

A misty landscape with a large tree and birds flying in the sky. The scene is hazy and atmospheric, with a large, leafy tree on the right side and many small birds scattered across the sky. The ground is a grassy field, and the overall color palette is muted greens and greys.

Experimental Challenges
to Connect the Dots Looking Backwards
**Experimental Challenges to bridge over
Histories of the Earth and Life**

Masahiko Hara

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Experimental Challenges to bridge over Histories of the Earth and Life

1. Background
what we have done
2. Missing Link
what we will do
3. Design for Experimental System
what we are preparing

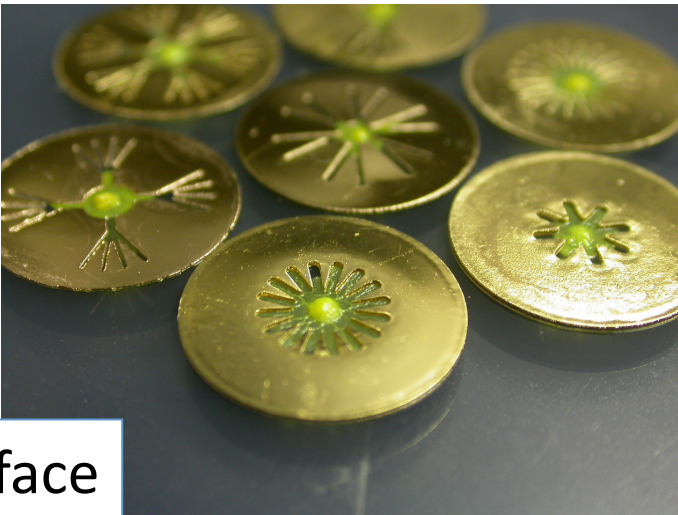
Background: Who am I ?

1985 RIKEN Frontier Research System 2003 Tokyo Tech

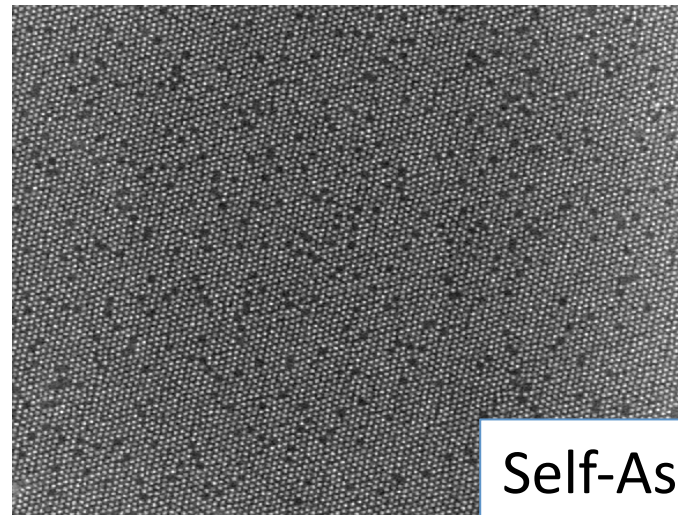
Material Science



Nanotechnology



Biointerface



Self-Assembly

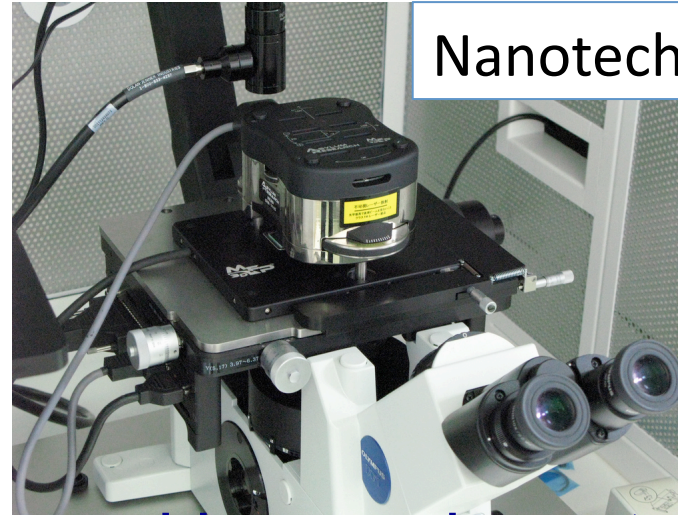
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Material Science

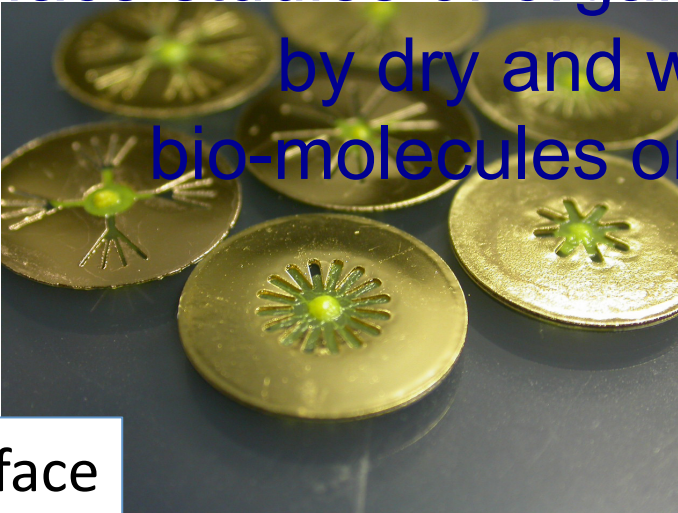


Nanotechnology

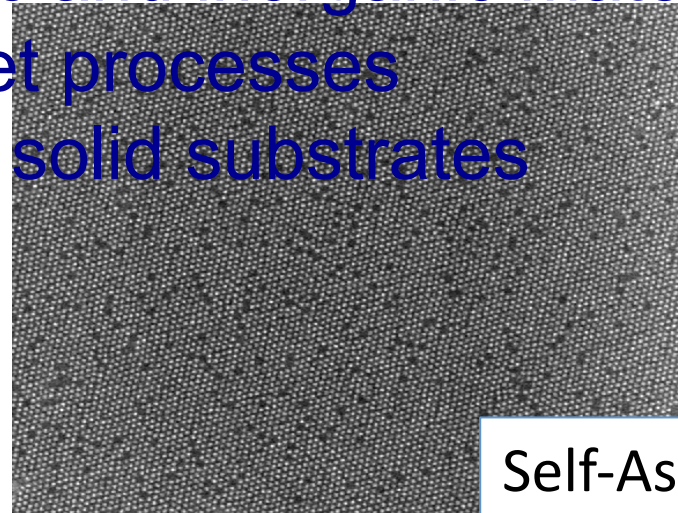


Interface studies of organic and inorganic materials
by dry and wet processes
bio-molecules on solid substrates

