Sequence selection by ligation under non-equilibrium conditions

- science update -

Dieter Braun

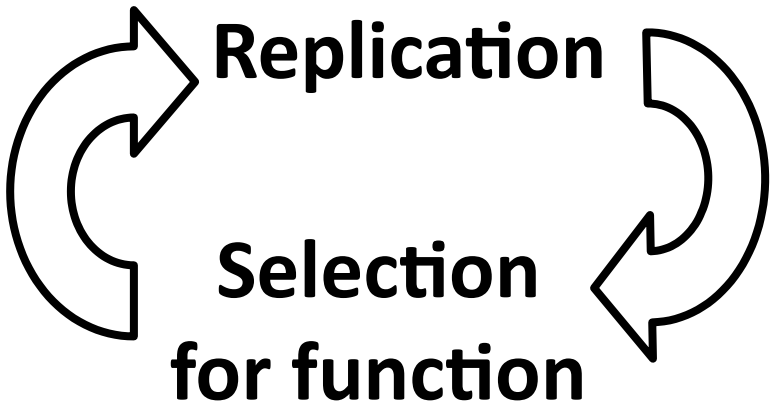
Patrick Kudella

With Sergei Maslov and
Alexei Tkachenko, University of Illinois

upcoming hybridization kinetic code:
Bernhard Altaner and Ulrich Gerland, TUM

indico.physik.lmu.de/event/63/

(In)stability of Evolution



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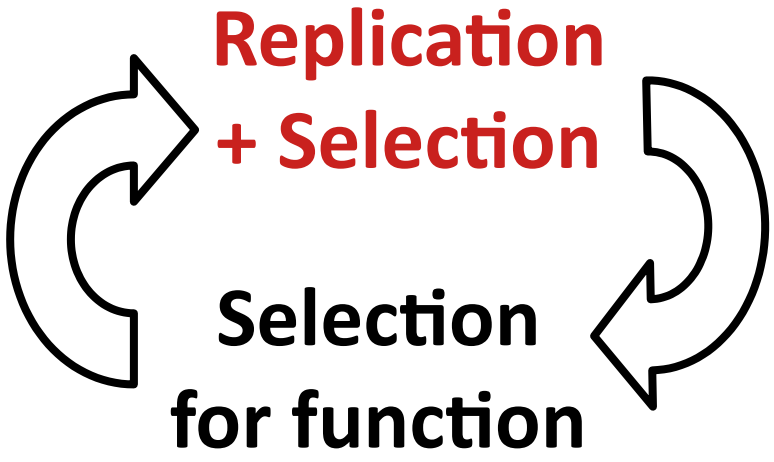
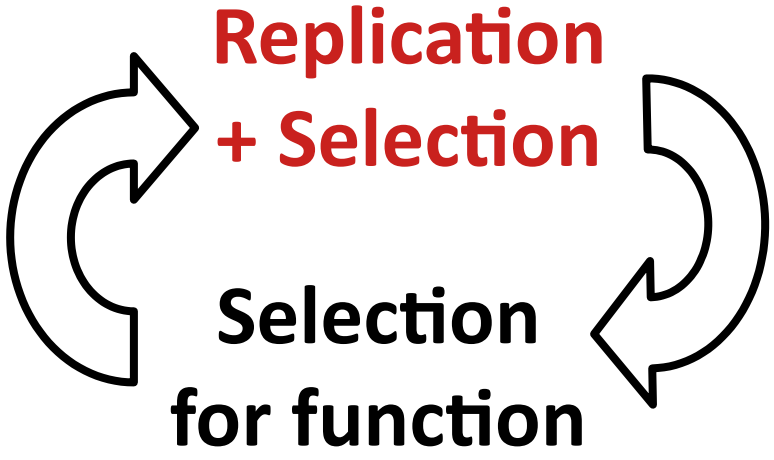


(In)stability of Evolution

- Tyranny of the shortest (Spiegelman)



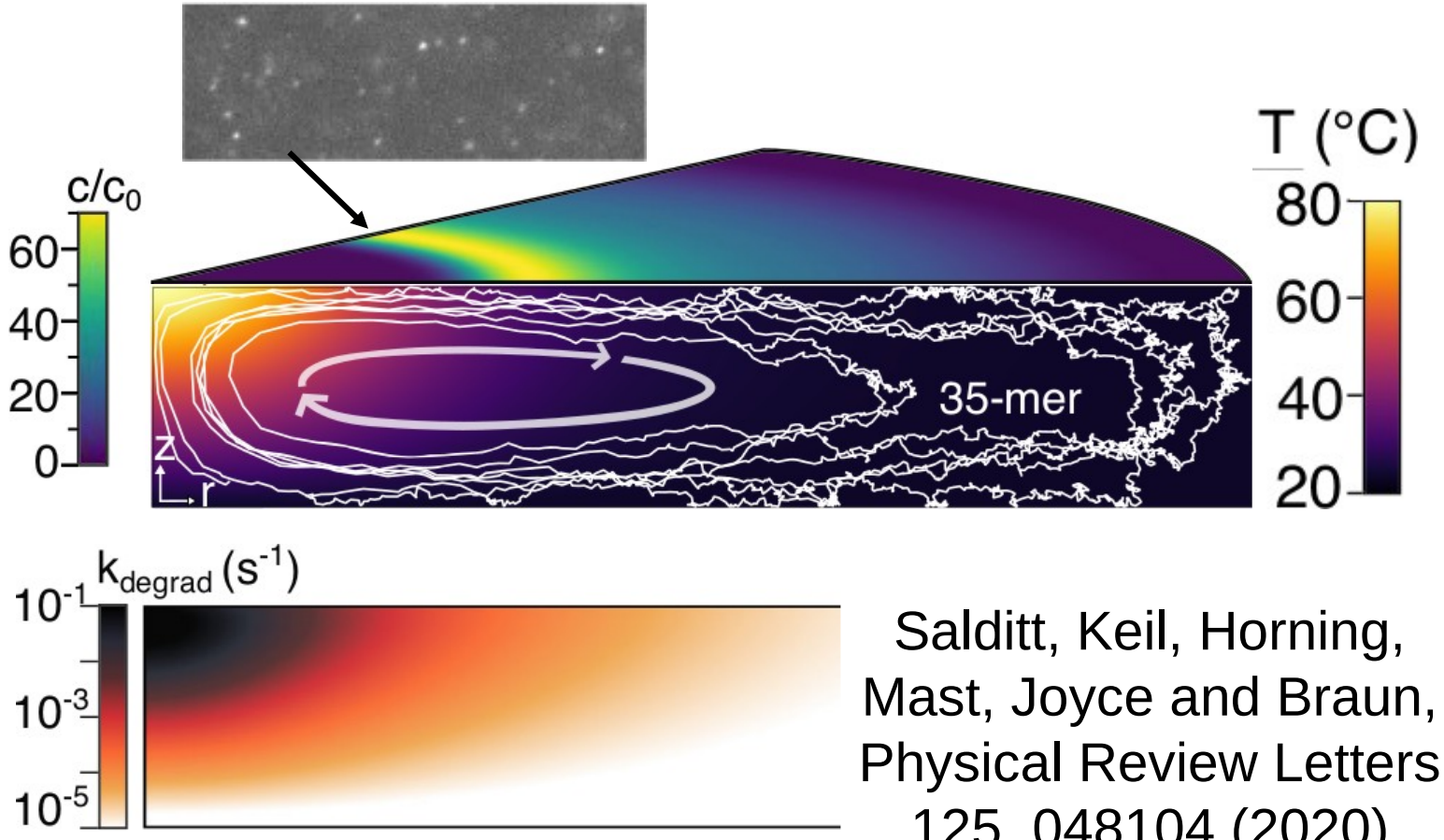
(In)stability of Evolution

Replication
+ Selection

Selection
for function

- Tyranny of the shortest (Spiegelman)

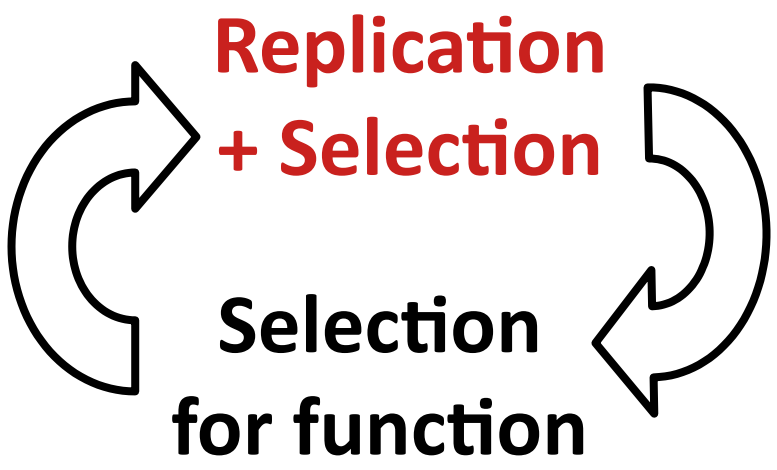
Lack of non-primer replication in Ribo-PCR



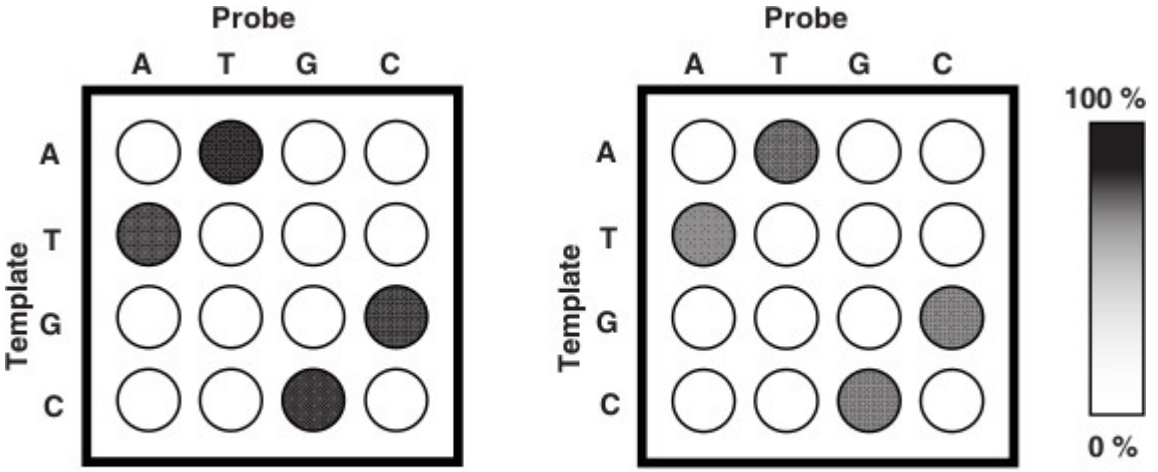
Salditt, Keil, Horning, Mast, Joyce and Braun, Physical Review Letters 125, 048104 (2020)

(In)stability of Evolution

Study templated ligation



Taq-Ligase: precision and low temperature performance



Yield of nick closure

Yield of ligation

Profiling the selectivity of DNA ligases in an array format with mass spectrometry, **Kim and Mrksich**, Nucleic Acid Research, doi:10.1093/nar/gkp827 (2010)

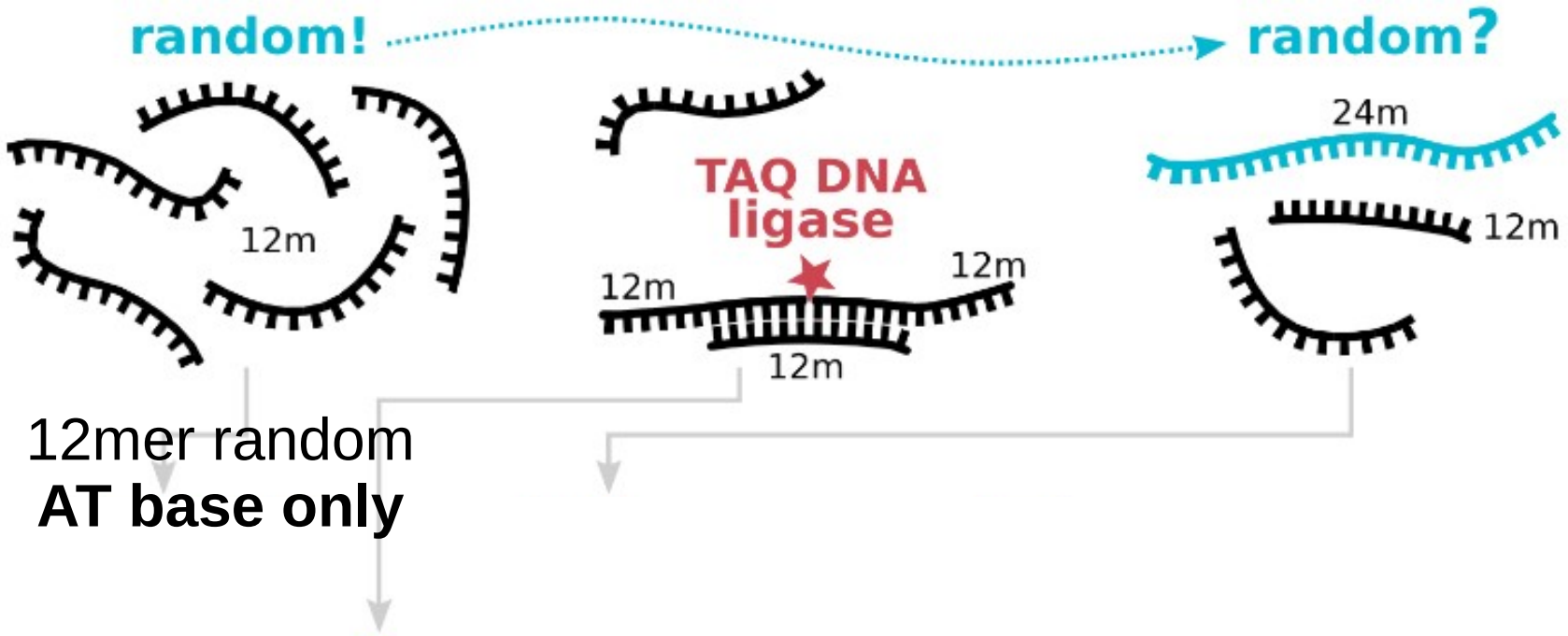
Illumina sequencing with Swift kit and LMU Gene Center facility

