Modelling respiro-fermentative dynamics of *Saccharomyces cerevisiae* batch culture to understand the evolution of life-history strategies

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Ecole de printemps de la chaire MMB

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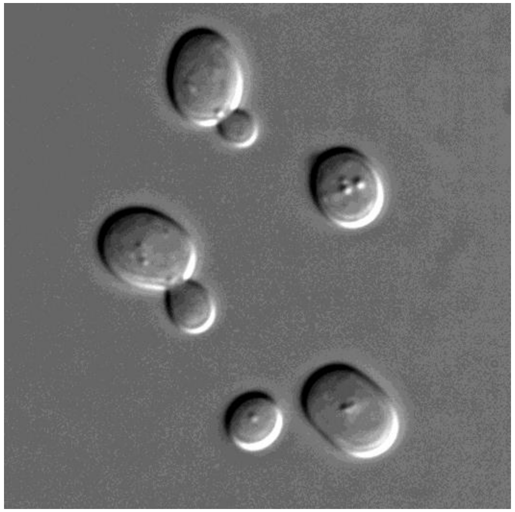
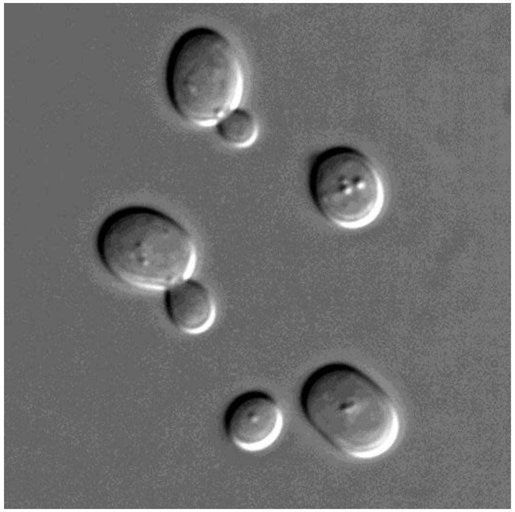
Saccharomyces cerevisiae



http://fr.wikipedia.org/wiki/Saccharomyces

Saccharomyces cerevisiae



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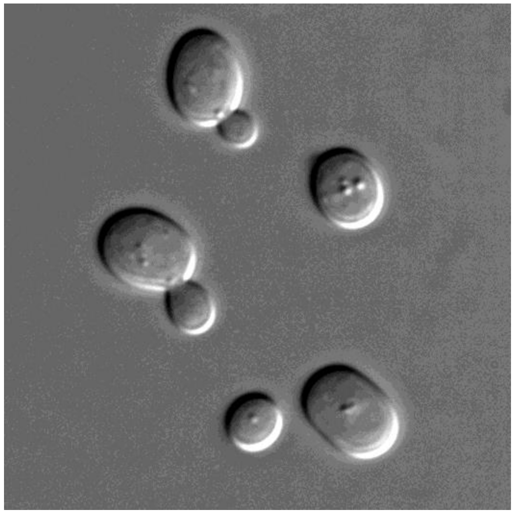

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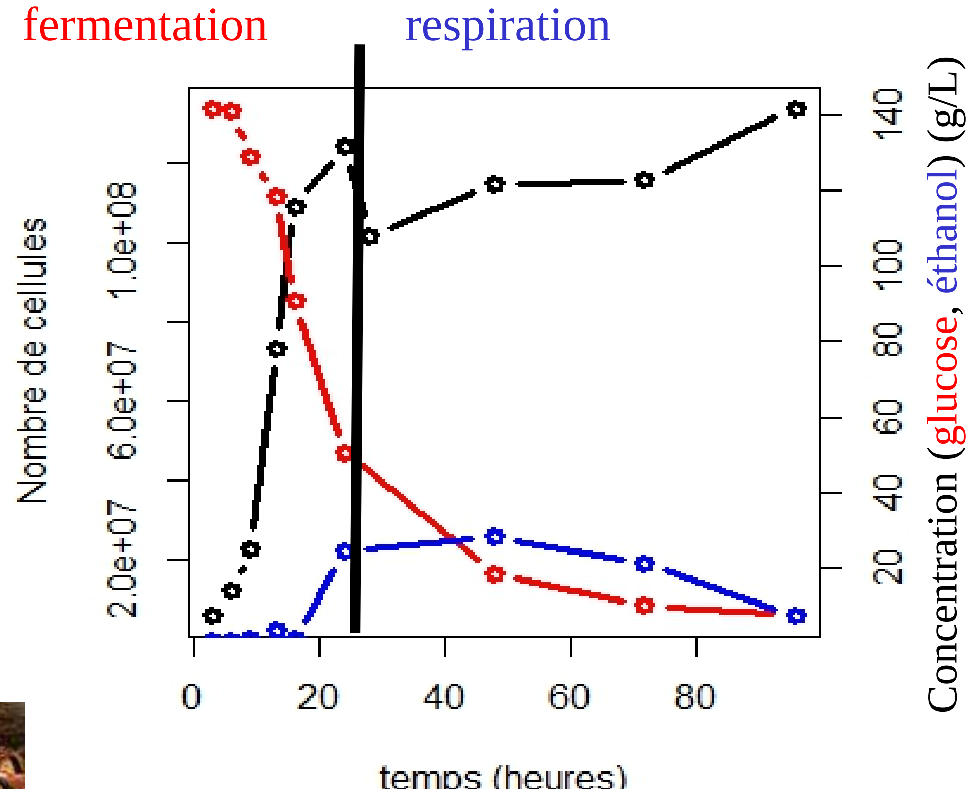