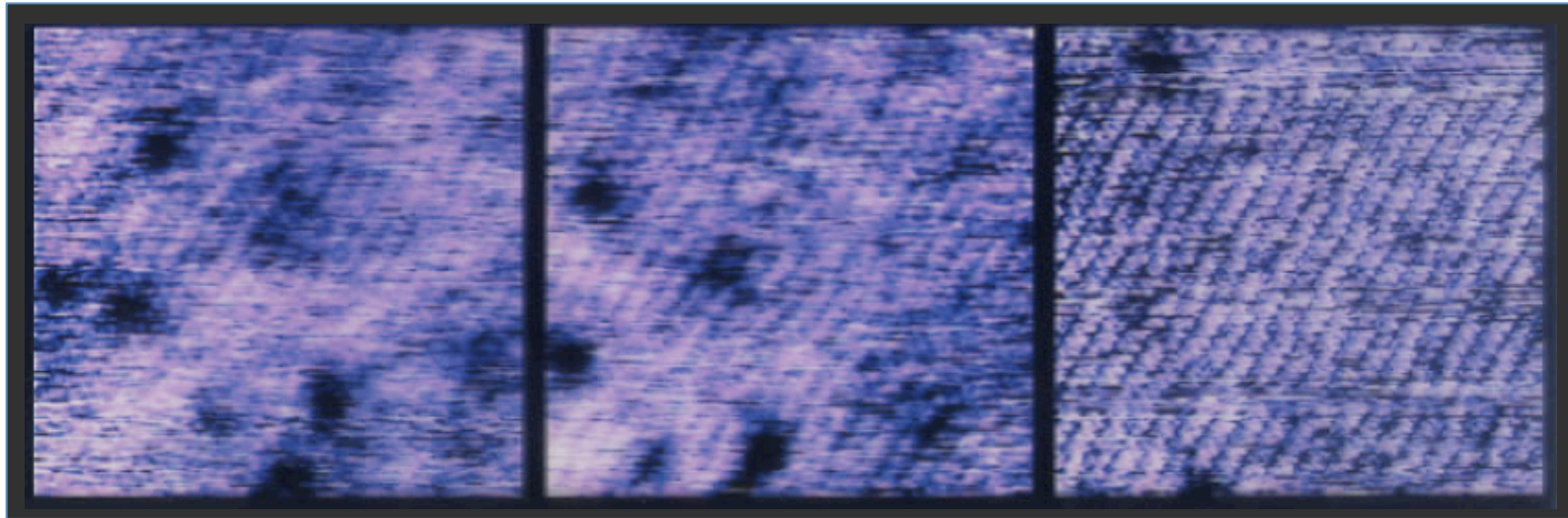
Biointerface



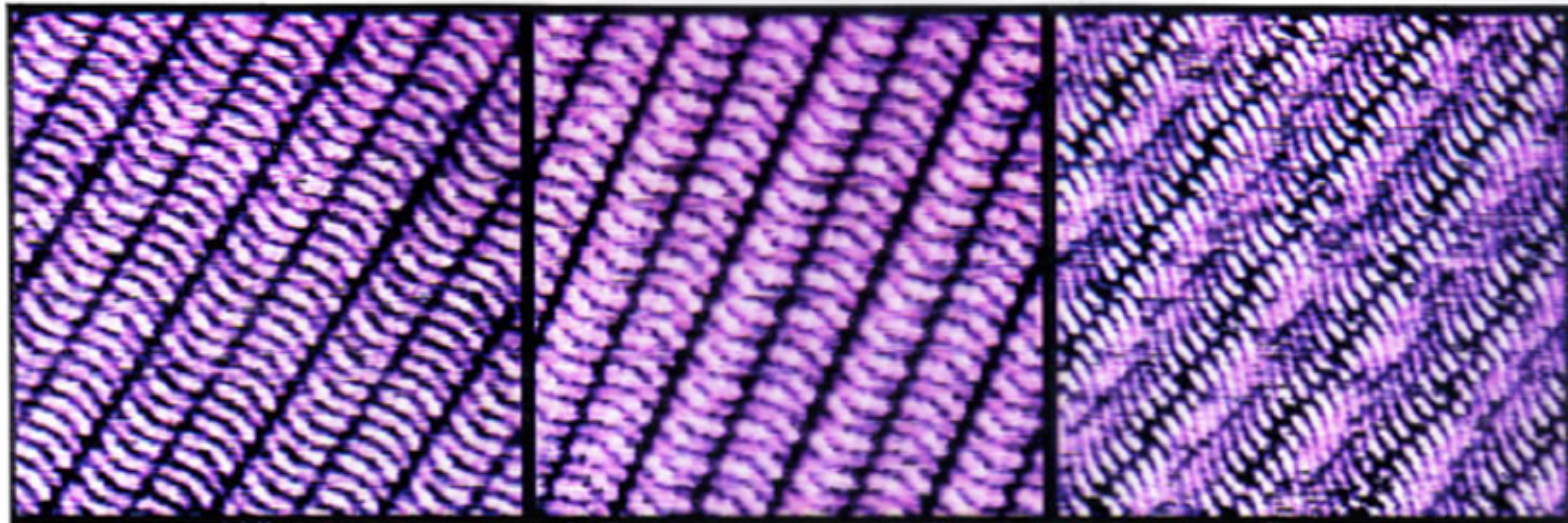
Self-Assembly



Direct Visualization of Self-Assembly Process on Metal Substrate

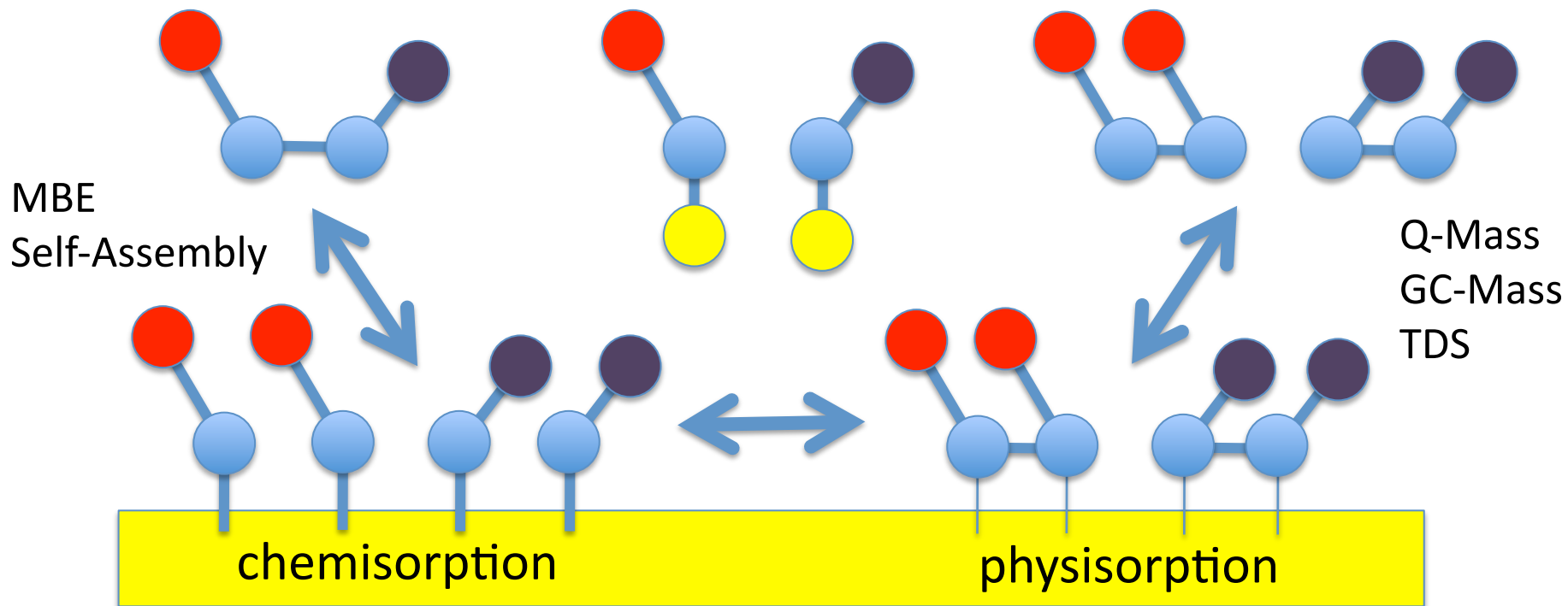


STM images from disordered to ordered molecular anchoring structures on MoS₂

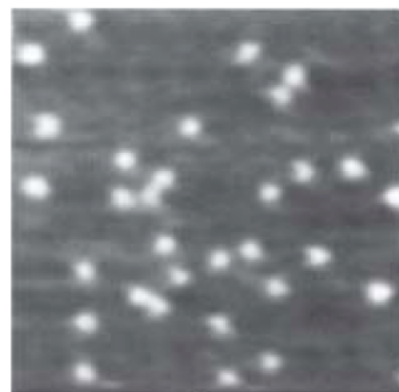
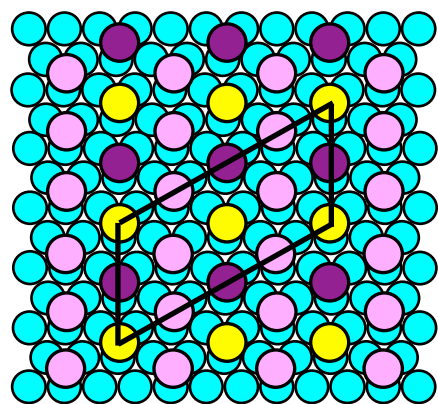
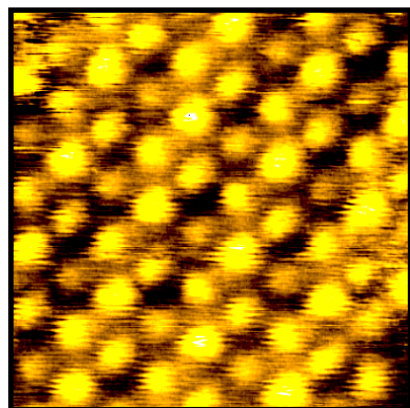


