

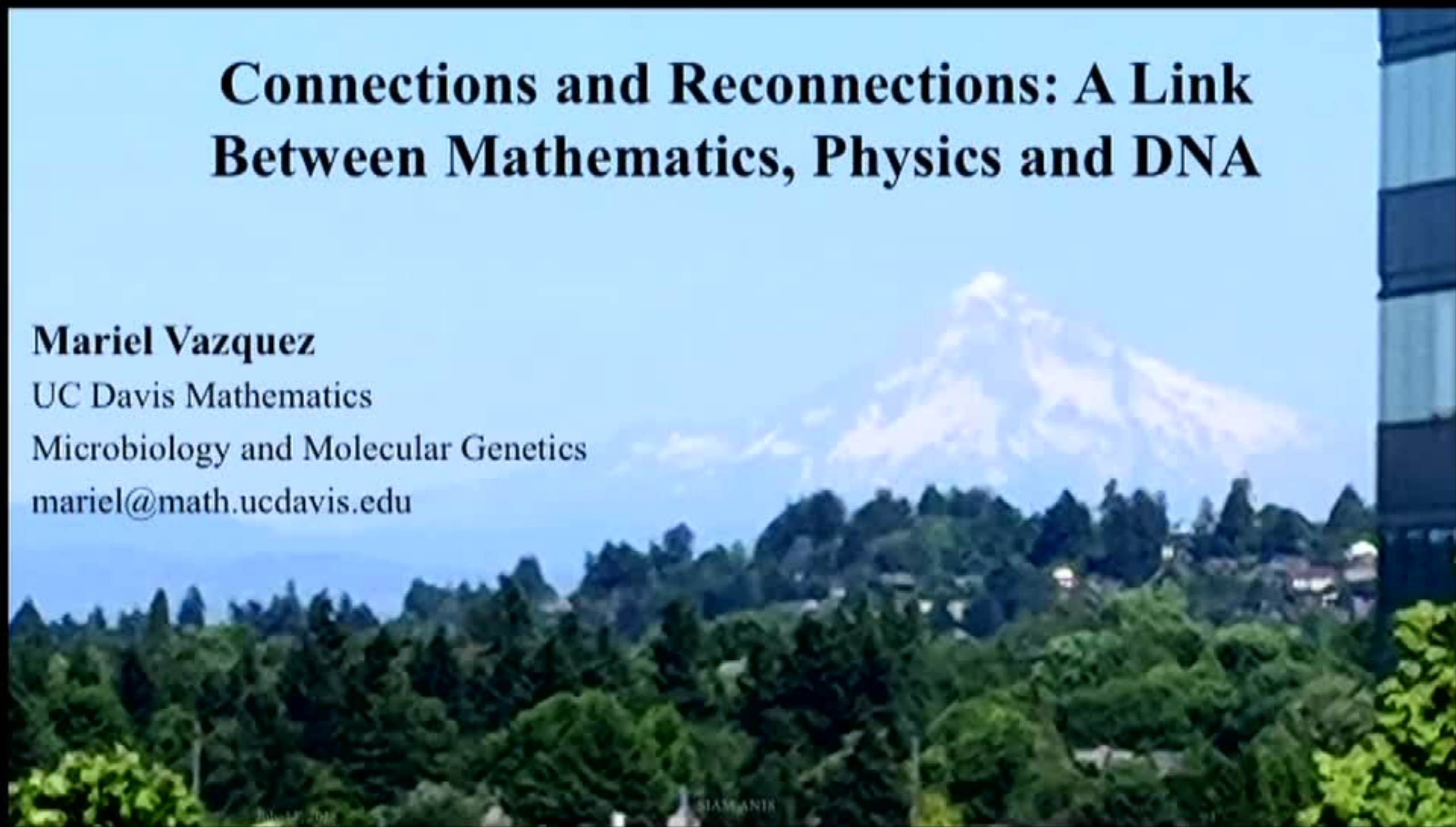
Connections and Reconnections: A Link Between Mathematics, Physics and DNA

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Microbiology and Molecular Genetics

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In memoriam,
Maryam Mirzakhani (1977-2017)

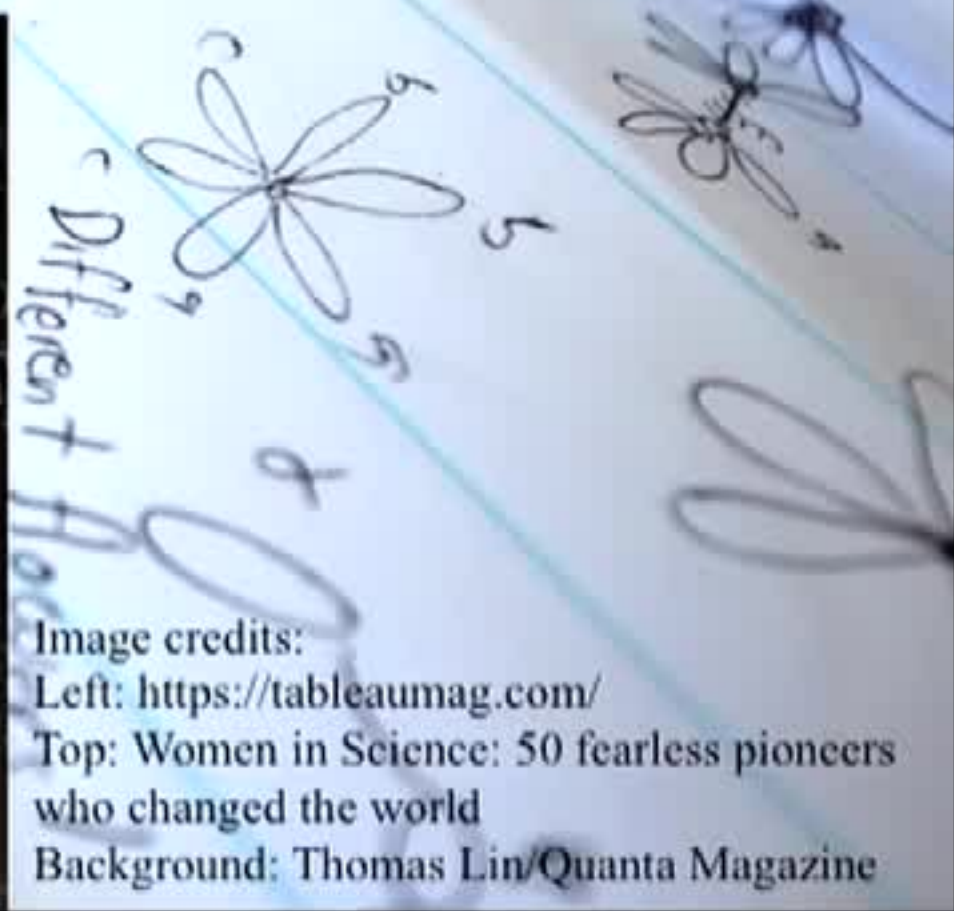
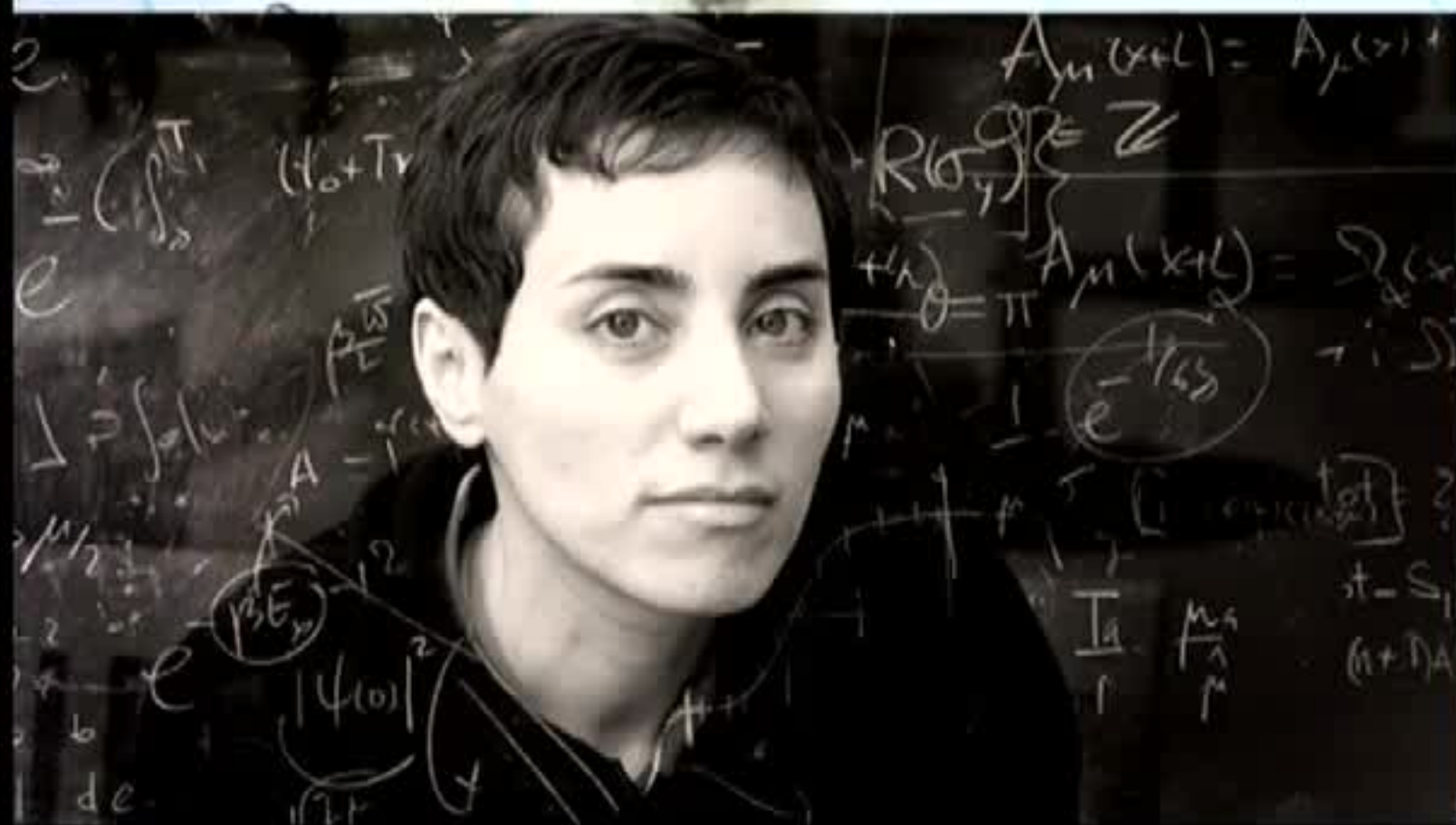


Image credits:
Left: <https://tableaumag.com/>
Top: Women in Science: 50 fearless pioneers who changed the world
Background: Thomas Lin/Quanta Magazine

Collaborators:

Javier Arsuaga – UC Davis
Yuanan Diao, UNC Charlotte
Carme Calderer, U of Minnesota

Allison Moore – UC Davis
Tye Lidman – N.C. State

Koya Shimokawa – Saitama U.
Kai Ishihara – Yamaguchi U.
Chris Soteros – U. Saskatchewan

David J. Sherratt – Oxford U.
Ian Grainge – U. of Newcastle

Rob Scharein – Hypnagogic
Software
R. Brasher – Microsoft

**Students (current and former):****Tangles:**

J. Lopez, C. Moreno, C. Price, Y. Saka, K. Wono, W. Zheng.

Recombo: M. Flanner, R. Stolz (UC Davis)

Nomenclature: S. Witte

Pathways: M. Yoshida (Saitama U.)

