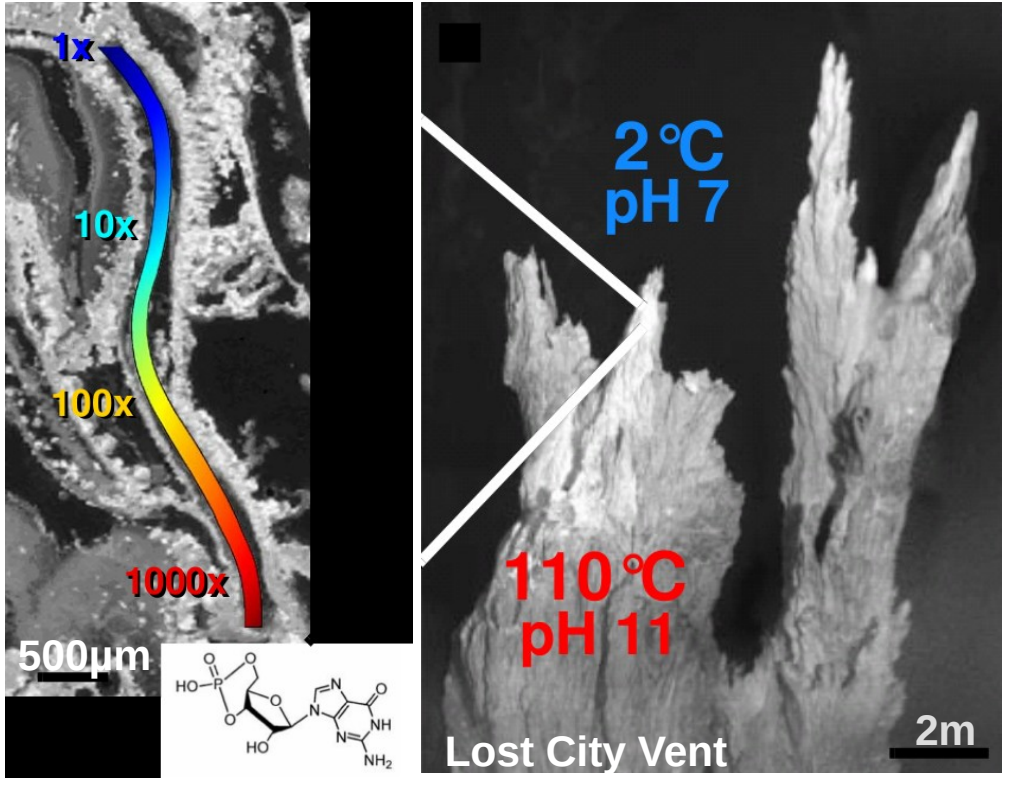
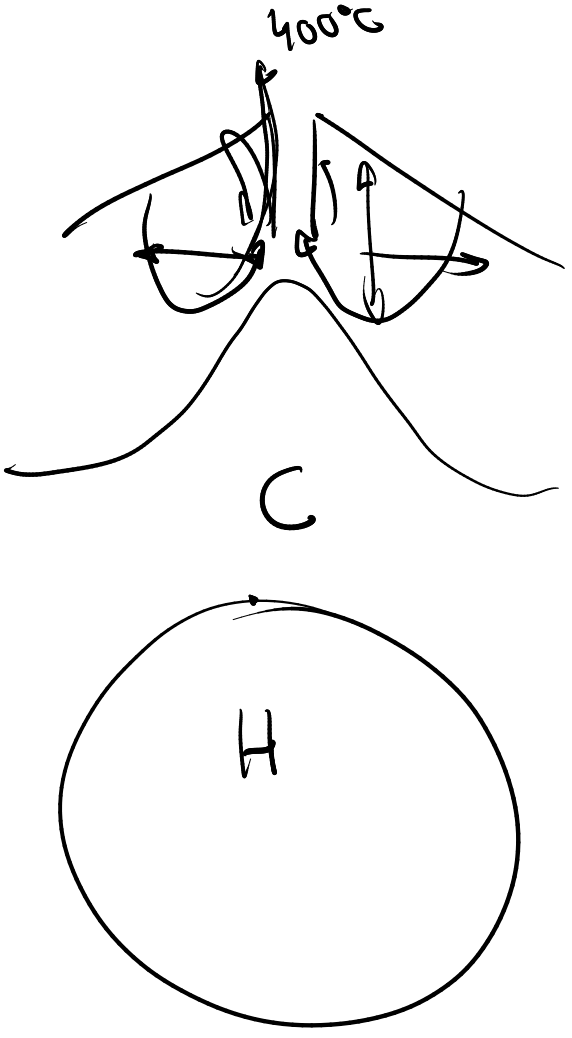
Accumulation by temperature gradients

Hot Vapor Settings

Accumulation by temperature gradients

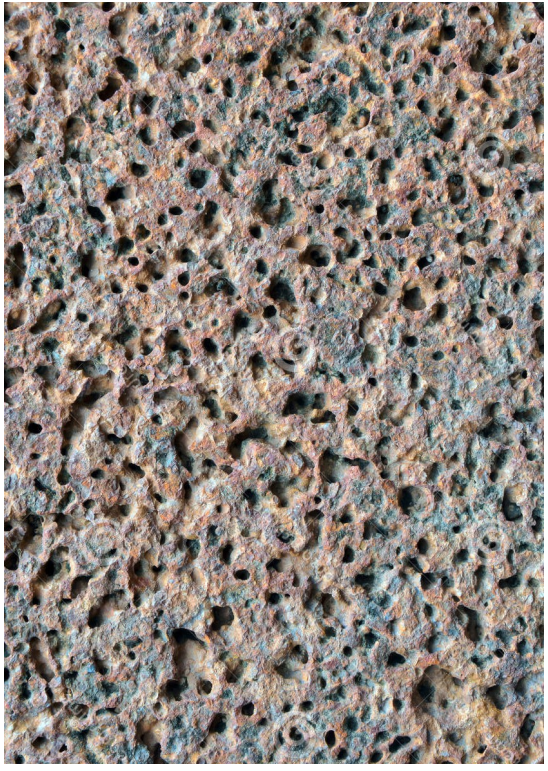
Hydrothermal Settings

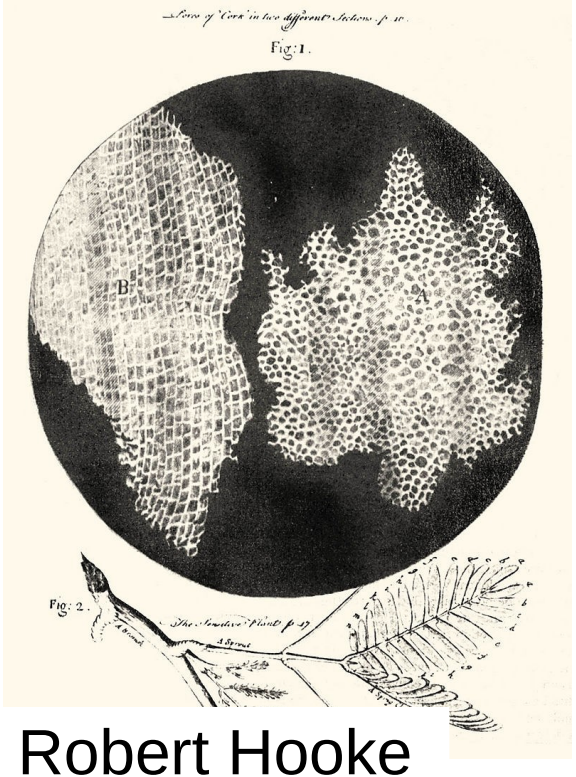




Accumulation by temperature gradients

Cells defined by Pores of Rock





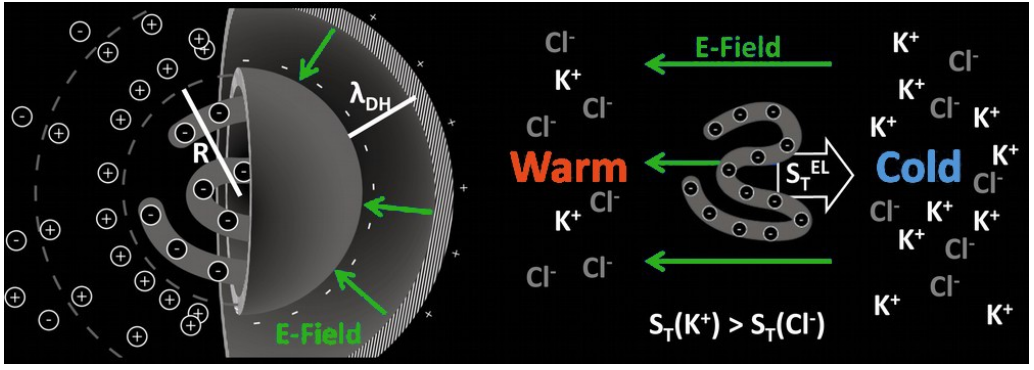
Robert Hooke

Accumulation by temperature gradients

Thermophoresis

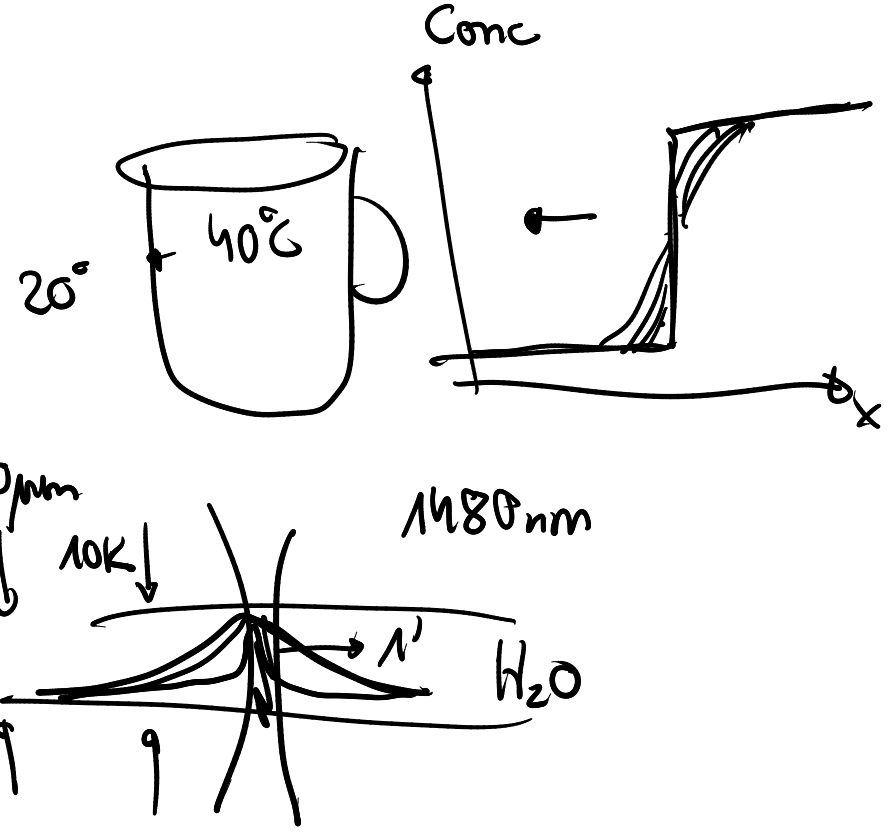
Local E-Field

Global E-Field



Duhr and Braun, PNAS 103, 19678 (2006)
Reichl, Herzog, Götz, and Braun, PRL 112, 198101 (2014)

$$S_T^{CM}\frac{R}{Z_{\text{eff}}^2}=\frac{e^2R/\lambda_{DH}}{16\pi k_BT^2\varepsilon_r\varepsilon_0(1+R/\lambda_{DH})^2}\times\left(1-\frac{\partial\ln\rho(T)}{\partial\ln T}-\frac{\partial\ln\varepsilon_r(T)}{\partial\ln T}\left(1+\frac{2\lambda_{DH}}{R}\right)\right)$$



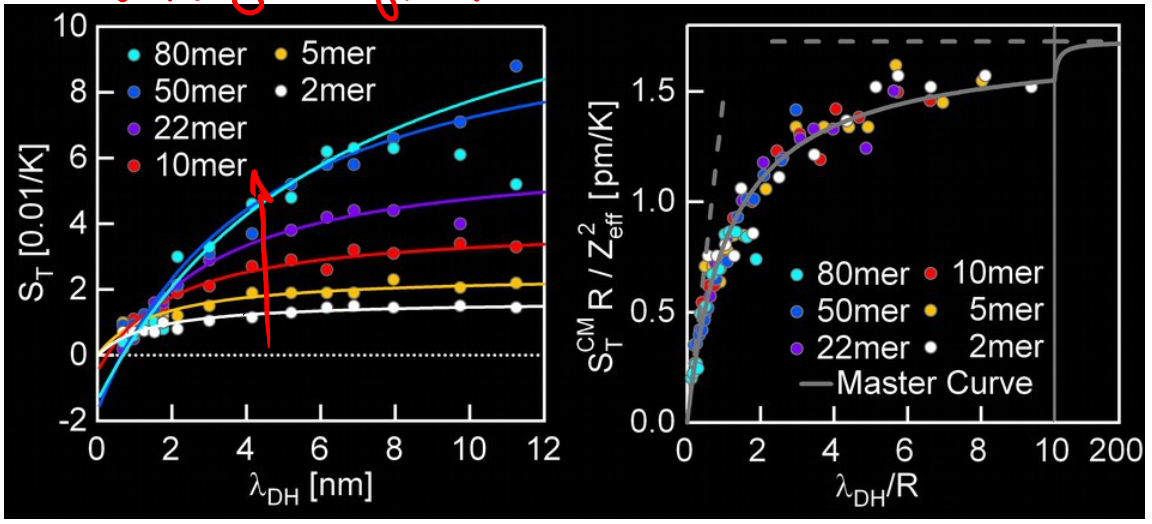
=> NanoTemper

Accumulation by temperature gradients

Thermophoresis

Warm → **Cold**

↓ Physiological concentrat



high Salt low salt

$$S_T^{CM}\frac{R}{Z_{eff}^2}=\frac{e^2 R/\lambda_{DH}}{16\pi k_B T^2 \varepsilon_r \varepsilon_0 (1+R/\lambda_{DH})^2}\times\left(1-\frac{\partial \ln \rho(T)}{\partial \ln T}-\frac{\partial \ln \varepsilon_r(T)}{\partial \ln T}\left(1+\frac{2\lambda_{DH}}{R}\right)\right)$$

