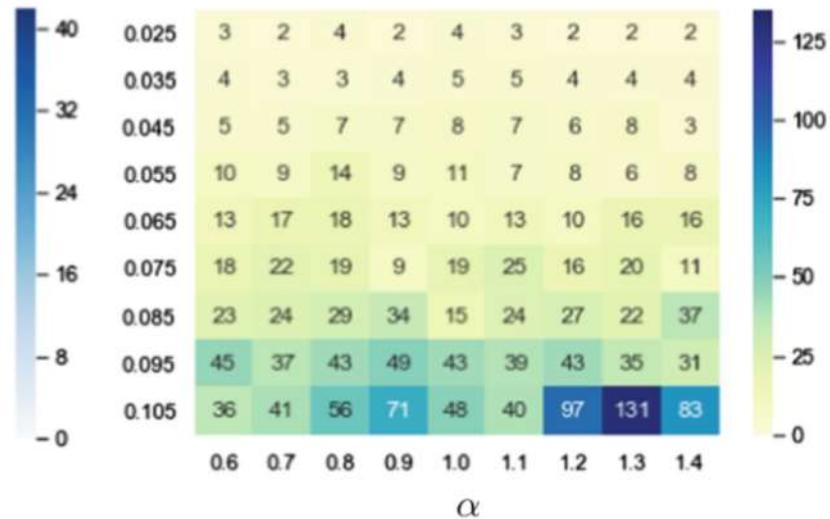


STOCHASTIC SIMULATIONS

Mean first branching age



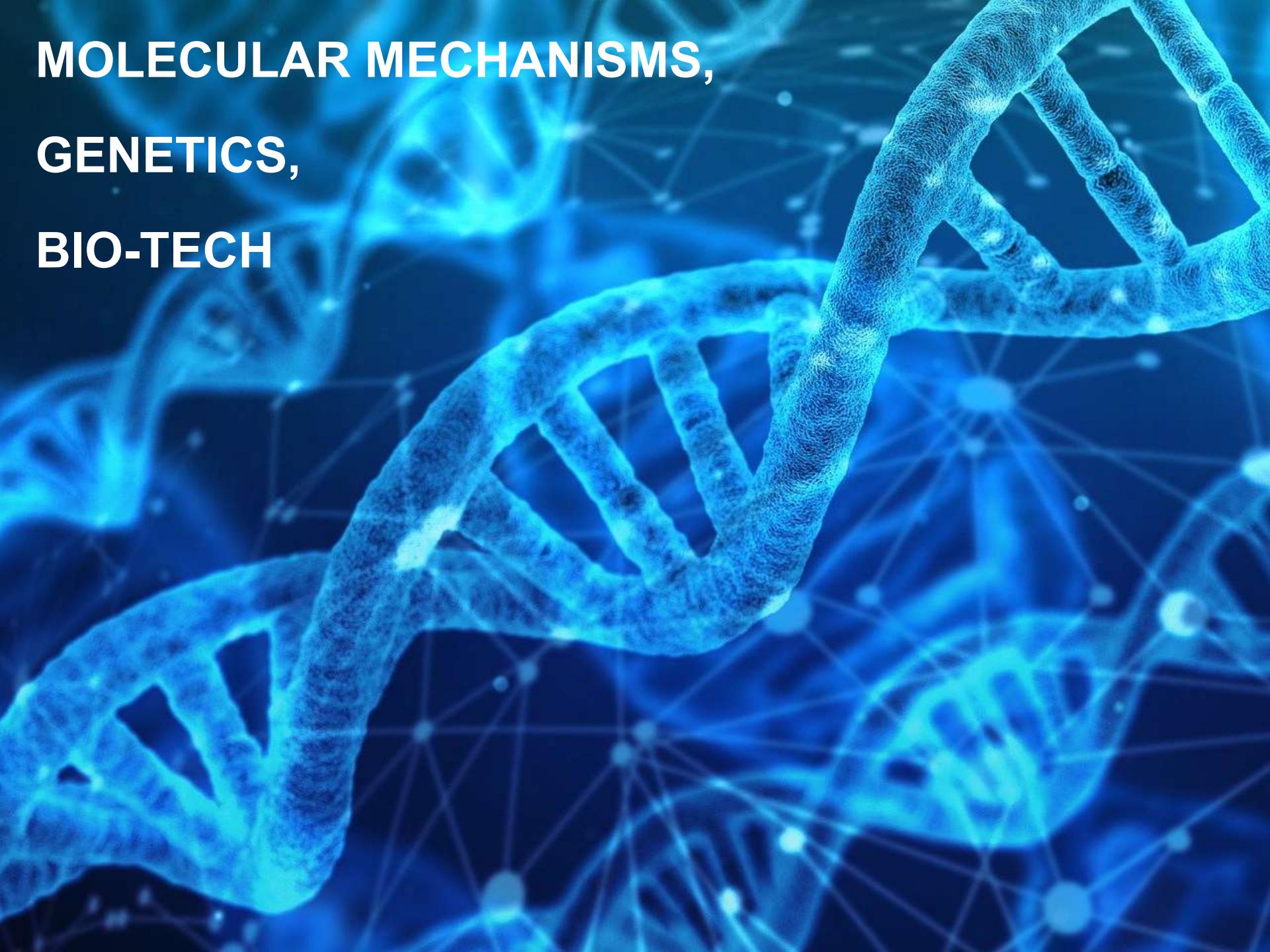
Mean number of branches at 40 years

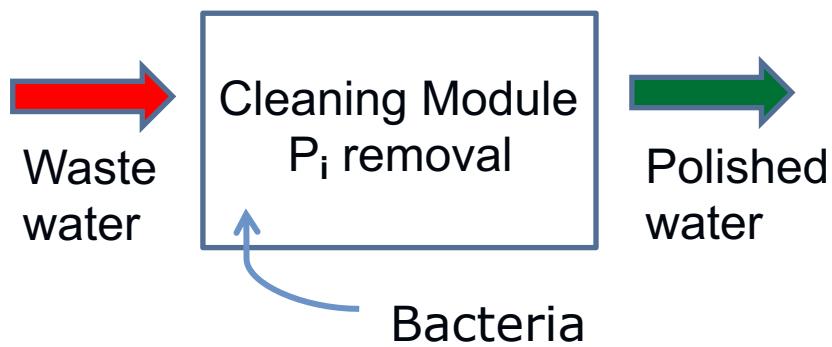


MOLECULAR MECHANISMS,

GENETICS,

BIO-TECH



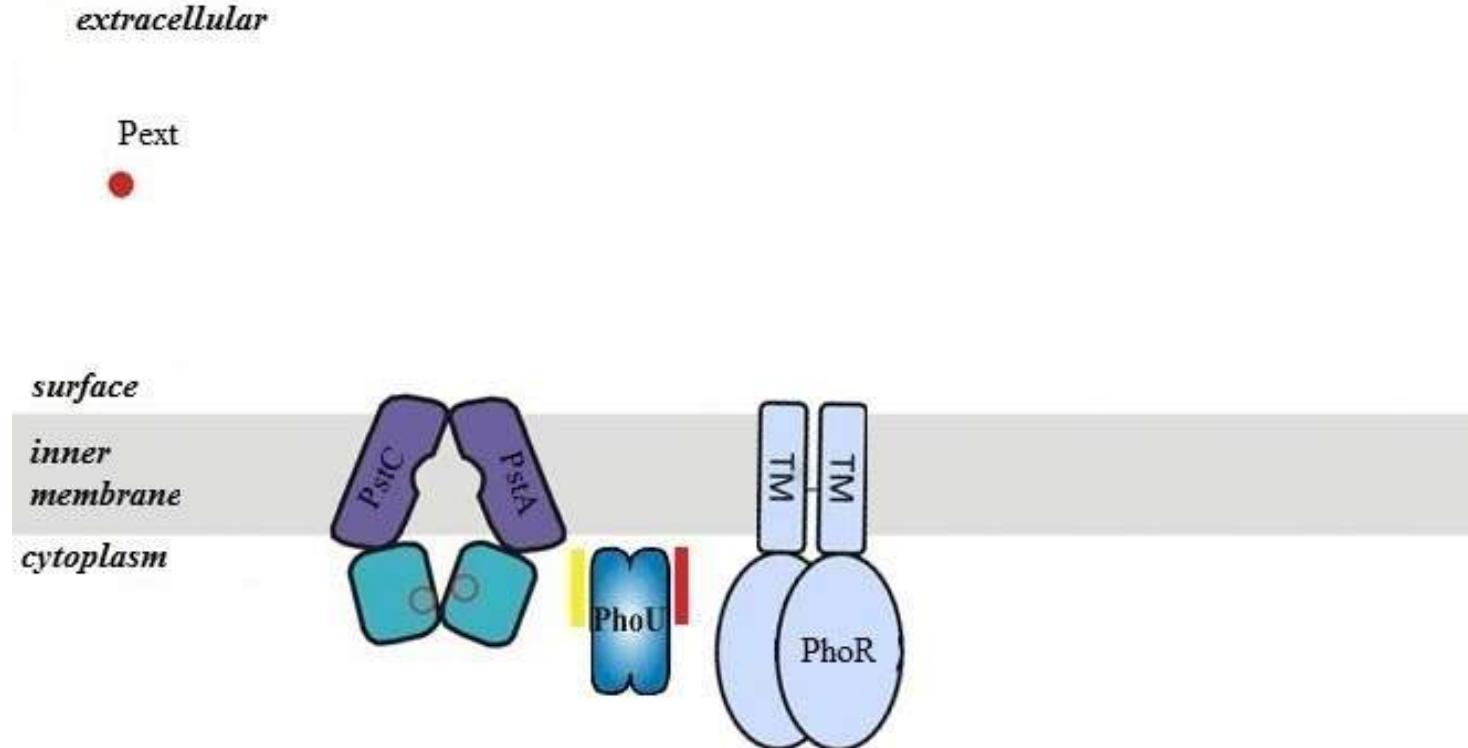


SOLUTION:
removing
inorganic
phosphate (P_i)