Thanks for discussions with Daniel Duzdevich and Irene Chen

Repeated templated ligation of random pools

12mer random
AT base only

Repeated templated ligation of random pools



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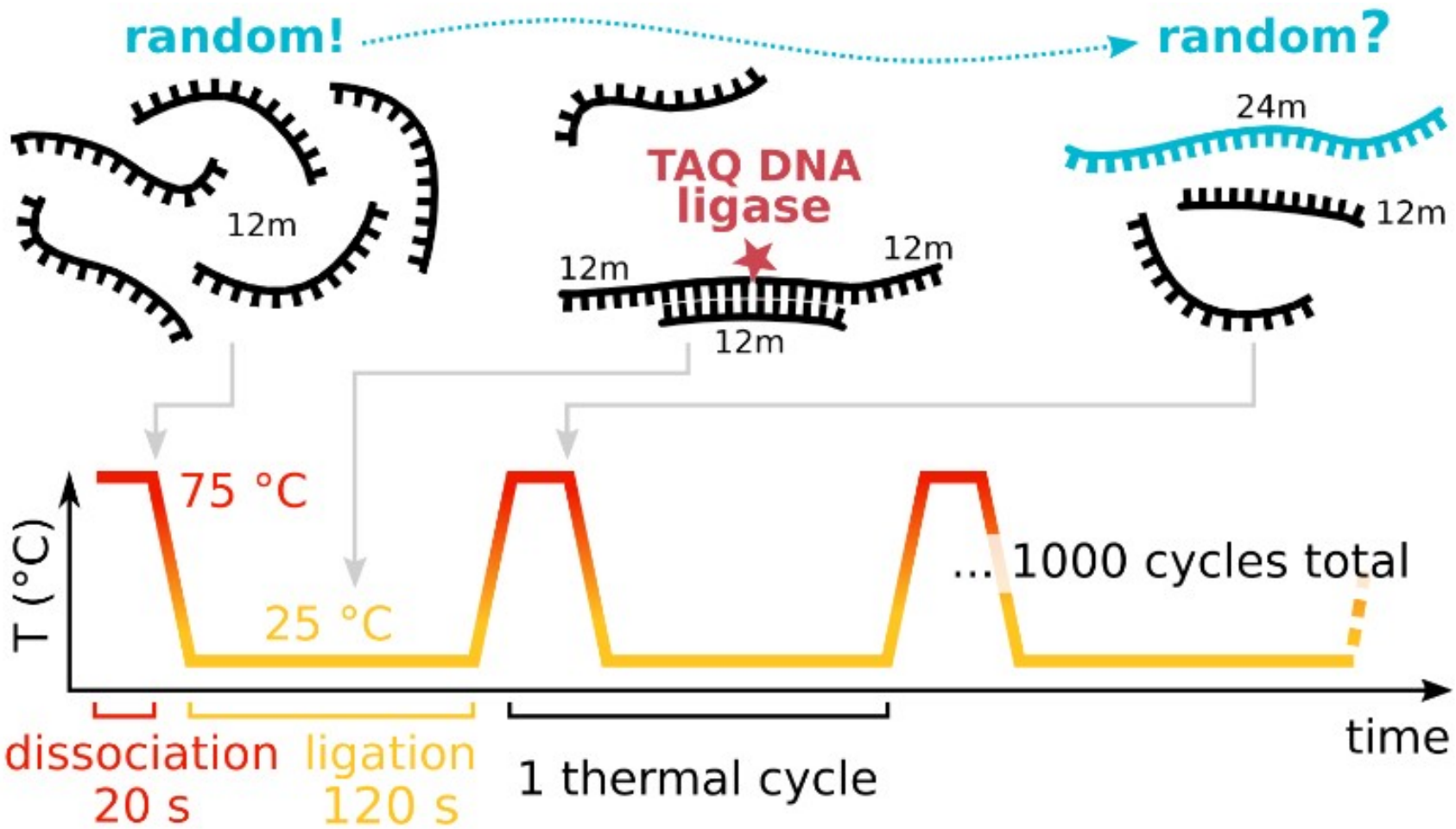

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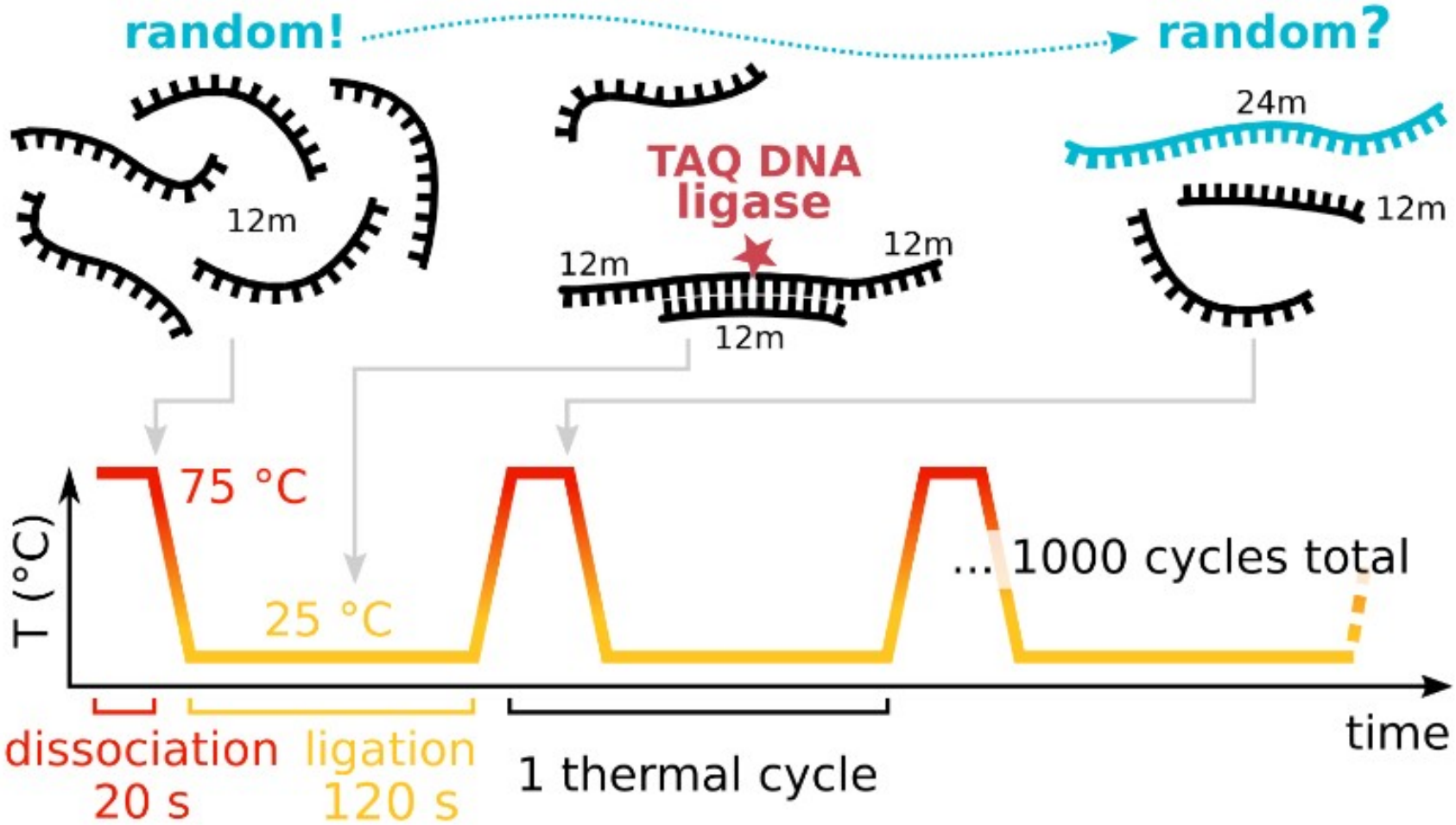

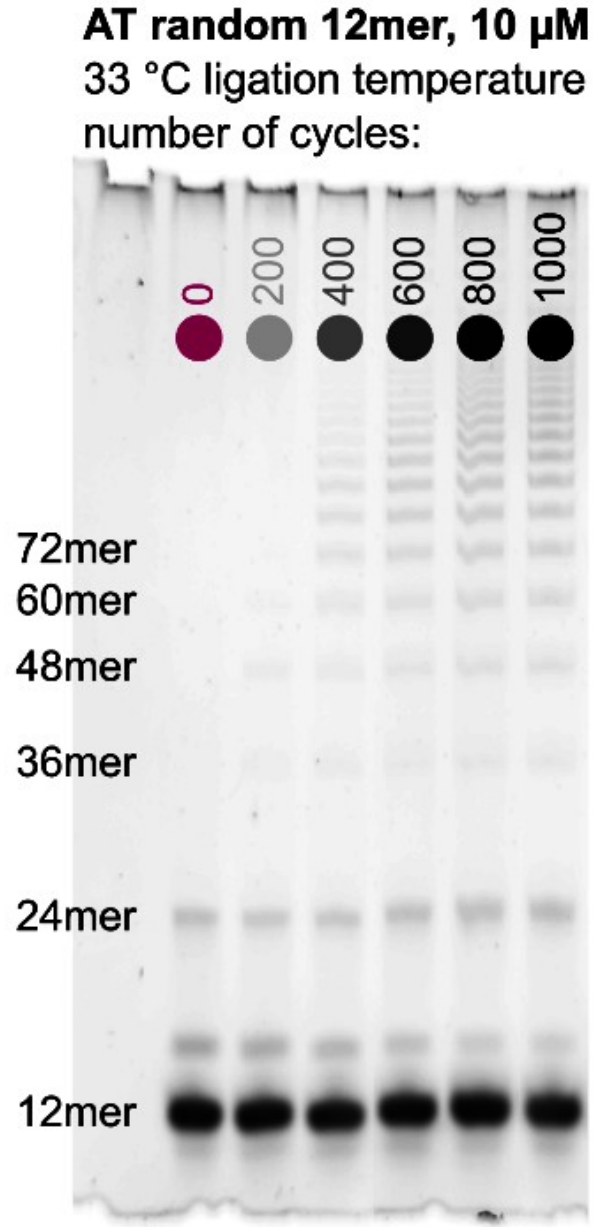

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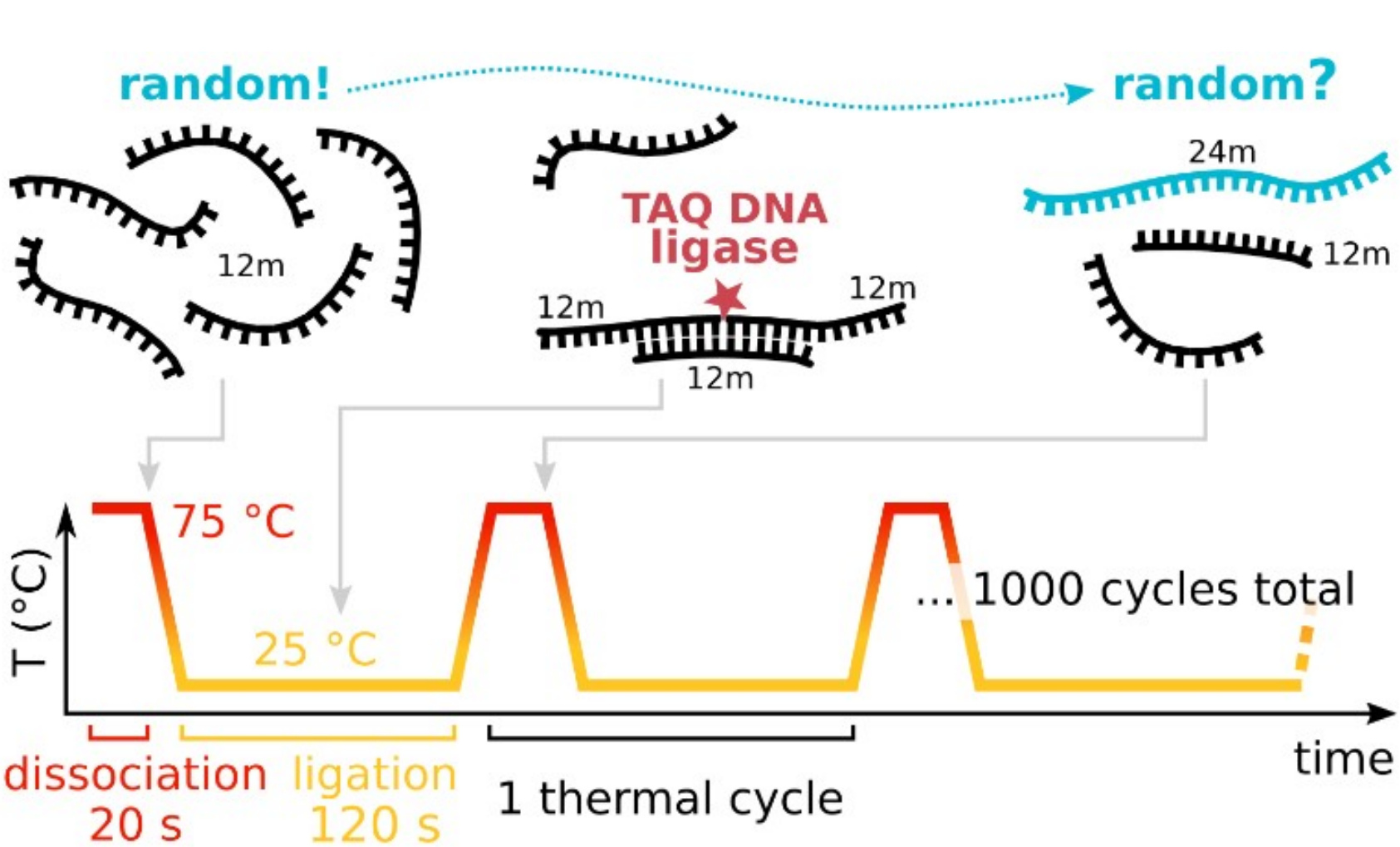
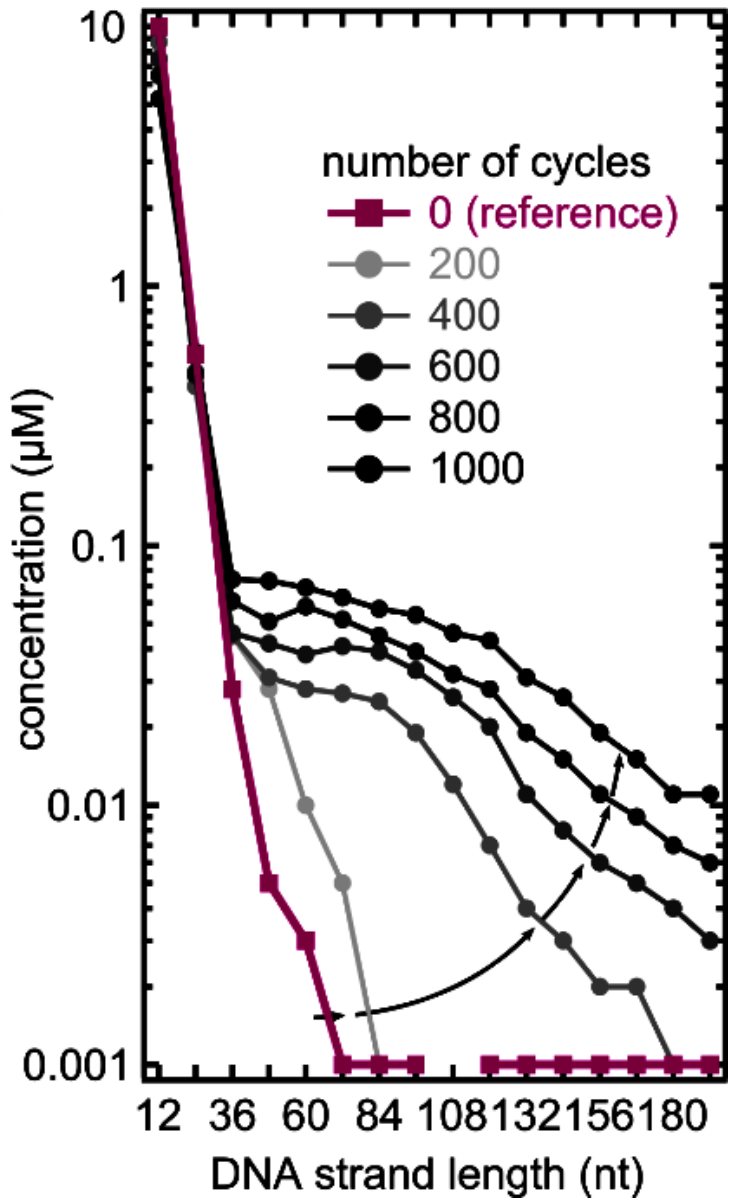
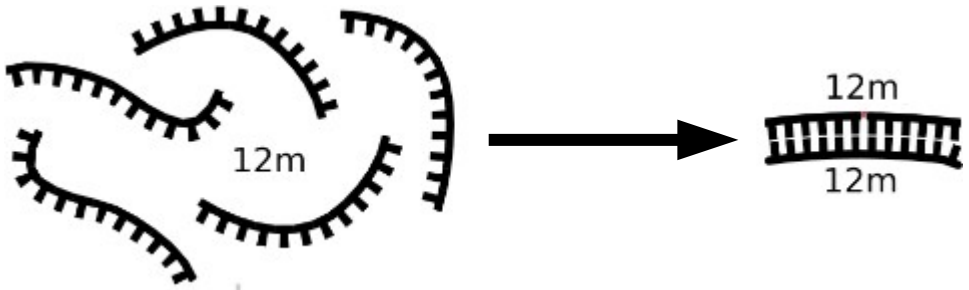




