Origins and Phases

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Gathering in Biosemiotics, 31 July - 4 August 2023, Copenhagen, Denmark

Phase as a Philosophical Notion in Simondon's Theory of Individuation

Gilbert Simondon (1924-1989)

a Processual Theory of Ontogenesis

metastable preindividual being

no phases

Process of Individuation

Phase Separation
("se déphaser")

"In a theory of the phases of being, becoming is … a perpetuated and renewed resolution, an amplifying, incorporating resolution that proceeds via crises, such that its sense is in each of its phases, not at its origin or its end alone."

Individuation in Light of Notions of Form and Information, Gilbert Simondon

Phase as a Philosophical Notion in Simondon's Theory of Individuation

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three modes of the process of individuation:

- **Physical**
- **Vital**
- **Psycho-collective**

Physical mode:

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- **Physical**
- **Vital**
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Physical mode:

metastable preindividual being — **no phases**

Process of Individuation → **Phase Separation**

stable individuated being — **distinct phases**

Vital mode:

How to extend the notion of phase to living systems?

Psycho-collective mode:

Phases and Phase Separation in Biophysics

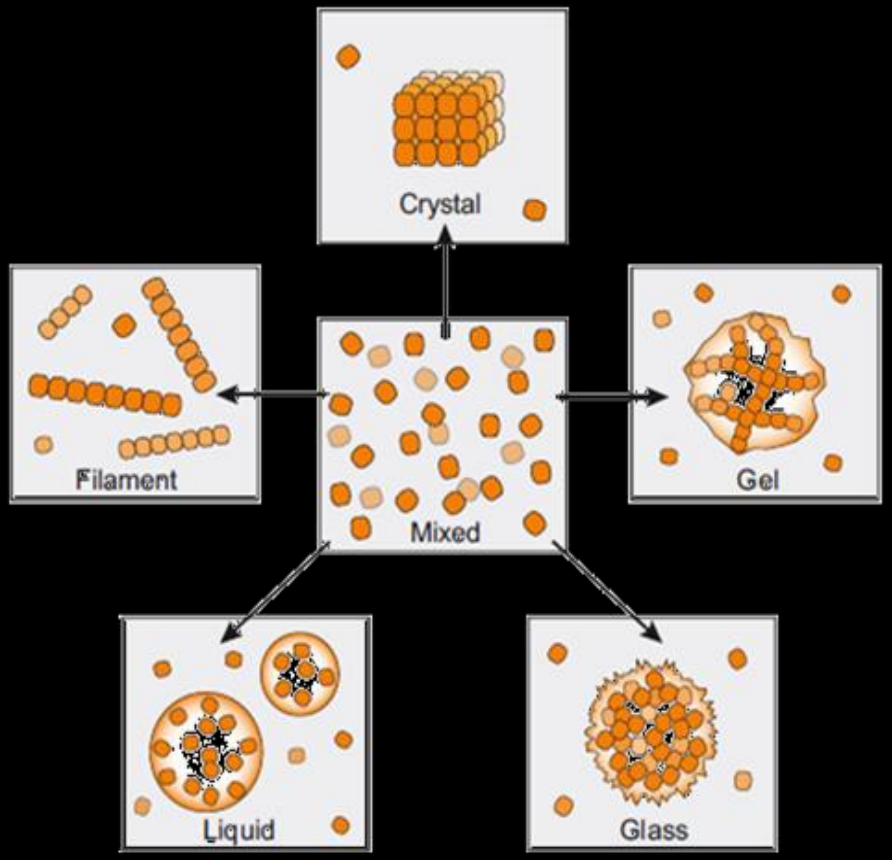
- **Dominantly fluidic environment**
- **More refined categories of phases**

From Alberti:

The wisdom of crowds: regulating cell function through condensed states of living matter

Journal of Cell Science (Review Article)

2017 Sep 1; 130(17), pp.2789-2796

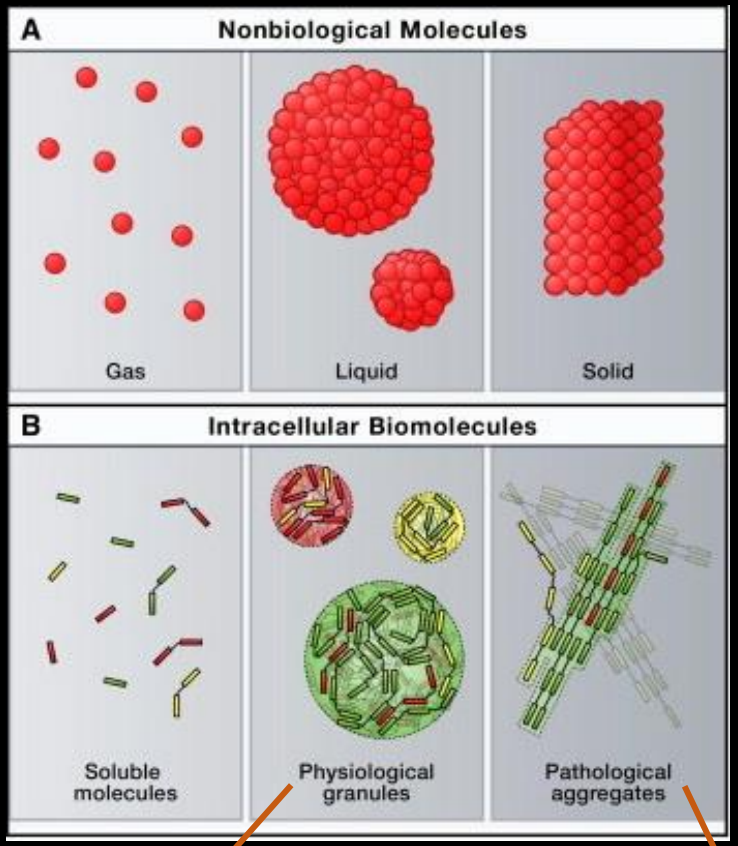


Different condensed states of proteins

Phases and Phase Separation in Biophysics

- Dominantly fluidic environment
- More refined categories of phases
- Physiological and pathological structures

From Weber and Brangwynne:
Getting RNA and Protein in Phase
Cell, **2012** Jun 8; 149(6), pp. 1188-91



RNPs, membraneless organelles, biomolecular condensates...