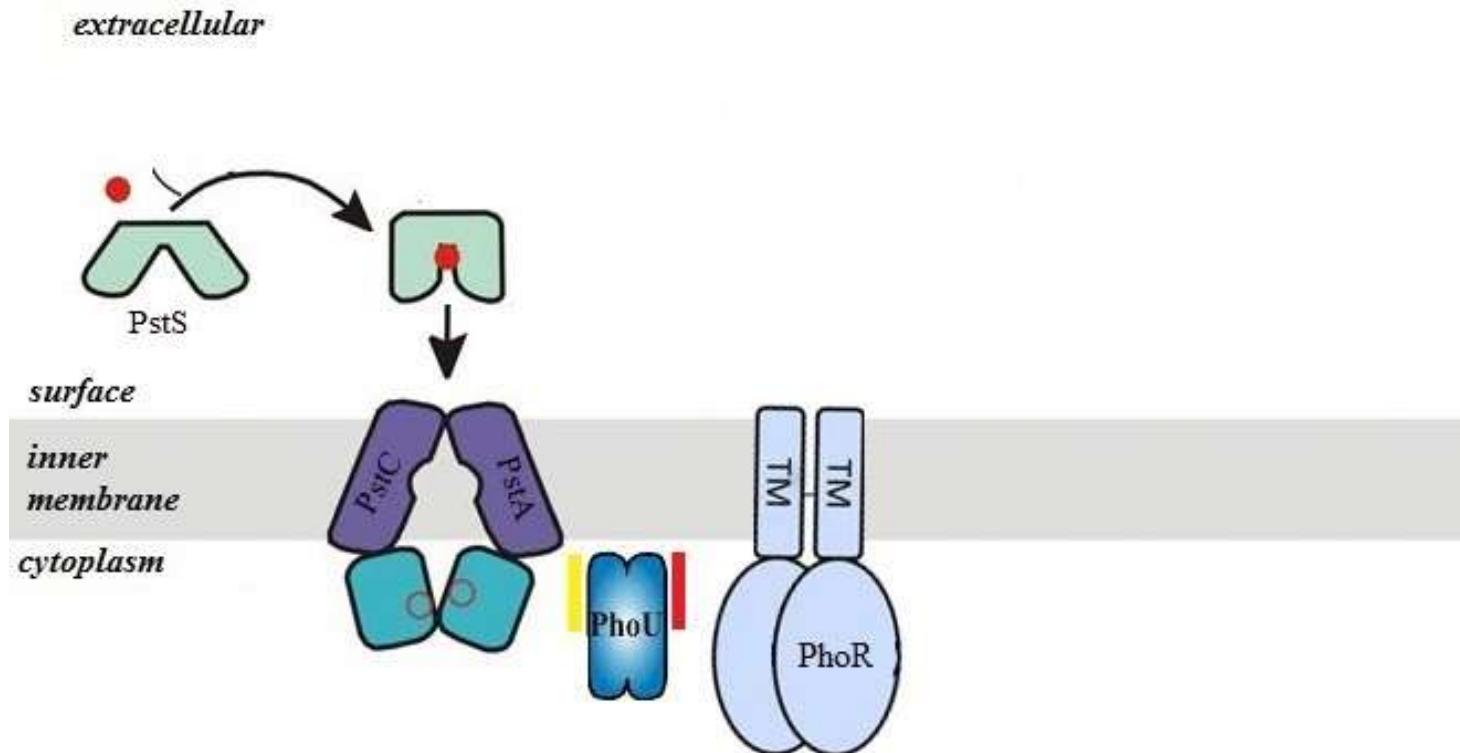
GOAL: improving
the water quality



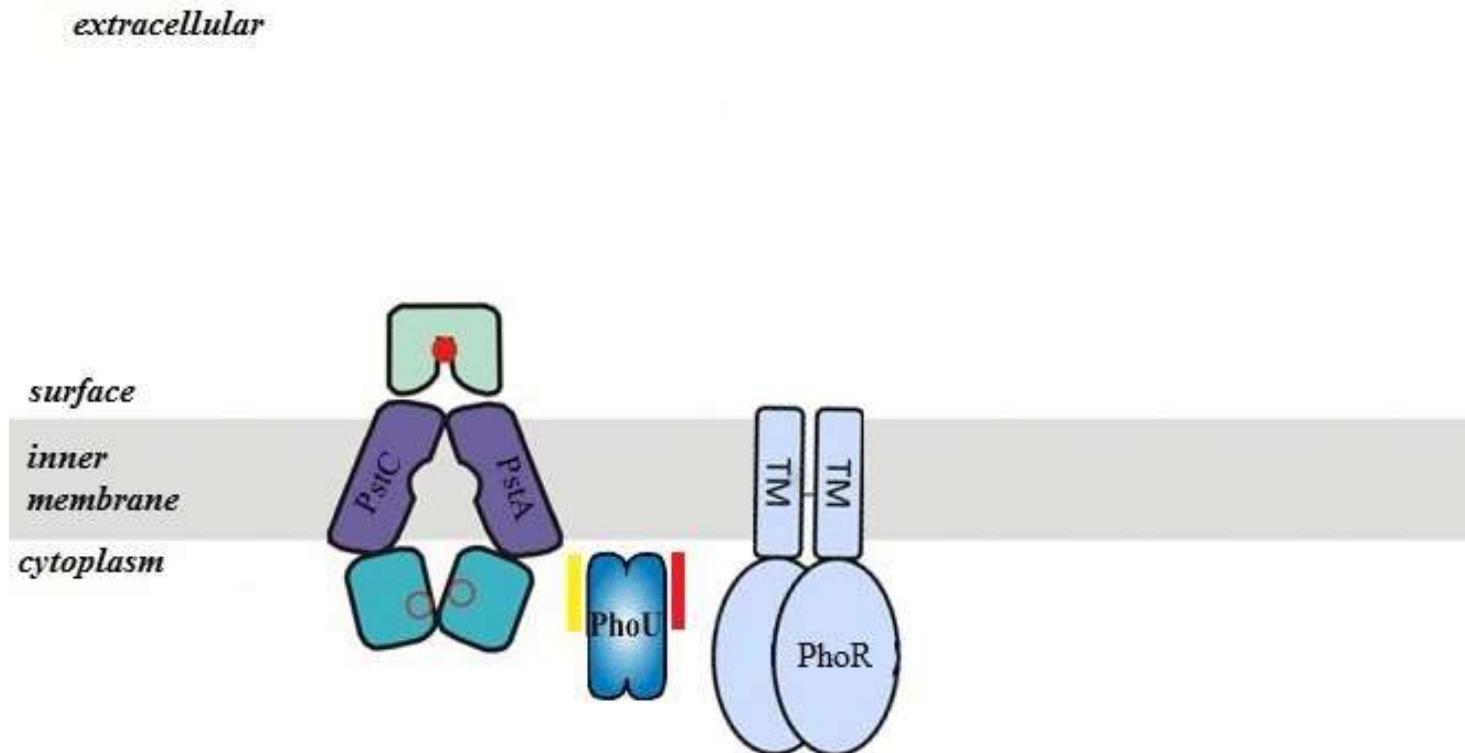
How does *E. coli* sense the environmental stimuli?