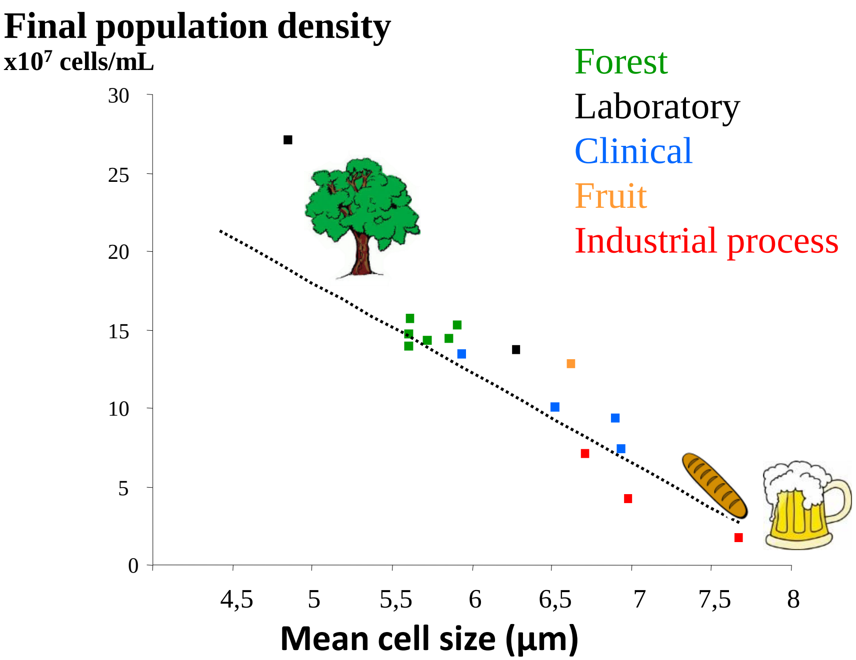
<u>Fermentation :</u>

Glucose $\longrightarrow$ CO_2 + Ethanol + 2 ATP

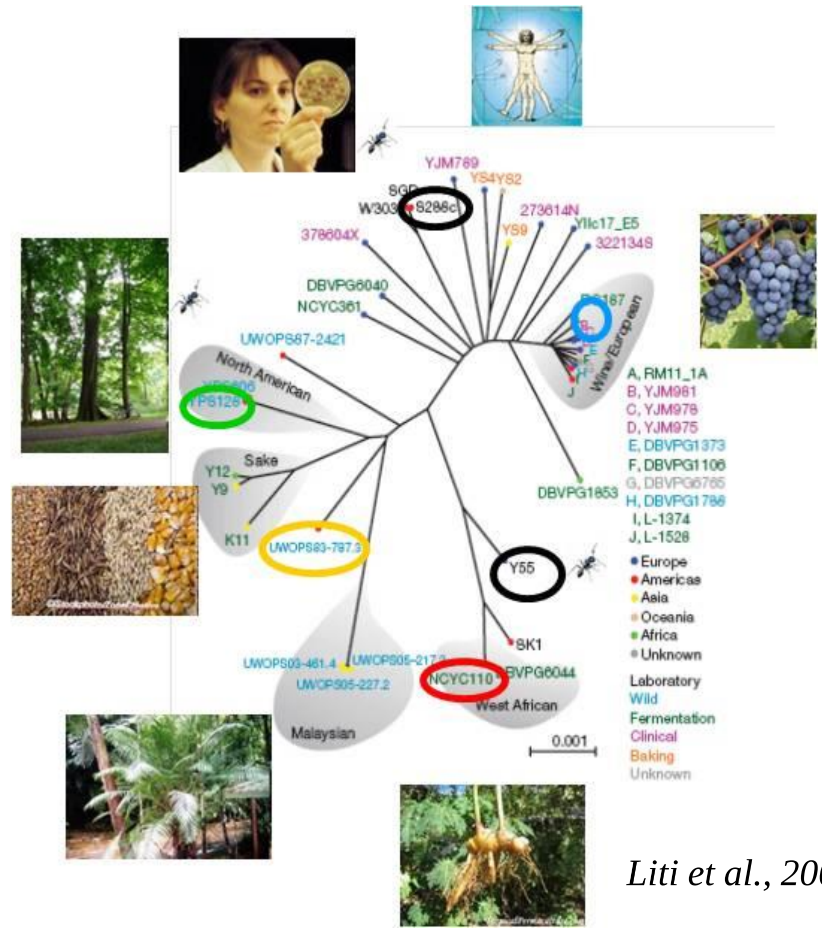
<u>Respiration:</u>

Ethanol + O_2 $\longrightarrow$ CO_2 + 32 ATP

Adaptation *in natura*



Spor et al., 2009



Liti et al., 2009

Adaptation *in vitro*

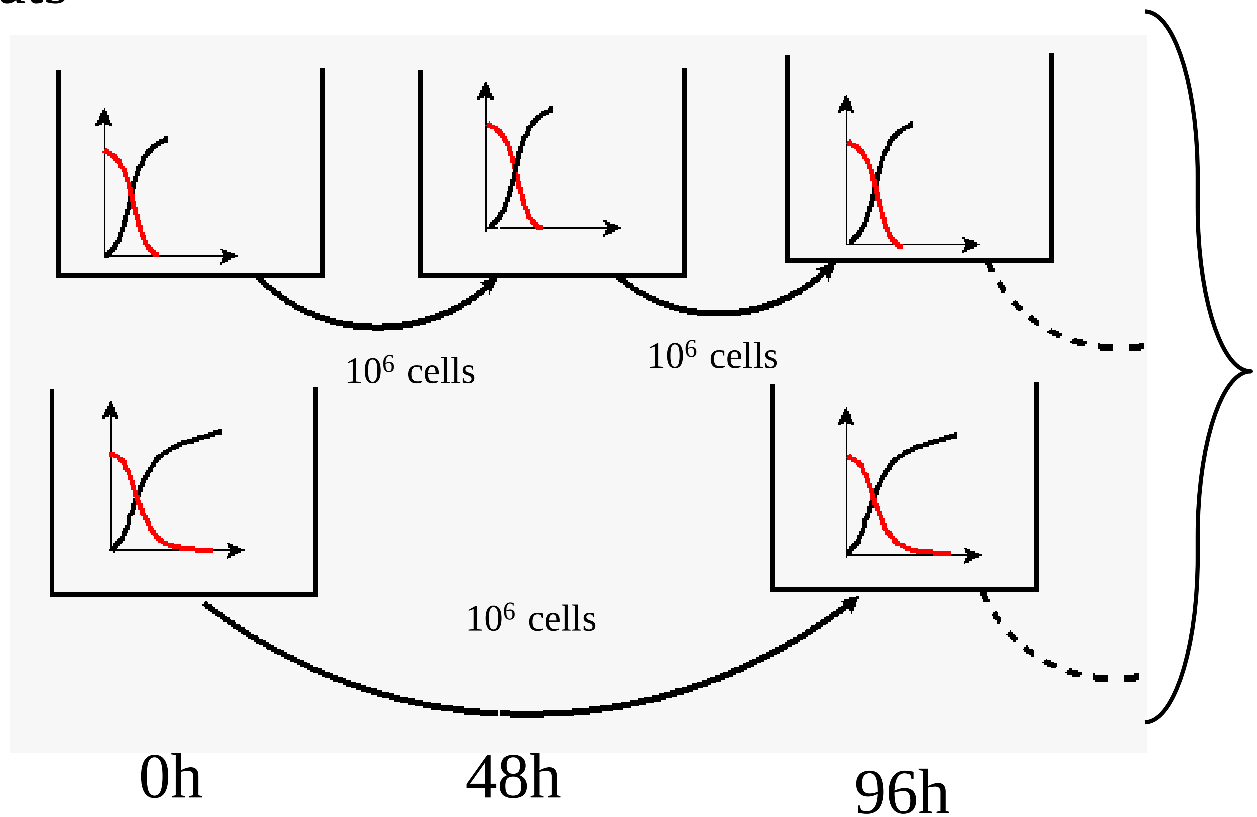
Experimental evolution: *(Spor et al., 2014)*

