

Blue Marble Space
Institute of Science

From the Origins of Life to the First Cells

Tony Z. Jia
tzjia@elsi.jp

Earth-Life Science Institute, Tokyo Institute of Technology
Blue Marble Space Institute of Science

The 69th TIEC Research and Presentation
May 22nd, 2021



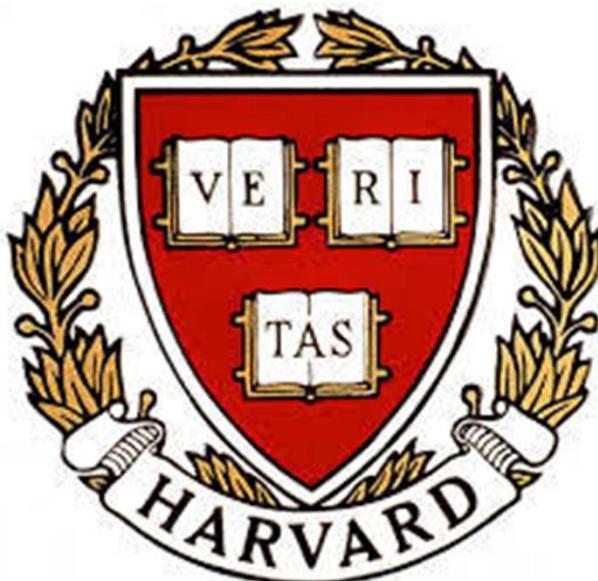
- BS Chemistry & Business, Economics, and Management at Caltech '10
 - Researched chloroplast protein expression and crystallography
 - Studied droplet ionization mass spectrometry for pulmonary surfactant lipids



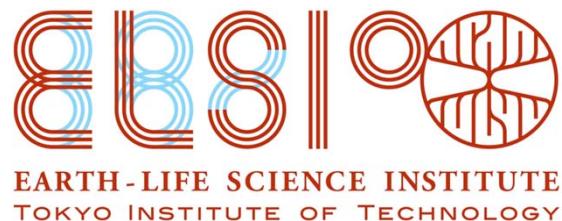
Caltech



- MS and PhD Chemistry at Harvard '16
 - Developed RNA sequencing technologies for non-coding RNA quantification
 - Studied nonenzymatic RNA polymerization and replication biochemistry



- Research Scientist at ELSI/Tokyo Institute of Technology since 2017
 - Various projects relating to Origin of Life and Astrobiology in chemistry, biology, materials science, and biotechnology



EARTH-LIFE SCIENCE INSTITUTE
TOKYO INSTITUTE OF TECHNOLOGY

- Affiliated Scientist of Blue Marble Space Institute of Science since 2019



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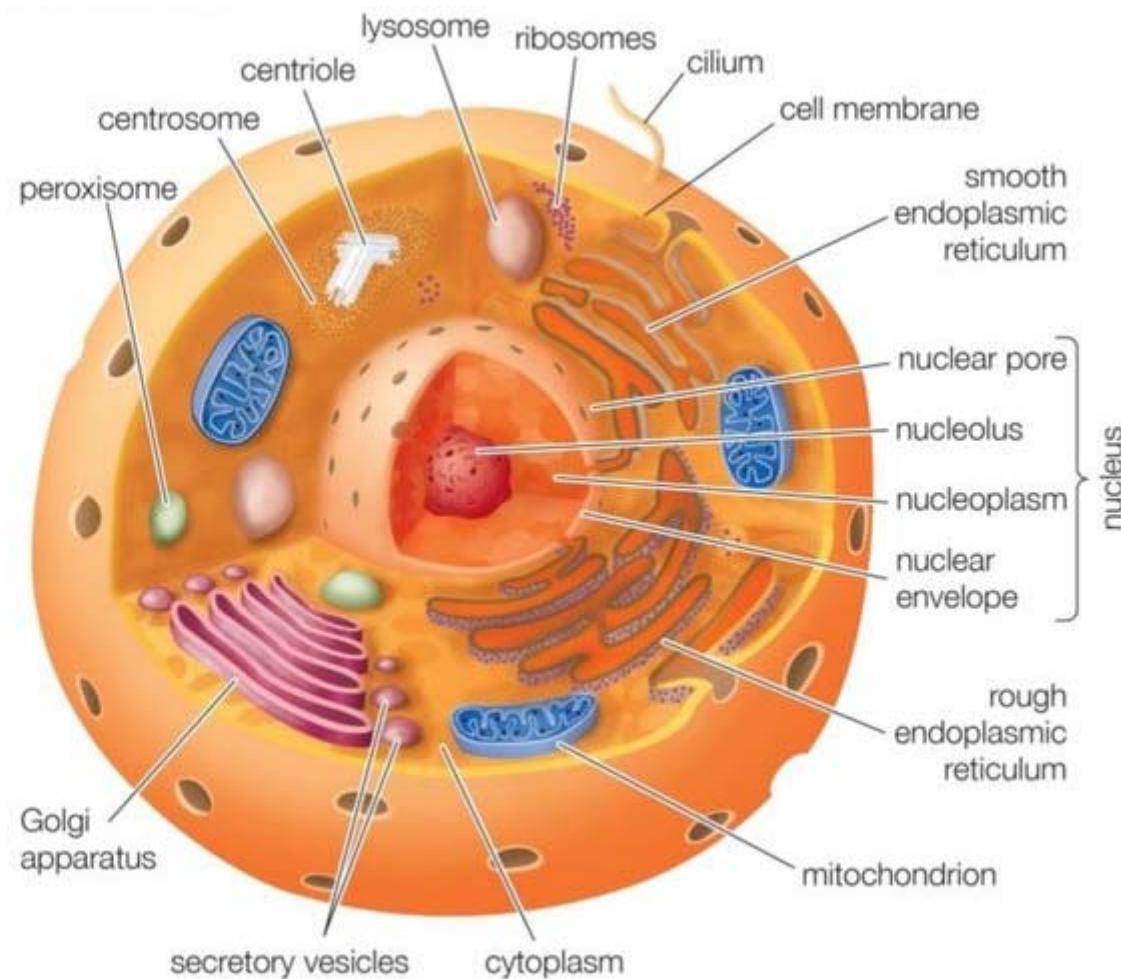
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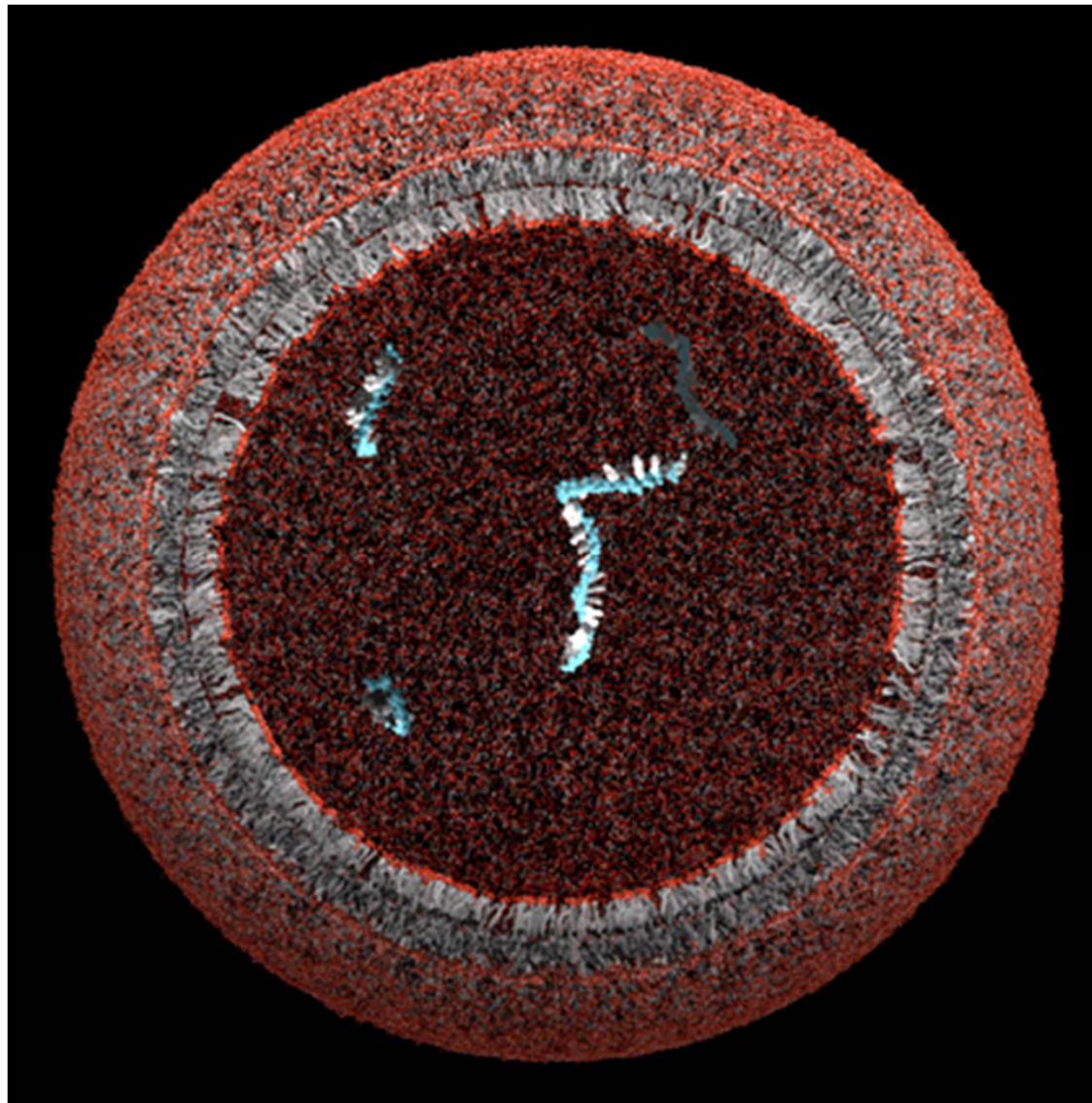