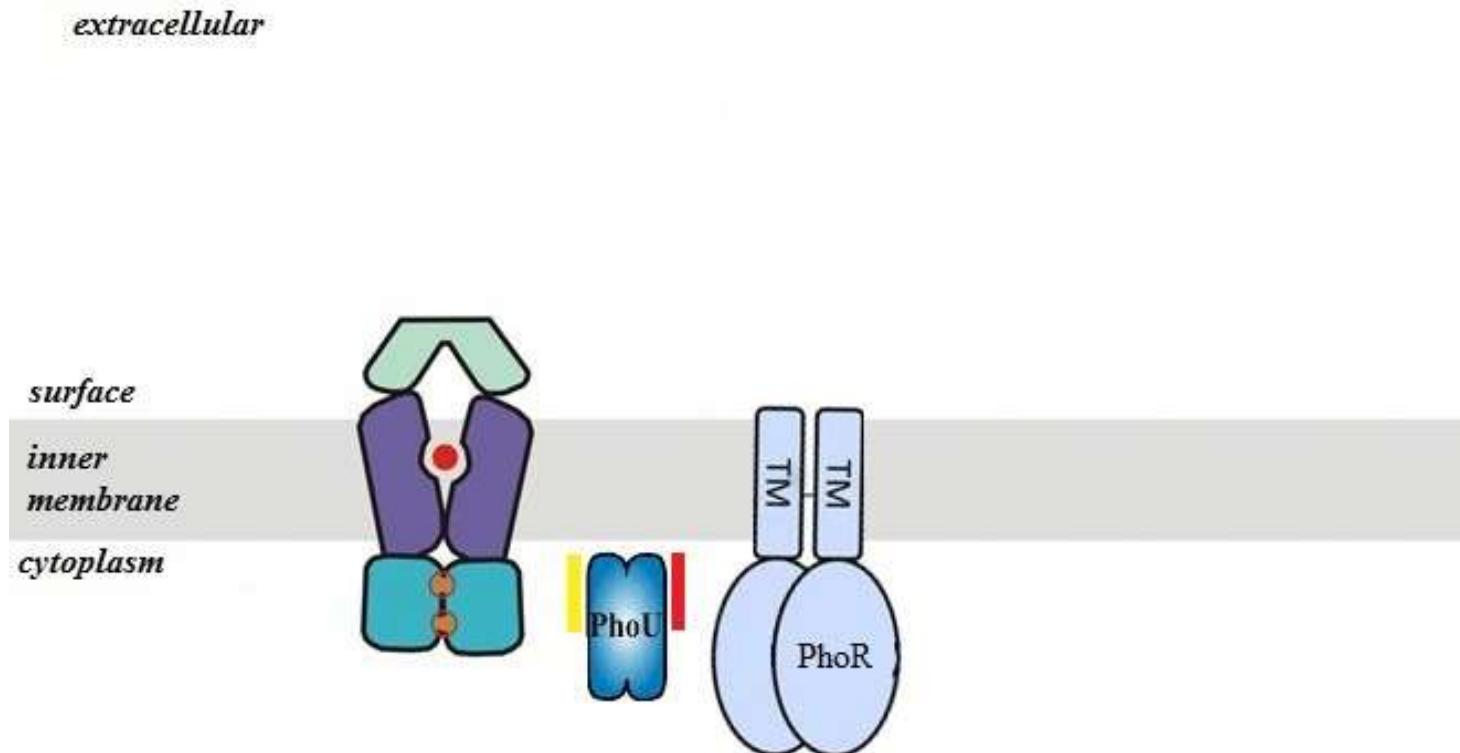
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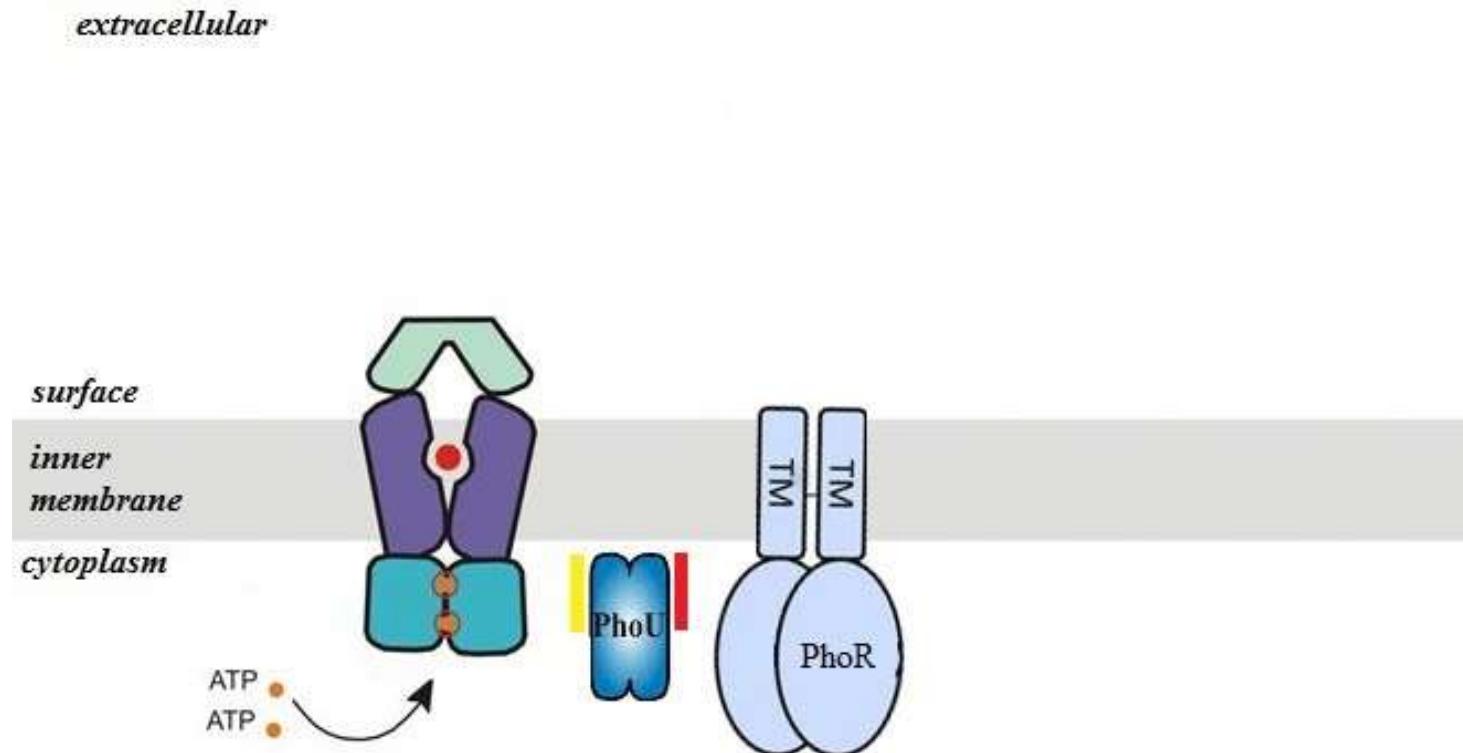
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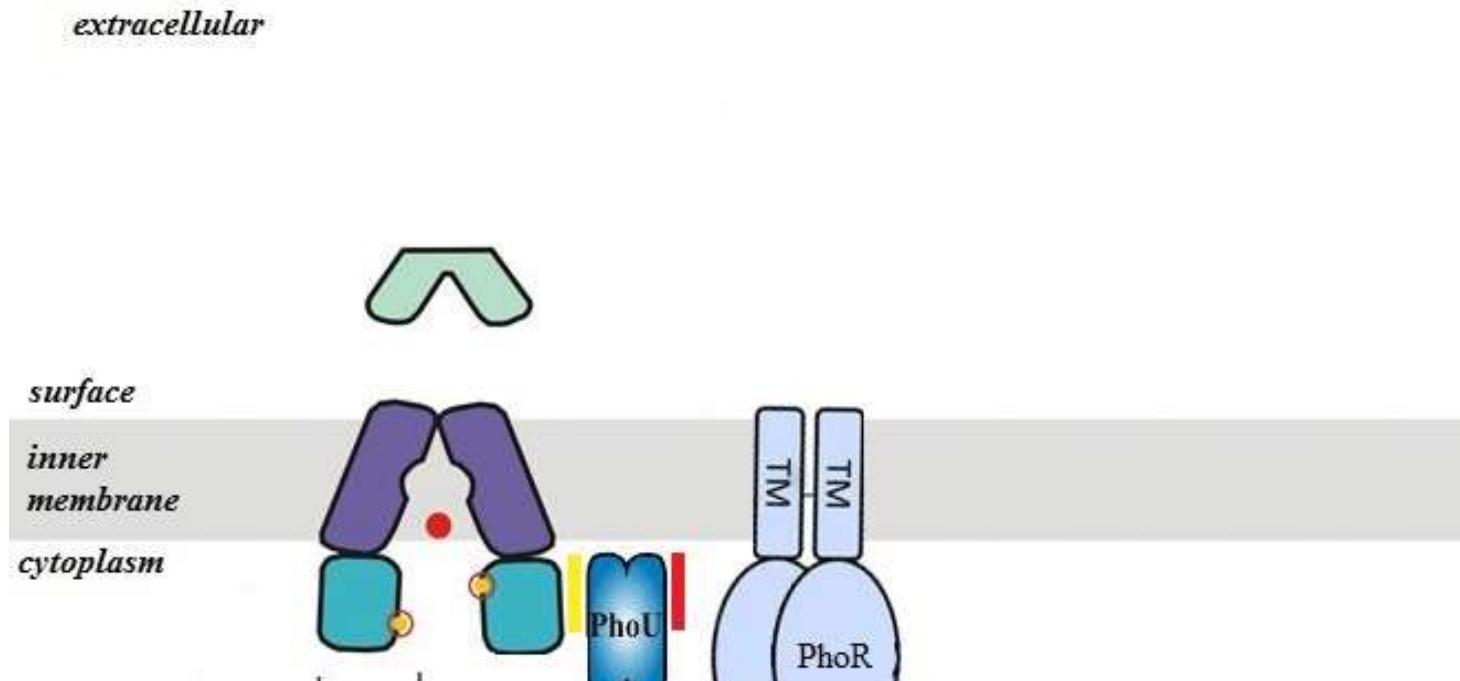
How does *E. coli* sense the environmental stimuli?



