Simulating Supercoiling in Prokaryotic DNA

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Prokaryotic DNA

- Single, circular segment of DNA.
- Freely floating in the cell.
- Not packaged into a chromosome.
- Genome is much smaller than in Eukaryotes.
  - E.g., *E. coli* have about 5 Mbp.

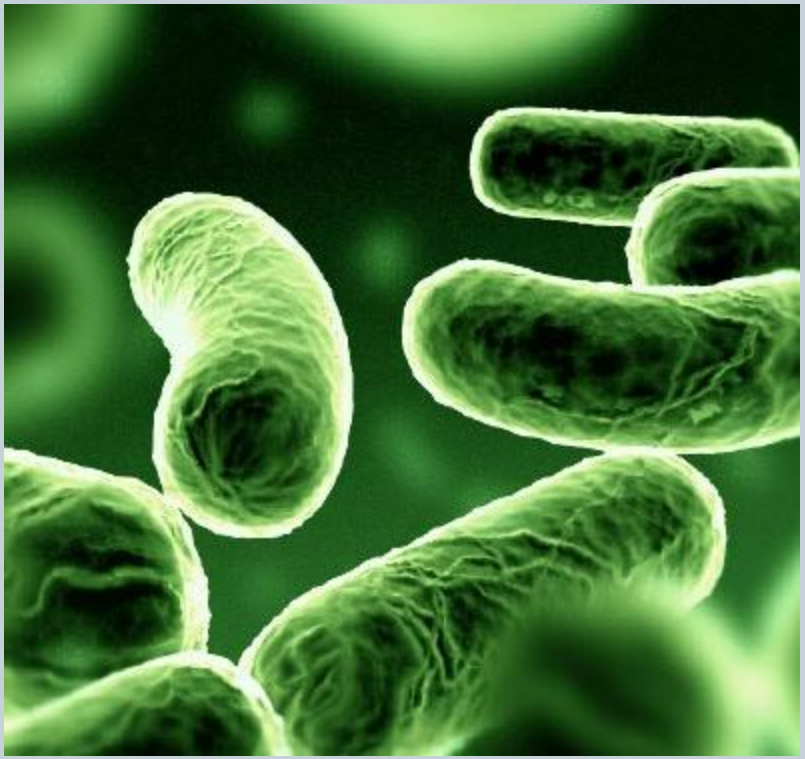


Image retrieved from http://www.vedicsciences.net/articles/dawkins-evolution-challenge.html

Supercoiling

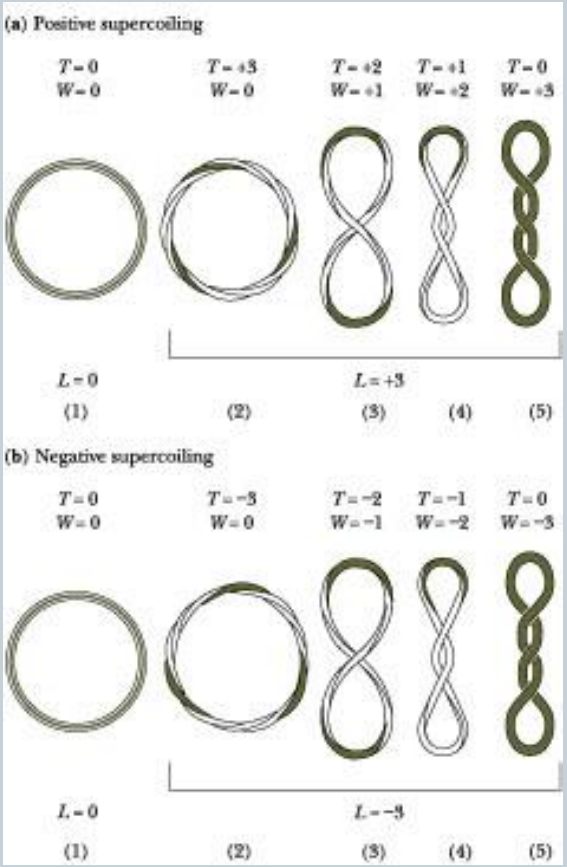


Image retrieved from http://web.virginia.edu/Heidi/chapter12/chp12.htm

- DNA normally has one rotation every ~10.4 bp.
- Certain enzymes (e.g. DNA gyrase) twist or untwist DNA.
- DNA contorts its shape in response to supercoiling.
- Purposes:
  - DNA packing, DNA replication.