STM images of self-assembled monolayers on MoS₂

Chemical Reactions at Surfaces

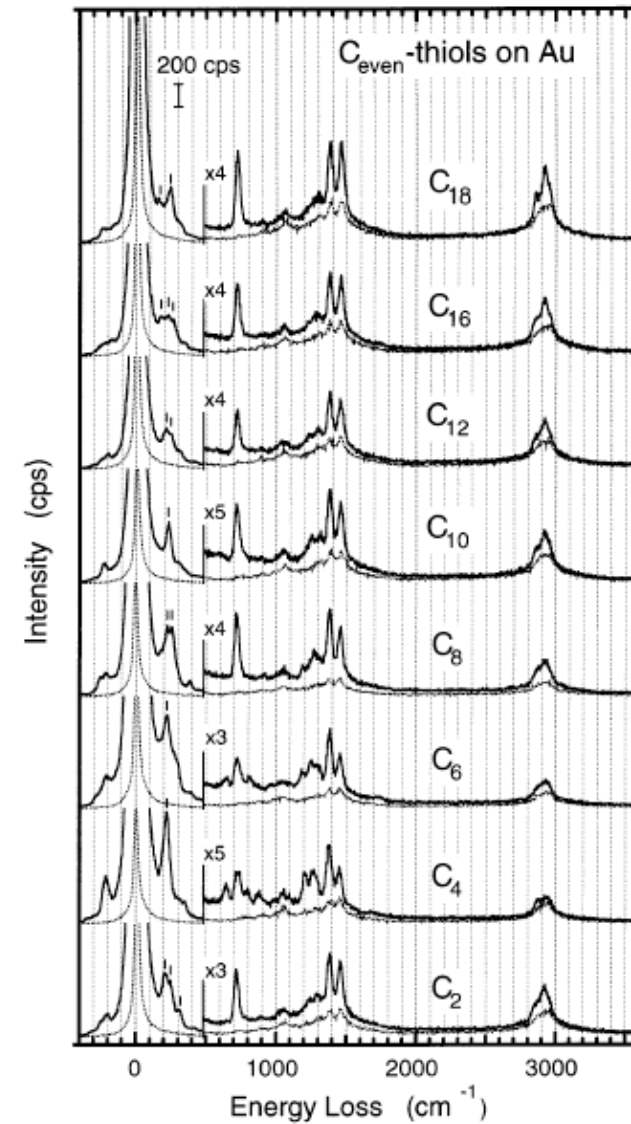
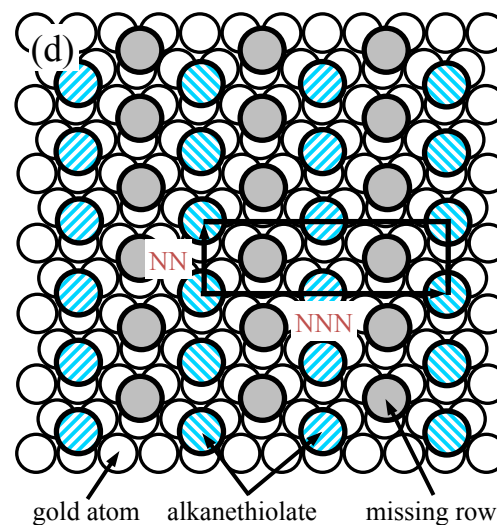
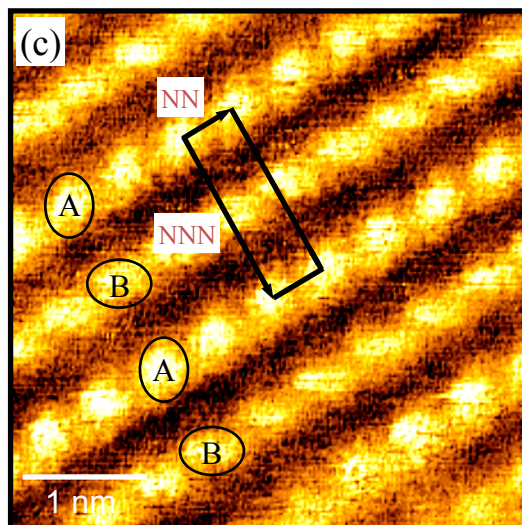
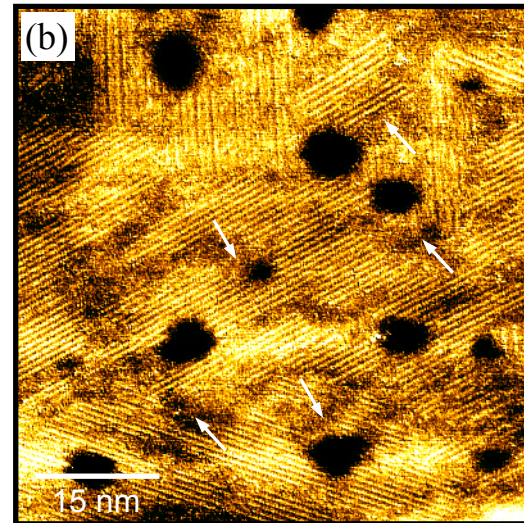
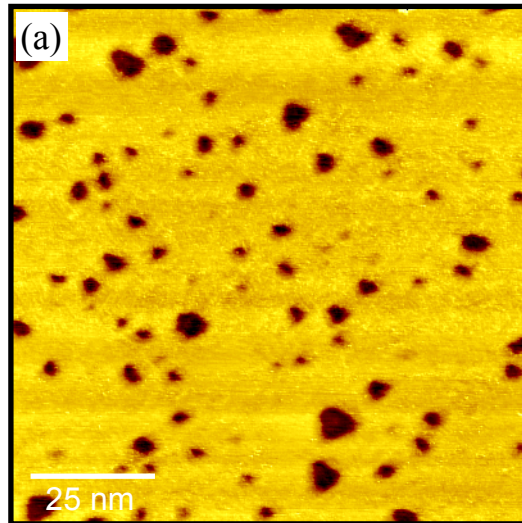


STM AFM, XPS, SPR, QCM etc.



Ertl (2007)