Prions, amyloids ...

Phases and Phase Separation in Biophysics

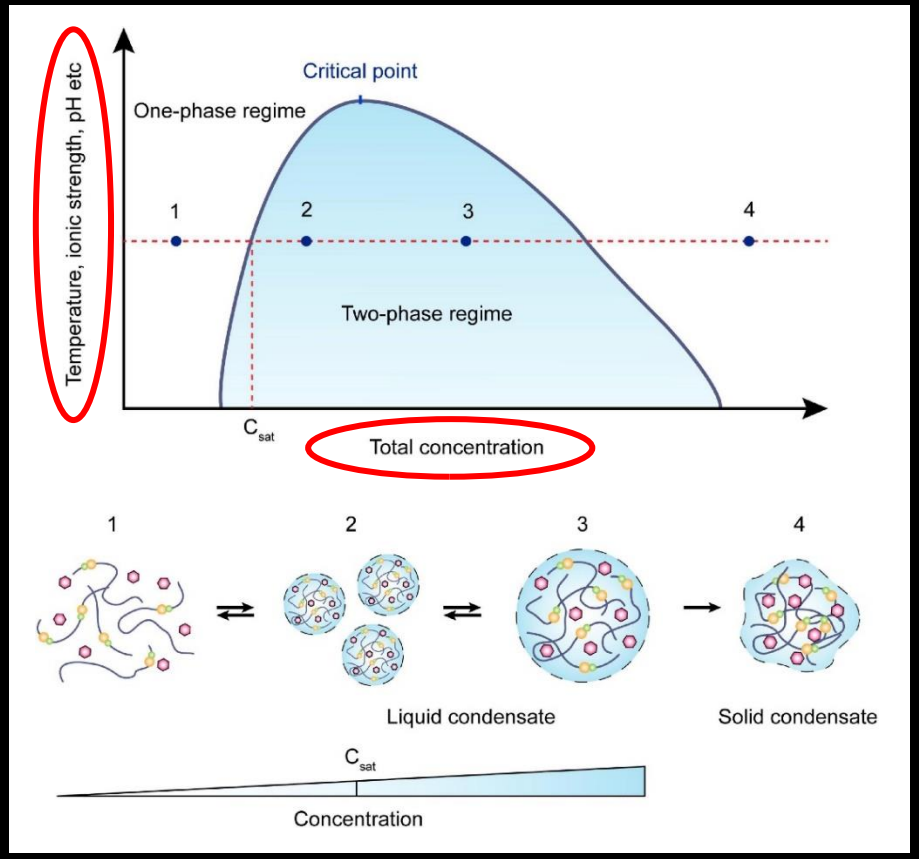
- **Dominantly fluidic environment**
- **More refined categories of phases**
- **Physiological and pathological structures**

- Biomolecular condensates
- Membraneless organelles
- Prion-Like Mechanisms (PriLiM)
- Coacervates: dense liquid droplets of macromolecules
- Liquid-Liquid Phase Separation (LLPS)
- Phase Separation (PS)

Phases and Phase Separation in Biophysics

- **Dominantly fluidic environment**
- **More refined categories of phases**
- **Physiological and pathological structures**
- **Several other variables than only temperature and pressure**

From Gao, Zhang, Chang, Zhang, Yang, Zhao:
Liquid-Liquid Phase Separation: Unraveling the Enigma of Biomolecular Condensates in Microbial Cells
Frontiers of Microbiology (Review Article)
2021 Oct 25; 12:751880



Phases and Phase Separation in Biophysics

- Dominantly fluidic environment
- More refined categories of phases
- Physiological and pathological structures
- Several other variables than only temperature and pressure
- Feedback-based phase tuning and functionality

From Feric, Marina and Misteli:

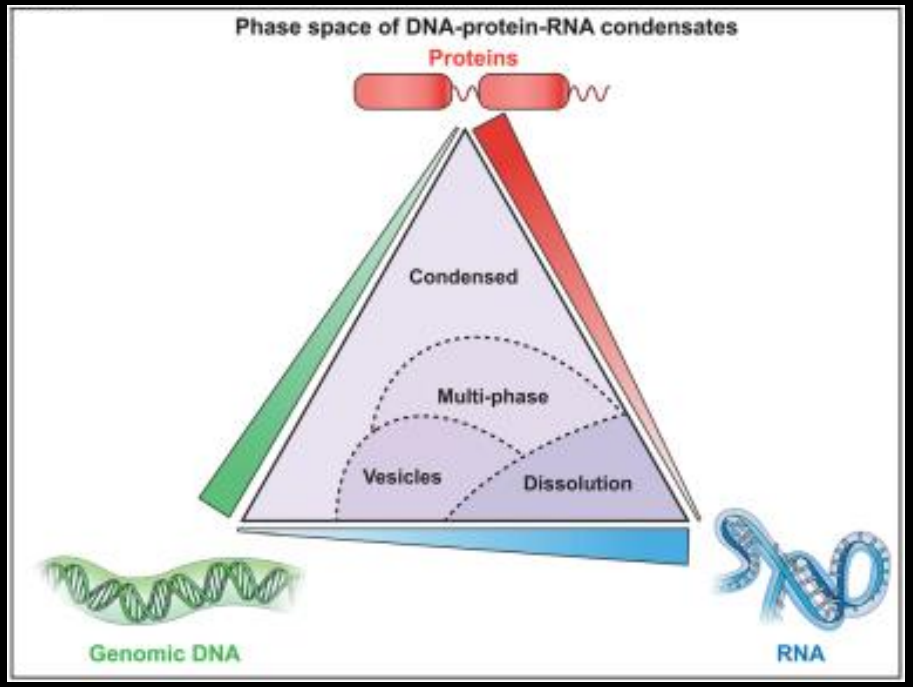
Function Moves Biomolecular Condensates in Phase Space

BioEssays : news and reviews in molecular, cellular and developmental biology

2022, Vol. 44; 5: e2200001

Structure of transcriptional condensates arising from (im)miscibility of their components.