Diff. coeff. Gradient of T

$$\vec{v}\cdot c = j = \frac{\#}{s\cdot A} = -D\nabla c - cD_T\nabla T$$

$$\doteq 0$$

$$\Rightarrow c = c_0 \exp\left(-\frac{D_T}{D}\cdot\Delta T\right)$$

$$c(T) = c_0 \exp\left(-\frac{D_T}{D}(T-T_0)\right)$$

$S_T = \frac{D_T}{D}$

$T(x,y)$

c_0

T_0

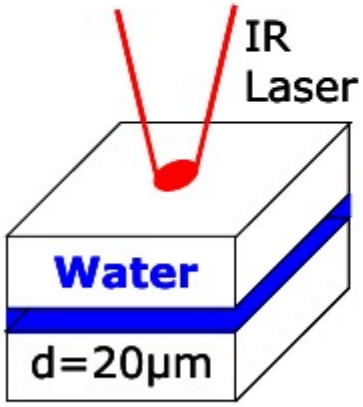
$c(x,y)$

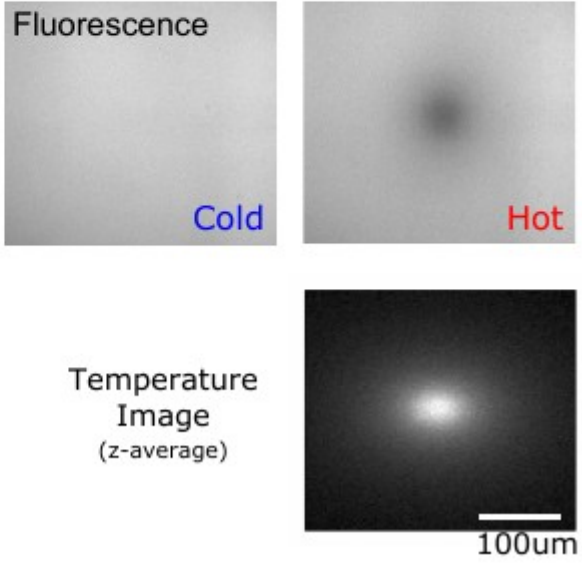
Accumulation by temperature gradients

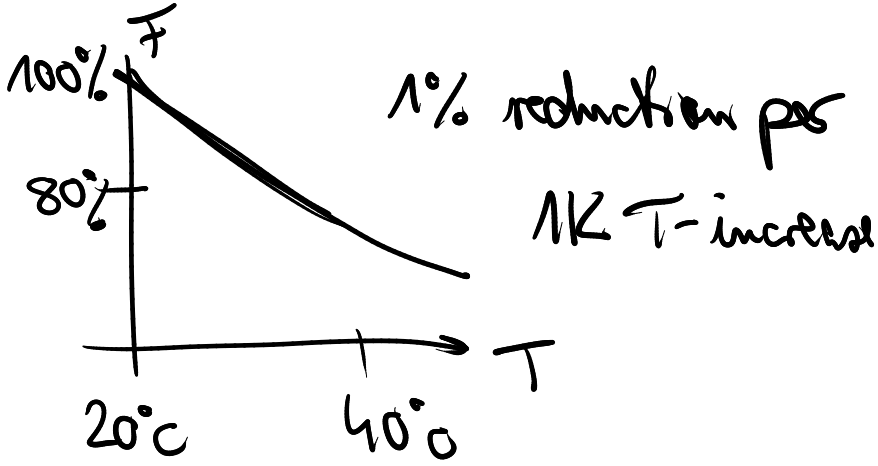
Thermophoresis of DNA

Warm → **Cold**

$v = -D_T \nabla T$ $\quad j = -D\nabla c - D_T c \nabla T$

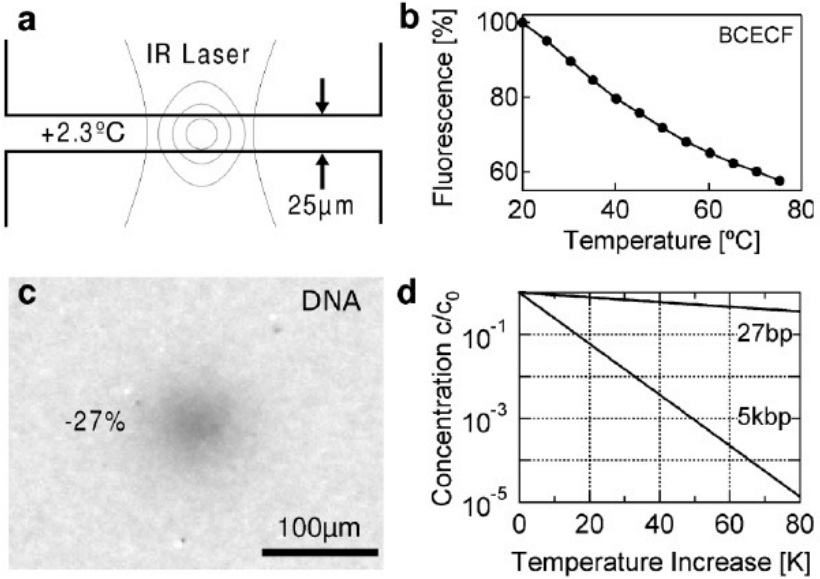


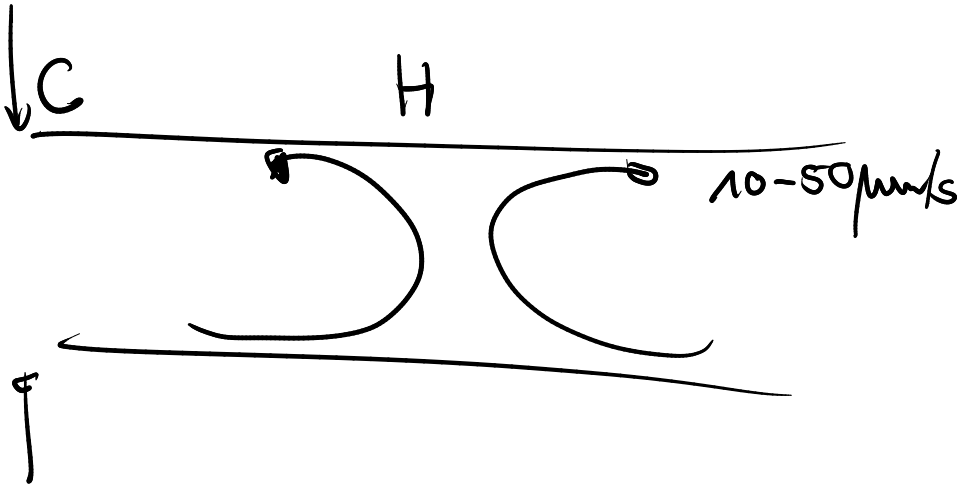




Trapping of DNA by Thermophoretic Depletion and Convection

Dieter Braun* and Albert Libchaber
Center for Studies in Physics and Biology, Rockefeller University, New York, New York 10021
(Received 2 May 2002; published 14 October 2002)





Accumulation by temperature gradients

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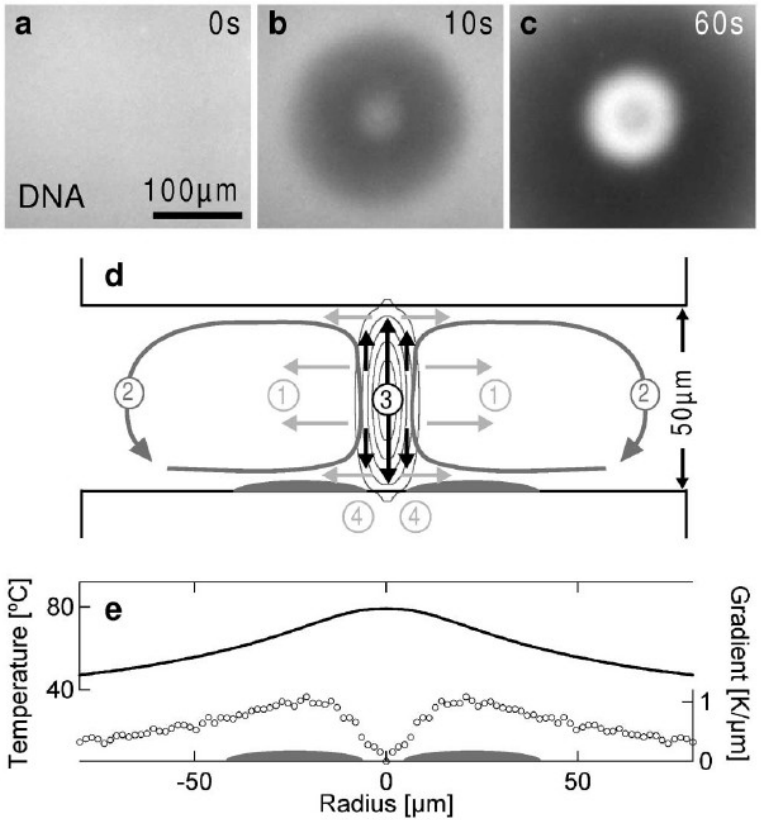
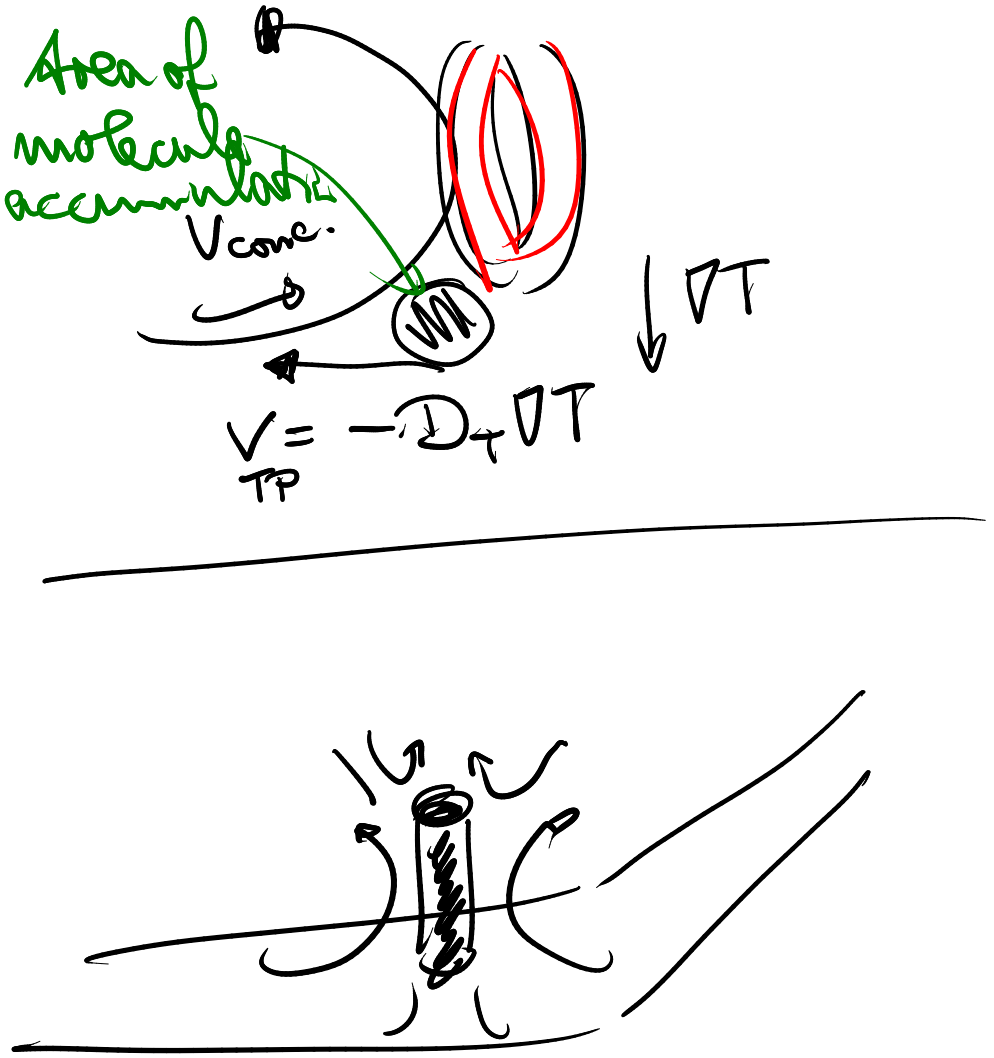
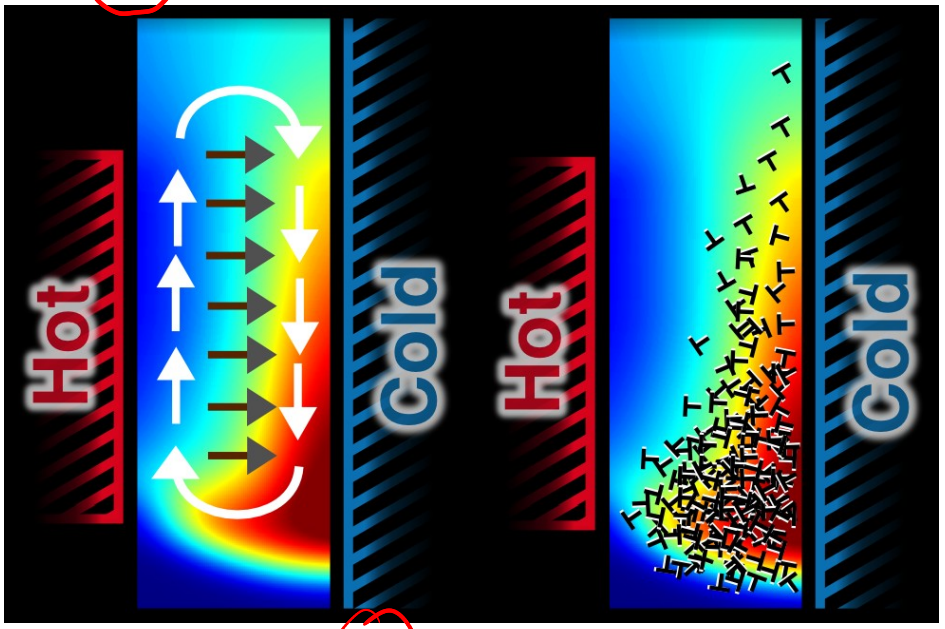