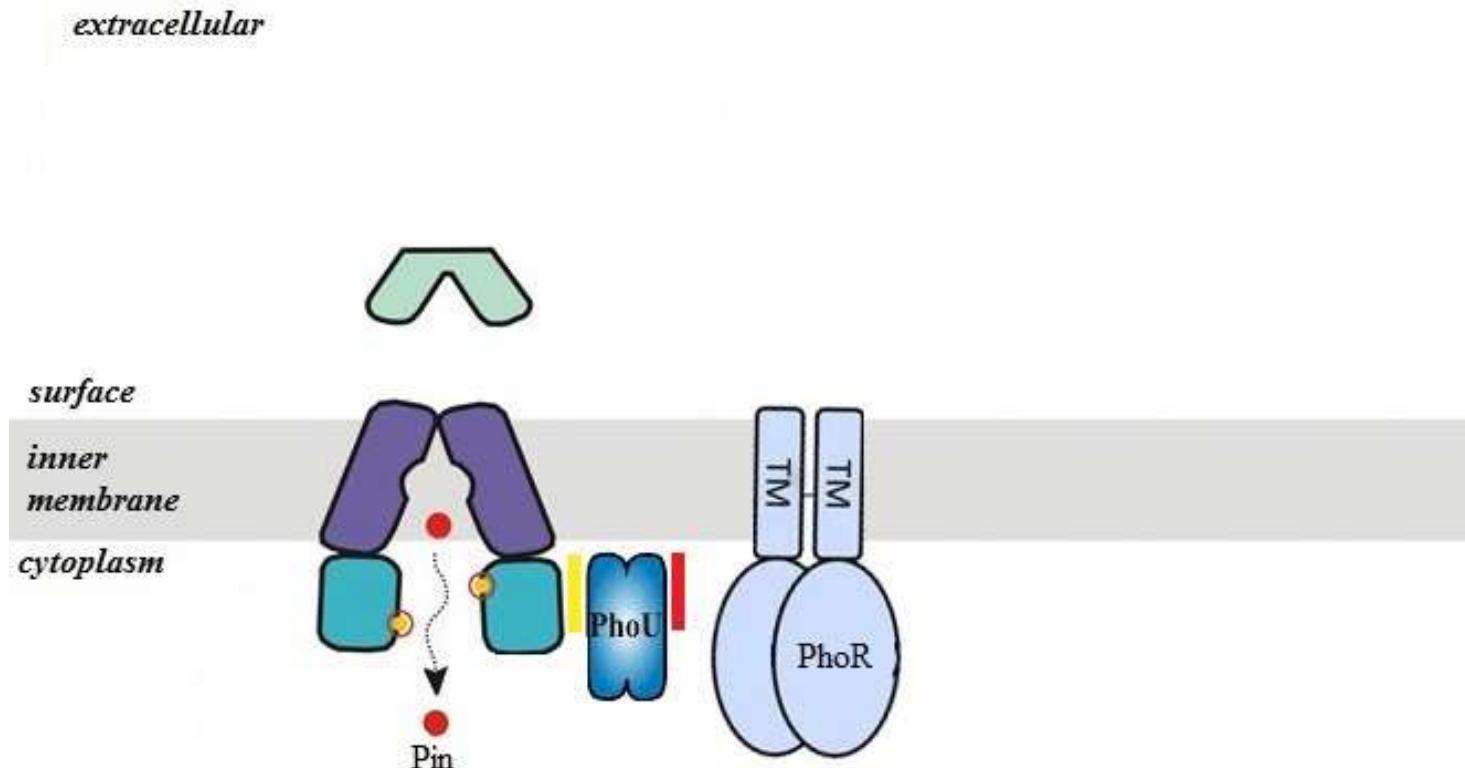
How does *E. coli* sense the environmental stimuli?



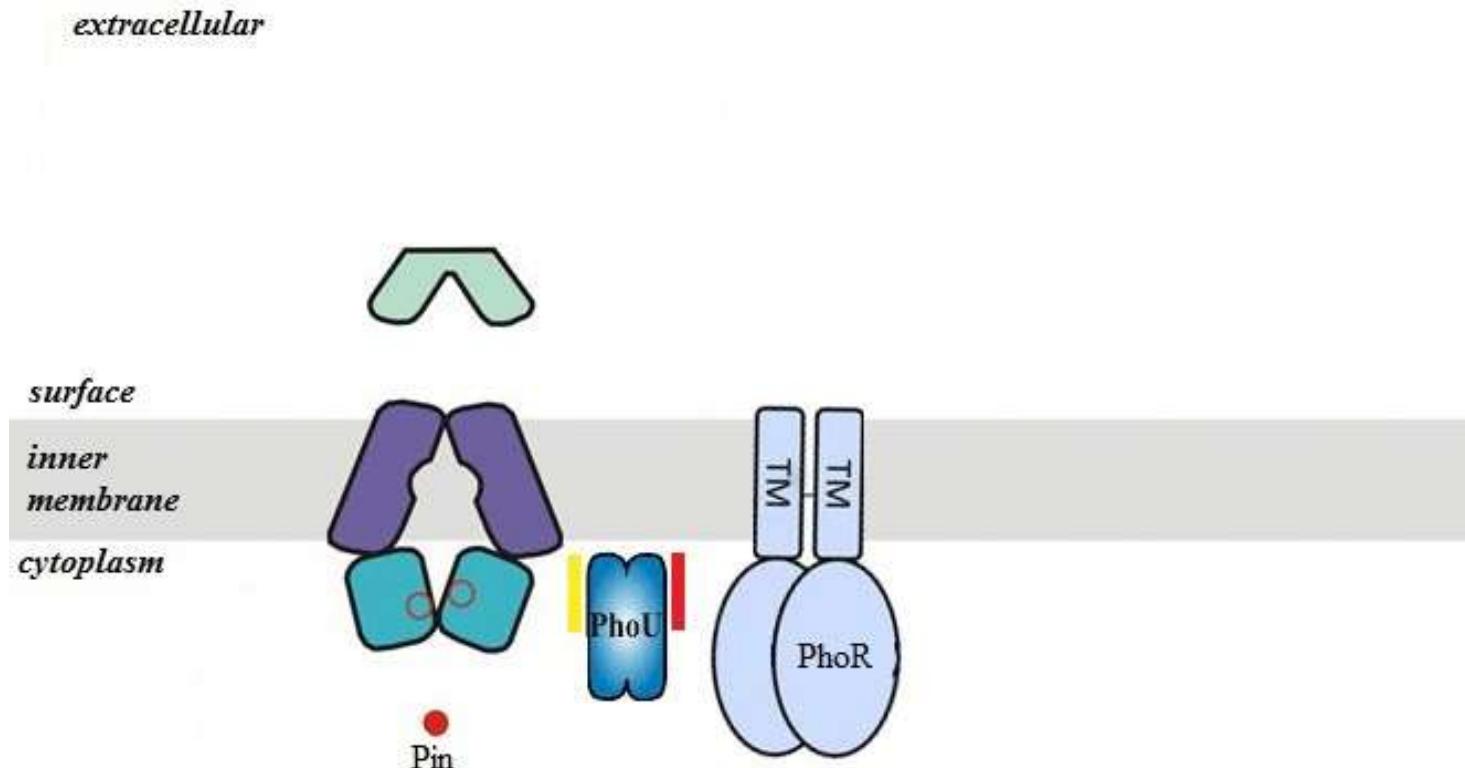
How does *E. coli* sense the environmental stimuli?



