

# Spatial Quorum Sensing Modelling Using Coloured Petri Nets and Simulative Model Checking

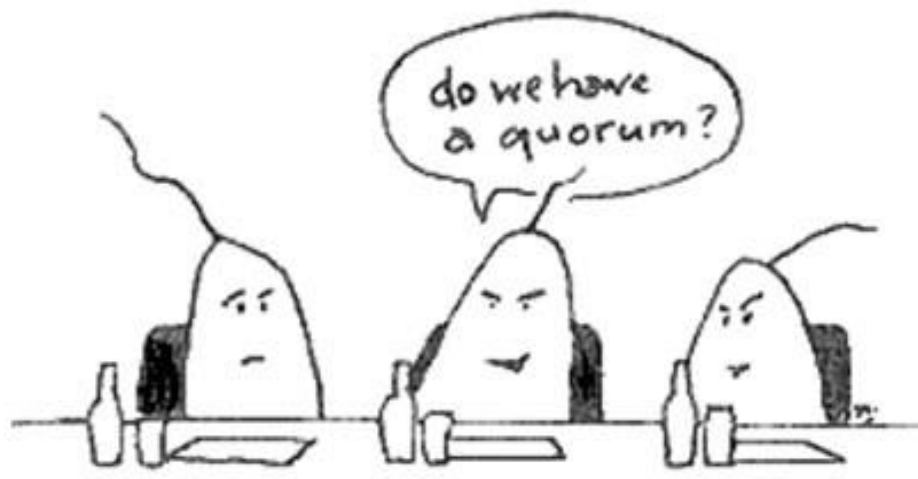
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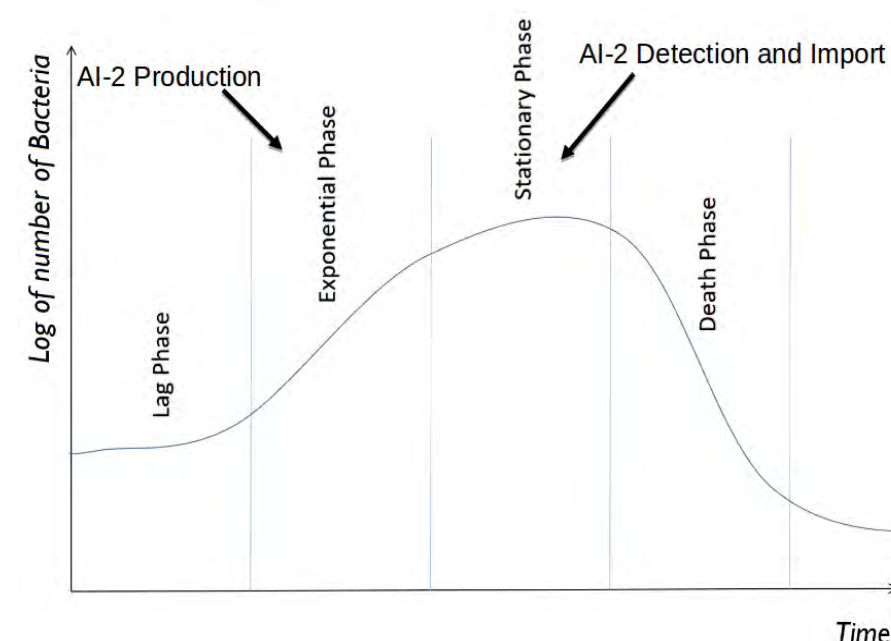
## 1 Bacterial Communication: Quorum Sensing

Bacterial communication based on population density is called quorum sensing. Quorum sensing has many consequences, which the most important one is biofilm formation.



Biofilm formation has two parts:

- The signalling molecule (AI) production in second phase of bacteria life
- Biofilm formation in the third phase.

