# AGING OF BIOFILMS USING A SINGLE-CELL GROWTH MODEL

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## INTRODUCTION:

Aging is a loss of function or an accumulation of damage with increasing age.

- Bacteria are not traditionally thought of as exhibiting aging [1].
- Aging has been demonstrated in single-celled organisms, but this is controversial [1, 2, 3, 4].

Strategies for dealing with damage:

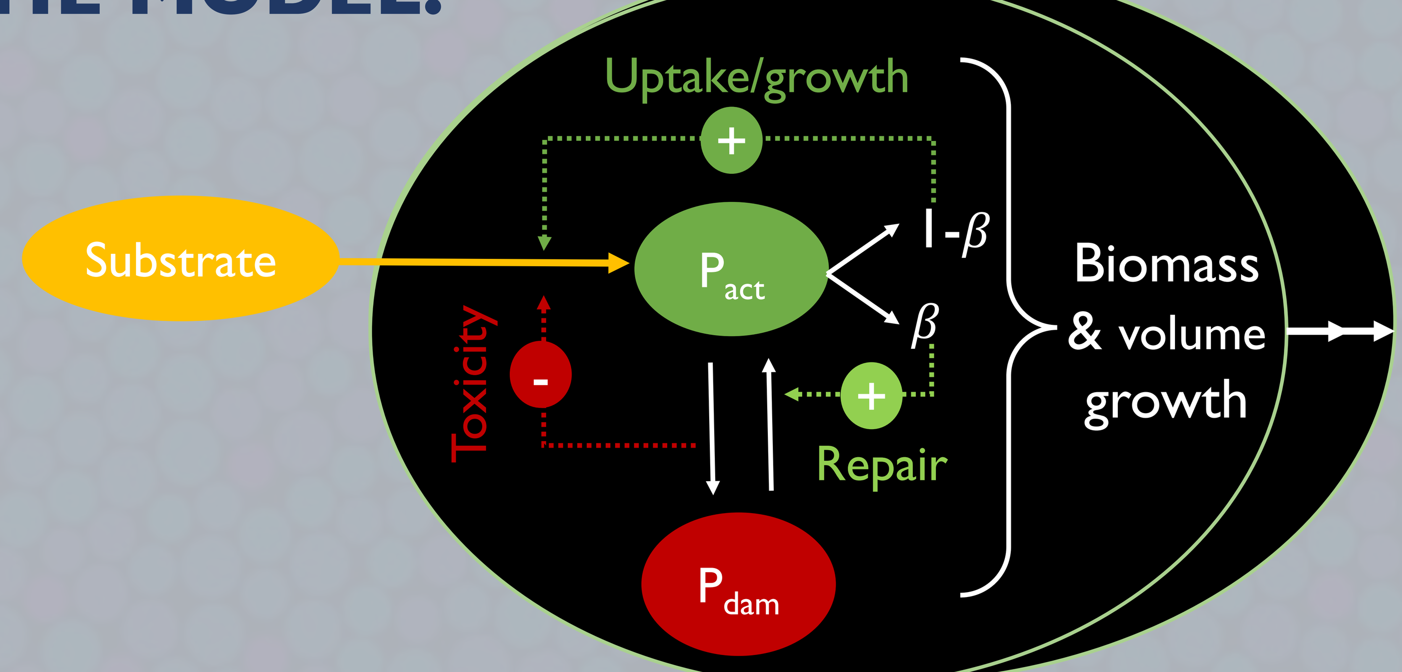
1. Asymmetric damage segregation at division, where the old pole cell inherits all of the damage, and the new pole cell is rejuvenated.
2. Repair of damage.

Our previous study, Clegg *et al.* (2014), found a fixed, optimal investment into repair to be a fitter strategy than segregation of damage for a unicellular organism.

## OBJECTIVES:

1. Develop an adaptive repair strategy for an individual cell within the model, so that repair adapts to the extent of cellular damage.
2. Test this strategy against the previous fixed, optimal repair rate in constant and dynamic environments (comparison with Clegg *et al.*, 2014).
3. Apply this to growth in biofilms.