Self-Assembly Process and Multiplicity of Adsorption States

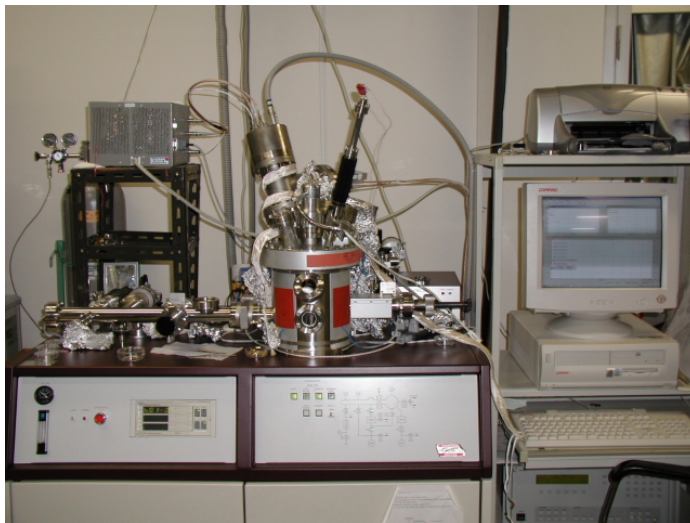


HREELS for S-Au Bound State

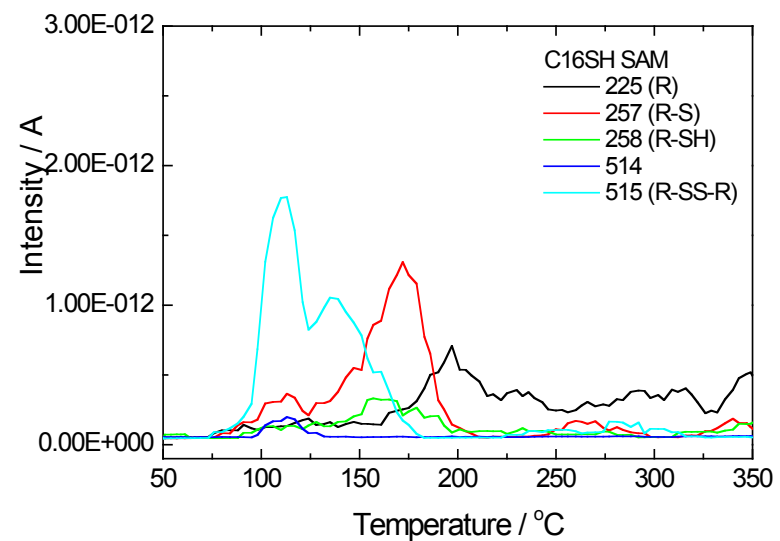
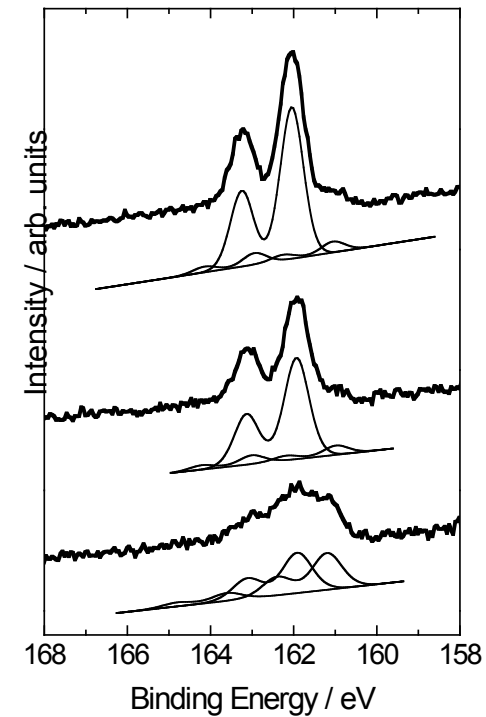
Self-Assembly Process and Multiplicity of Adsorption States



Angle-Resolved XPS



Thermal Desorption Spectroscopy



Experimental Challenges to bridge over Histories of the Earth and Life

1. Background
what we have done
2. **Missing Link**
what we will do
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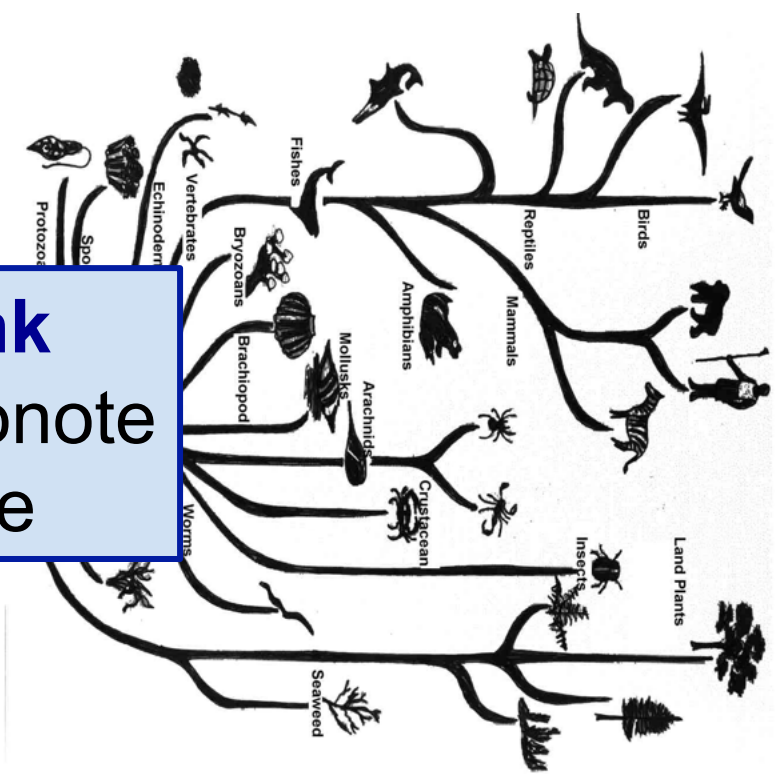
Chemical Evolution Experiments with Early Earth Materials

Chemical Evolution

Evolution of Life



Missing Link
Birth of Commonote
Origin of Life



Histories of the Earth

Biochemistry

Q8. What could be Catalyst on Early Earth ?

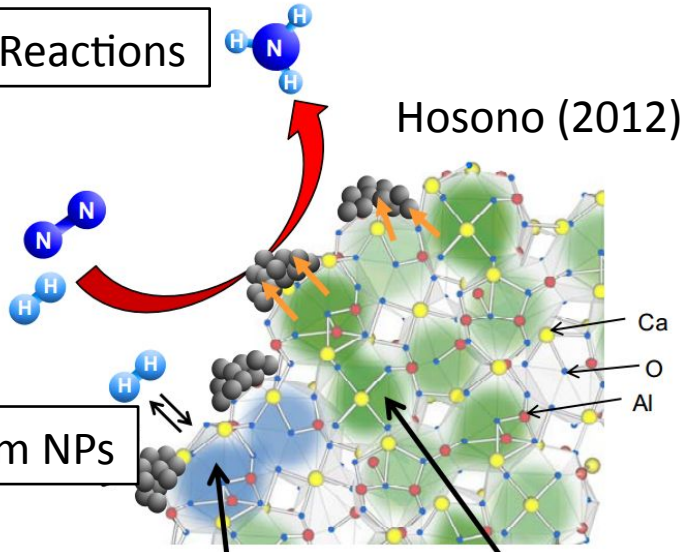
Histories of the Earth

Catalyst Chemistry



Early Earth Environment

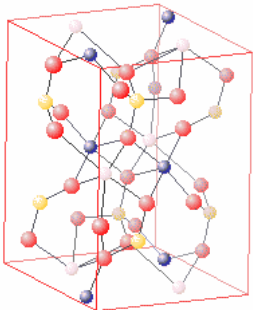
Chemical Reactions



Ruthenium NPs

カゴの中に取り込まれた水素イオン(H⁺)

カゴの中に取り込まれた電子



- oxygen atom O
- magnesium
- calcium atom
- silicon atom Si

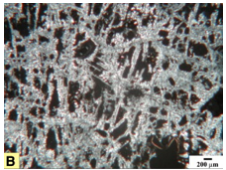
Early Earth Elements

22	23	24	25	26	27	28	29	30
Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
40	41	42	43	44	45	46	47	48
Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd
72	73	74	75	76	77	78	79	80
Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg

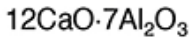
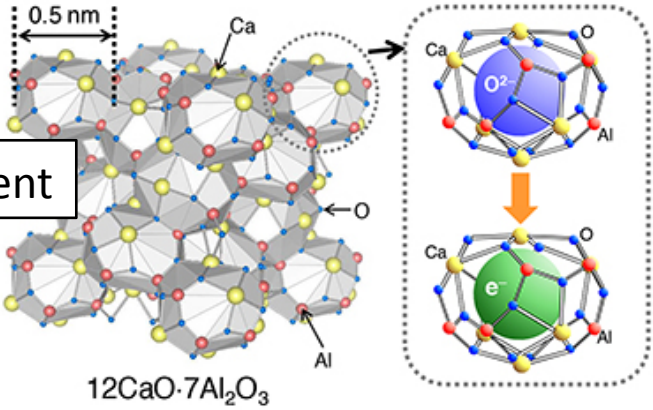


Anorthosite

Early Earth Rocks



Porous Cement



Q8. What could be Catalyst on Early Earth ?

