Stochastic Spatial Model for Yeast Biofilm Social Interactions: Investigating the Fitness Benefits of Within-Strain Cooperation

Adrienna Bingham, Aparajita Sur, Leah Shaw, Helen Murphy

William and Mary

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Susceptibility of Cooperation

- Cooperation requires individuals to engage in behaviors that are costly to themselves, but beneficial to others
- Do not normally form stable communities
- They are susceptible to cheaters
  - Cheaters benefit from cooperation, but do not contribute
- Cheaters outgrow cooperators
- Cooperators become extinct


[1]

[1] https://kids.nationalgeographic.com/animals/vampire-bat/#vampire-bat-hanging.jpg

Kin Recognition

- Kin selection results from an increase in the cooperative gene in a population
- Therefore, cooperation can evolve through kin selection


[3]

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[2] https://nationalzoo.si.edu/animals/black-tailed-prairie-dog

[3] https://digitalmedia.fws.gov/digital/collection/natdiglib/id/23473/rec/5

[4] Waldman, B. (1988). The ecology of kin recognition. Annual review of ecology 499 and systematics 19(1)

Kin Recognition

- Kin selection results from an increase in the cooperative gene in a population
- Therefore, cooperation can evolve through kin selection
- One way kin selection works is with kin recognition

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- Ability of an individual to recognize kin or individual in genetic lineage [4]
- Cooperators restrict cooperation to kin
- Most examples of cooperation are kin recognition

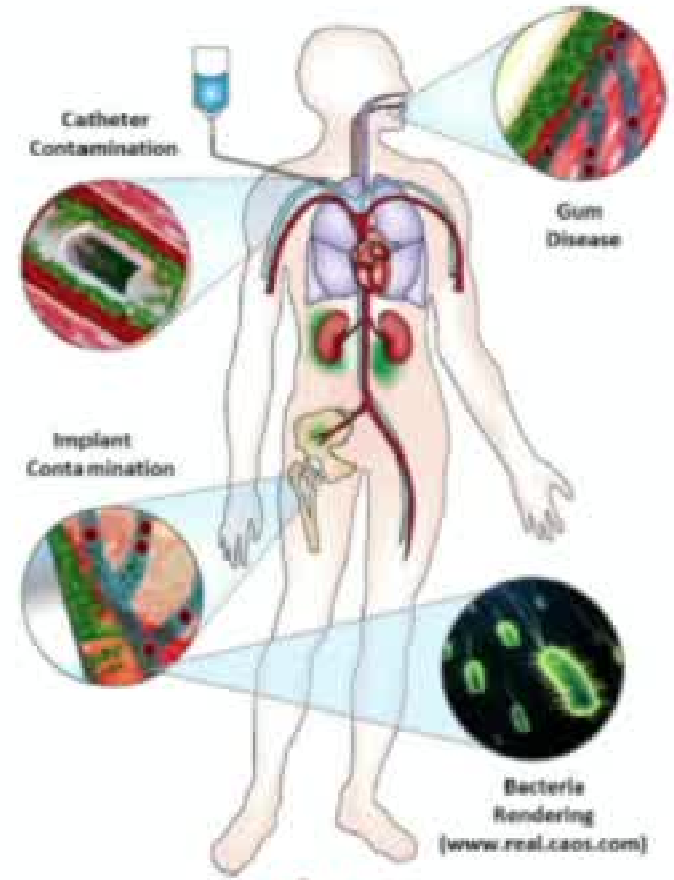
[2] https://nationalzoo.si.edu/animals/black-tailed-prairie-dog

[3] https://digitalmedia.fws.gov/digital/collection/natdiglib/id/23473/rec/5

[4] Waldman, B. (1988). The ecology of kin recognition. Annual review of ecology 499 and systematics 19(1)

Cooperation in Microbial Communities

- Much more research being done on social interaction in microbes
- Biofilms are microbial cooperative communities
  - Attached to a surface
  - Protected by an extracellular matrix
  - Kin selection evident just because of clonal growth [5]
- Is there a benefit for cooperators in biofilms to express kin recognition?