The Modern Cell



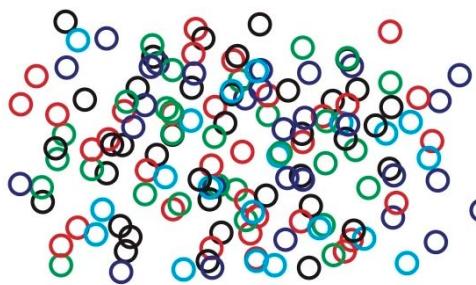
MBoC

A Primitive Compartment

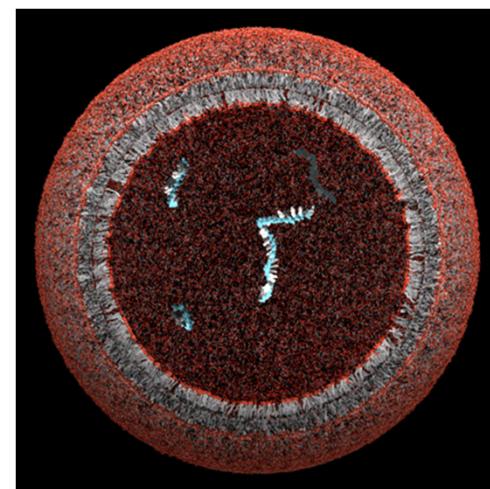


Theory of Origin of Life Research

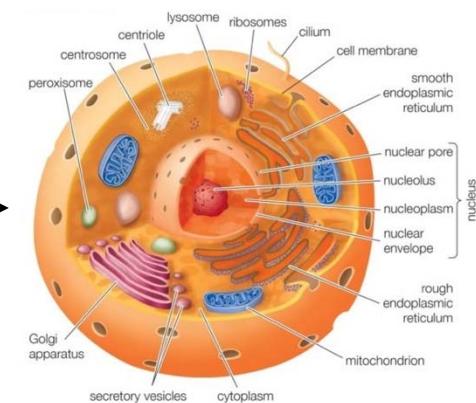
Prebiotic Chemistry



Primitive Compartment



Modern Cell



Compartments are Crucial to Origins of Life

- Concentrate and Segregate Reactants
- Promote Chemical Reactions and Rates
- Catalysis
- Forming Barriers with the External Environment
- Protect Molecules from Degradation
- Promotion of Evolution
- Prevents Diffusion of Genetic Materials
- Controlled Movement



Liquid Liquid Phase Separation

- Results in soft, condensed matter (non-solid) phase
- Similar to colloids
- Membrane free compartmentalization
- Exchange of molecules between phases
- Can be formed from simple molecules
- Used in drug delivery, chemical reactors
- Biological Phase Separation

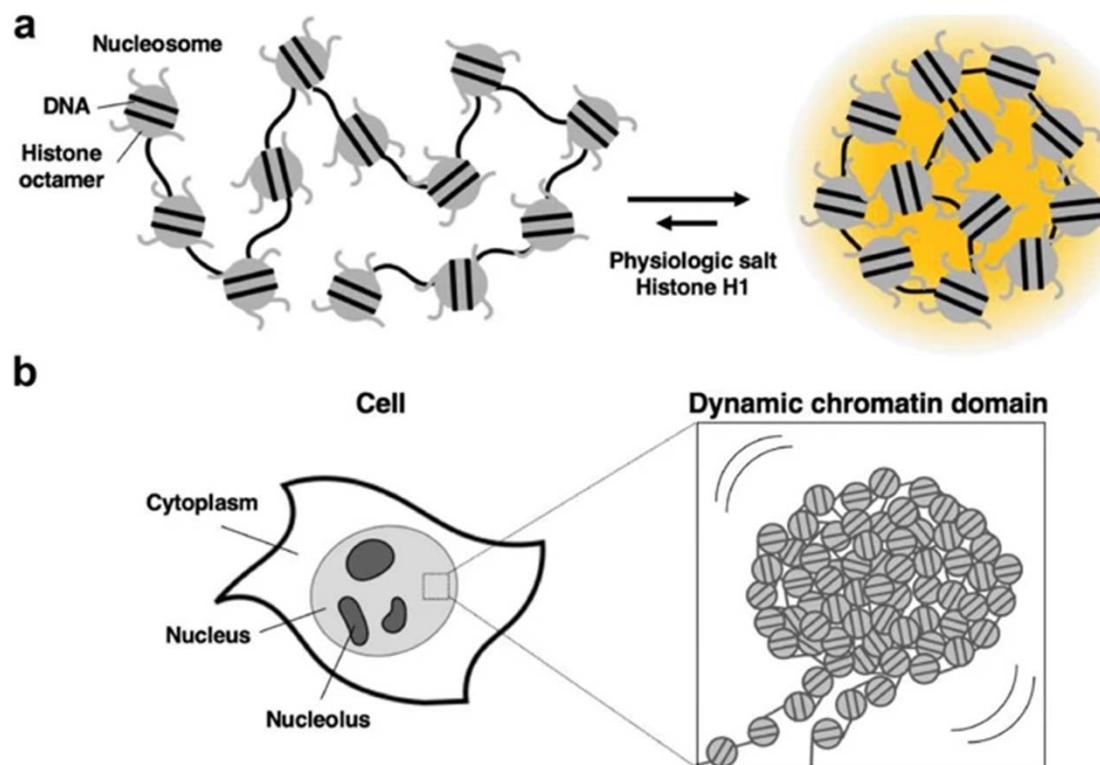


Liquid Liquid Phase Separation

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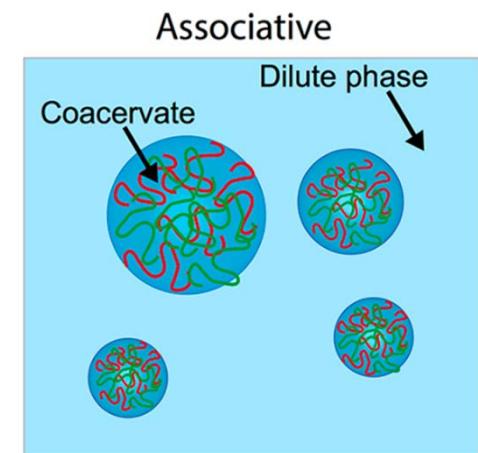
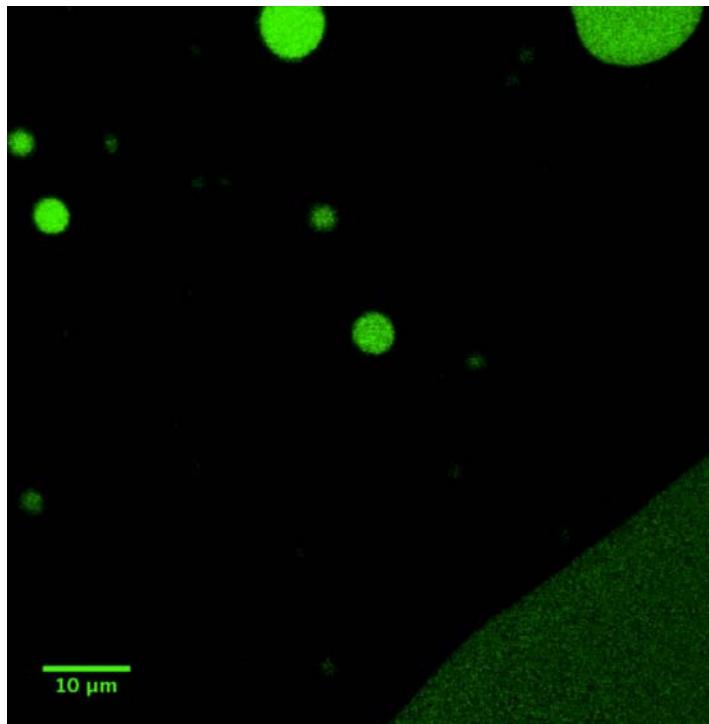
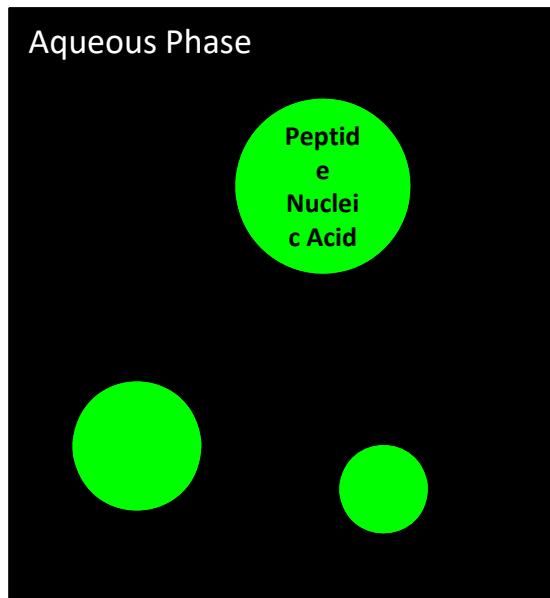
Liquid Liquid Phase Separation