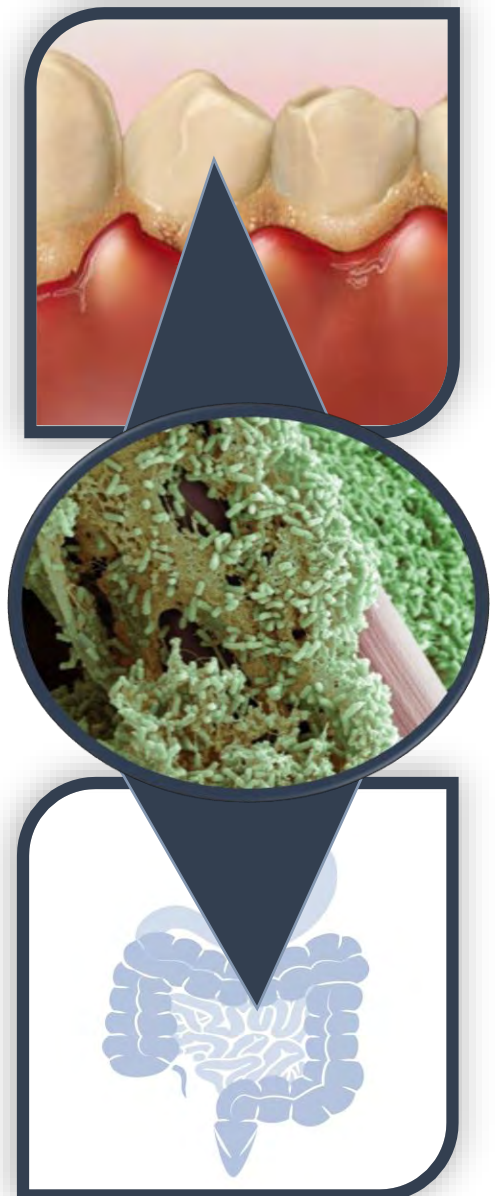


## 2 Why Biofilm is Important?

Biofilm makes the bacteria resistant to environmental changes and antibiotics. They are the cause of 65% of hospital infections and may increase the risk of cancer.