Software: Knotplot.com;
circos.ca

Topological Molecular Biology

<http://arsuaga-vazquez-lab.faculty.ucdavis.edu>



NSF Math Biology

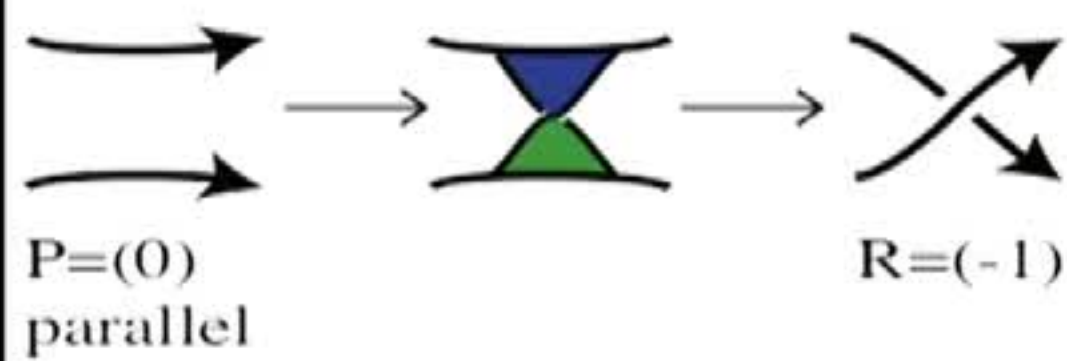


NSF CAREER

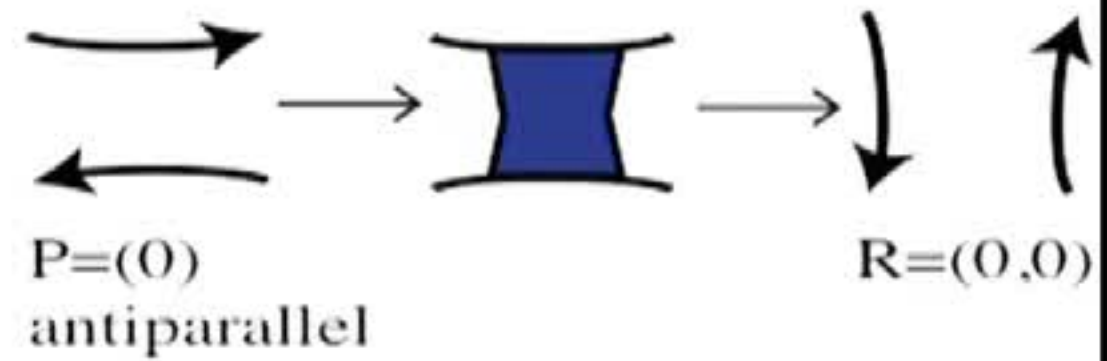


NIH R01

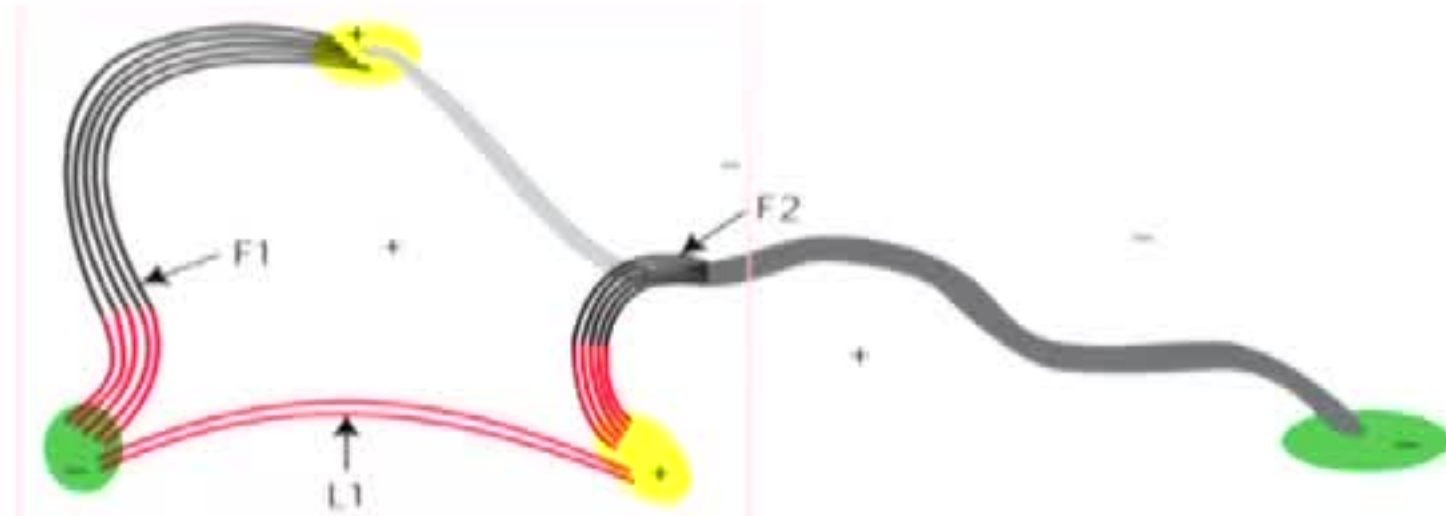
Local reconnection



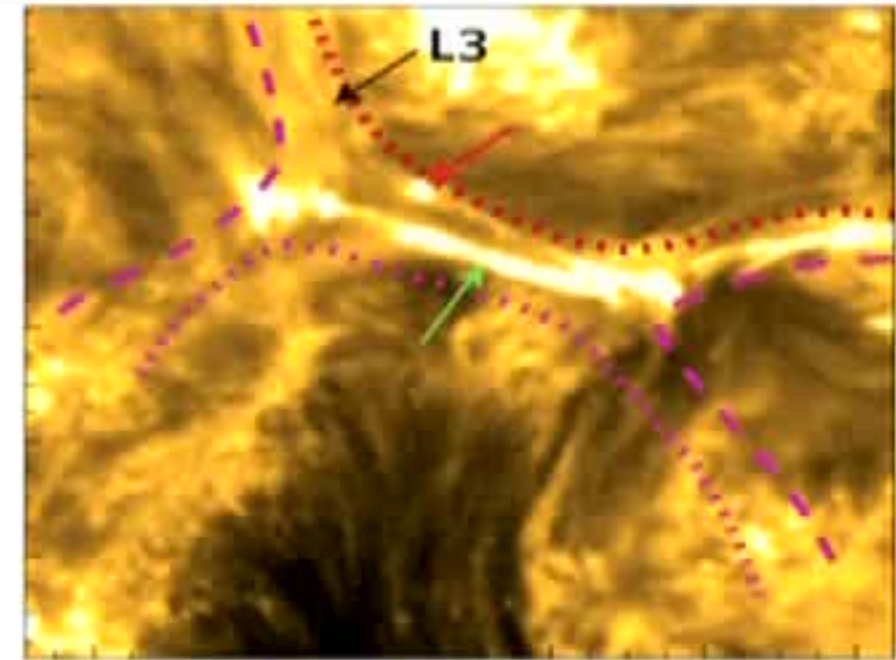
or



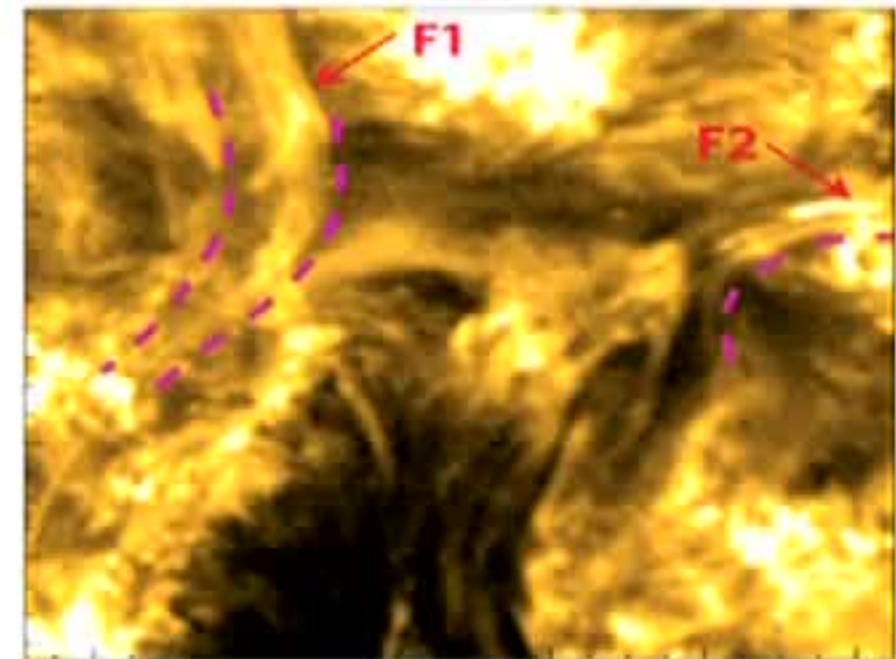
Magnetic reconnection in solar coronal loops



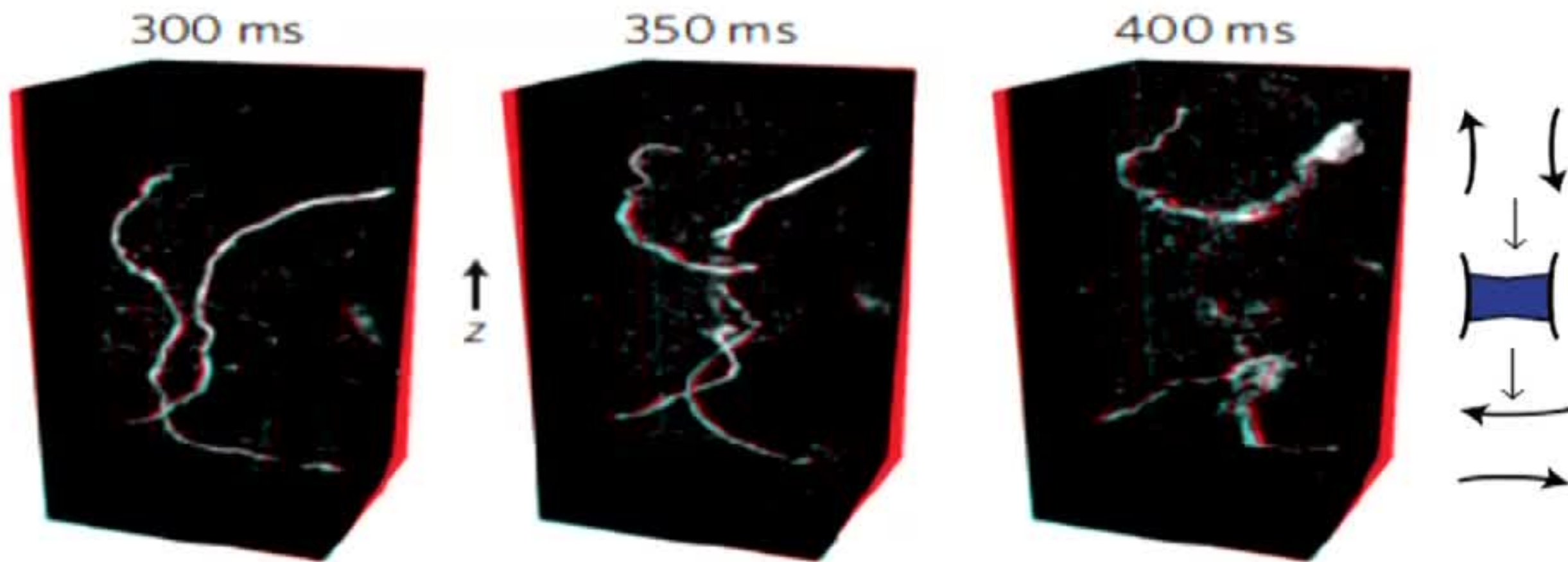
Li et al., Magnetic reconnection between a solar filament and nearby coronal loops, Nature Physics 12, 847–851 (2016)



AIA 171 Å 01:01:12 UT



Reconnection of fluid vortices



Kleckner and Irvine, 2013

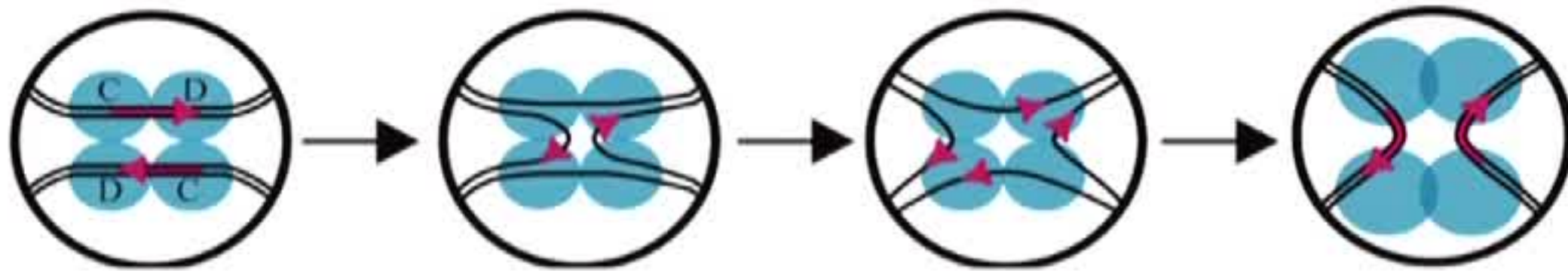
July 11, 2014

NEW ANGE

10

DNA site-specific recombination

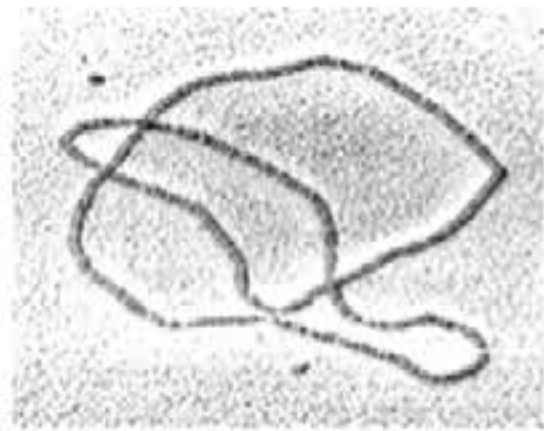
Site-specific recombinases bind two short and identical DNA sites. They act by a cut-recombine and paste mechanism: **Local reconnection**.



Changes in the DNA mediated by these enzymes can have important phenotypic effects.

A circular DNA molecule is modeled as a mathematical knot

Circular DNA
Molecule



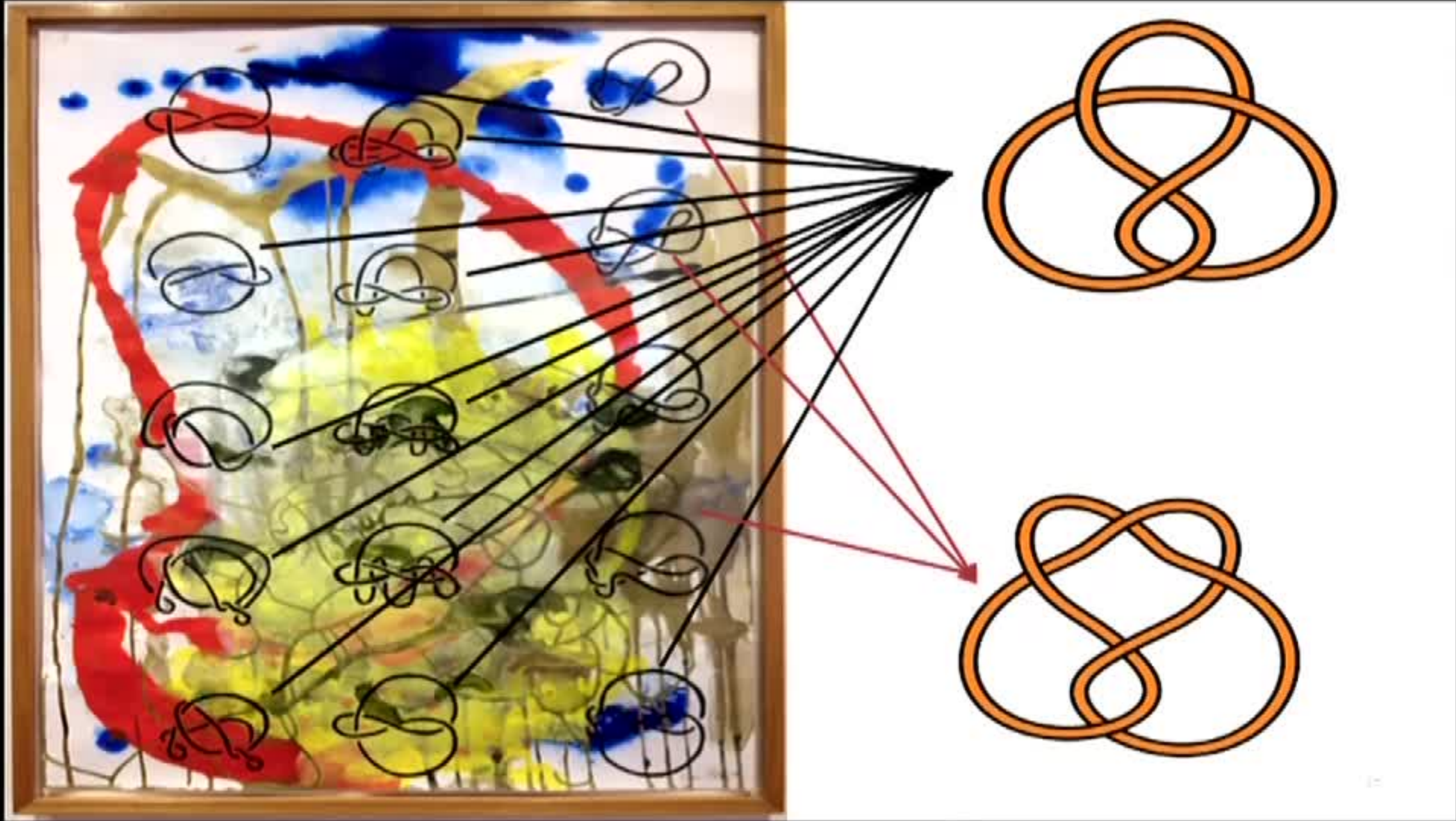
DNA knot




Circle with no
intersections in
3-dimensions
= **KNOT**



Mathematical knot





Chirality



Javier Arsuaga



Reuben Brasher



Shawn Witte



Michelle Flanner



Juliet Portillo



Yuanan Diao



Rob Scharein

Chirality

Portillo, J., Diao, Y., Scharein R., Arsuaga, J., Vazquez, M., On the mean and variance of the writhe of random polygons, *J. Phys. A: Math. Theor.* 44 (2011)