Yoshizawa, S. et al. *Biophys. Rev.* **2020**



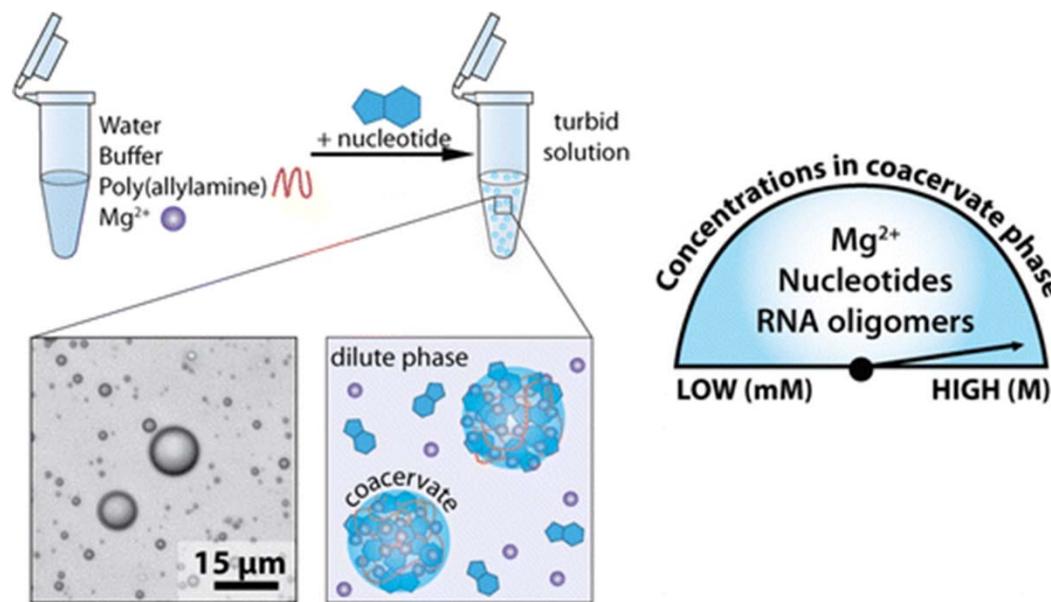
Complex Coacervates



Poudyal et al., *Biochem.* 2018
Jia et al., *OLEB.* 2014



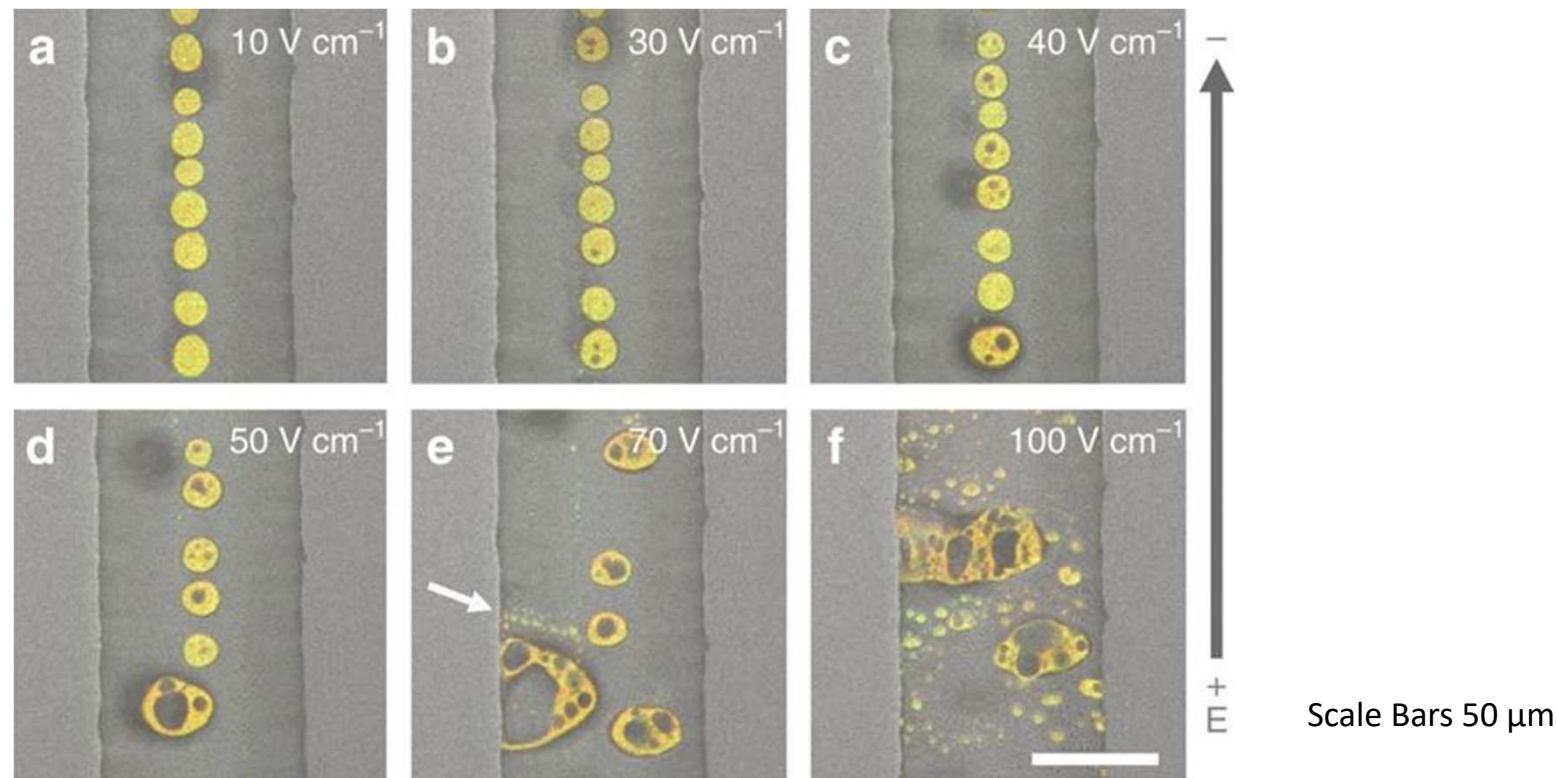
Coacervates Segregate and Concentrate Biomolecules



Frankel, Bevilacqua, Keating. *Langmuir* 2016



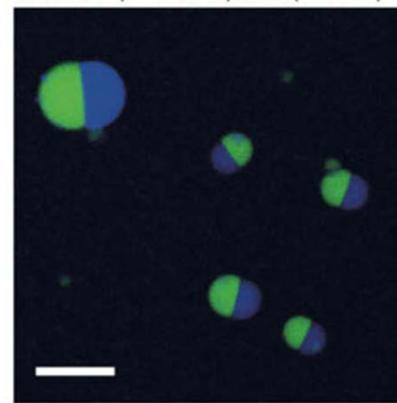
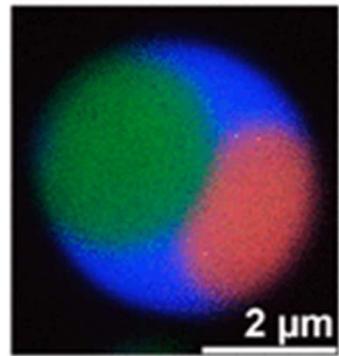
Coacervates Grow and Divide



Yin, et al. *Nature Comms.* 2016



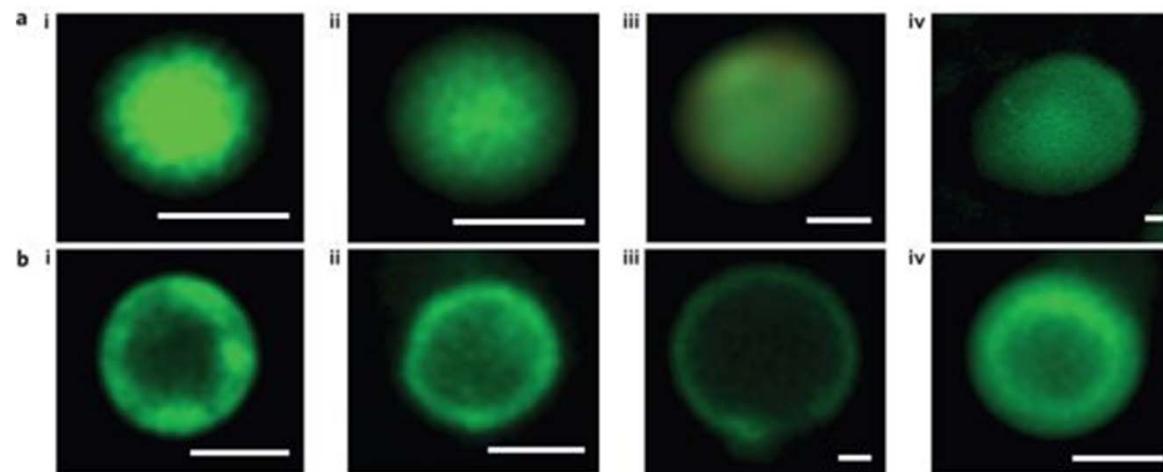
Coacervates as Multiphase Compartments



Scale Bars 30 μm (right)
Mountain and Keating, *Biomacromolecules*, 2019
Sato et al., *Science Advances*, 2020



Coacervates Scaffold Membrane Assembly

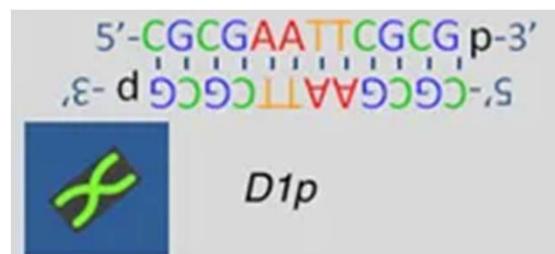
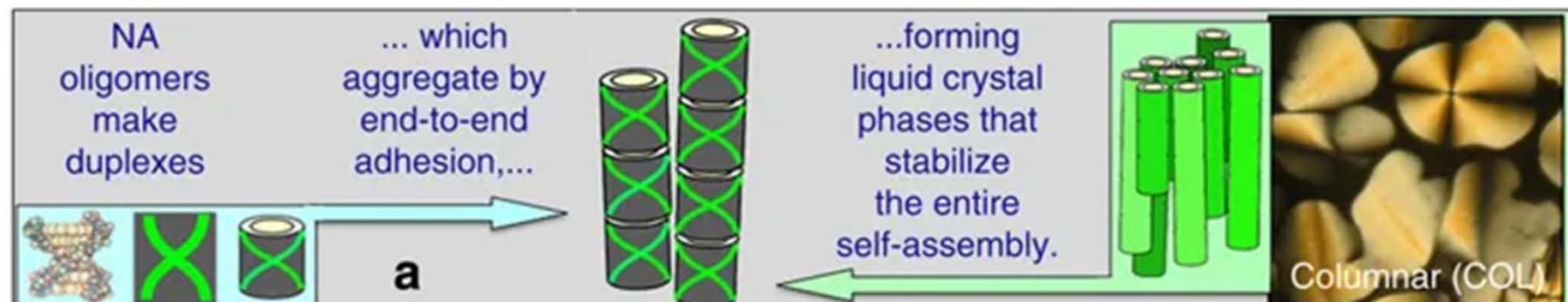