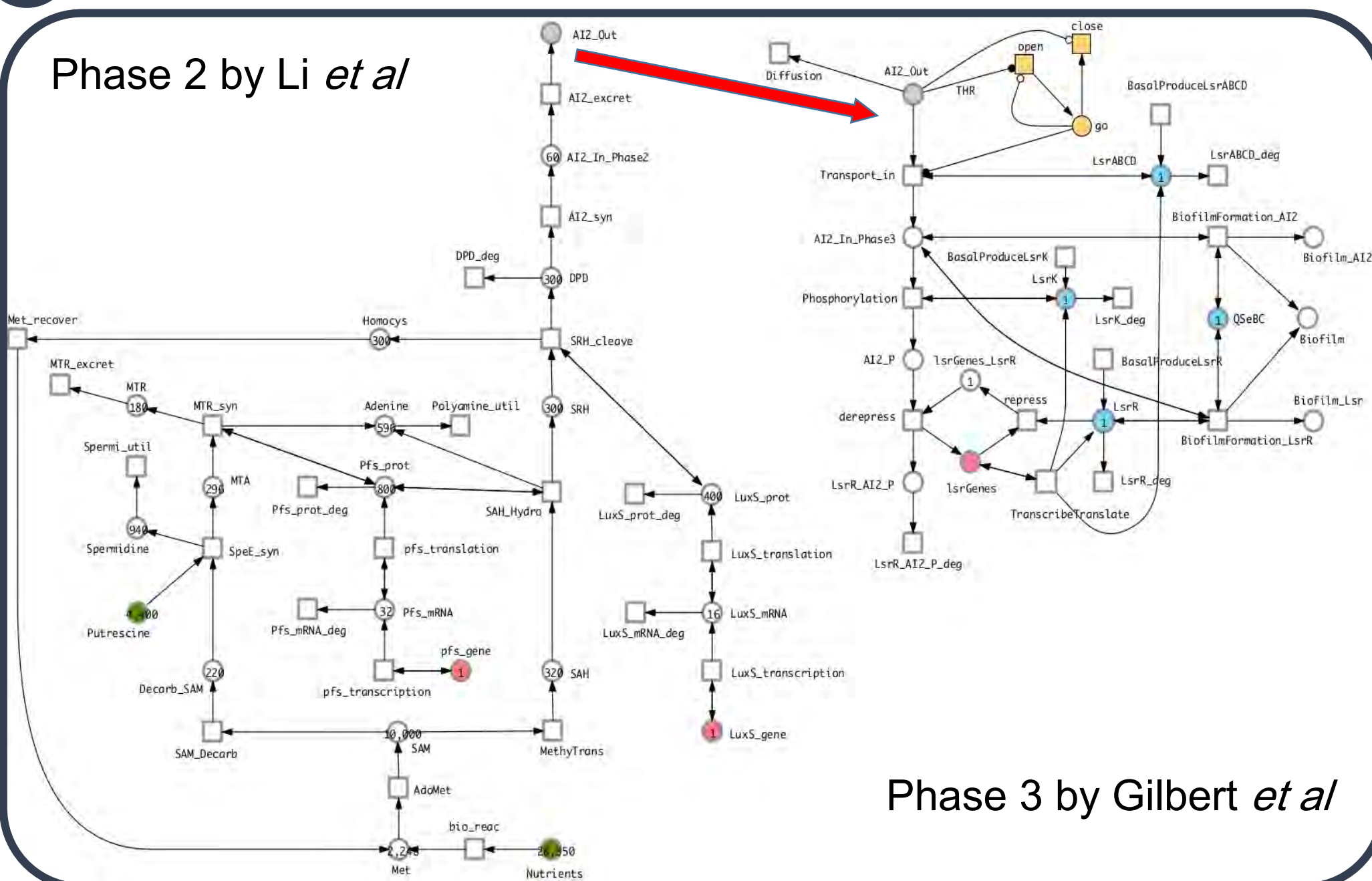
On teeth, the undisturbed biofilm transforms to form tooth plaques.

In the gut, biofilm can cause gut related discomforts and diseases.



