Reproduction leads to higher population fitness: as simple as that

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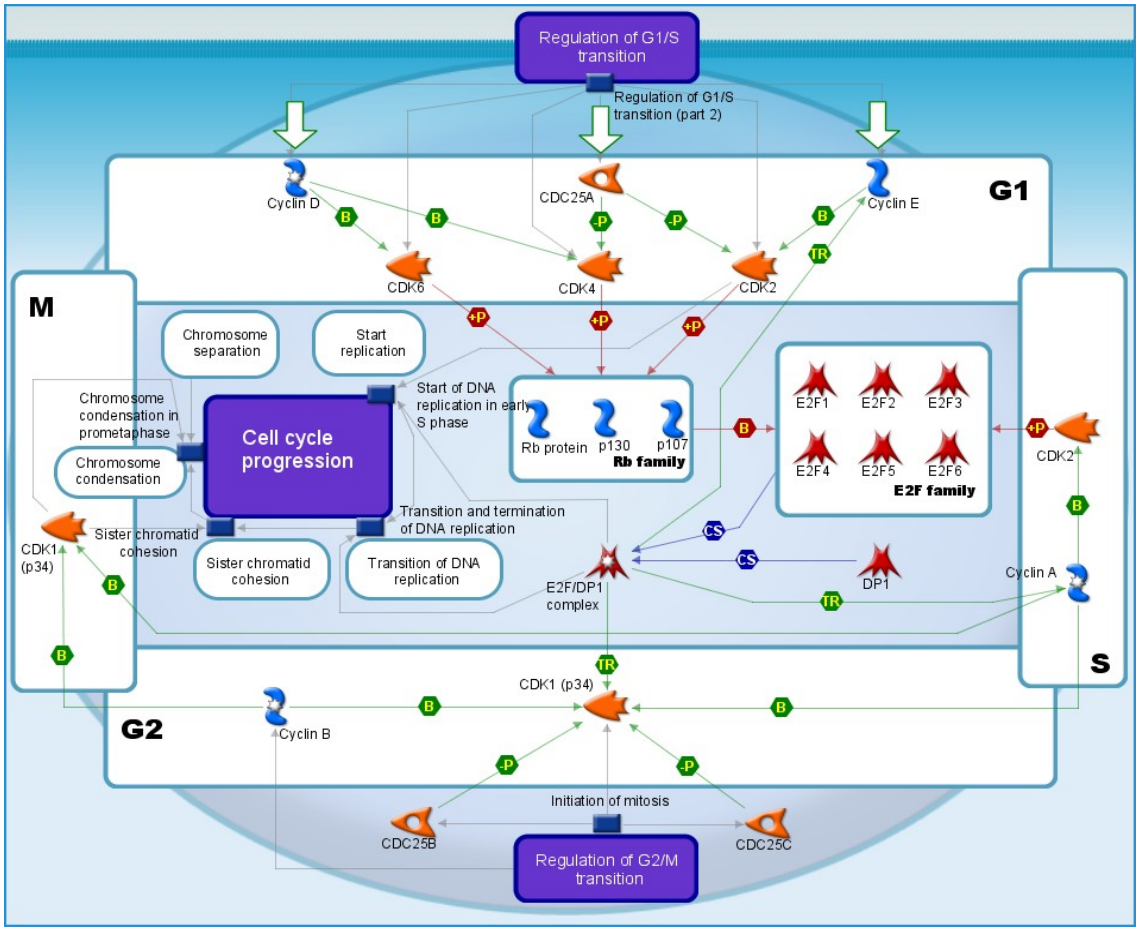
Prof. Sergio Caracciolo
Prof. Jorge Kurchan

Biological processes are complex!



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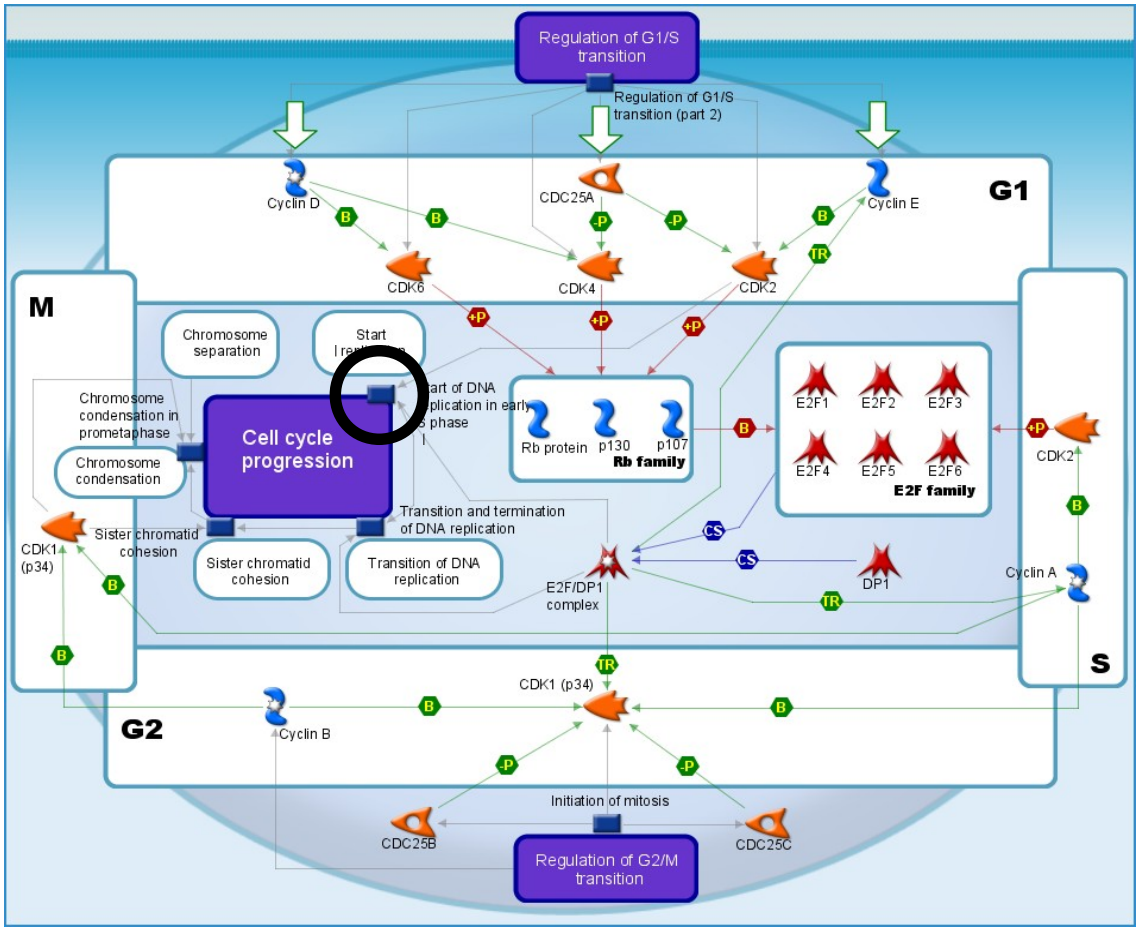

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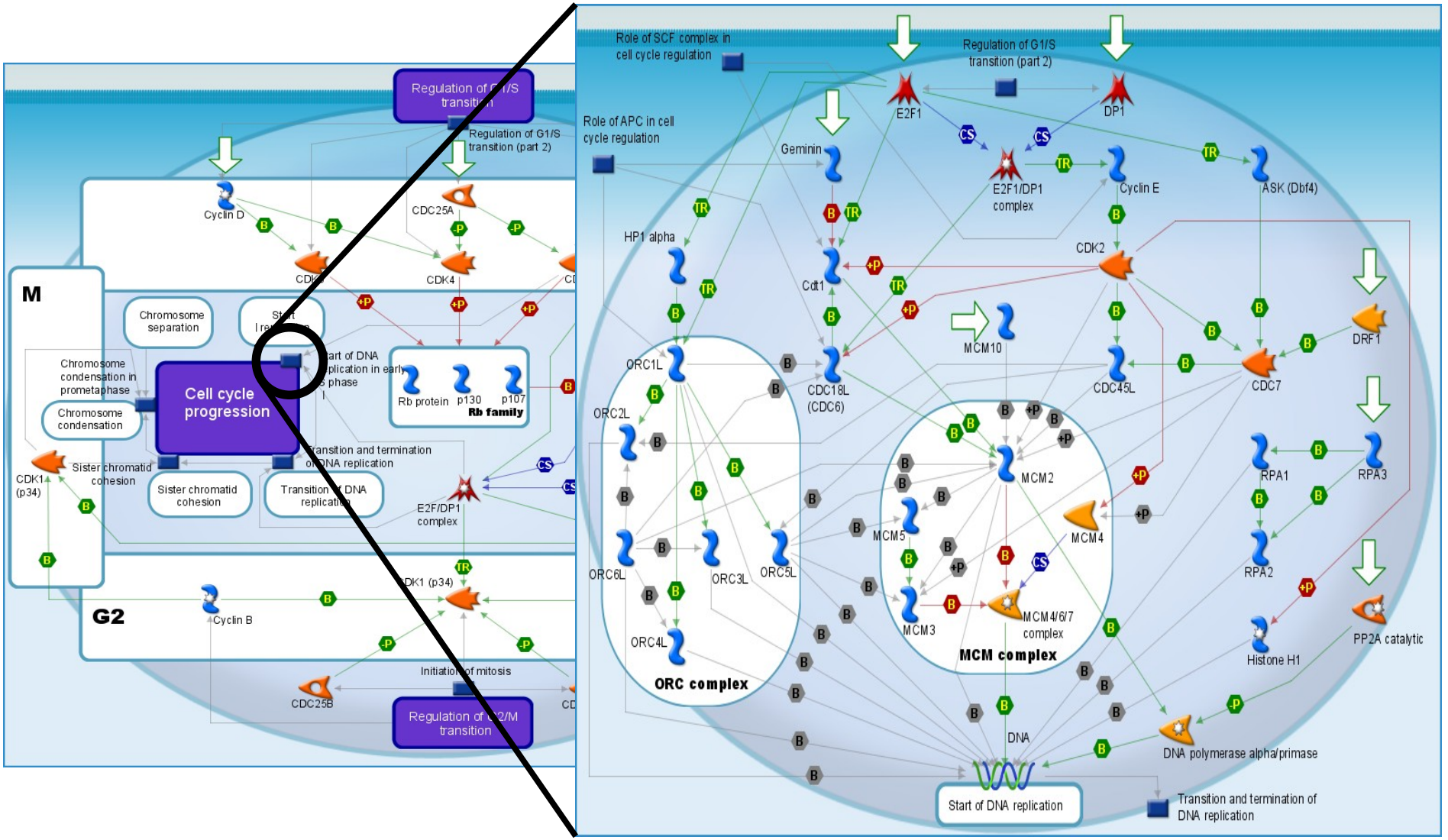

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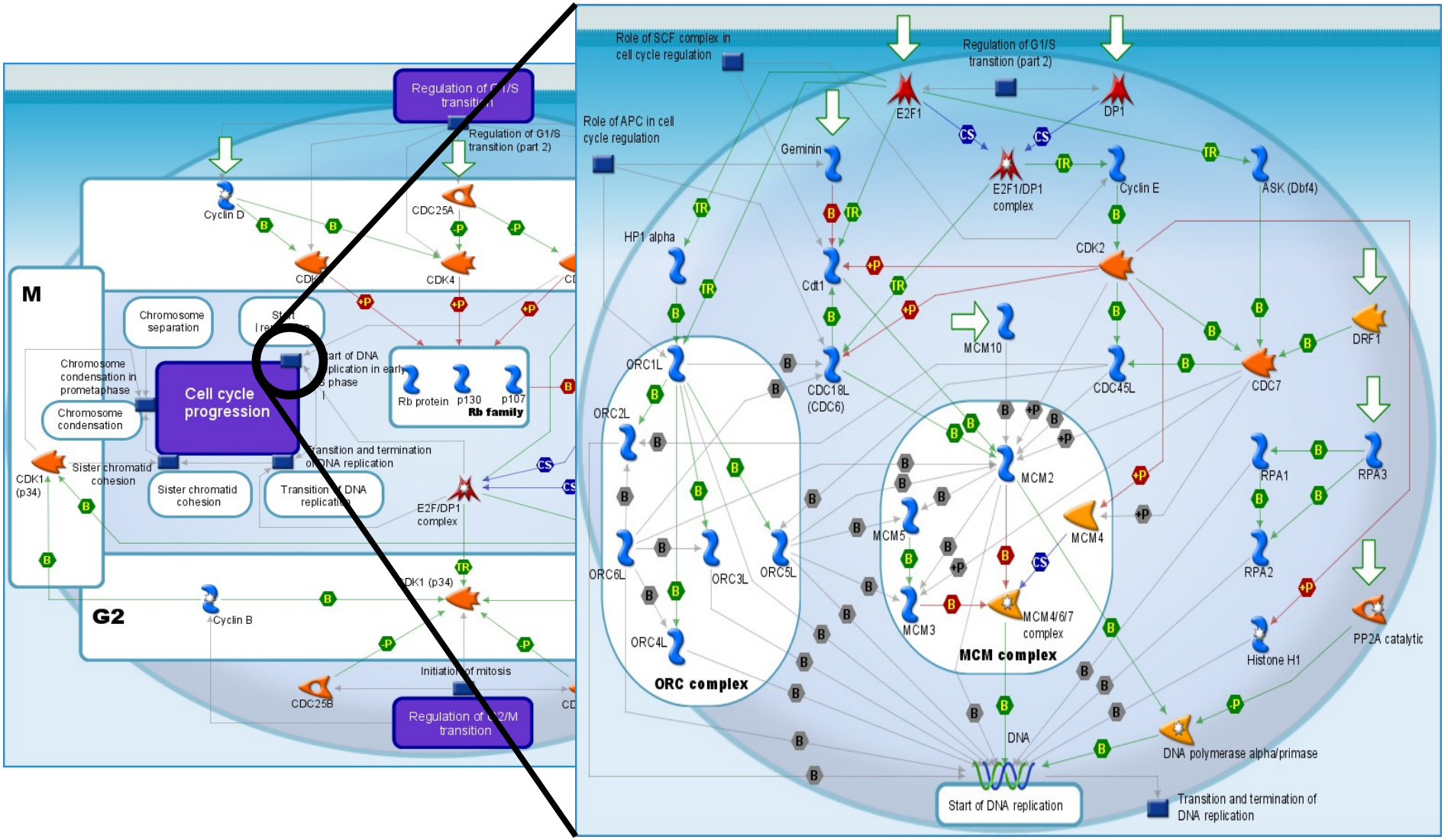


Do we really need to take everything into account?