6 strains from different environment

4 environments

3 replicats

72 « evolved » strains



x2

Glucose:
10 or 150g/L

Traits convergency

<u>Experimental evolution:</u> *(Spor et al., 2014)*

6 strains from different environment

4 environments

3 replicats

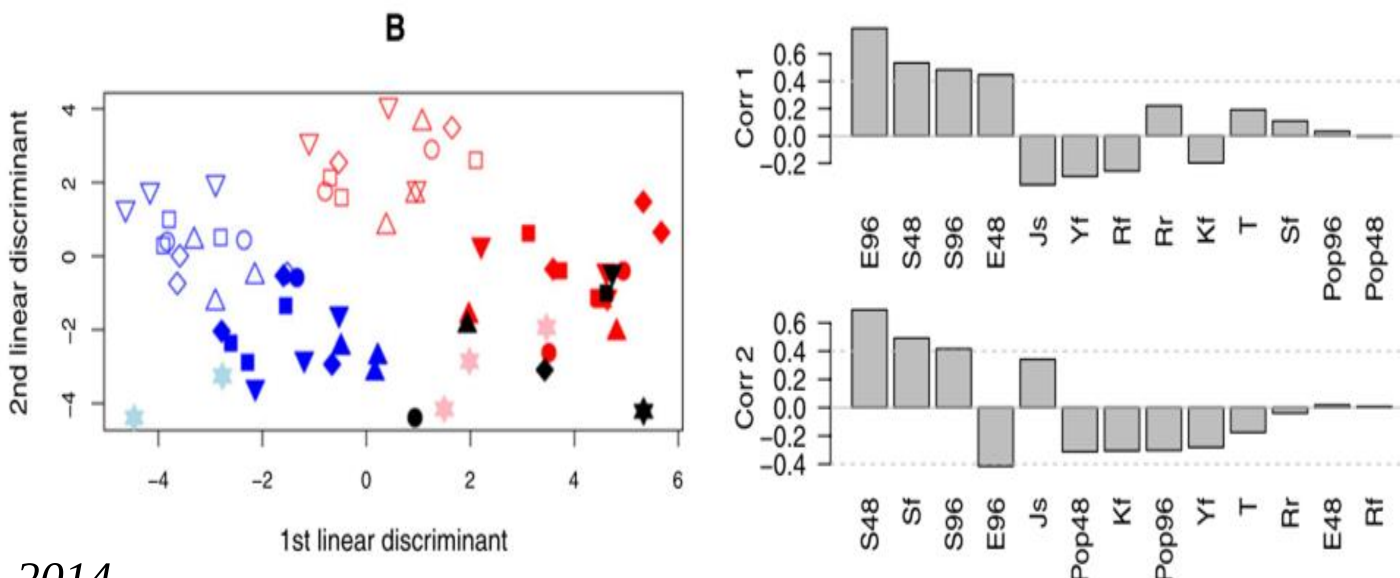
72 « evolved » strains

1%-96h

15%-96h

1%-48h

15%-48h



Spor et al., 2014

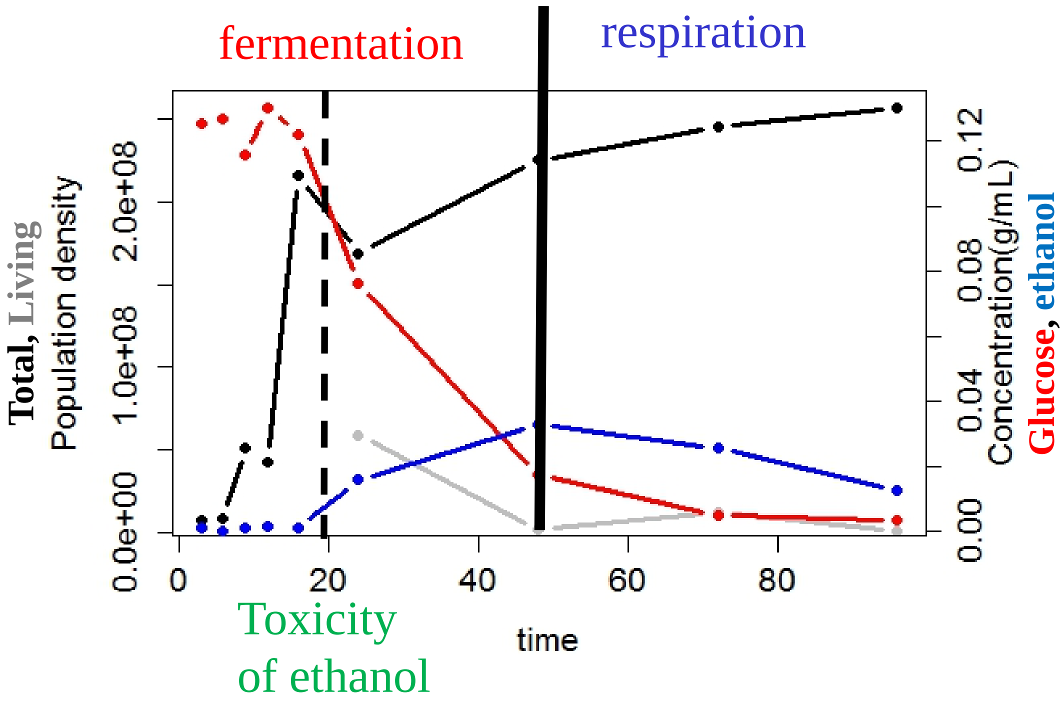
What are the traits which determine the outcome of the competition in a seasonal environment?

Traits that influence fitness.

Characterization of mutant frequencies dynamics in a resident population.

Determinants of the mutant frequencies dynamics.