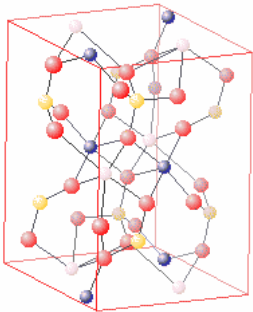
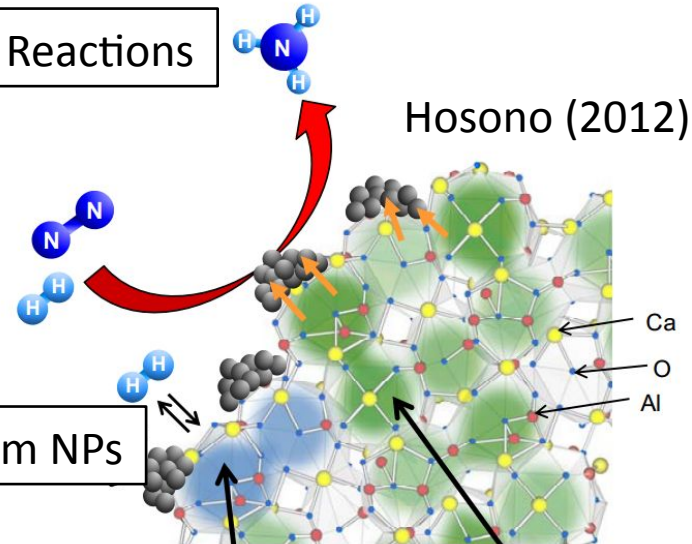
Histories of the Earth

Catalyst Chemistry



Early Earth Environment

Chemical Reactions



- oxygen atom O
- magnesium
- calcium atom
- silicon atom Si

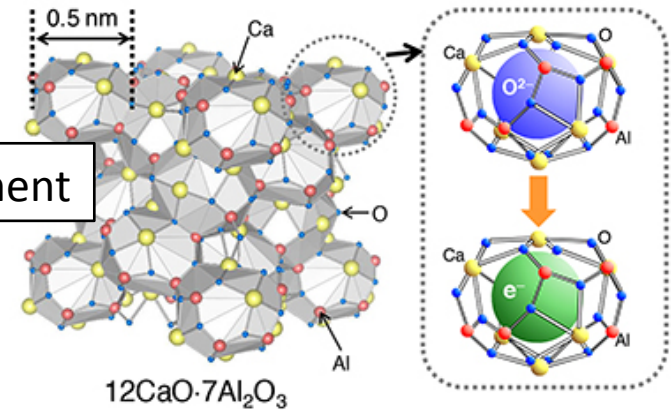
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Ruthenium NPs

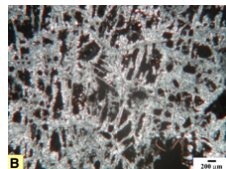
カゴの中に取り込まれた水素イオン(H⁺)

カゴの中に取り込まれた電子



Anorthosite

Early Earth Rocks



Porous Cement

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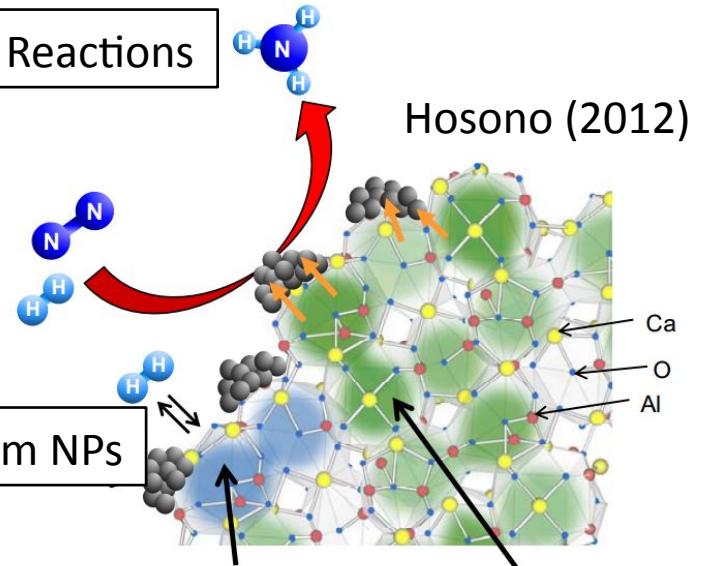
Histories of the Earth



Early Earth Environment

Catalyst Chemistry

Chemical Reactions



Early Earth Elements

- oxygen atom O
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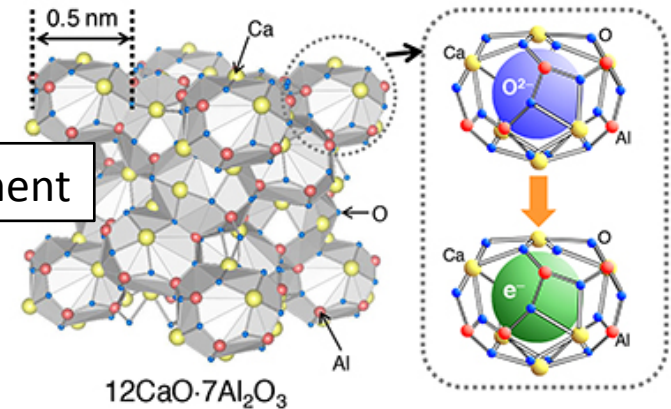
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Elements Structures and Environment

Ruthenium NPs

カゴの中に取り込まれた水素イオン(H⁺)