Why templated ligation is out of equilibrium



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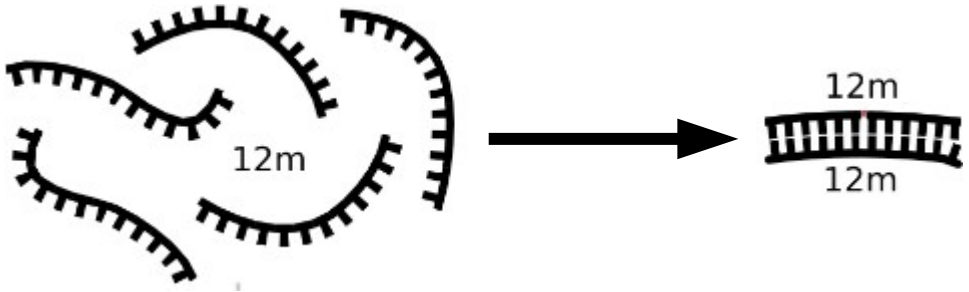
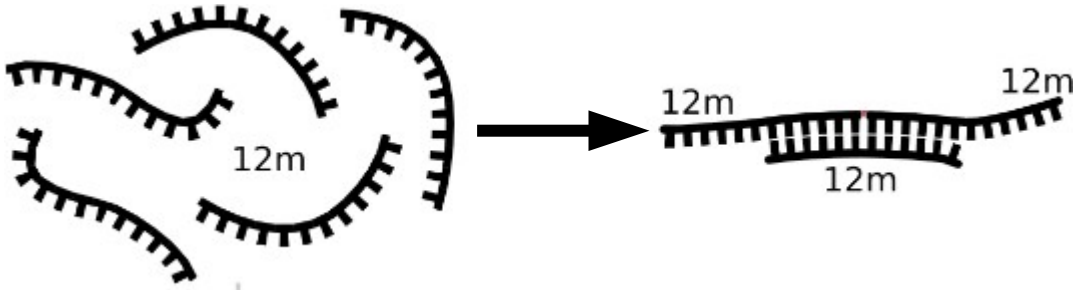


Hybridization
no competition $k_{on}^{\hat{hyb}} = 1\,\mu M^{-1} s^{-1}$



Gao, Wolf, Georgiadis, Nucleic acids research, 34(11), 3370-3377 (2006)
Ouldridge, Šulc, Romano, Doye, Louis, Nucleic acids research, 41(19), 8886-8895 (2013)

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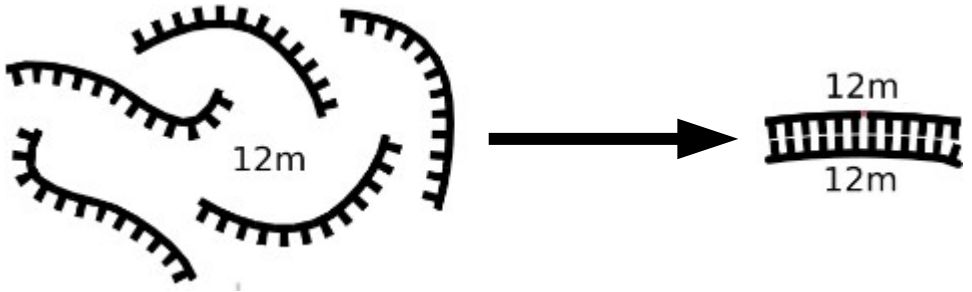

Sequence space

AT $t = \frac{k_{on}^{hyb}}{10\,\mu M} 2^{12} = 410\,s$

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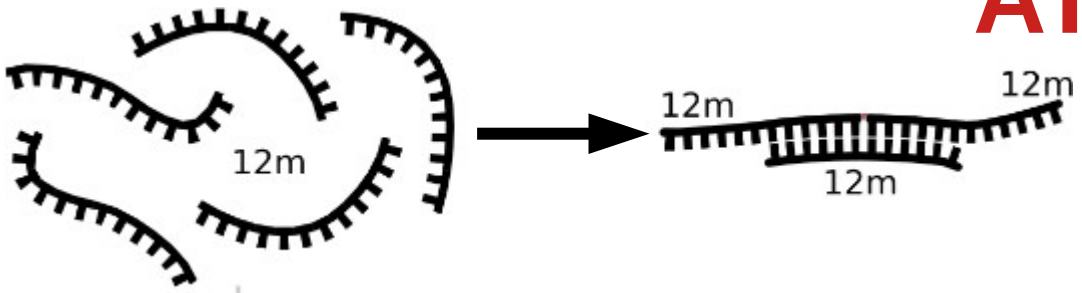

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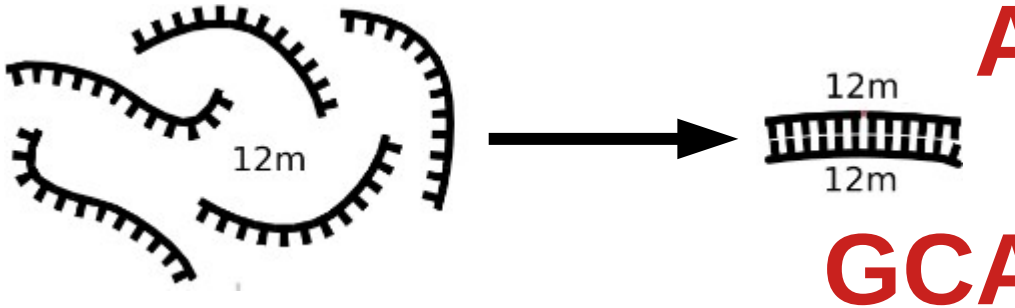

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GCAT $t = \frac{k_{on}^{hyb}}{10\,\mu M} 4^{12} = 19\,days$

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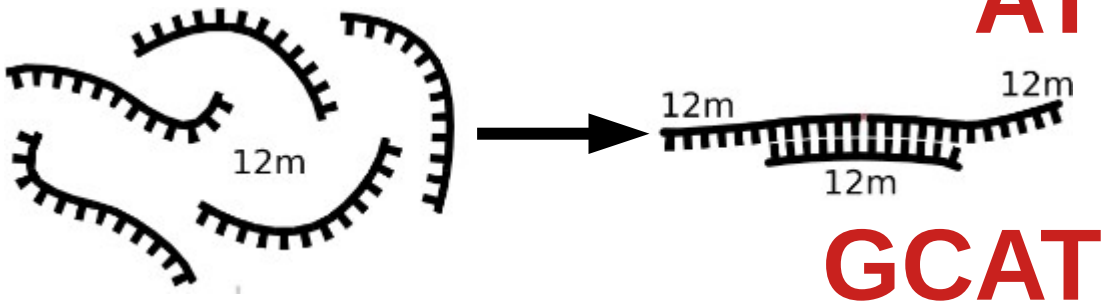

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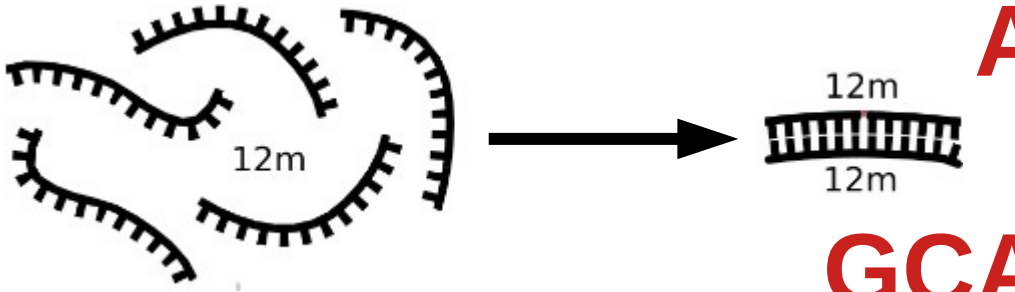

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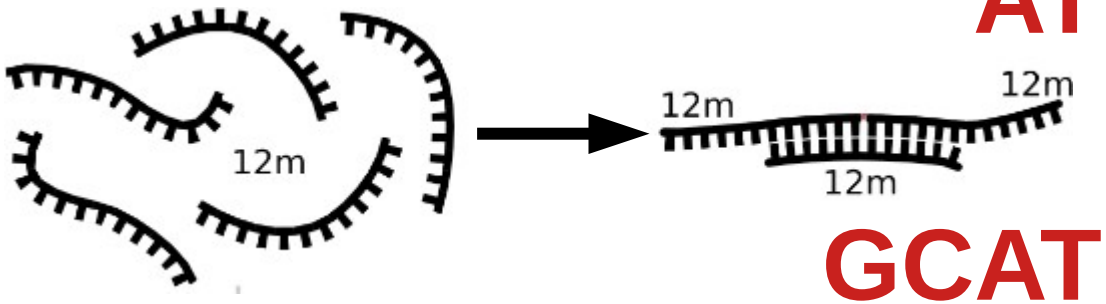

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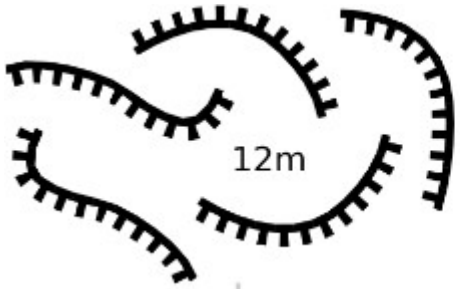

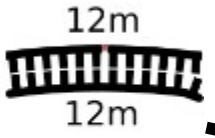

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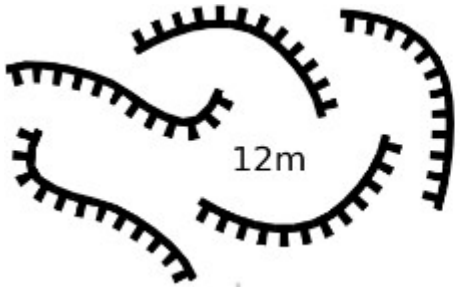

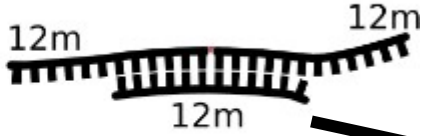

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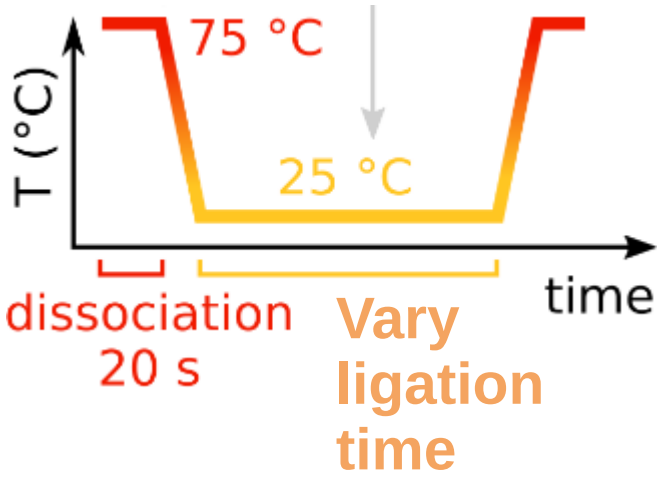

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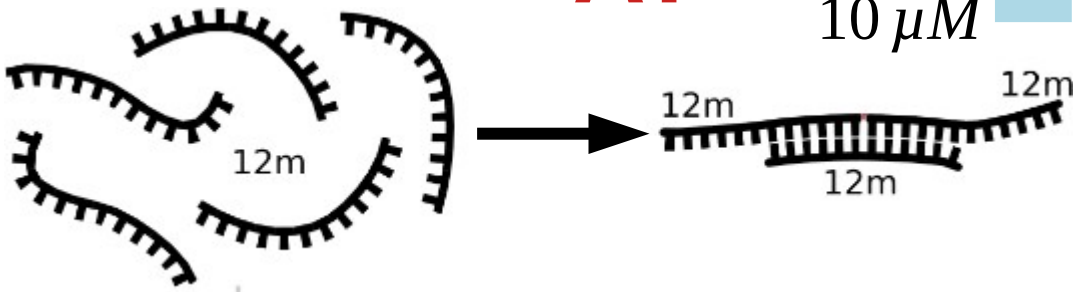

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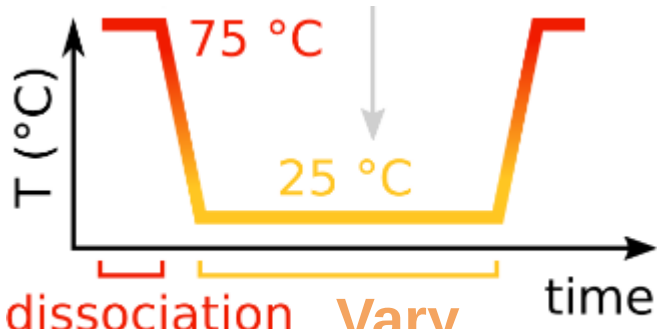

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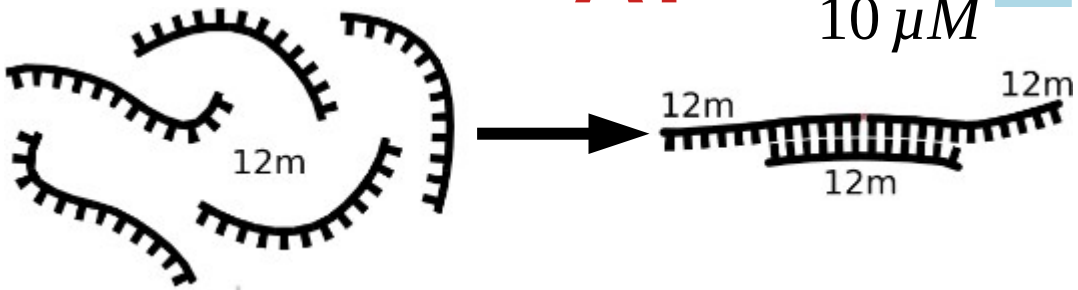