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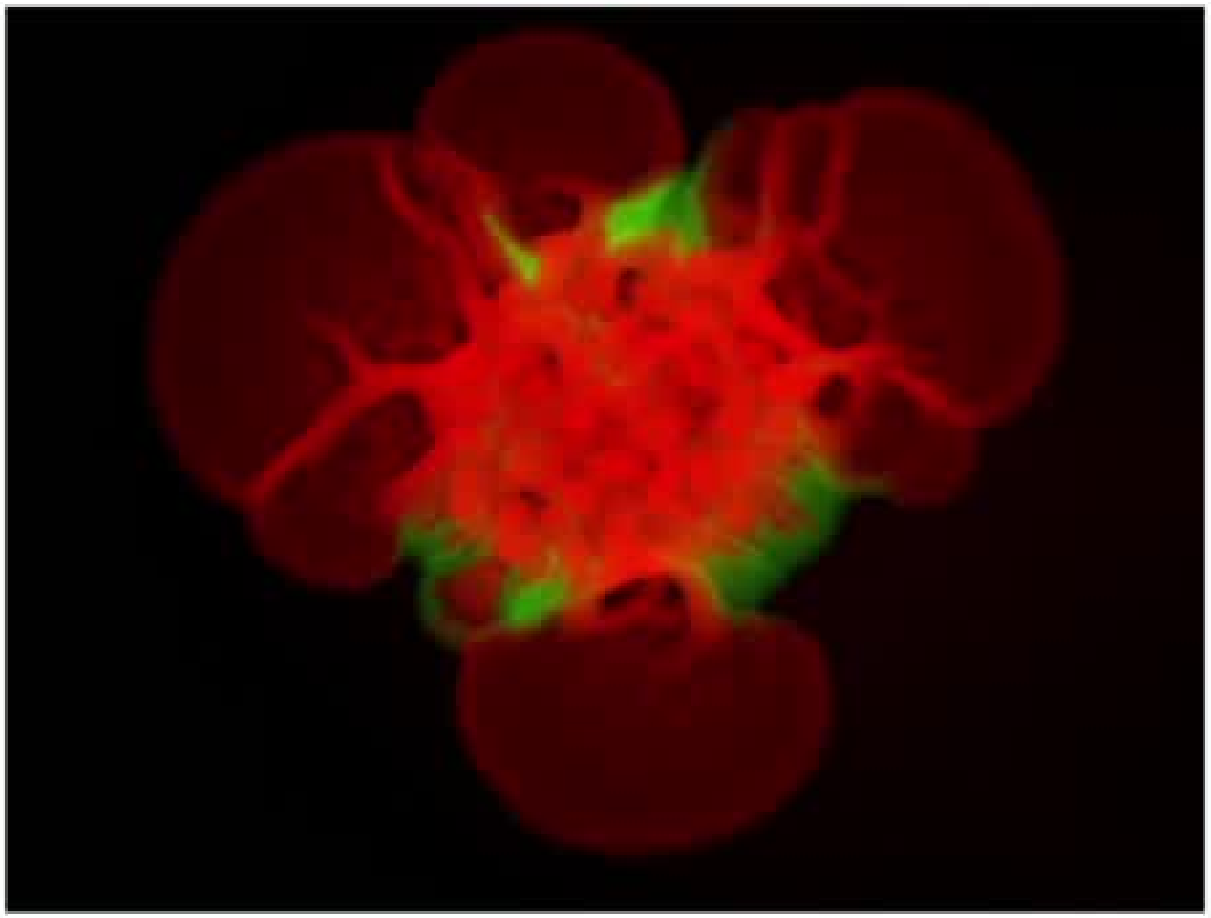
[5] Nadell, Drescher, Foster (2016). Spatial structure, cooperation and competition in biofilms. Nat Rev Micro.

[6] Bixler & Bhushan (2012). Biofouling: lessons from nature. Phil. Transactions of the Royal Soc. of London.