Brasher, R., Scharein, R., Vazquez, M., New biologically motivated knot table, *Biochem Soc. Trans.* 41(2) (2013)

Stochastic simulations of DNA packaging in bacteriophage capsids, Brian Cruz, SFSU masters thesis 2014

Cubic lattice links, grid links, writhe and chirality, Shawn Witte, UC Davis PhD Thesis (expected summer 2019)



Brian Cruz



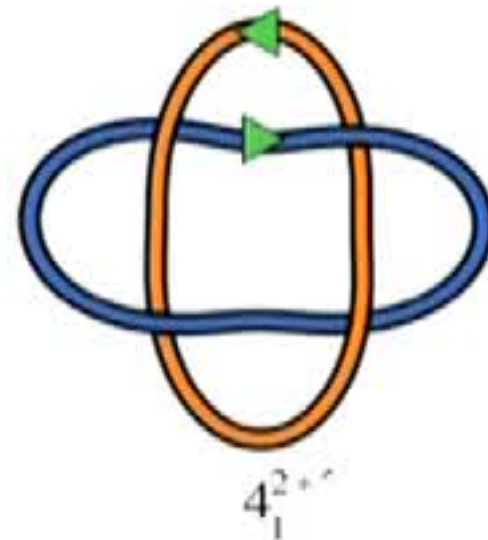
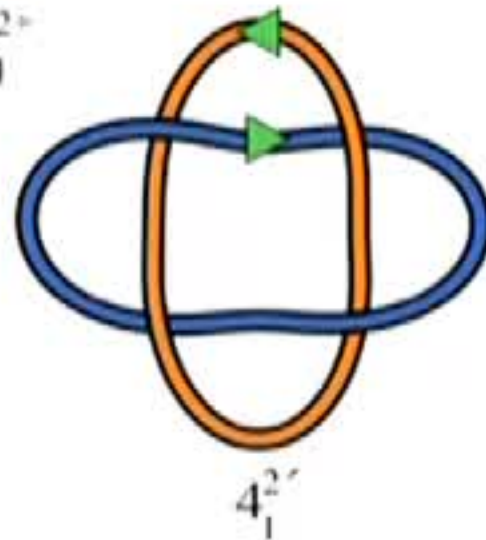
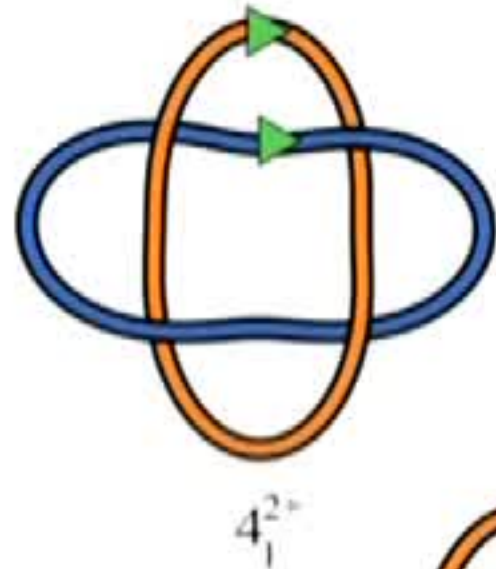
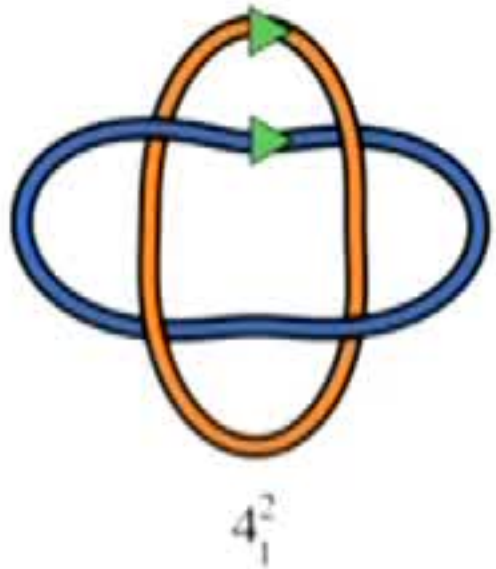
Tamara Christiani



Carme Calderer

Witte, S., Flanner, M., and Vazquez, M., A symmetry motivated link table, *in preparation*

Nomenclature for 4-crossing torus links



Recombo: computational model for local reconnection



Reuben Brasher, PhD
Microsoft



Robert Stolz
PhD candidate UCD



Rob Scharein
Hypnagogic Software



Michelle Flanner
Jr Specialist UCD

Stepwise Model of DNA unlinking by XerCD-*dif*-FtsK

(Ip et al., 2003; Grainge et al., 2007)

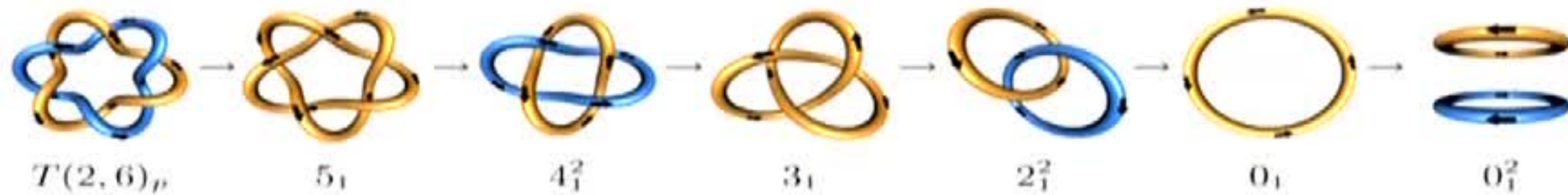
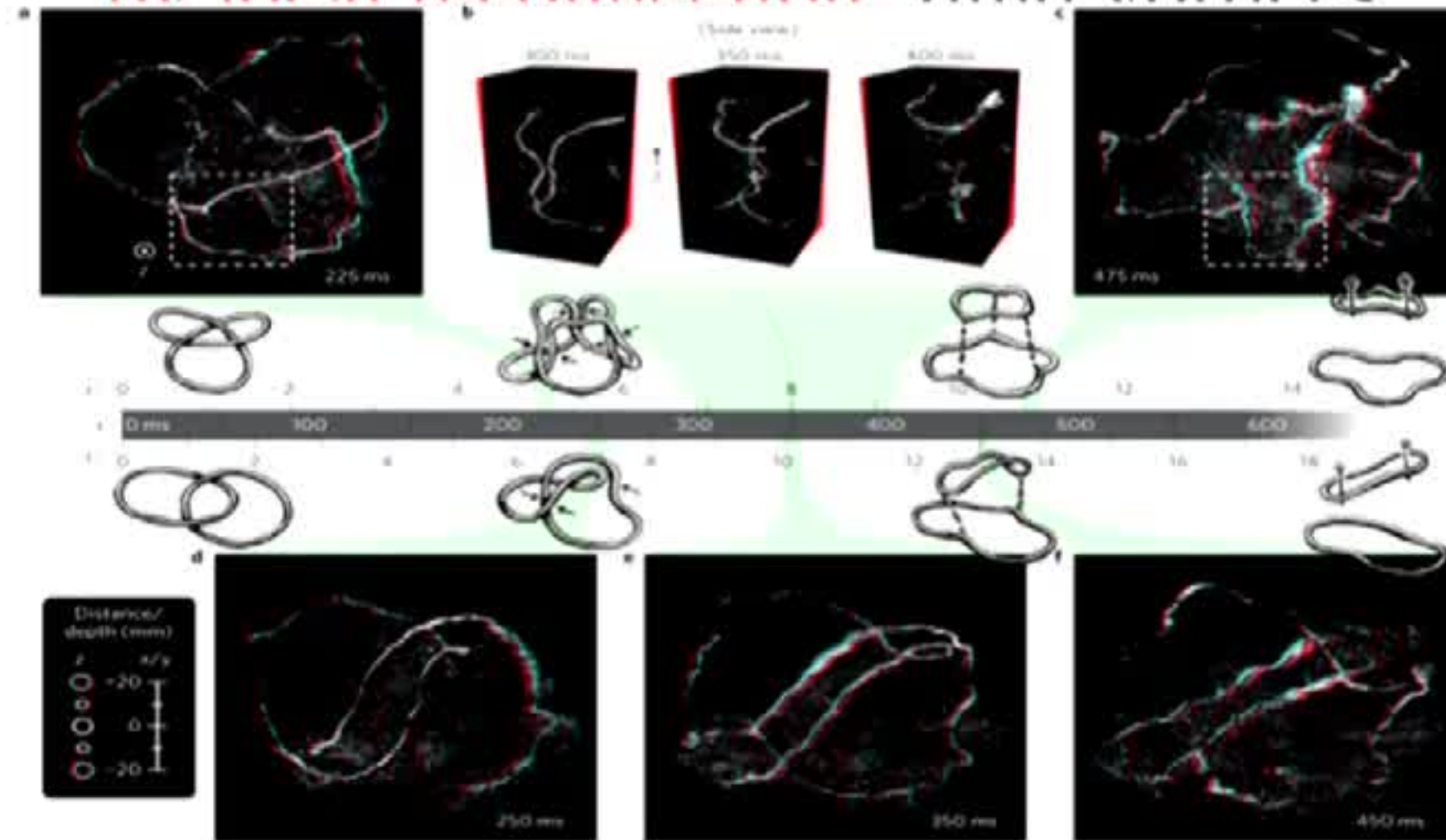