Linking Number

- Quantitatively describes how objects are intertwined.
- L = T + W

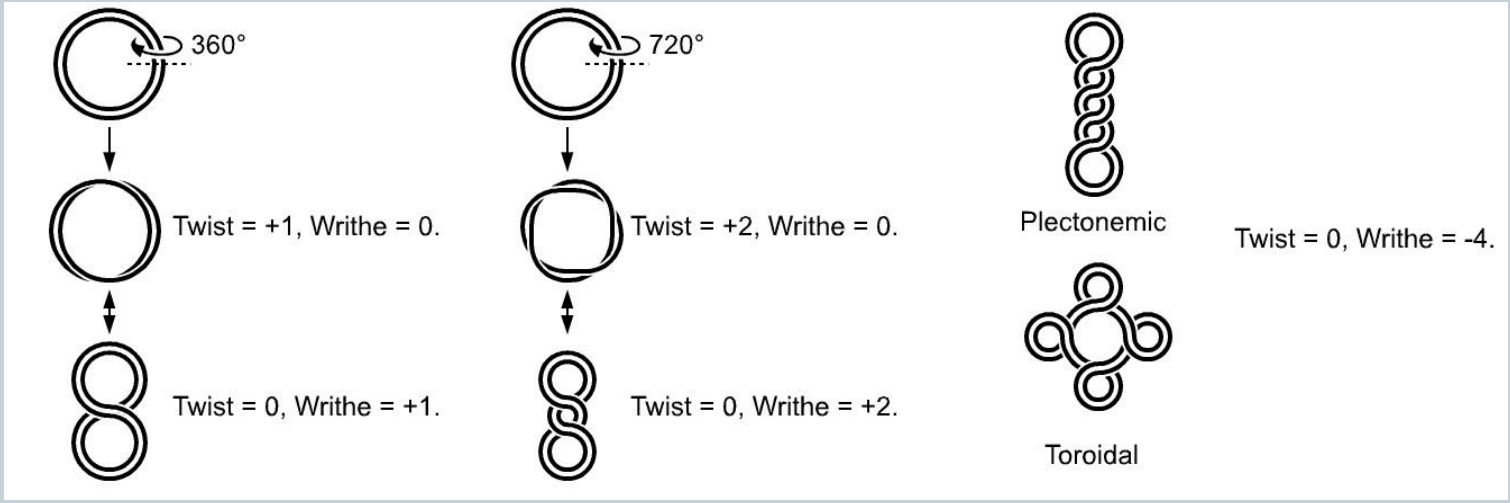
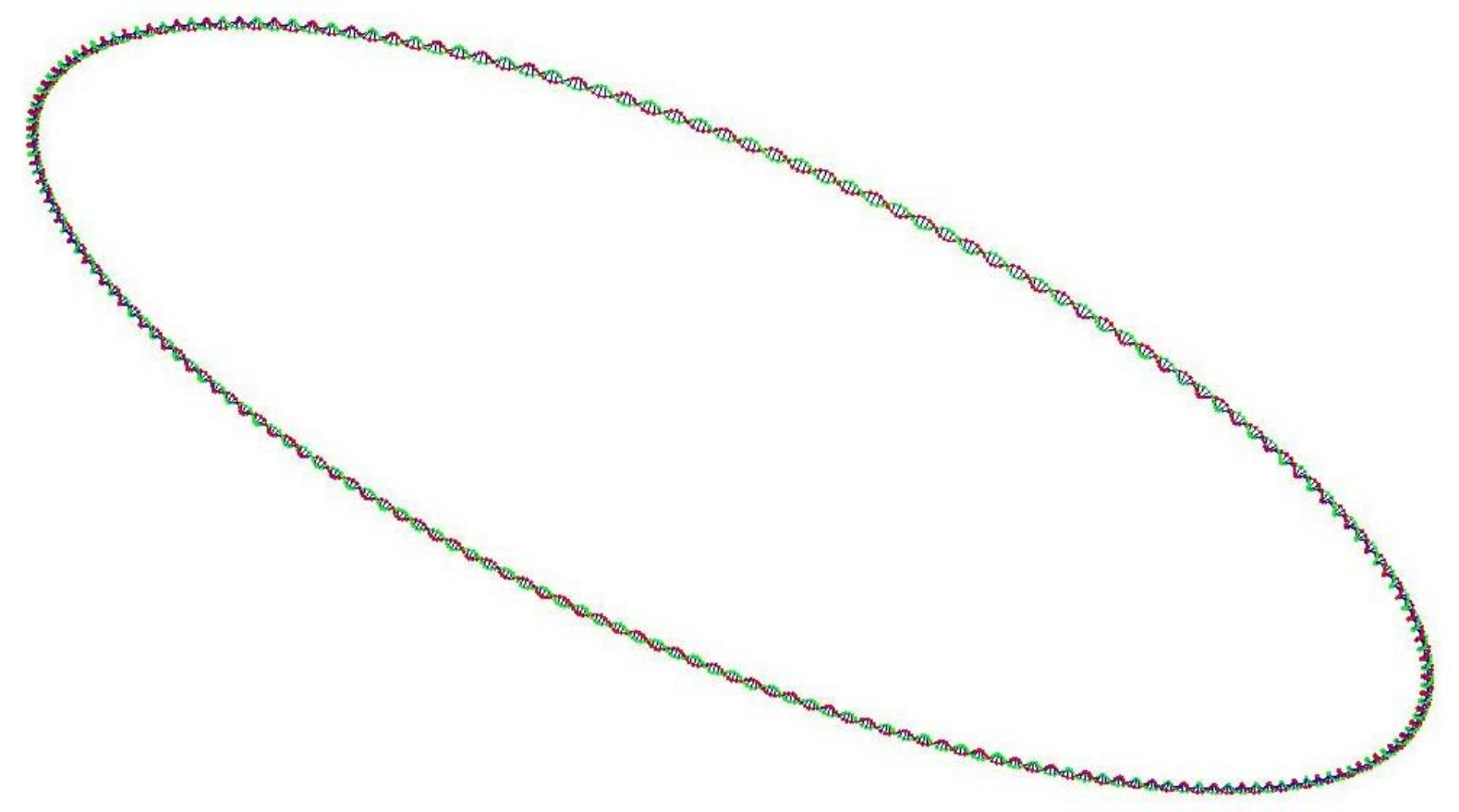
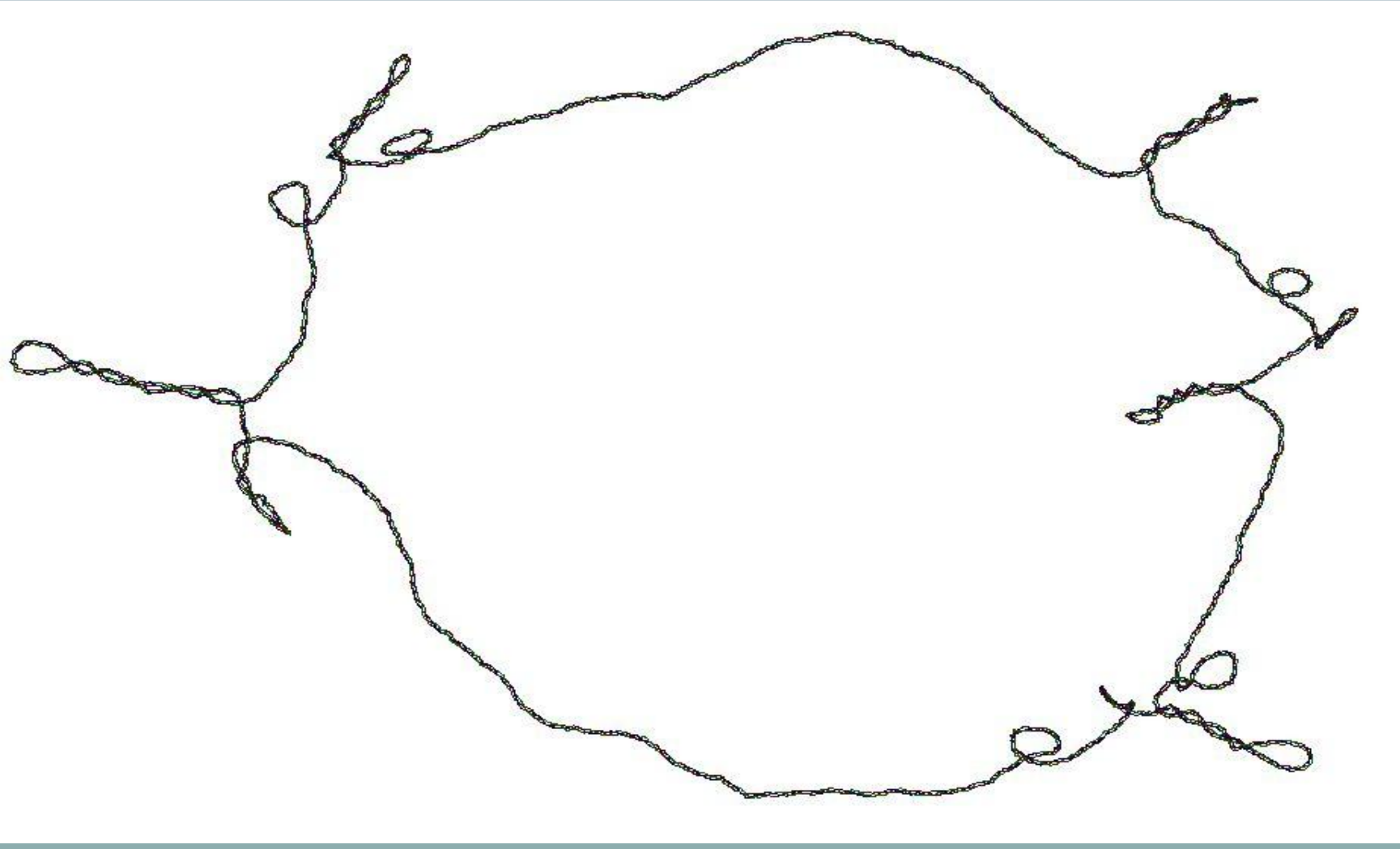