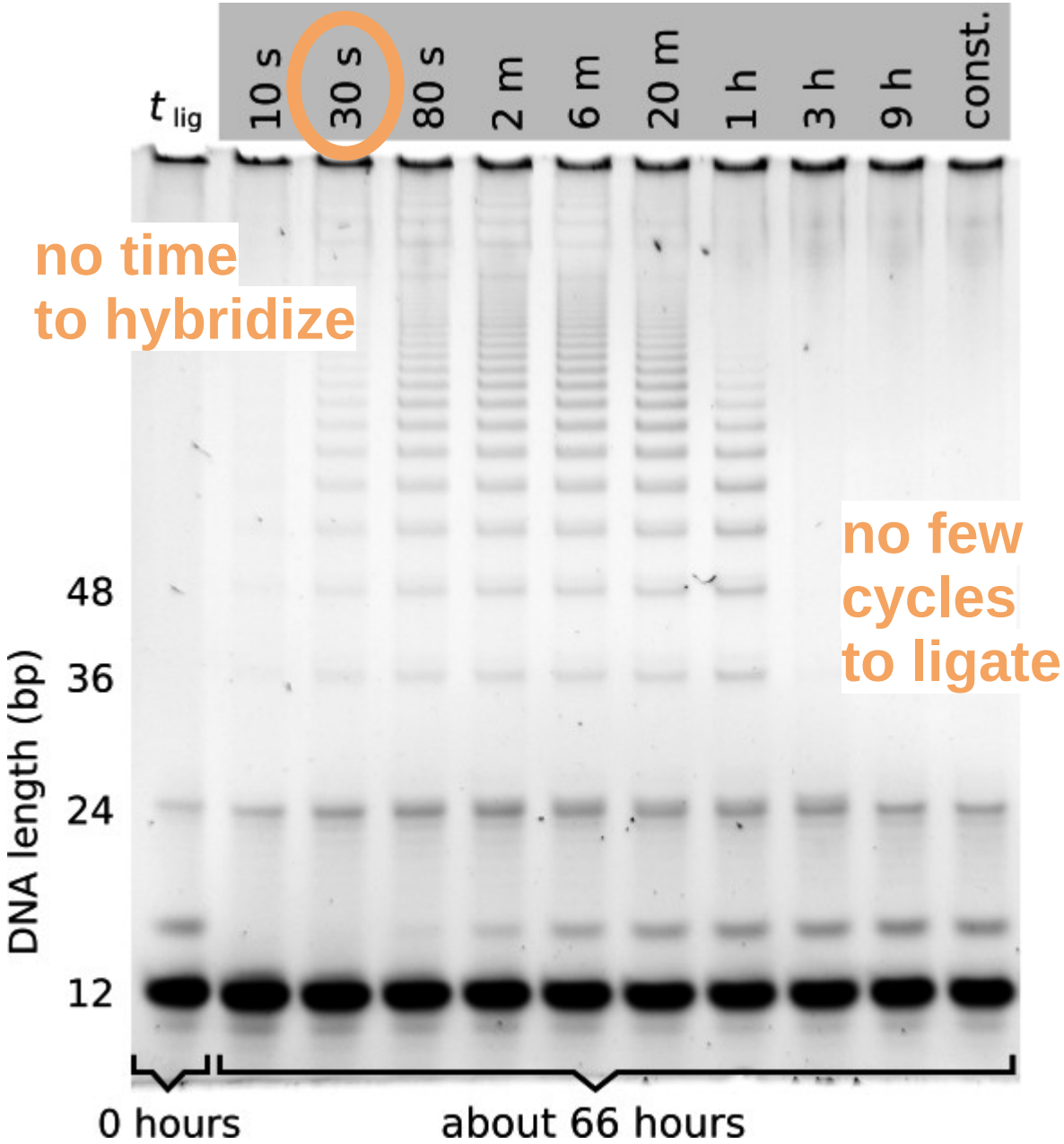

Dynamics in sequence space

Spontaneous emergence of autocatalytic information-coding polymers, J. Chem. Physics (2015)
Onset of natural selection in populations of autocatalytic heteropolymers, J. Chem. Physics (2018)

With Sergei Maslov and Alexei Tkachenko, University of Illinois

Dynamics in sequence space

Replication amplifies patterns at the ligation site

Replication avoids hairpins by evolving complementary pools

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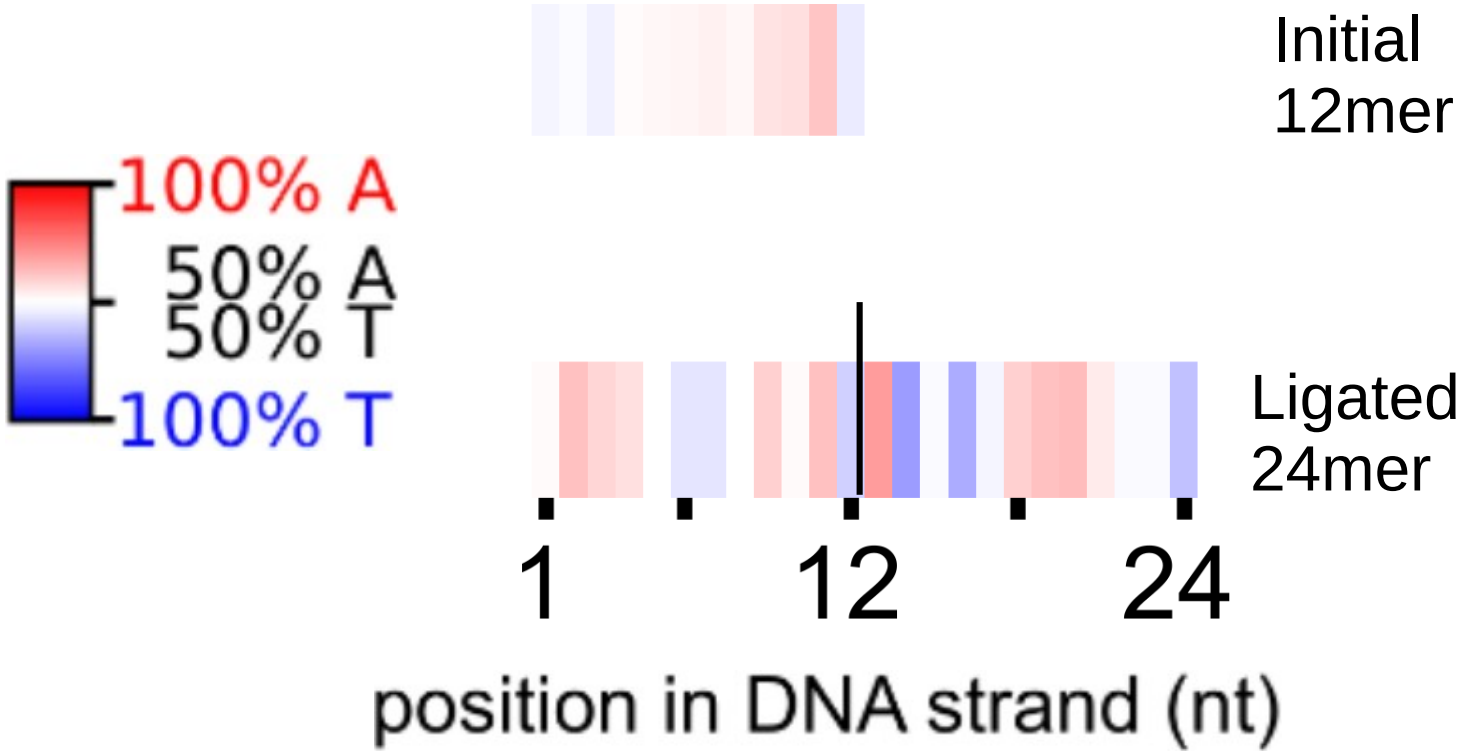

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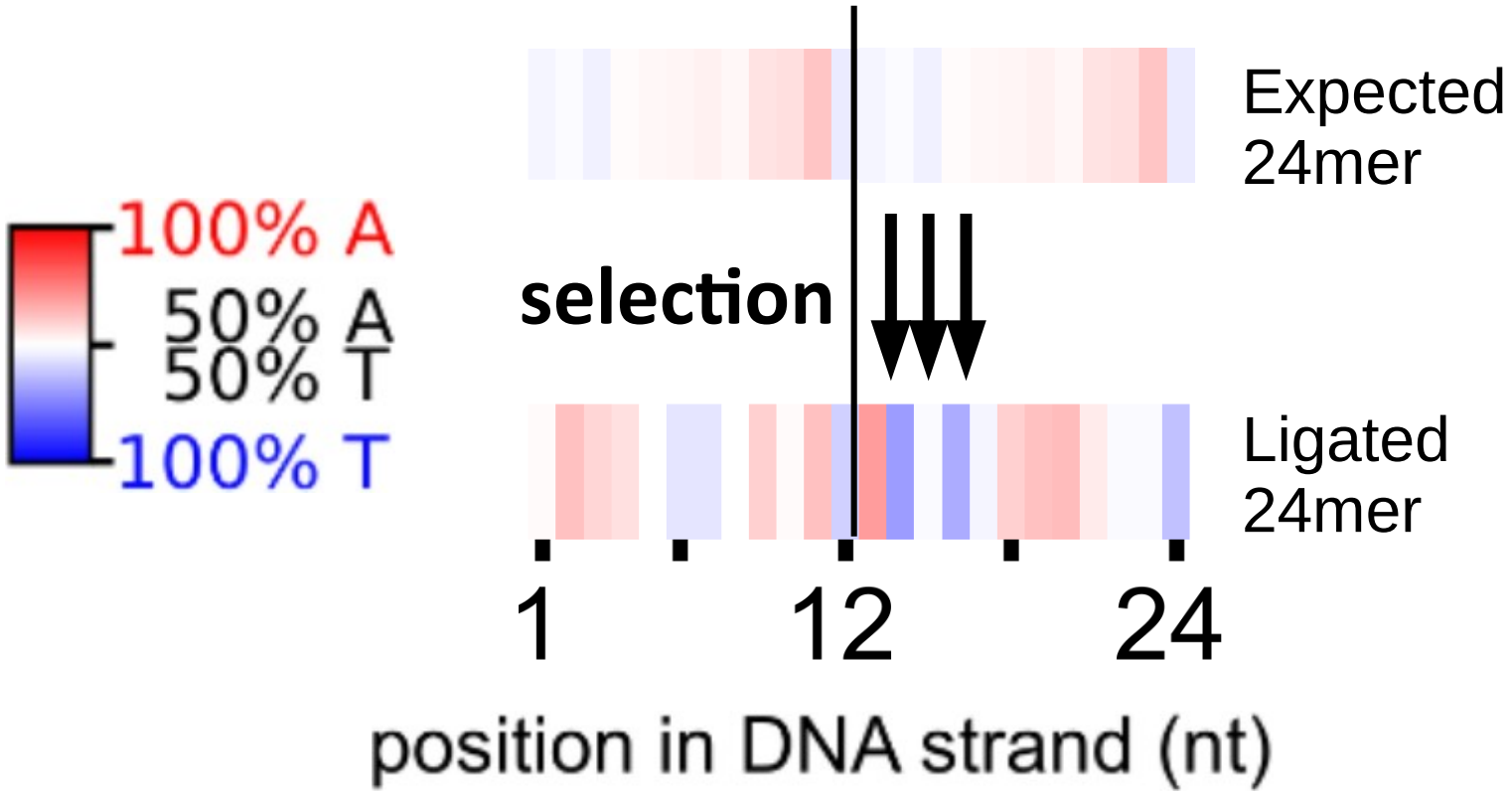

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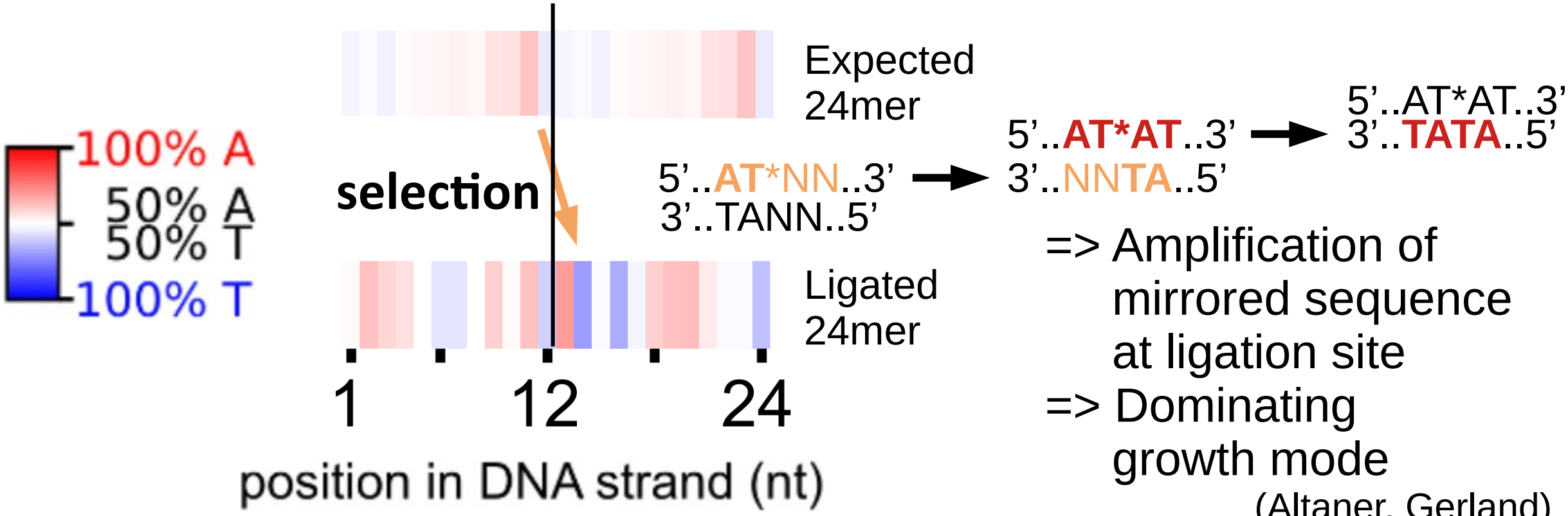

=> Amplification of mirrored sequence at ligation site

=> Dominating growth mode

(Altaner, Gerland)