## 3 Combining 2 Models of Two different Phases

Phase 2 by Li *et al*

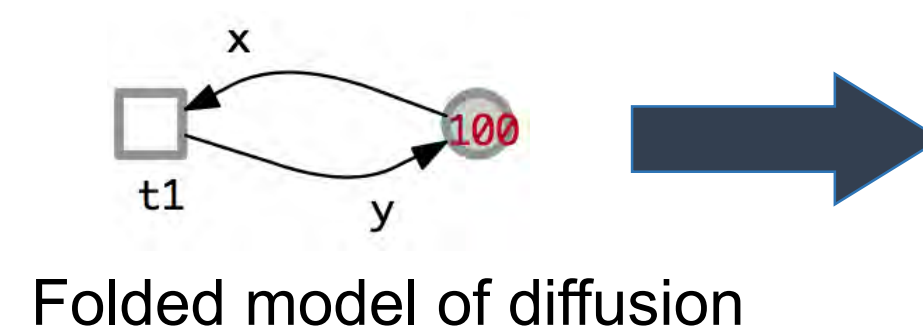


Phase 3 by Gilbert *et al*

## 4 Coloured Petri Nets

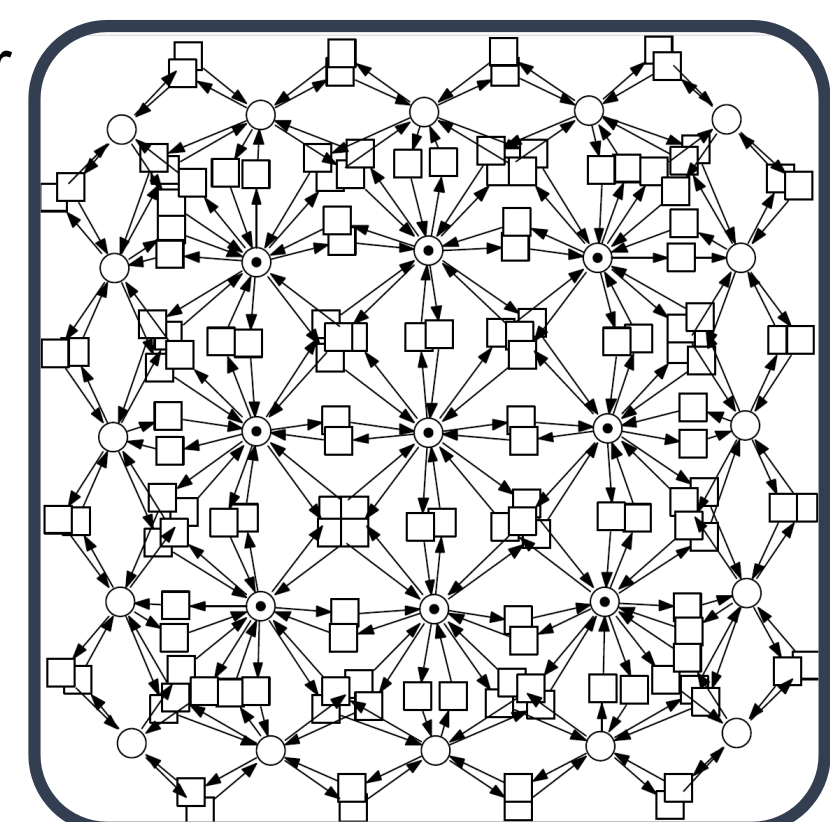
Coloured Petri nets can be used to model space, location and multi-dimensional attributes of the model.

Using Coloured Petri nets we can fold a repeated network in one model. It is easier to update and edit the folded model.