Accumulation by temperature gradients

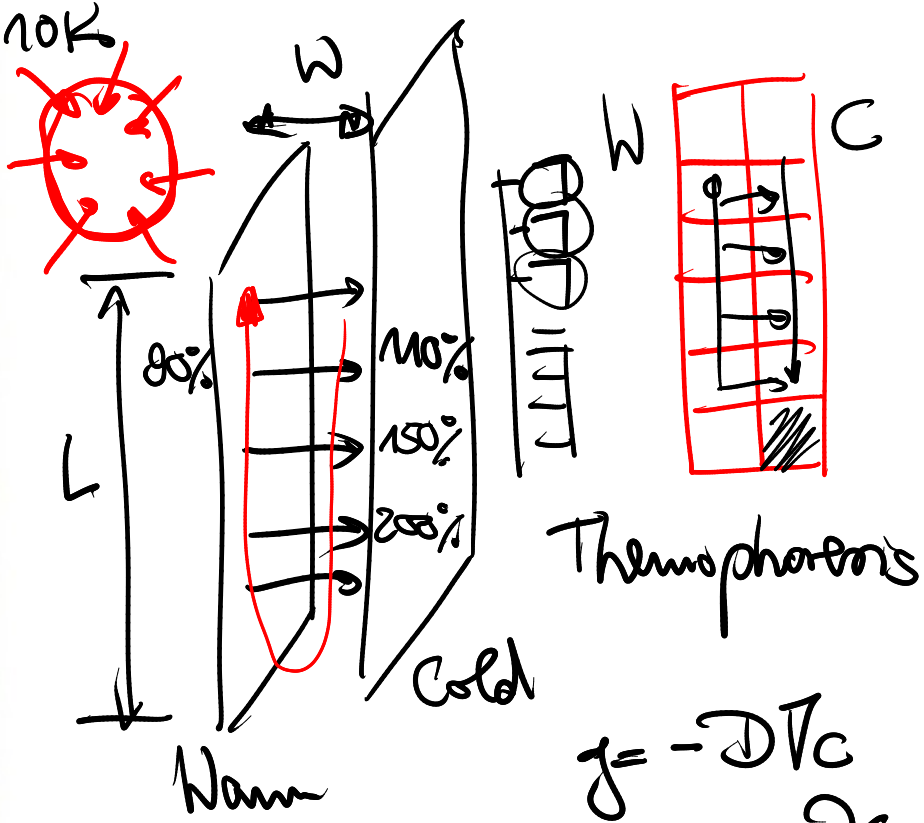
Accumulation by heat flow



Convection
Thermophoresis

PRL 2002, PNAS 2007, NanoLetters 2009, PRL 2010, APL 2015, PCCP 2016

$$\frac{c}{c_0} = \exp\left(+0.4 \frac{D_T}{D} \cdot \Delta T \cdot \frac{L}{h}\right)$$



$$j = -D\nabla c$$

$$= -D\frac{\partial c}{\partial x}$$

$$j = -D\frac{\Delta c}{\Delta x}$$

1.5 — 100x

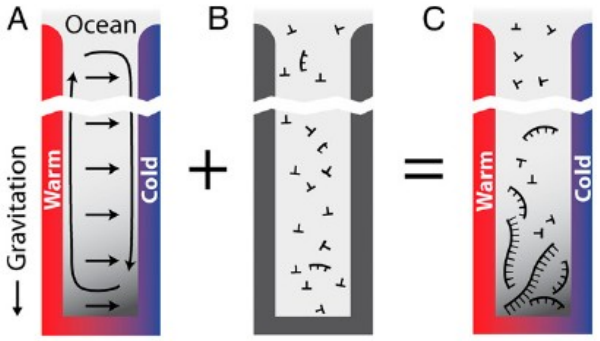
1.5 — 10x

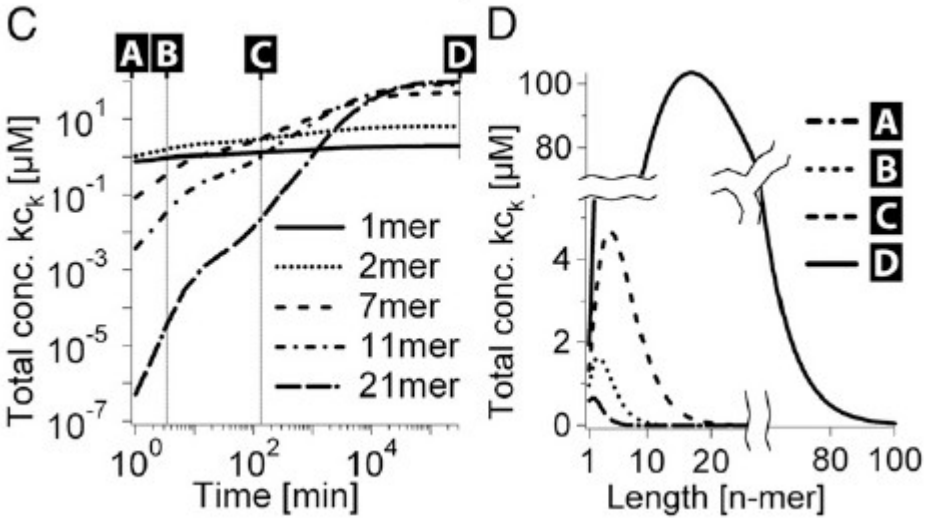
Simulation with Comsol

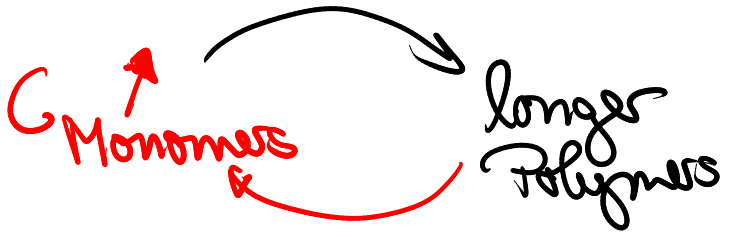
Accumulation and Polymerization

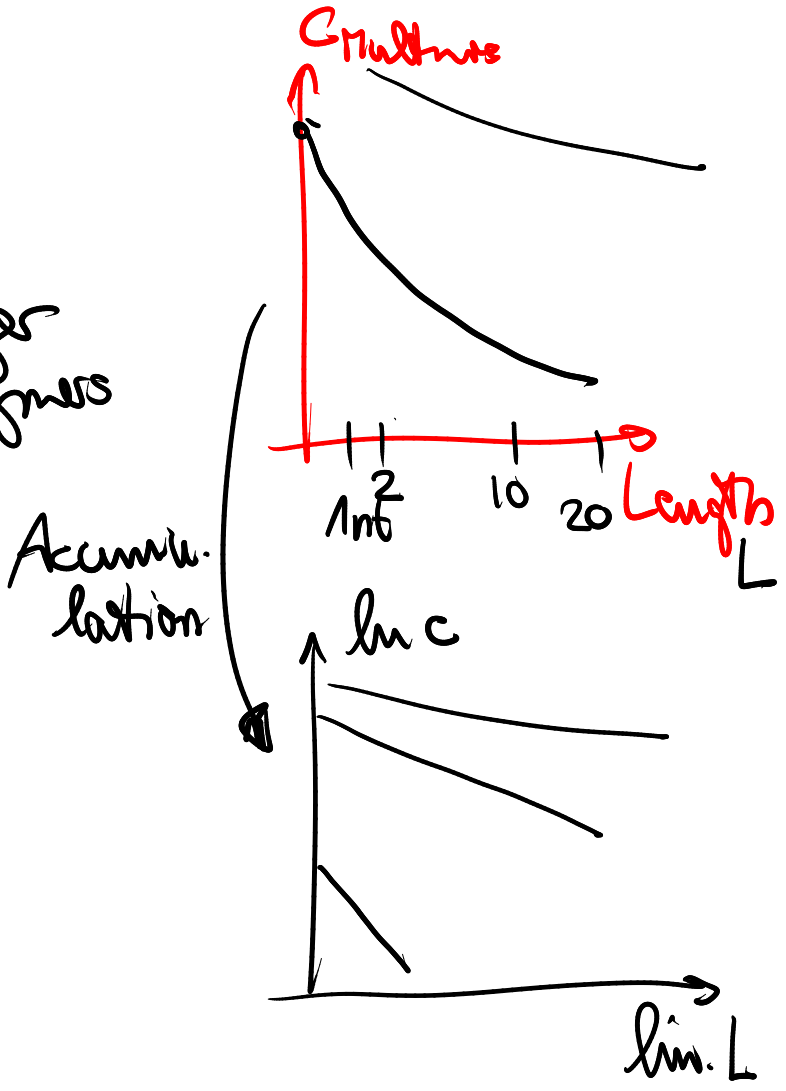
Escalation of polymerization in a thermal gradient

Christof B. Mast[a,1], Severin Schink[b,1], Ulrich Gerland[b], and Dieter Braun[a,2]