Batch culture model



$$\frac{dG}{dt} = -\sum_i J_{fi} \frac{G}{K_f + G} N_i$$

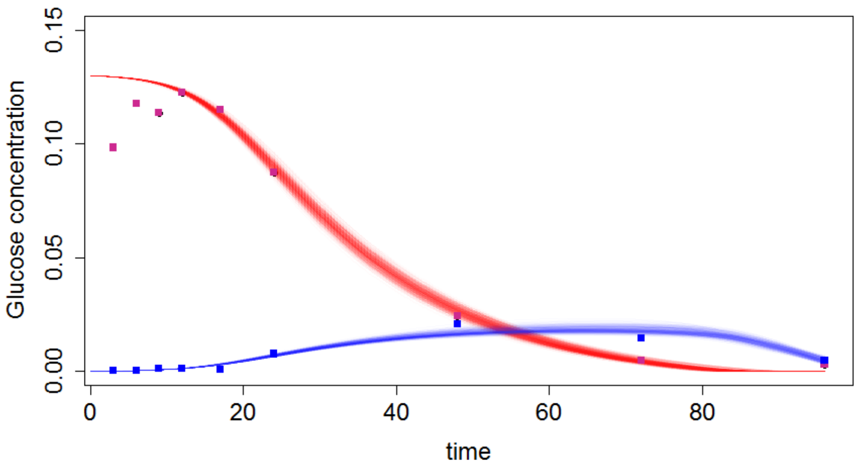
$$\frac{dN_i}{dt} = r_{fi} \frac{G}{K_{fi} + G} . \exp\left(-\frac{E}{E_{m,i}}\right) . N_i + r_{ri} \frac{E}{K_{ri} + E} \left(\frac{K_{Ci}}{K_{Ci} + G}\right) N_i - m . N_i$$

$$\frac{dE}{dt} = \sum_i J_{fi} \frac{G}{K_f + G} p_i N_i - \sum_i J_{ri} \frac{E}{K_{ri} + E} \left(\frac{K_{Ci}}{K_{Ci} + G}\right) N_i$$

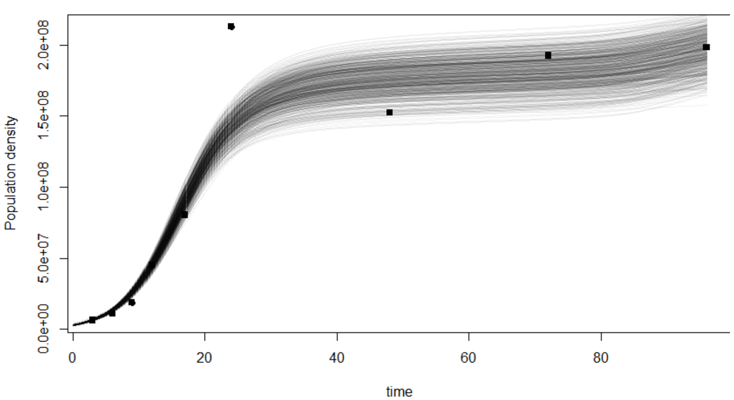
Adapted from *MacLean et al., 2006*

Inference of the parameters

Inference by ABC method,
Toni et al.



Parameters	Boundary set
Glucose comsuption rate J_f	10^{-11}-2.10^{-10} (g.cell^{-1}.h^{-1})
Fermentation growth rate r_f	0.2-0.6 (h^{-1})
Fermentation yield p	0-0.5
« Affinity » of the reaction K	10^{-7}-10^{-2} (g/mL)
Ethanol comsuption rate J_r	10^{-11}-10^{-9} (g.cell^{-1}.h^{-1})
Fermentation growth rate r_r	0.01-0.1 (h^{-1})
Inhibition of Glucose on resp. Kc	10^{-7}-10^{-2} (g/mL)
Mortality rate m	0.01-0.4 (h^{-1})
Toxic effect of ethanol Em	10^{-4}-10^{-2} (g/mL)



$$\frac{dG}{dt} = -\sum_i J_{fi} \frac{G}{K_f+G} N_i$$

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$$\frac{dE}{dt} = \sum_i J_{fi} \frac{G}{K_f+G} p_i N_i - \sum_i J_{ri} \frac{E}{K_{ri}+E} \left(\frac{K_{Ci}}{K_{Ci}+G}\right) N_i$$

