Segregation of Ring Polymers: What is the Importance of Entropy in the Bacterial Nucleus

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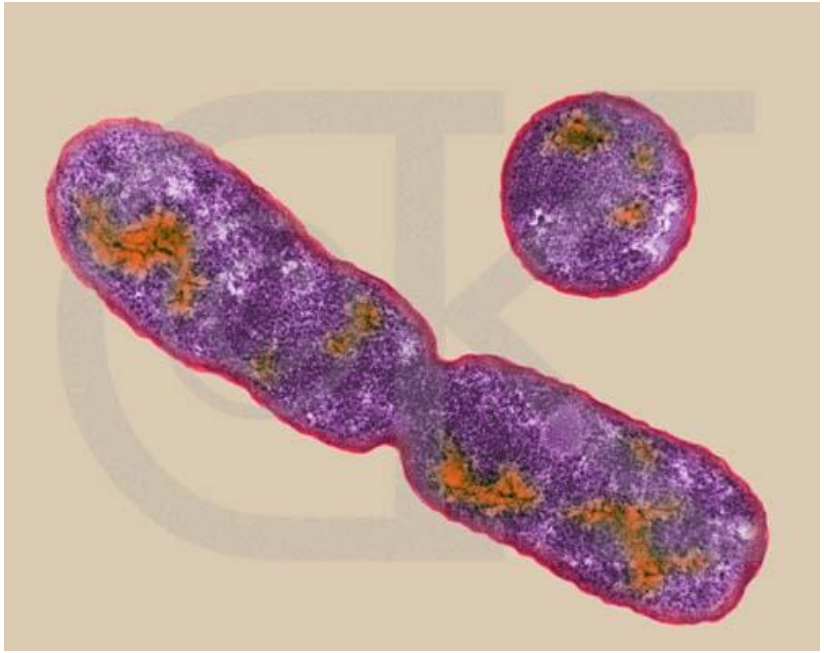
Background

- Even for the relatively well-studied E. coli bacteria where DNA replication is understood, segregation is still a mystery
- Main source of difficulty is the great length of the DNA compared to the cell (Jun et al. 2010)



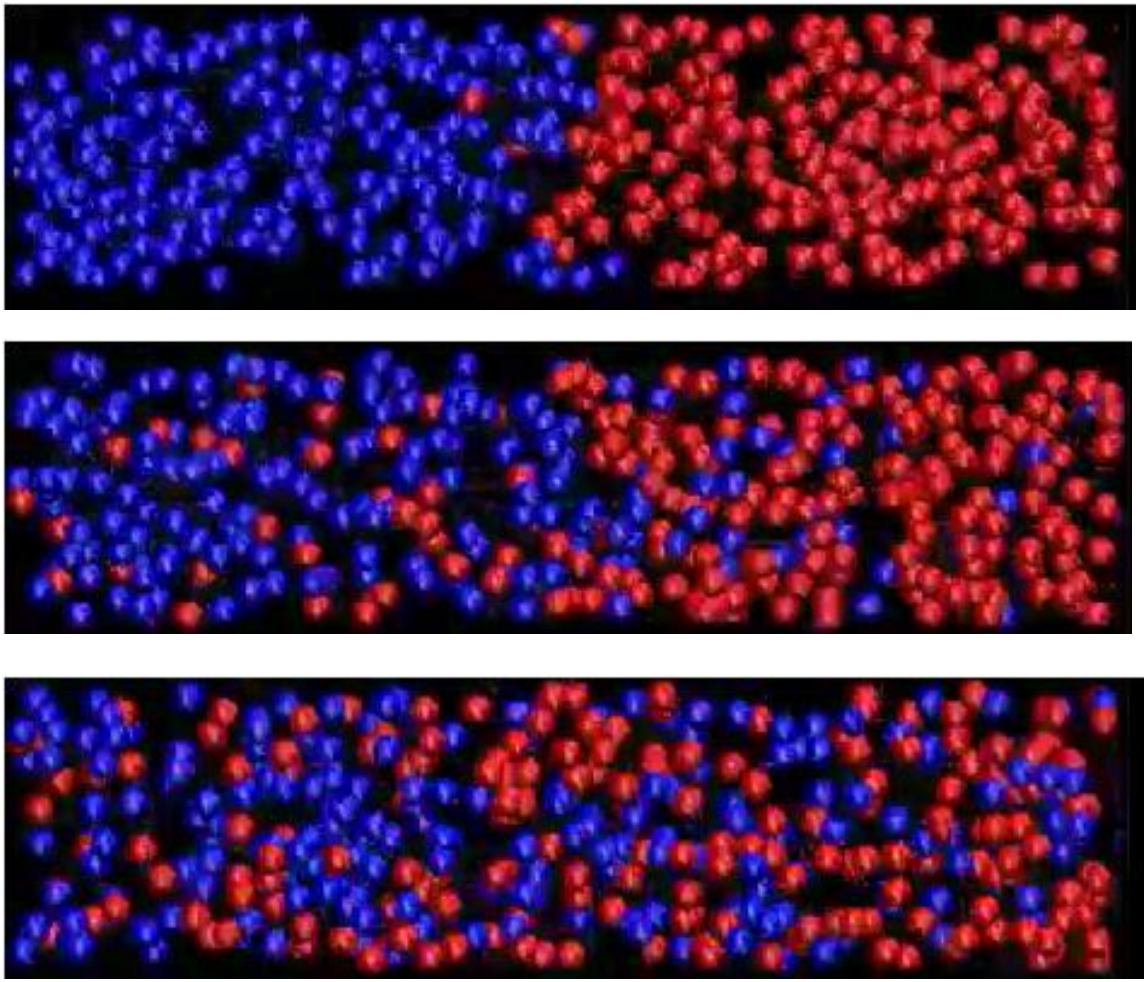
Jun and Wright 2010. Entropy as the driver of chromosome segregation.
Picture:
http://www2.estrellamountain.edu/faculty/farabee/biobk/biobookmito.html