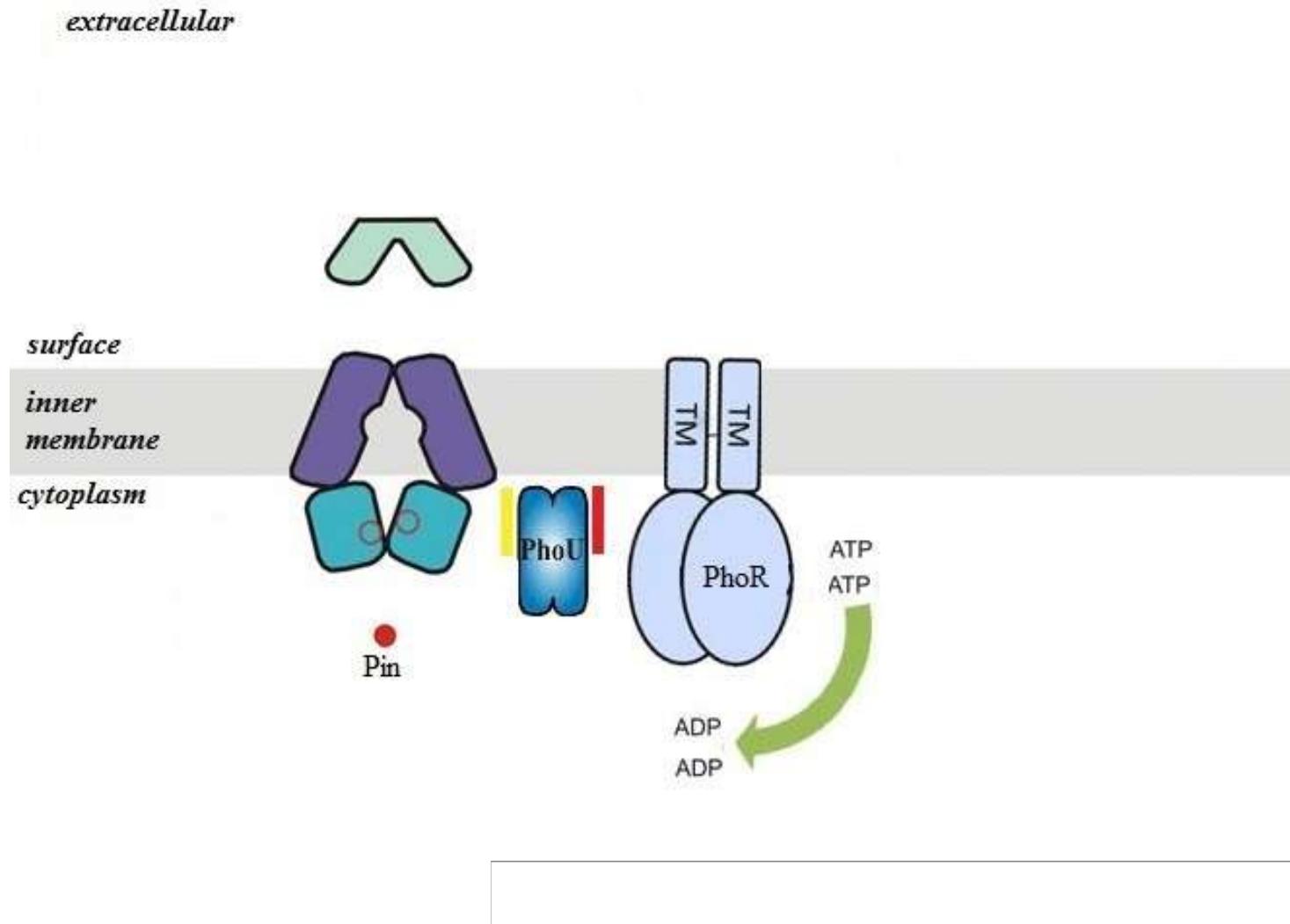
How does *E. coli* sense the environmental stimuli?



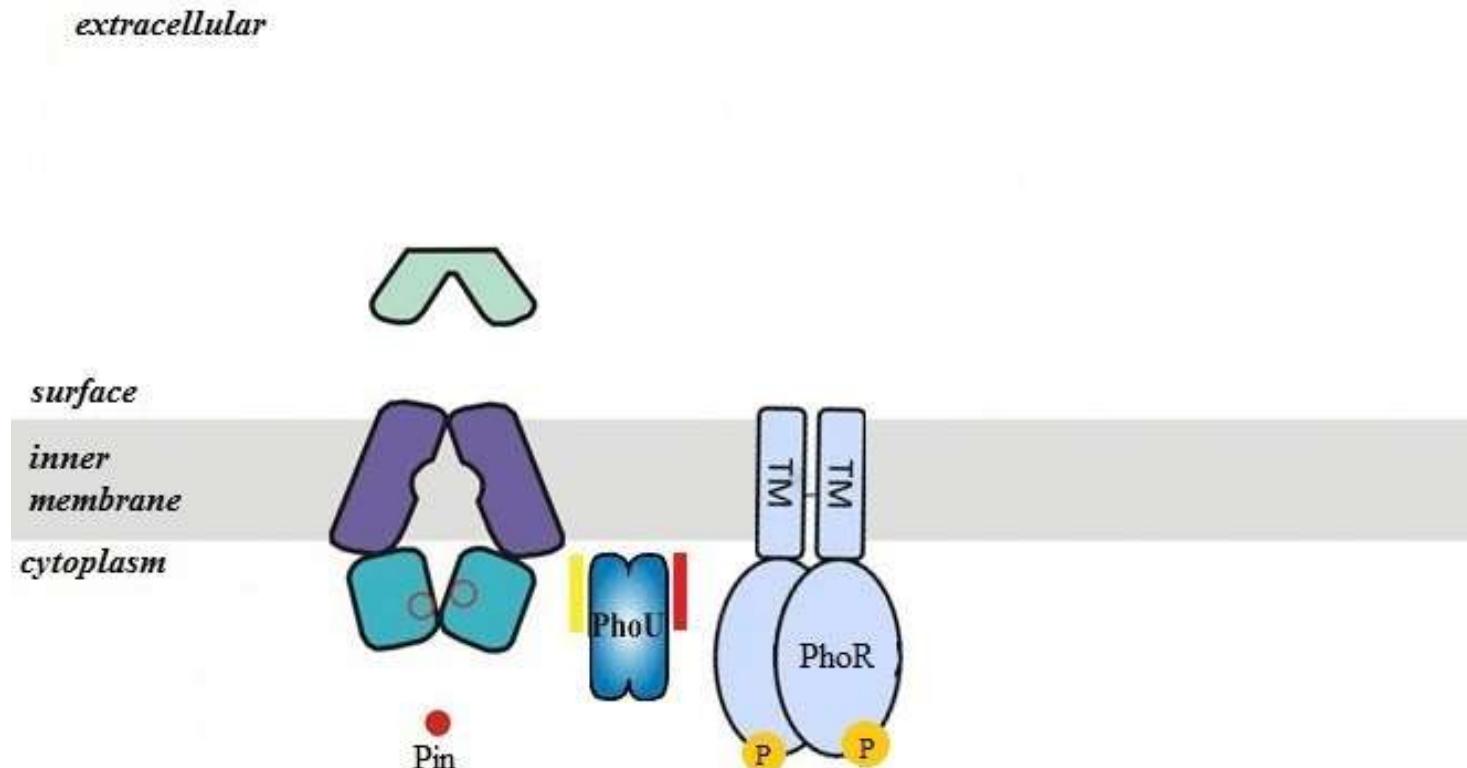
How does *E. coli* sense the environmental stimuli?



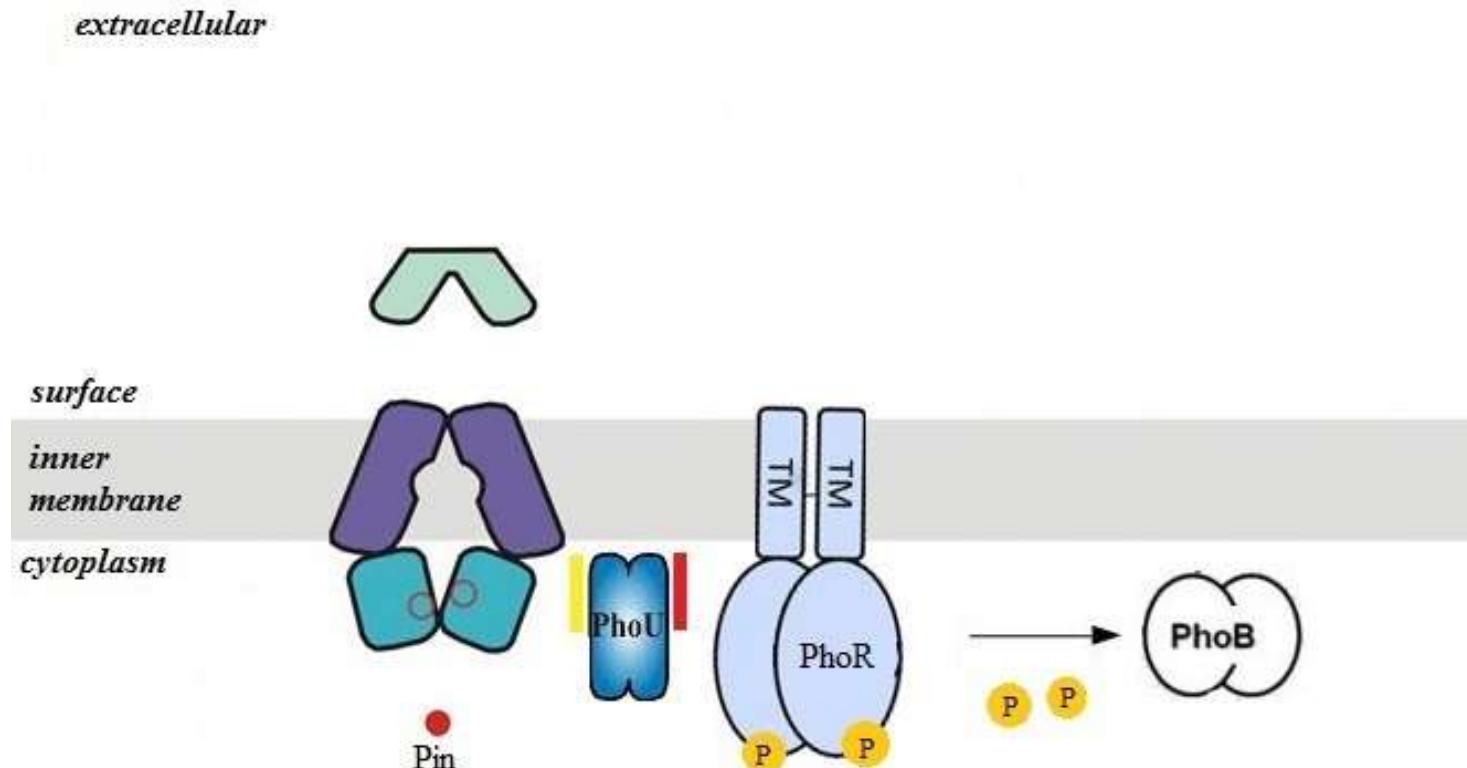
How does *E. coli* sense the environmental stimuli?