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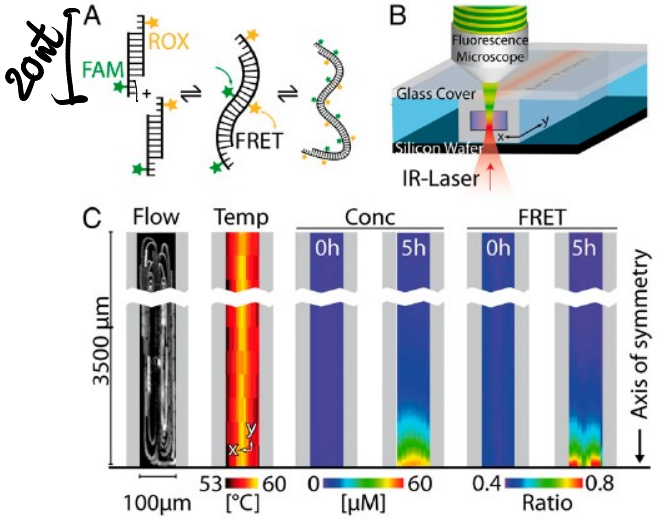
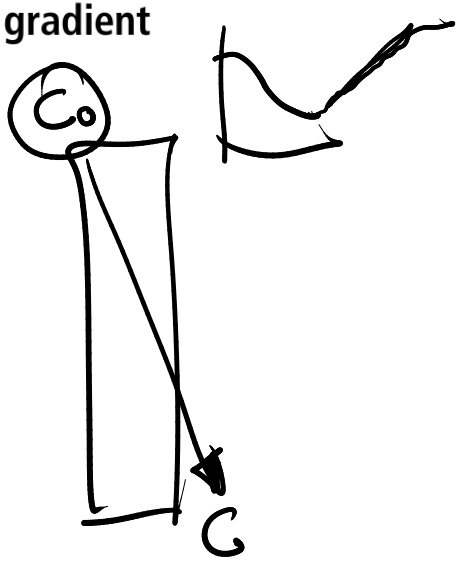
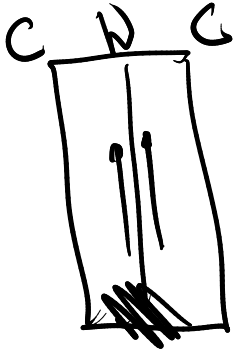
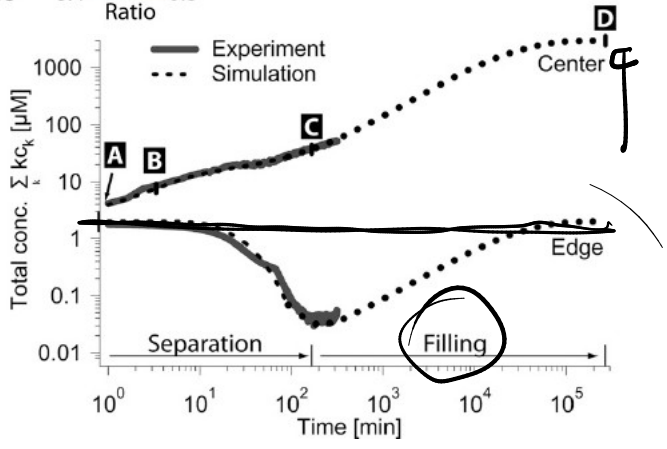
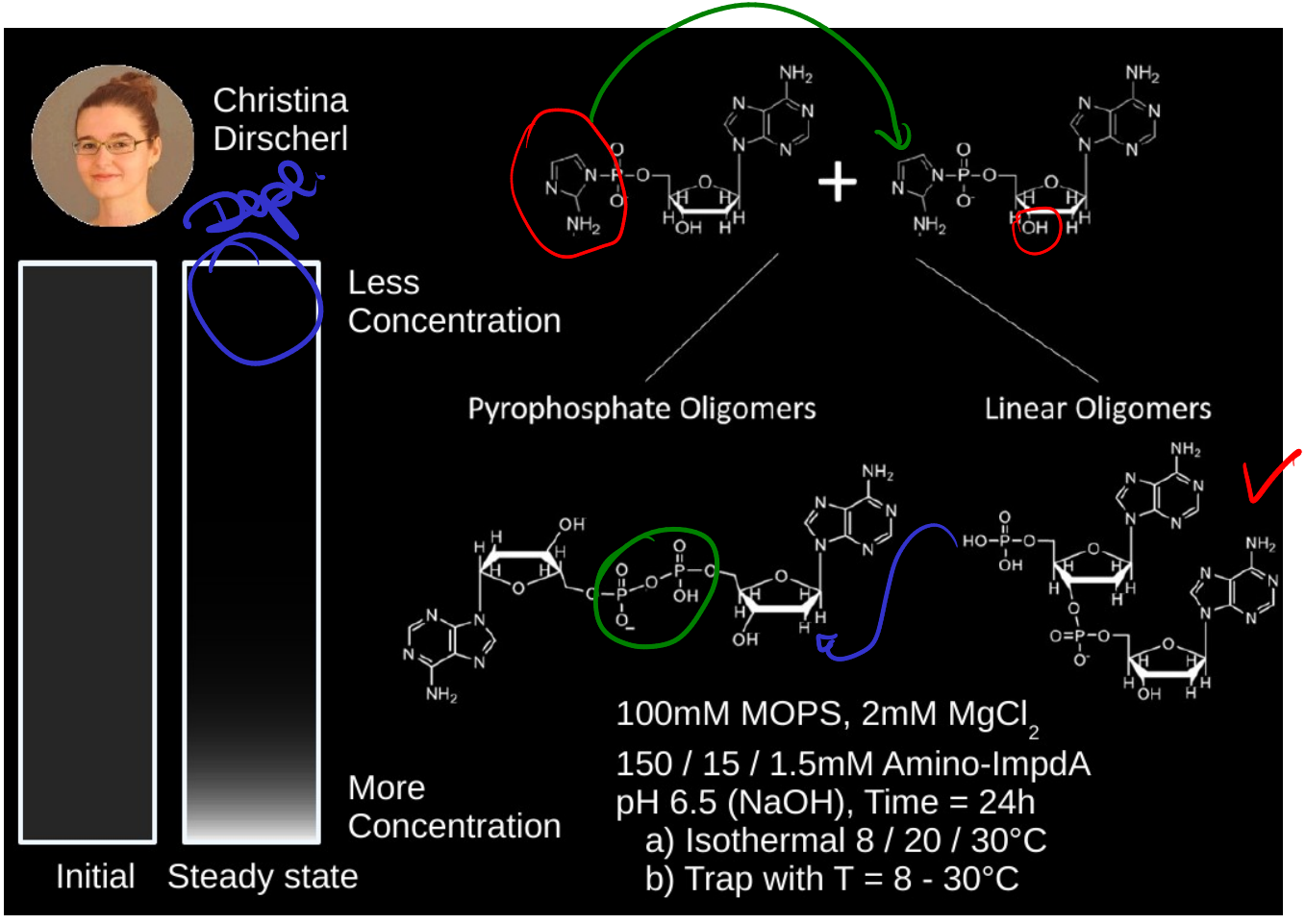