Previous Work

- work by Jun et al. (2006) proposed an entropic driving force for the segregation of E. coli 's circular chromosomes during cell division (as opposed to separation driven mainly by proteins)
- This is counterintuitive since if the chains were unlinked, entropy would cause mixing of the two

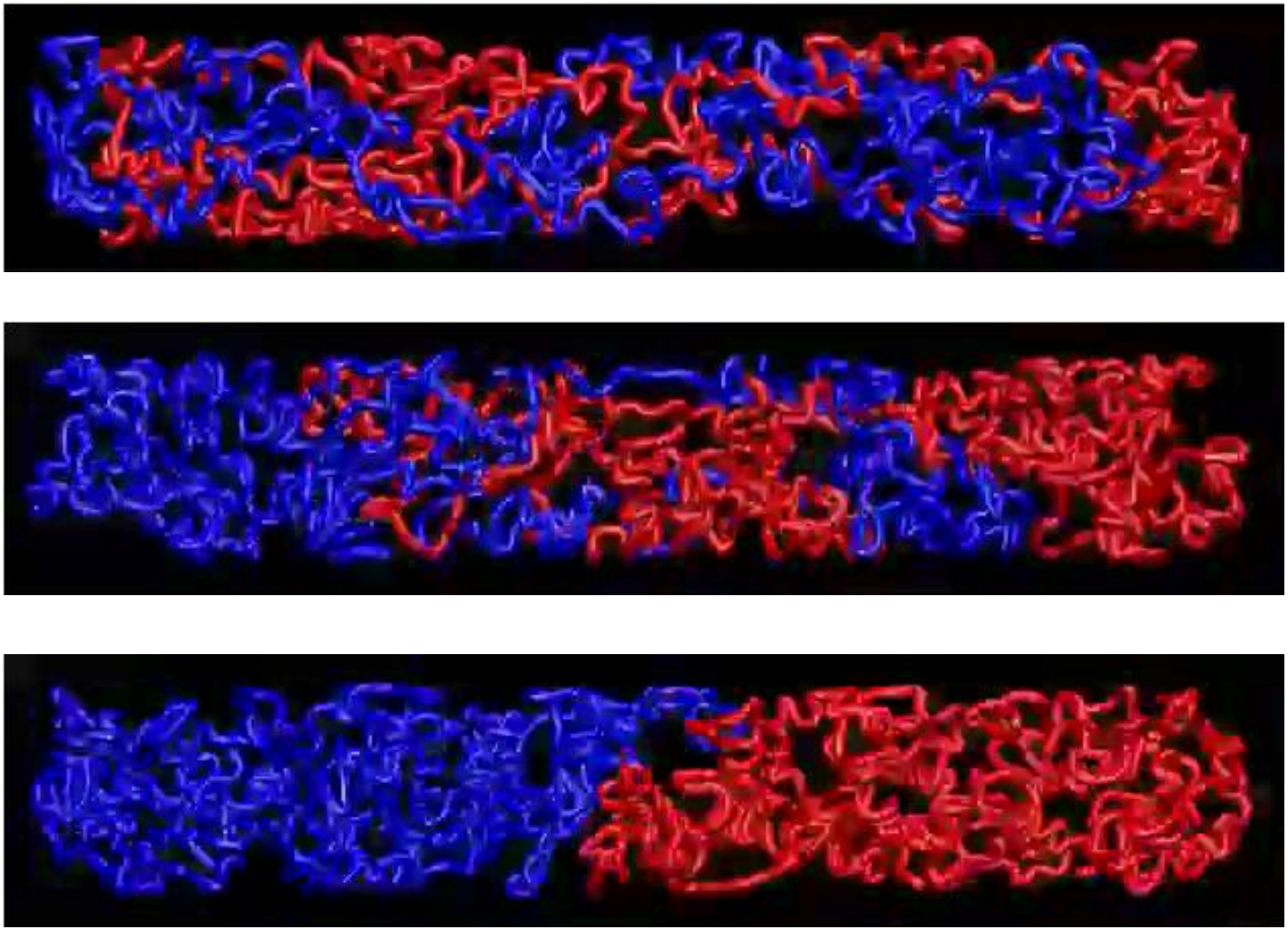
Jun et al. 2006. Entropy-driven spatial organization of highly confined polymers: Lessons for the bacterial chromosome. PNAS 103(33) pp.12388-12393