What is really essential?

A cell can:

- Reproduce = create offsprings with same traits
- Mutate = change traits

What is really essential?

A cell can:

→ Reproduce = create offsprings with same traits

→ Mutate = change traits

Traits:

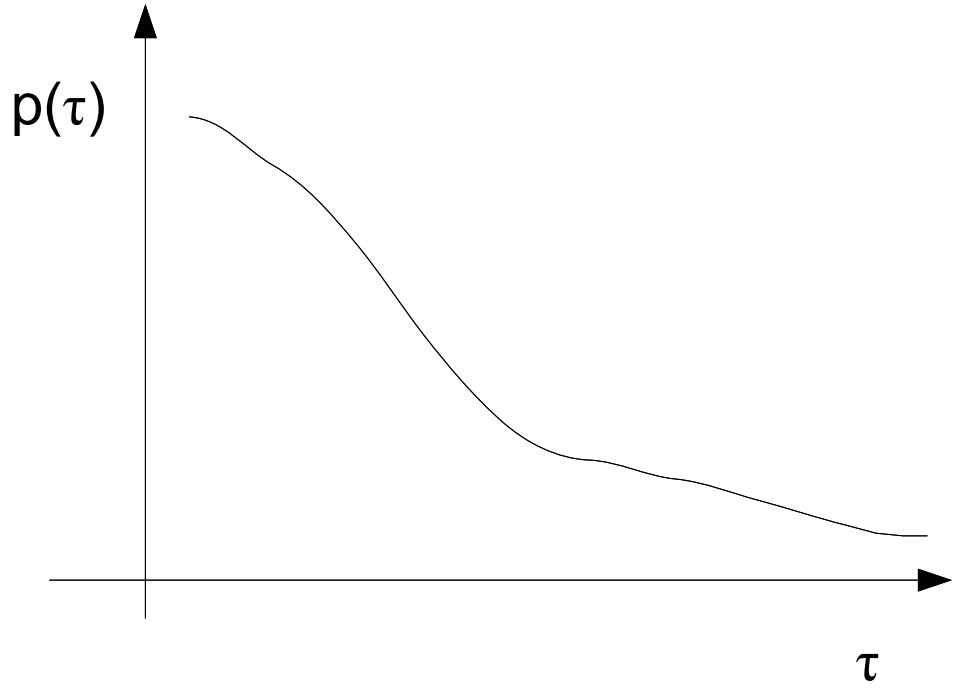
λ = fitness (ability to generate offsprings)

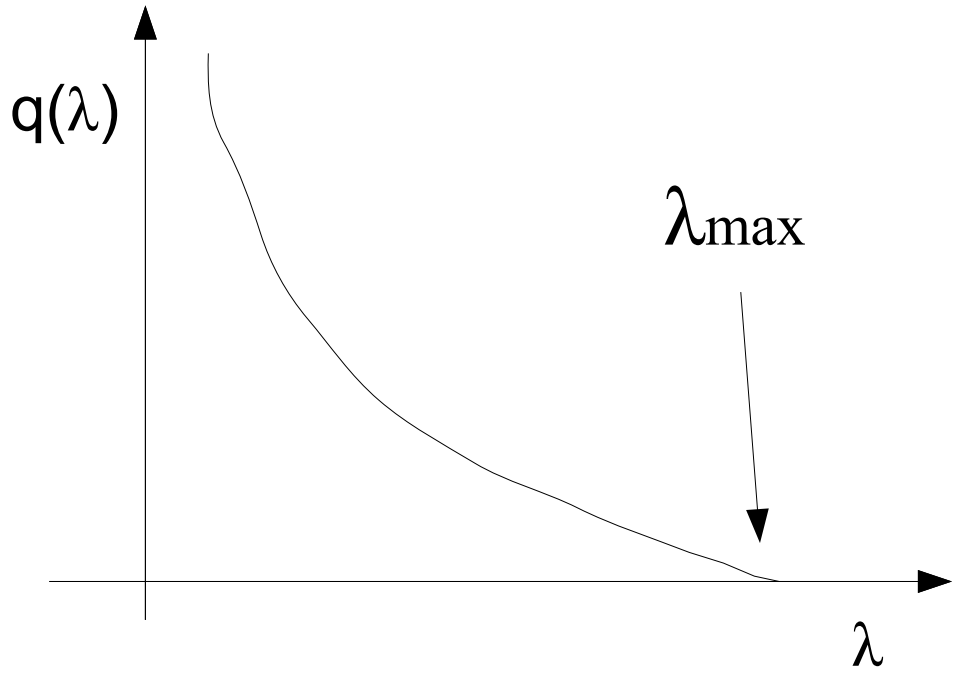
τ = mutation time

Create N cells,
with random τ, λ

τ follows $p(\tau)$

λ follows $q(\lambda)$



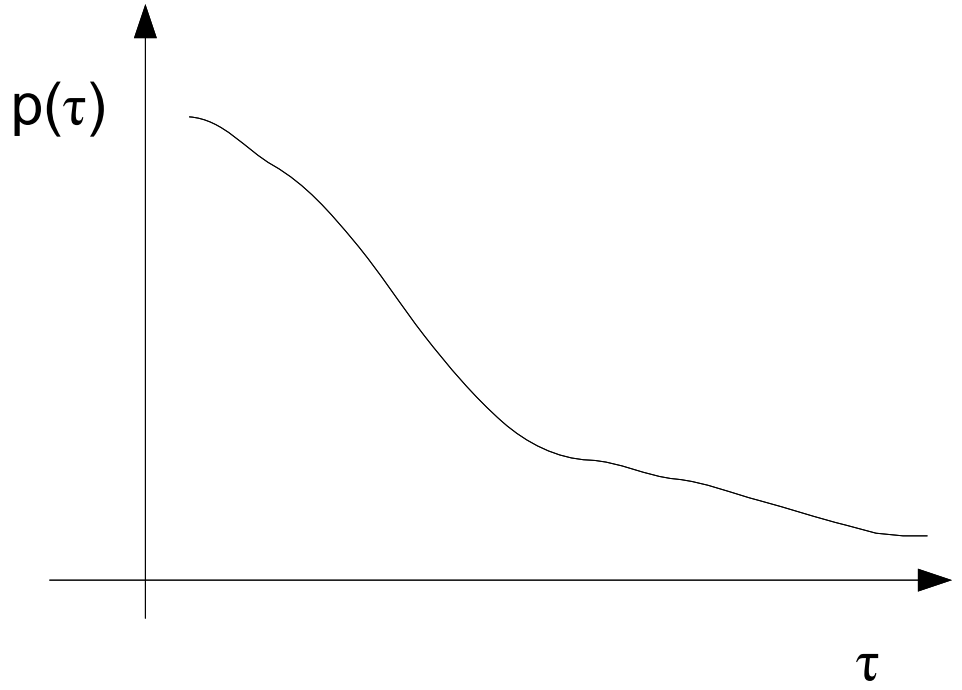


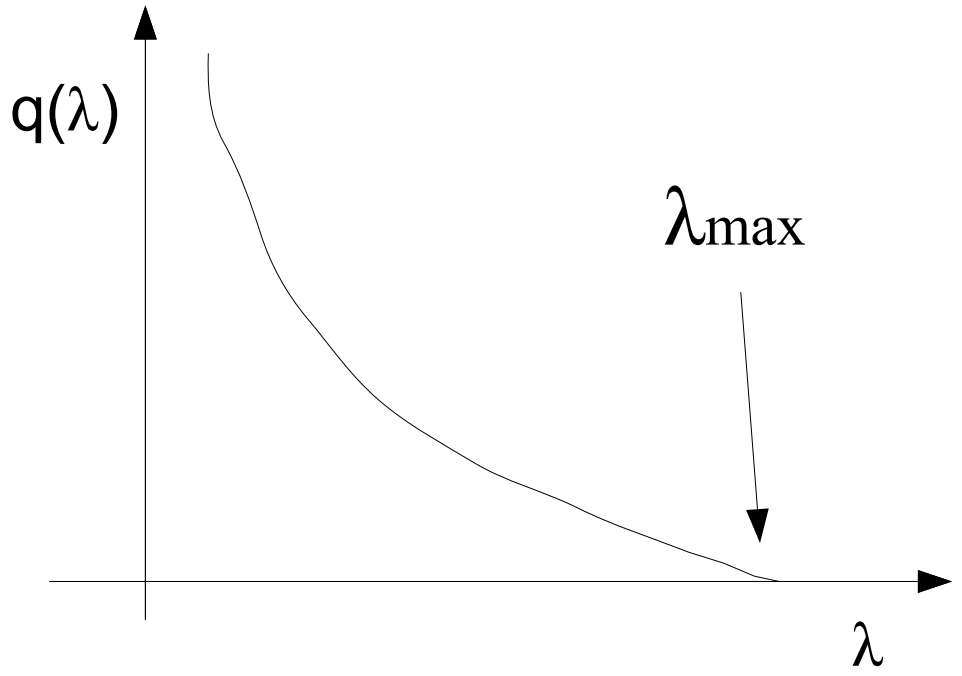
Create N cells,
with random τ, λ

τ follows $p(\tau)$

τ and λ are
not correlated

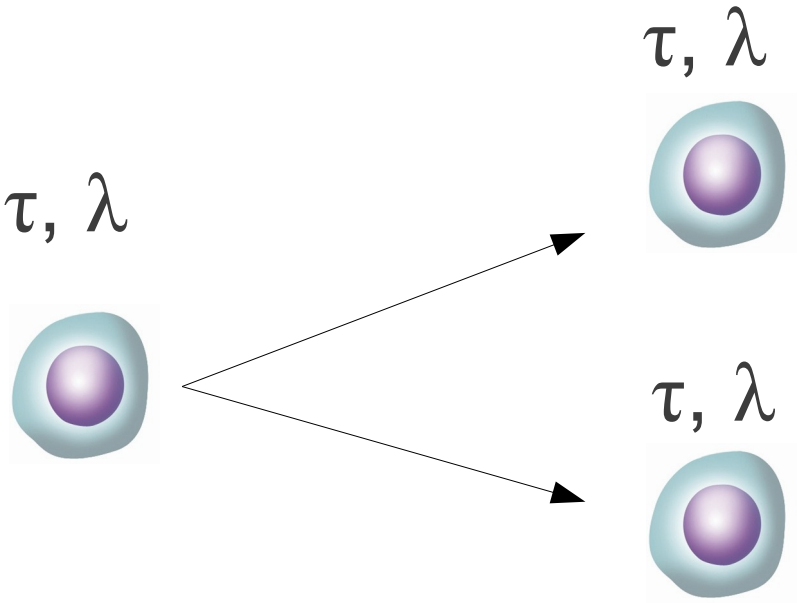
λ follows $q(\lambda)$





Each time step, each cell:

Reproduction,
with rate λ



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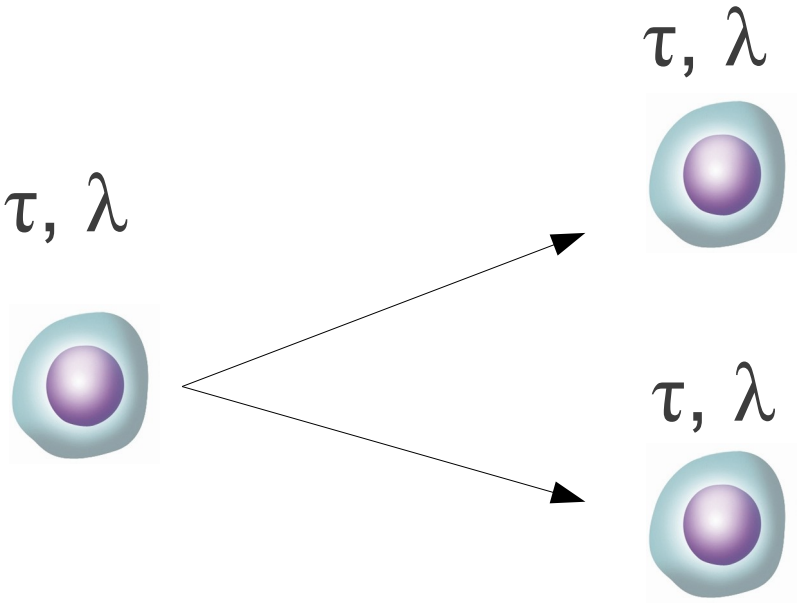
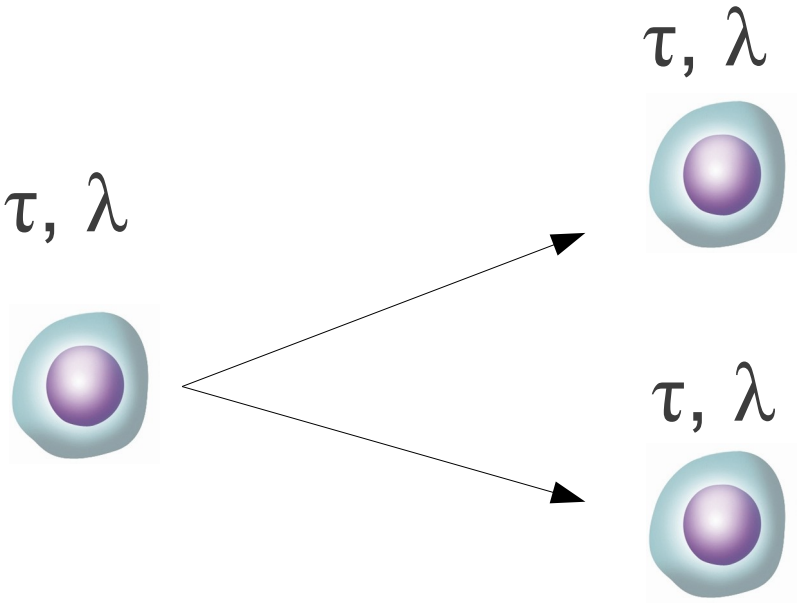