With Sergei Maslov and Alexei Tkachenko, University of Illinois

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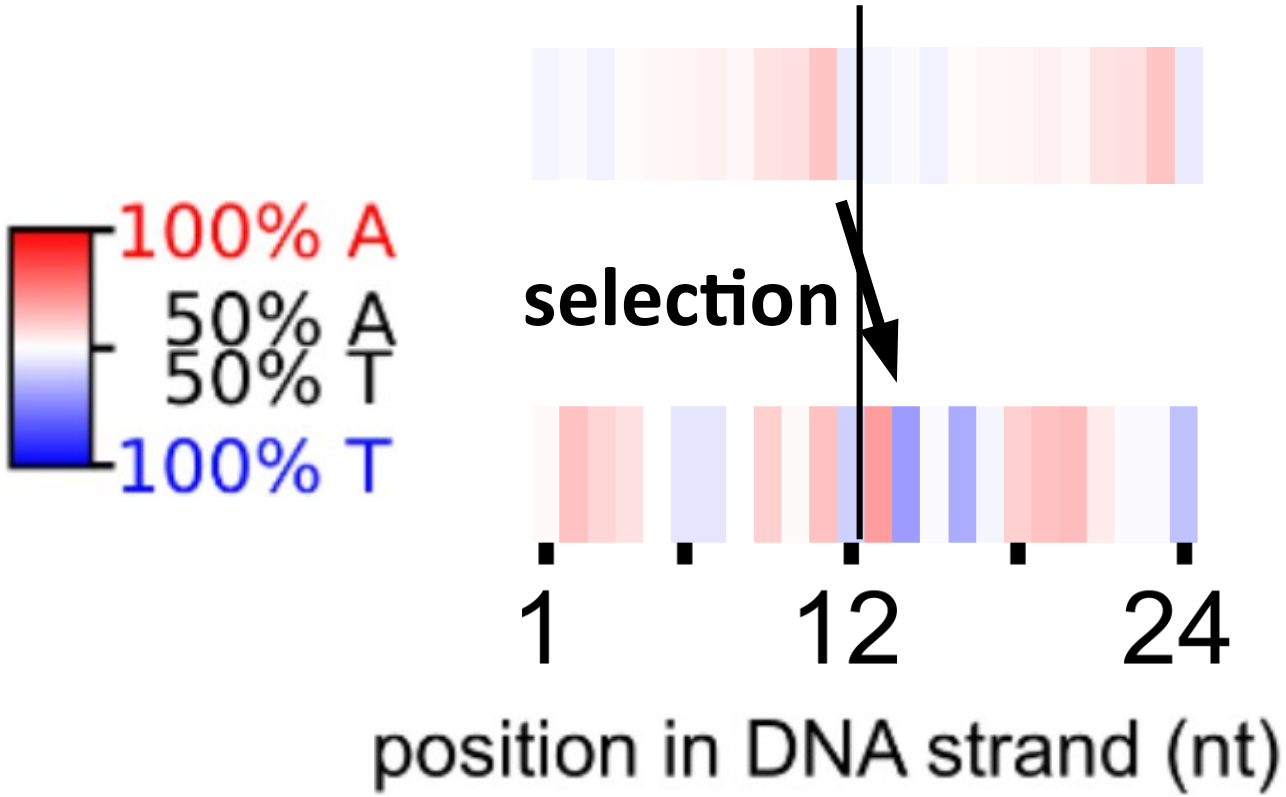

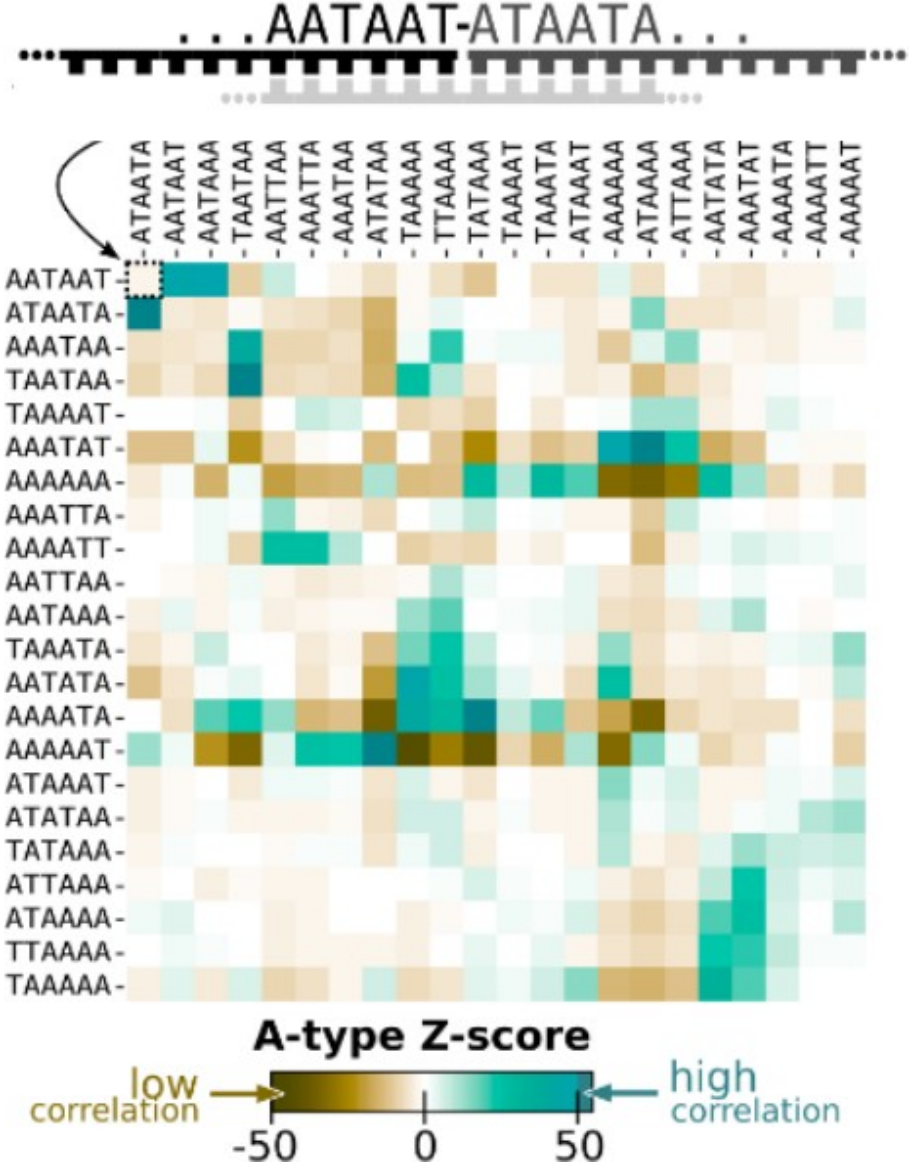

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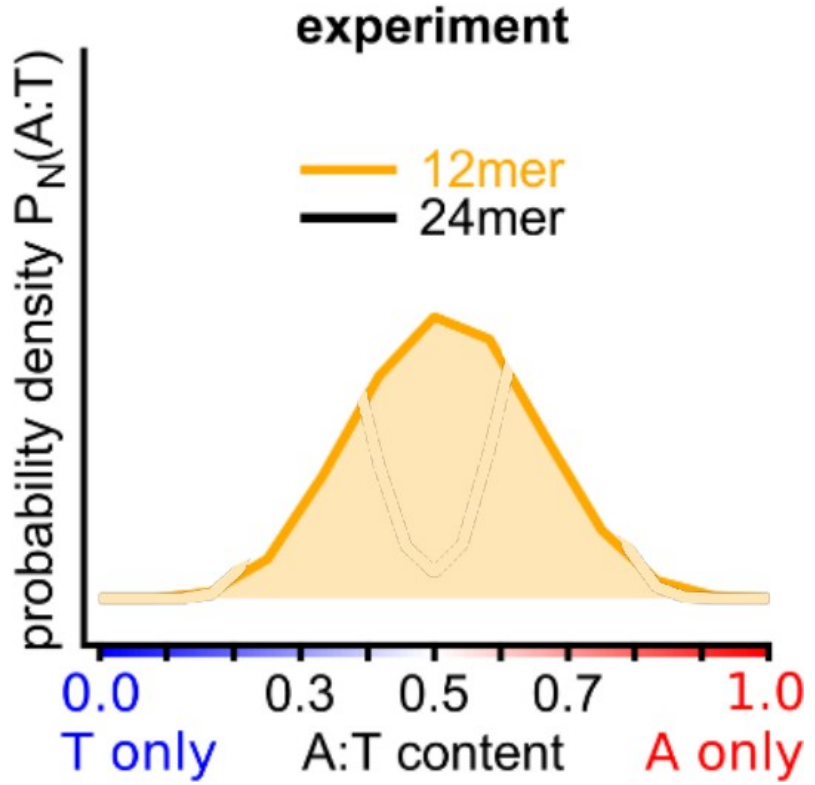

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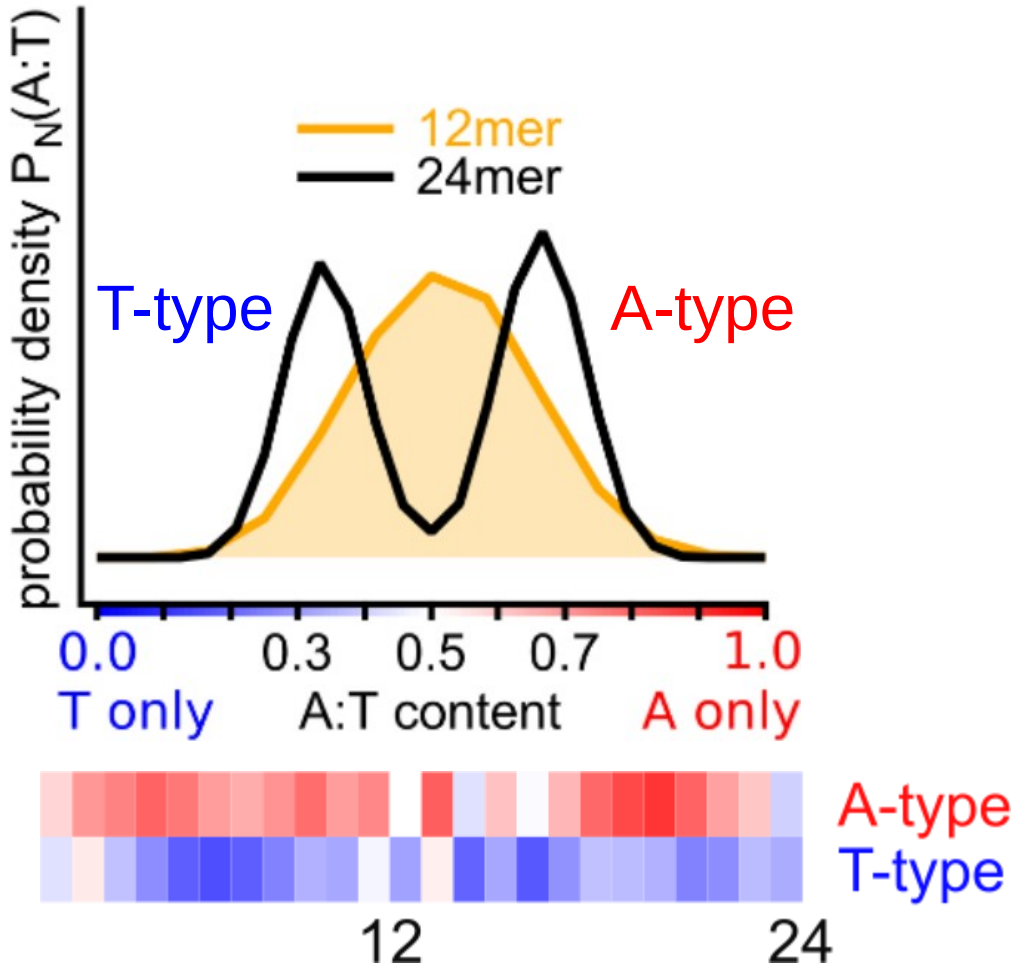

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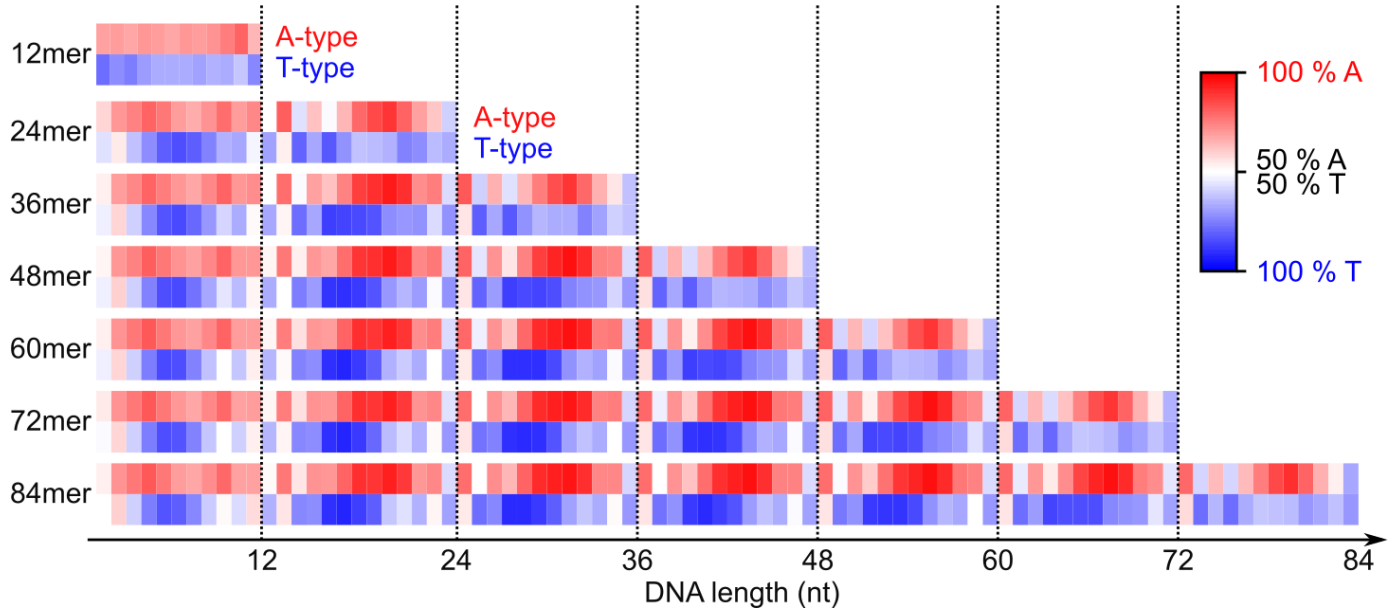