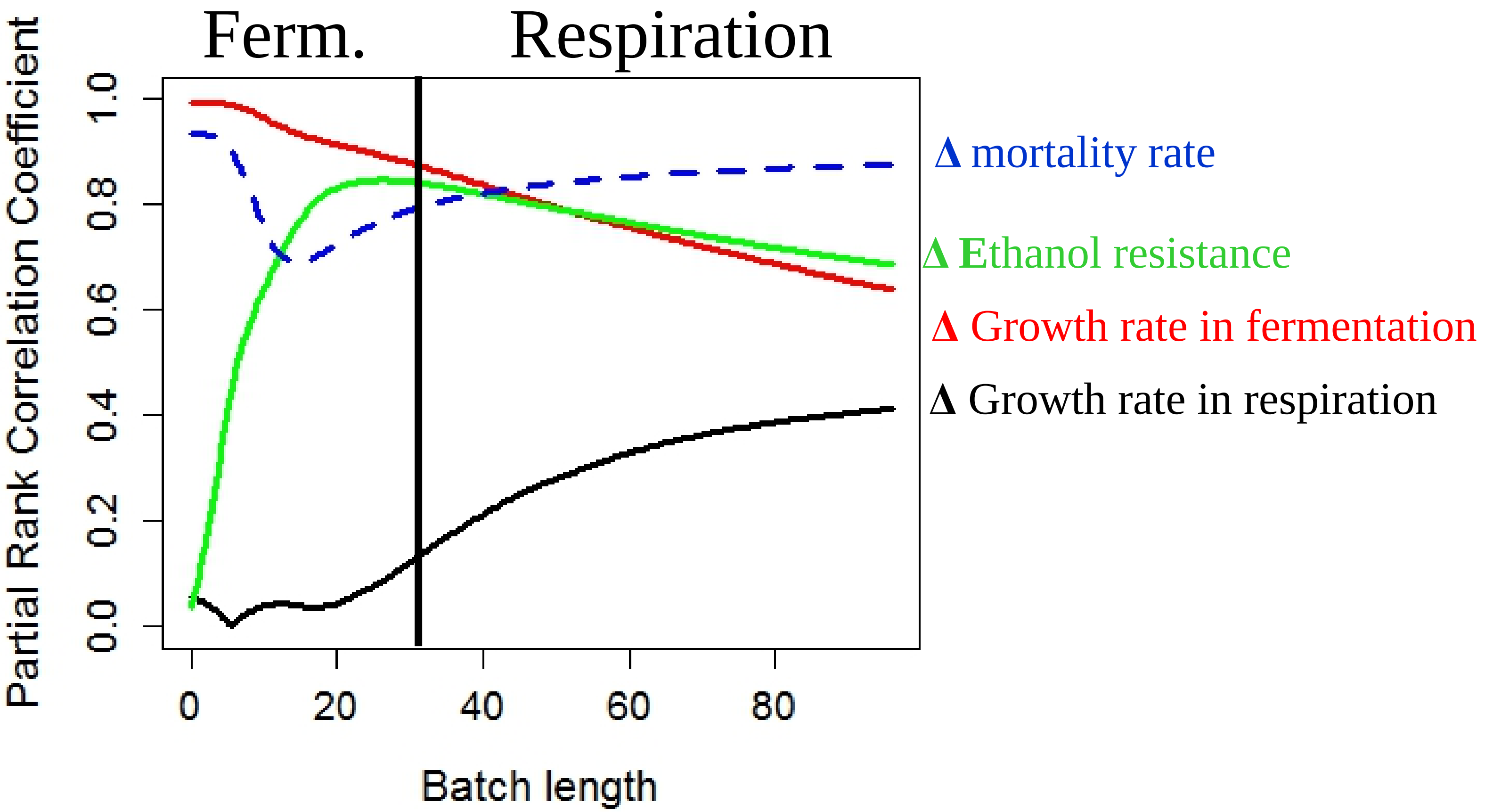
Competitions *in Silico*

- Sampling of 100 strains (Latin Hypercube Sampling)
- Initial frequency of the mutant : 0.001%
- 10 000 competitions.
- Fitness definition:

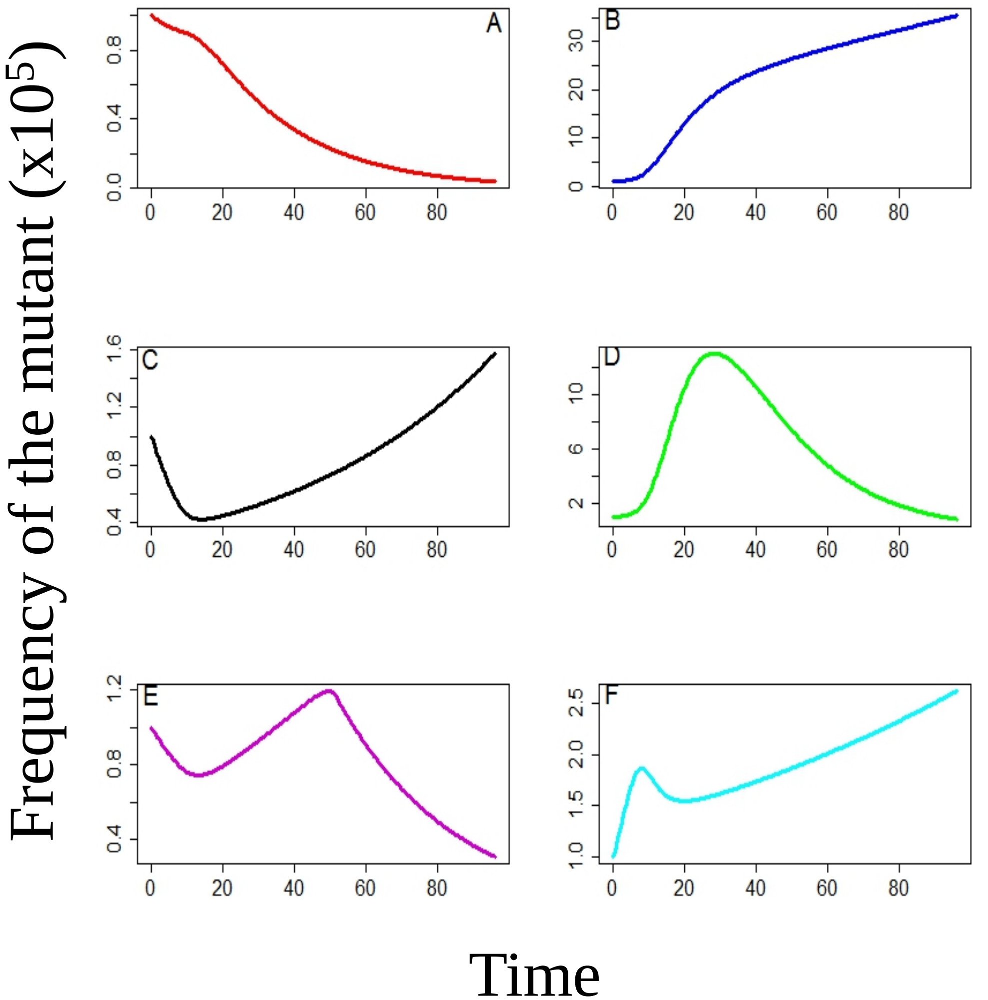
$$W_{1/2}(t) = \ln\left(\frac{N_1(t)}{N_1(0)}\right) - \ln\left(\frac{N_2(t)}{N_2(0)}\right)$$

N_i is the density of strain i.