Mutation,
with rate $1/\tau$

Each time step, each cell:

Reproduction,
with rate λ



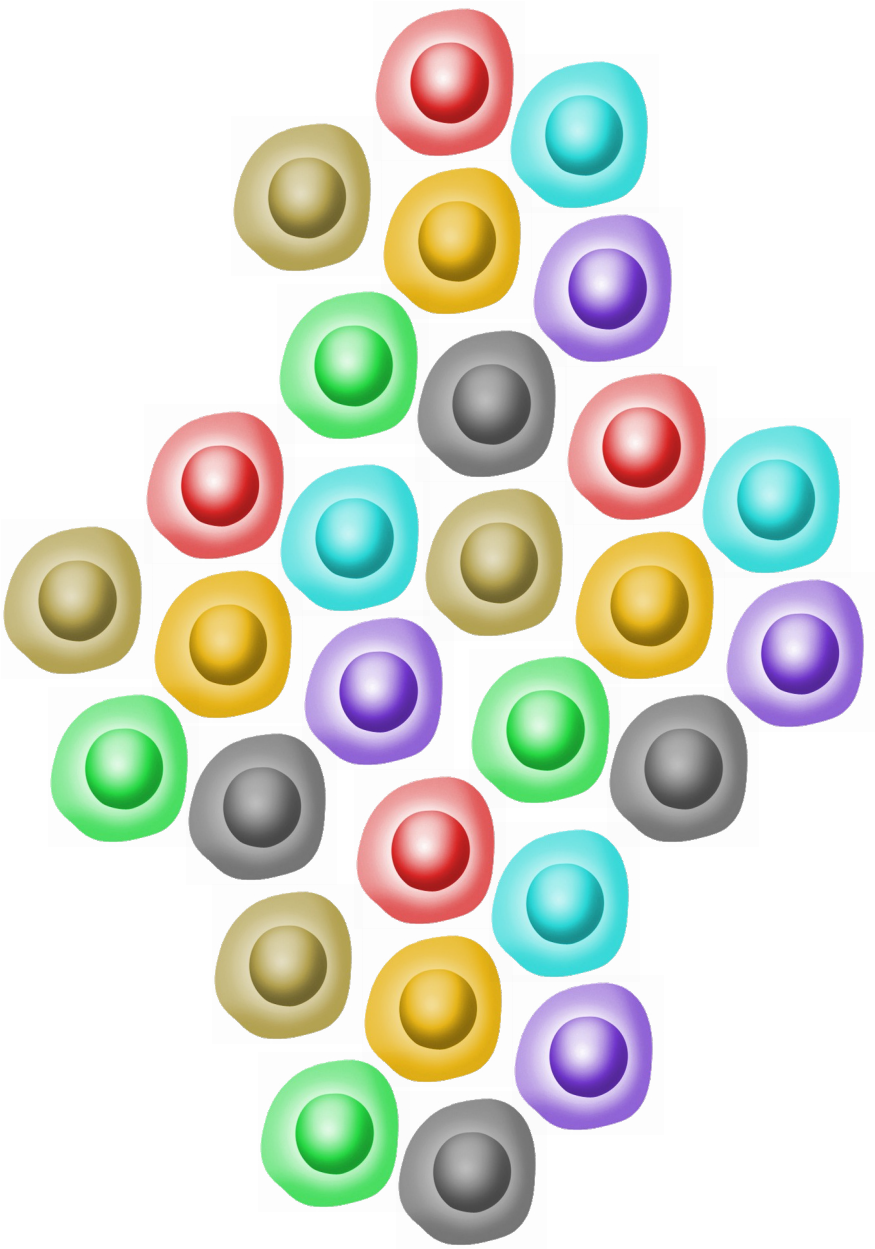
Mutation,
with rate $1/\tau$

To preserve N, kill randomly

What happens: sketch

First phase:

Randomness



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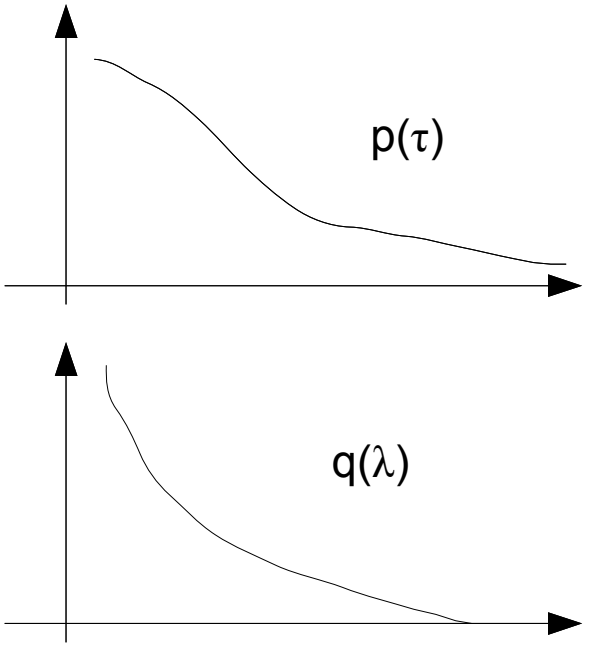
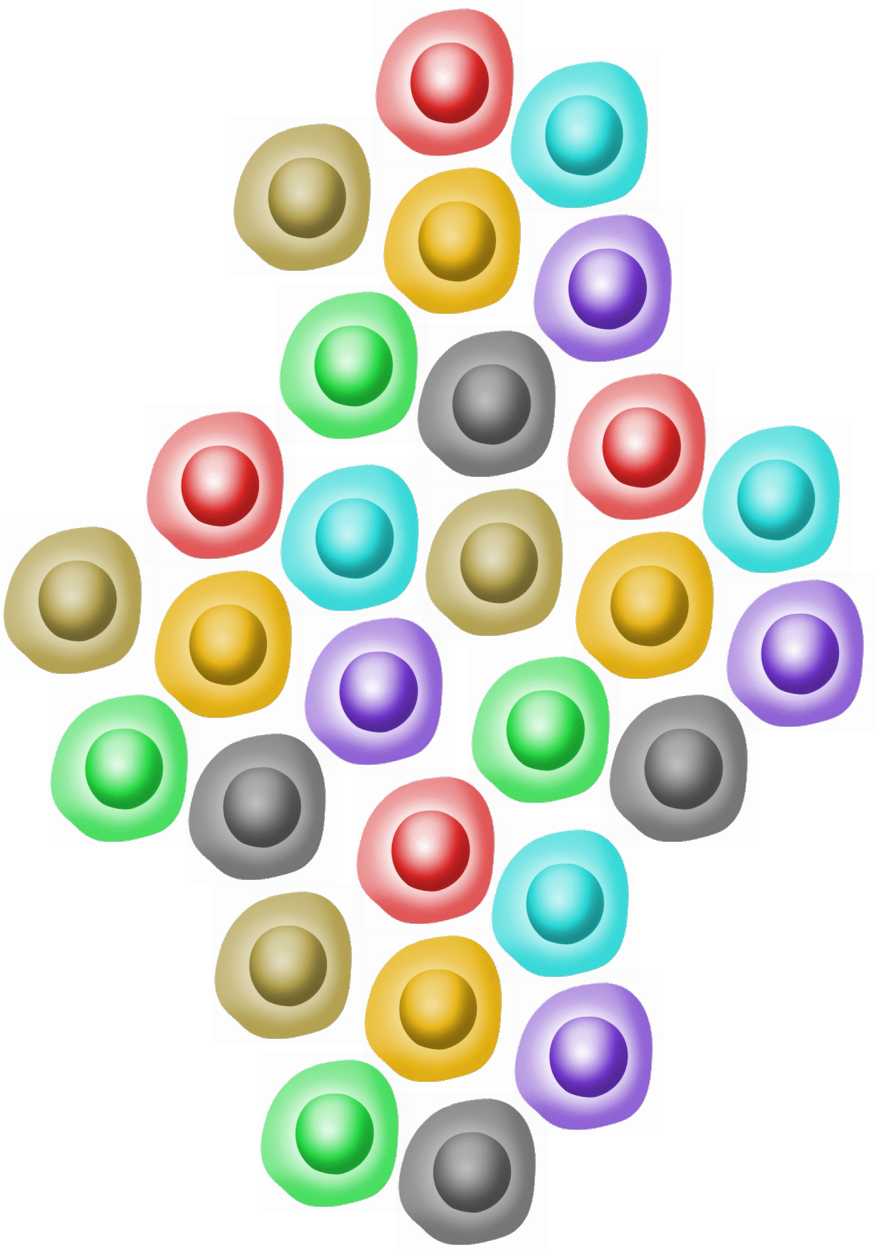




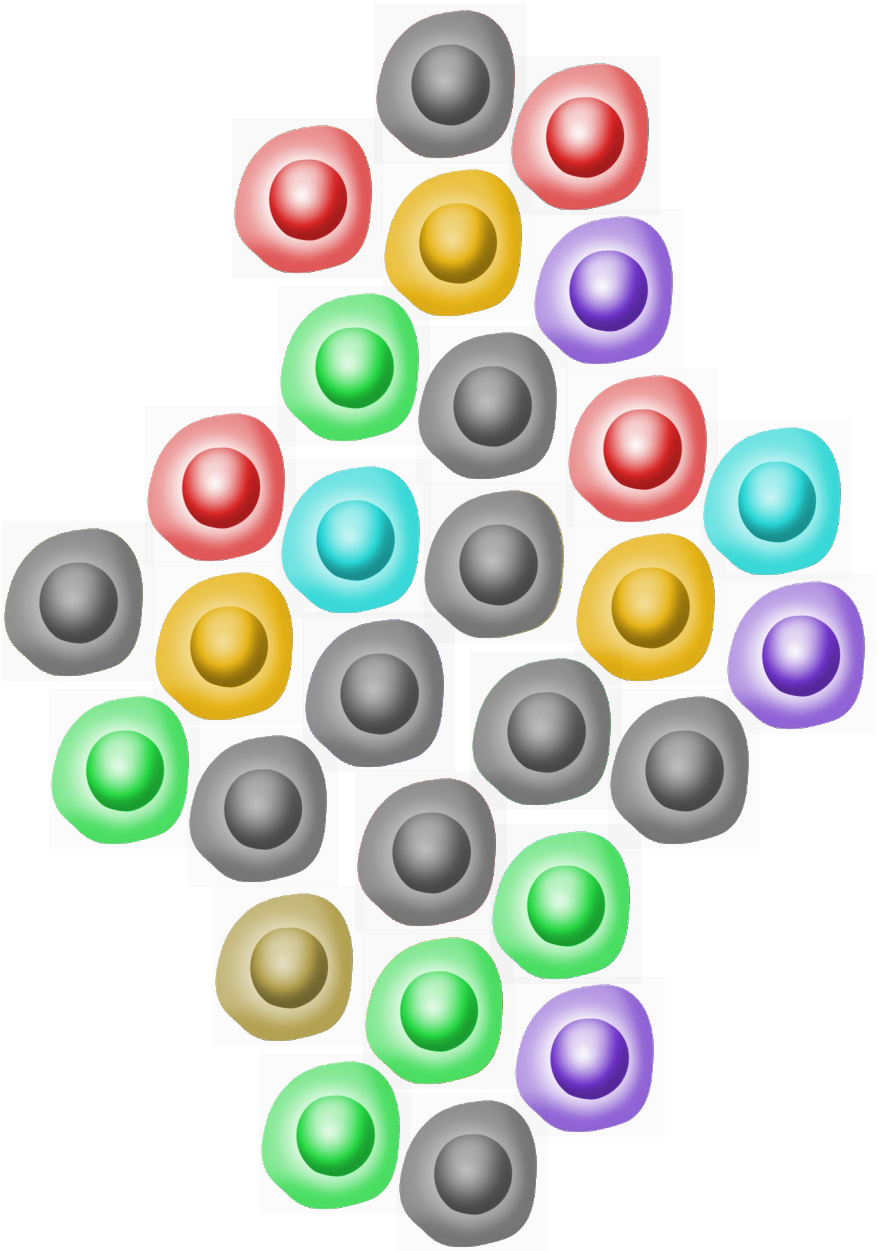
What happens: sketch

First phase:

Randomness

Second phase:

Condensation



What happens: sketch

First phase:

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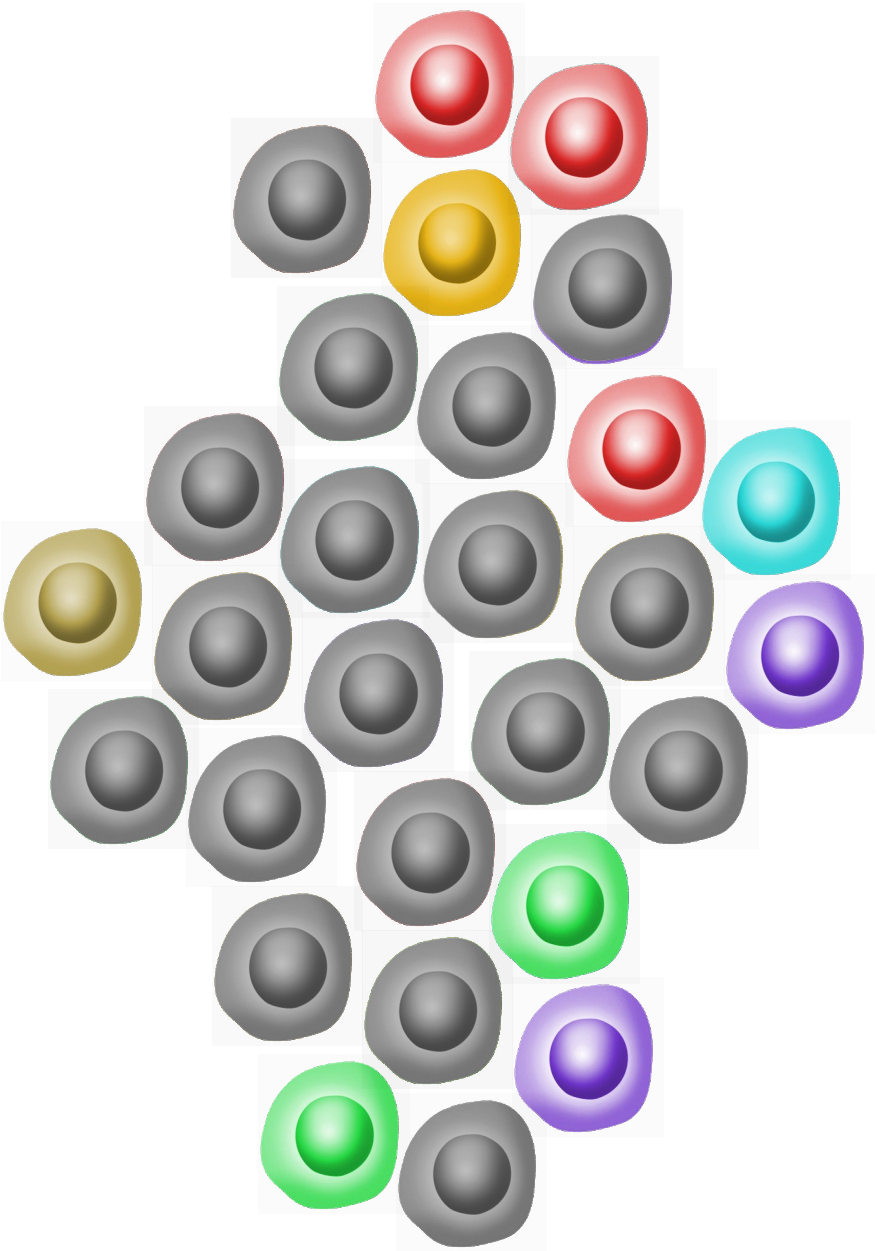