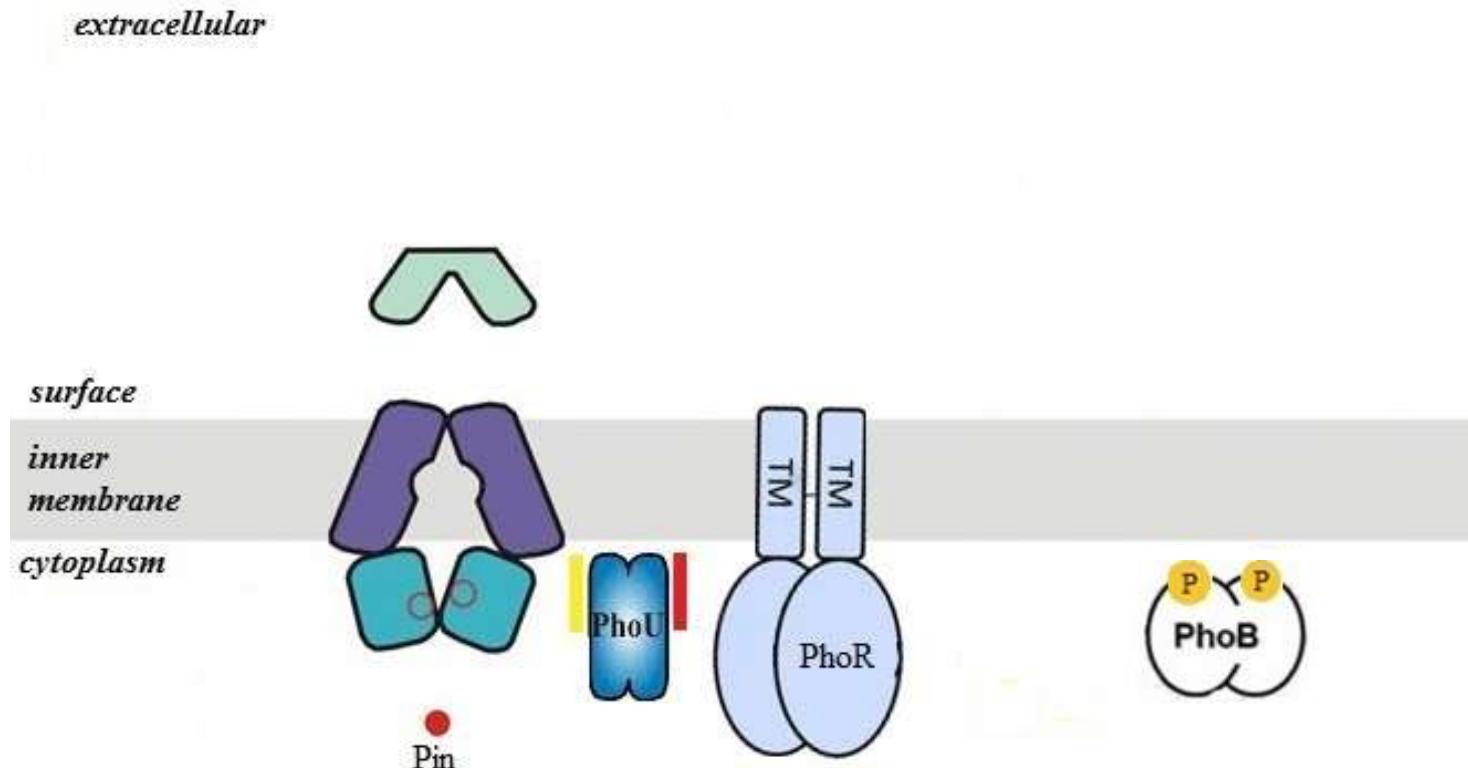
How does *E. coli* sense the environmental stimuli?



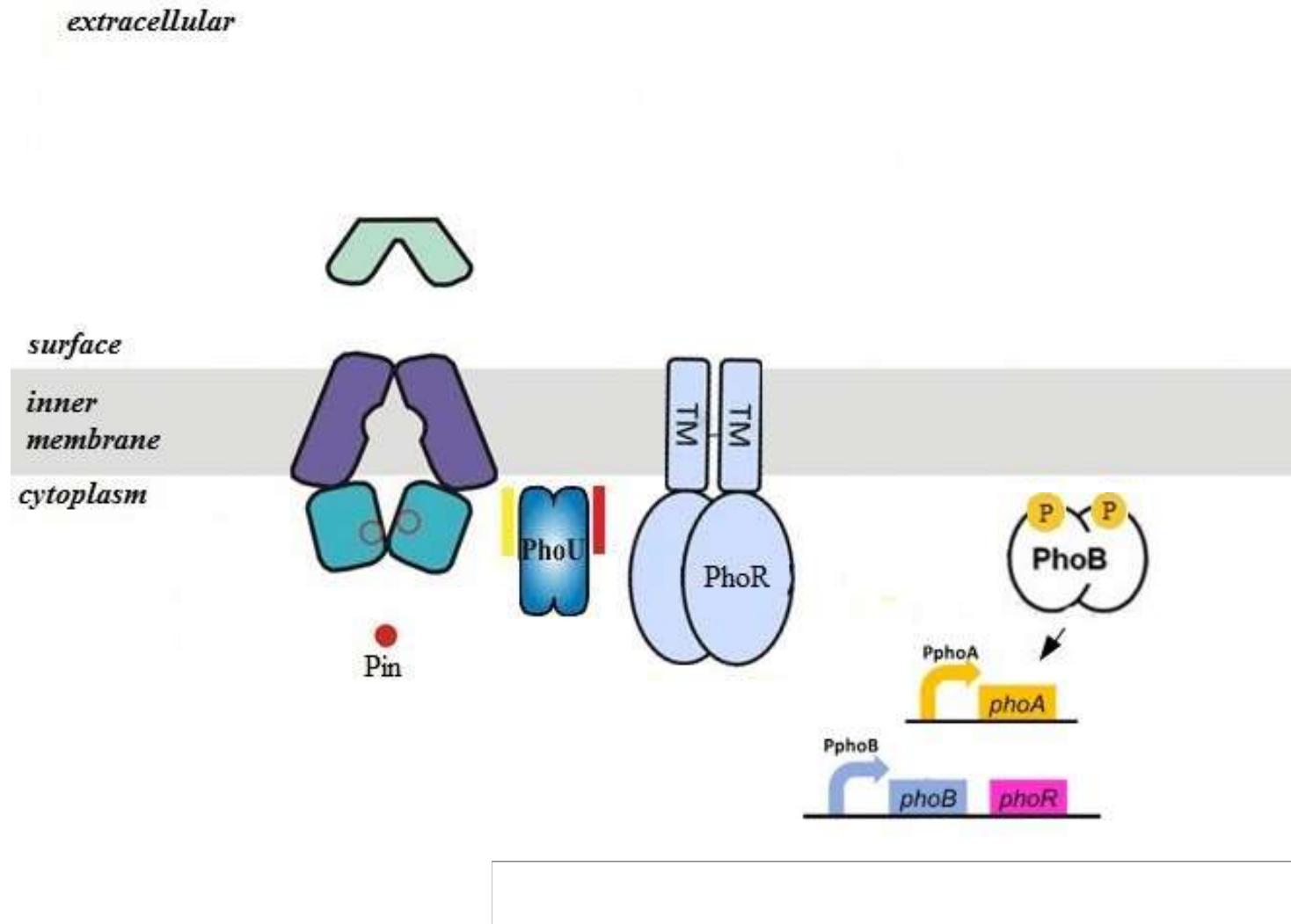
How does *E. coli* sense the environmental stimuli?



How does *E. coli* sense the environmental stimuli?



How does *E. coli* sense the environmental stimuli?