[7] http://www.tactengineering.com

Saccharomyces cerevisiae

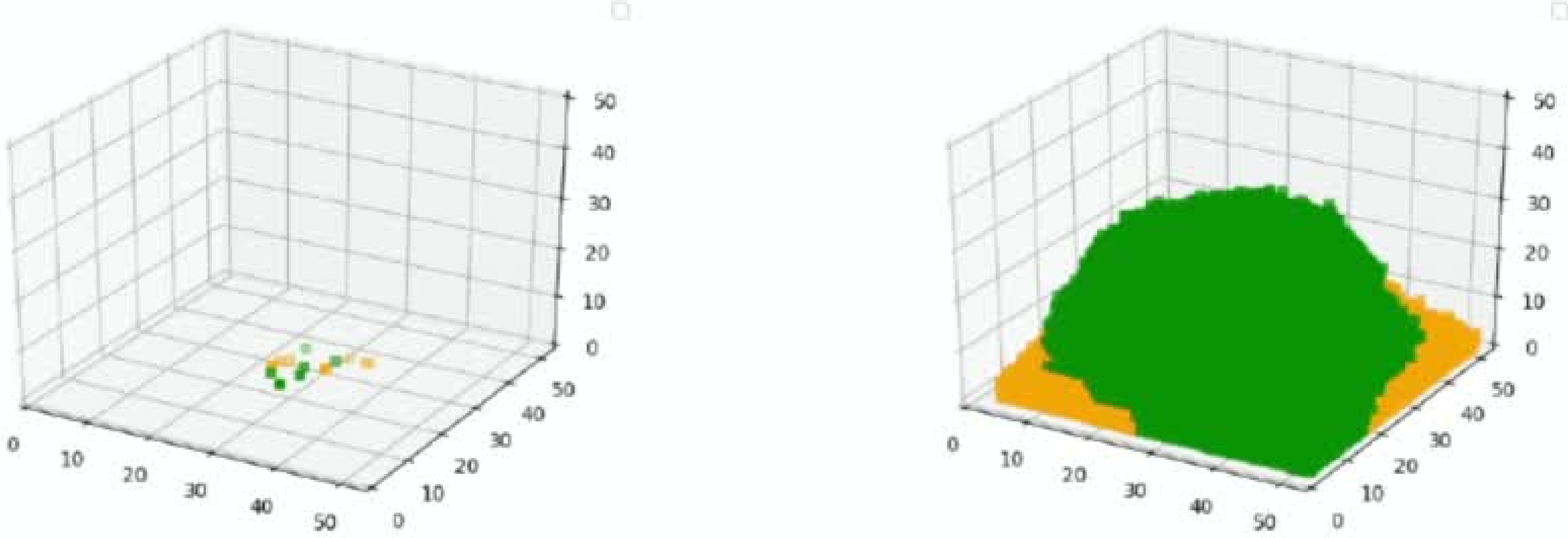


- Model organism
- Common laboratory yeast/baker's yeast
- Exhibit social behaviors such as biofilm formation and cooperation [8]
- Now shown to exhibit kin recognition [9]

[8] Reynolds, T. B. and G. R. Fink (2001). Bakers yeast, a model for fungal biofilm formation. Science.

[9] Smukalla, et al. 2008 FLO1 Is a variable green beard gene that drives biofilm-like cooperation in budding yeast. Cell.

Simulating the Growth of Biofilms

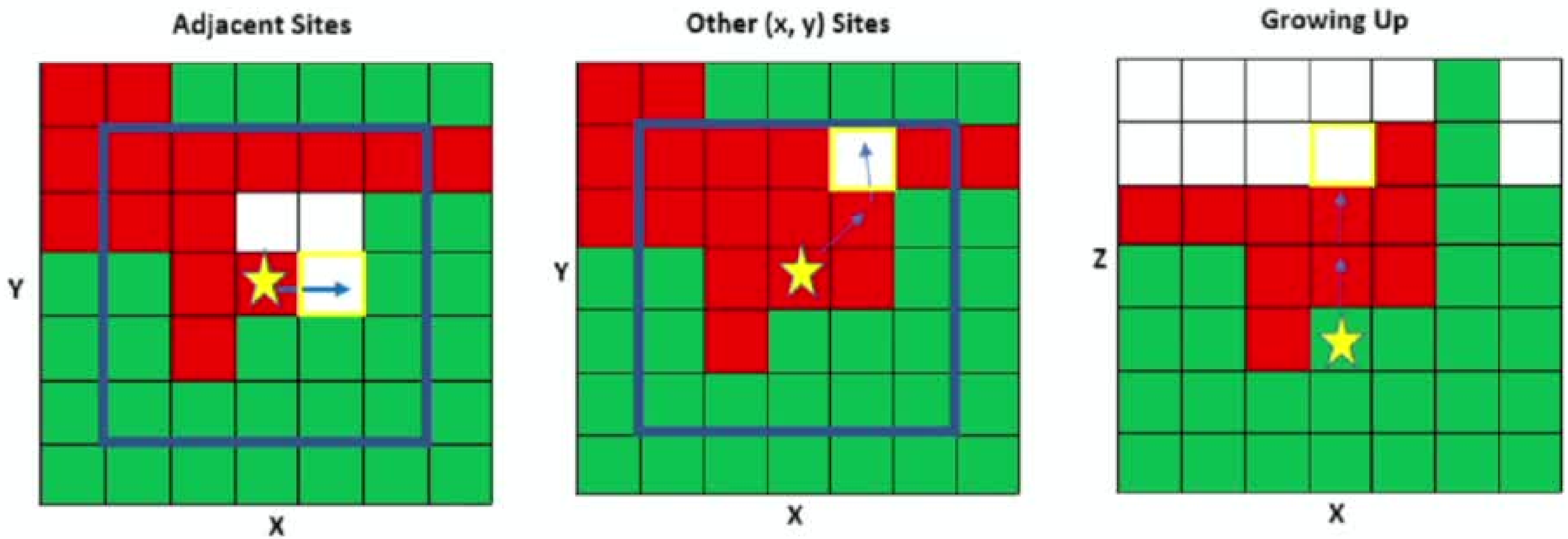


- Based off Momeni et al. [10]
- Discrete time Monte Carlo simulation
- Incorporates kin recognition in three dimensional array
- Vary social scenario by changing growth rate parameters