## THE MODEL:

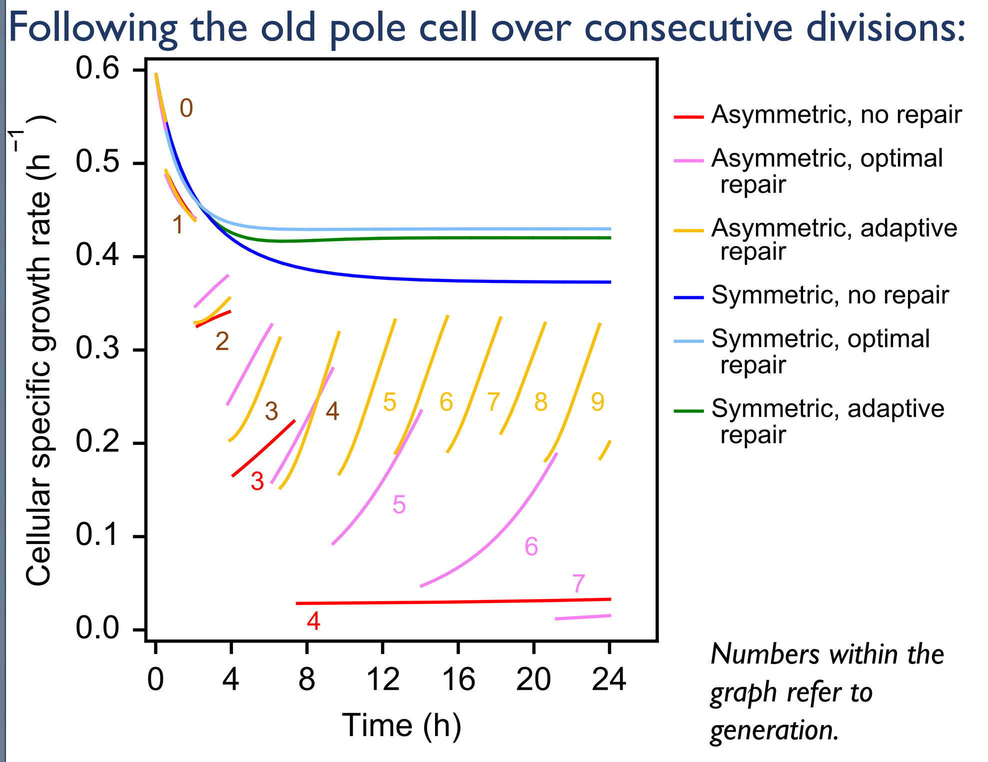



$$P_{dam} \rightarrow P_{gro}^{dam} + P_{rep}^{dam} \qquad P_{act} \rightarrow P_{gro}^{act} + P_{rep}^{act}$$

- Substrate is taken into the cell and converted into biomass.
- Damage is toxic and proportional to cellular specific growth rate.
- Two main strategies for dealing with damage are compared here:
  1. Damage is segregated asymmetrically at division (DS).
  2. Repair ($\beta$) is adaptive, relative to current cellular damage level, and costly (growth is then $1-\beta$), division is symmetric (AR).

## COMPARISON WITH CLEGG *ET AL.* (2014):

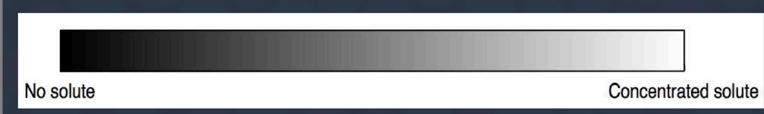
Following the old pole cell over consecutive divisions:



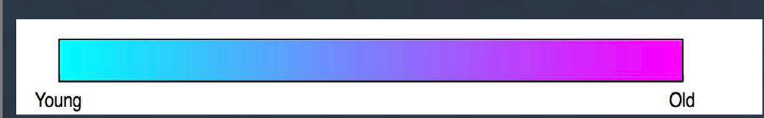

*Numbers within the graph refer to generation.*

- Comparing with all strategies used by Clegg *et al.* (2014).
- *Symmetric strategies:* fixed, optimal repair leads to the highest growth rate.
- *Asymmetric strategies:* adaptive repair cells stay relatively young and therefore have the highest growth rate, but this is costly.
- *Constant environment:* the symmetric fixed, optimal repair is the fittest strategy.
- *Dynamic environment (chemostat):* the symmetric adaptive repair is the fittest strategy.
- *Why is adaptive repair not always the fittest strategy?*
  - Extrinsic mortality balances birth rate keeping population size constant.
  - There is therefore no advantage to the ability to survive past a few generations in age.
  - Having a high growth rate in the first few generations gives the highest fitness benefit in this environment.

### Solute:

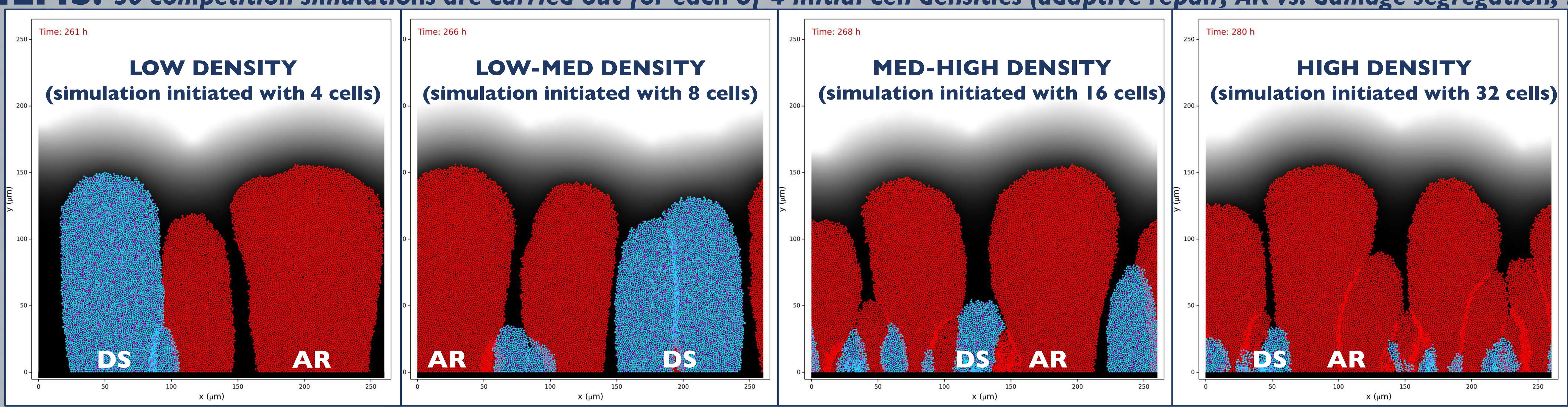



### Single species biofilms:




### Two species biofilms:

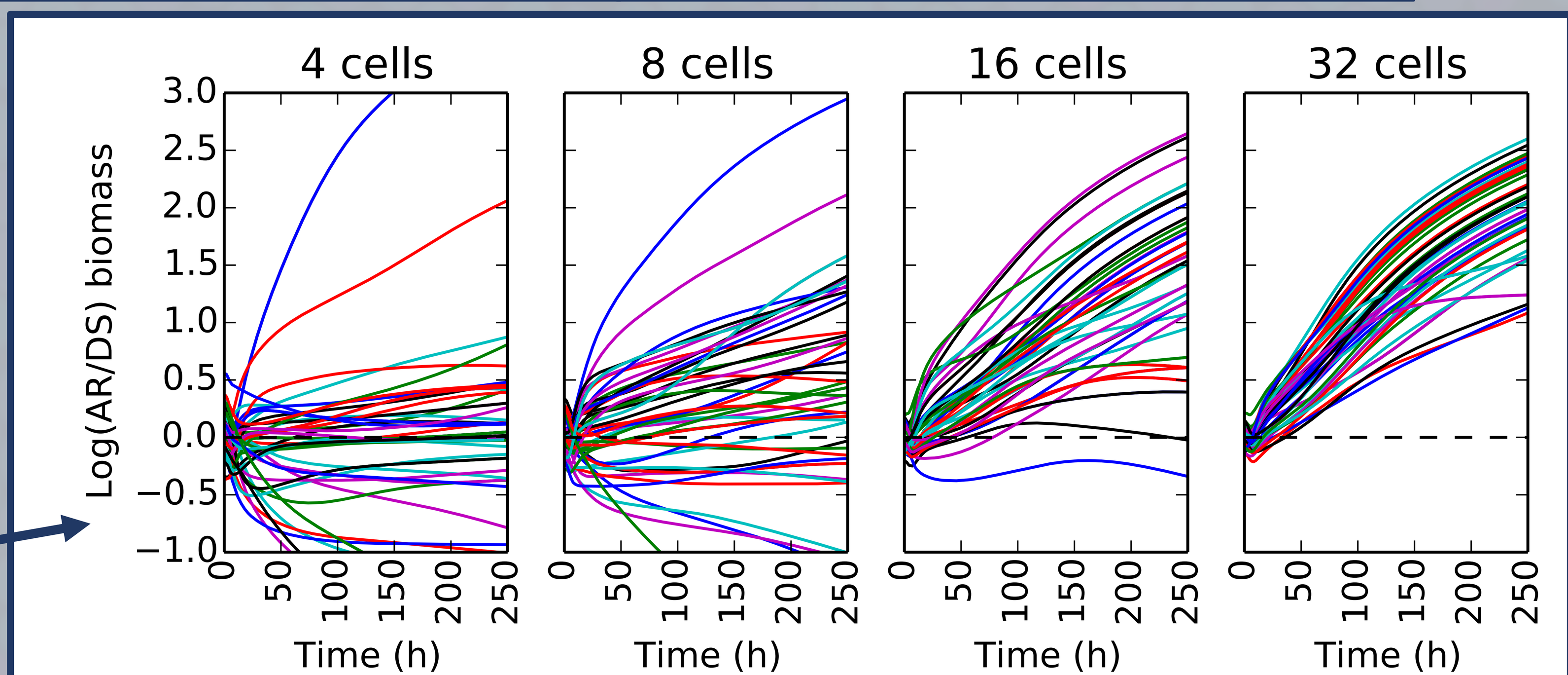

## BIOFILMS: *50 competition simulations are carried out for each of 4 initial cell densities (adaptive repair, AR vs. damage segregation, DS)*




### HOW SHOULD THE FITTEST STRATEGY BE DETERMINED?

- First to reach height threshold, number of cells in active layer, mean growth rate, number of cells, ratio of biomass…
- The adaptive repair strategy always wins.
  - For every initial cell density.
  - Using every measure of fitness considered here.
- The margin by which adaptive repair is fitter than damage segregation, and the significance of the outcome, depends upon initial cell density.
- The more cells the simulation is initiated with, the clearer the winner.

➔ **Log ratio of biomass:** Log(adaptive repair/damage segregation).




## CONCLUSIONS:

***Constant/dynamic:*** Adaptive repair is the fitter strategy only when the environment is stressful, meaning that the benefit of repair outweighs the cost.

***Biofilms:*** Adaptive repair is again the fitter strategy, but the significance of this depends upon initial cell density. If initial cell density is low, the adaptive repair wins marginally more frequently, but there is no significantly fitter strategy. At higher initial cell densities, the adaptive repair strategy is clearly the fitter strategy.

## REFERENCES:

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