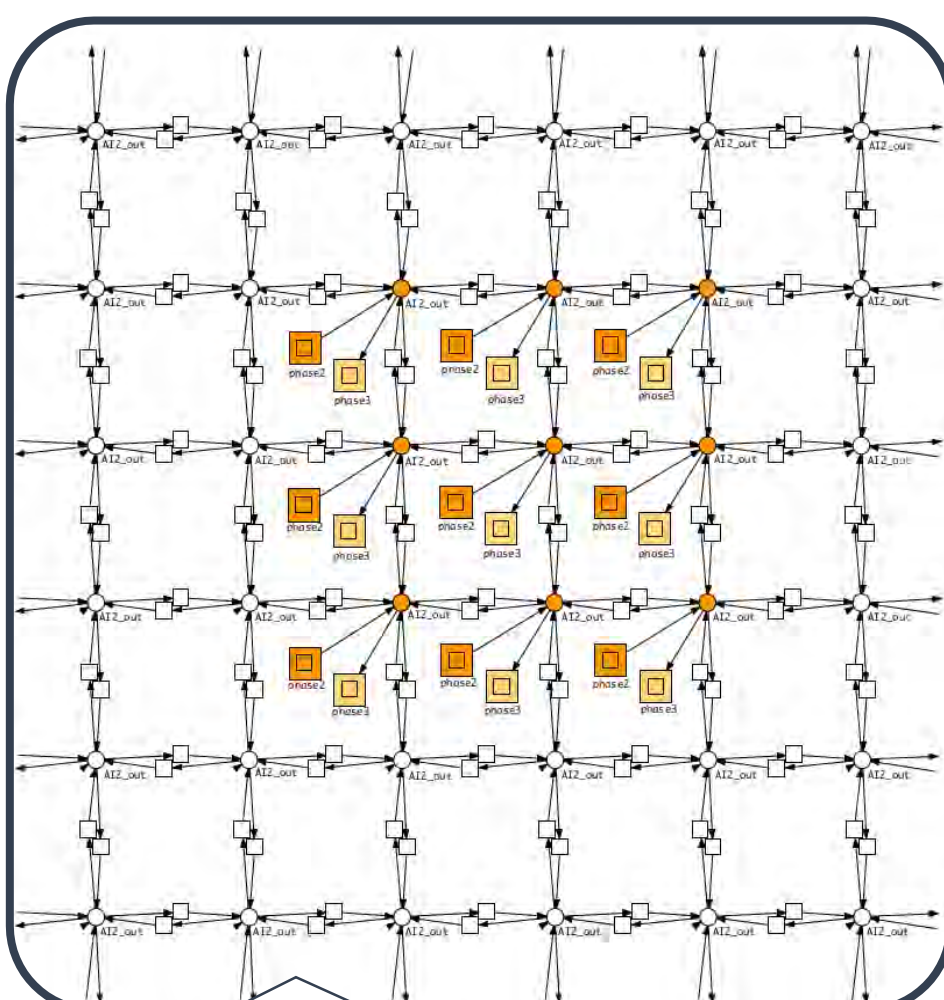
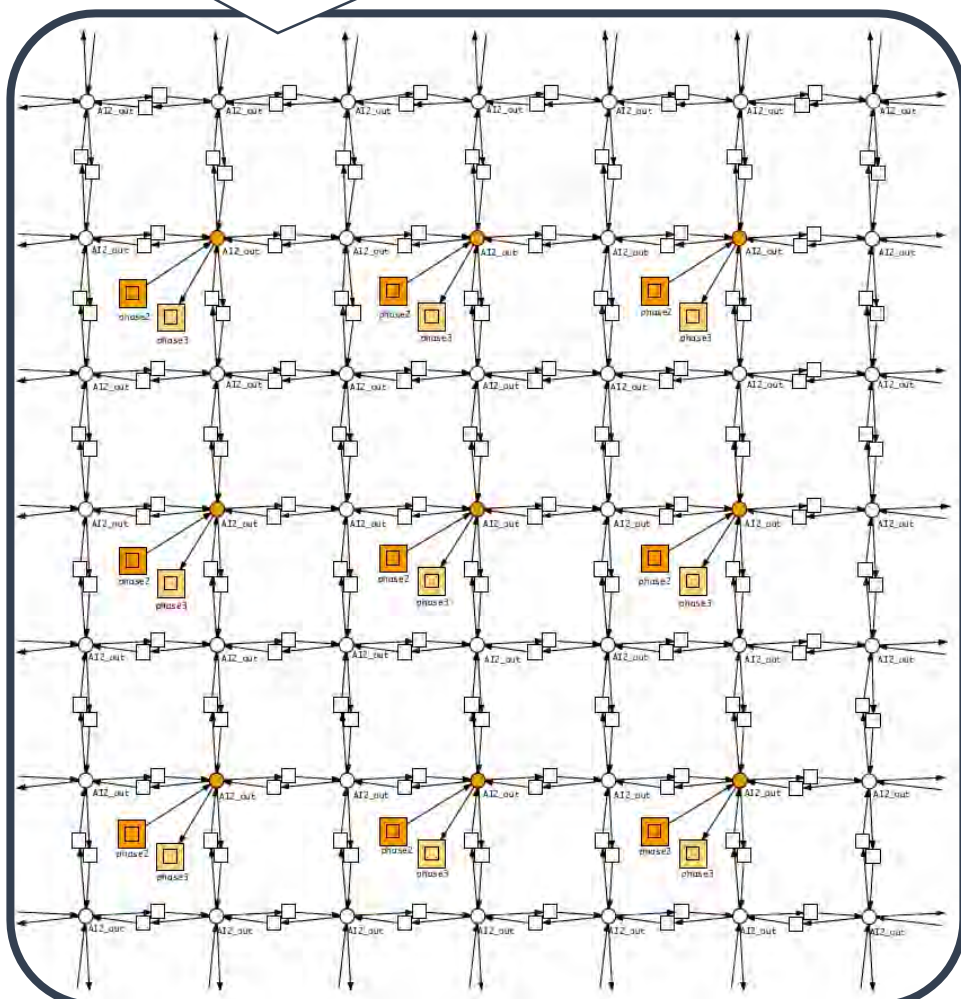
Finally, we can unfold it and see how the model looks like on a 2D or 3D grid and then simulate the unfolded version