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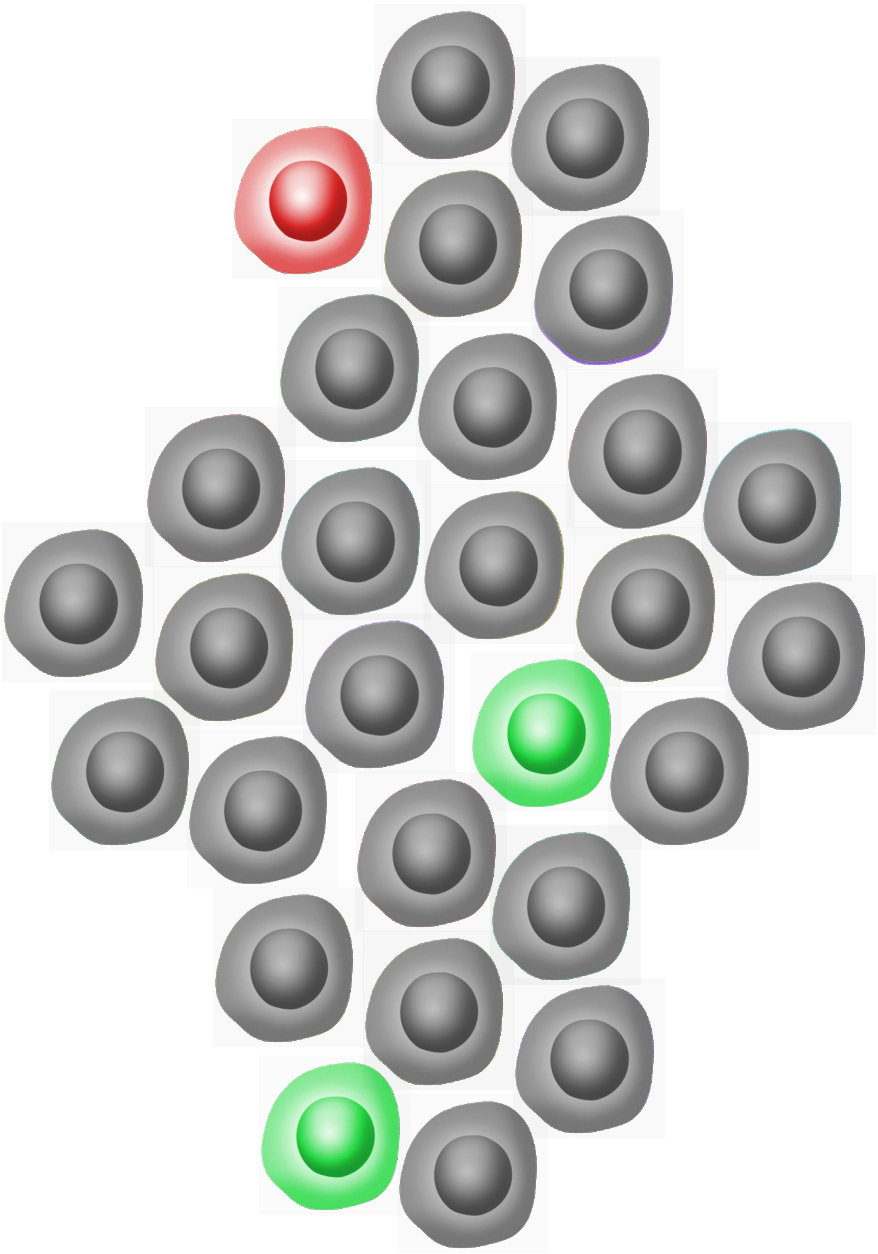
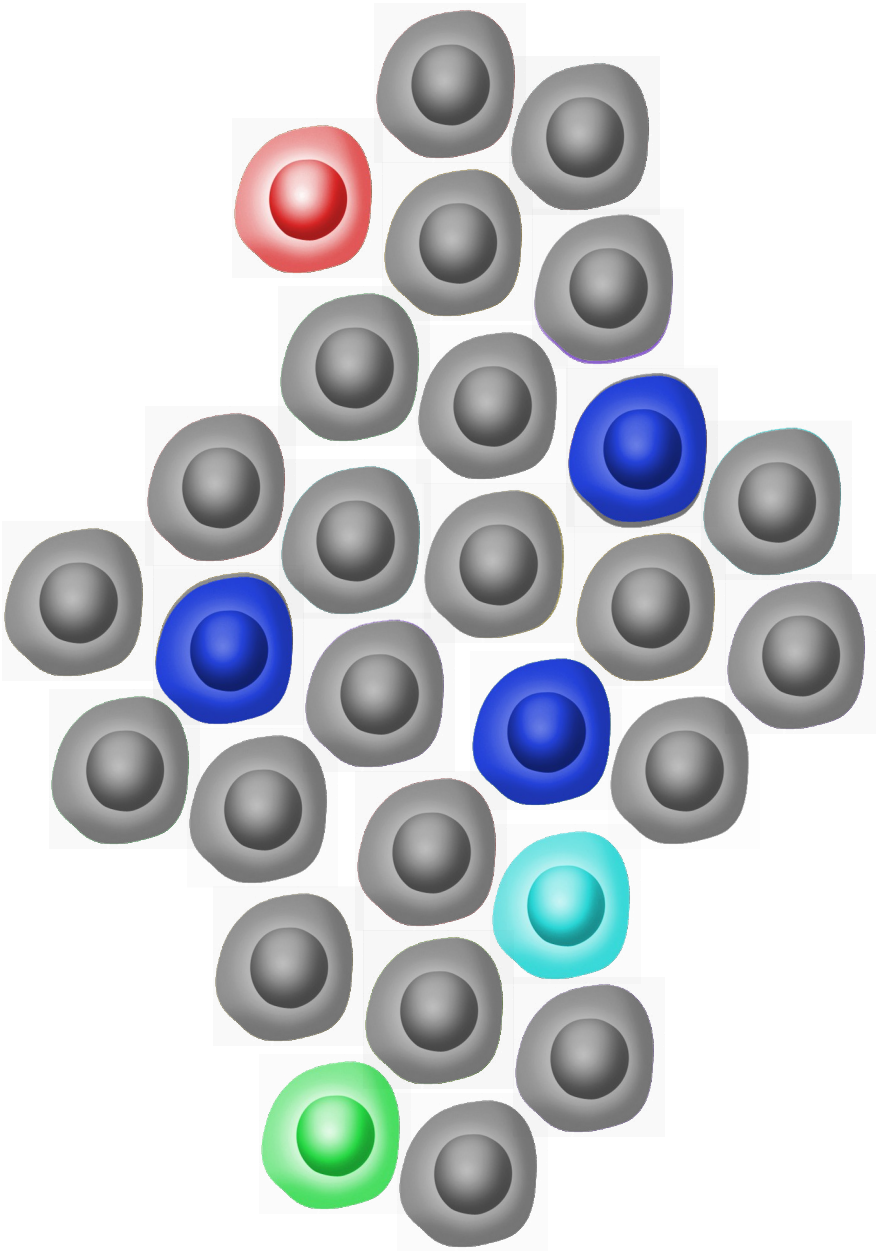


What happens: sketch

First phase:
Randomness

Second phase:
Condensation

Third phase:
Takeovers



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First phase:
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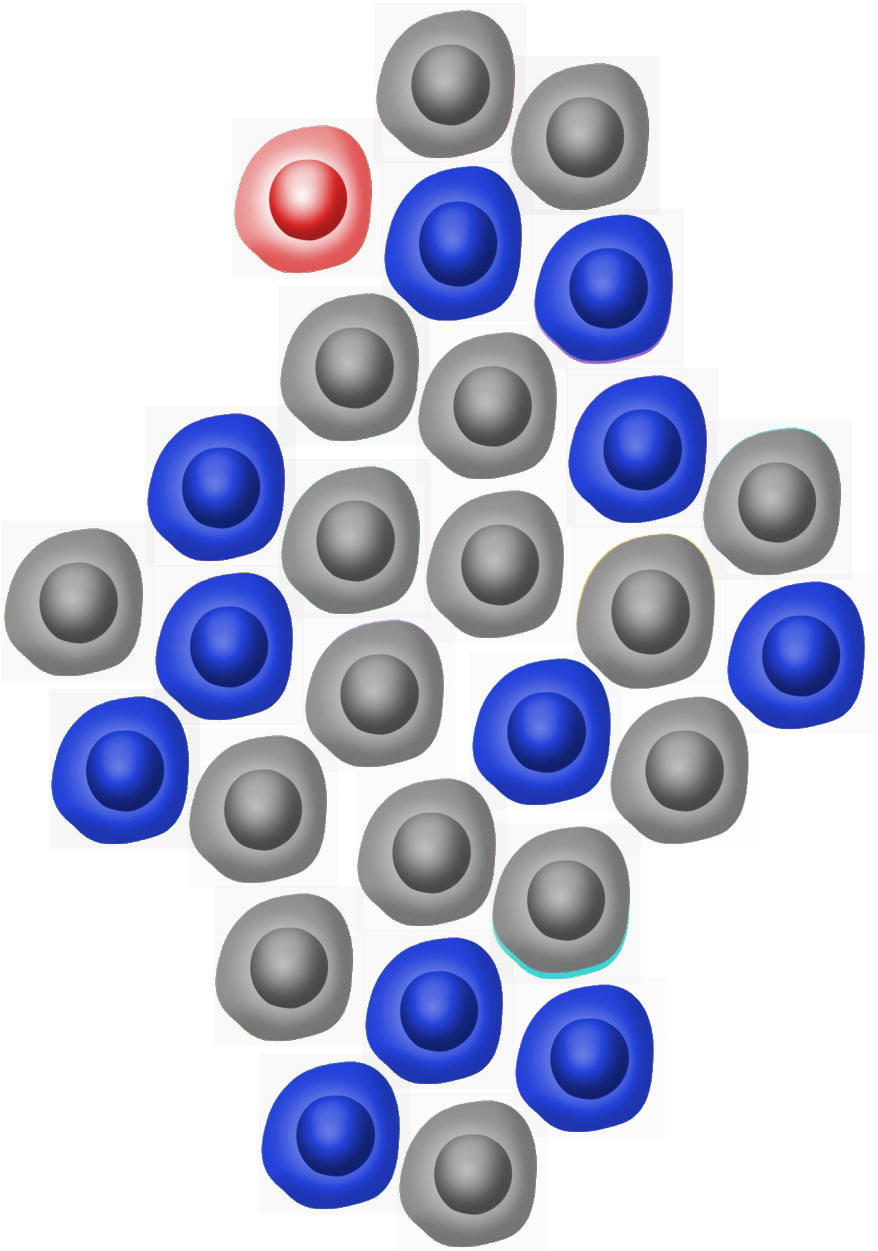