Scale Bars 1 μ m

Tang, et al. *Nature Chem.* 2014



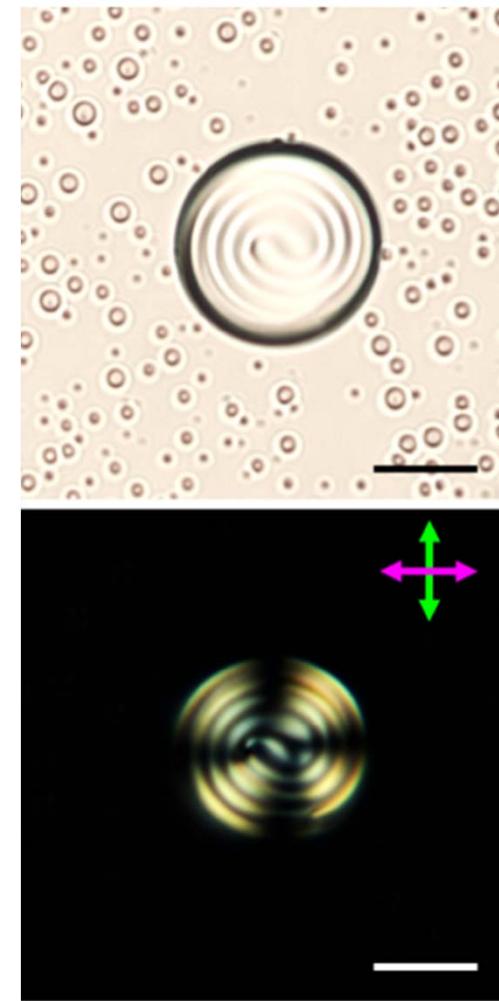
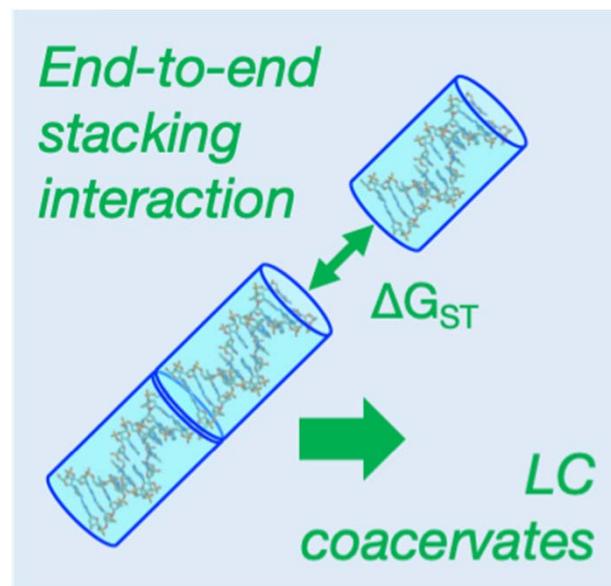
Coacervates as Primitive Compartments – DNA Liquid Crystal Assembly/Scaffolding



D1p



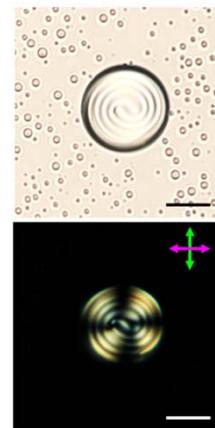
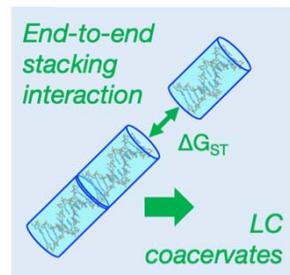
Coacervates as Primitive Compartments – DNA Liquid Crystal Assembly/Scaffolding