Image retrieved from http://upload.wikimedia.org/wikipedia/commons/1/1e/Circular_DNA_Supercoiling.png

Simulation using spatial coordinates



Simulated Supercoiling

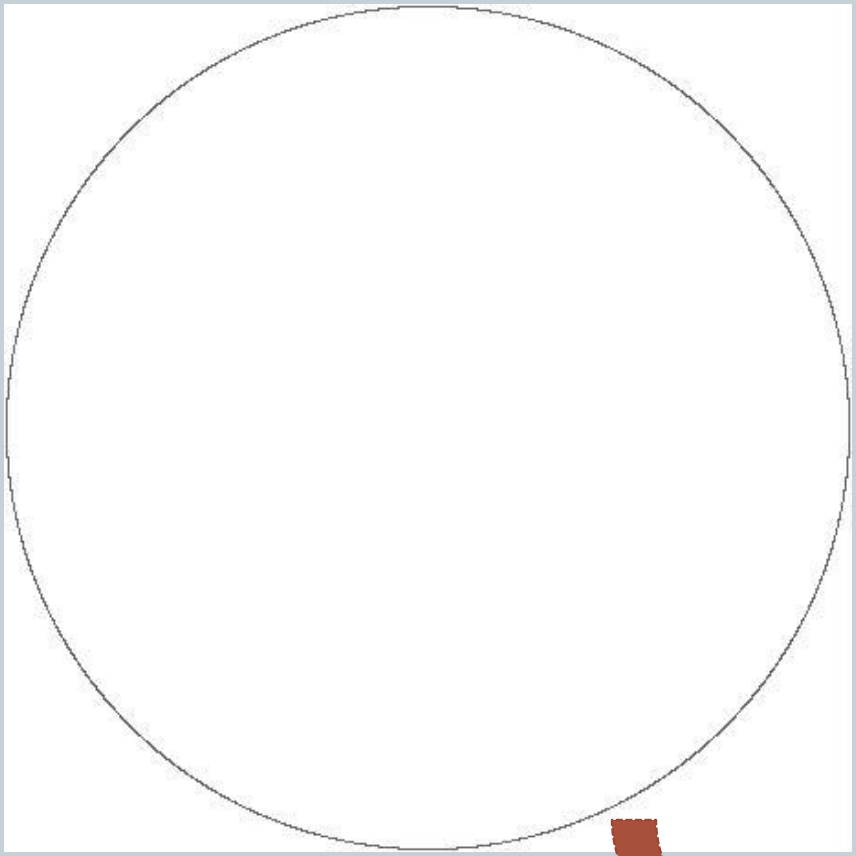


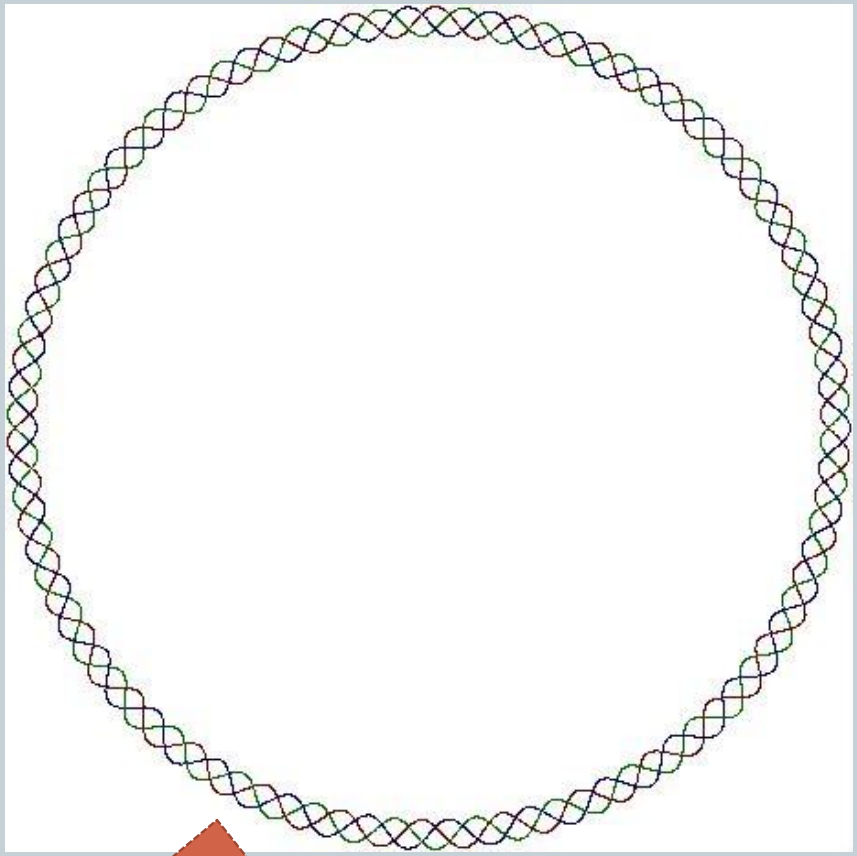
The Simulation

Problem:

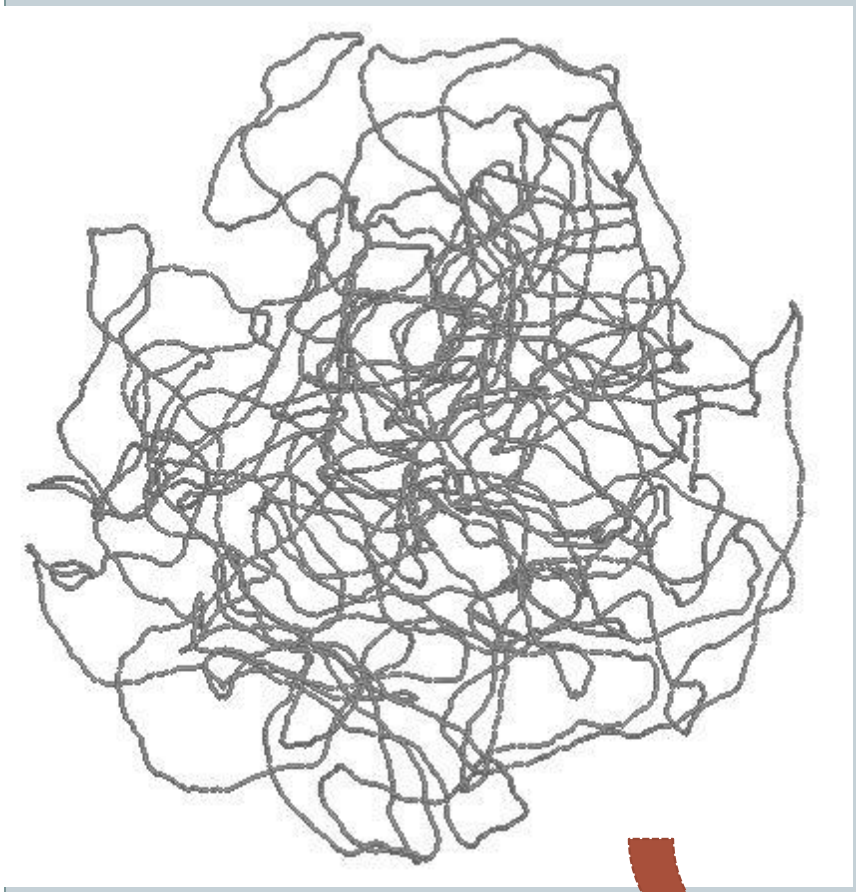
1. Algorithm to construct the strands of DNA.
2. Model the behavior of the constructed polymer using molecular dynamics.