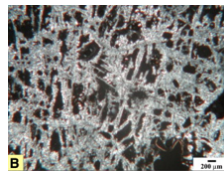
カゴの中に取り込まれた電子



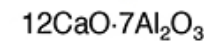
Early Earth Rocks



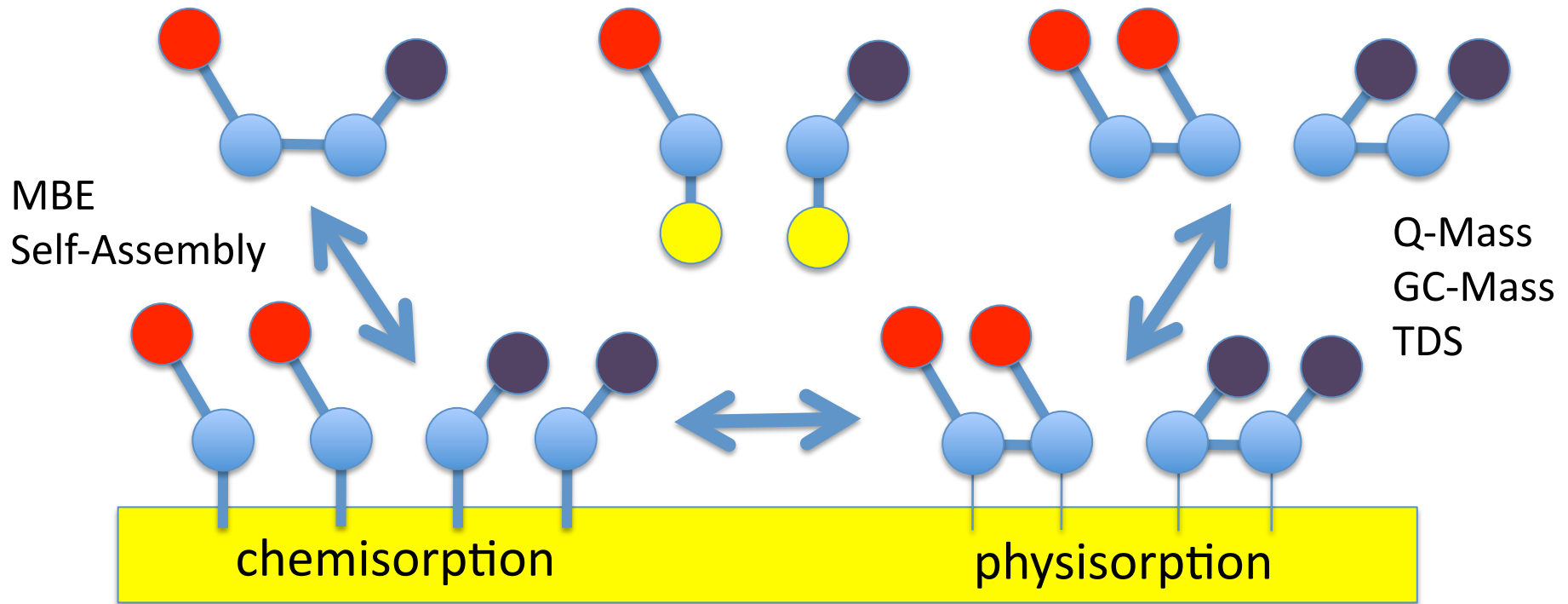
Anorthosite



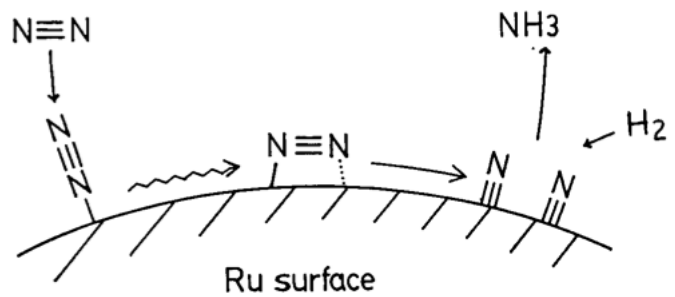
Porous Cement



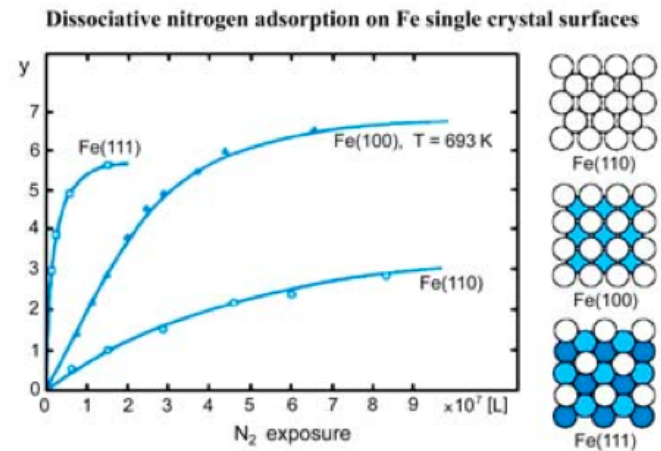
Chemical Reactions at Surfaces



STM AFM, XPS, SPR, QCM etc.



Aika (1994)

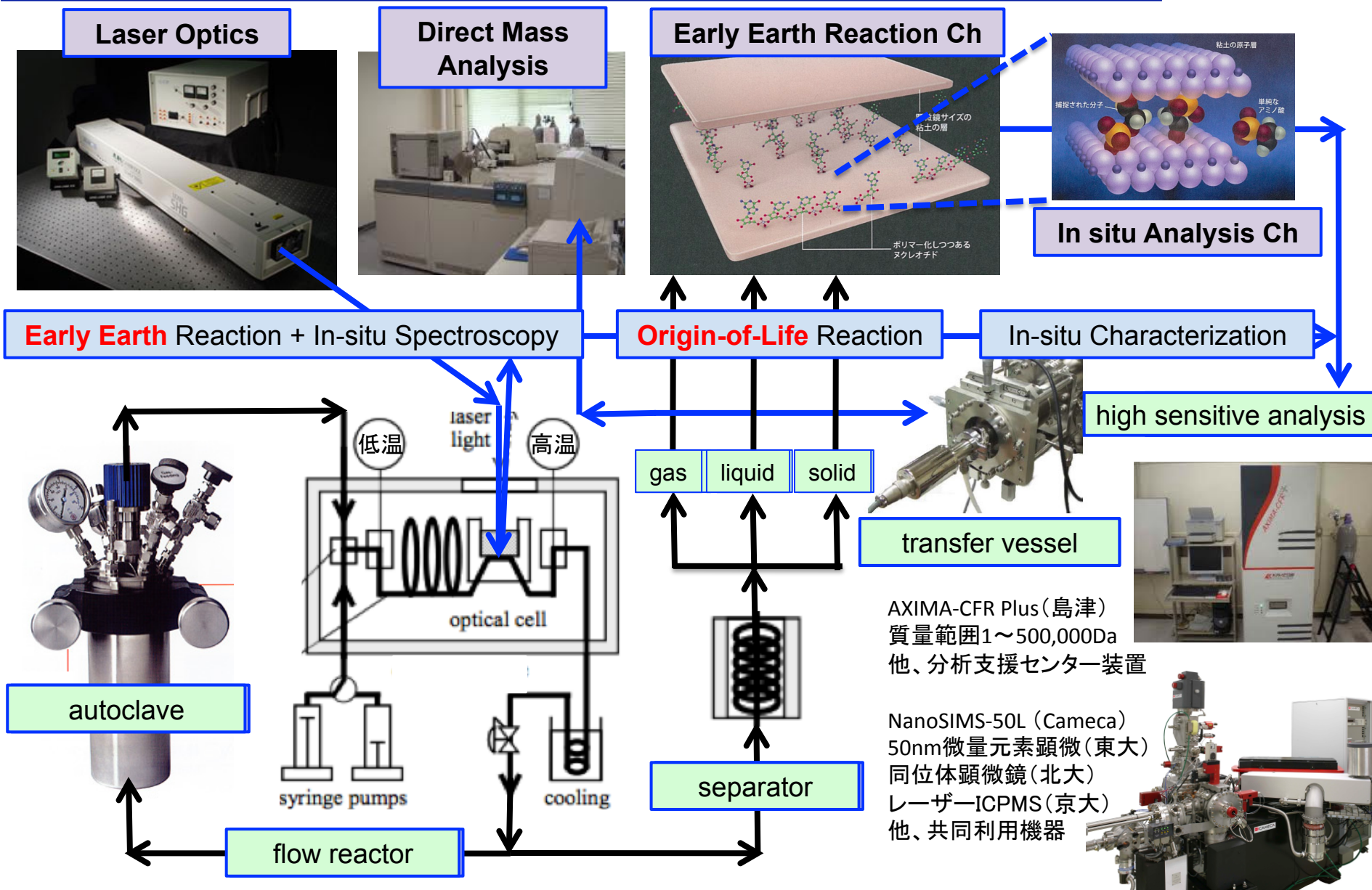


Experimental Challenges to bridge over Histories of the Earth and Life

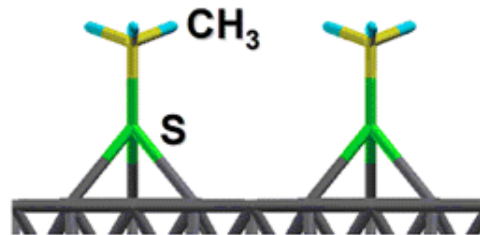
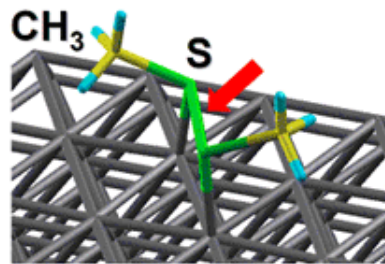
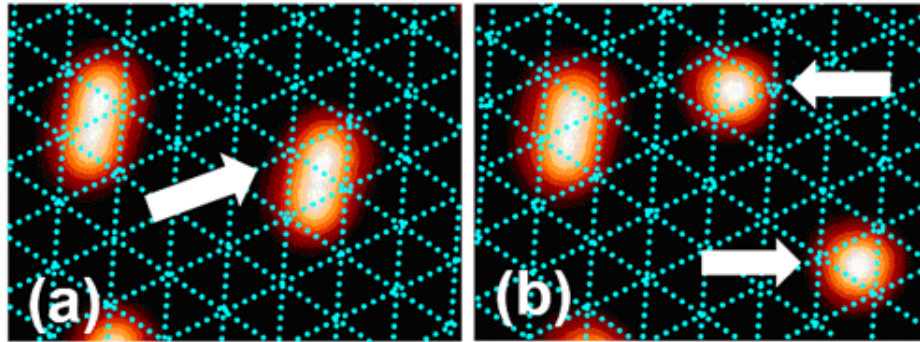
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Experimental System to bridge over Histories of the Earth and Life

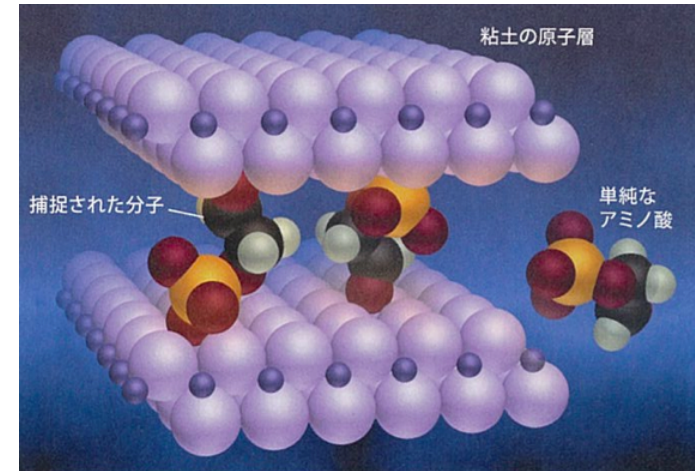
Early Earth Environment and Origin-of-Life Experiment (2013)