Correlation between fitness and traits



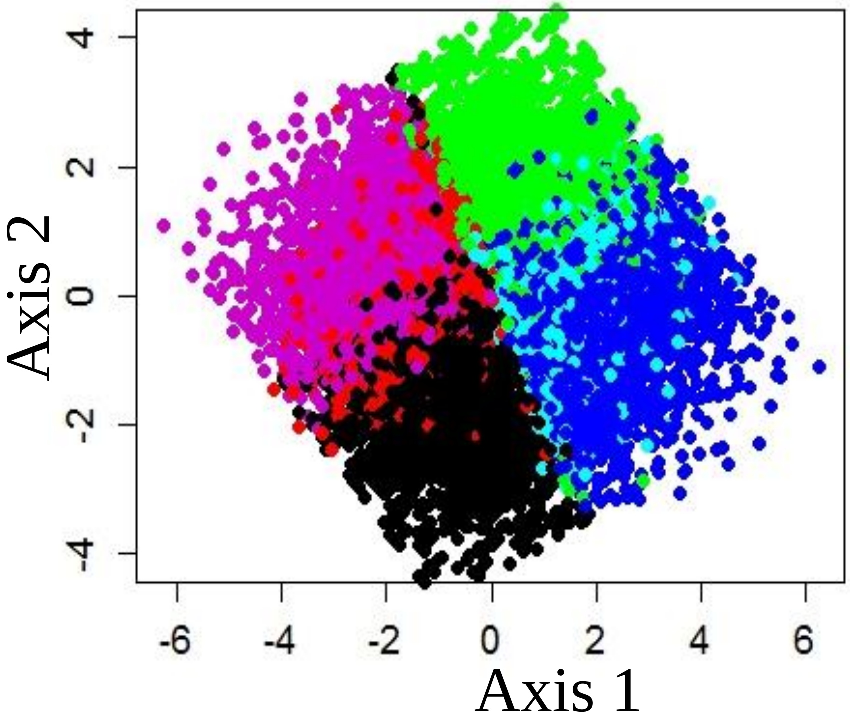
Different mutant frequencies dynamics

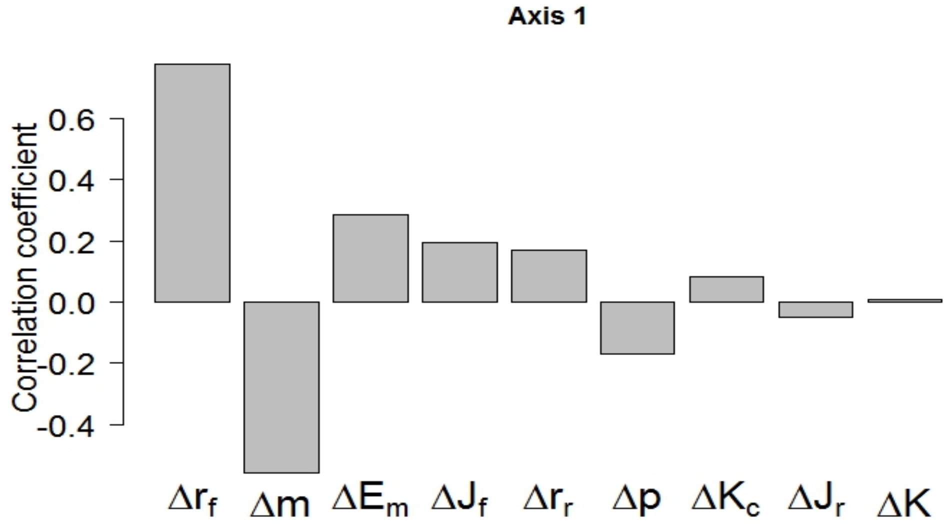


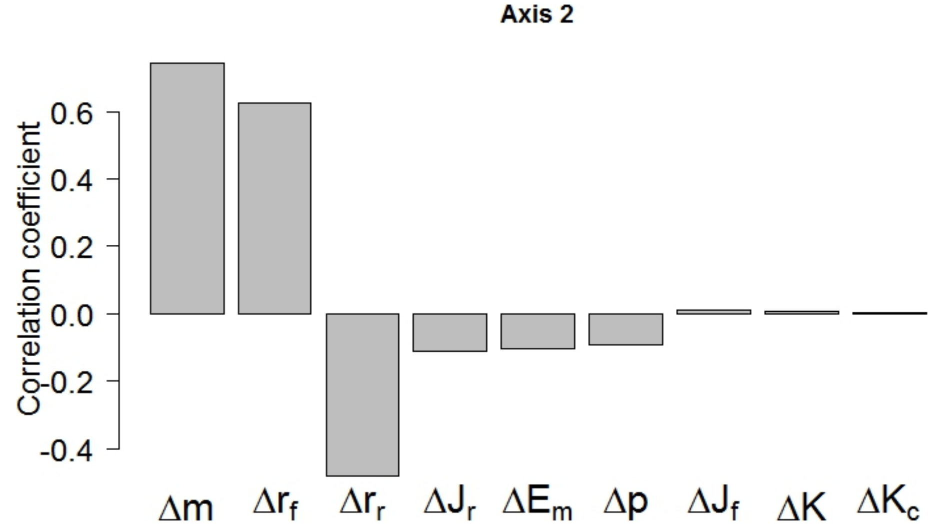
- 6 types of possible dynamics of frequency of the mutant.

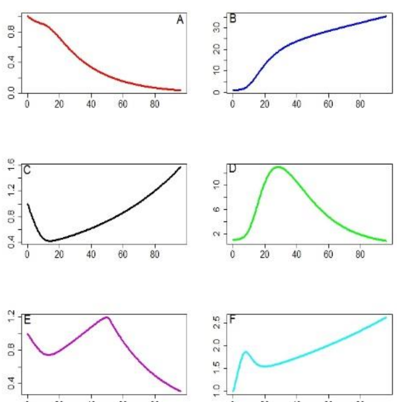
- Low frequency = low chance to go to the next batch.