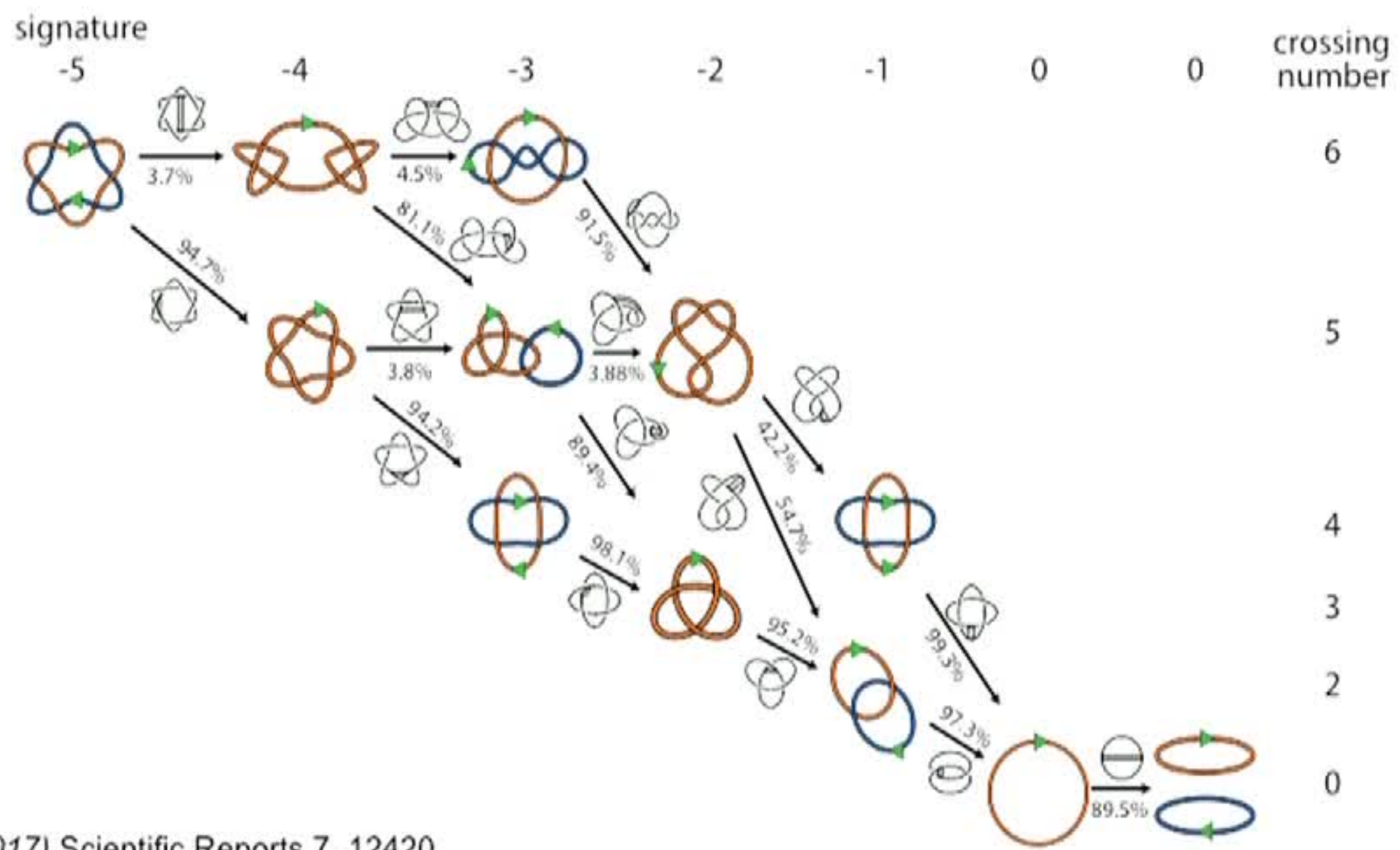
Image from Shimokawa et al., 2013

Topology simplification

by local reconnection: fluid vortices



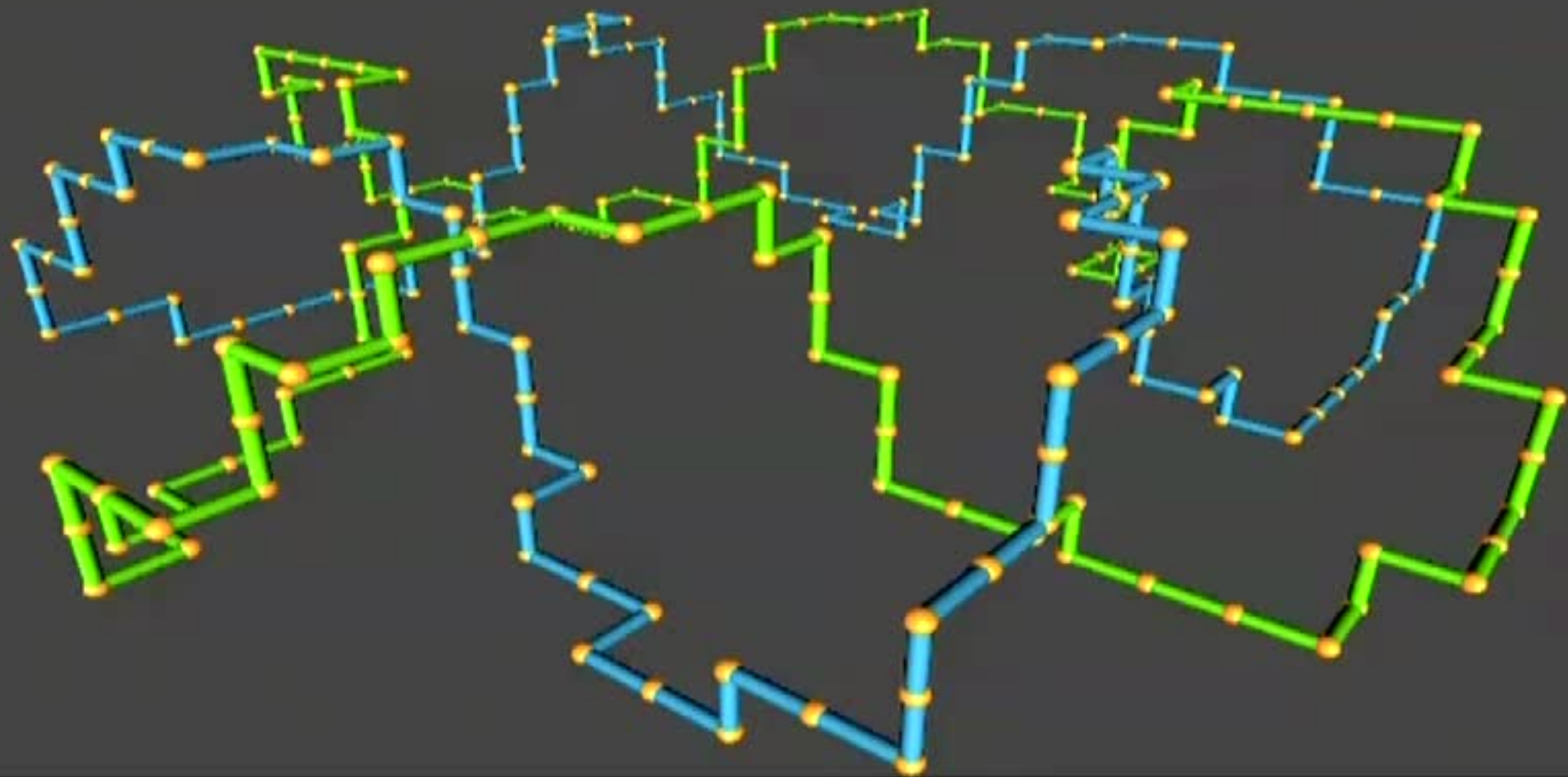
Kleckner and Irvine, *Nature Physics* (2013)