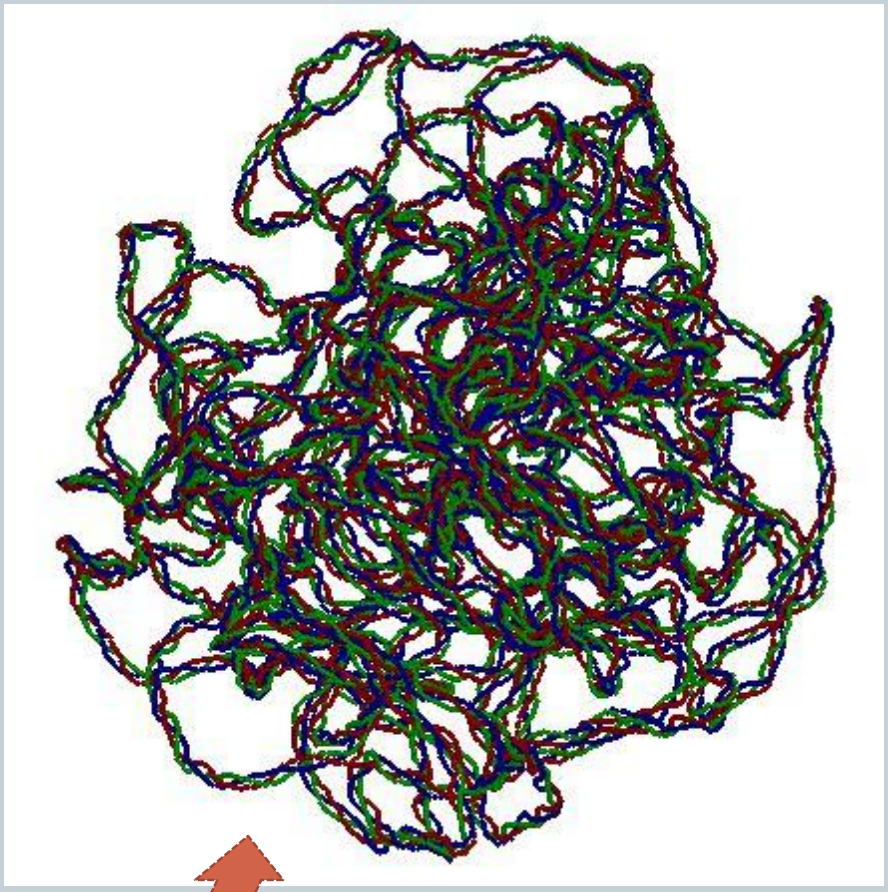
1. DNA Structure Algorithm





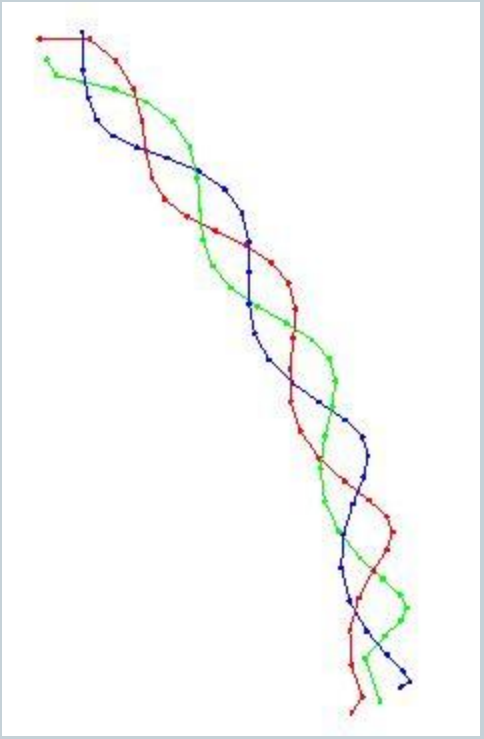
DNA Structure Algorithm (cont.)

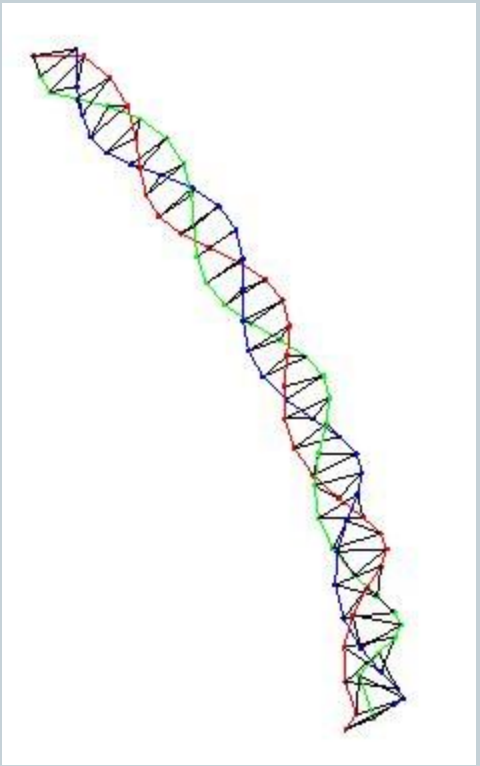




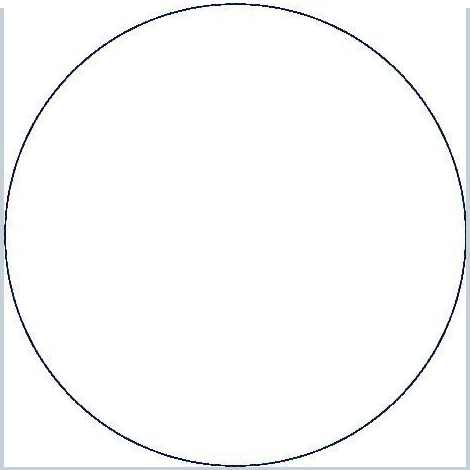
2. Molecular Dynamics

- Simulate behavior using polymer physics.
  - Consecutive points on the polymer held together with harmonic (spring) bonds.