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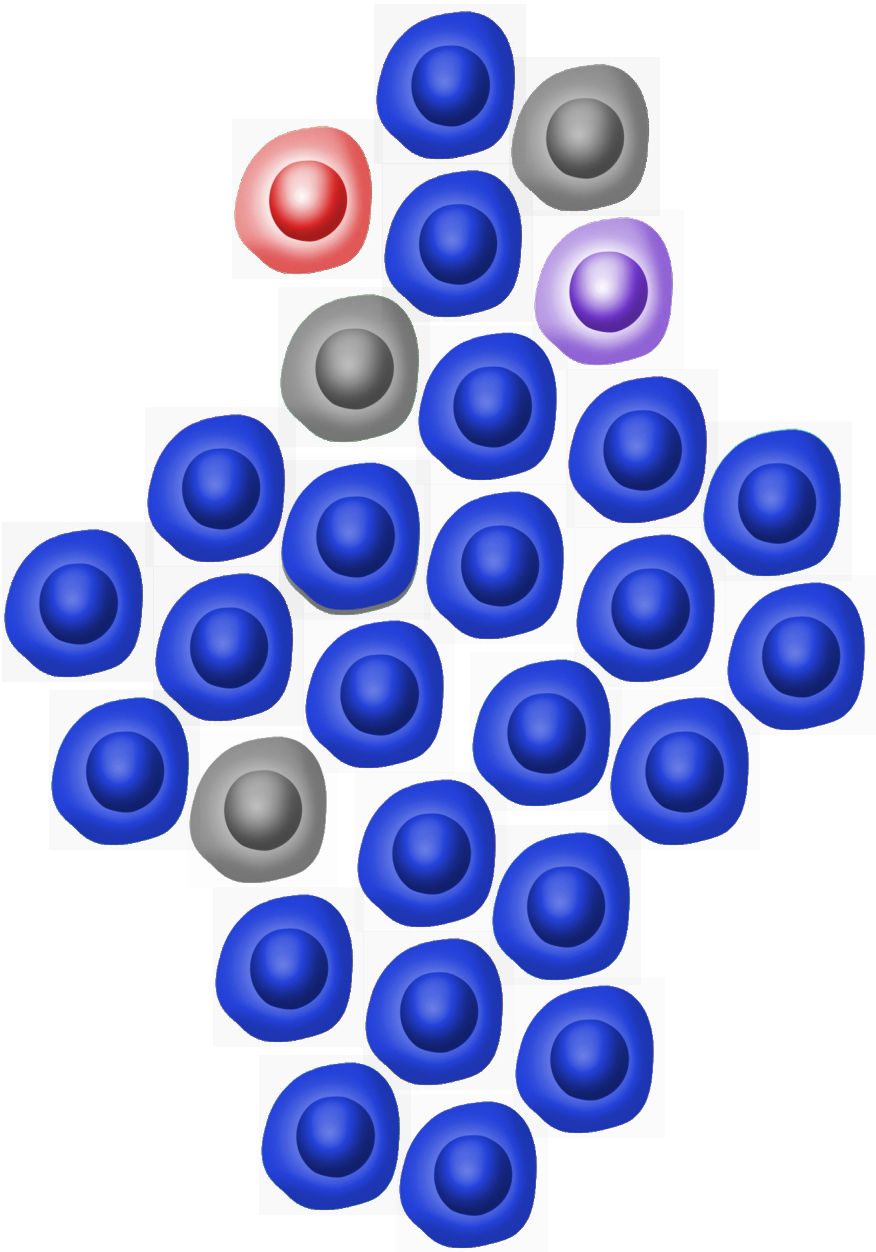
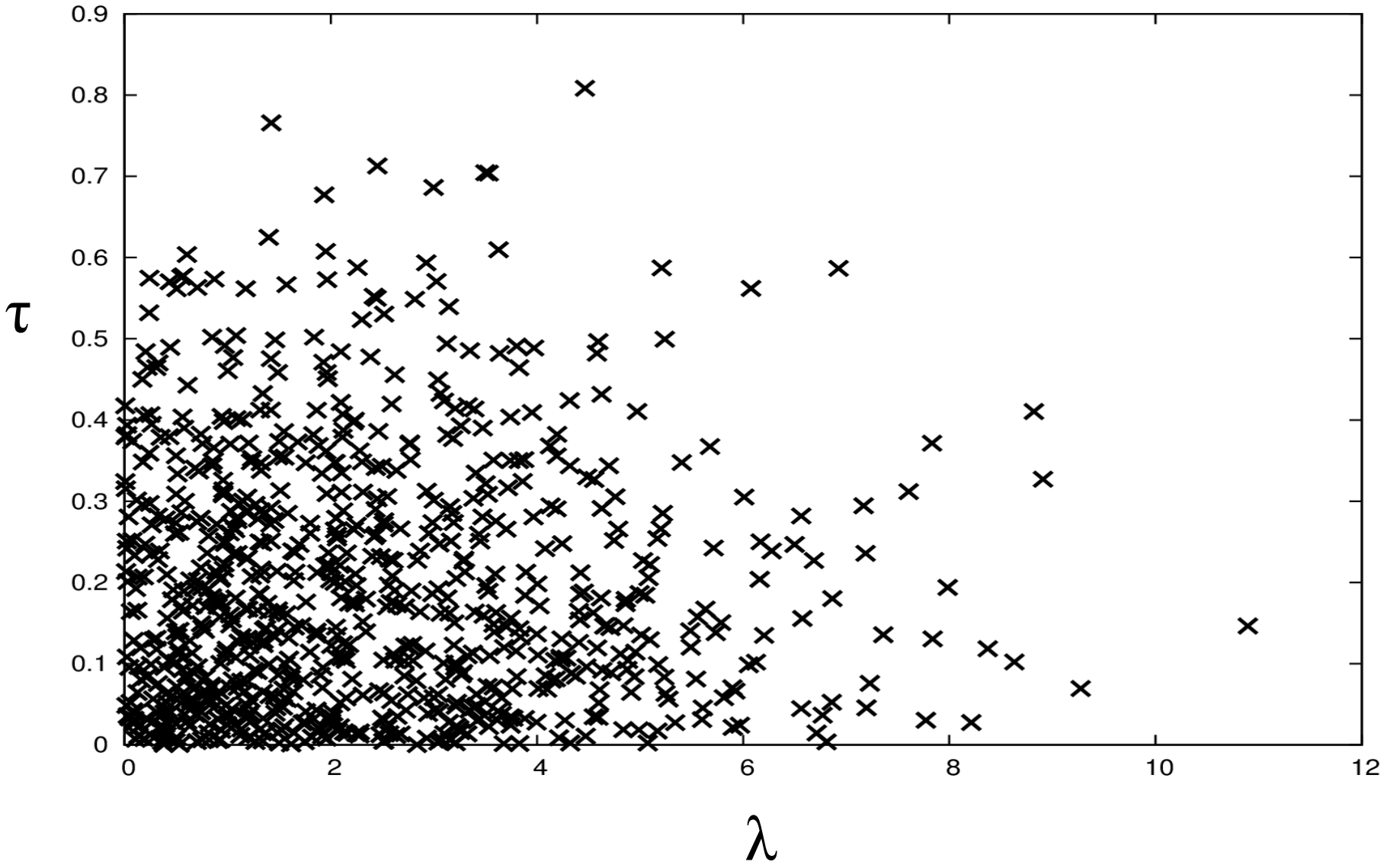


Cells become fitter
but also more stable:
lower $1/\tau - \lambda$

Effect due to reproduction
(collective)



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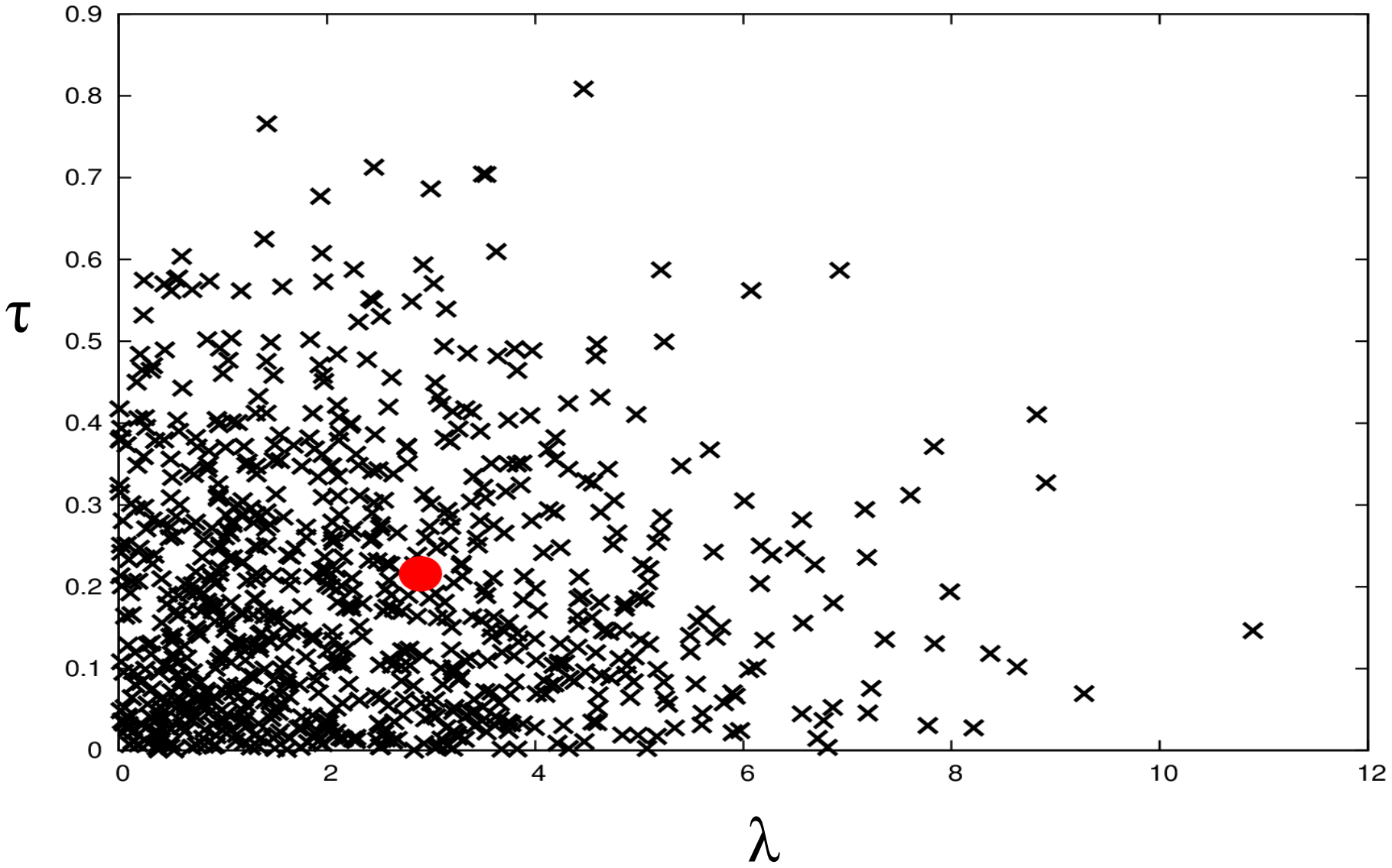

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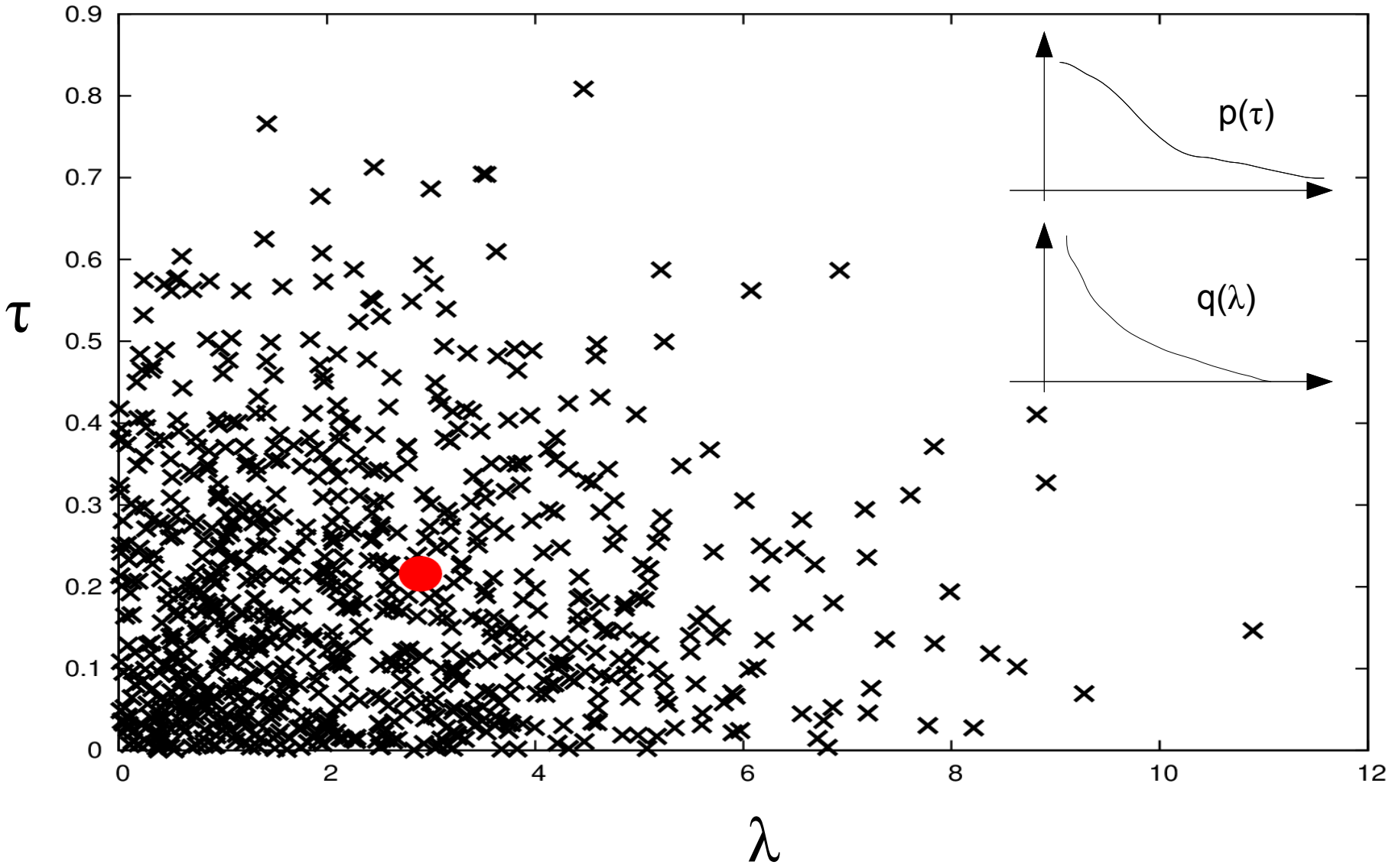