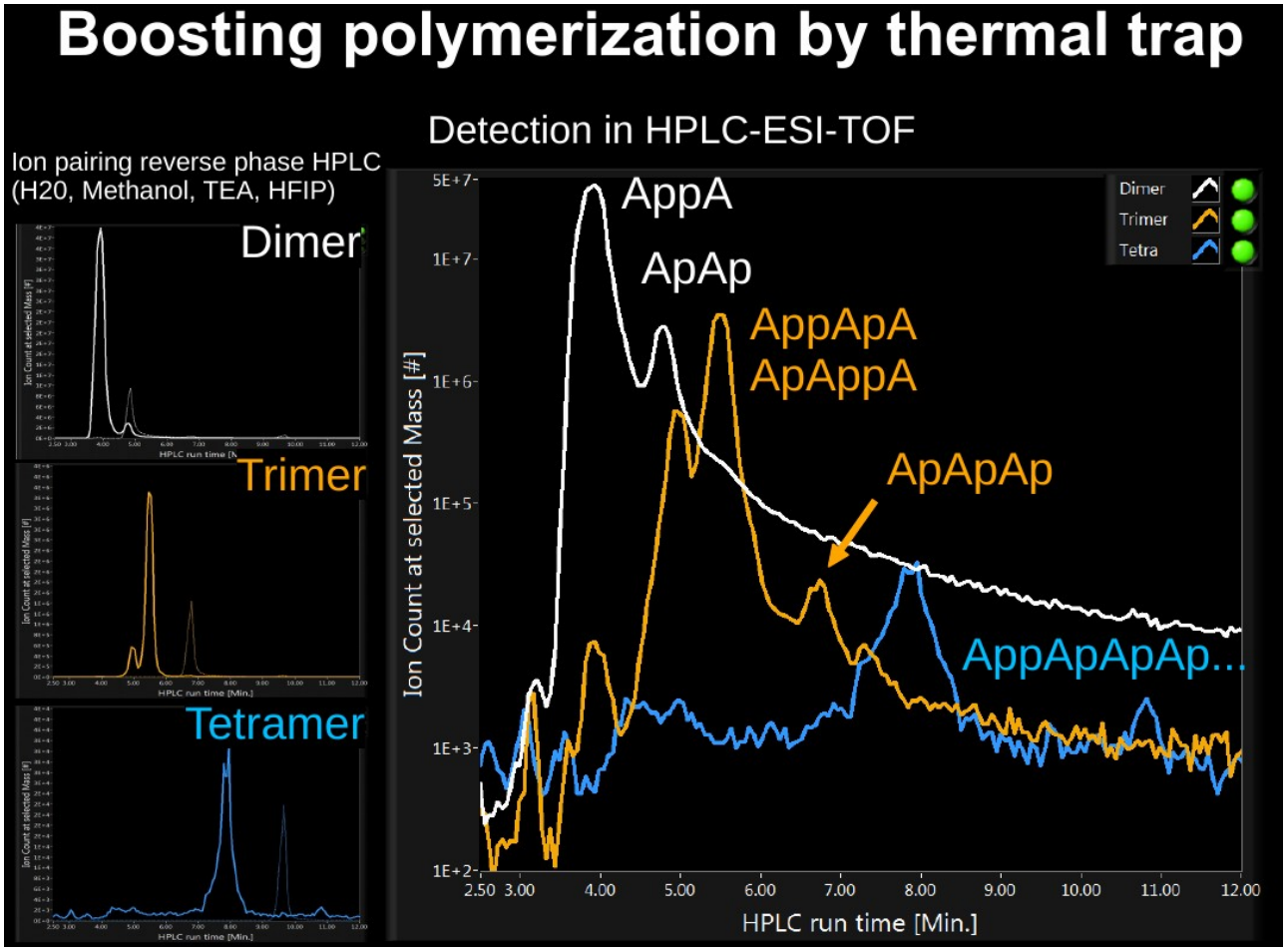


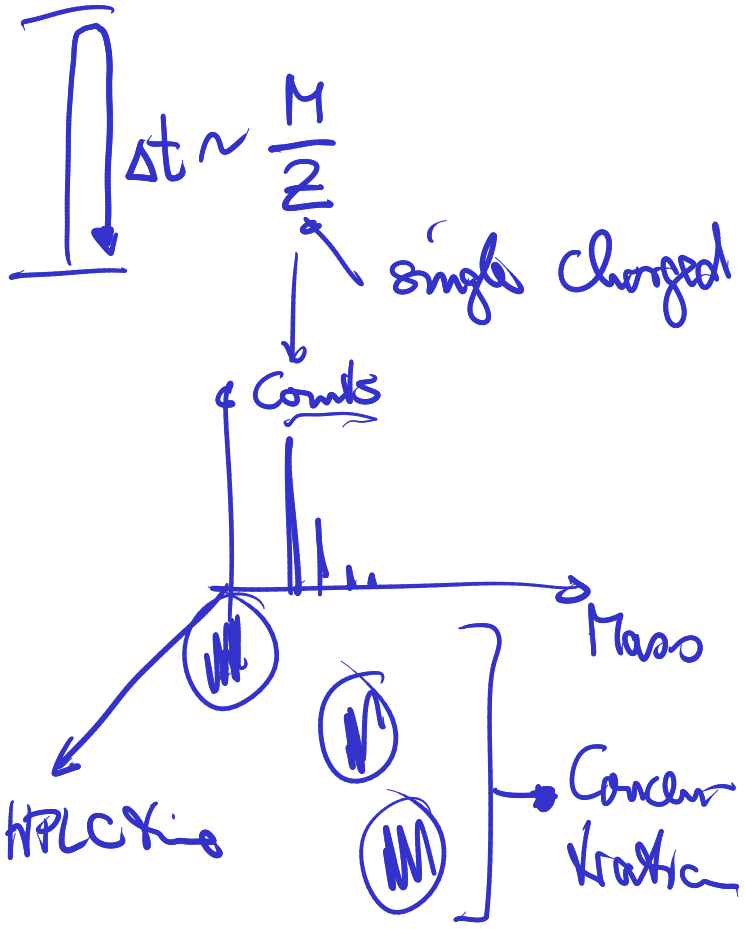


Accumulation and Polymerization

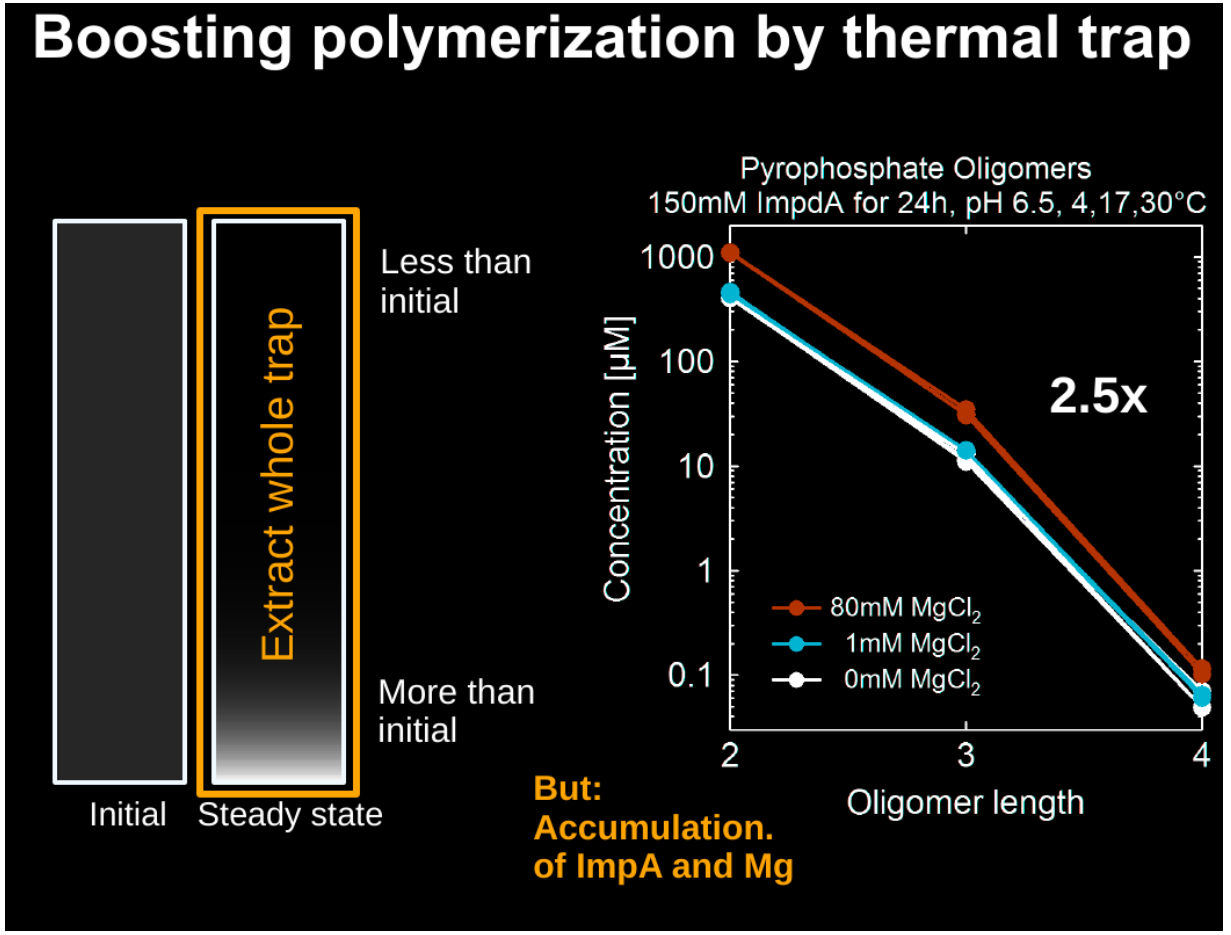


Accumulation and Polymerization

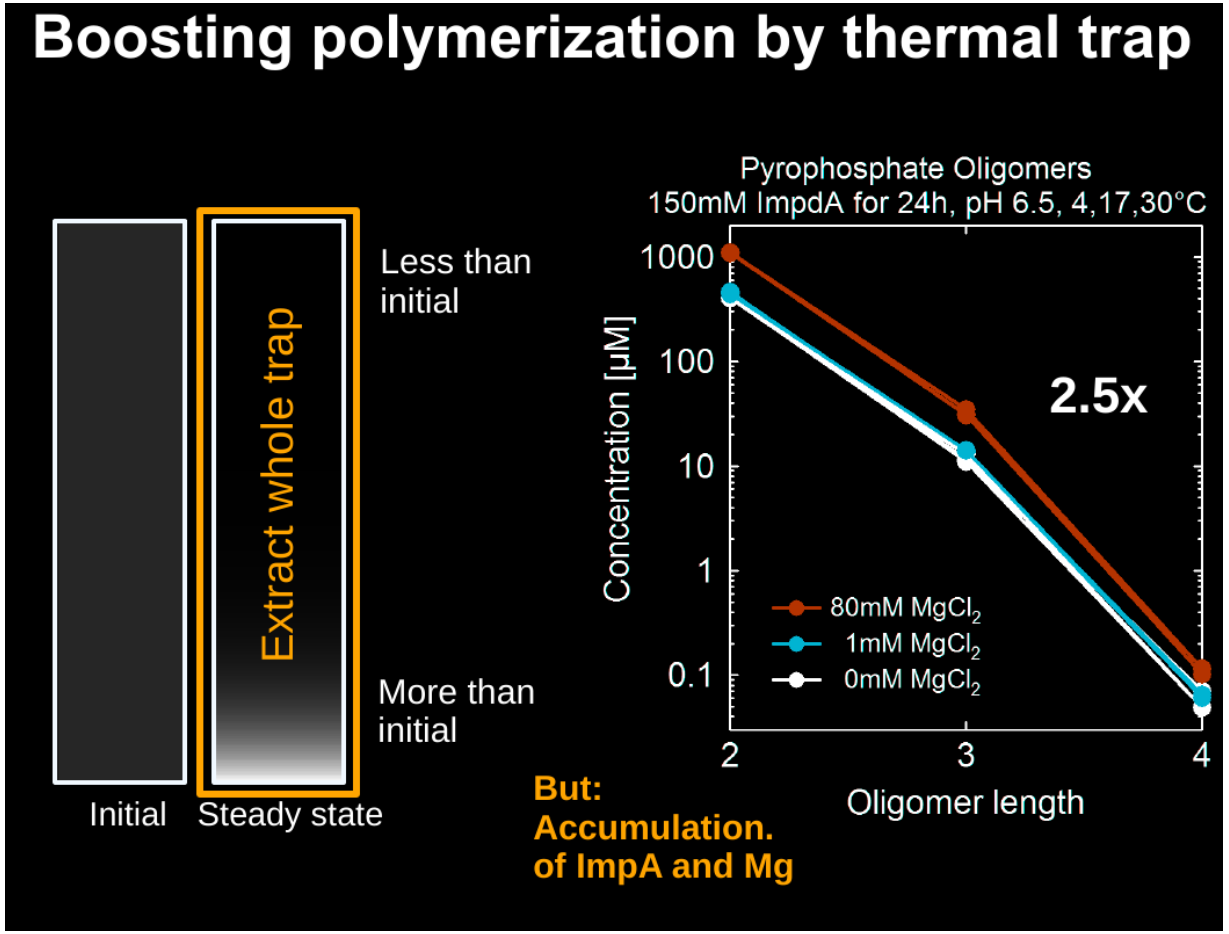


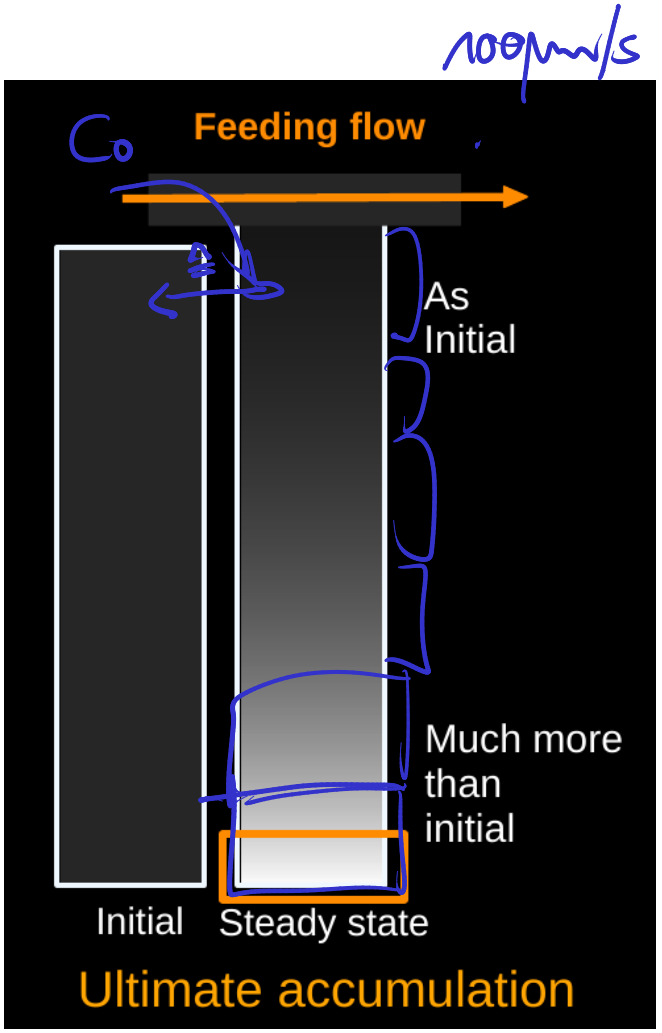


Accumulation and Polymerization

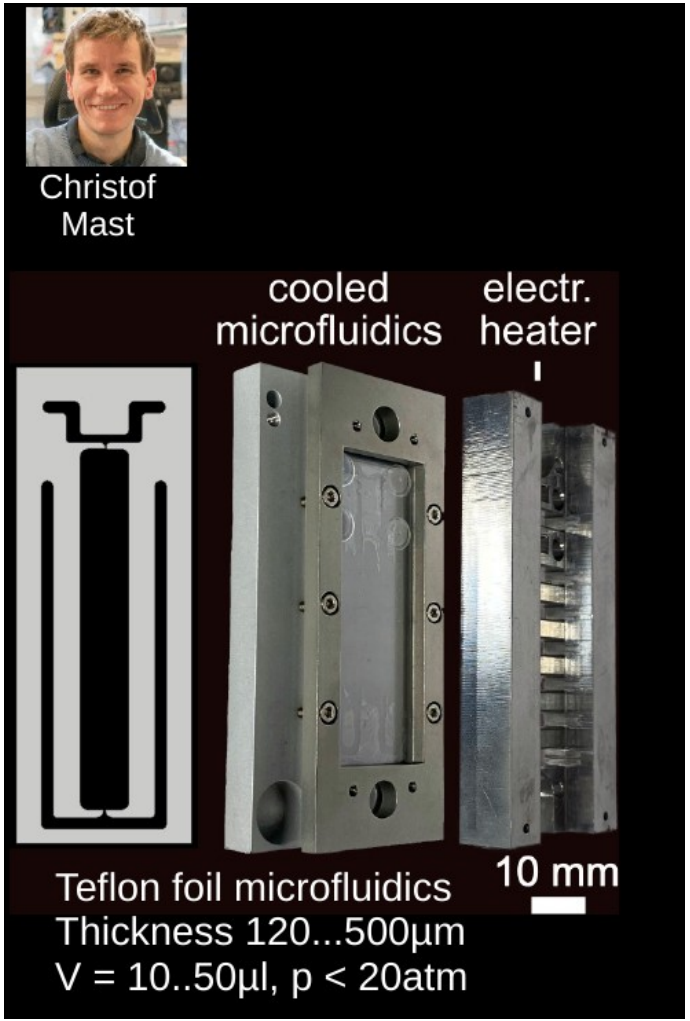


Accumulation and Polymerization

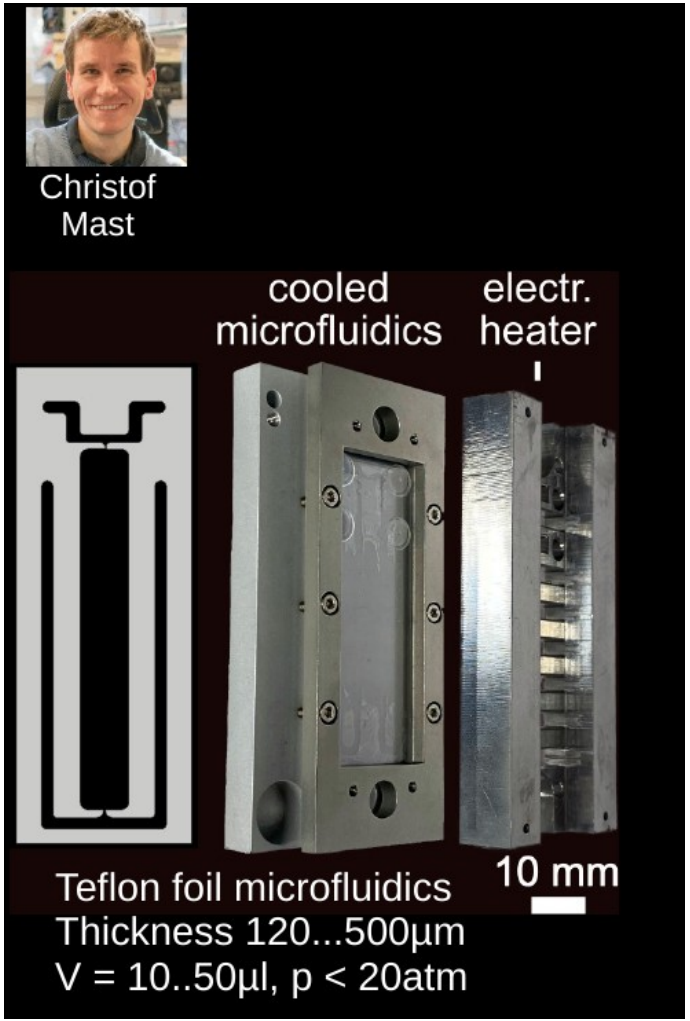


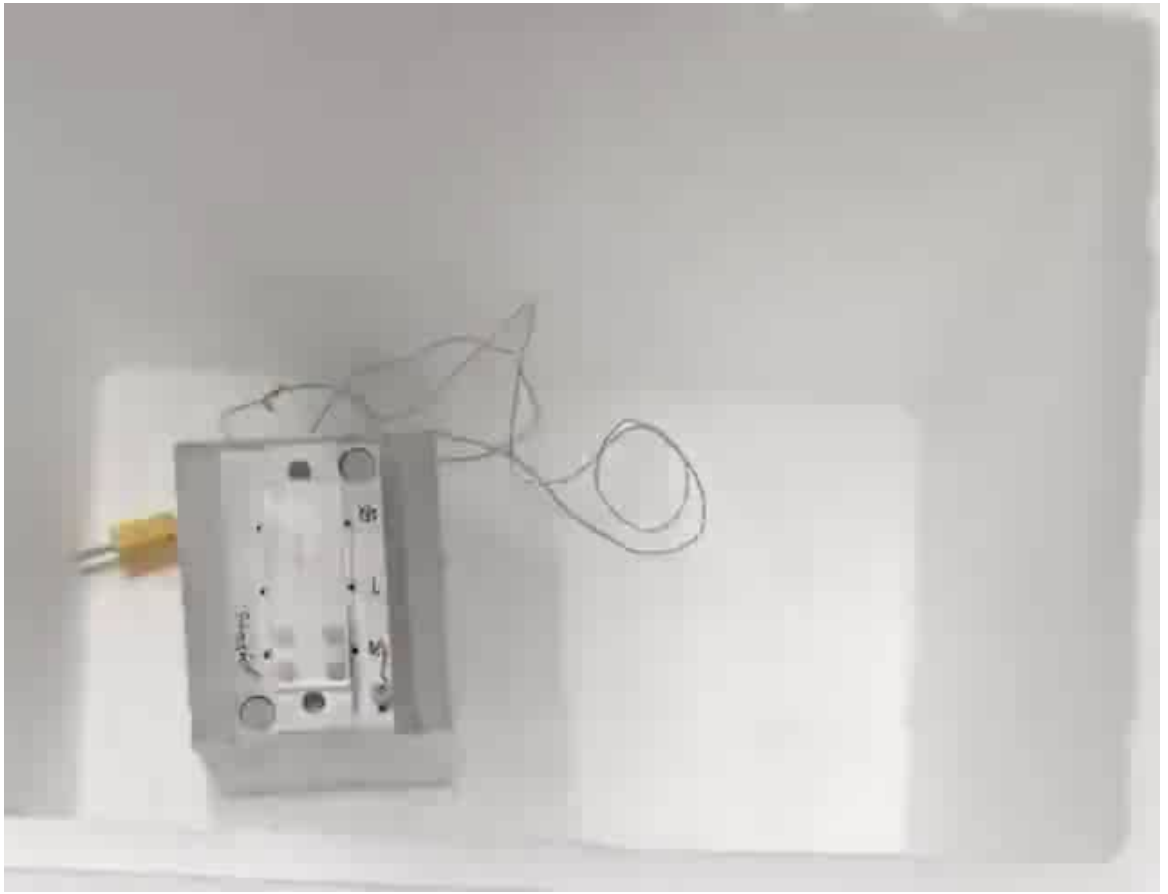