Unlinked Mixing



Picture source: http://www.sysbio.harvard.edu/csb/jun/research.html

Linked Segregation



Picture source: http://www.sysbio.harvard.edu/csb/jun/research.html

My Question

- How does variation of additional factors influence separation?
- Varying:
  - length of polymer
  - stiffness of polymer
  - geometry of confining capsid (shape of bacterial nucleoid)
- Studying longer and potentially more realistic chains

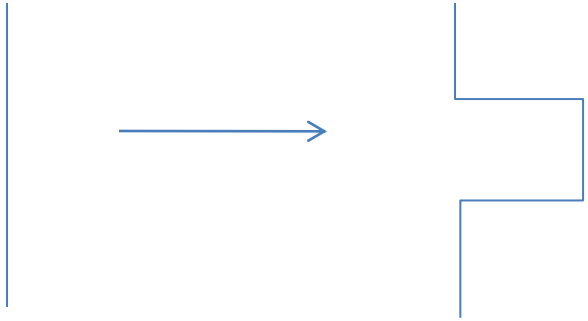
Overview of Approach

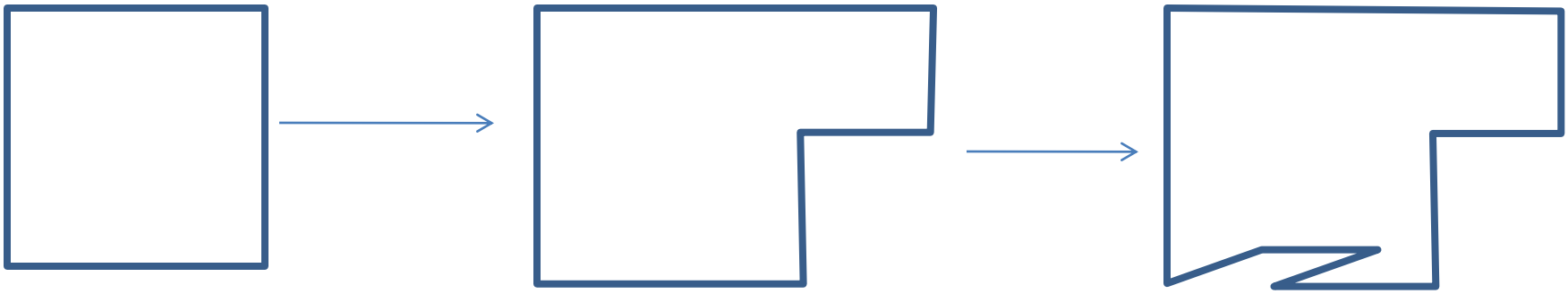
- 2 parts:
  - Grow two non-entwined DNA rings (model chromosome replication)
  - Use molecular dynamics to study the separation of the rings (model chromosome segregation)
- Polymer is modeled as monomers connected by springs