Modelling

Model ~ 29 reactions:



⋮

Modelling

Model ~ 29 reactions:



16 ODEs

$$\begin{aligned} \frac{dDiPhoR(t)}{dt} = & r_{6r}.DiPhoRp(t) - r_6.DiPhoR(t) \\ & + r_{11}.DiPhoRp-PhoB(t) + r_{21}.mRNAb(t) \\ & - r_{24}.DiPhoR(t) - r_{13}.DiPhoR(t).PhoBp(t) \\ & + r_{13r}.DiPhoR-PhoBp(t) + r_{14}.DiPhoR-PhoBp(t) \end{aligned}$$

Modelling

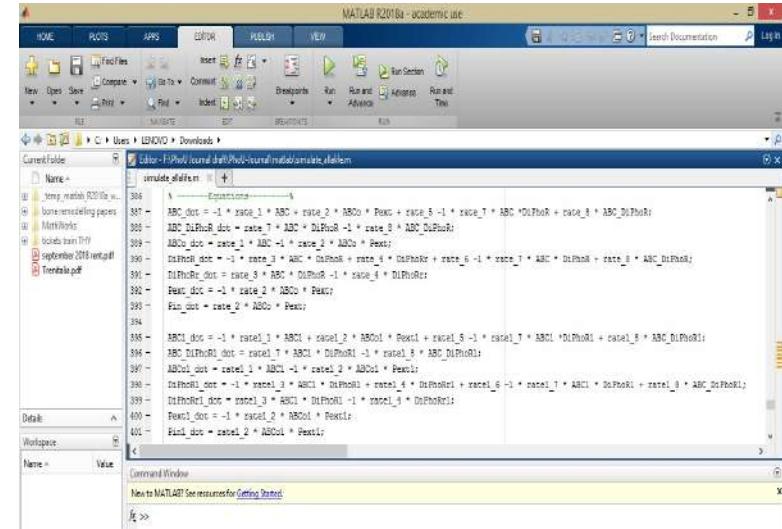
Model ~ 29 reactions:



16 ODEs

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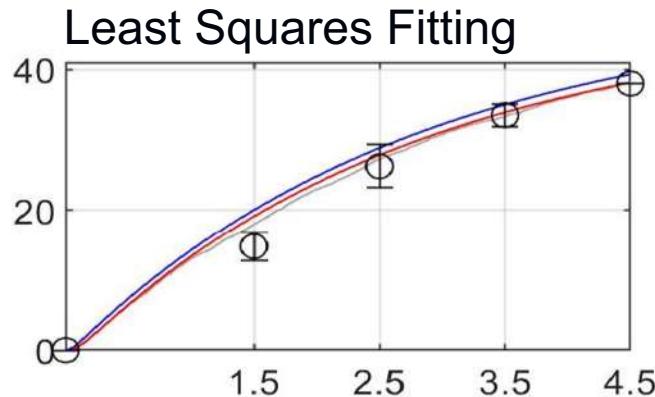
Matlab code



```
% -- Expressions -- %
387 ABC_DiPhoR_dot = rate_1 * ABC1 + rate_2 * ABC2 + Peox + rate_5 -1 * rate_7 * ABC_DiPhoR + rate_3 * ABC_DiPhoR;
388 ABC_DiPhoB_dot = rate_7 * ABC + DiPhoB -1 * rate_8 * ABC_DiPhoB;
389 ABC_DiPhoBp_dot = rate_2 * ABC -1 * rate_3 * ABC_DiPhoBp;
390 DiPhoB_dot = rate_3 * ABC + DiPhoB + rate_4 * DiPhoB + rate_6 -1 * rate_7 * ABC + DiPhoB + rate_8 * ABC_DiPhoB;
391 DiPhoR_dot = rate_9 * ABC + DiPhoR -1 * rate_4 + DiPhoR;
392 Peox_dot = rate_1 * rate_2 * ABC + Peox;
393 Peox_dot = rate_2 * ABC * Peox;
394 ABC1_dot = -1 * rate_1 * ABC1 + rate_2 * ABC2 + Peox1 + rate_5 -1 * rate_7 * ABC1_DiPhoR1 + rate_3 * ABC_DiPhoR1;
395 ABC1_DiPhoR1_dot = rate_1 * ABC1 + DiPhoR1 -1 * rate_8 * ABC_DiPhoR1;
396 ABC2_dot = rate_1 * ABC1 + rate_2 * ABC2 + Peox2;
397 DiPhoB1_dot = -1 * rate_1 * ABC1 + DiPhoB1 + rate_4 * DiPhoB1 + rate_6 -1 * rate_7 * ABC1_DiPhoR1 + rate_3 * ABC_DiPhoR1;
398 DiPhoB1_dot = rate_1 * ABC1 + DiPhoB1 -1 * rate_8 * ABC_DiPhoR1;
399 Peox1_dot = -1 * rate_2 * ABC2 + Peox1;
400 Peox1_dot = rate_2 * ABC2 * Peox1;
```

Modelling

Model ~ 29 reactions:



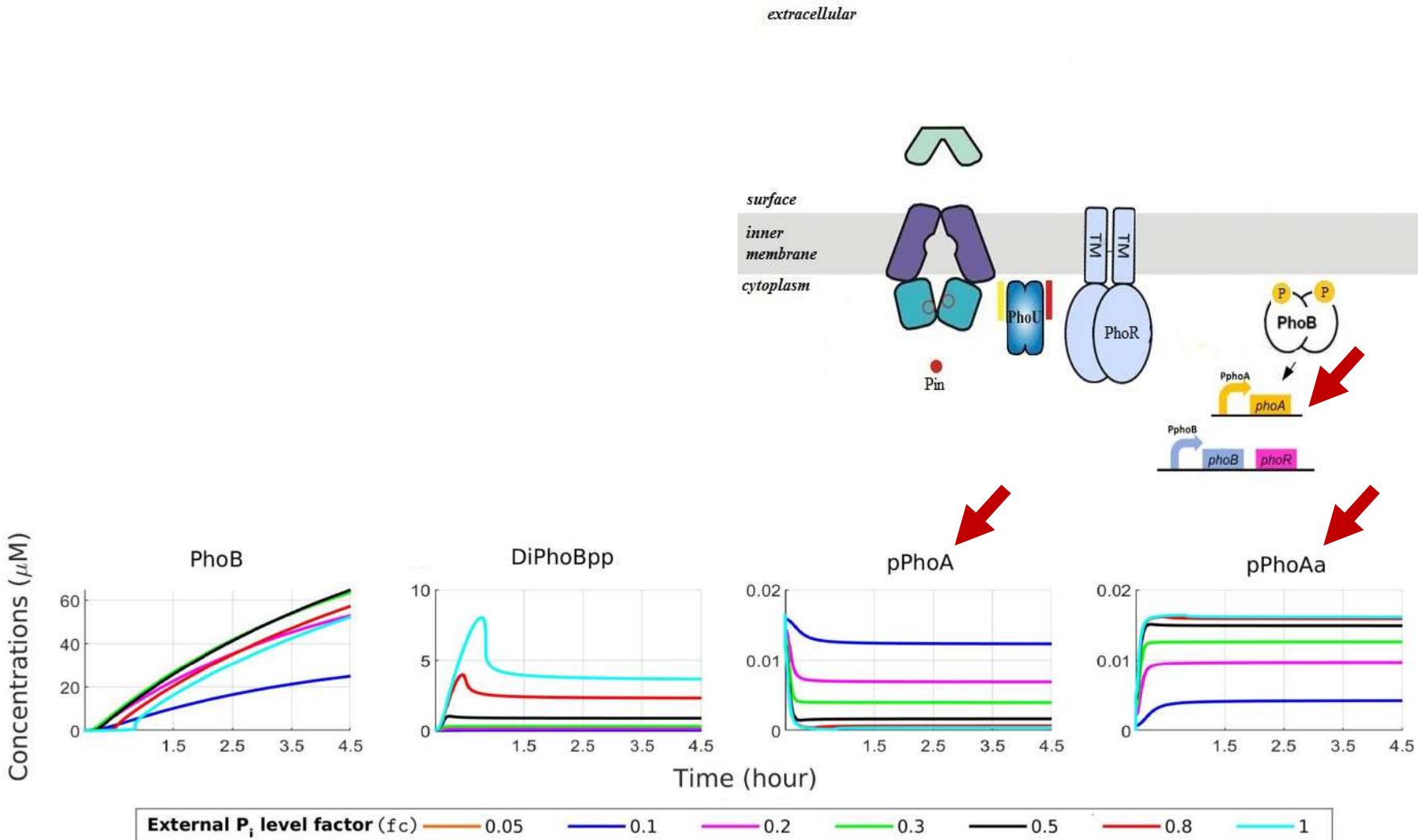
16 ODEs

$$\begin{aligned} \frac{d\text{DiPhoR}(t)}{dt} = & r_{6r}.\text{DiPhoRp}(t) - r_6.\text{DiPhoR}(t) \\ & + r_{11}.\text{DiPhoRp-PhoB}(t) + r_{21}.\text{mRNA}_B(t) \\ & - r_{24}.\text{DiPhoR}(t) - r_{13}.\text{DiPhoR}(t).\text{PhoB}_P(t) \\ & + r_{13r}.\text{DiPhoR-PhoB}_P(t) + r_{14}.\text{DiPhoR-PhoB}_P(t) \end{aligned}$$