Stolz *et al.* (2017) Scientific Reports 7, 12420

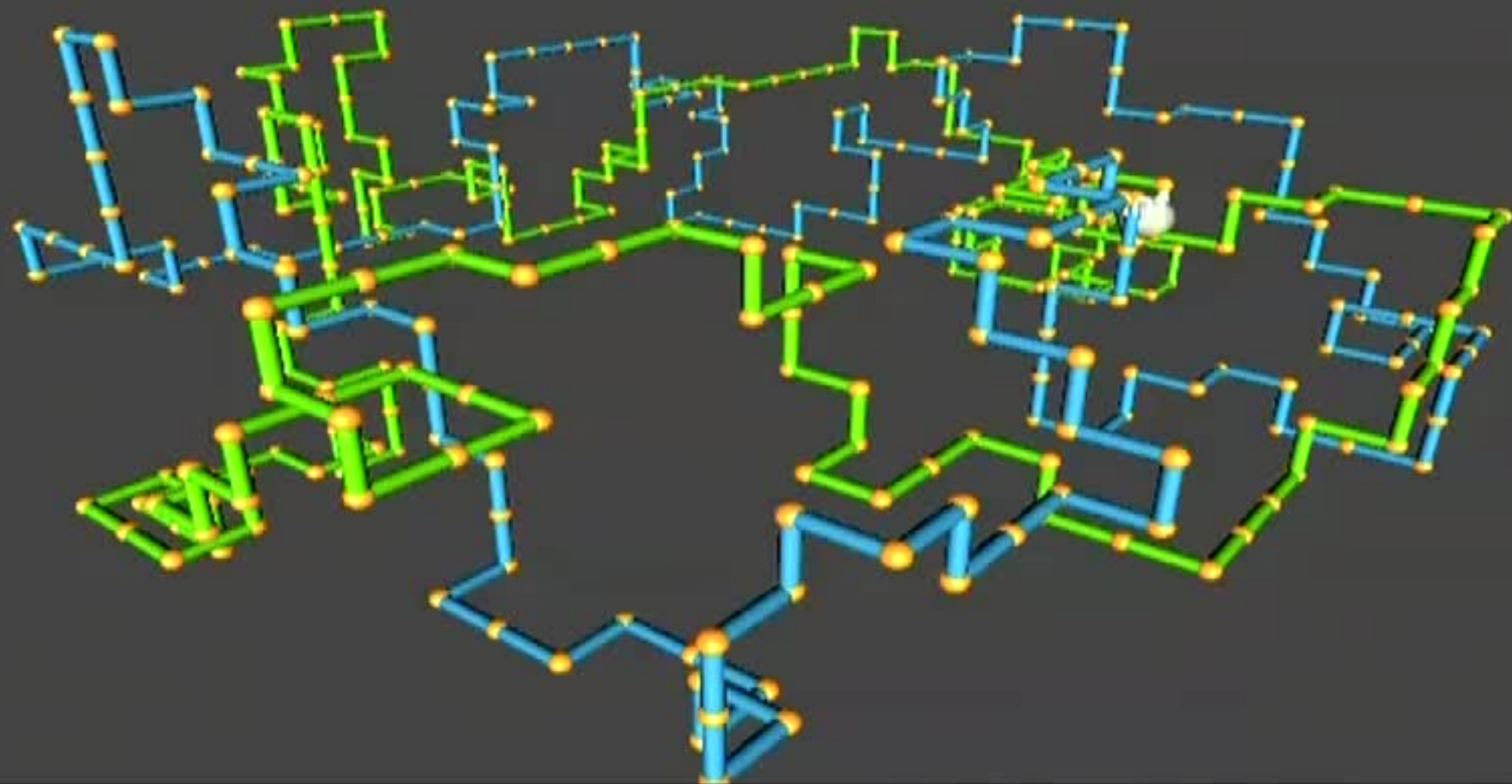
direct recombination

8.2.1c



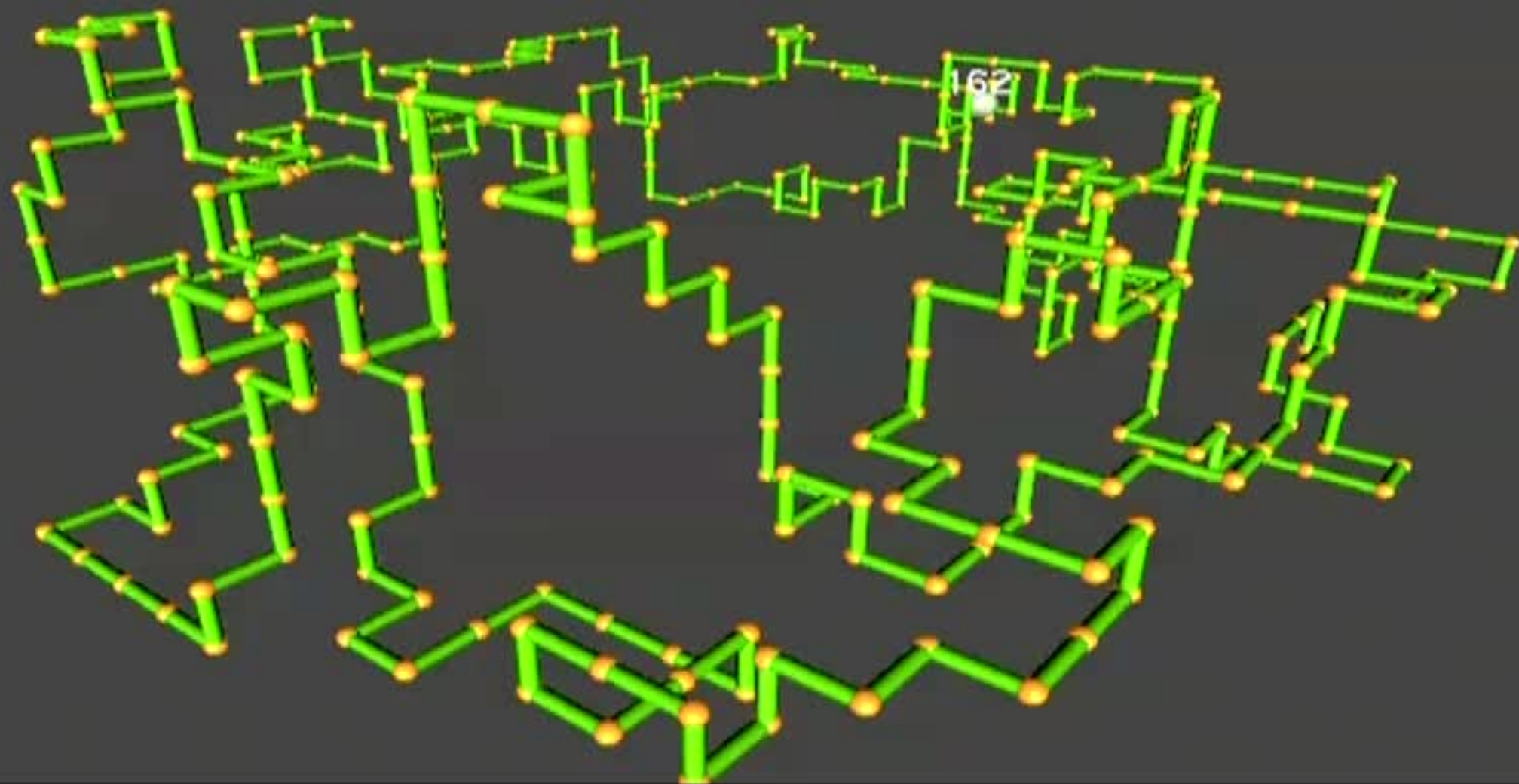
direct recombination

8.2.1c



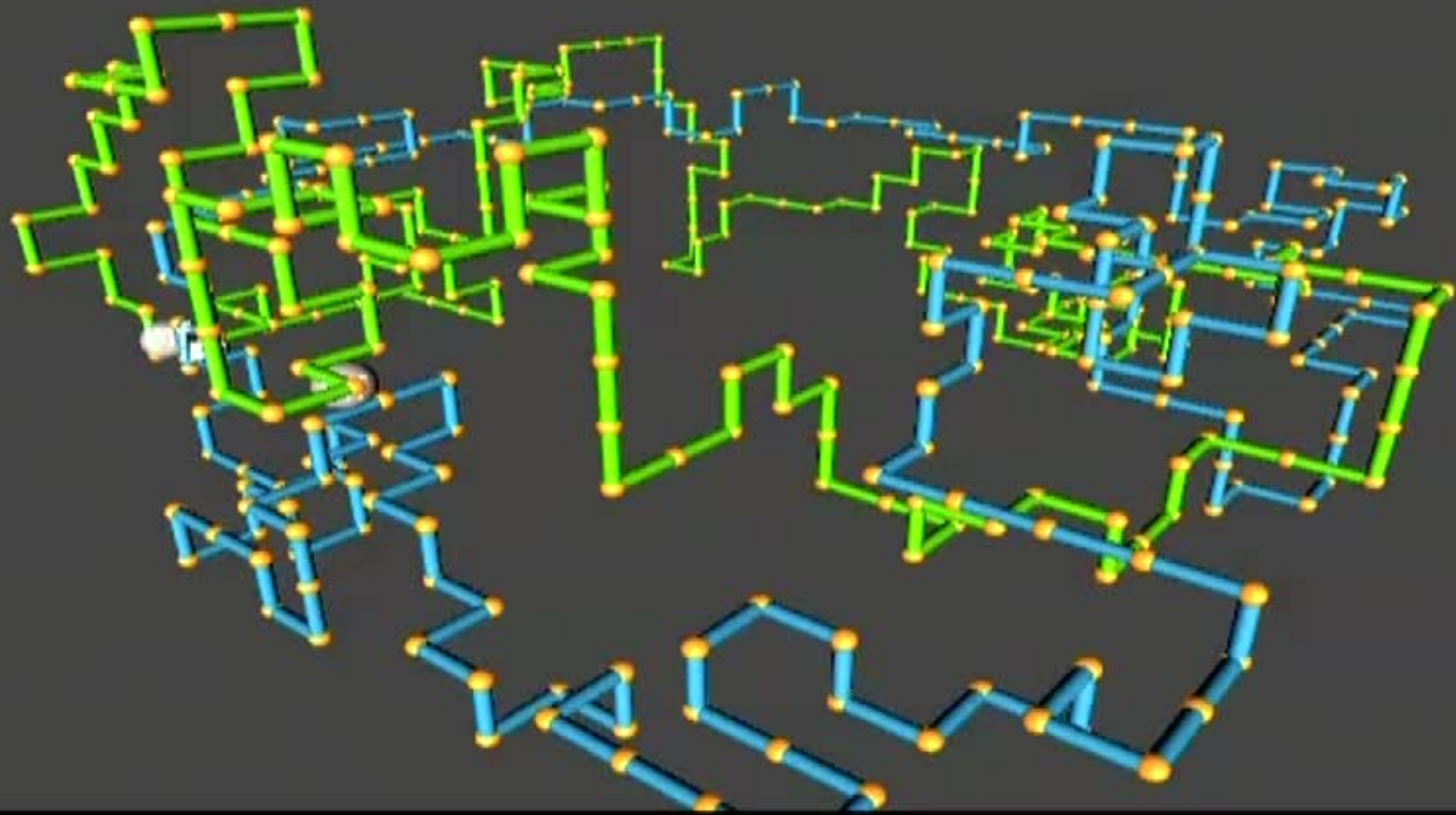
direct recombination

7_1s



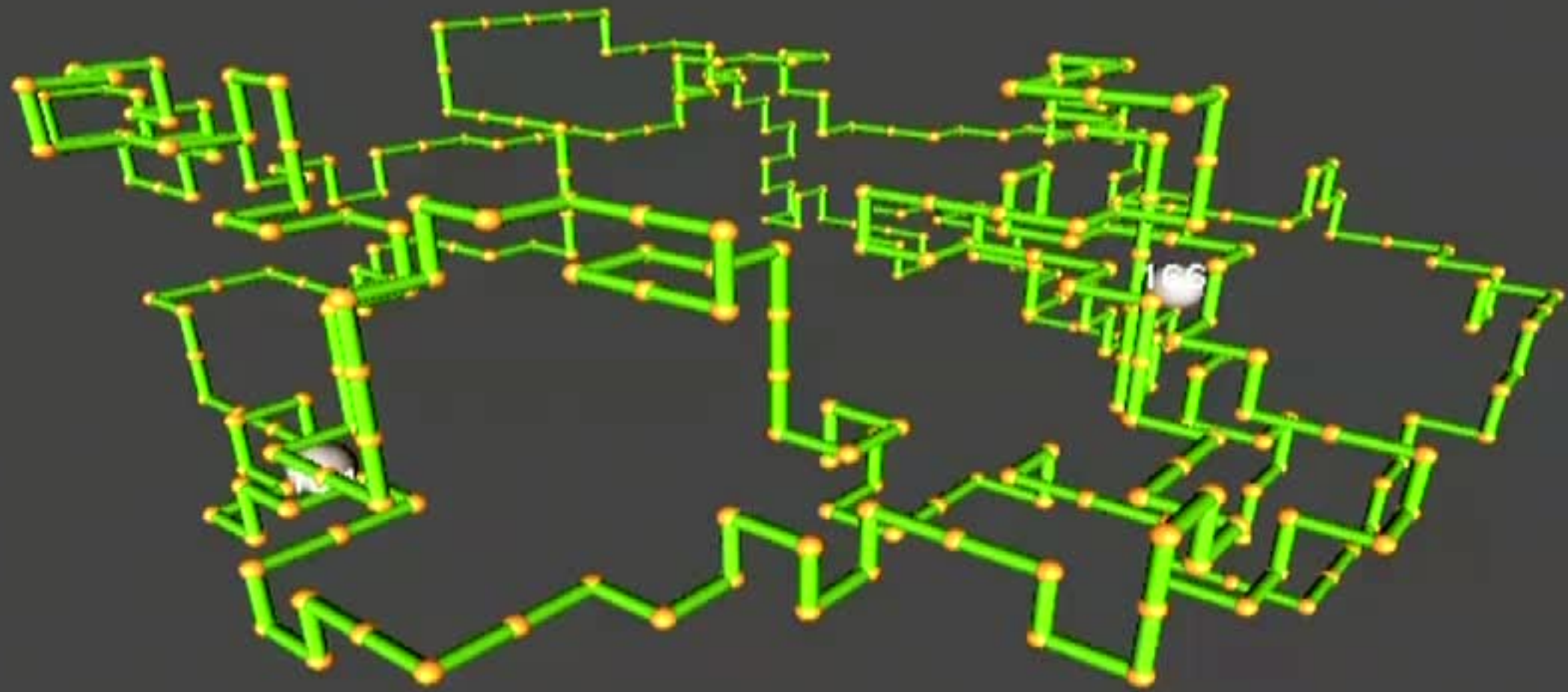
direct recombination

6.2.1d



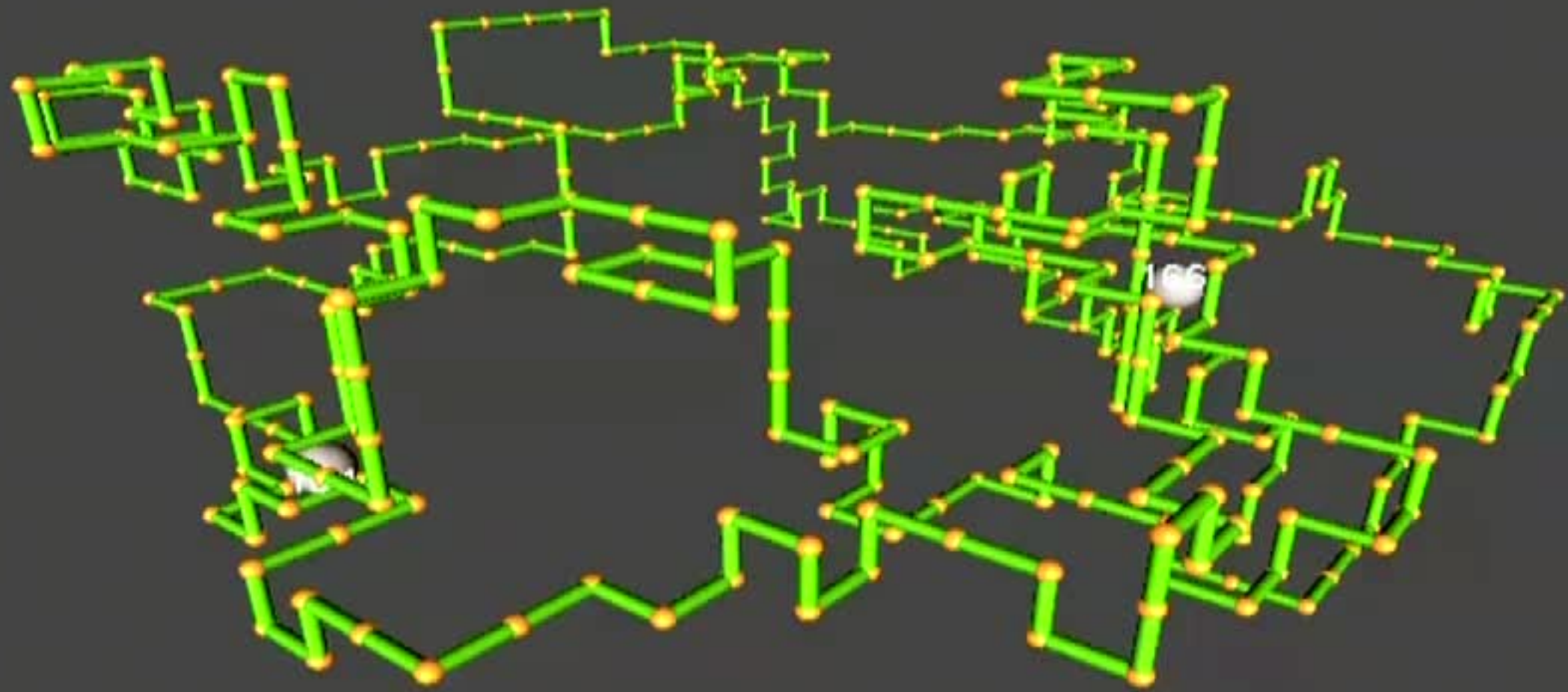