Links between traits and dynamics

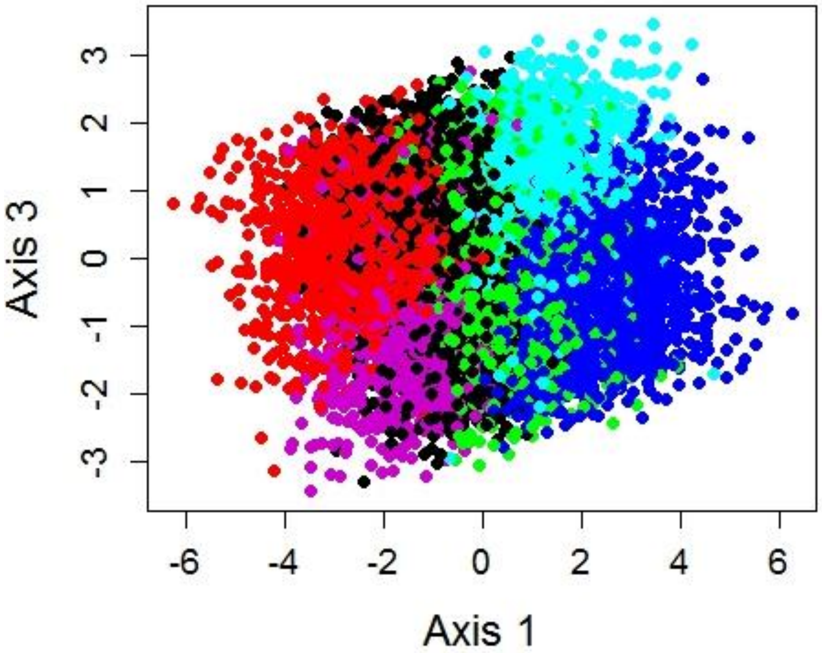


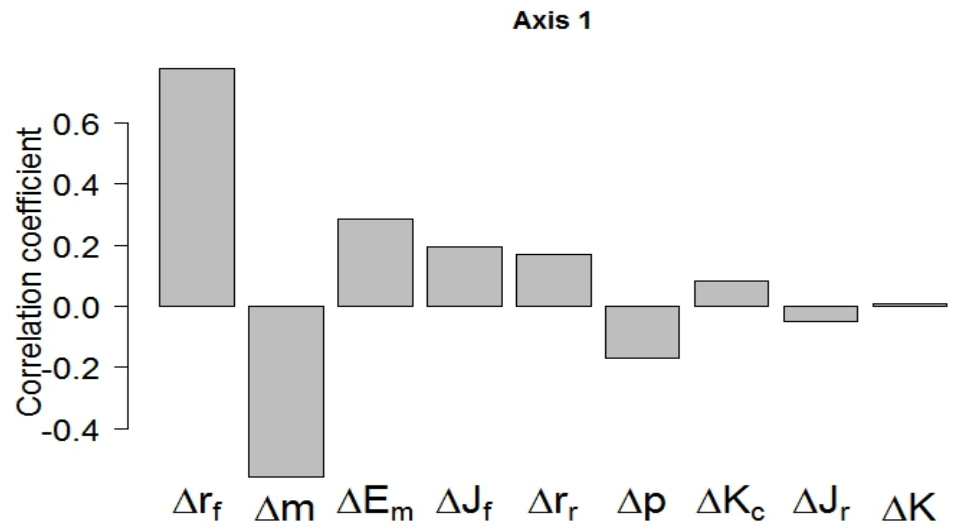


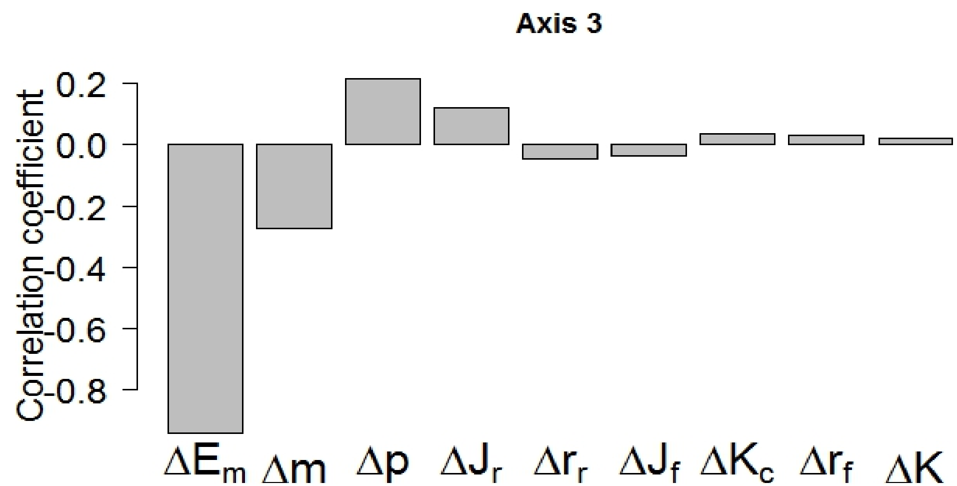


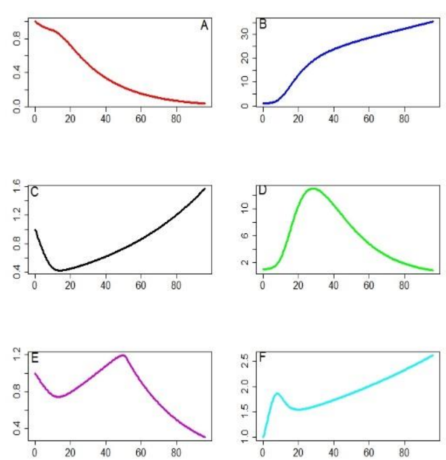


Links between traits and dynamics

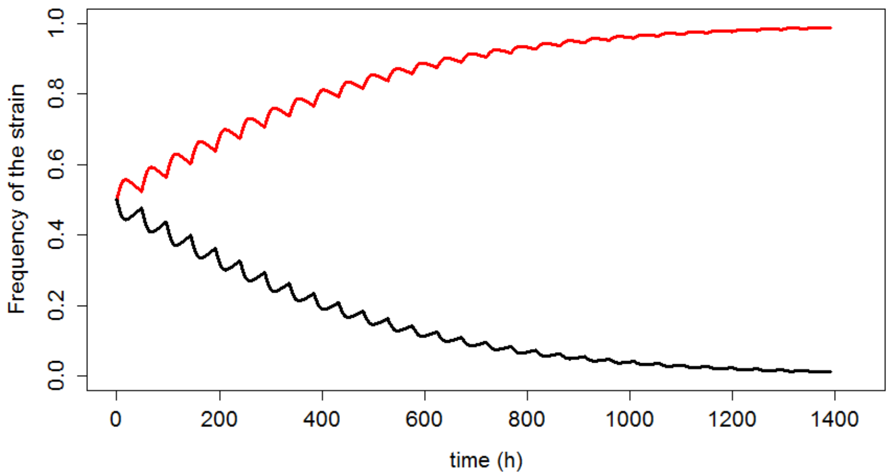


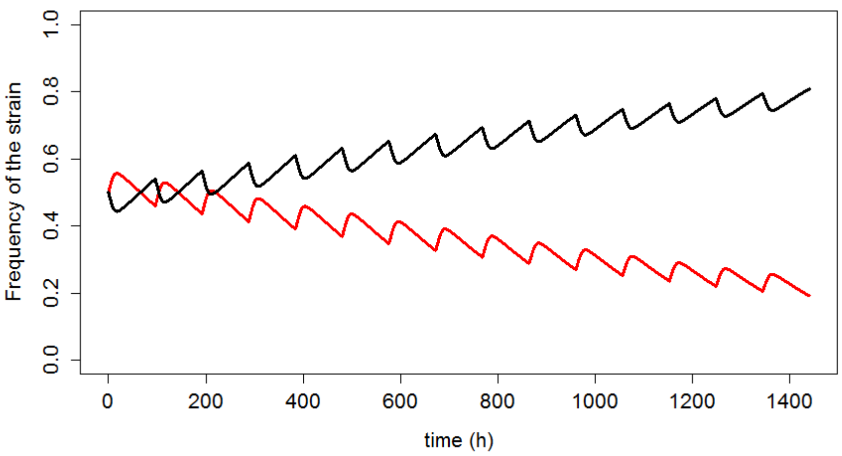






Effect of the length of the batch

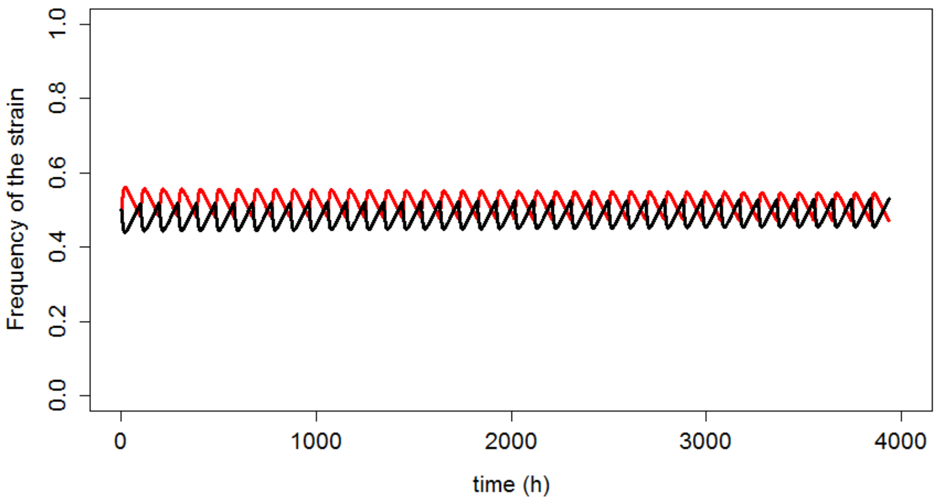




Parameters	**Red**	**Black**
m	0.106	0.1
J_f	7.10^{-11}	7.10^{-11}
r_f	0.43	0.4
Em	9.10^{-3}	9.10^{-3}
p	0.25	0.25
J_r	2.10^{-10}	2.10^{-10}
r_r	0.05	0.05