Accumulation and Polymerization



Accumulation and Polymerization





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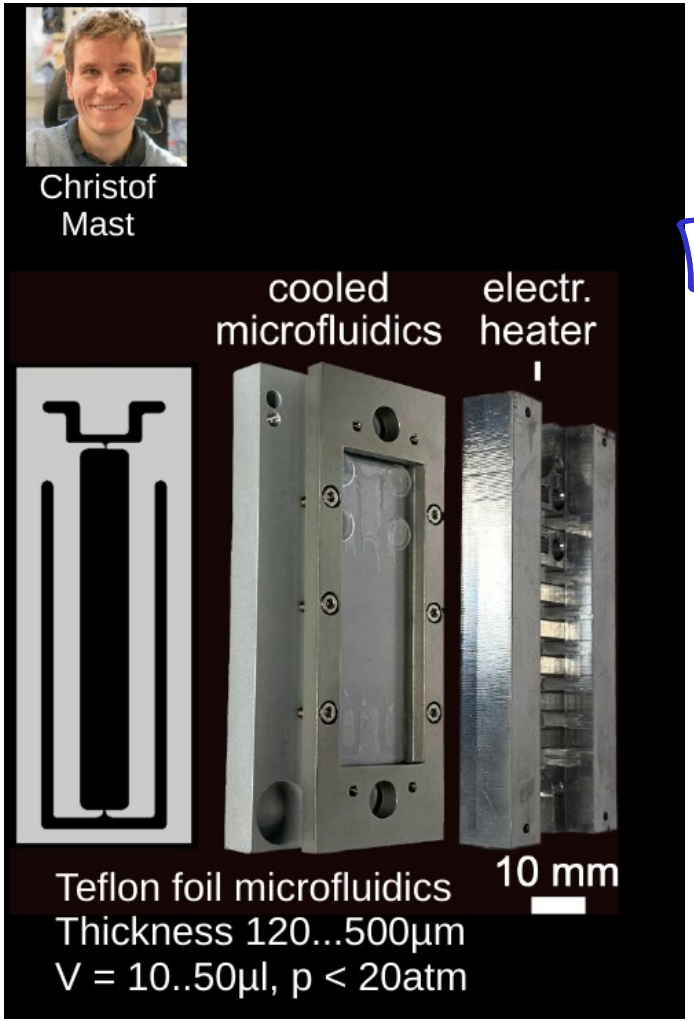
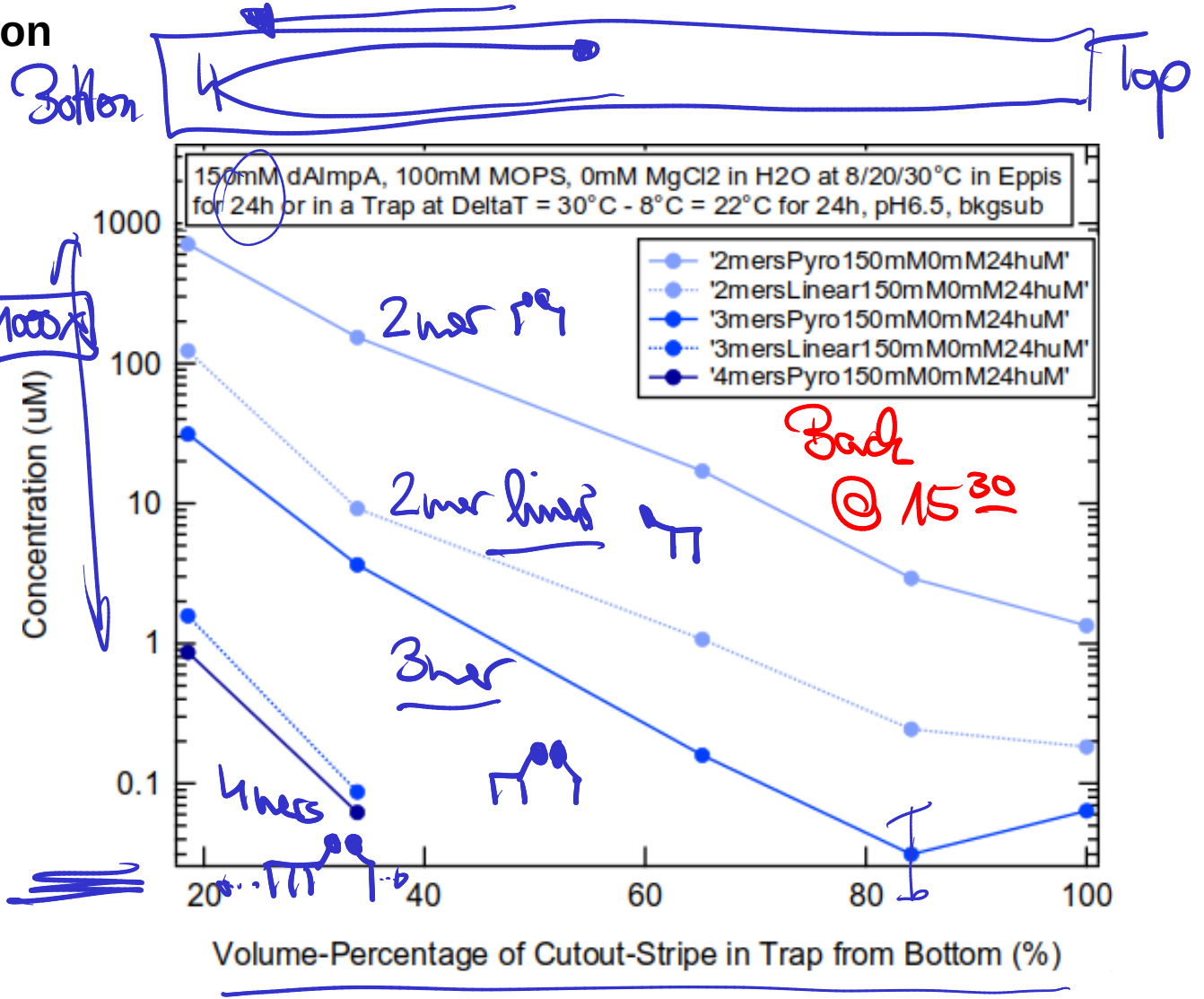




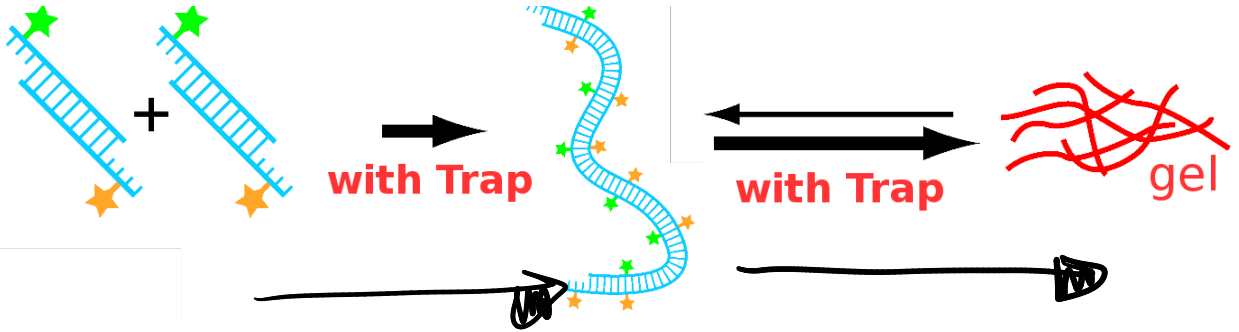
Accumulation and Polymerization leads to gels

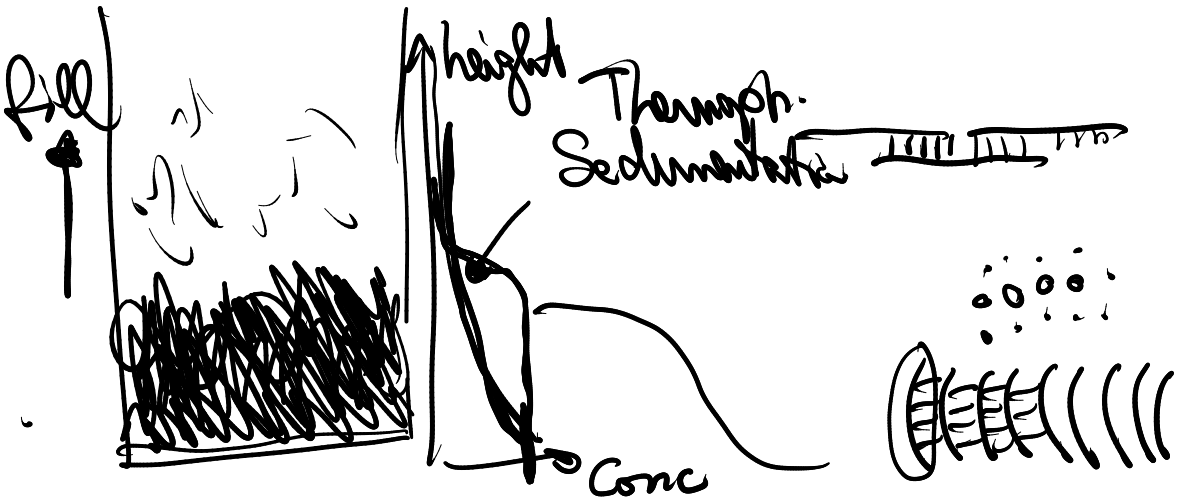
DNA Hydrogels Hot Paper

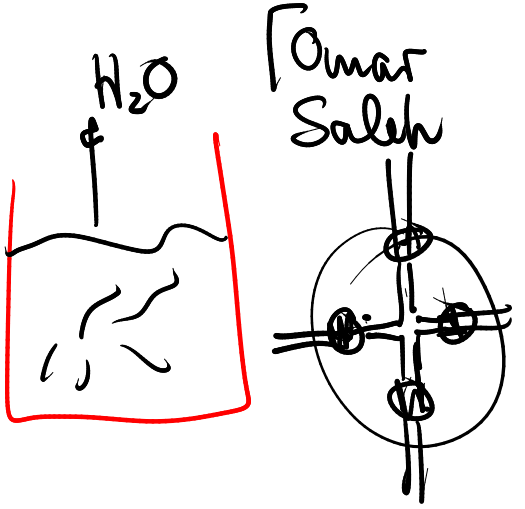
International Edition: DOI: 10.1002/anie.201601886
German Edition: DOI: 10.1002/ange.201601886