direct recombination

5_1s



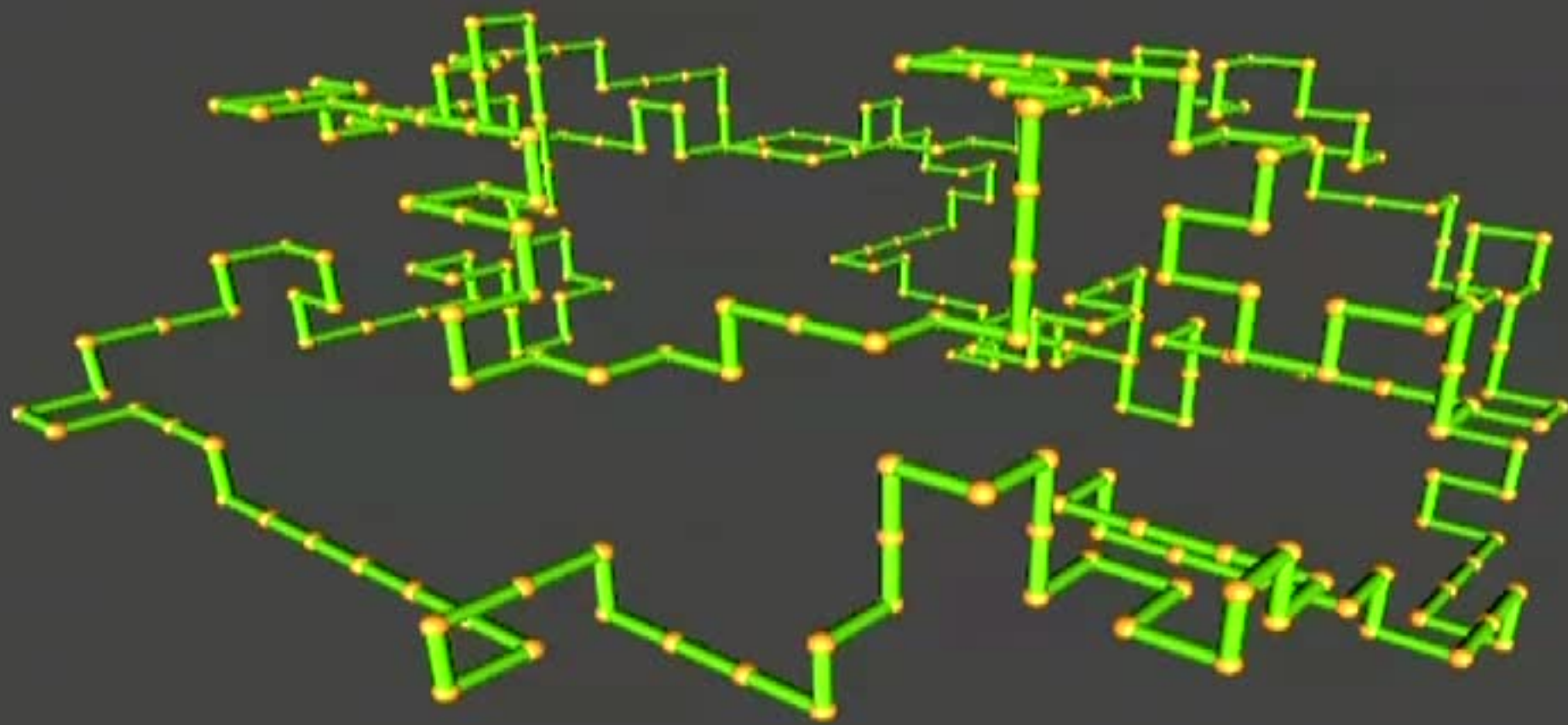
direct recombination

5_1s



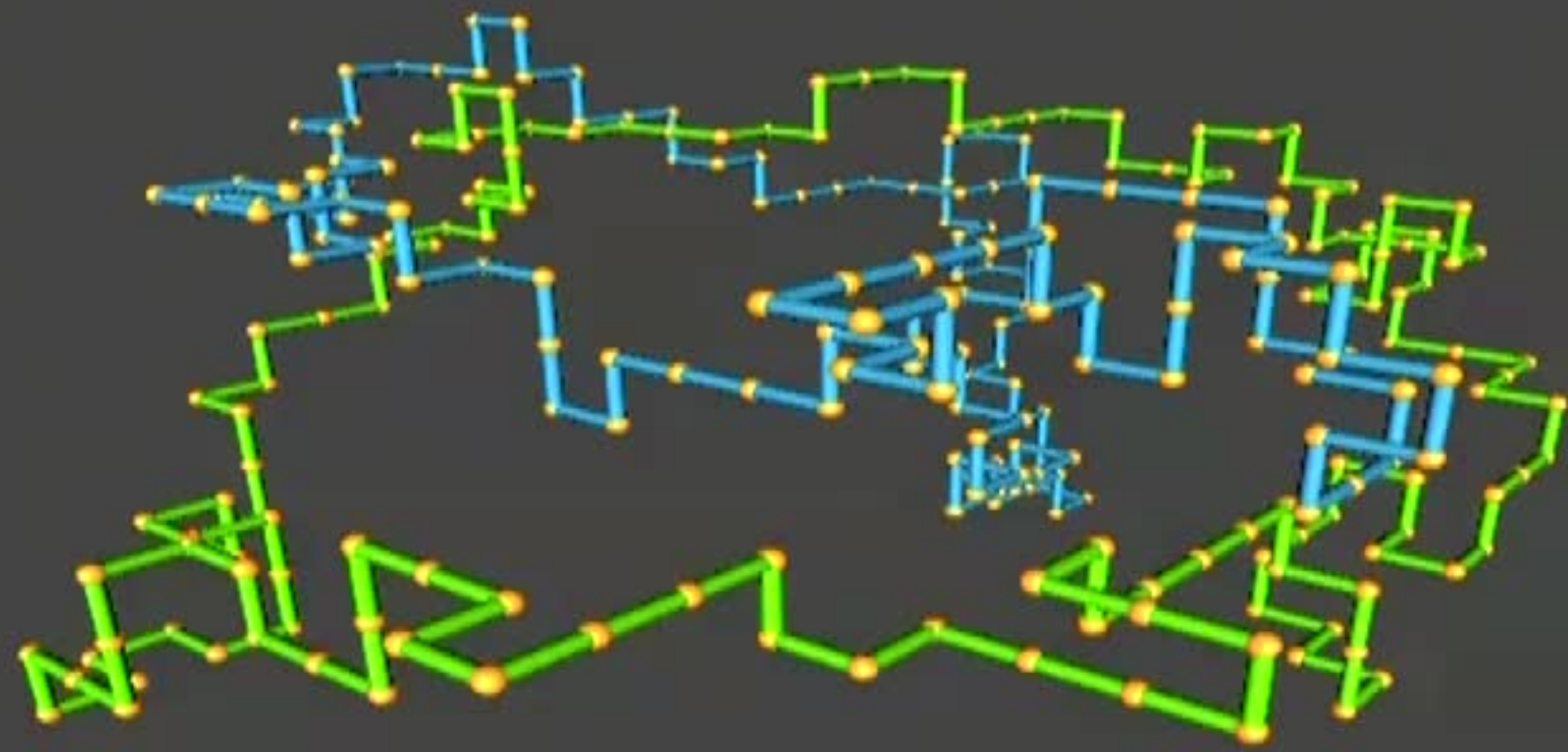
direct recombination

3_1s



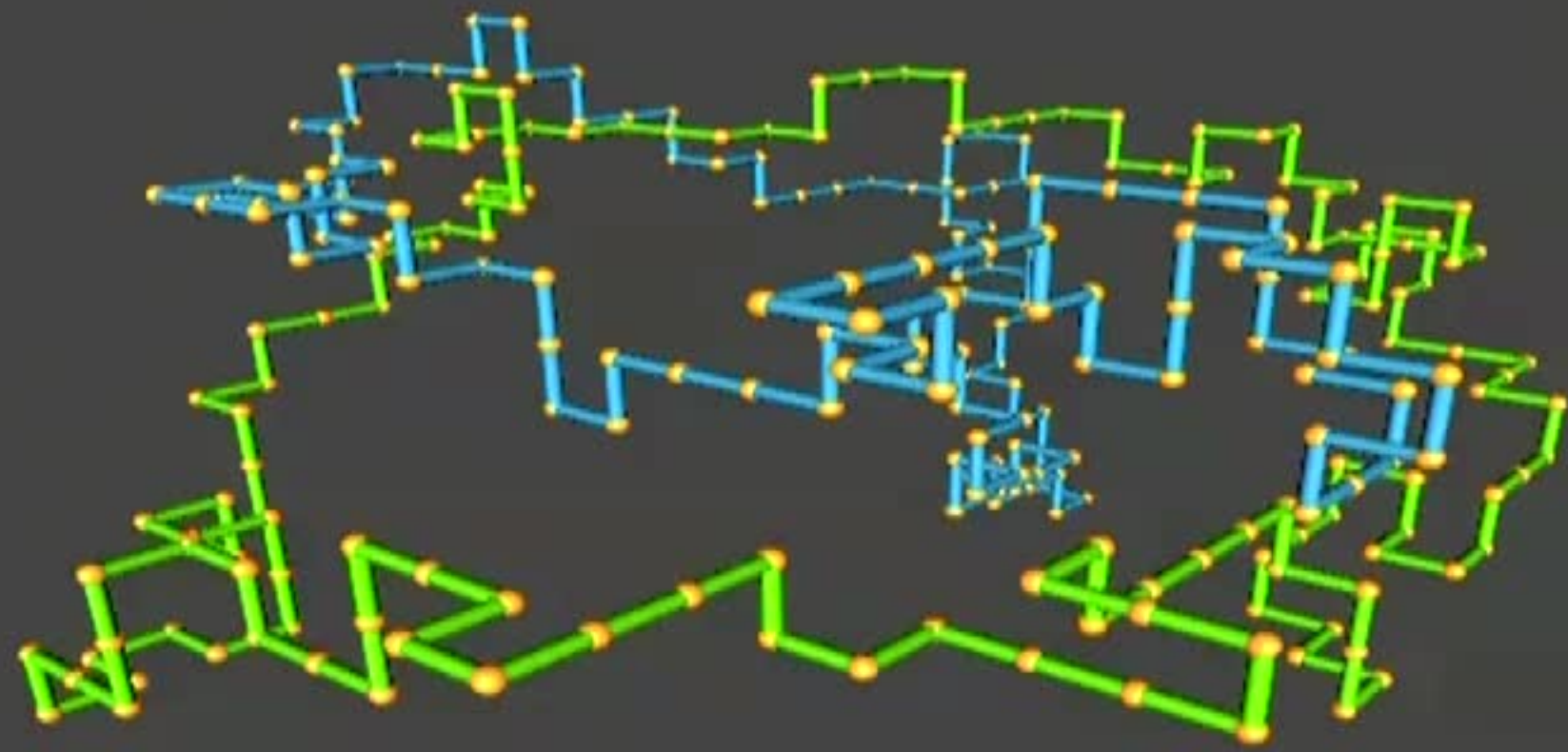
direct recombination

2.2.1b



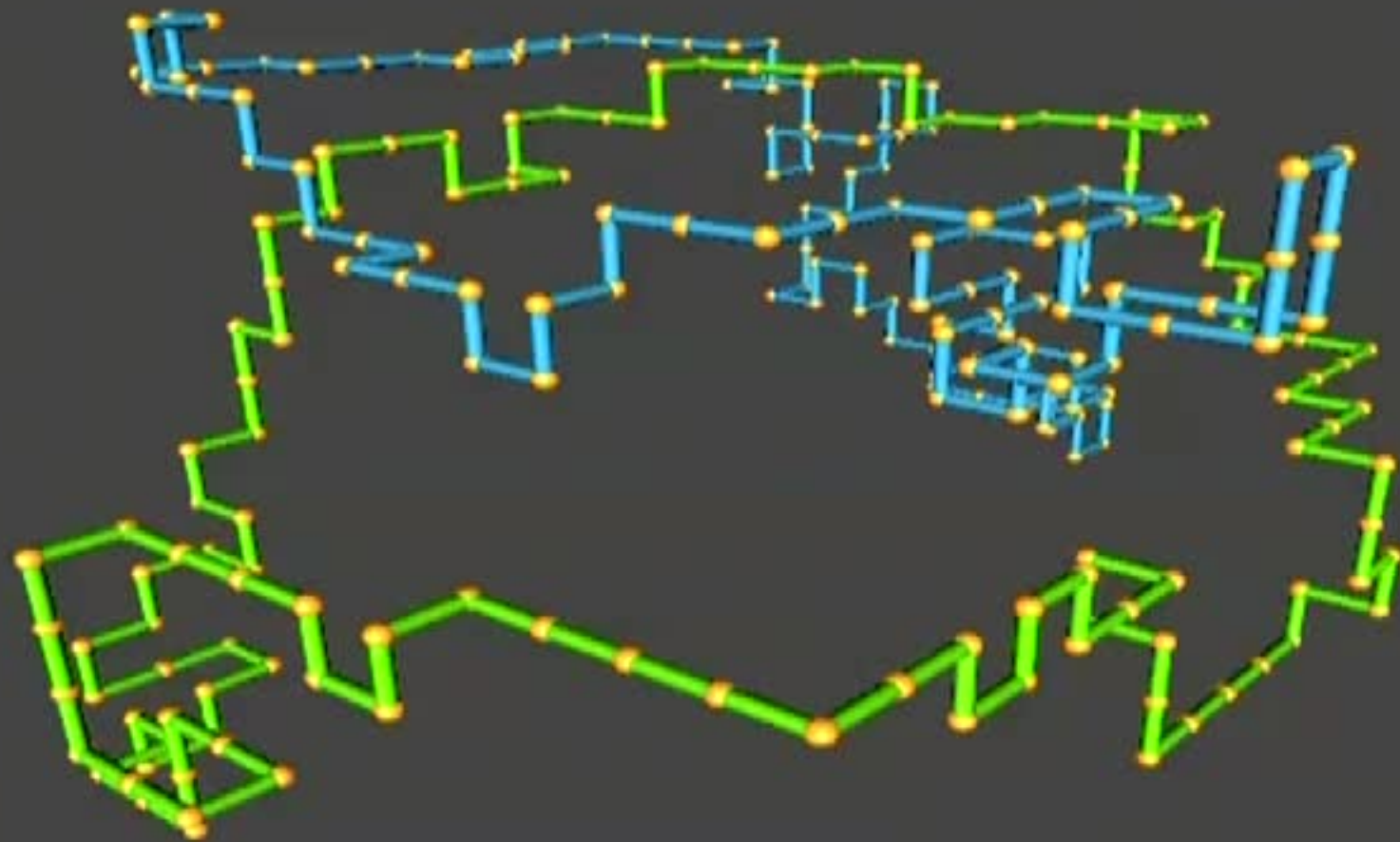
direct recombination

2.2.1b



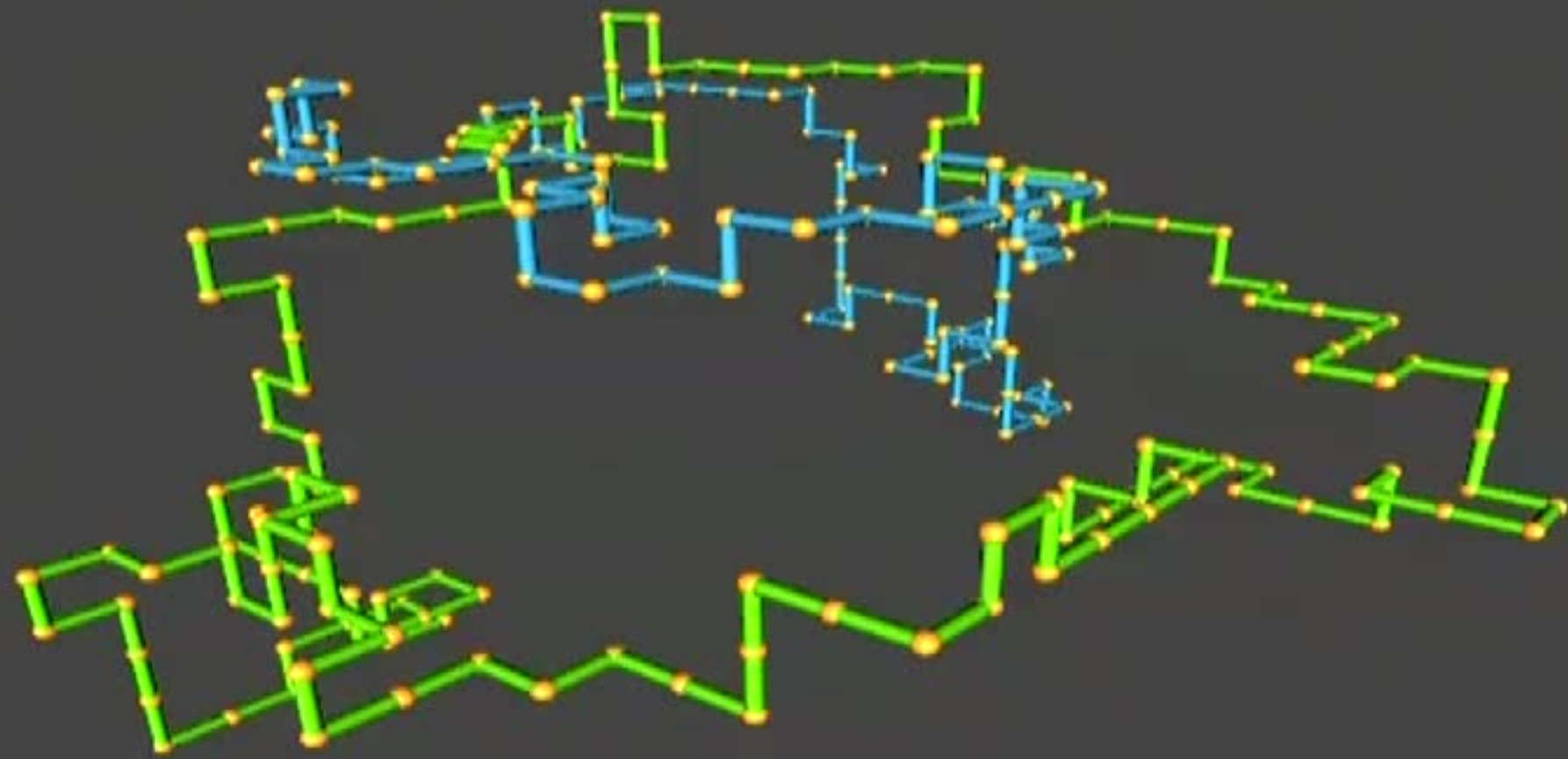