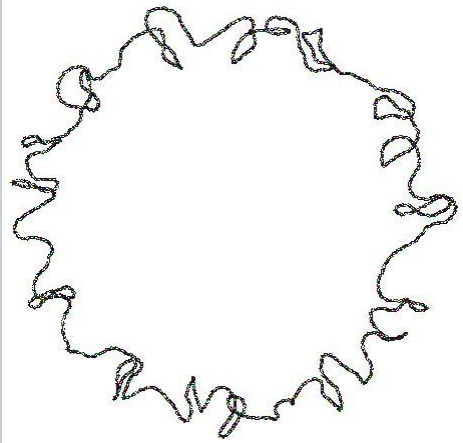




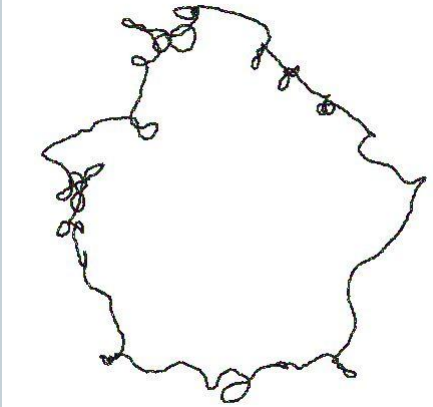
Example Simulation



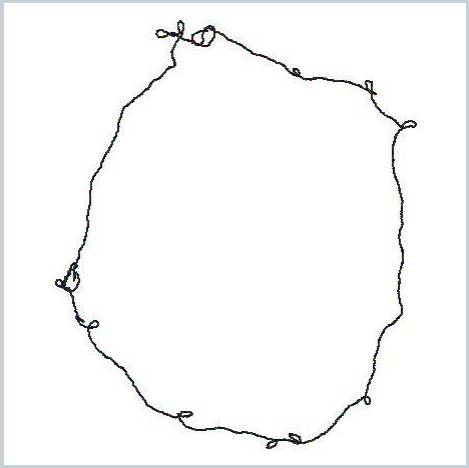
0 time steps



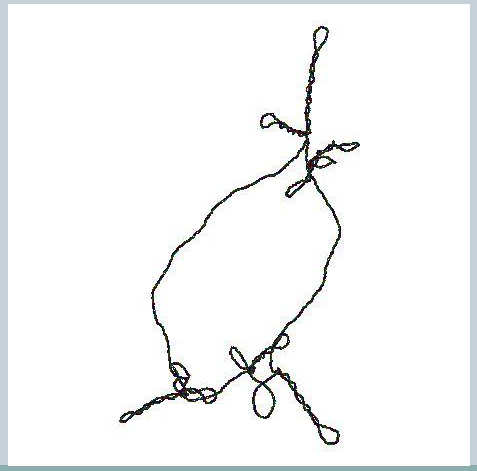
10 time steps



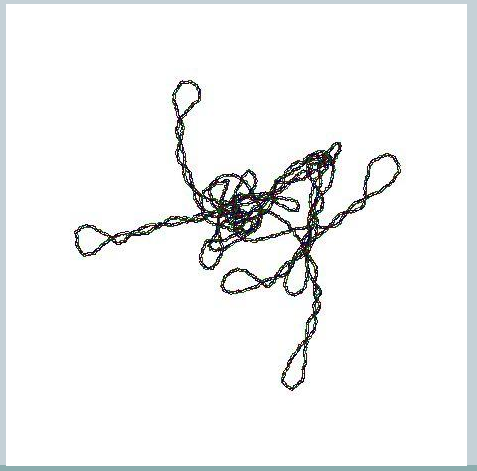
30 time steps



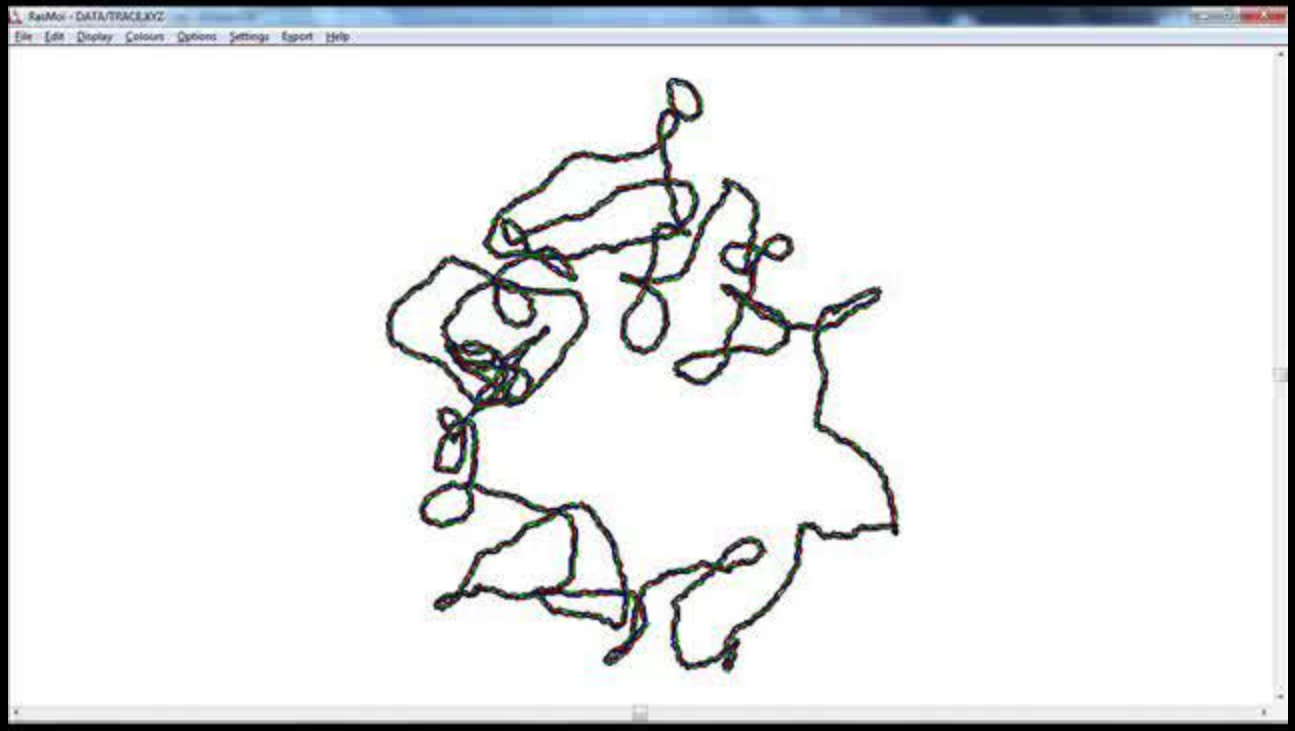
60 time steps



120 time steps



199 time steps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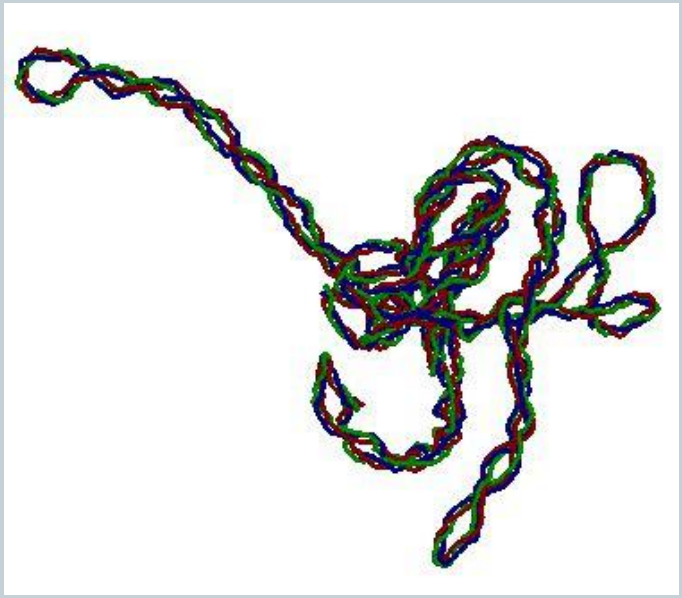