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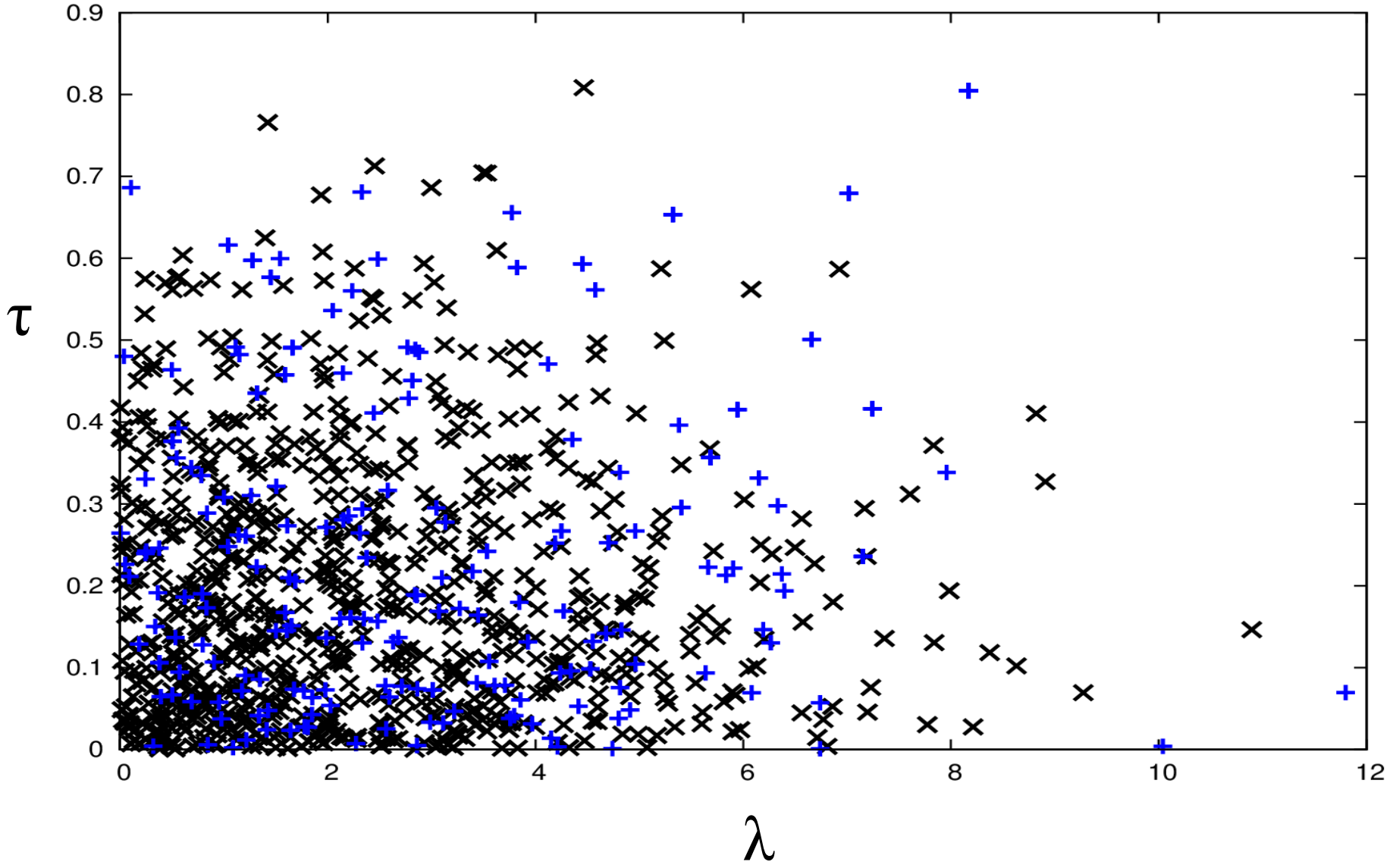

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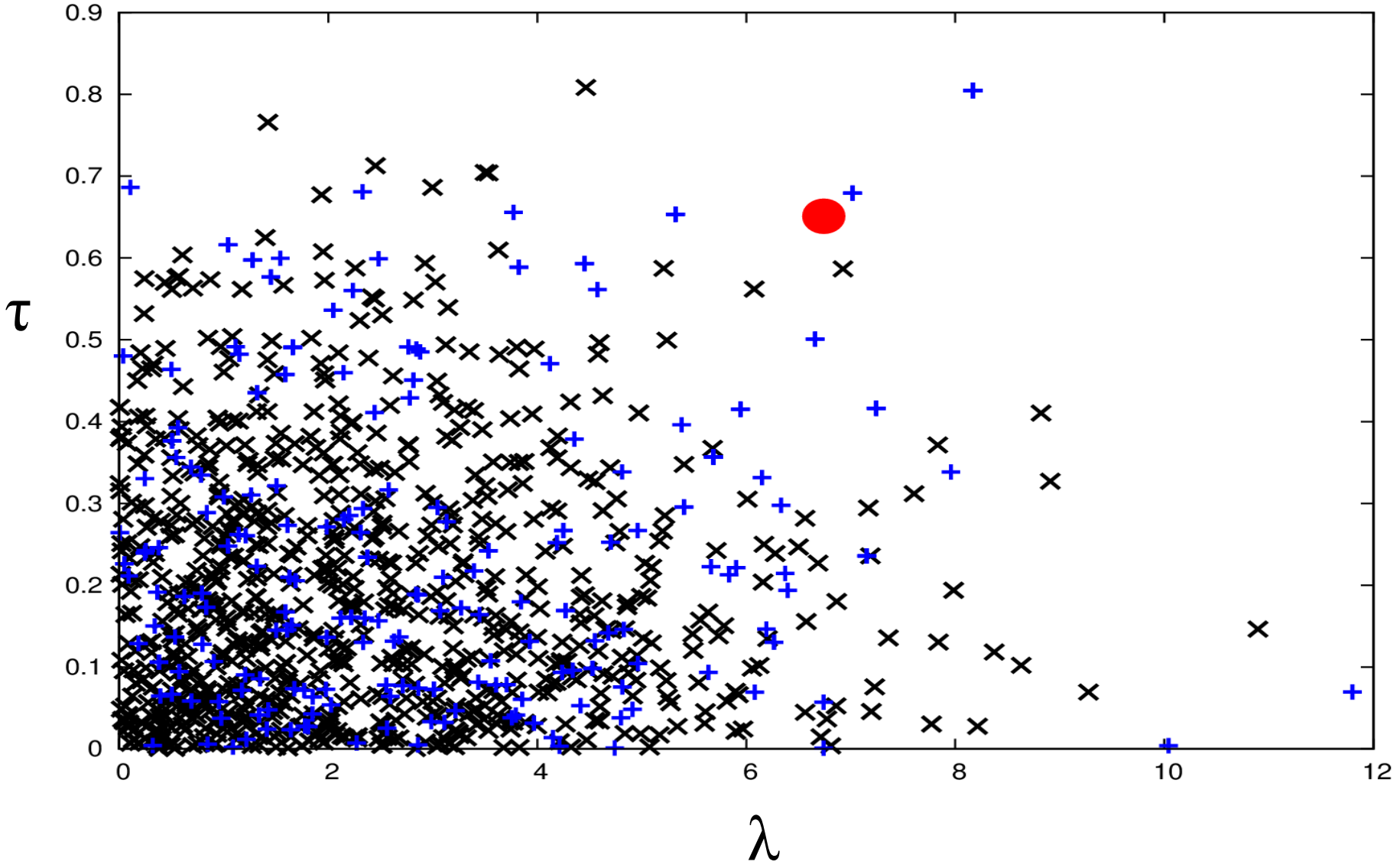

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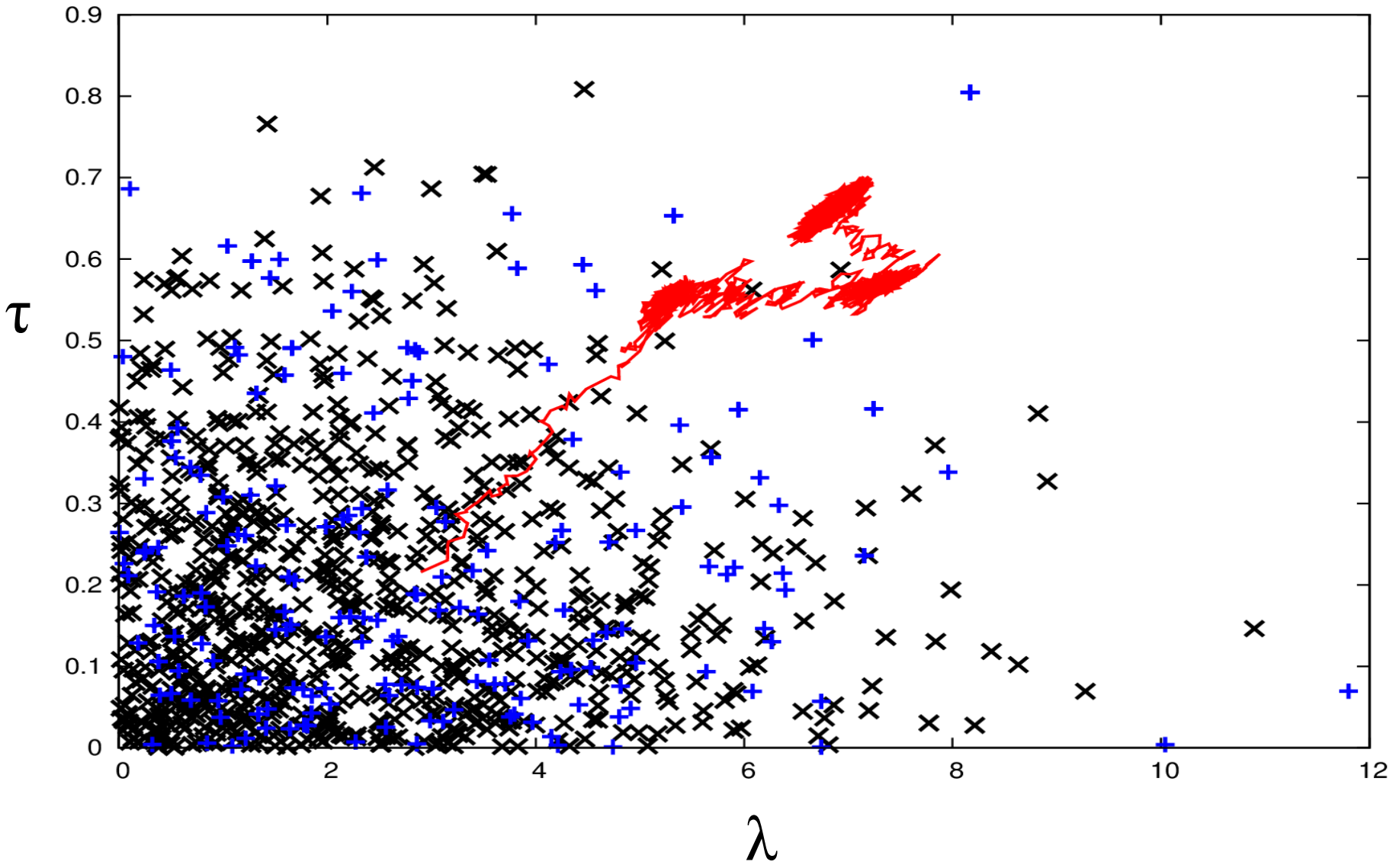