Fraccia and Jia,
ACS Nano, 2020



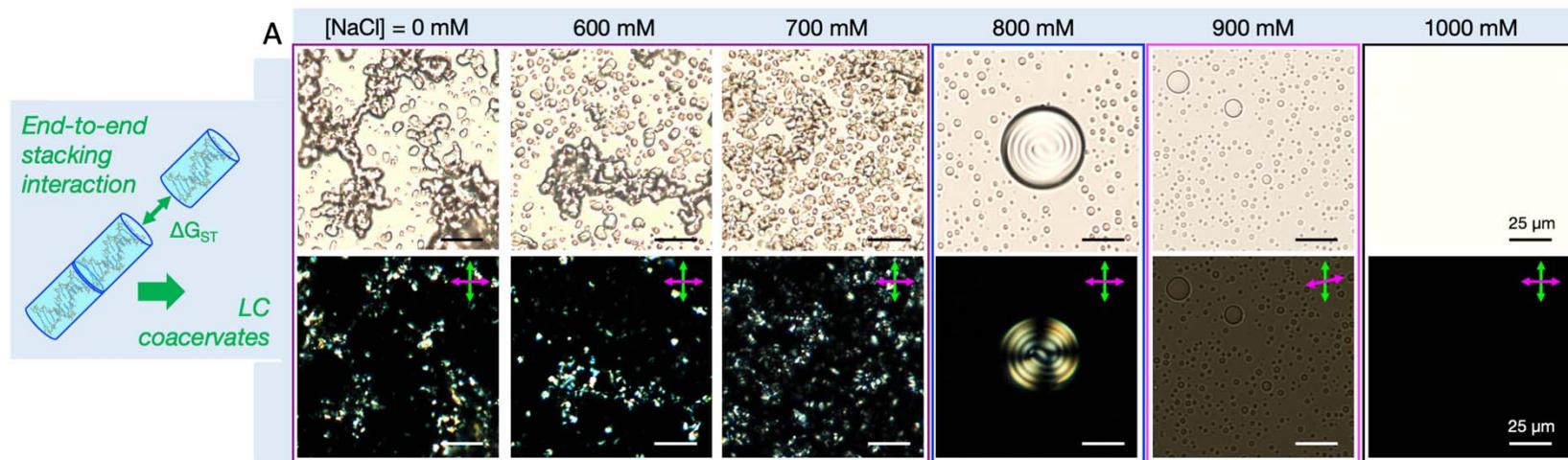
DNA Liquid Crystal Coacervates



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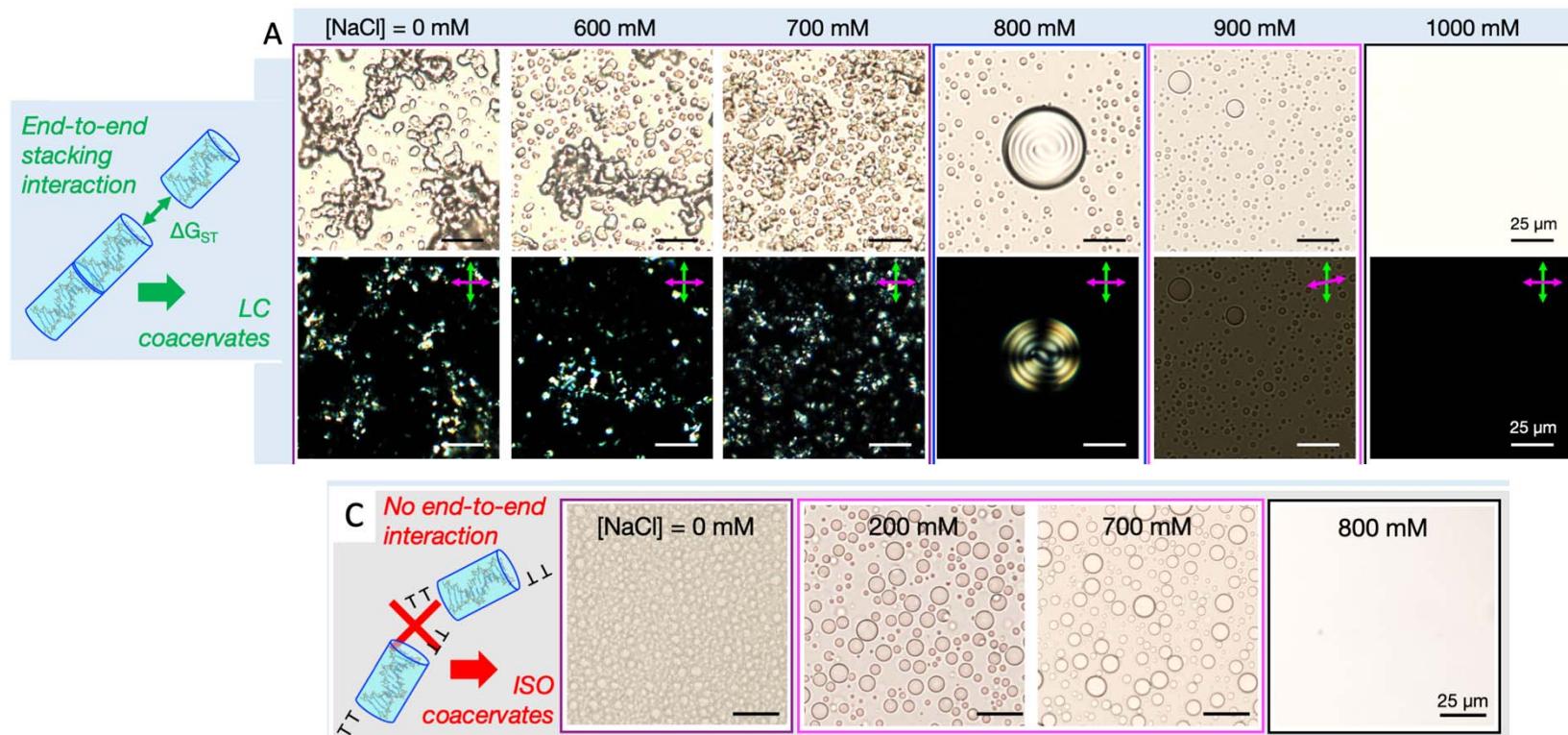
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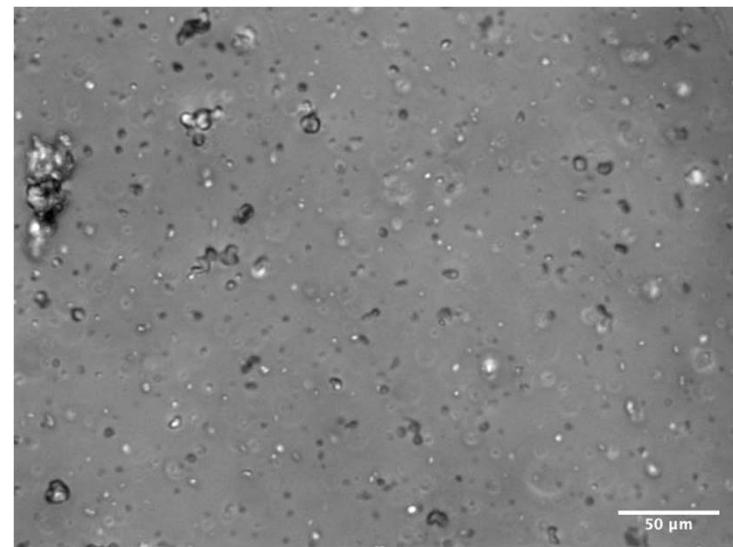
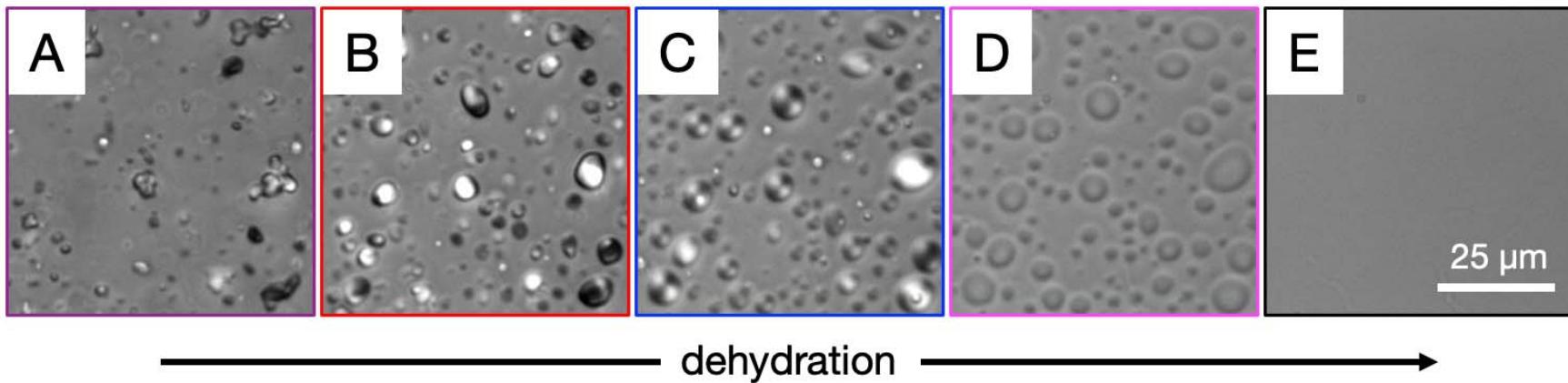


DNA Liquid Crystal Coacervates



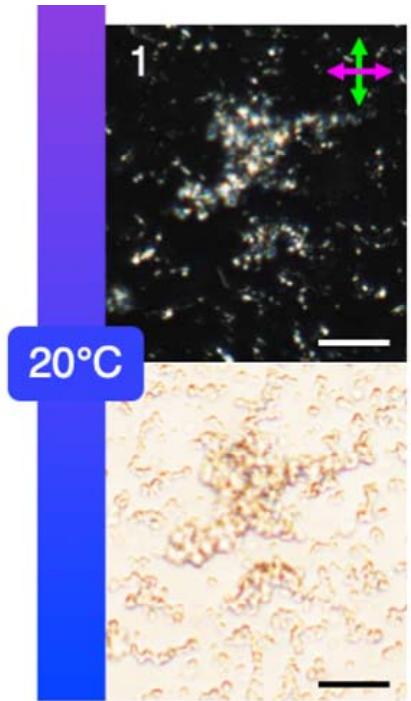
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ACS Nano, 2020