Heat-Flow-Driven Oligonucleotide Gelation Separates Single-Base Differences

*Matthias Morasch, Dieter Braun, and Christof B. Mast**







2D, 3D: Phase transition

1D: Cannot undergo Phase transition

Accumulation and Polymerization leads to gels

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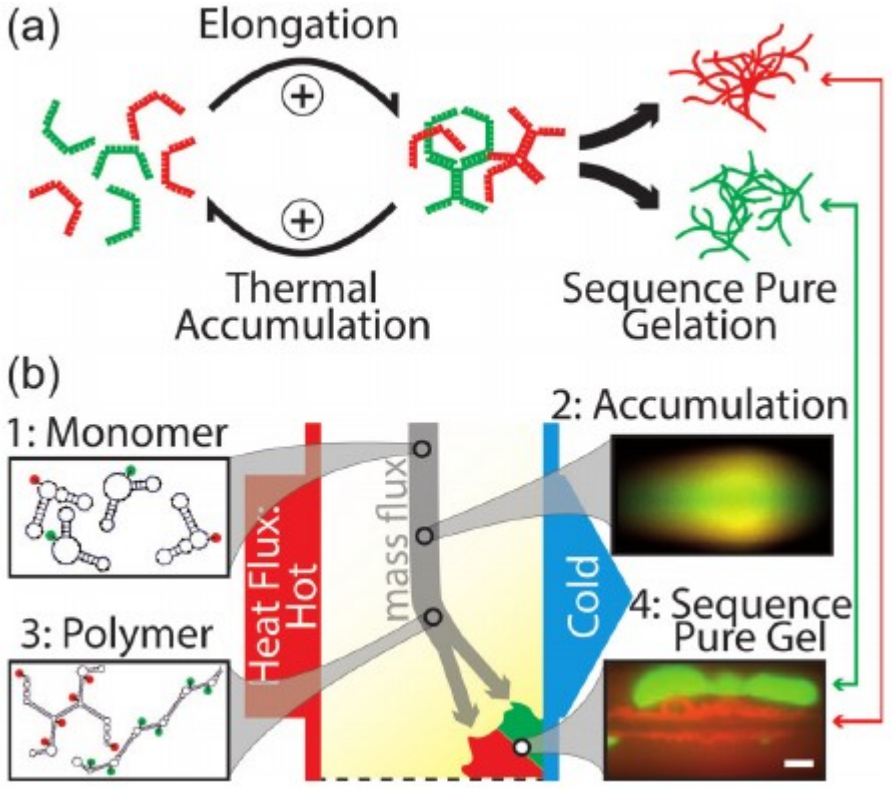
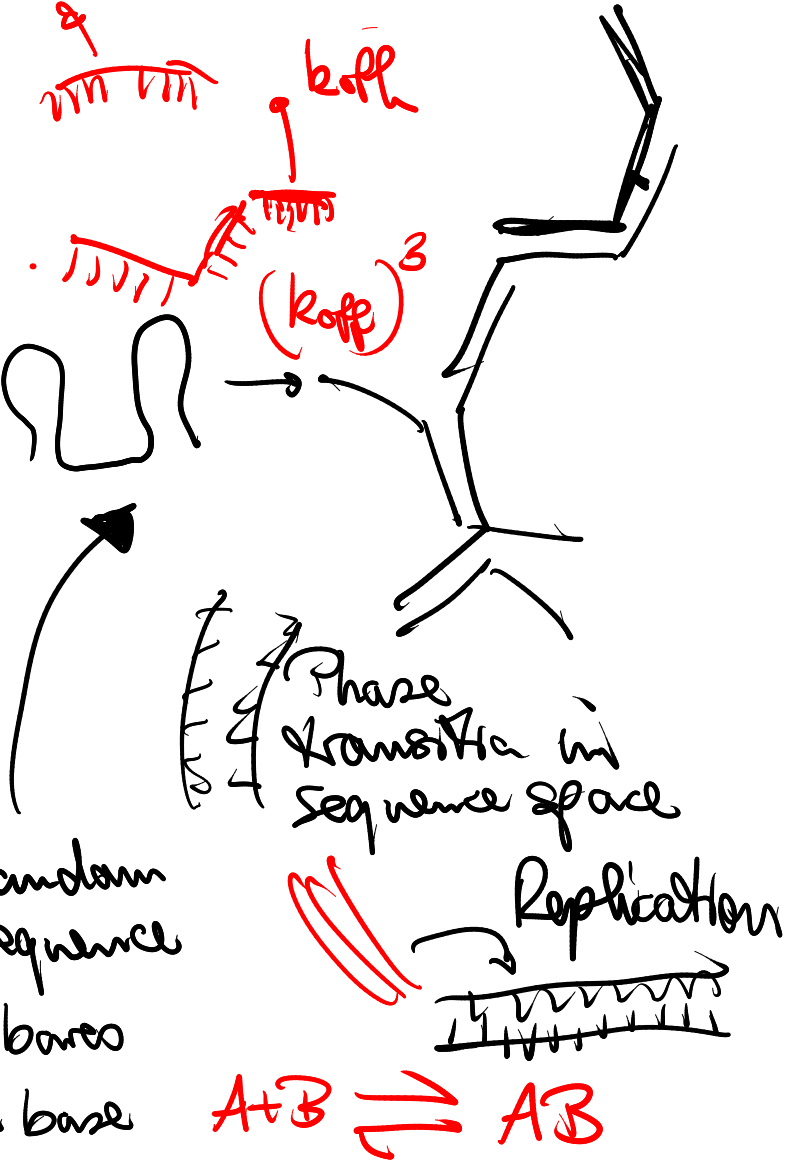
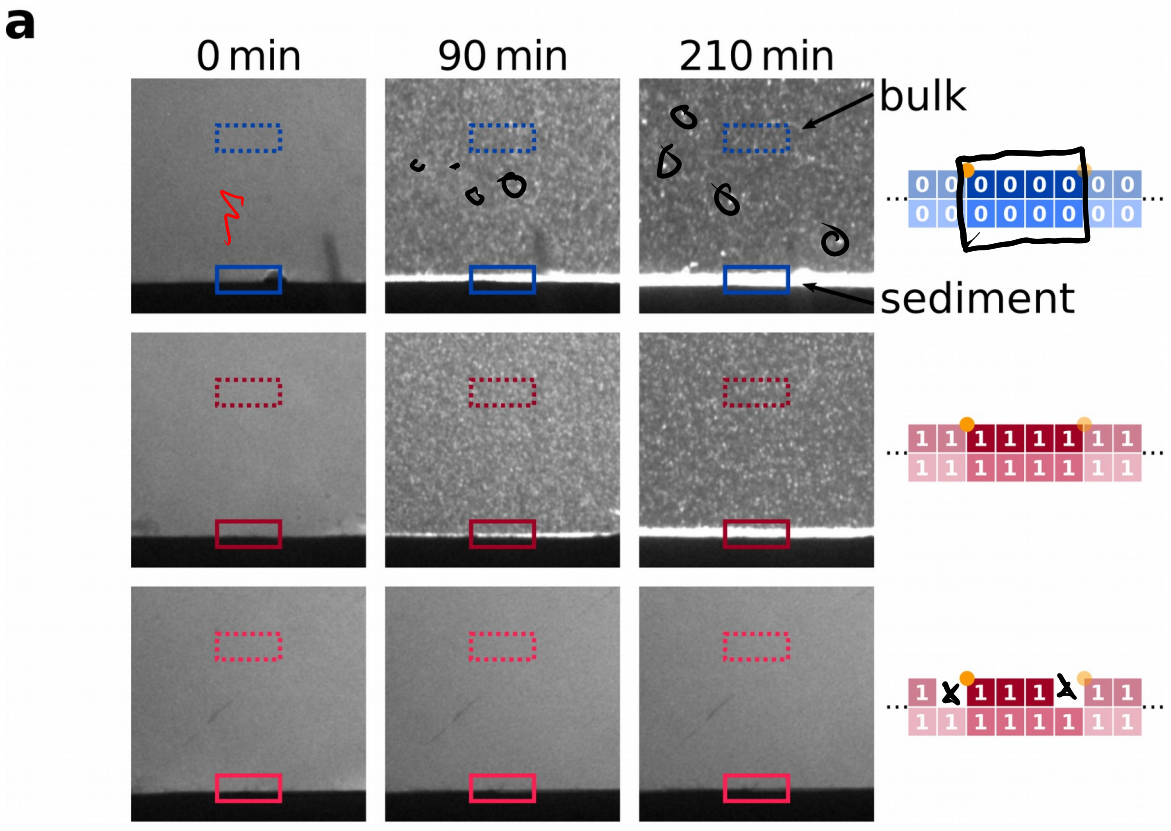
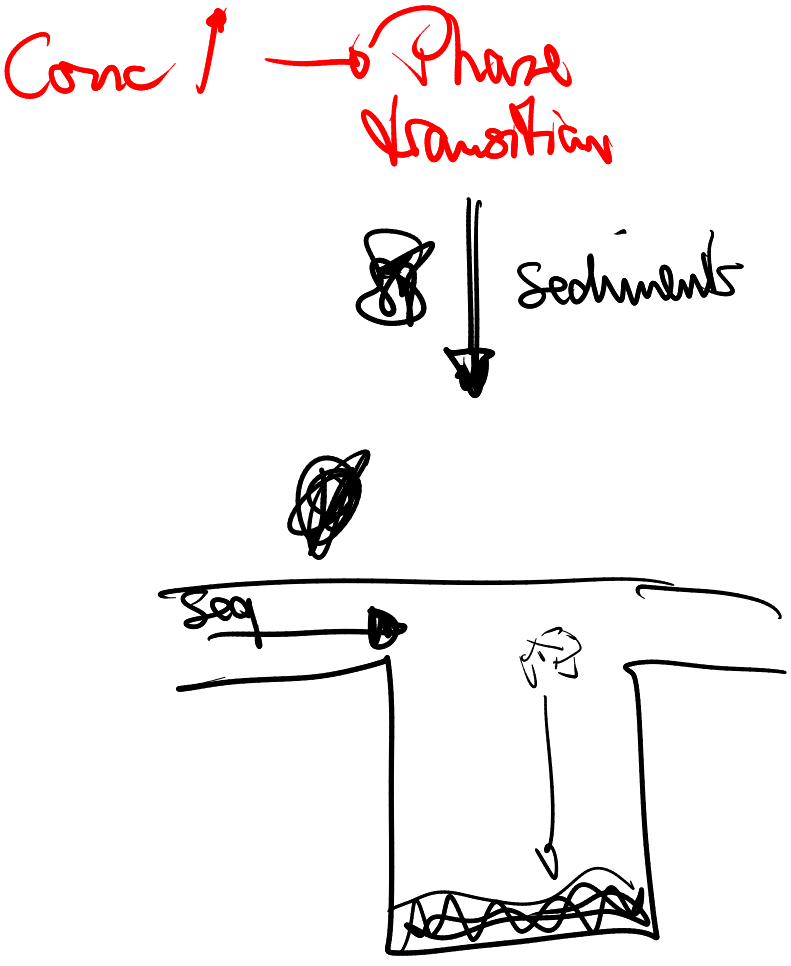


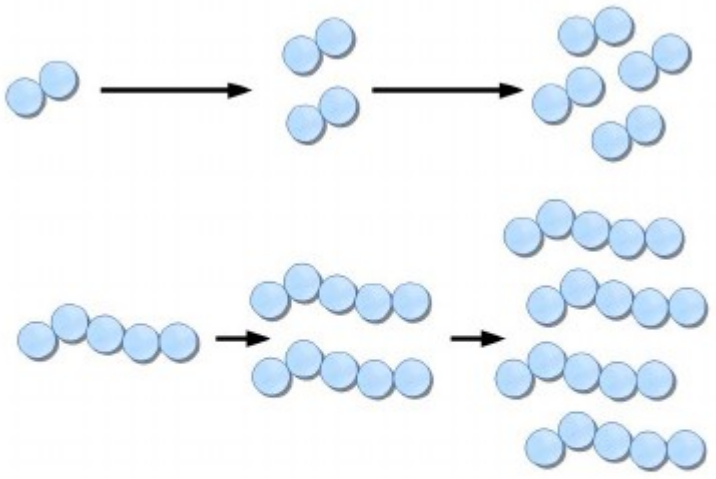


Gelation and sedimentation





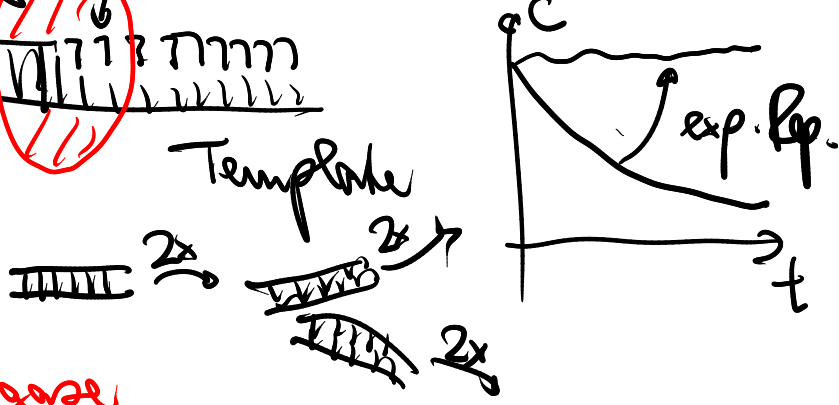
Replication driven by temperature gradients



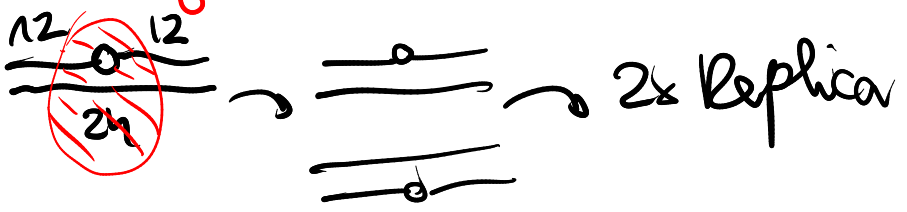
Replication
by Convection

Base by base | 50 nt/s (PCR) | 2-AI: 1nt/h

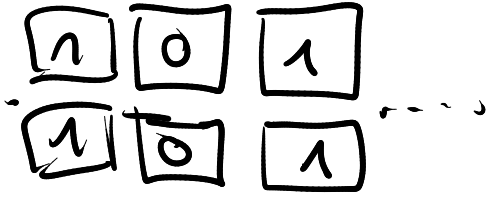
Primer — Helicase — activate Nucleotides