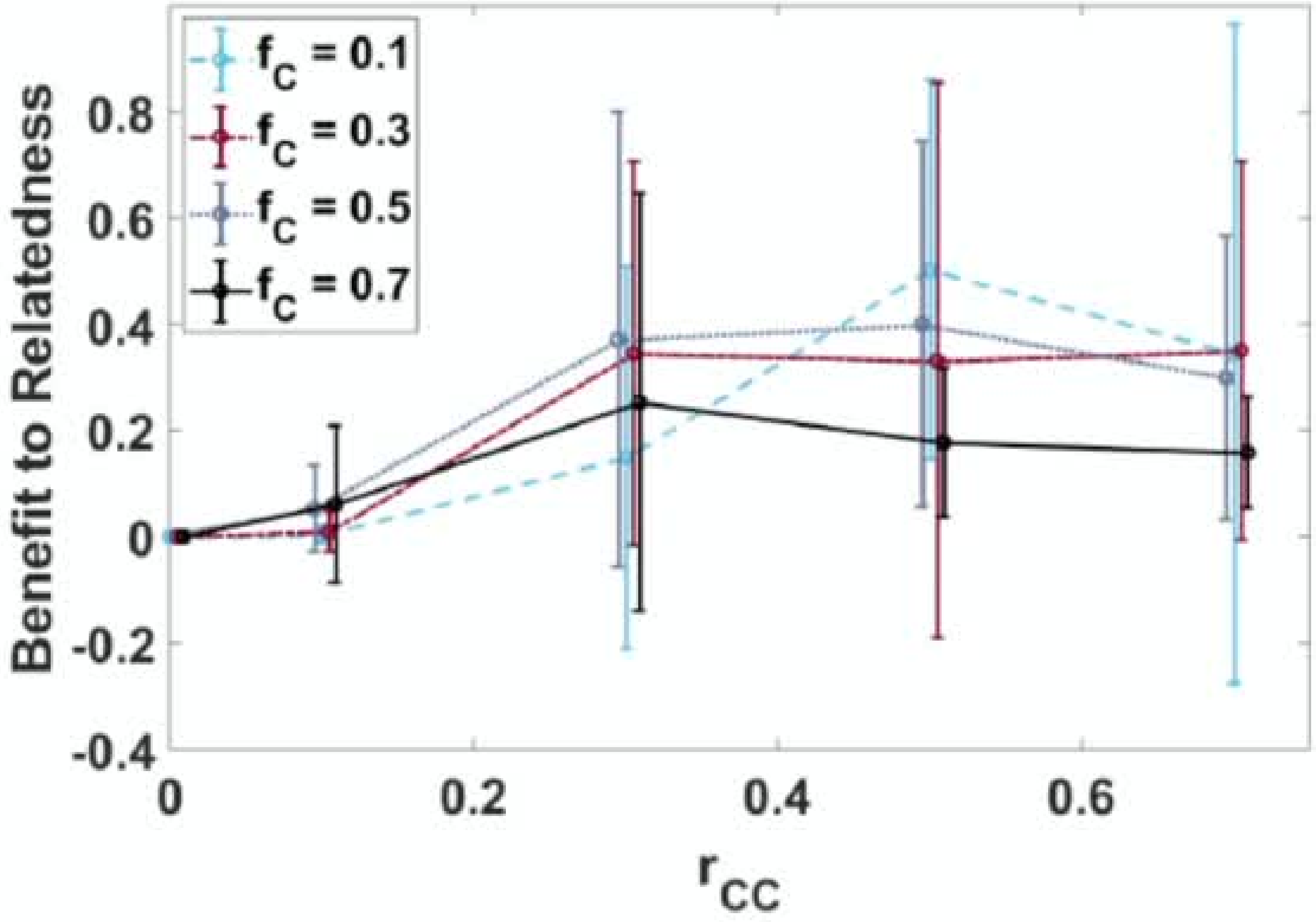
[10] Momeni et al. (2013). Strong inter-population cooperation leads to partner intermixing in microbial communities. Elife, 2, e00230.