Unfolded 2D diffusion model



## 5 Space, Location and Sparseness

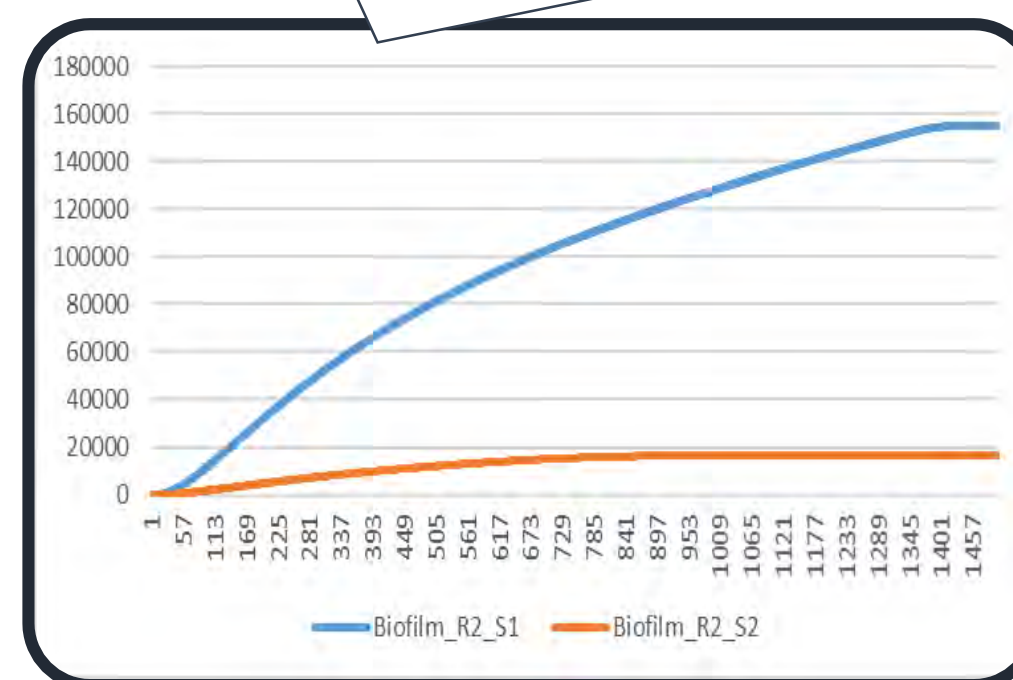
A colony of 9 bacteria located with one empty position between each occupied one