Ternary DNA-protein-RNA phase diagram indicating various phases depending on the relative composition of the condensate.



Phases and Phase Separation in Biophysics

- Dominantly fluidic environment
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- Physiological and pathological structures
- Several other variables than only temperature and pressure
- Feedback-based phase tuning and functionality
- Non-equilibrium activities and active mechanisms

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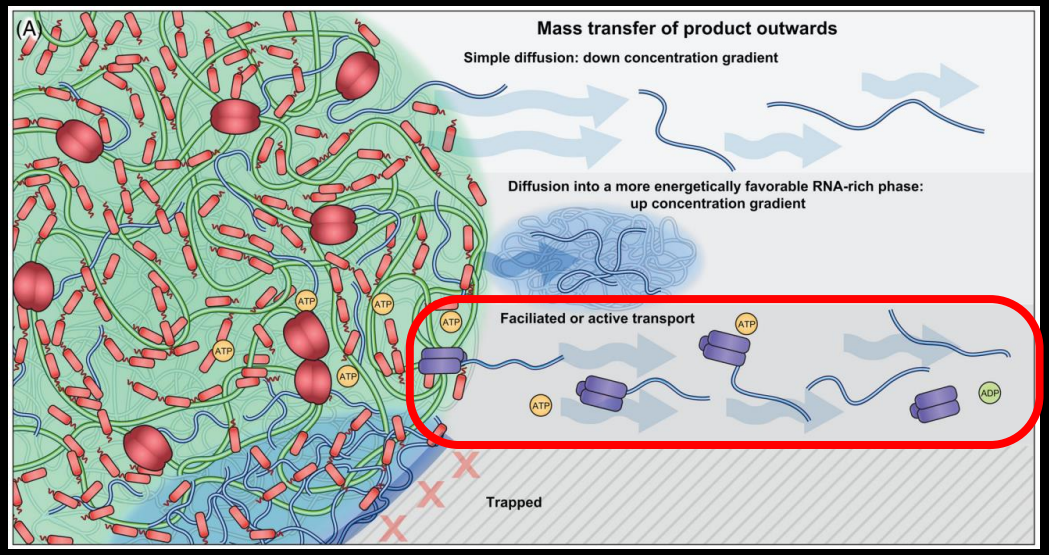
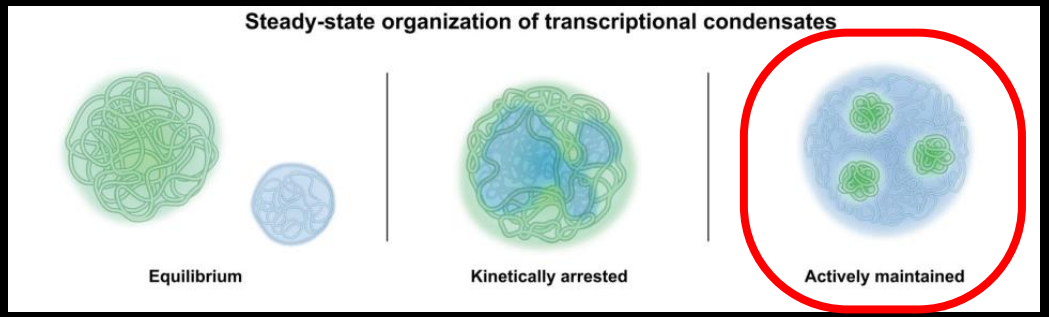




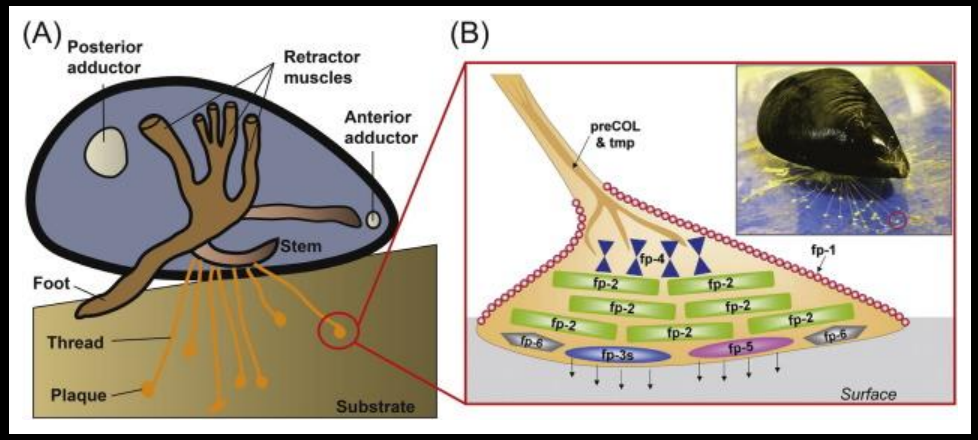
Phases and Phase Separation in Biophysics

From Astoricchio, Alfano, Rajendran, Temussi, Pastore:

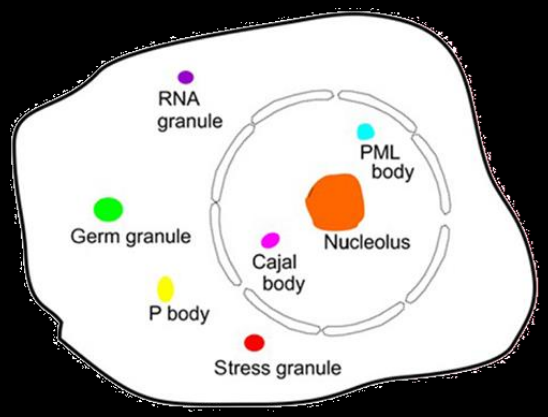
The Wide World of Coacervates: From the Sea to Neurodegeneration

Trends in Biochemical Sciences

2020; Vol. 45, Issue 8, pp. 706-717



Marine organisms often produce **extracellular coacervates** to solve the problem of achieving and maintaining **strong adhesion on polar surfaces underwater** (surface adhesion).