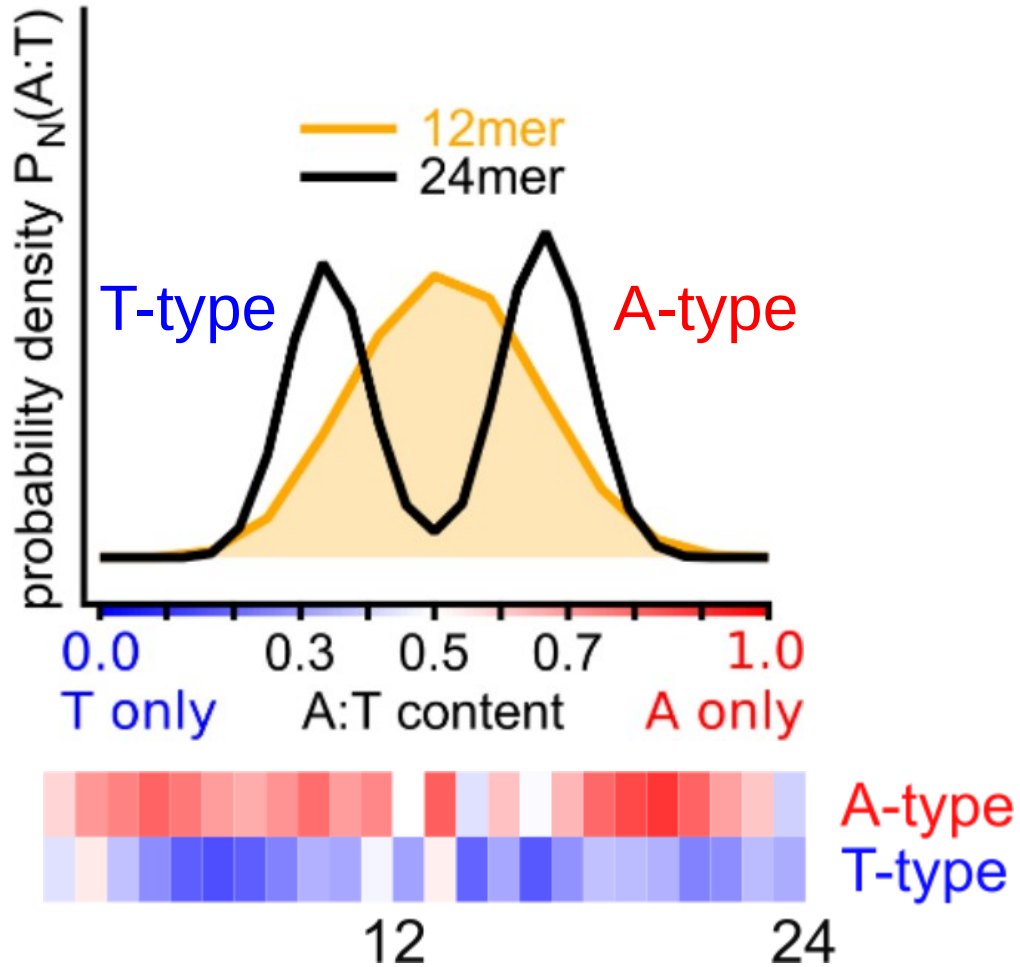

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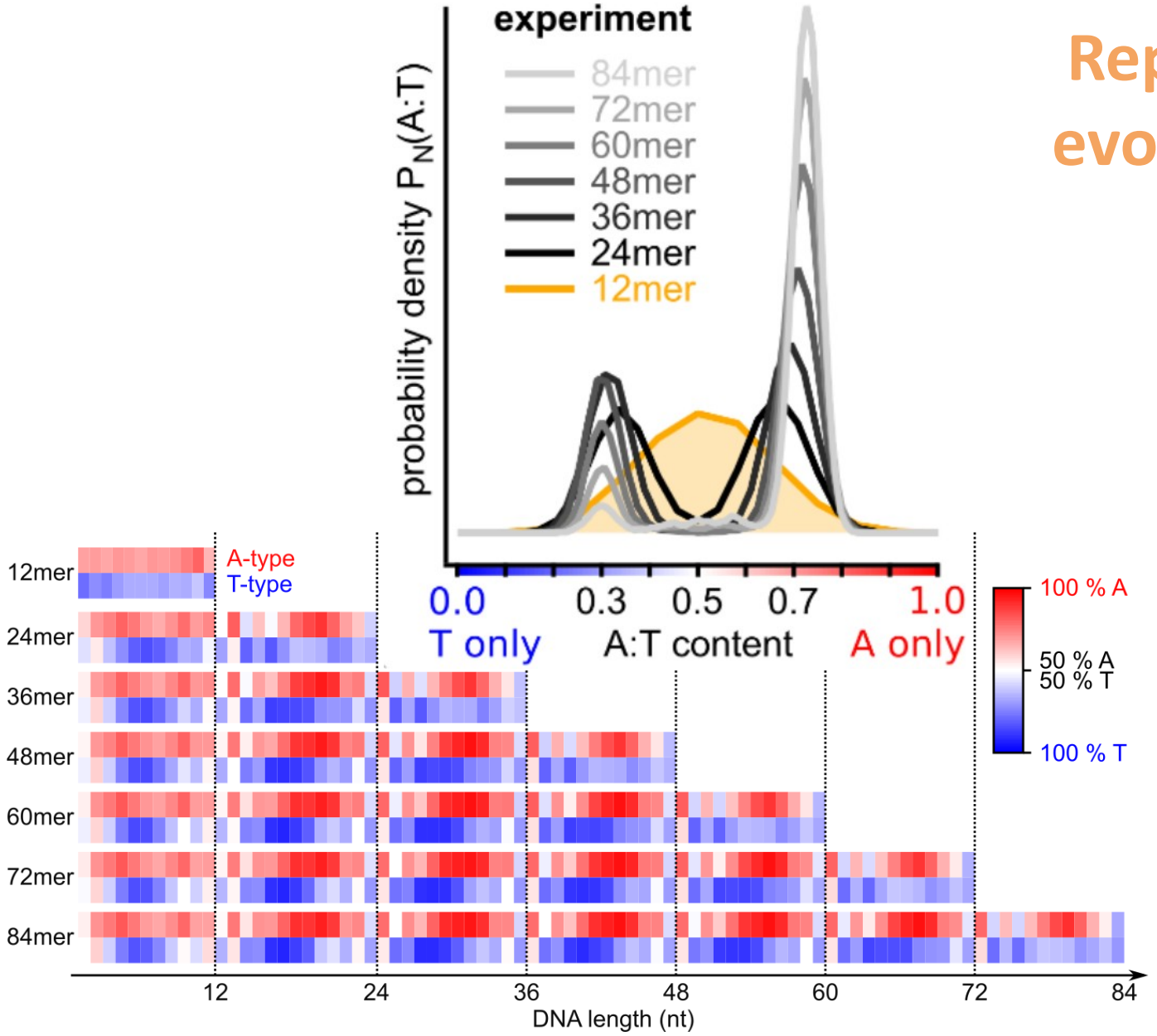

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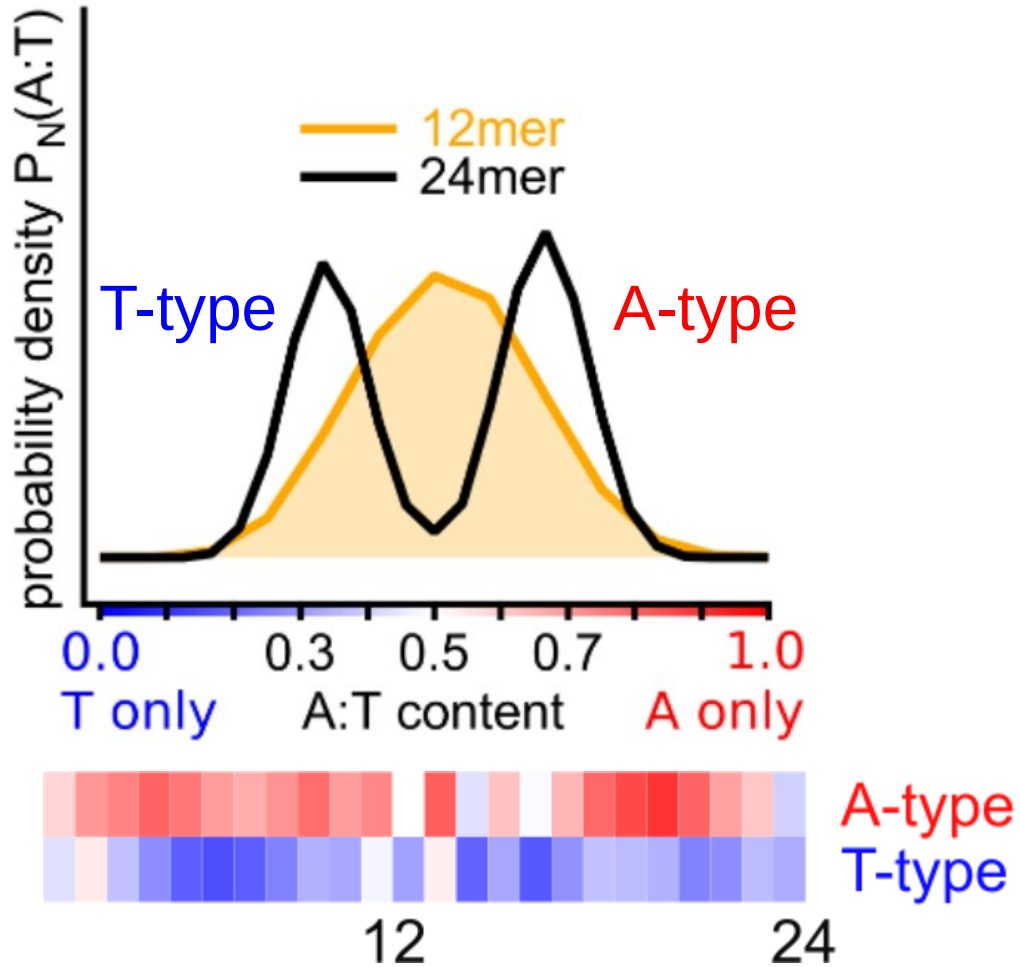

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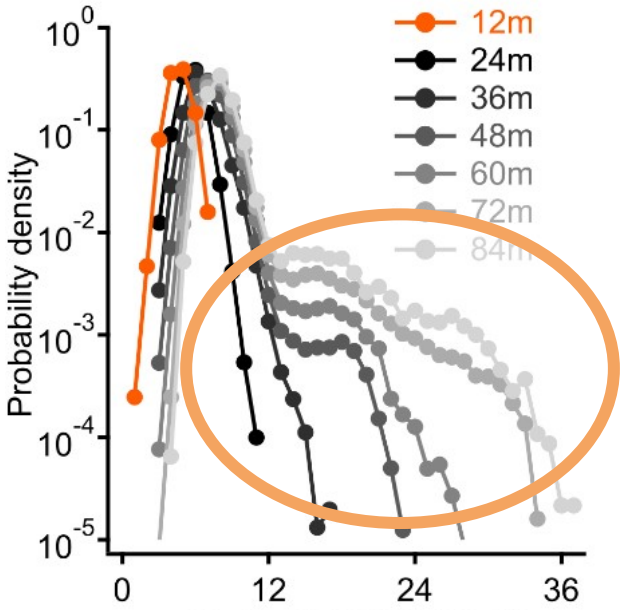