Part 1: Growing 2 DNA Rings

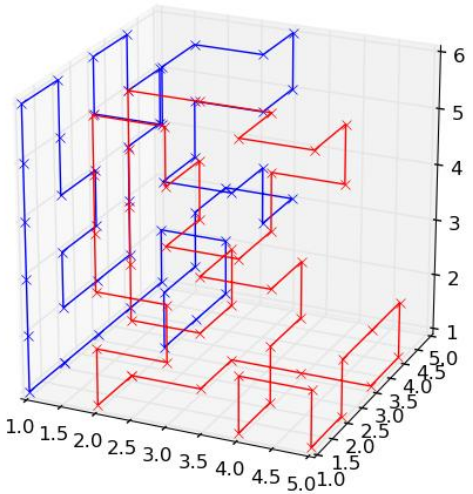
- Start with two small rings on a 3-D lattice
- Use iterative process to grow rings closer together
- DNA rings must be close together but not entangled

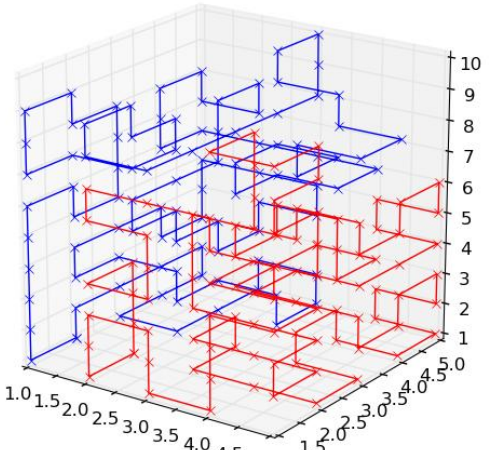
Iterative Growth Process

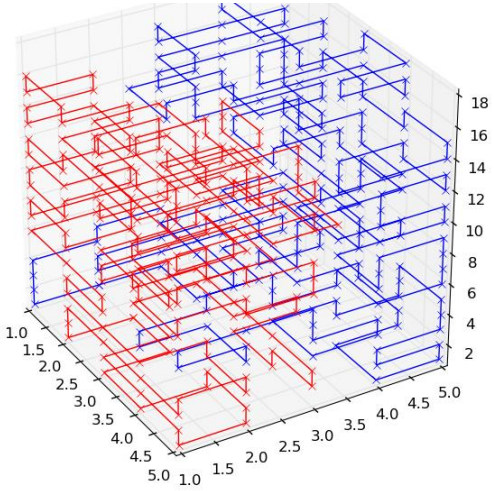


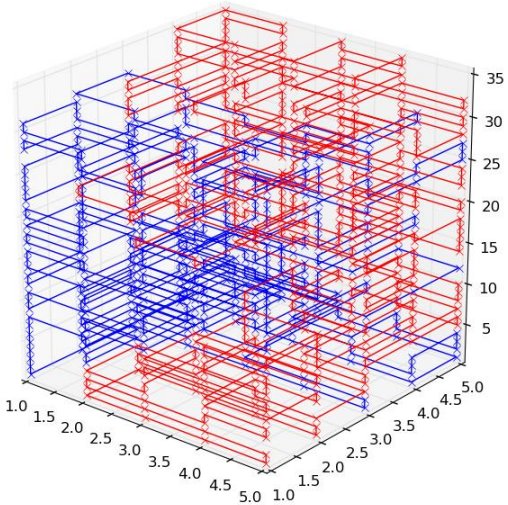


Stages of Ring Growth









Part 2: Molecular Dynamics Simulation

- Simulate the grown rings within a capsid
  - Polymer = monomers attached by springs
  - Capsule = combination sphere and cylinder
- Simulate forces of system and track motion of monomers over time
- Use movement of centers of mass of the rings over time to track separation

Future Significance

- Important starting point for understanding segregation of more complicated polymers
- Could also have implications for chromosome segregation in more complicated cells

Thanks to:

- The PRIMES program
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