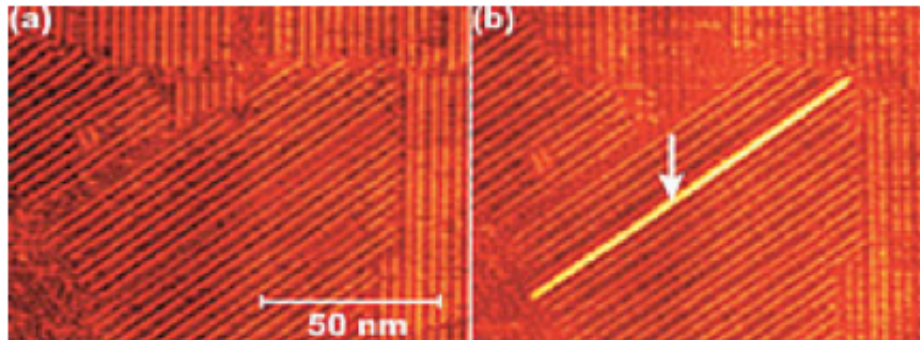
Chemical Reactions at Surfaces



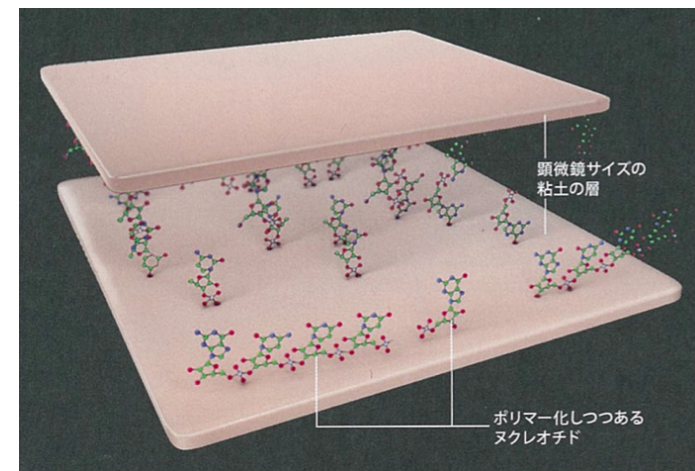
Kawai & Kim (2008)



Nikkei Science (2009)

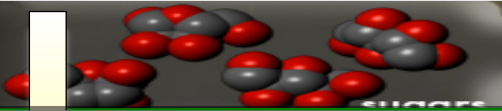



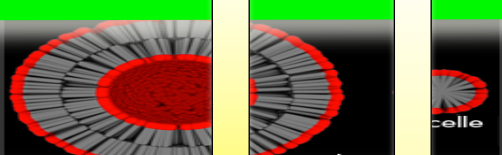
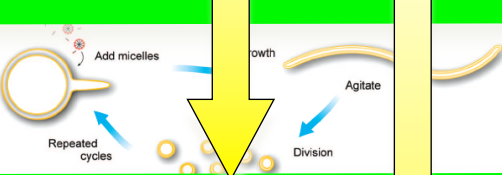

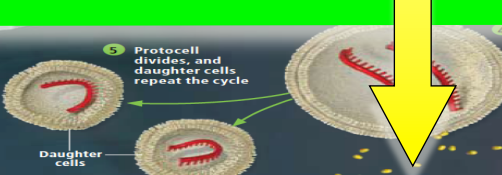


Okawa & Aono (2003)



Nikkei Science (2009)

Another Missing Link for Exploring "Origin of Life"

stage in origin of life		experimental condition
1 → base, ribose, phosphate		Pentoses and base stabilized, etc.
2 → RNA nucleotide		aqueous solution (40C), UV irradiation for destroying co-products, etc.
3 → long-strand RNA		eutectic phase (-18.4C), metal-ions, etc. montmorillonite clay (4C, 37C), etc.
4 → fatty acid		mineral surface, hydrothermal system (300C), etc.
5 → membrane (vesicle)		micro-capillary thermal diffusion (5C to 50C), etc.
6 → division		photochemical (dye + thiol), etc.
7 → protocell		aqueous solution, activated nucleotides spontaneously cross the membrane and participate in copying, etc.
8 → replication (metabolism & division)		

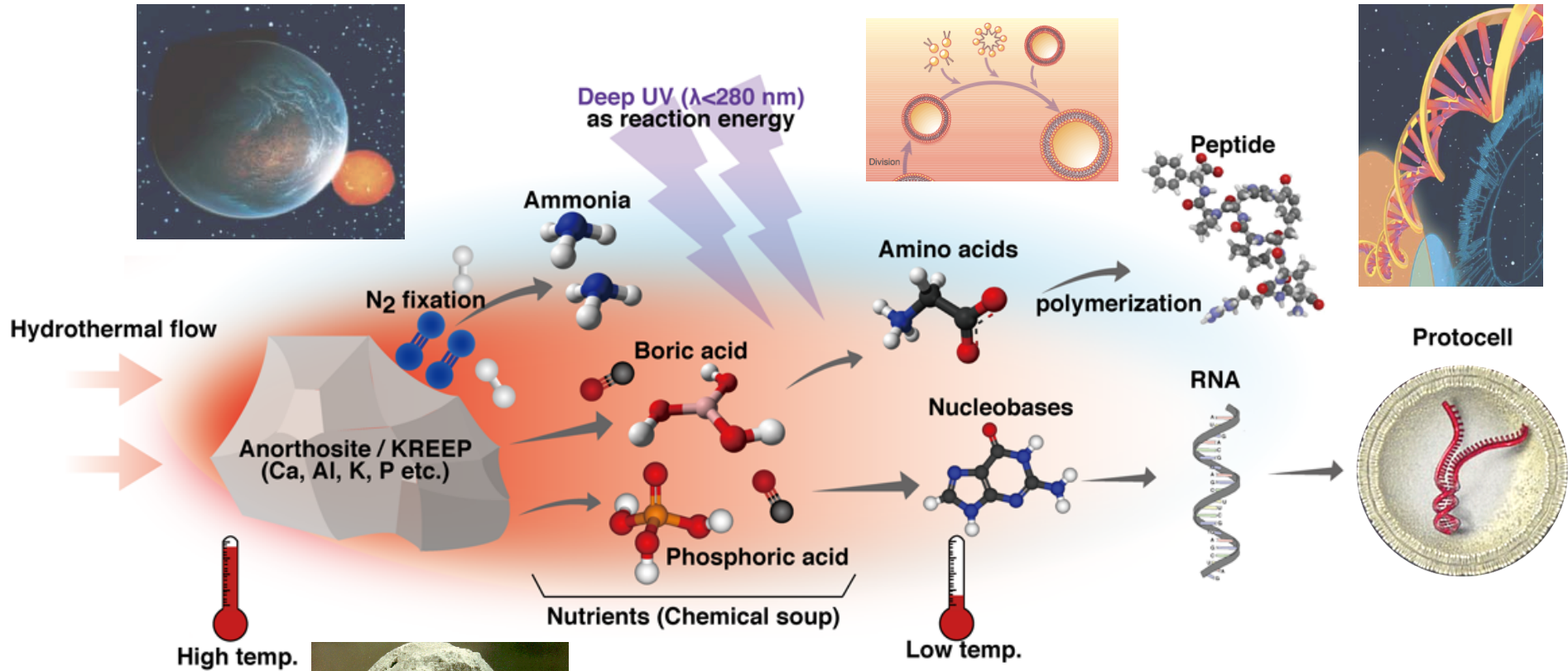
**"Trans-Stage Emergences"
in Early-Earth Conditions**

**Knowledge from
Earth Science**

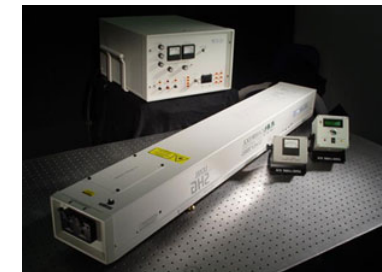
Experimental Approach to bridge over Histories of the **Earth** and **Life**