Intracellular coacervates or **membraneless organelles** have also been observed in a wide spectrum of cell types.

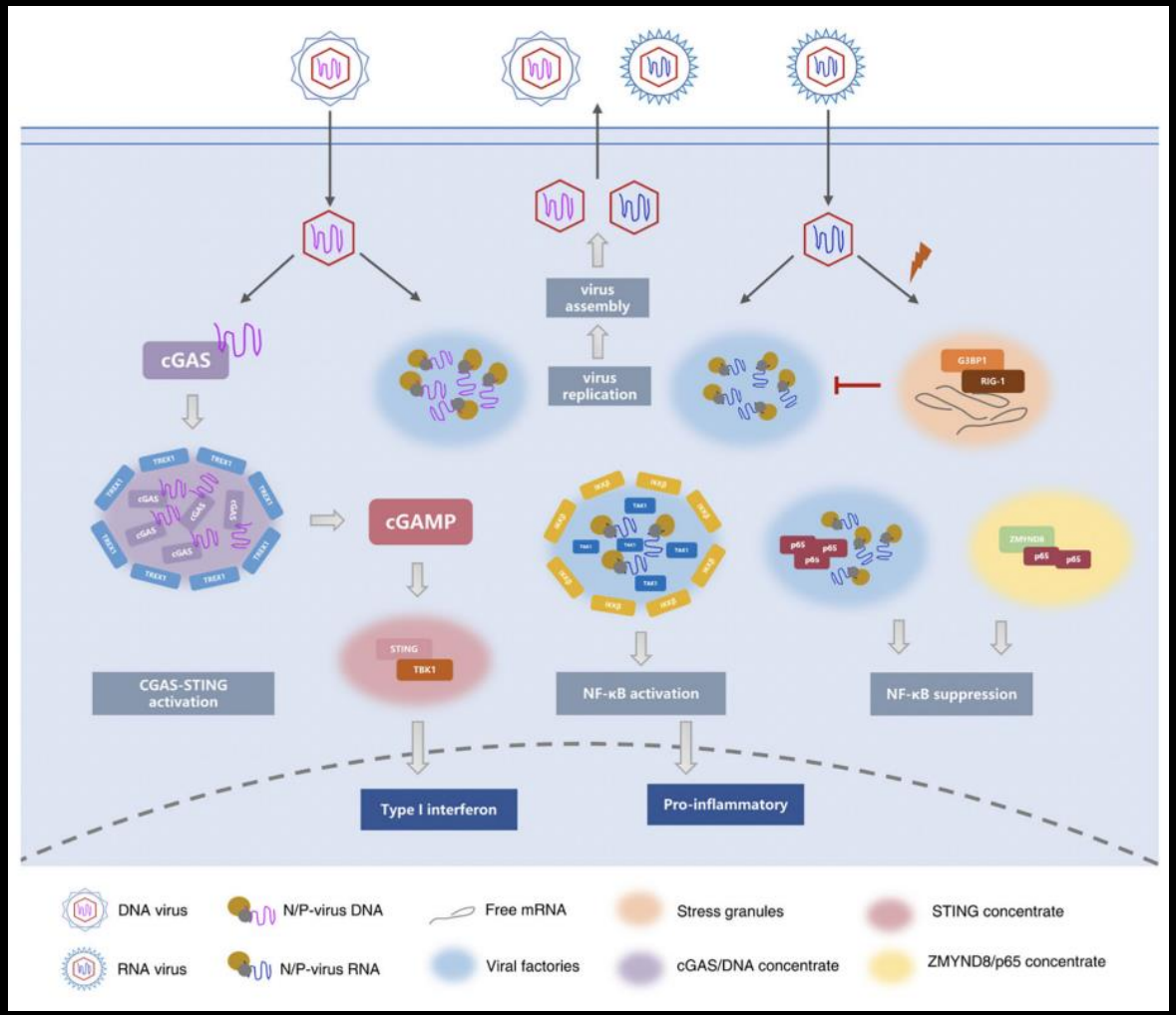
Phases and Phase Separation in Biophysics

From Wen, Ma:

Phase Separation Drives the Formation of Biomolecular Condensates in the Immune System

Frontiers in Immunology

2022 Nov. 10, 13 986589



Phase separation in innate immune and inflammatory responses.