Cell Growth

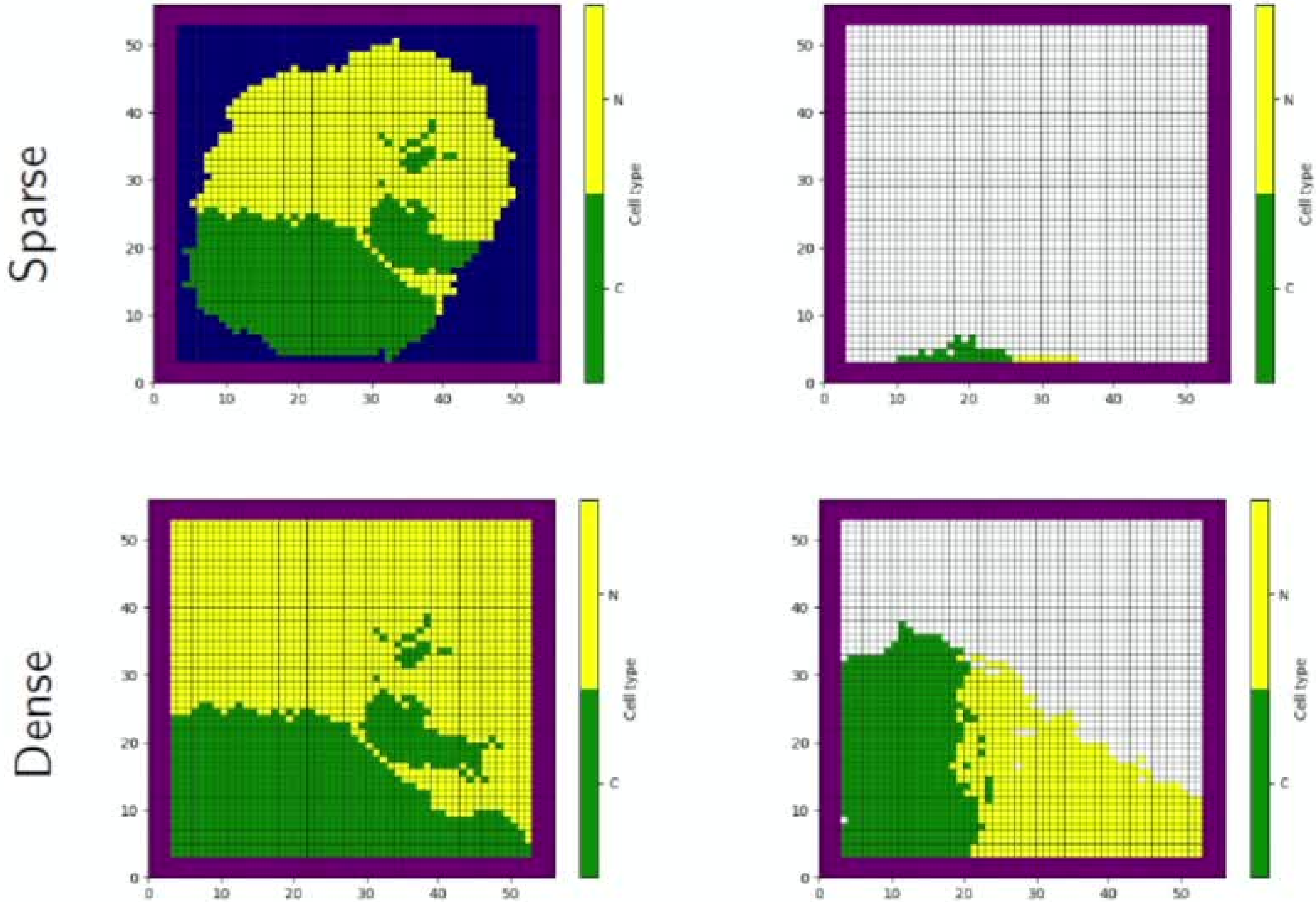
- Select a random cell to divide
- Determine the probability it will divide
- Find an empty spot
- Move cells so daughter cell can be placed



Benefit to Relatedness in Varying Abundance



Benefit to Relatedness in Varying Densities



Conclusions

- While we know kin selection is evident in biofilms, we show there is a benefit to kin recognition
- The benefit to kin recognition is highest for intermediate cooperation effect
- For populations with more abundant cooperators, the benefit to kin recognition is not as high
- Cooperators engaging in kin recognition tend to do better in higher density populations