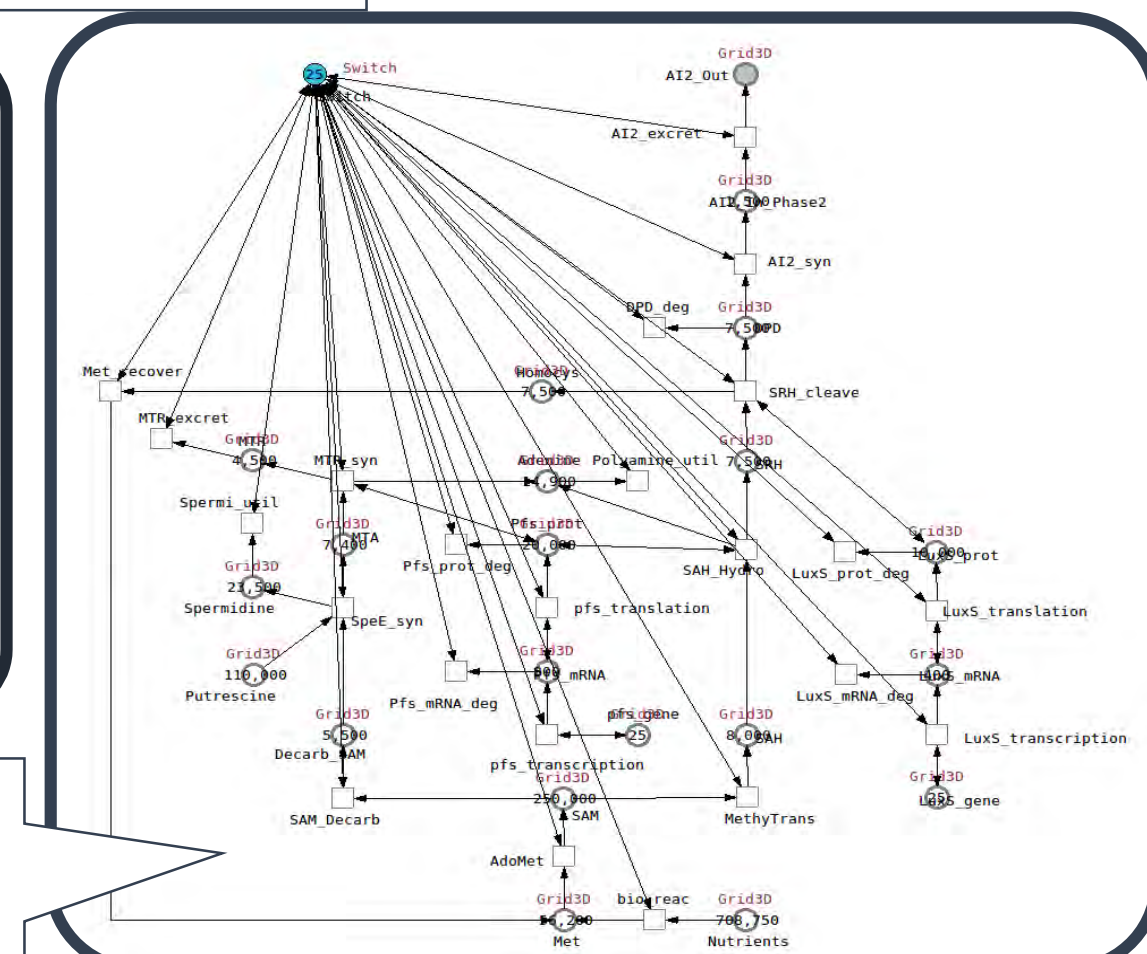
A colony of Compact bacteria with no gaps between occupied positions

## 6 Results and Further Work

Result of the study:  
More biofilm in compact population



Further work:  
Switch System to control AI production in a heterogeneous population



References

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2. Rossi, E., Cimdins, A., Lüthje, P., Brauner, A., Sjöling, Å., Landini, P., Römling, U.: "It's a gut feeling"—Escherichia coli biofilm formation in the gastrointestinal tract environment. *Critical Reviews in Microbiology*, 1–30 (2017)
3. Maslowski, K.M., Mackay, C.R.: Diet, gut microbiota and immune responses. *Nature immunology* 12(1), 5–9 (2011)
4. Novak, E.A., Shao, H., Daep, C.A., Demuth, D.R.: Autoinducer-2 and QseC control biofilm formation and in vivo virulence of *Aggregatibacter actinomycetemcomitans*. *Infection and immunity* 78(7), 2919–2926 (2010)
5. Gilbert, D., Heiner, M., Ghanbar, L. and Chodak, J., 2018. Spatial quorum sensing modelling using coloured hybrid Petri nets and simulative model checking.