Thriving Biophysics Research on Phase Separation

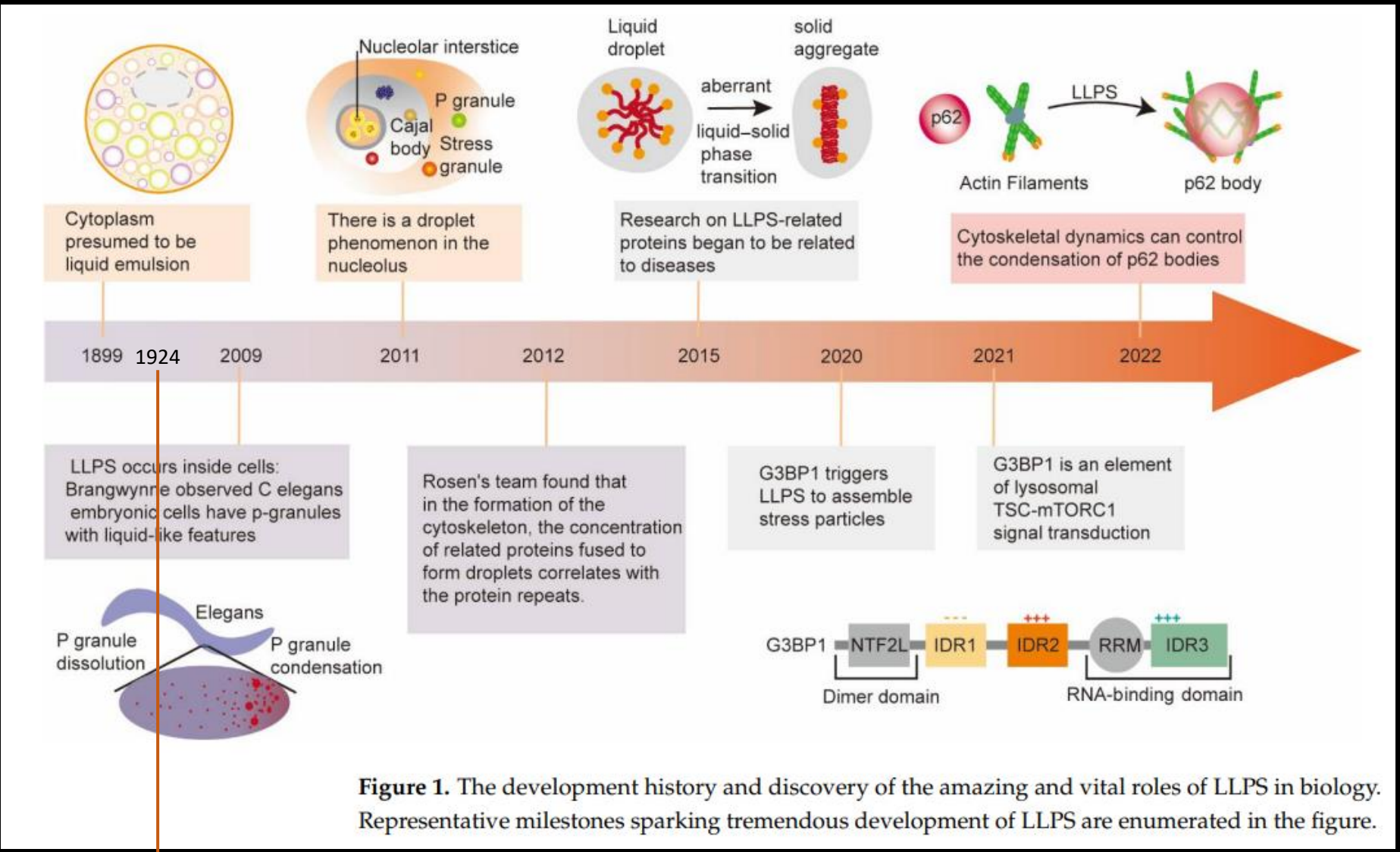


Figure 1. The development history and discovery of the amazing and vital roles of LLPS in biology. Representative milestones sparking tremendous development of LLPS are enumerated in the figure.

Oparin: abiogenesis, LLPS, coacervates

From: Chen, Huai, Mao, Wang, Ru, Qian, Yang: **Liquid–Liquid Phase Separation of Biomacromolecules and Its Roles in Metabolic Diseases**. *Cells*, **2022**, 11, 3023.