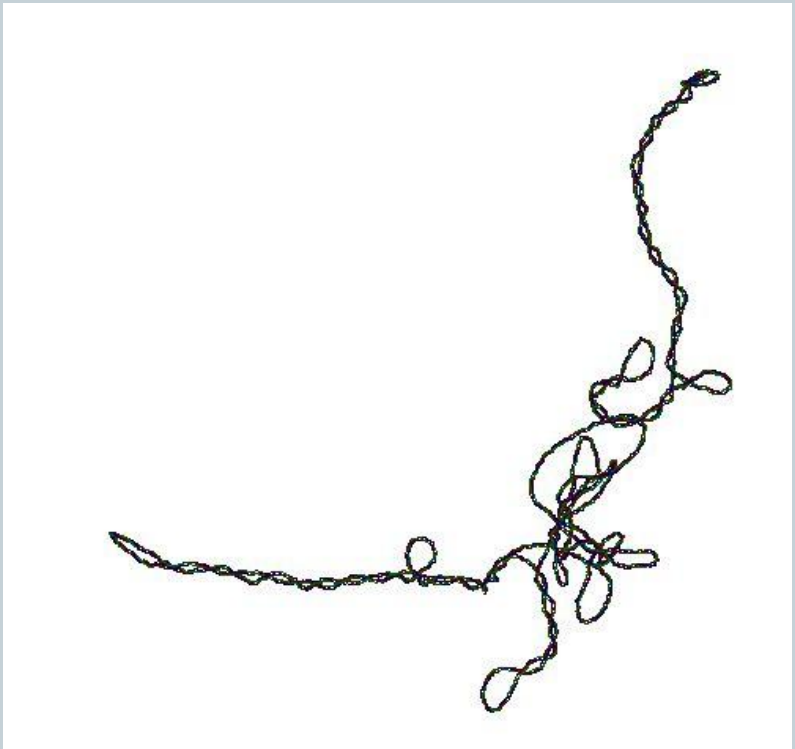
Results



- General model for DNA structure.
- Evident realistic supercoiling effects.
- Polymer maintains twist throughout simulation.
  - Calculated linking number at each stage in a simulation.

Future Research and Applications

- It has been proposed that supercoiling aids in DNA segregation during DNA replication.
- We will test this hypothesis and compare to experimental data.



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