direct recombination

2.2.1b



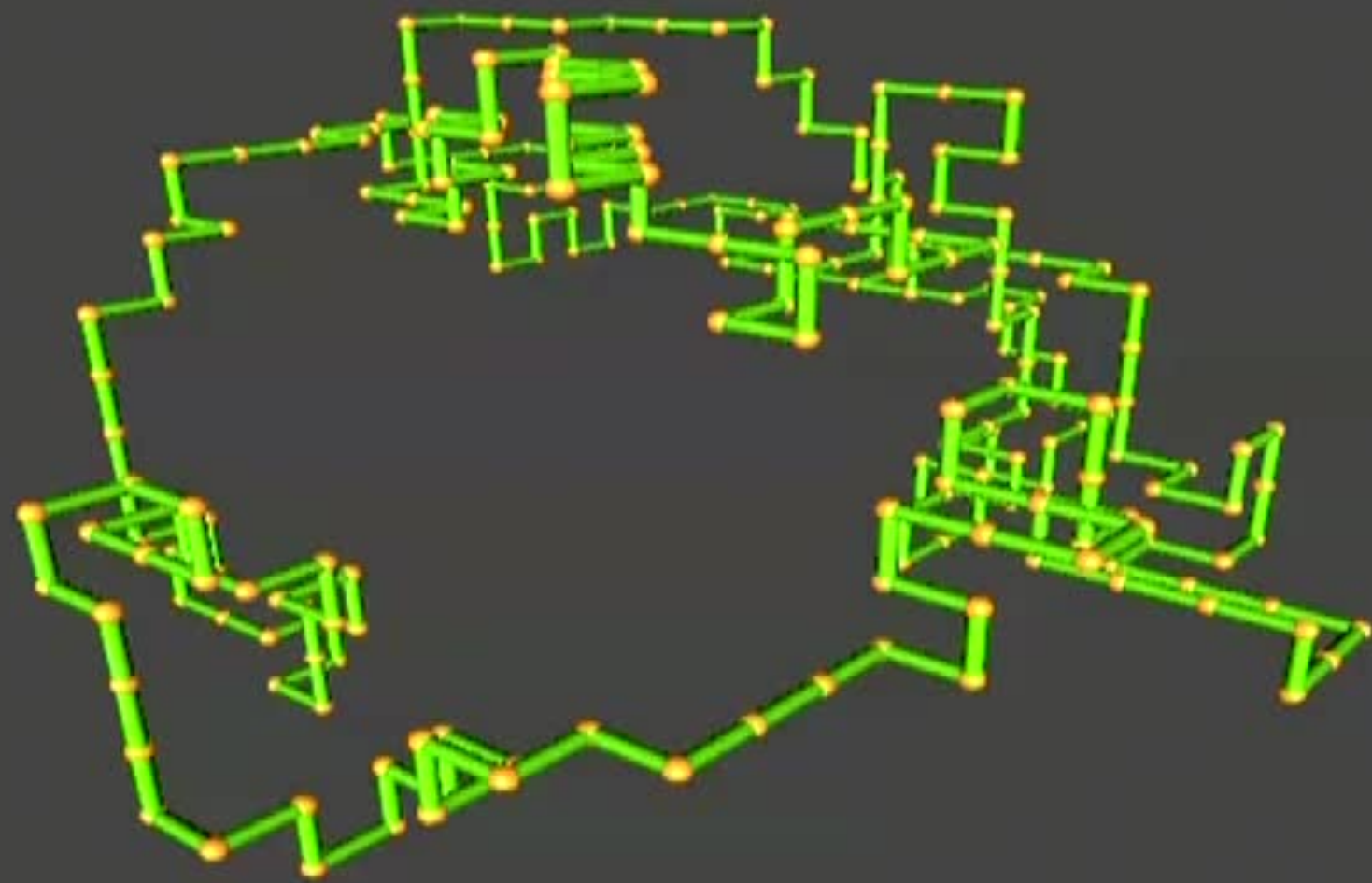
direct recombination

2.2.1b



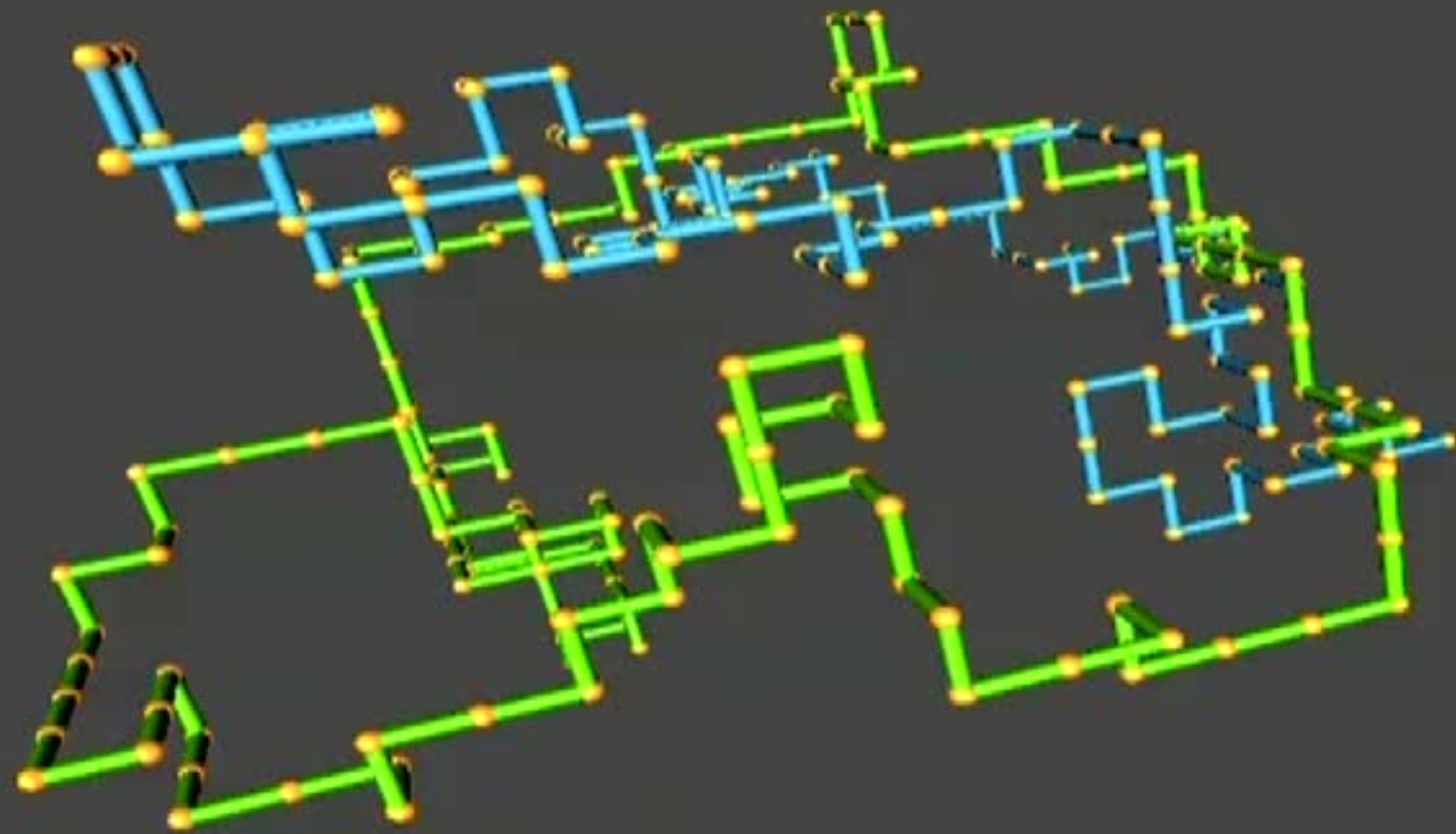
direct recombination

0_1



direct recombination

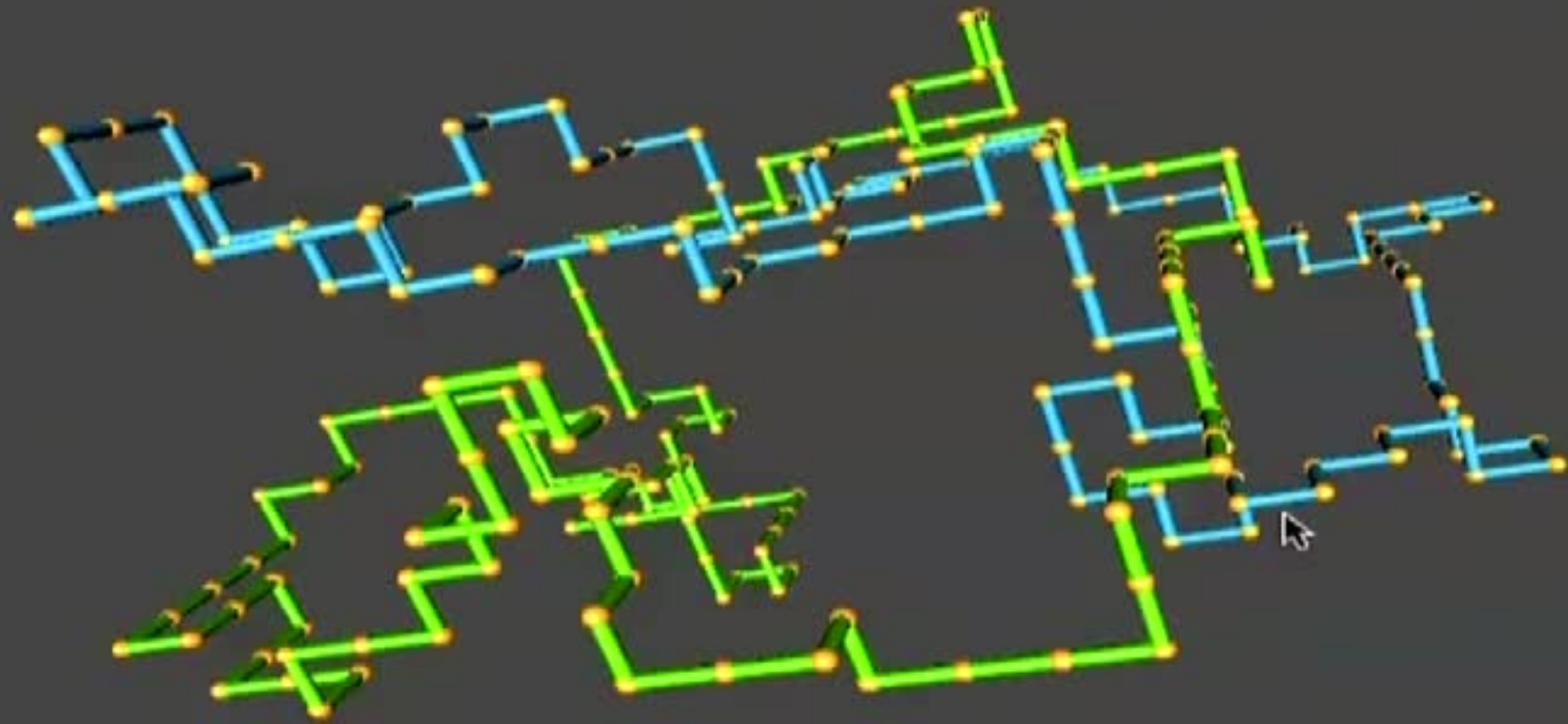
0.2.1a



42

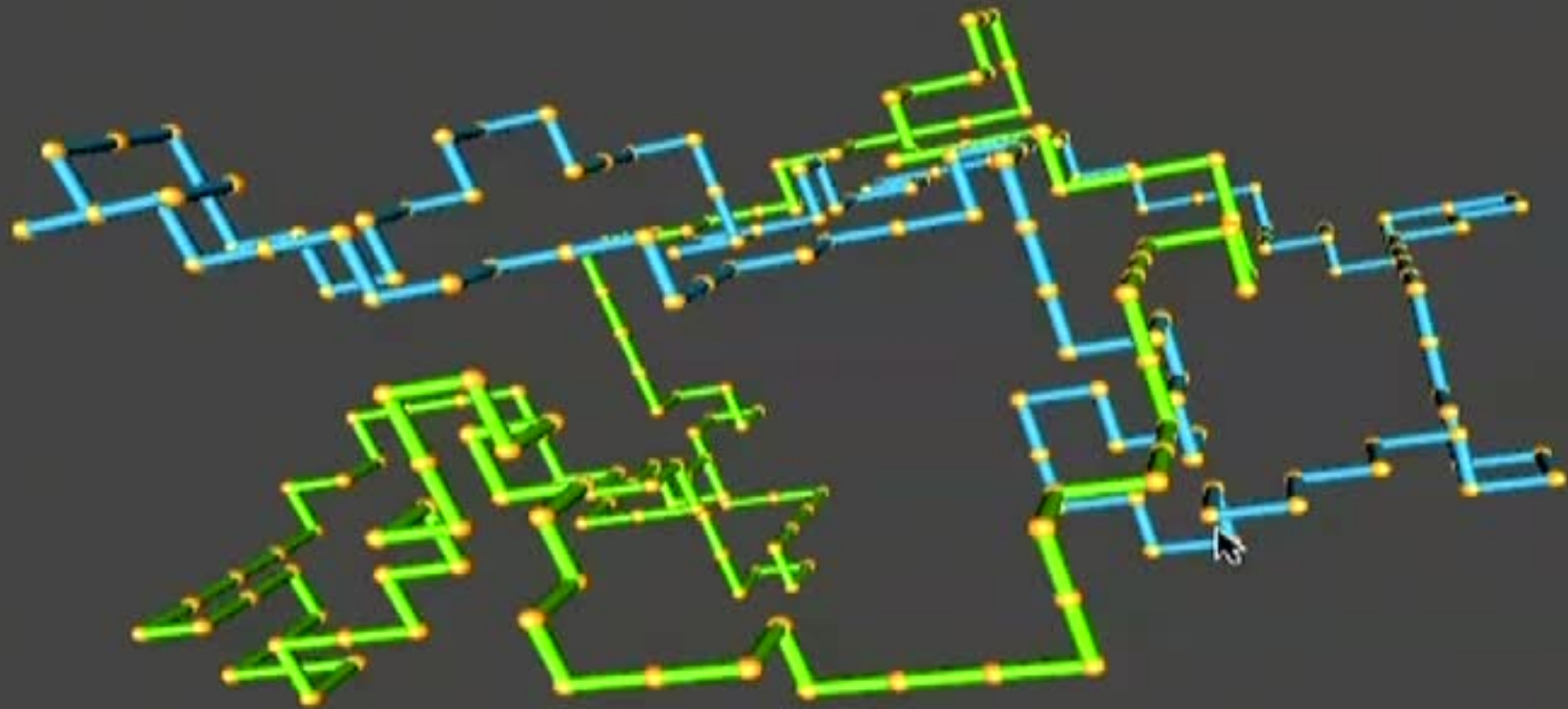
direct recombination

0.2.1a



direct recombination

0.2.1a



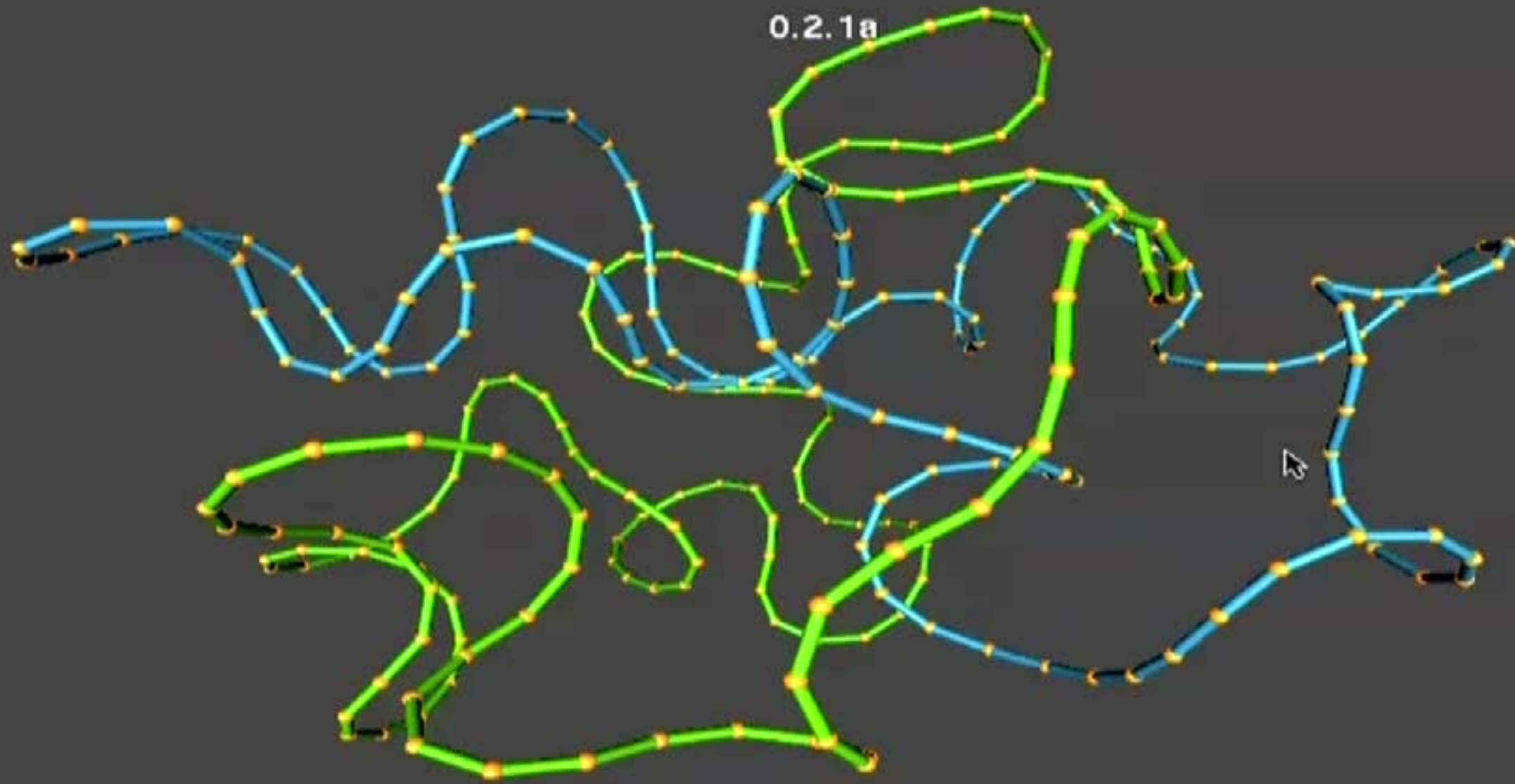