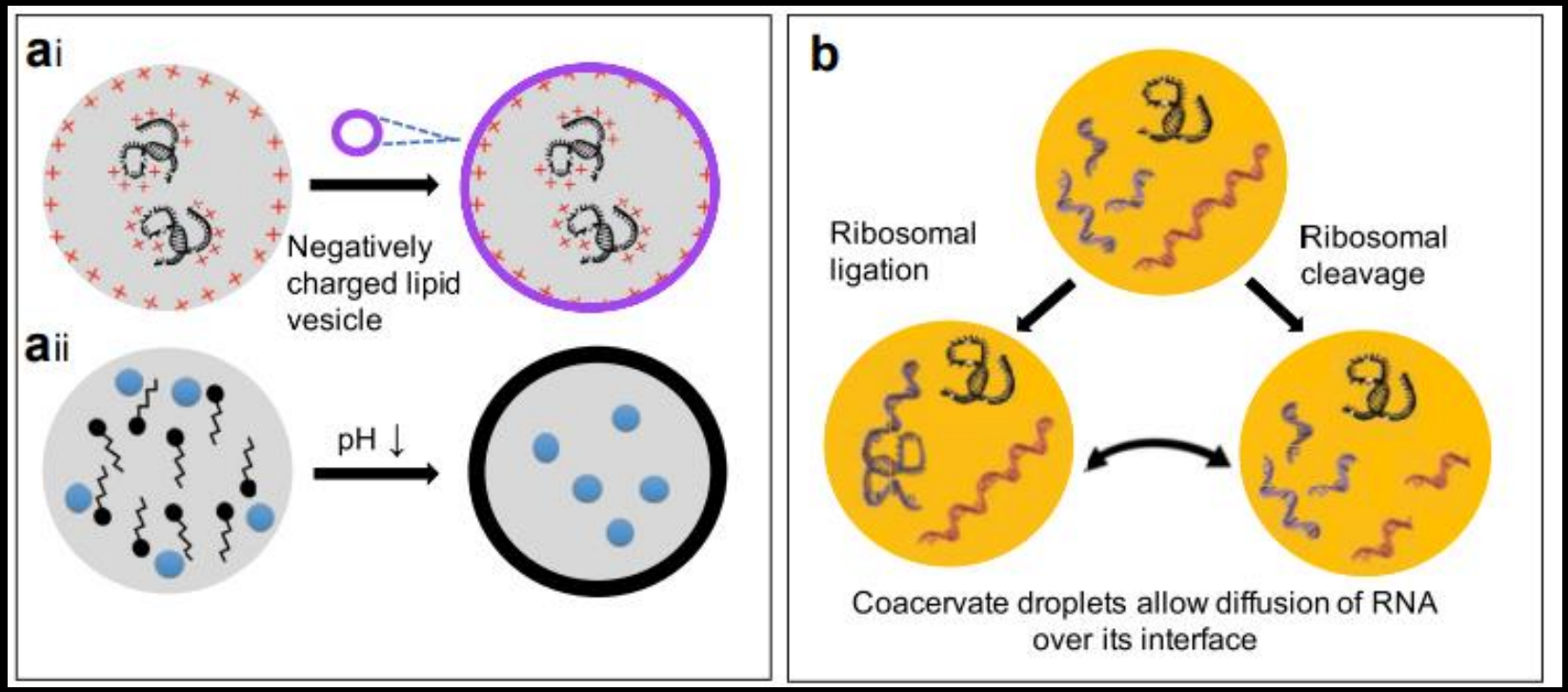
Phase Separation in the Origin of Life

From Ghosh, Bose, Tang:

Can coacervation unify disparate hypotheses in the origin of cellular life?

Colloid & Interface Science (Current Opinion)
2021; Volume 52, 101415, ISSN 1359-0294

Figure 3. The role of **coacervation in hypothetical origin of life scenarios**:
(a) Coacervation and the **lipid world**. (b) Coacervates and the **RNA world**.



Phase Separation in the Origin of Life

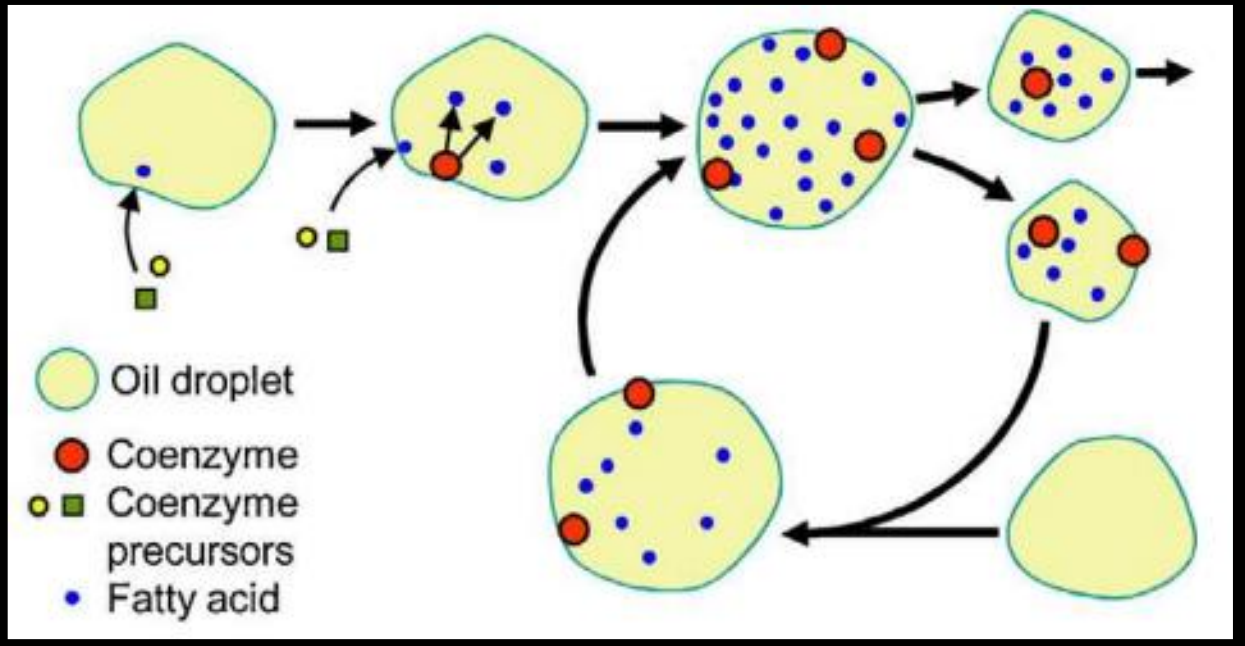
From Sharov:

Coenzyme world model of the origin of life

Biosystems

2016; 144; pp. 8-17

Scenario of coenzyme self-reproduction on oil droplets: a coenzyme molecule makes the surface hydrophilic via oxidation of hydrocarbons; this change facilitates **synthesis of coenzymes from precursors on the surface**. Hydrophilic oil droplets easily divide and may coalesce with new oil droplets (i.e., capture new oil resource)