Matlab code

```
% -- Equations -- %
308 ABC_DiPhoR_dot = rate_1 * ABC + rate_2 * Peoc + rate_3 * race_1 * ABC * DiPhoR + rate_4 * ABC * DiPhoRp;
309 ABC_DiPhoRp_dot = rate_5 * ABC * DiPhoR -1 * rate_6 * ABC * DiPhoRp;
310 ABC_Peoc_dot = rate_7 * ABC * Peoc + rate_8 * Peoc;
311 race_1_dot = -1 * rate_3 * ABC * DiPhoR + rate_4 * DiPhoRp + rate_5 -1 * rate_7 * ABC * DiPhoR + rate_8 * ABC * DiPhoRp;
312 DiPhoR_dot = rate_9 * ABC * DiPhoR -1 * rate_10 * ABC * DiPhoRp;
313 DiPhoRp_dot = rate_11 * ABC * DiPhoR + rate_12 * ABC * DiPhoRp;
314 DiPhoR1_dot = -1 * race_1 * ABC * DiPhoR1 + race_2 * ABC * DiPhoRp1;
315 DiPhoR11_dot = race_1 * ABC * DiPhoR1 -1 * race_2 * ABC * DiPhoRp1;
316 ABC_DiPhoR1_dot = race_3 * ABC * DiPhoR1 -1 * race_4 * Peoc;
317 ABC_DiPhoRp1_dot = race_5 * ABC * DiPhoR1 -1 * race_6 * ABC * DiPhoRp1;
318 DiPhoR11_dot = -1 * race_1 * ABC * DiPhoR1 + race_4 * DiPhoRp1 + race_5 -1 * race_7 * ABC * DiPhoRp1 + race_8 * ABC * DiPhoRp1;
319 DiPhoR111_dot = race_1 * ABC * DiPhoR1 -1 * race_2 * ABC * DiPhoRp1;
320 Peoc_dot = race_2 * ABC * Peoc;
321 Peoc1_dot = rate_2 * ABC * Peoc;
322 race_1_dot = -1 * race_1 * ABC * race_2 * ABC1 * race_1 * race_5 -1 * race_7 * ABC1 * DiPhoR1 + race_8 * ABC * DiPhoRp1;
323 ABC1_DiPhoR_dot = race_1 * ABC1 * DiPhoR1 -1 * race_8 * ABC * DiPhoRp1;
324 ABC1_DiPhoRp_dot = race_1 * ABC1 * DiPhoR1 -1 * race_2 * ABC * Peoc;
325 ABC1_Peoc_dot = race_1 * ABC1 * DiPhoR1 -1 * race_2 * ABC * Peoc;
326 DiPhoR11_dot = -1 * race_1 * ABC1 * DiPhoR1 + race_4 * DiPhoRp1 + race_5 -1 * race_7 * ABC1 * DiPhoRp1 + race_8 * ABC * DiPhoRp1;
327 DiPhoR111_dot = race_1 * ABC1 * DiPhoR1 -1 * race_2 * ABC1 * DiPhoRp1;
328 Peoc1_dot = -1 * race_2 * ABC1 * Peoc;
329 Peoc1_dot = race_2 * ABC1 * Peoc;
```

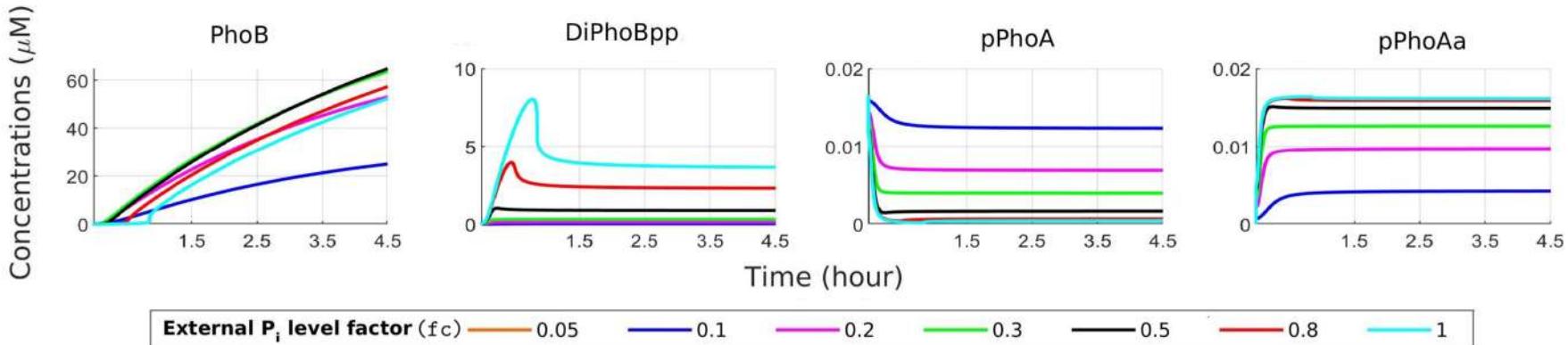
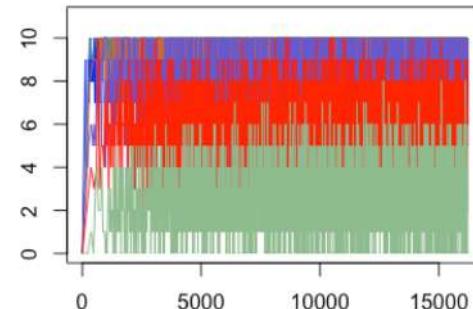
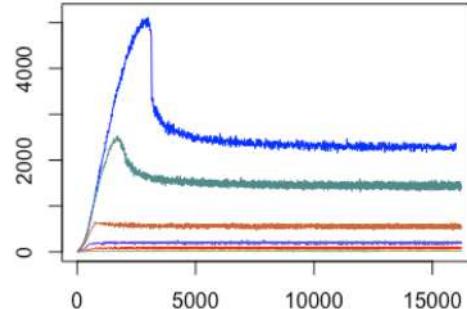
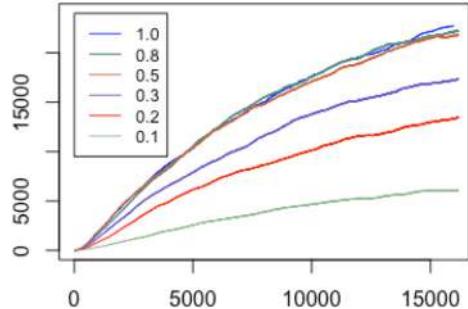
Simulation



Uluşeker et al., A Dynamic Model of the Phosphate Response System with Synthetic Promoters in *E. coli*. ECAL 2017.

Uluşeker et al. Dynamic mechanisms of phosphate response with synthetic promoters in *Escherichia coli*, *Scientific Reports*, 2019.

Simulation



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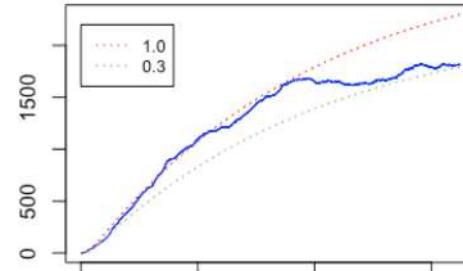
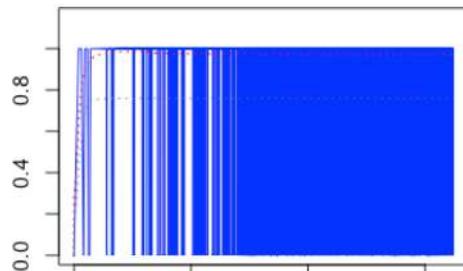
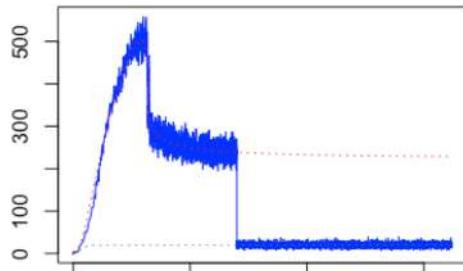
Information Flow

reactions

```

r01 : DiPhoR      -> DiPhoRp
r02 : DiPhoRp     -> DiPhoR
r03 : DiPhoRp     -> DiPhoRpp
r04 : DiPhoRpp    -> DiPhoRp
r05 : DiPhoRpp + PhoB -> DiPhoRpp_Phob
r06 : DiPhoRpp_Phob -> DiPhoRpp + PhoB
r07 : DiPhoRpp_Phob -> DiPhoRp + PhoBp
r08 : DiPhoRp + PhoB -> DiPhoRp_Phob
r09 : DiPhoRp_Phob -> DiPhoRp + PhoB
r10 : DiPhoRp_Phob -> DiPhoR + PhoBp
r11 : PhoBp + PhoBp -> DiPhoBpp
r12 : DiPhoBpp    -> PhoBp + PhoBp
r13 : DiPhoR + PhoBp -> DiPhoR_Phobp
r14 : DiPhoR_Phobp -> DiPhoR + PhoBp
r15 : DiPhoR_Phobp -> DiPhoR + PhoB
r16 : DiPhoBpp + pPhoA -> pPhoAa
r17 : pPhoAa       -> DiPhoBpp + pPhoA
r18 : DiPhoBpp + pPhoB -> pPhoBa
r19 : pPhoBa       -> DiPhoBpp + pPhoB
r20 : pPhoAa       -> pPhoAa + mRNAa
r21 : mRNAa        -> mRNAa + PhoA
r22 : pPhoBa       -> pPhoBa + mRNAb
r23 : mRNAb        -> mRNAb + PhoB
r24 : mRNAb        -> mRNAb + DiPhoR
r25 : PhoA          ->
r26 : PhoB          ->
r27 : DiPhoR        ->
r28 : mRNAa         ->
r29 : mRNAb         ->

```



extracellular