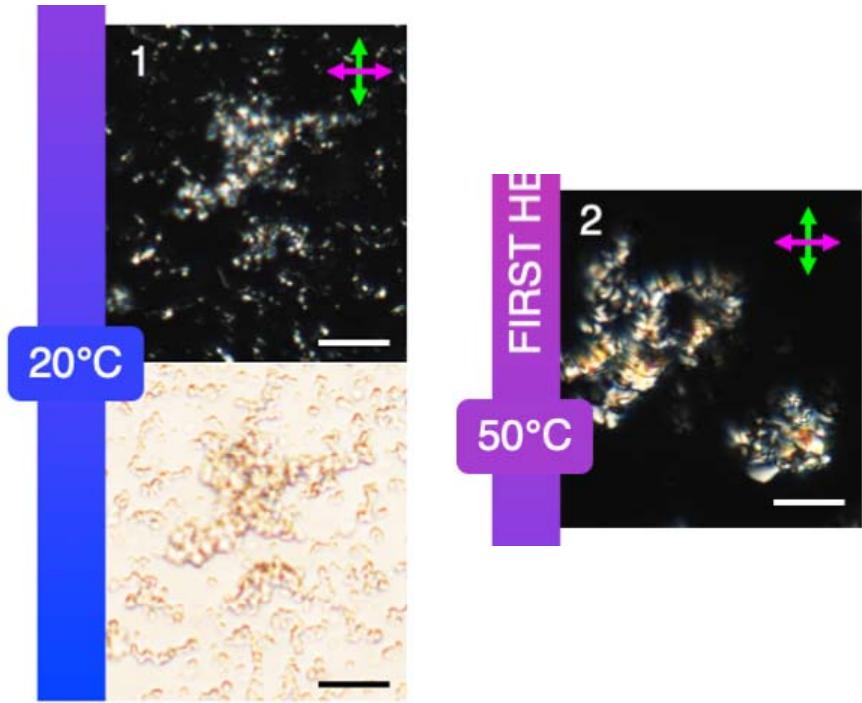
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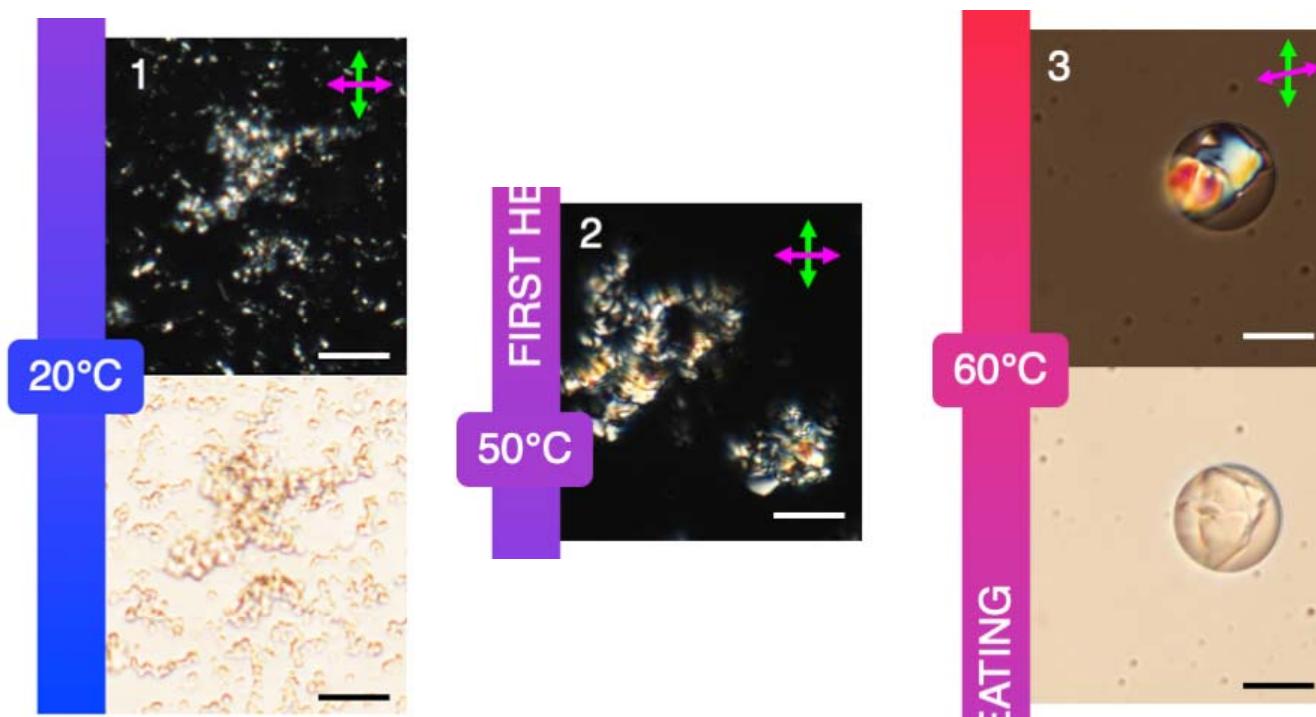
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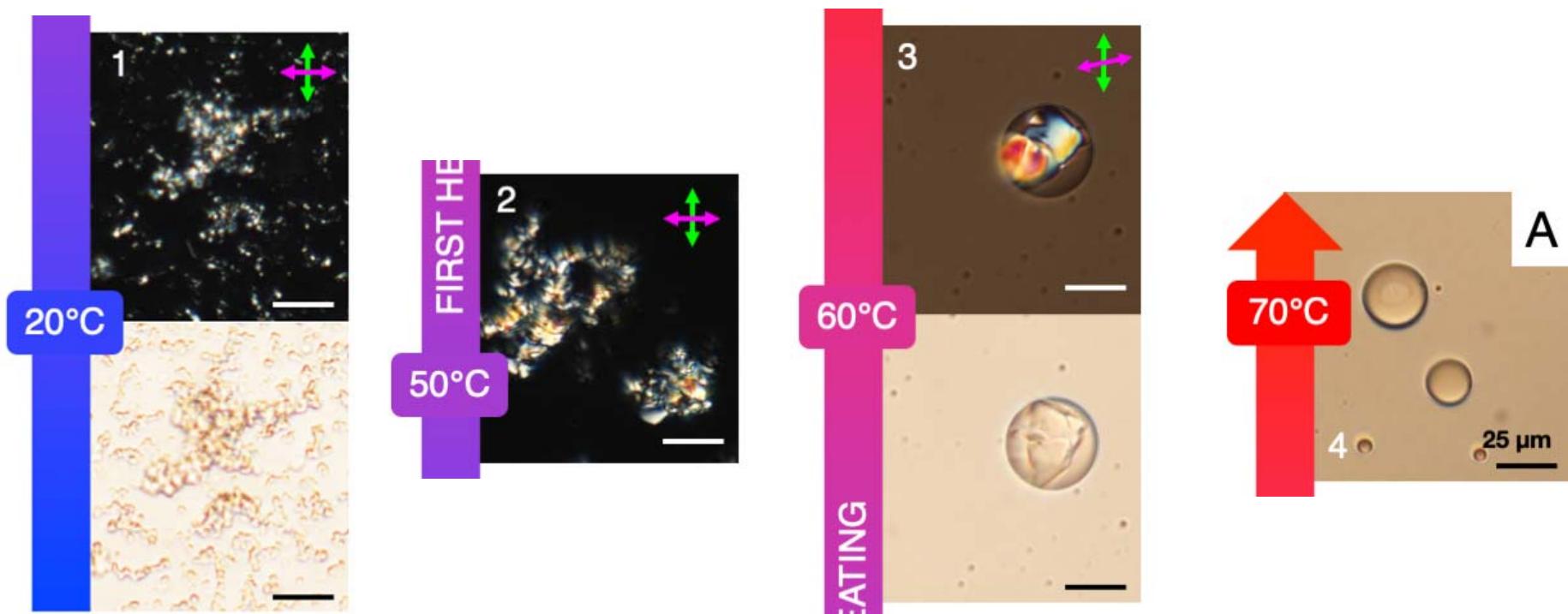
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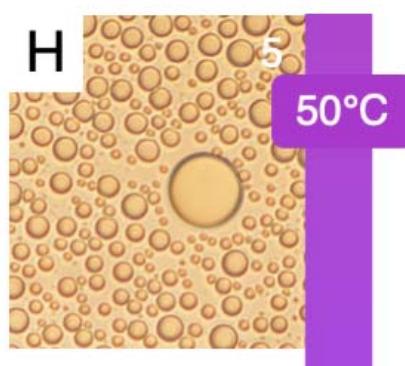
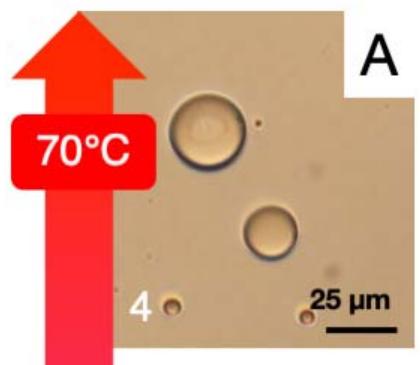
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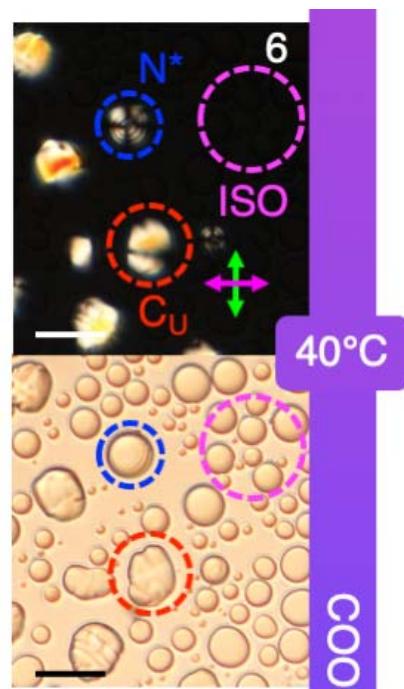
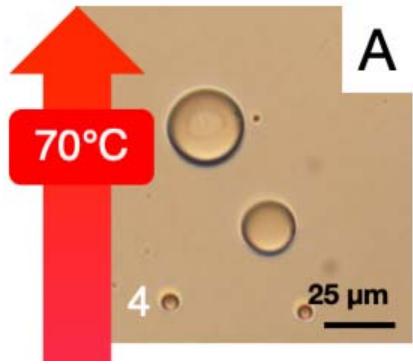
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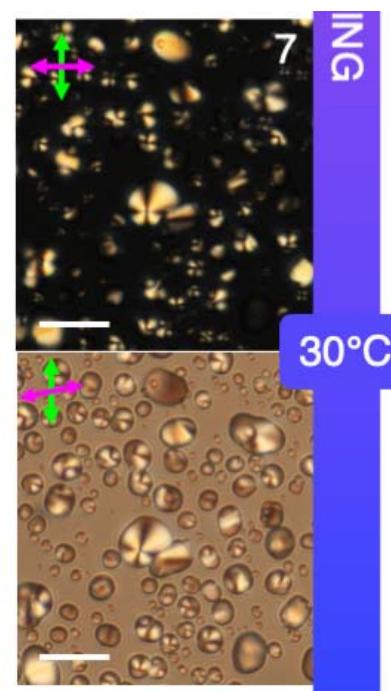
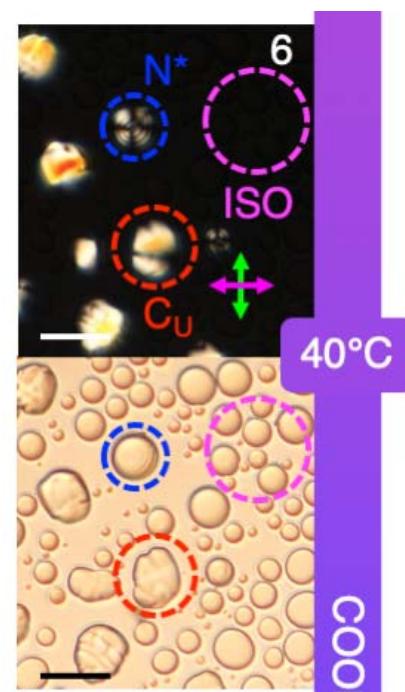
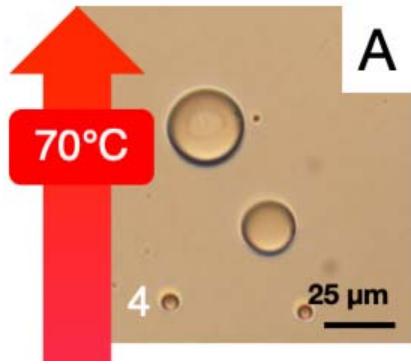
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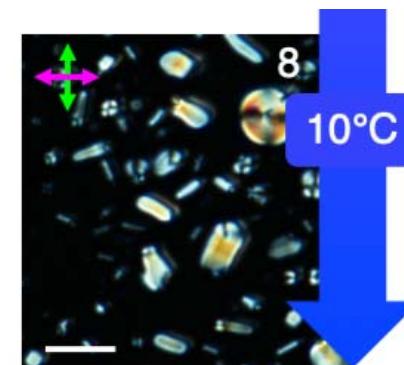
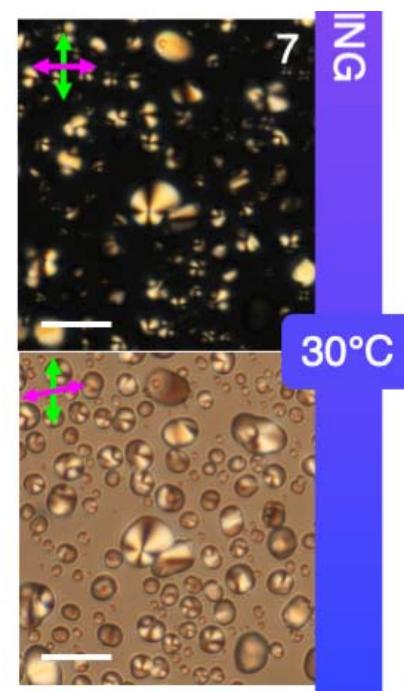
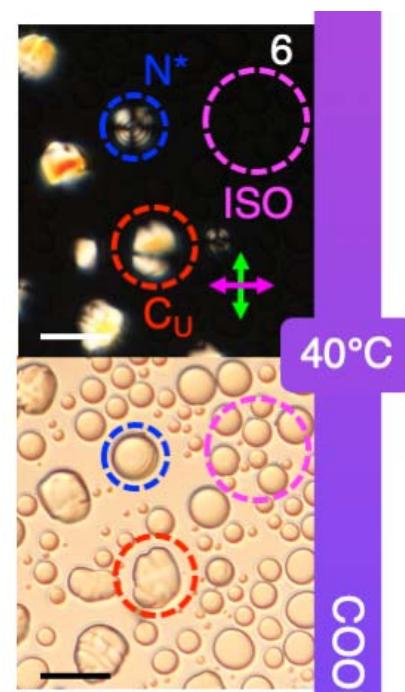
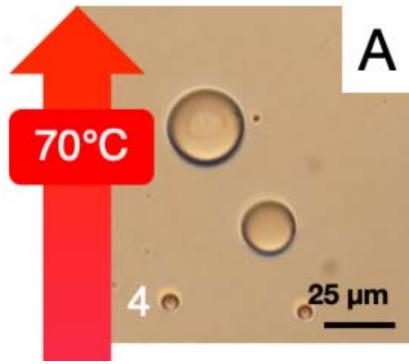
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ACS Nano, 2020