Kc	8.10^{-4}	8.10^{-4}
K	5.10^{-4}	5.10^{-4}

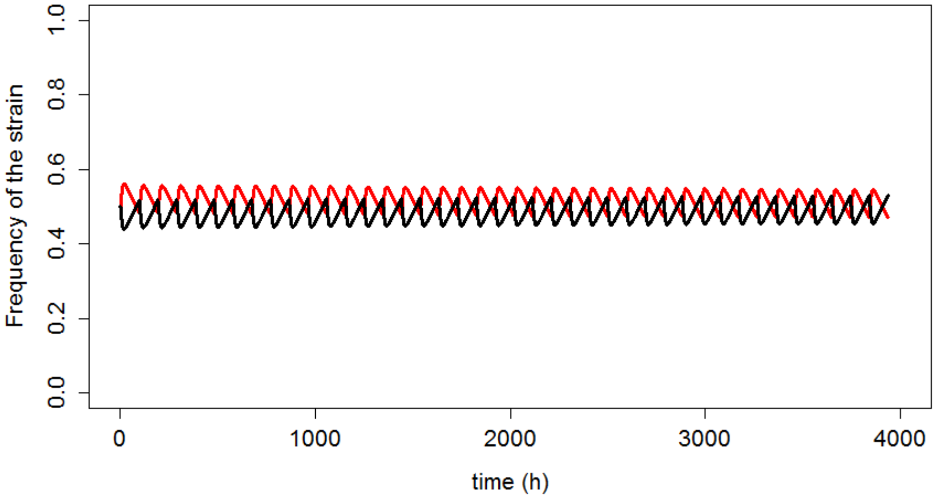
Future developments

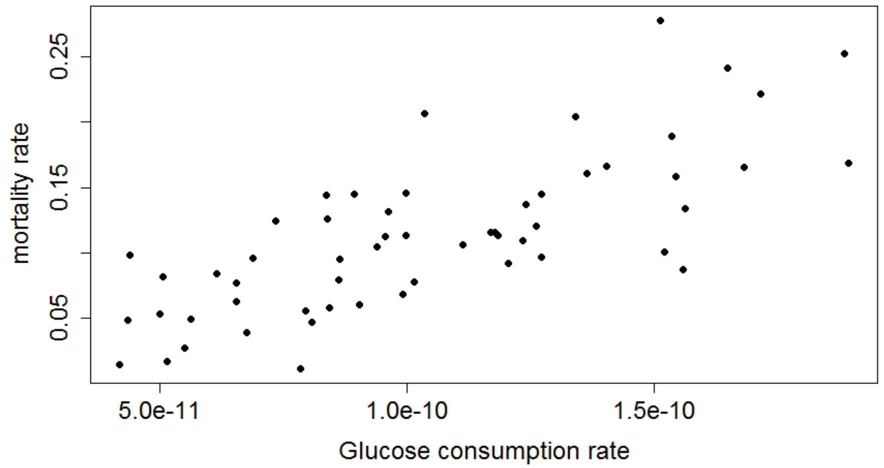
- Study the frequency dependence of fitness



Future developments

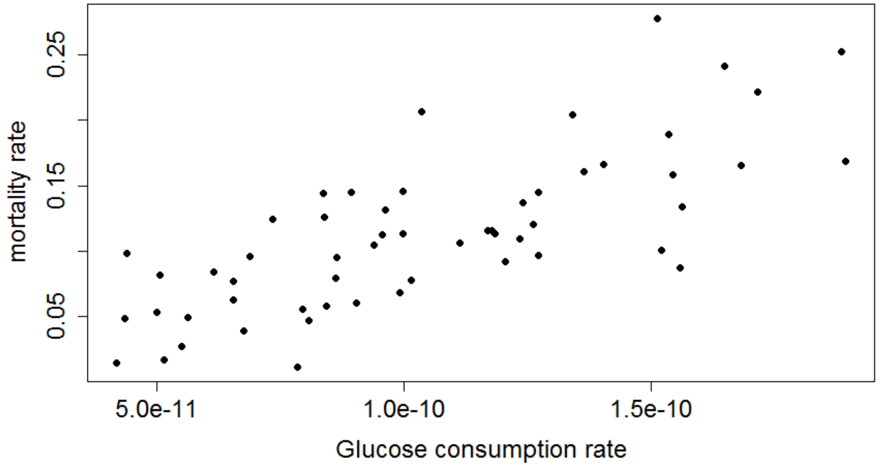
- Study the frequency dependence of fitness
- Add trade-off between the traits

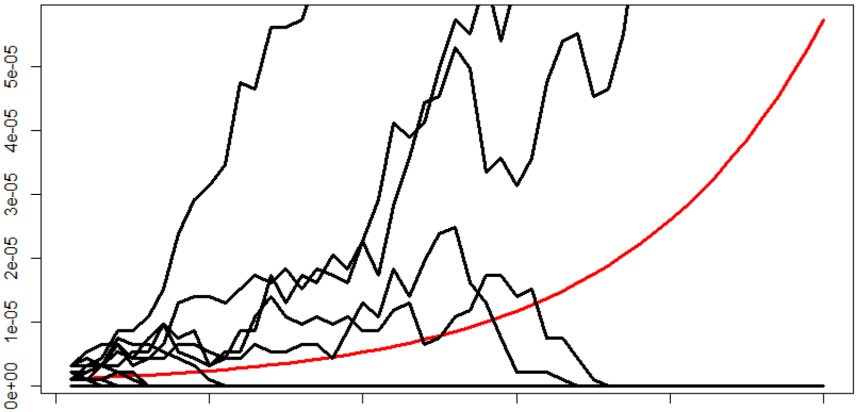




Future developments

- Study the frequency dependence of fitness
- Add trade-off between the traits
- Adding random process





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