direct recombination

0.2.1a



direct recombination

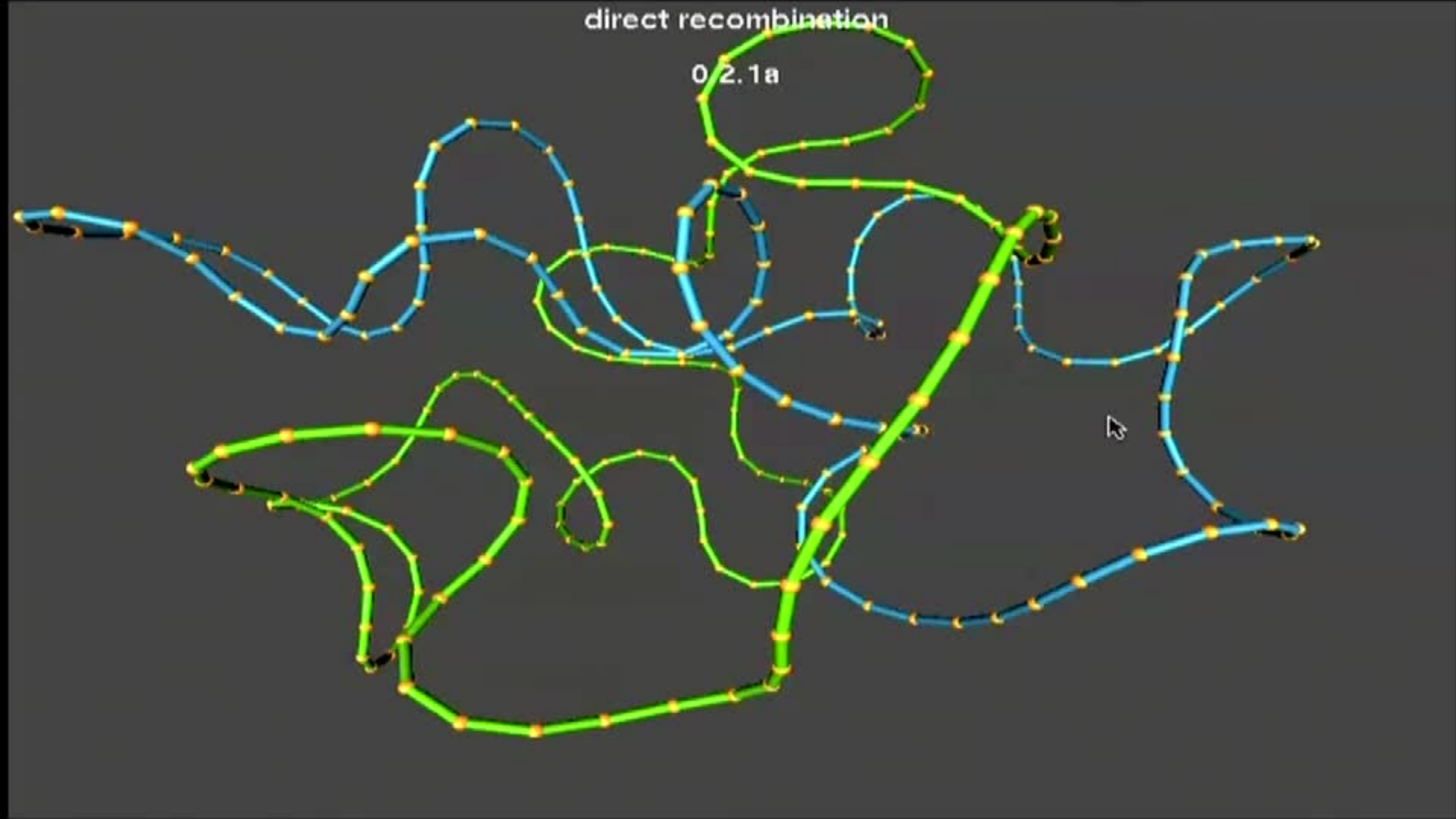
0.2.1a



L_2

direct recombination

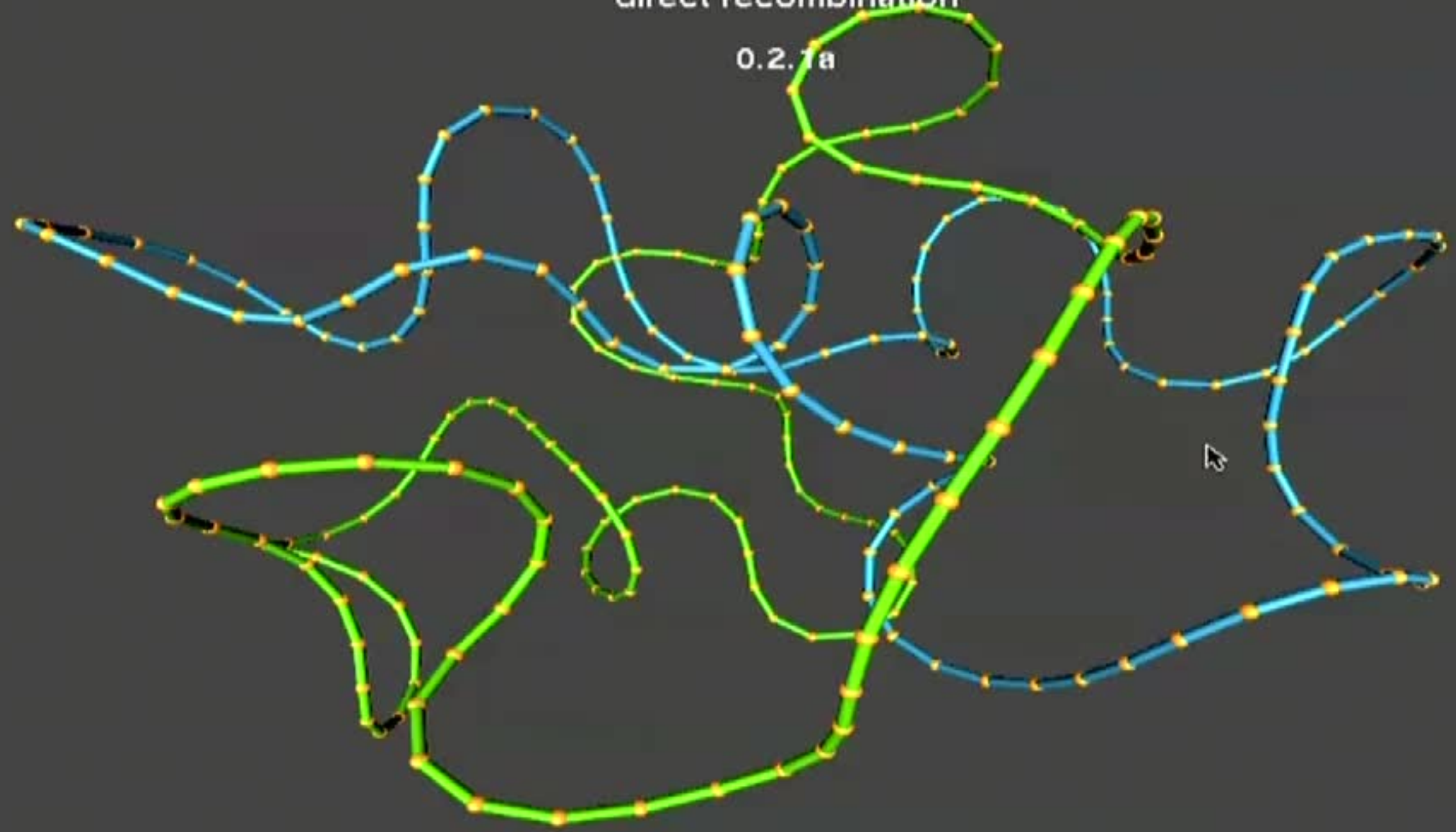
0 2.1a



direct recombination

0.2.7a

L₂



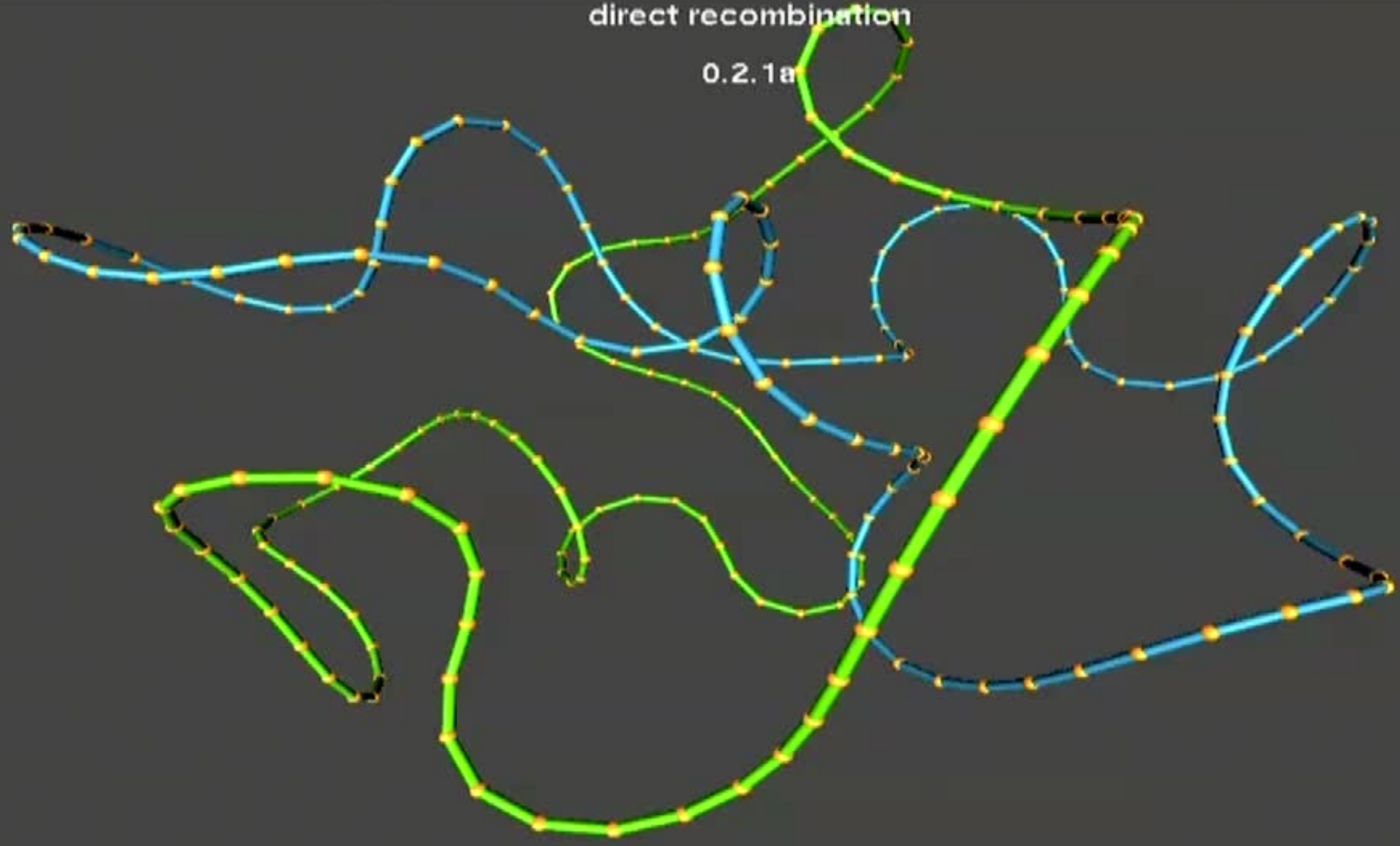
direct recombination

0.2.10



direct recombination

0.2.1a



direct recombination

0.2.1a