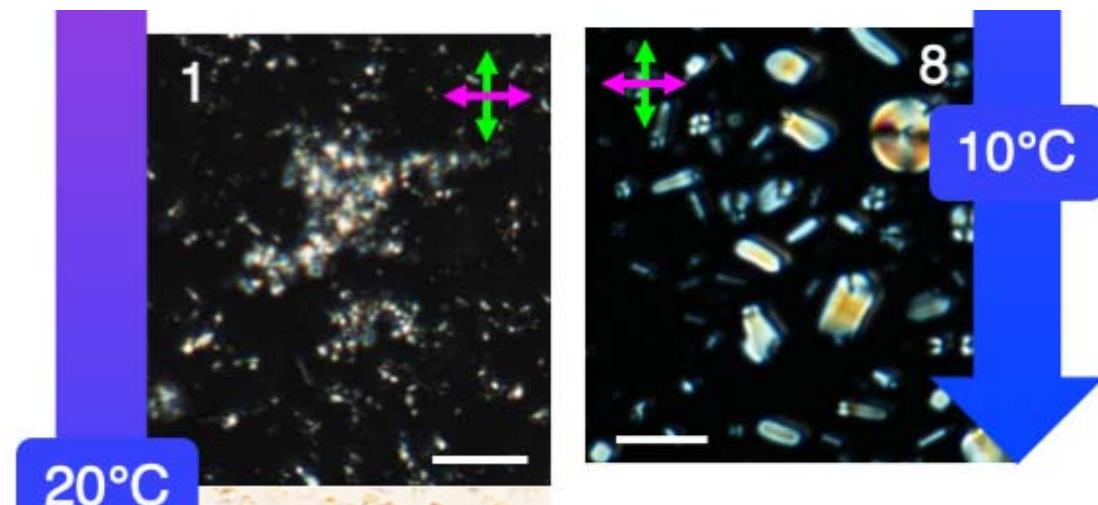
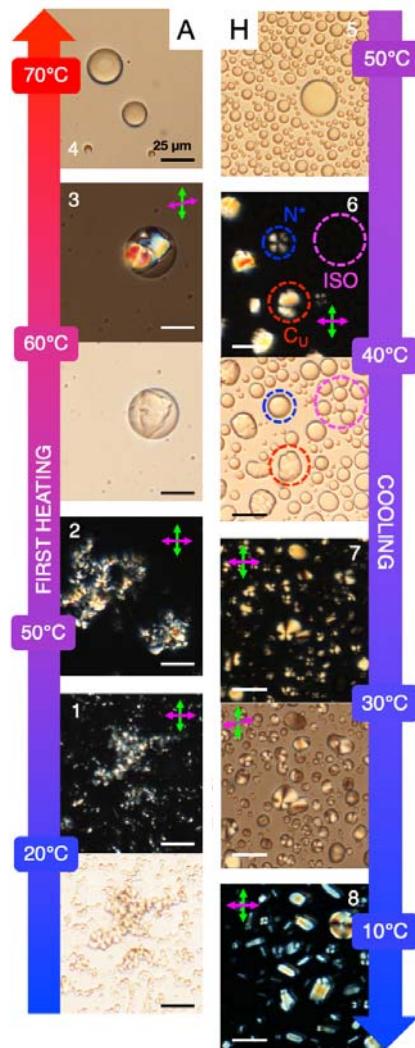
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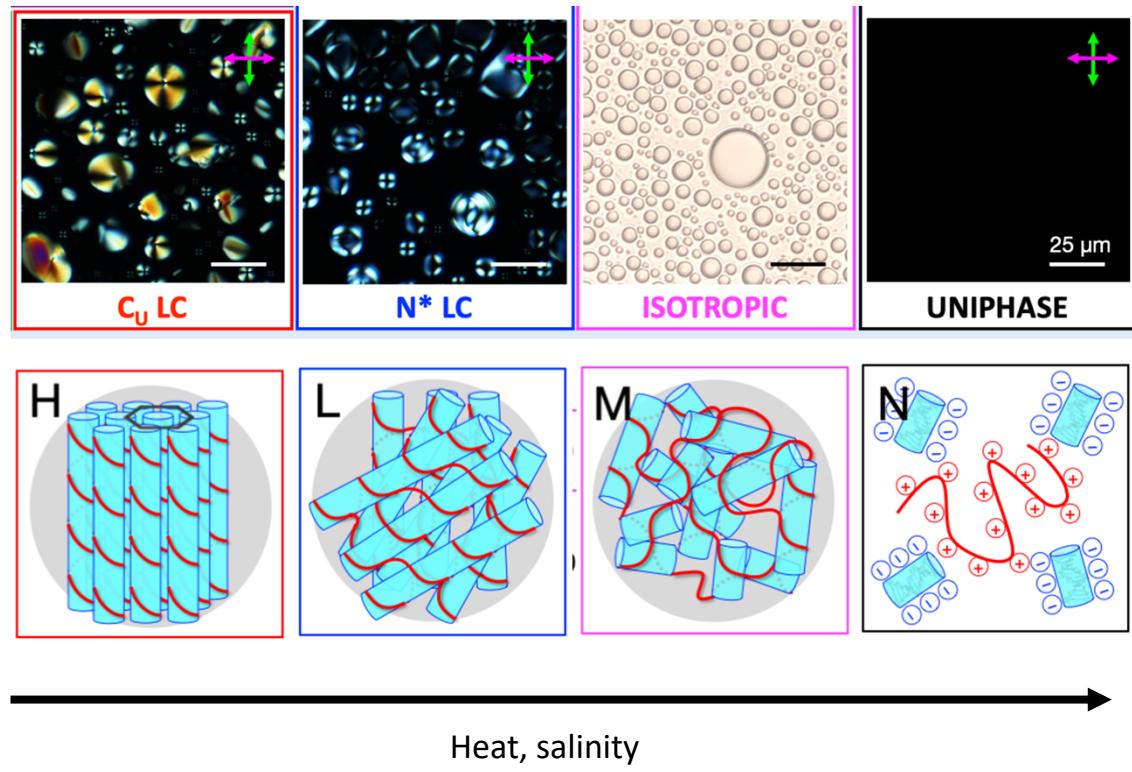




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ACS Nano, 2020

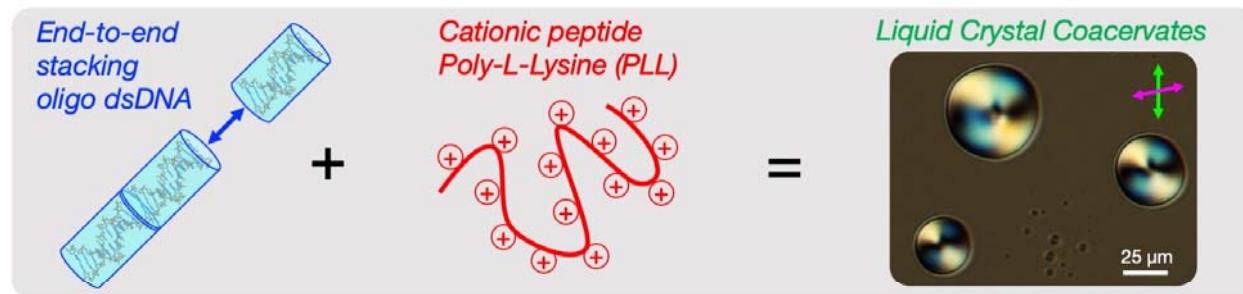


DNA Liquid Crystal Coacervates

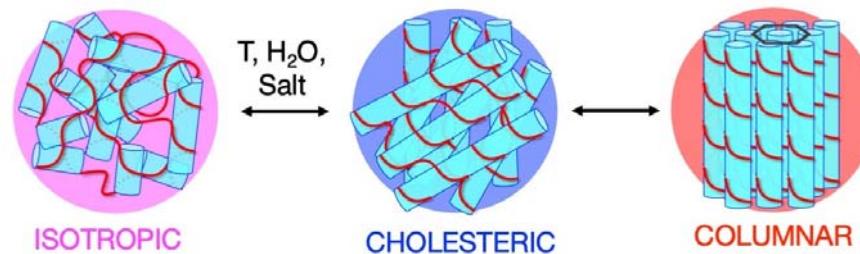


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ACS Nano, 2020





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Liquid Crystal Coacervates Composed of Short Double-Stranded DNA and Cationic Peptides

Tommaso P. Fraccia^{*||} and Tony Z. Jia^{||}



Article

Liquid Crystal Peptide/DNA Coacervates in the Context of Prebiotic Molecular Evolution