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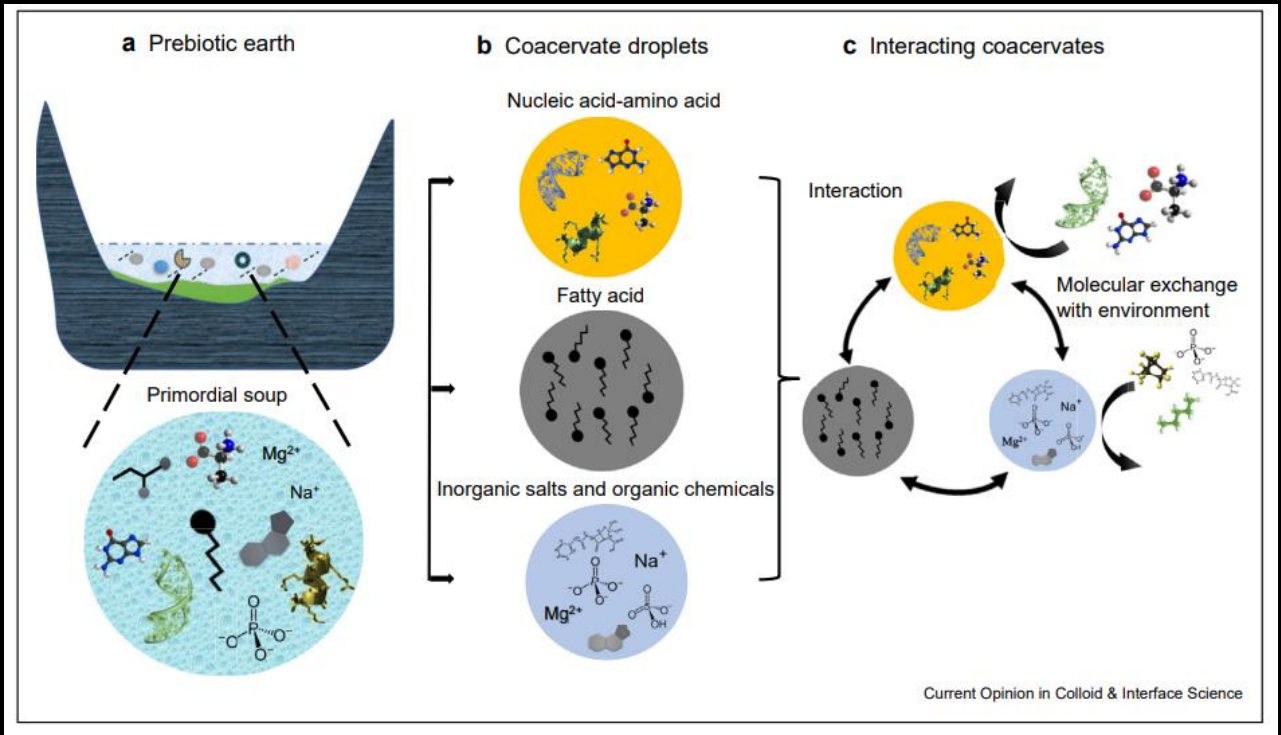

Figure 1. Coacervate formation on prebiotic Earth.
(a) A primordial soup on prebiotic Earth may have contained biomolecular precursors.
(b) Coacervation, a phase separation process, could have enriched the biomolecular precursors in the membrane-free coacervate droplets to facilitate reactions.
(c) Coacervates can concentrate reactants, support enzyme reactions and allow the exchange of ions and small molecules with surrounding media and other compartments.

Phase Separation in the Origin of Life

Matsuo and Kurihara:

Proliferating coacervate droplets as the missing link between chemistry and biology in the origins of life

Nature communications

2021, **12**, 5487

Phase as a Philosophical Notion in Simondon's Theory of Individuation

Gilbert Simondon (1924-1989)

"... the vital mode intervenes by decelerating the physical individuation..."

a prolonged transient state

capacity for ongoing origination

Physical mode: metastable preindividual being **no phases** → **Process of Individuation** / **Phase Separation** → stable individuated being **distinct phases**

Vital mode: tensions only partially resolved, "preindividual charge" not exhausted

How to extend the notion of phase to living systems?

Psycho-collective mode:

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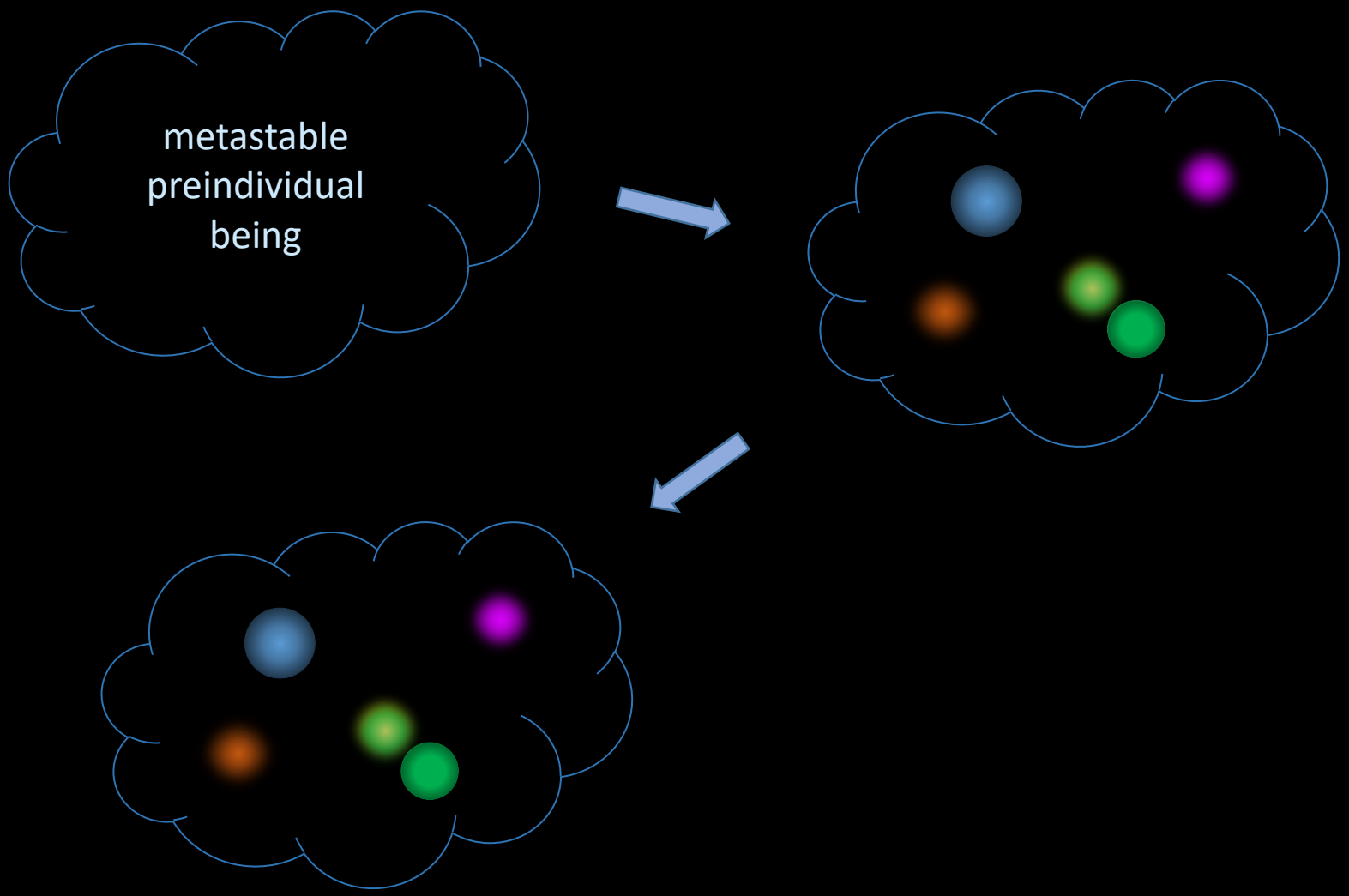
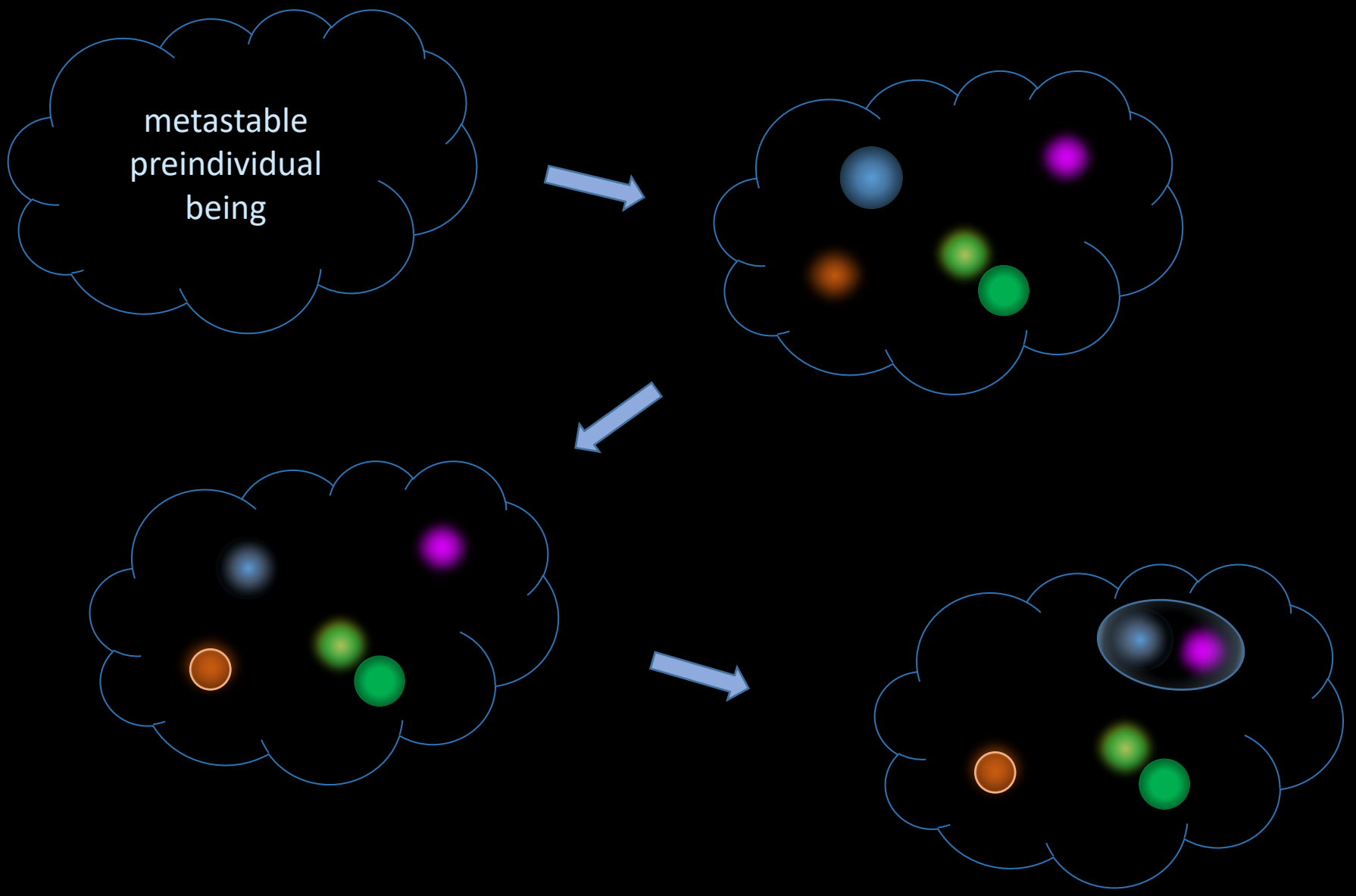
Partial Resolutions …



Partial Resolutions …



Partial Resolutions ... ... Code Plurality

Jesper Hoffmeyer & Claus Emmeche

"... the chain of events which sets life apart from non-life.... needs **at least two codes**: one code for action (behaviour) and one code for memory."

Code-duality and the semiotics of nature, (1991)
Jesper Hoffmeyer & Claus Emmeche

Thank you!

... how different types of codes may have emerged via Phase Separation and Phase-Tuning at successive leaps of vital individuation...