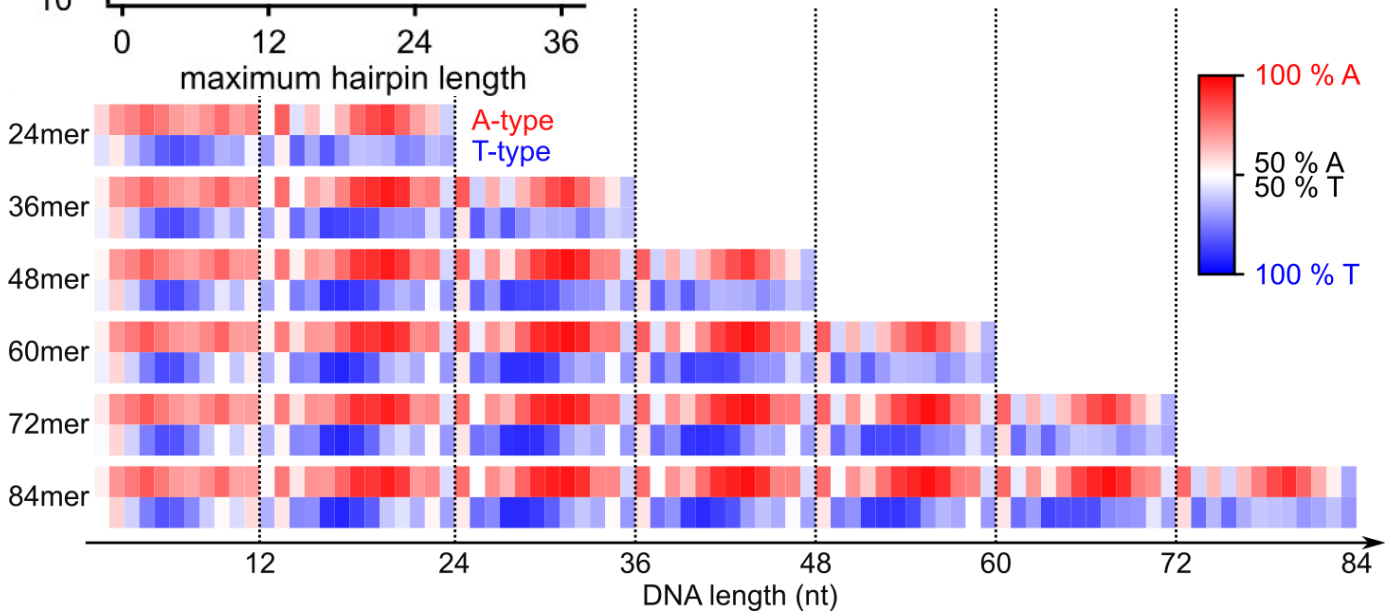

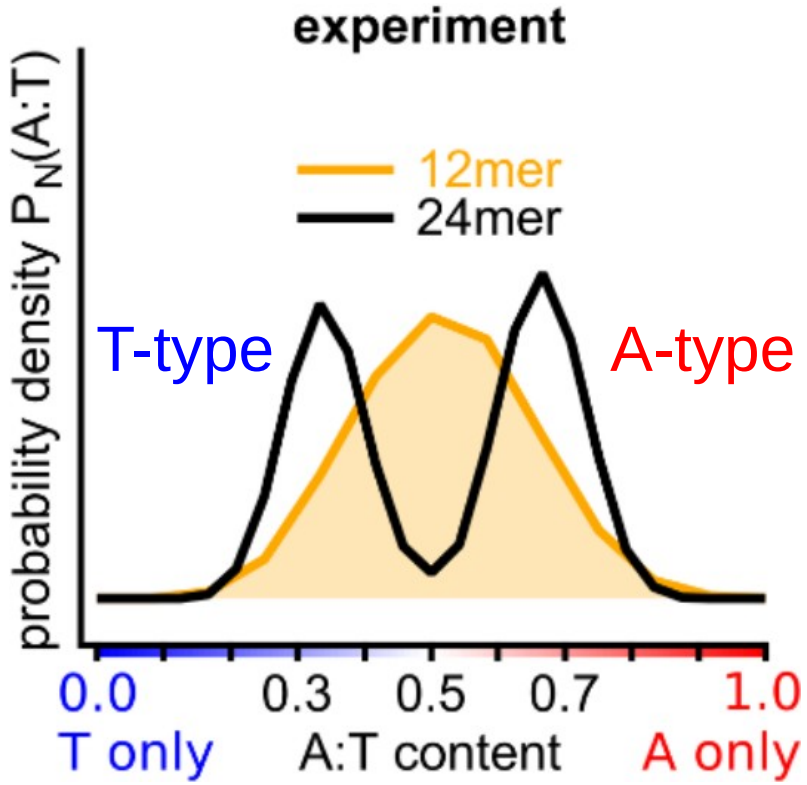

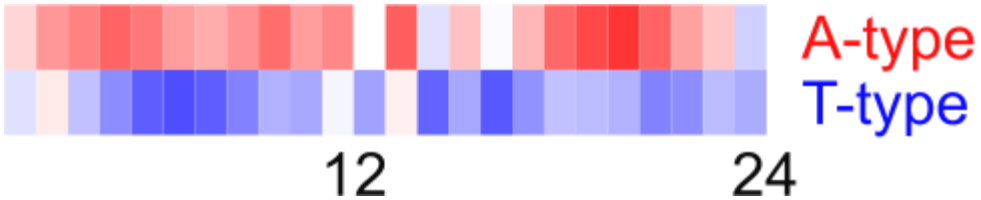

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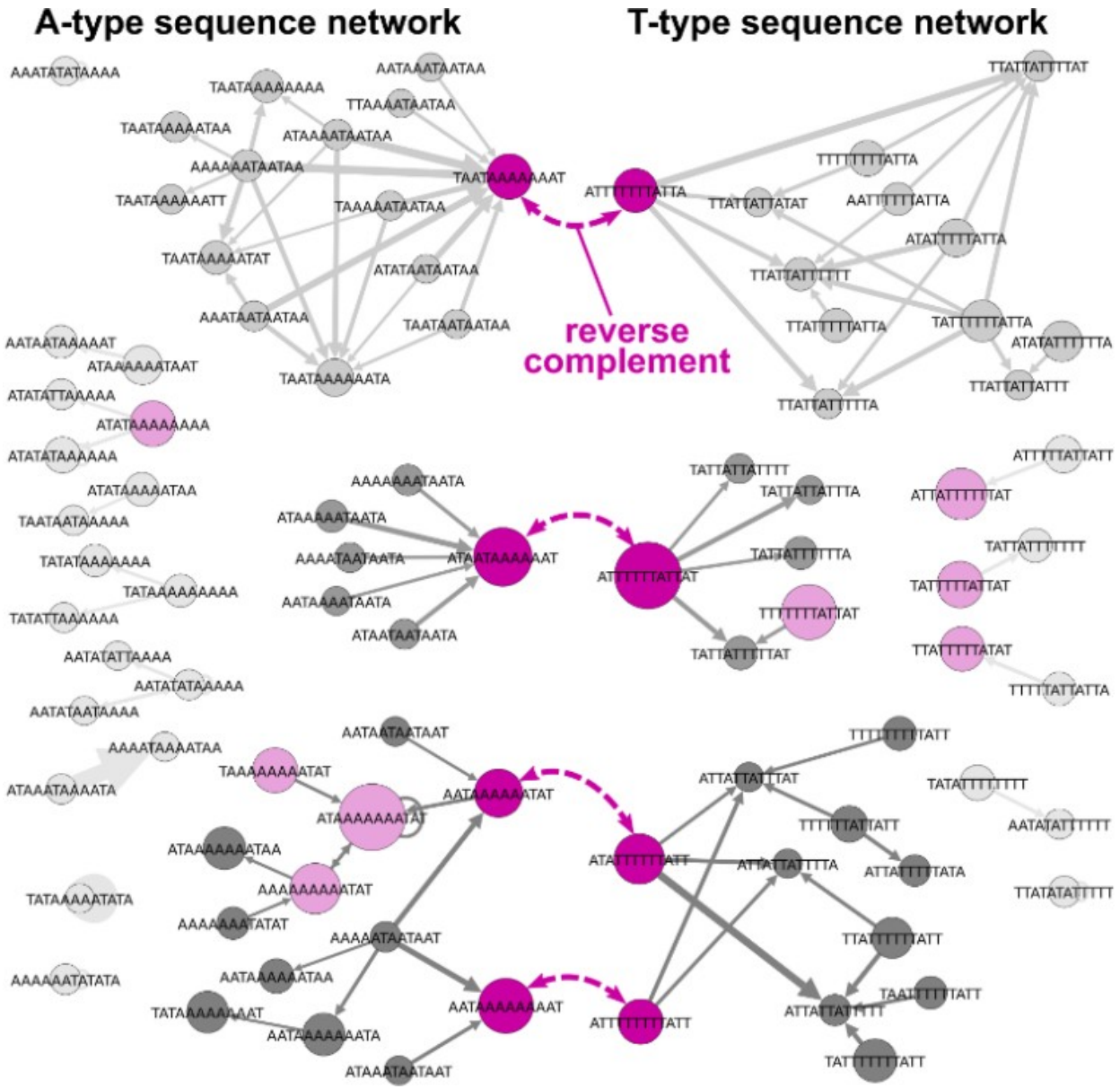

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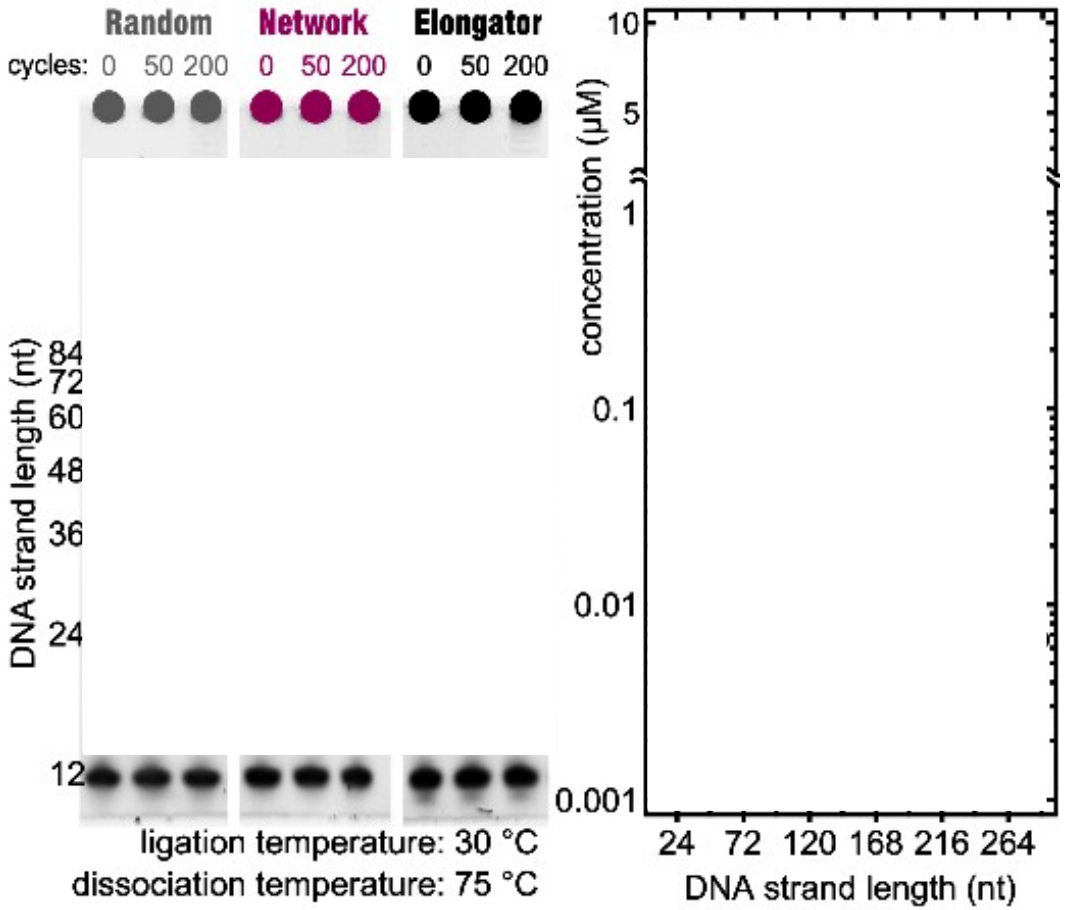
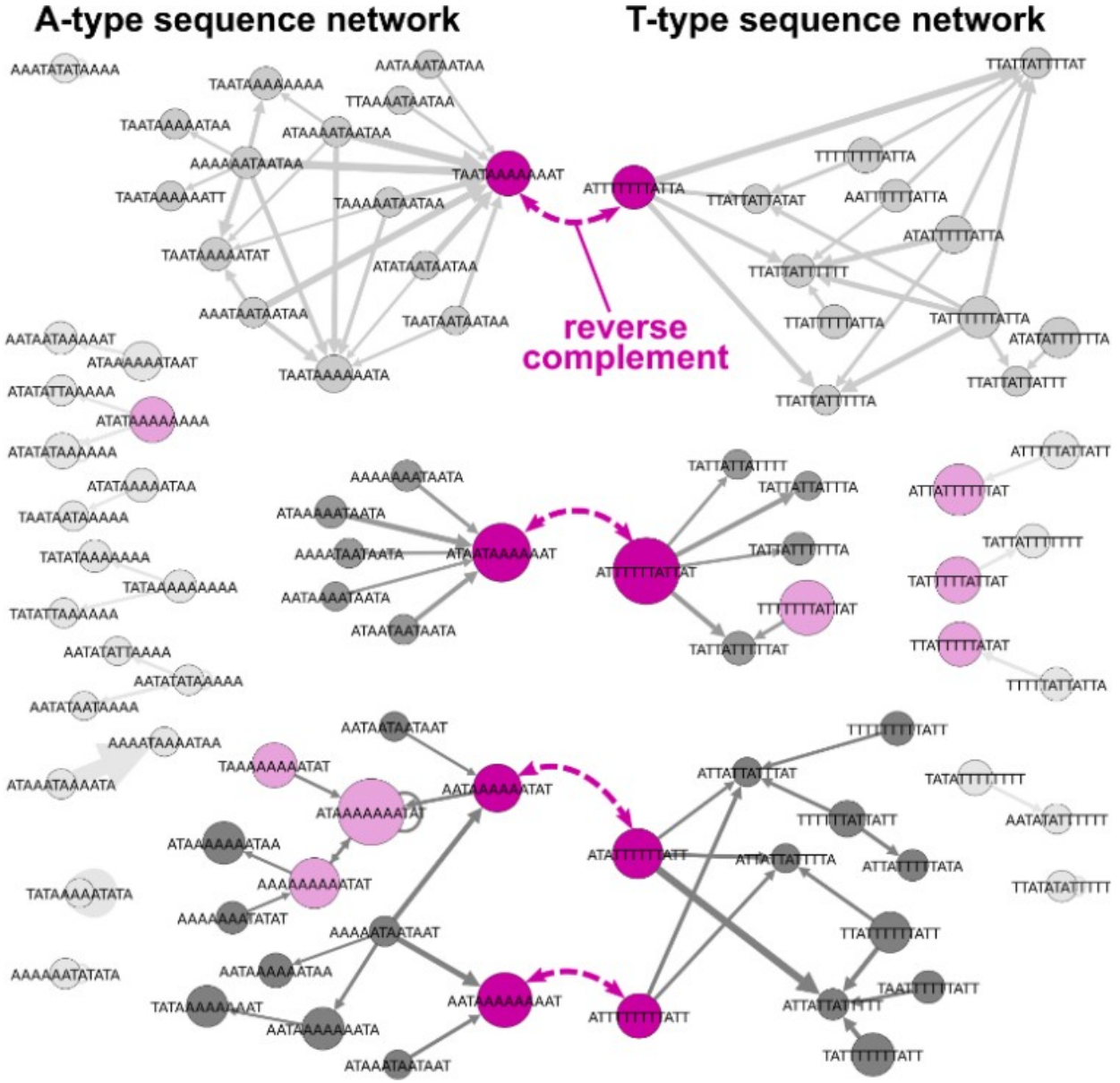
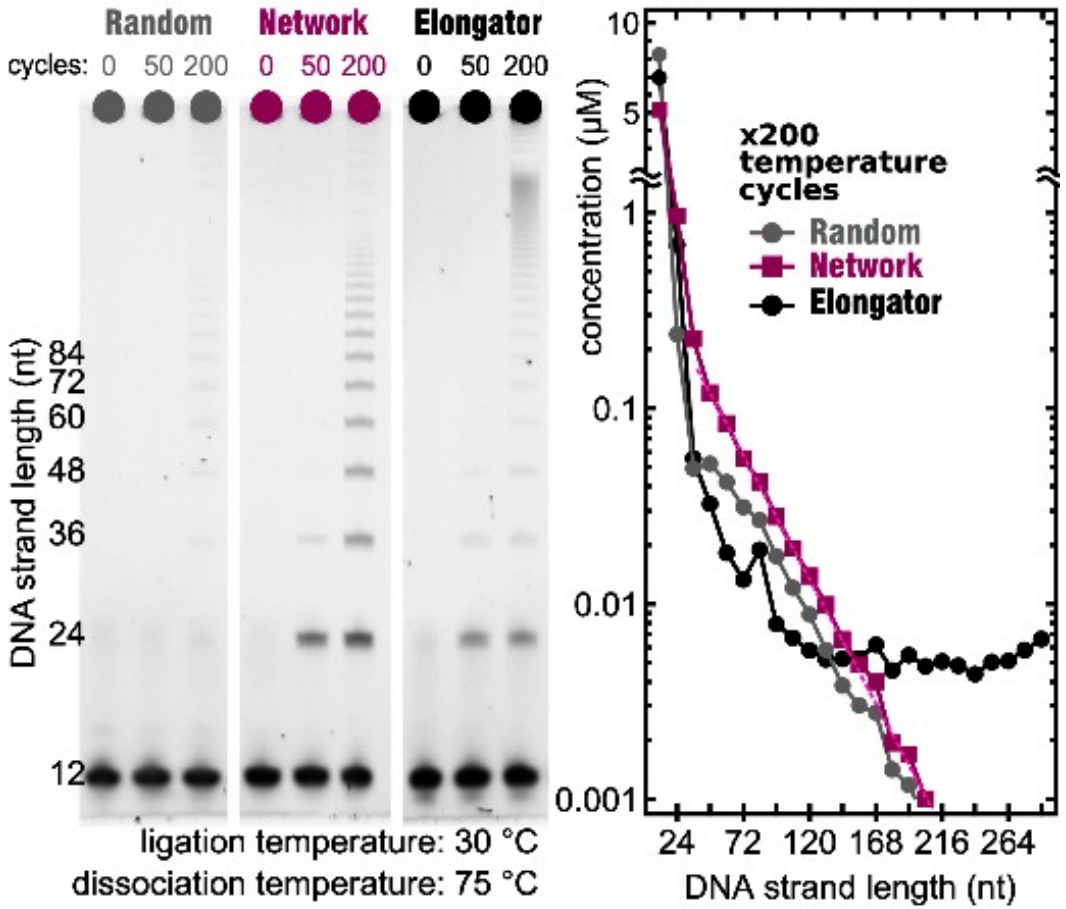


Random	Network	Elongator
AAAATAAAATAT	ATAATAAAAAAT	ATATTTTTTATA
ATAATTAAATAA	AATAAAAAAAAT	TATAAAAAATAT
TAAAAATTATTT	AATAAAAAATAT	AAATATATAAAA
TTAAATTTTATA	TAATAAAAAAAT	TTTTATATATTT
TATTTAATTTTT	ATTTTTTATTAT	AAAATATATAAA
TAAAAATTAATA	ATATTTTTTATT	TTTATATATTTT
AAAATAATTTAT	ATTTTTTTTATT	TATTTTTTTTAT
TTATATAAAATA	ATTTTTTTATTA	ATAAAAAAAATA