Tony Z. Jia^{1,2,*†} and Tommaso P. Fraccia^{3,*†}

¹ Earth-Life Science Institute, Tokyo Institute of Technology, 2-12-1-IE-1 Ookayama, Meguro-ku, Tokyo 152-8550, Japan

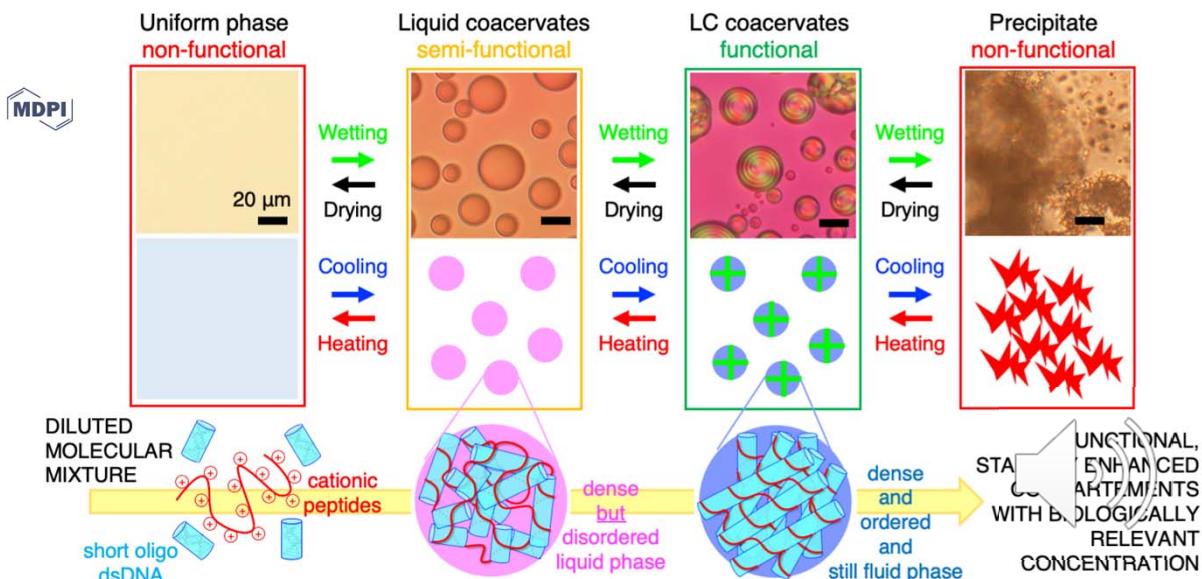
² Blue Marble Space Institute of Science, 1001 4th Ave., Suite 3201, Seattle, WA 98154, USA

³ Institut Pierre-Gilles de Gennes, CBI, ESPCI Paris, Université PSL, CNRS, 75005 Paris, France

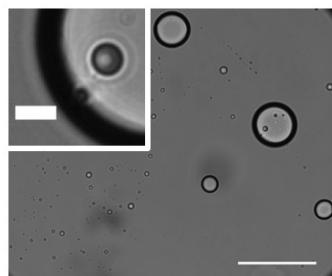
* Correspondence: tzjia@elsi.jp (T.Z.J.); tommaso.fraccia@espci.fr (T.P.F.)

† These authors contributed equally.

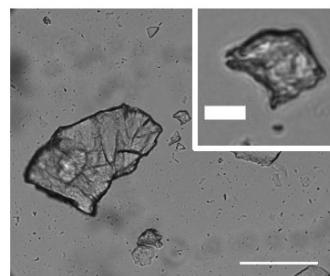
Fraccia and Jia,
Crystals, 2020



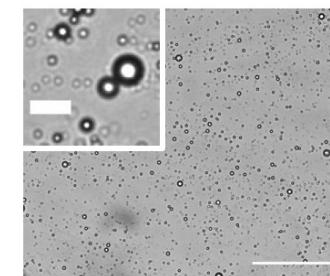
Polyester Microdroplets



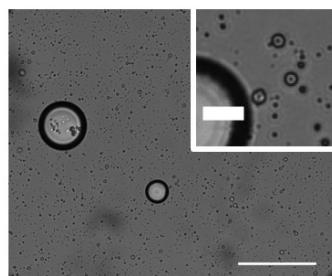
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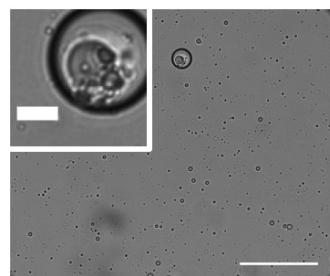
polyGA



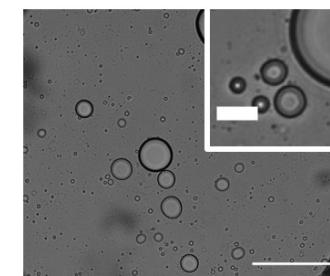
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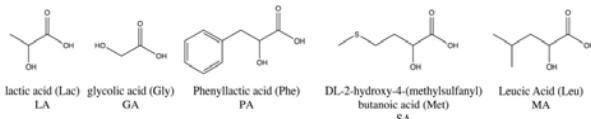
polySA



polyMA



All 5



Jia, Chandru, et al. PNAS 2019



Membraneless polyester microdroplets as primordial compartments at the origins of life

Tony Z. Jia^{a,b,1,2}, Kuhan Chandru^{a,c,d,1,2}, Yayoi Hongo^a, Rehana Afrin^a, Tomohiro Usui^{a,e}, Kunihiro Myojo^f, and H. James Cleaves II^{a,b,g,h}

^aEarth-Life Science Institute, Tokyo Institute of Technology, Meguro-ku, 152-8550 Tokyo, Japan; ^bBlue Marble Space Institute of Science, Seattle, WA 98154;

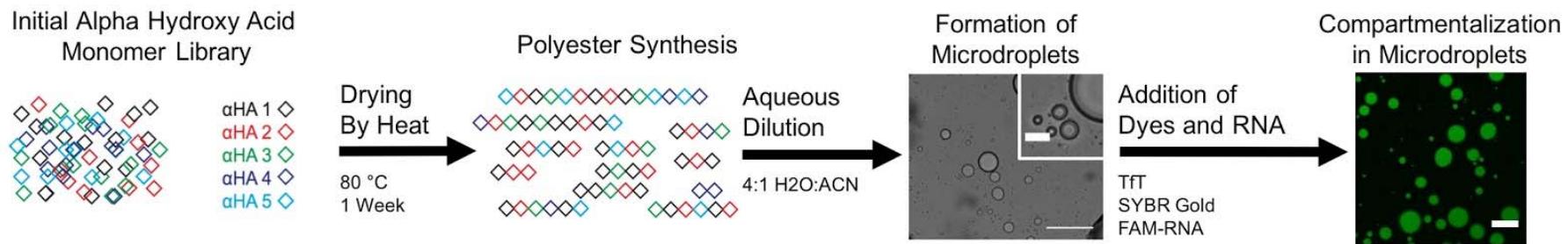
^cDepartment of Physical Chemistry, University of Chemistry and Technology, Prague, 16628, Prague 6 – Dejvice, Czech Republic; ^dSpace Science Centre, Institute of Climate Change, National University of Malaysia, 43650 UKM Bangi, Selangor Darul Ehsan, Malaysia; ^eInstitute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Sagamihara, 252-5210 Kanagawa, Japan; ^fDepartment of Earth and Planetary Sciences, Tokyo Institute of Technology, Meguro-ku, 152-8551 Tokyo, Japan; ^gInstitute for Advanced Study, Princeton, NJ 08540; and ^hCenter for Chemical Evolution, Georgia Institute of Technology, Atlanta, GA 30332

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Concept Paper

Polyesters as a Model System for Building Primitive Biologies from Non-Biological Prebiotic Chemistry

Kuhan Chandru^{1,2,*}, Irena Mamajanov³, H. James Cleaves II^{3,4,5,6} and Tony Z. Jia^{3,4,*} 



Incorporation of Basic α -Hydroxy Acid Residues into Primitive Polyester Microdroplets for RNA Segregation

Tony Z. Jia,* Niraja V. Bapat, Ajay Verma, Irena Mamajanov, H. James Cleaves, II, and Kuhan Chandru*

Jia, et al. PNAS. 116(32), 15830-15835 (2019)

Chandru, et al. Life. 10(1), 6 (2020)

Jia, et al. Biomacromolecules. 2021, 22(1), 10.1021/acs.biomac.0c01697 (2021)



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(ELSI)



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(UCT-Prague)



Tommaso P Fraccia
(ESPCI/IPGG)



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 - Dr. Irena Mamajanov
 - Dr. Yutetsu Kuruma (JAMSTEC)
 - Dr. Kosuke Fujishima
 - Dr. Tommy (Po-Hsiang) Wang (NCU)
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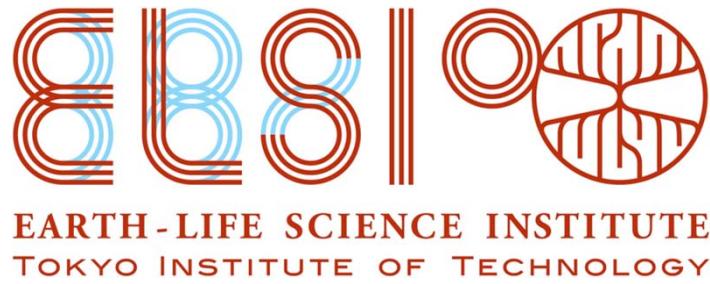


Tokyo Tech



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- Nara Medical University, etc.
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- Okayama University Institute for Planetary Materials
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- University of New South Wales
 - Dr. Anna Wang
- IPGG/ESPCI
 - Dr. Tommaso Fraccia
- ENS
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Thank you!

tzjia@elsi.jp

tonyjia@bmsis.org

 [@t_z_jia](https://twitter.com/t_z_jia)

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