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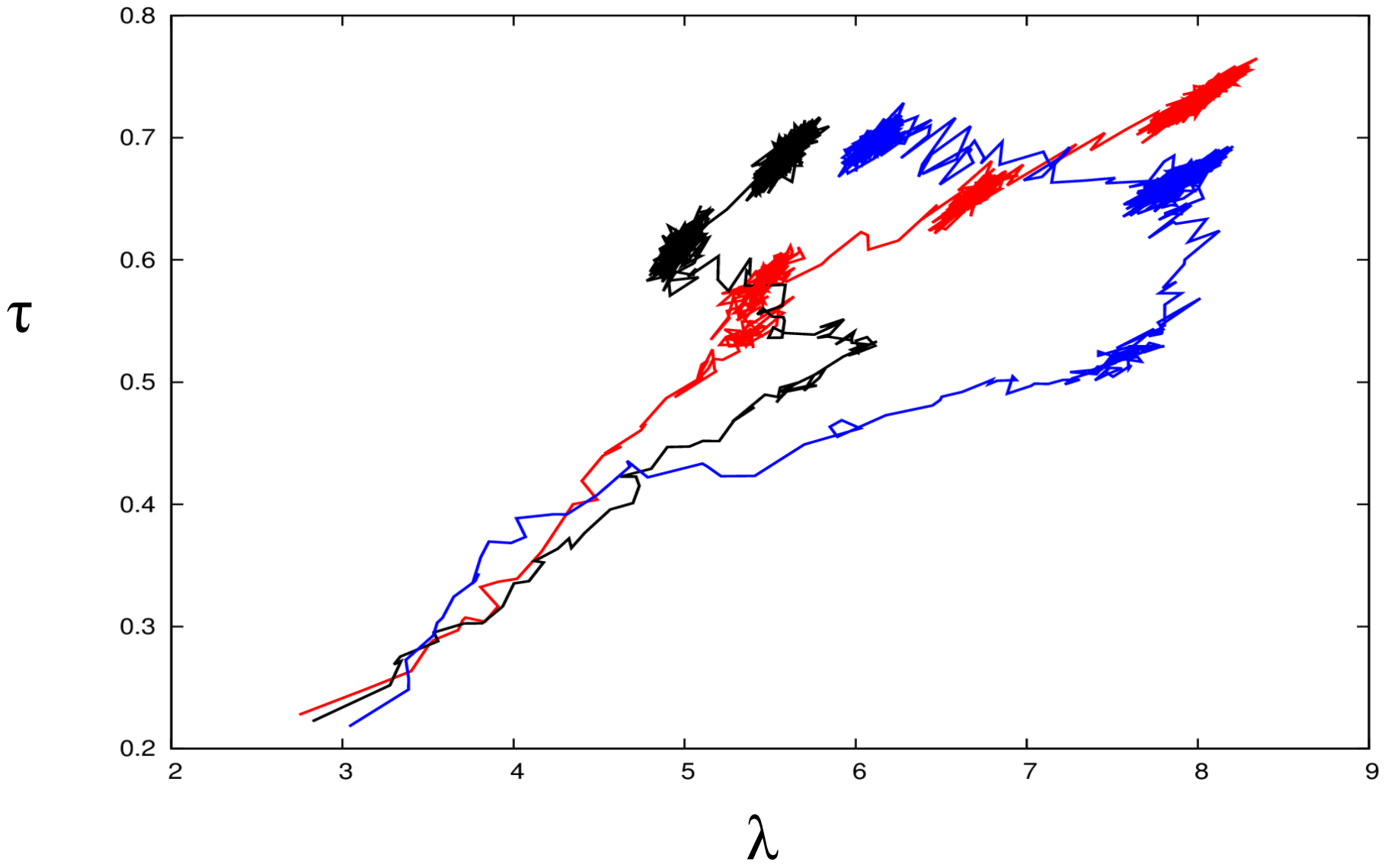
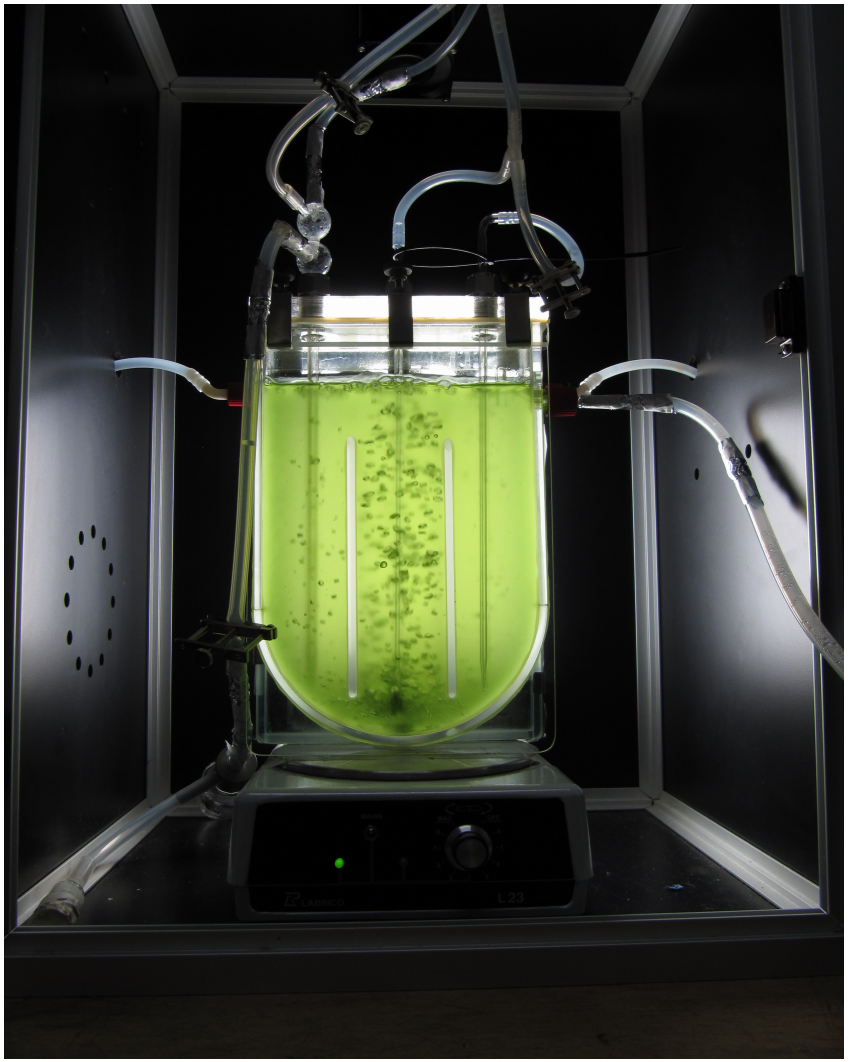
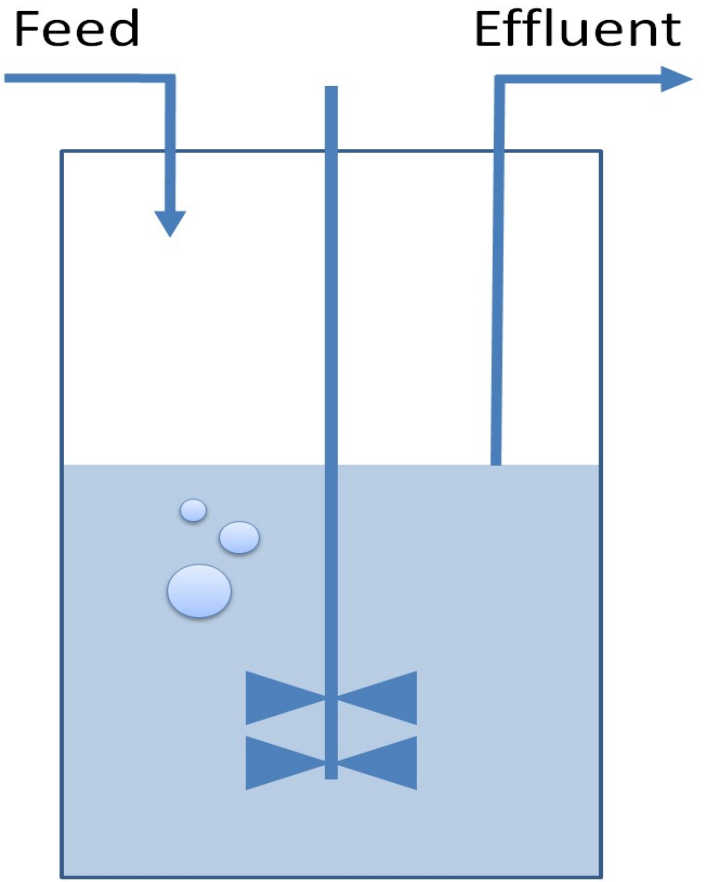


The model works for well-mixed, fully-connected environment

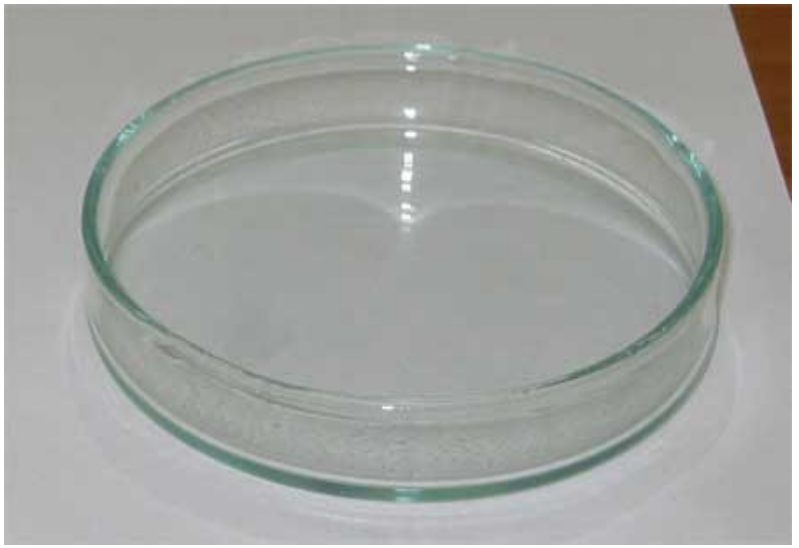
(e.g. chemostat)

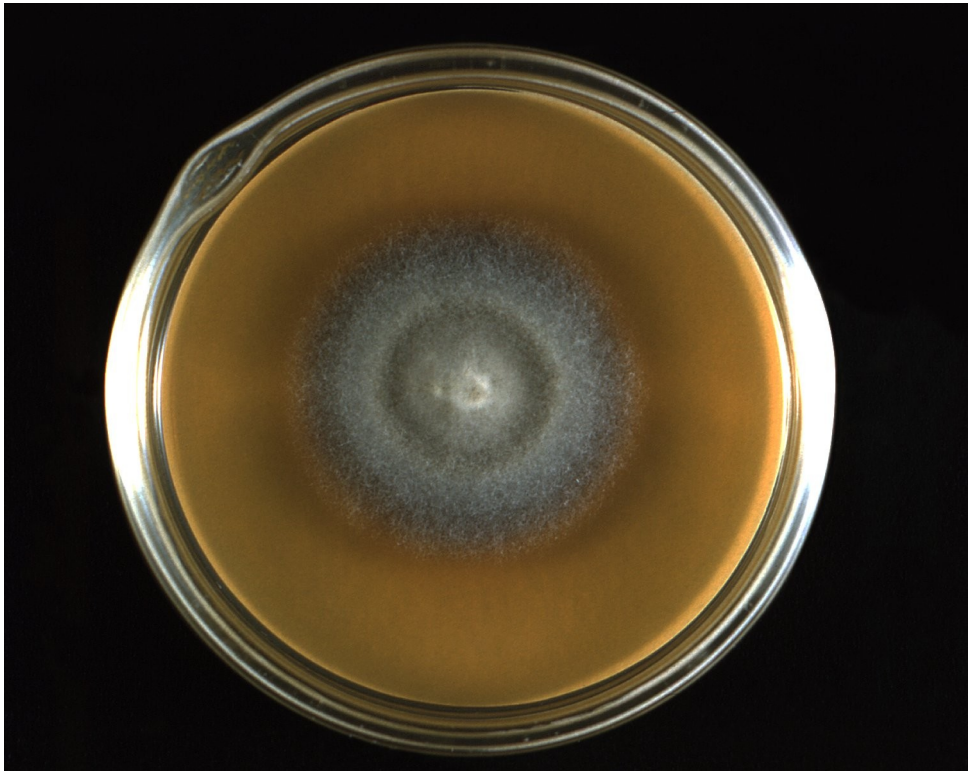




What about space?