Dynamics in sequence space



Random	Network	Elongator
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ATAATTAAATAA	AATAAAAAAAAT	TATAAAAAATAT
TAAAAATTATTT	AATAAAAAATAT	AAATATATAAAA
TTAAATTTTATA	TAATAAAAAAAT	TTTTATATATTT
TATTTAATTTTT	ATTTTTTATTAT	AAAATATATAAA
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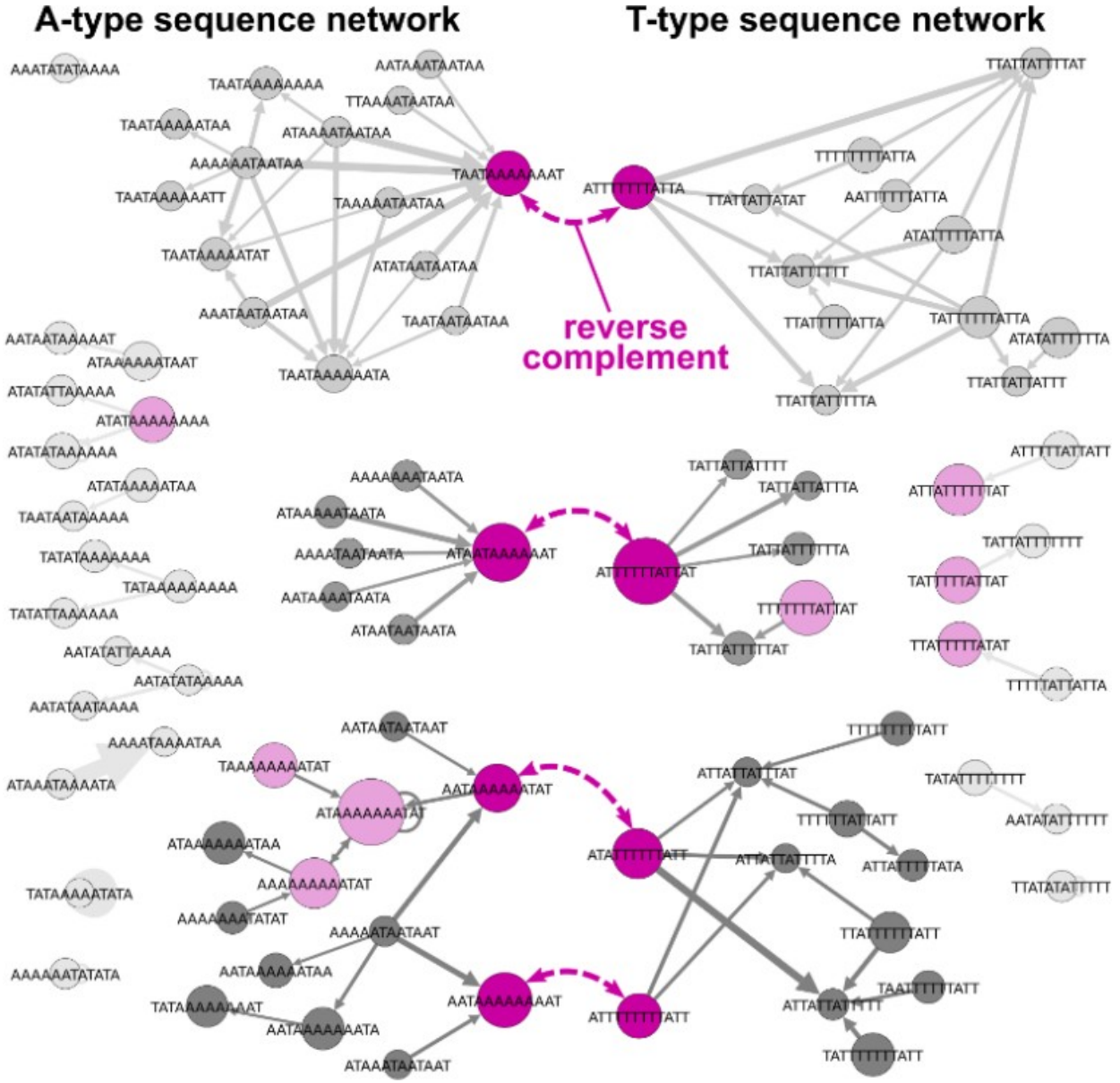
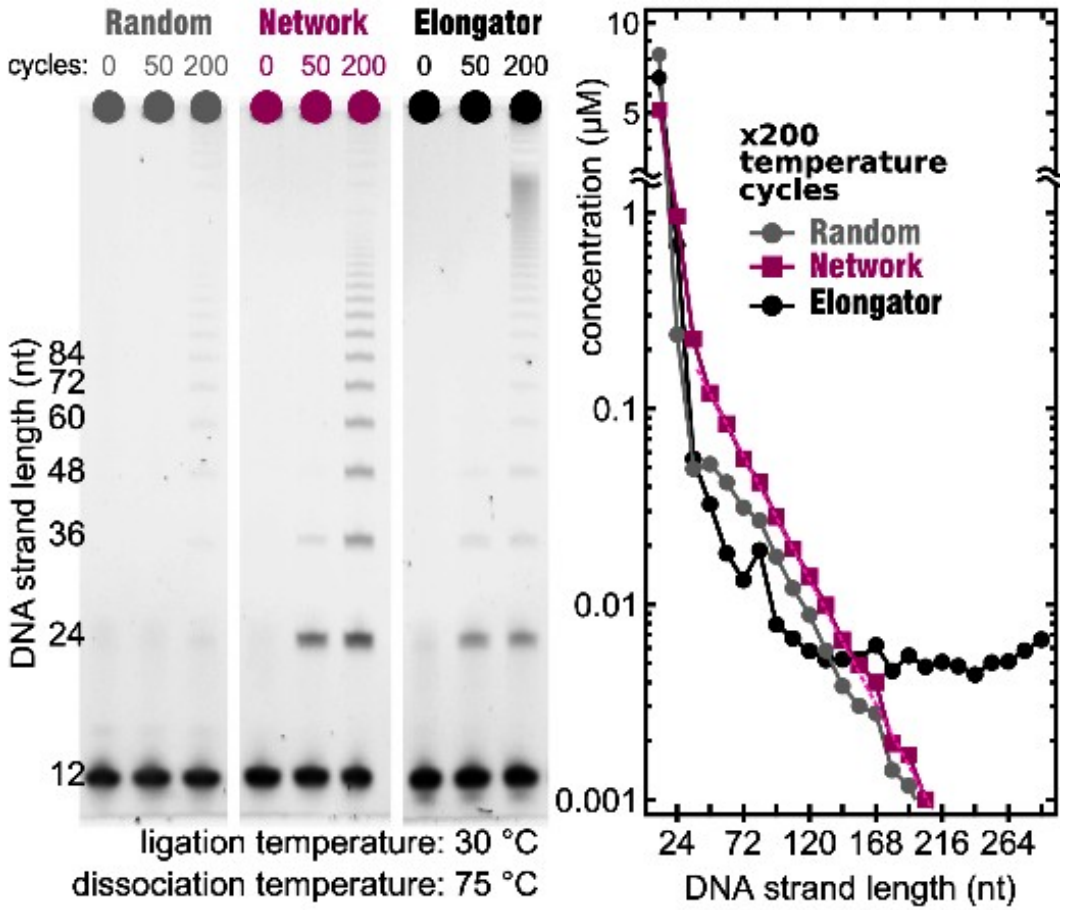


Dynamics in sequence space



Random	Network	Elongator
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ATAATTAAATAA	AATAAAAAAAAT	TATAAAAAATAT
TAAAAATTATTT	AATAAAAAATAT	AAATATATAAAA
TTAAATTTTATA	TAATAAAAAAAT	TTTTATATATTT
TATTTAATTTTT	ATTTTTTATTAT	AAAATATATAAA
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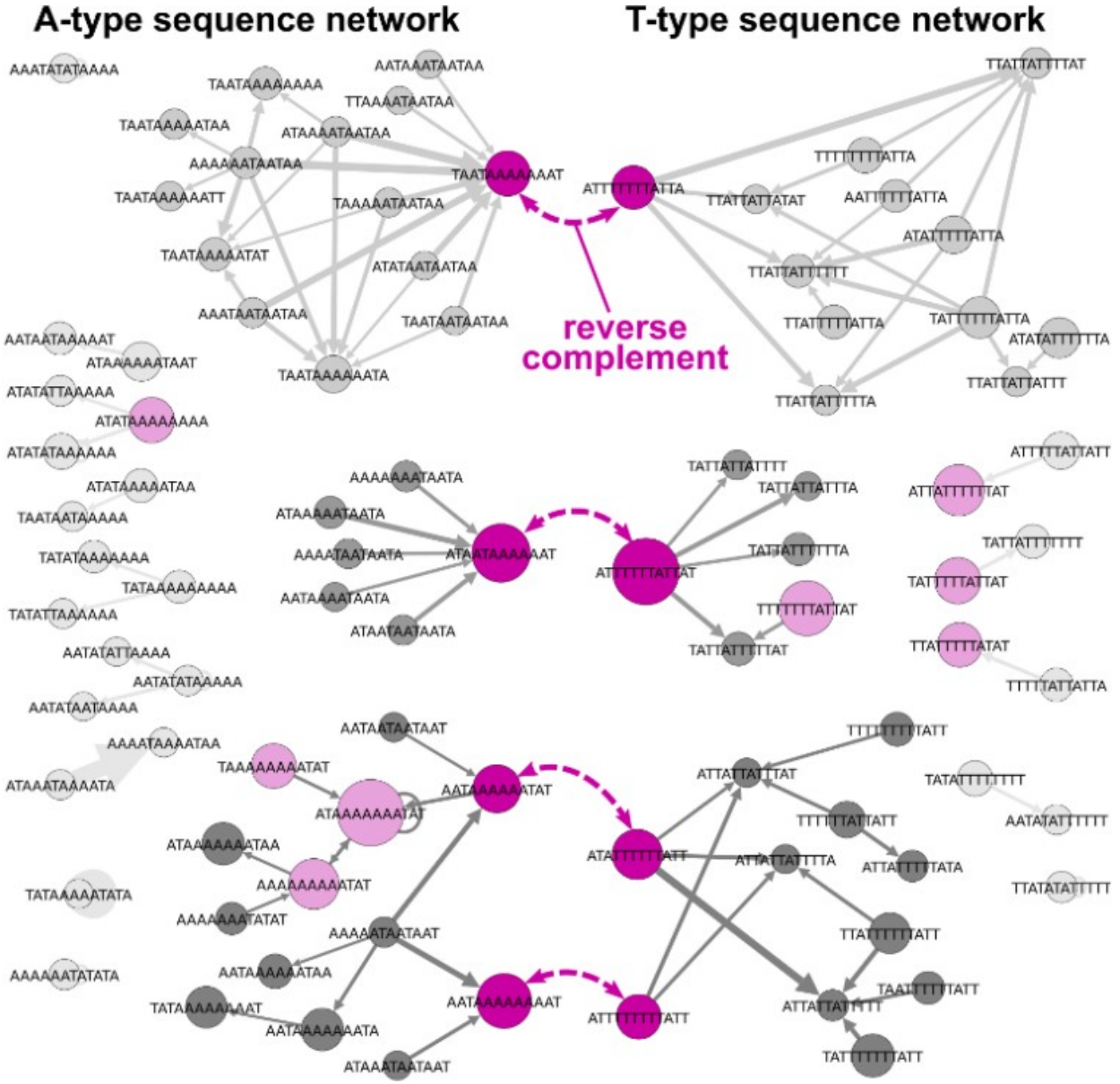
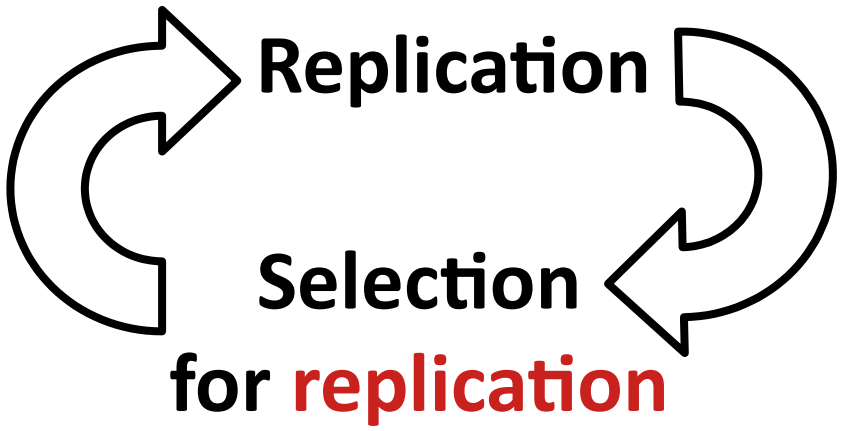
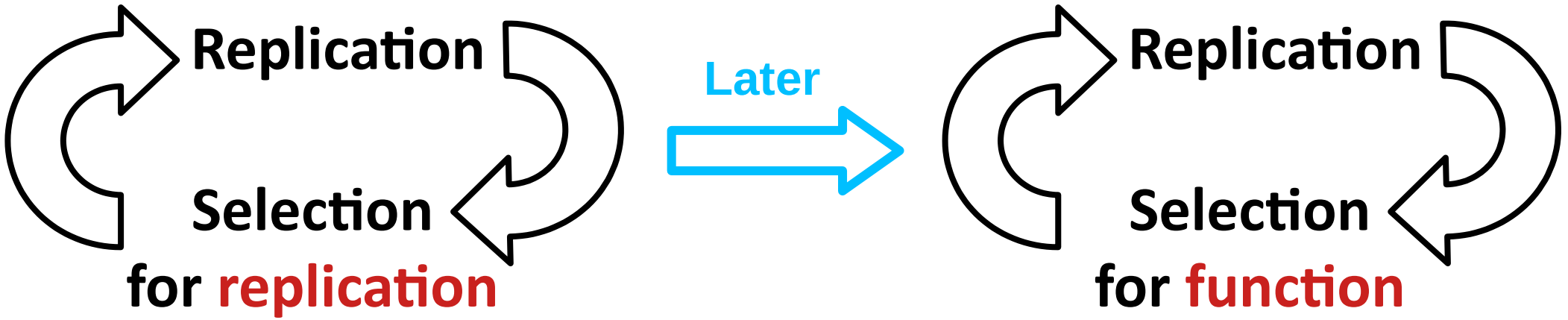
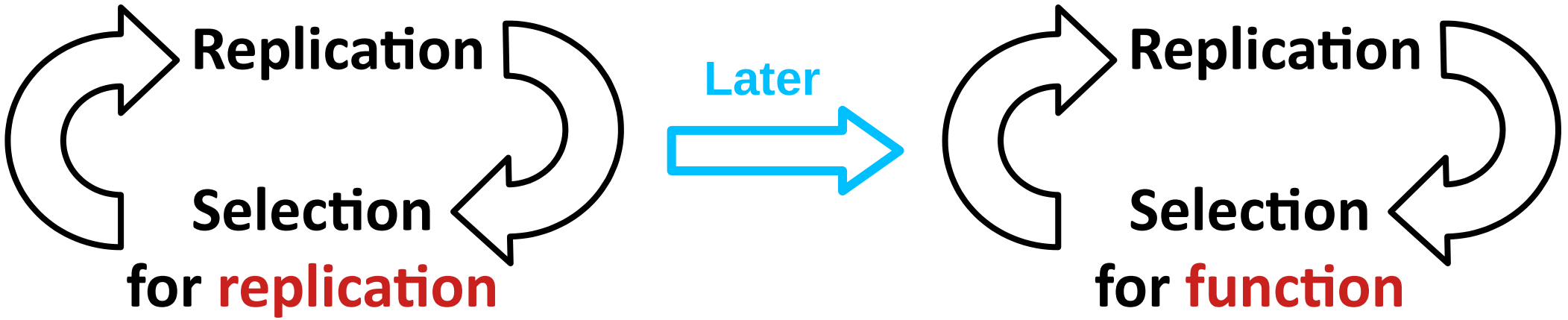
TTATATAAAATA	ATTTTTTTATTA	ATAAAAAAAATA




Replication
Selection
for replication


Replication
Selection
for replication
Later
Replication
Selection
for function

Fast replication selects small sequence spaces



Fast replication selects small sequence spaces