Ligase

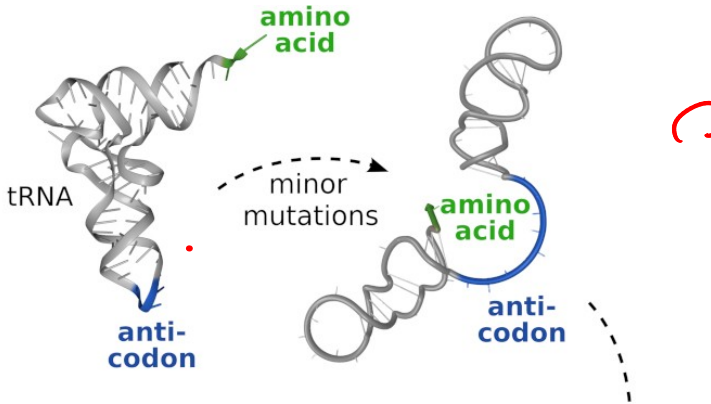


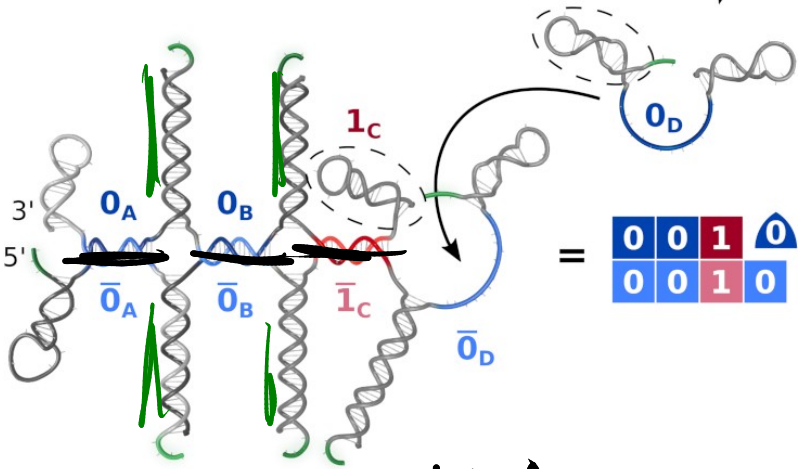
2x Replica



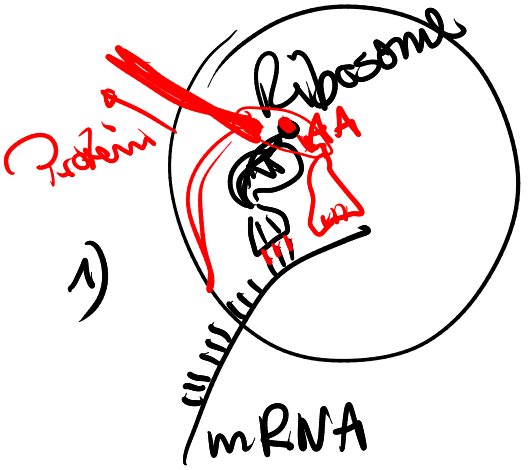
Metasequence

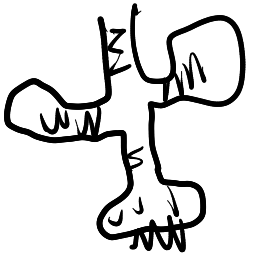
Replication driven by temperature gradients



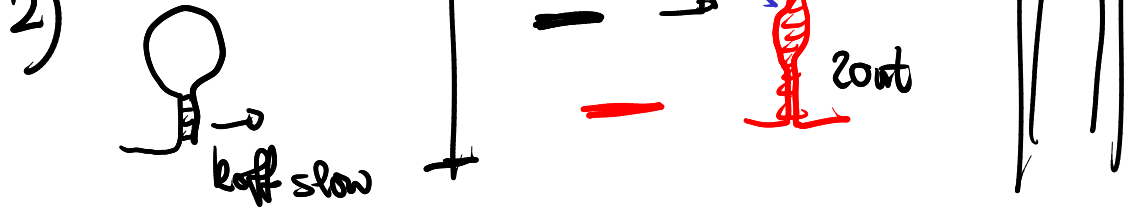


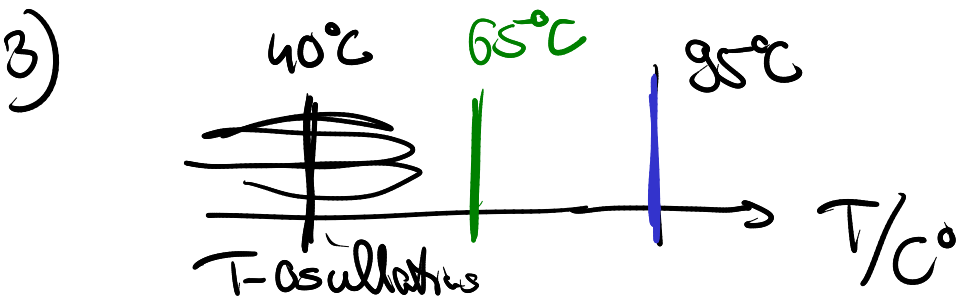
— opening at 40°



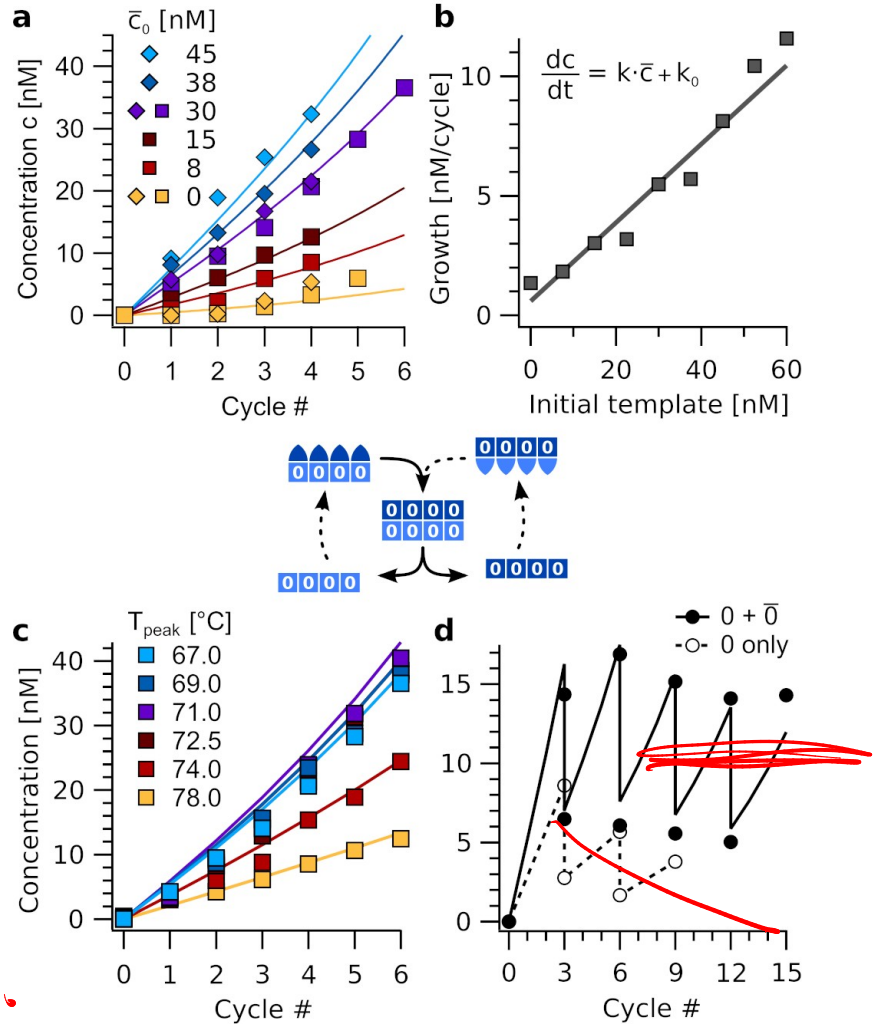


20 tRNA : useful for replication?





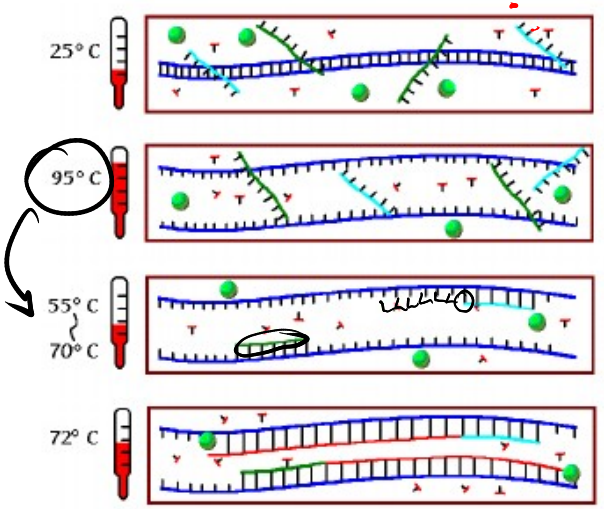
Replication driven by temperature gradients



Replication driven by temperature gradients

Polymerase Chain Reaction (PCR)

Taq Polymerase

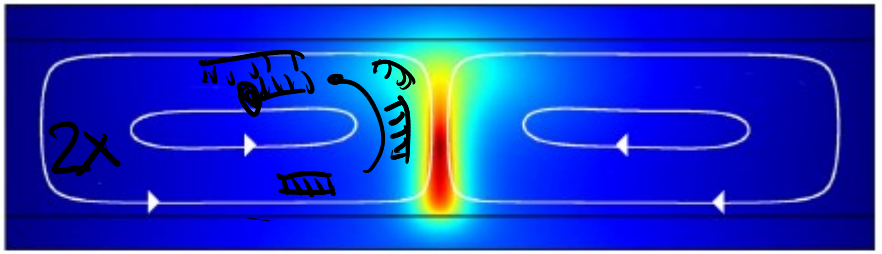


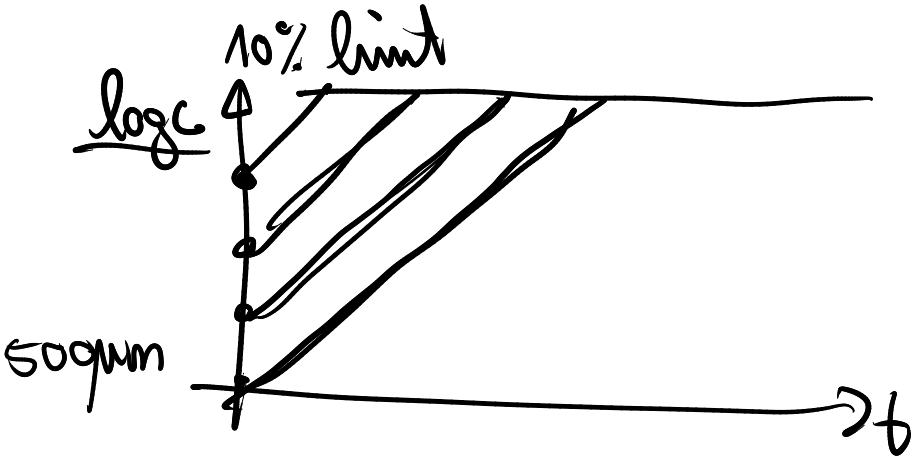
Protein is Thermostable:

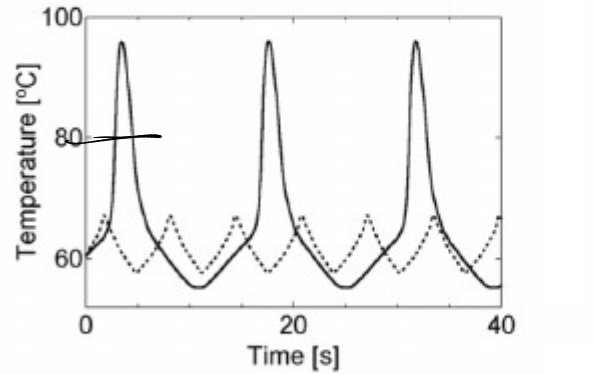
- 30 Min @ 95°C
- 50 nt/s

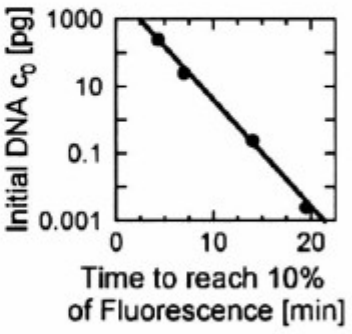
Replication driven by temperature gradients

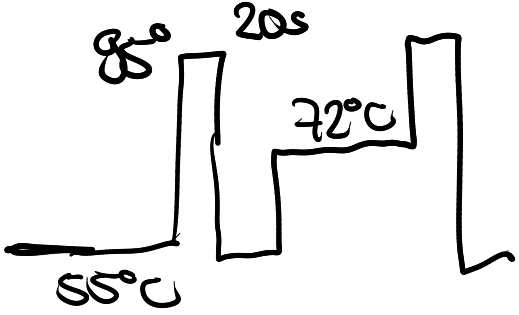
Replication by Convection (PCR)











Length independent Replication
(80-2000 base pairs)

Braun, Goddard & Libchaber, PRL 91, 158103 (2003)