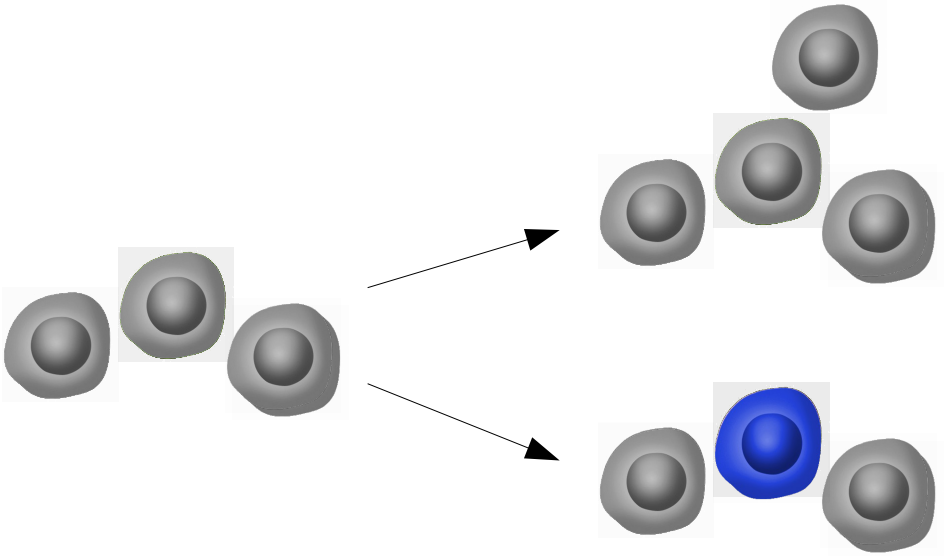
Process in two dimensions: Petri Dish



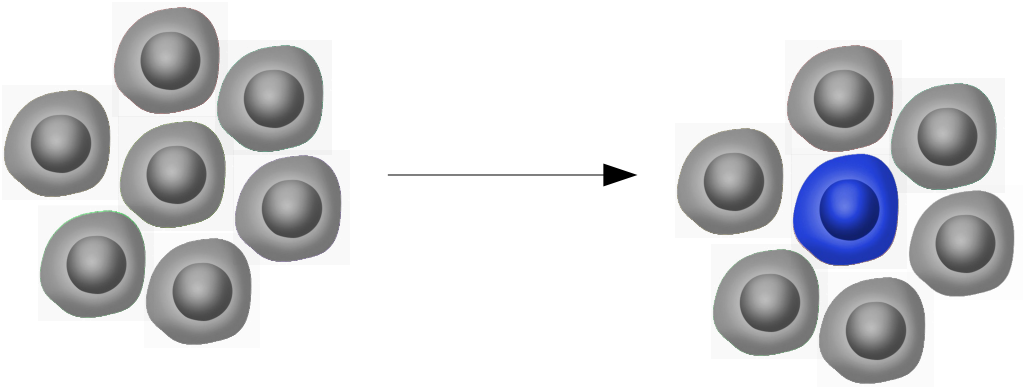


The model

Free space:
reproduce/mutate

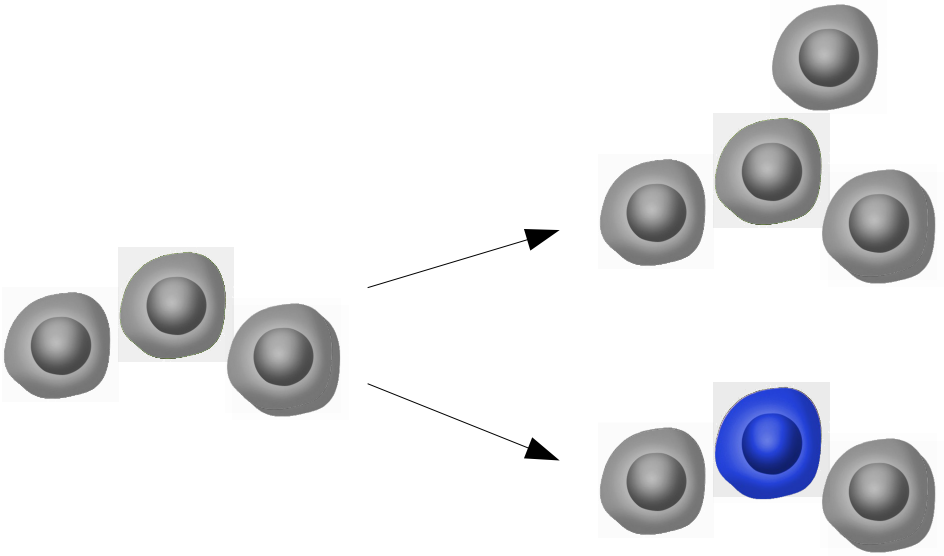


No free space:
mutate only



The model

Free space:
reproduce/mutate



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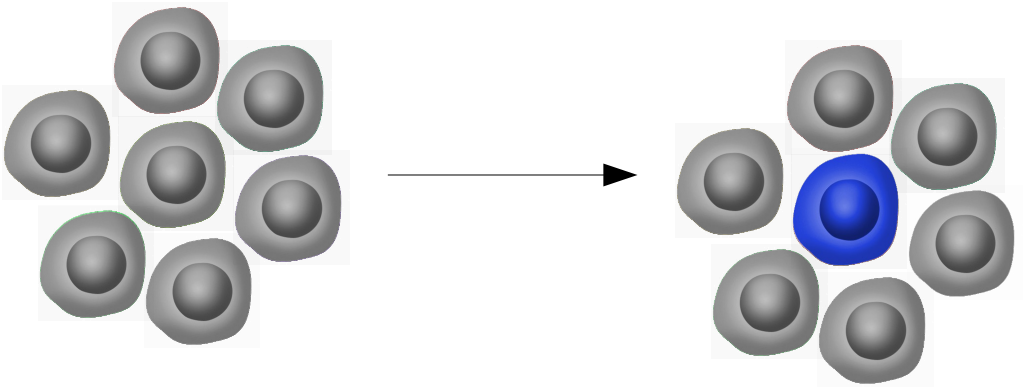
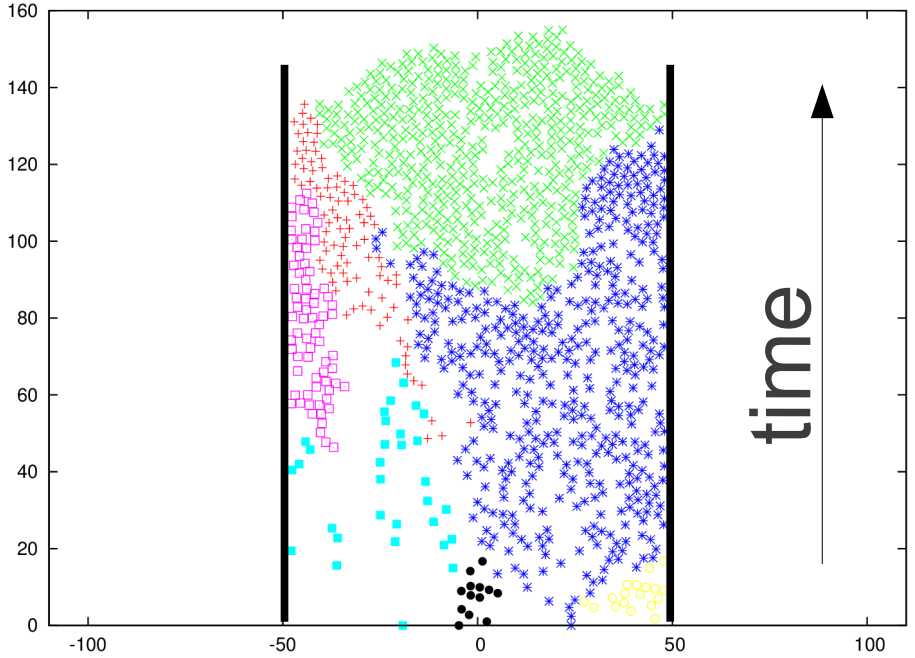


Results:

Longer times to
reach condensation

Selection only while
reproduction is active



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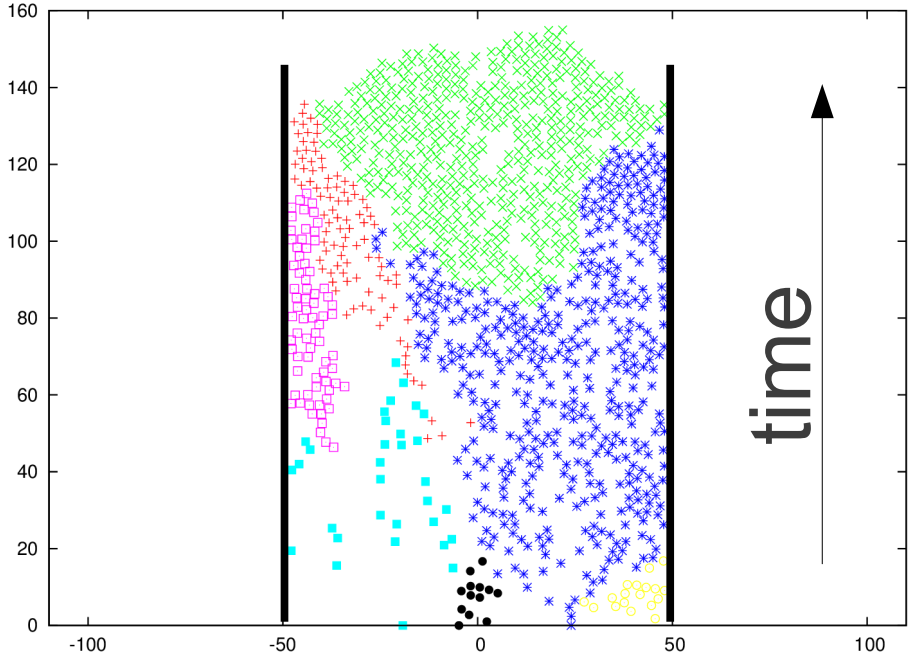

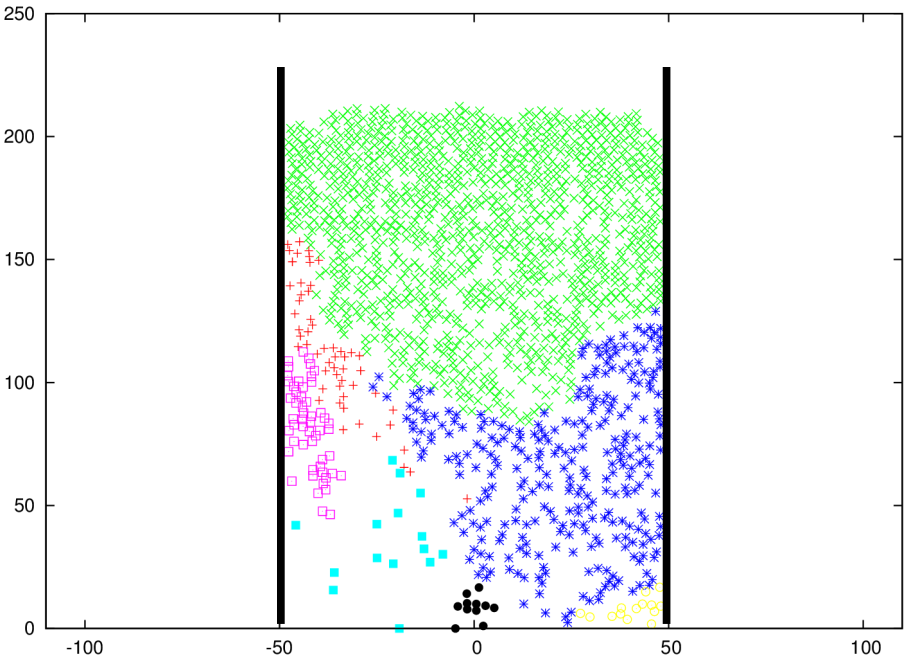

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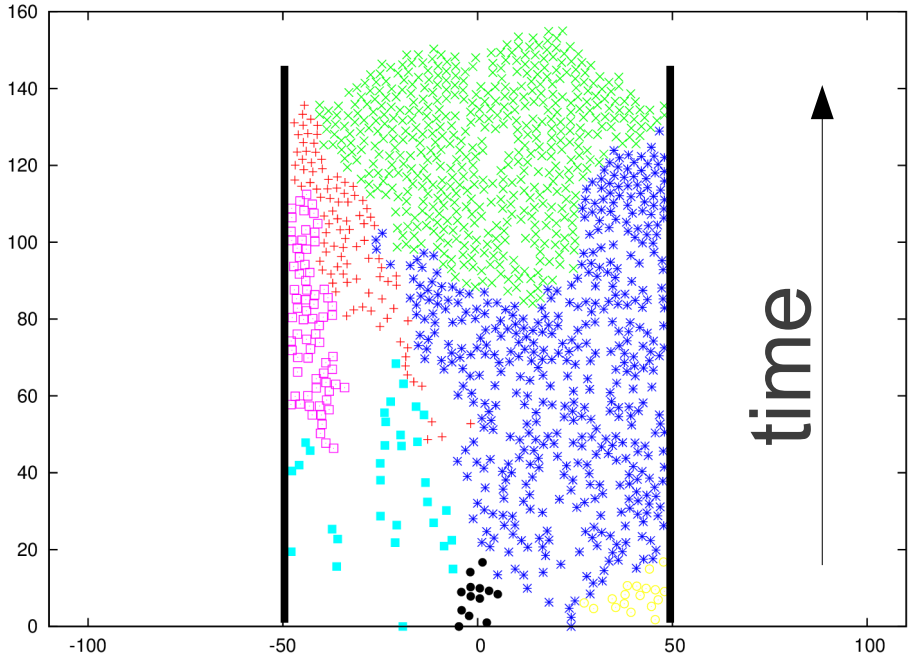

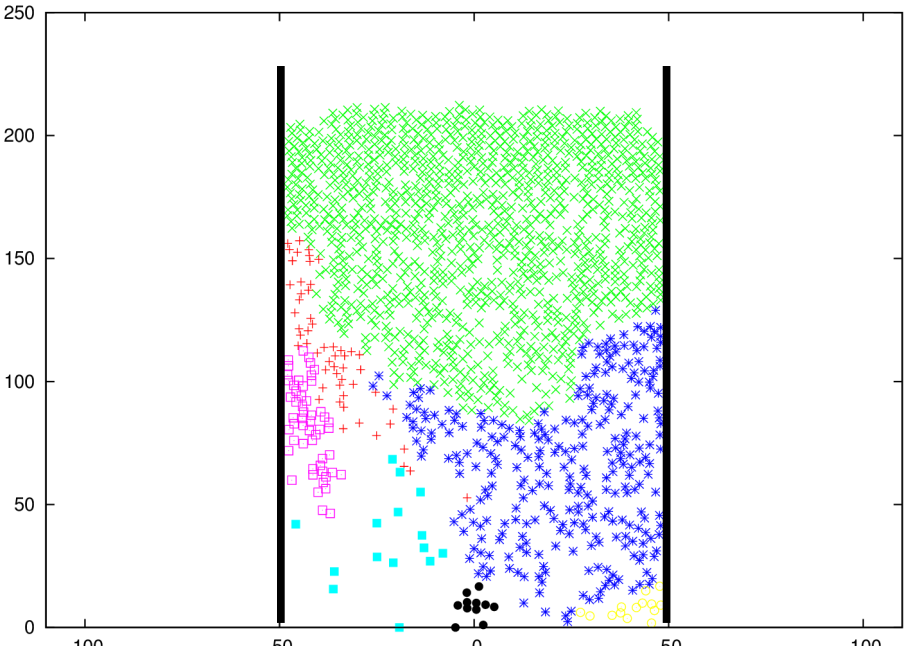

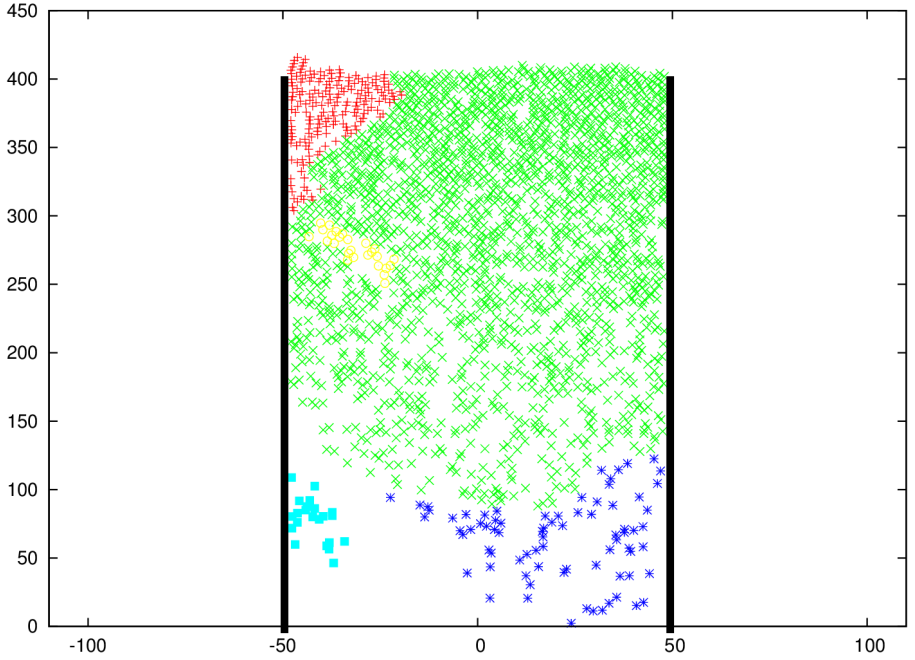

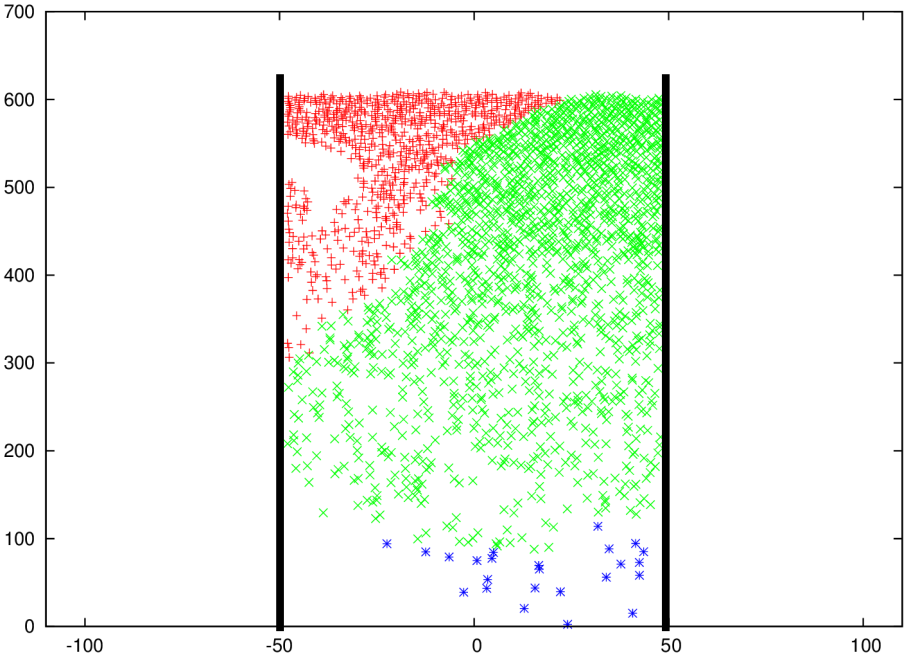

Longer times to reach condensation

Selection only while reproduction is active

And much more...

Thank you.