Early-Earth Reaction

Origin-of-Life Reaction



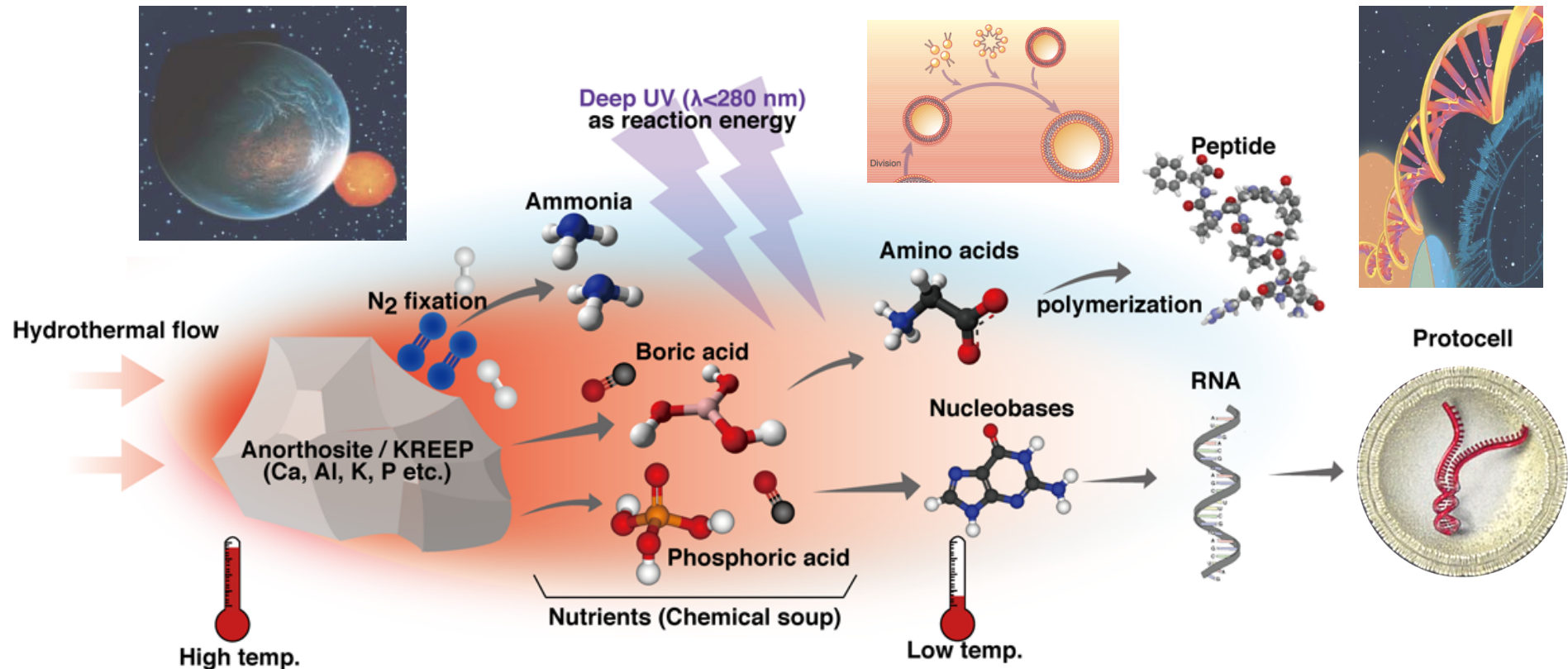
Anorthosite
KREEP (Potassium + Rare Earth Elements + Phosphorus)
+ UVC (200-280nm), UVB (280-340nm), UVA (340-400nm)
and more...



Experimental Approach to bridge over Histories of the **Earth** and **Life**

Early-Earth Reaction

Origin-of-Life Reaction



Key Approaches from **Early-Earth** to **Origin-of-Life** Reactions

- > Replication of the Early-Earth Surface (Hydrothermal Conditions, UV Irradiation etc.)
- > Synthesis of Nutrients from the Early-Earth Hydrothermal Reactions of Rocks
- > Synthesis of Biomolecules from Early-Earth Nutrients to Amino Acids, RNA and Protocell
- > Elucidation of Evolution Mechanism using Advanced Analytical Tools

2013

2014

2015

2016

2017~

Establishment of Experimental System

Implementation of Real-Time Feedback

Early Earth Elements and Origin-of-Life Experiment I
Beyond Haber-Bosch, Chemical Soup to Polymerization Reaction

Origin-of-Life Experiment II
Reaction Substrates and RNA Formation

Origin-of-Life Experiment III
Membrane, Vesicles to Protocell Replication

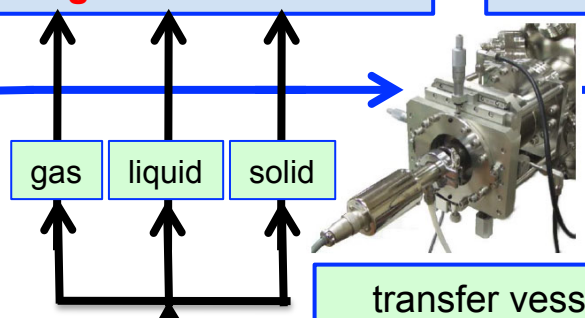
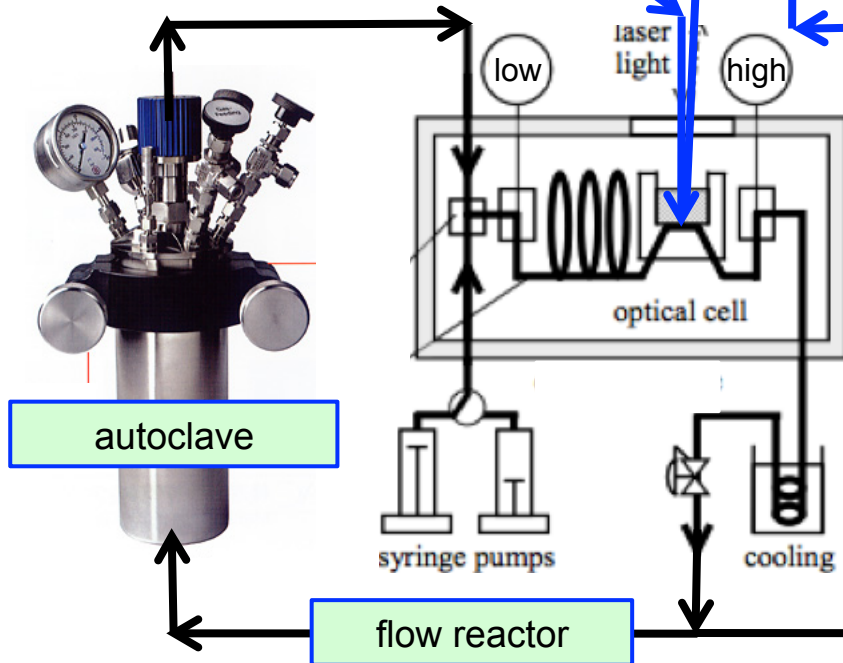
Experimental System to bridge over Histories of the Earth and Life

Early Earth Reaction + In-situ Spectroscopy

Origin-of-Life Reaction

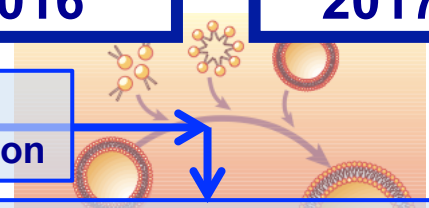
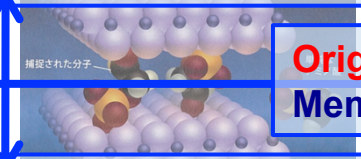
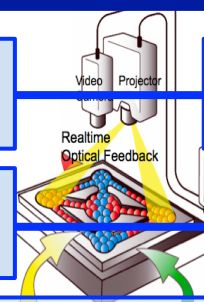
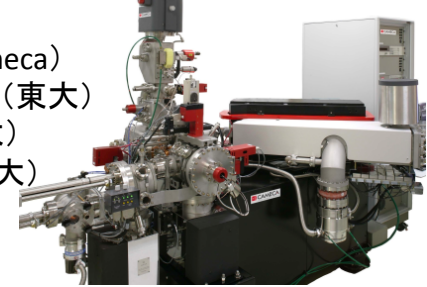
In-situ Characterization

high sensitive analysis



AXIMA-CFR Plus (島津)
質量範囲1~500,000Da
他、分析支援センター装置

NanoSIMS-50L (Cameca)
50nm微量元素顕微鏡 (東大)
同位体顕微鏡 (北大)
レーザーICPMS (京大)
他、共同利用機器

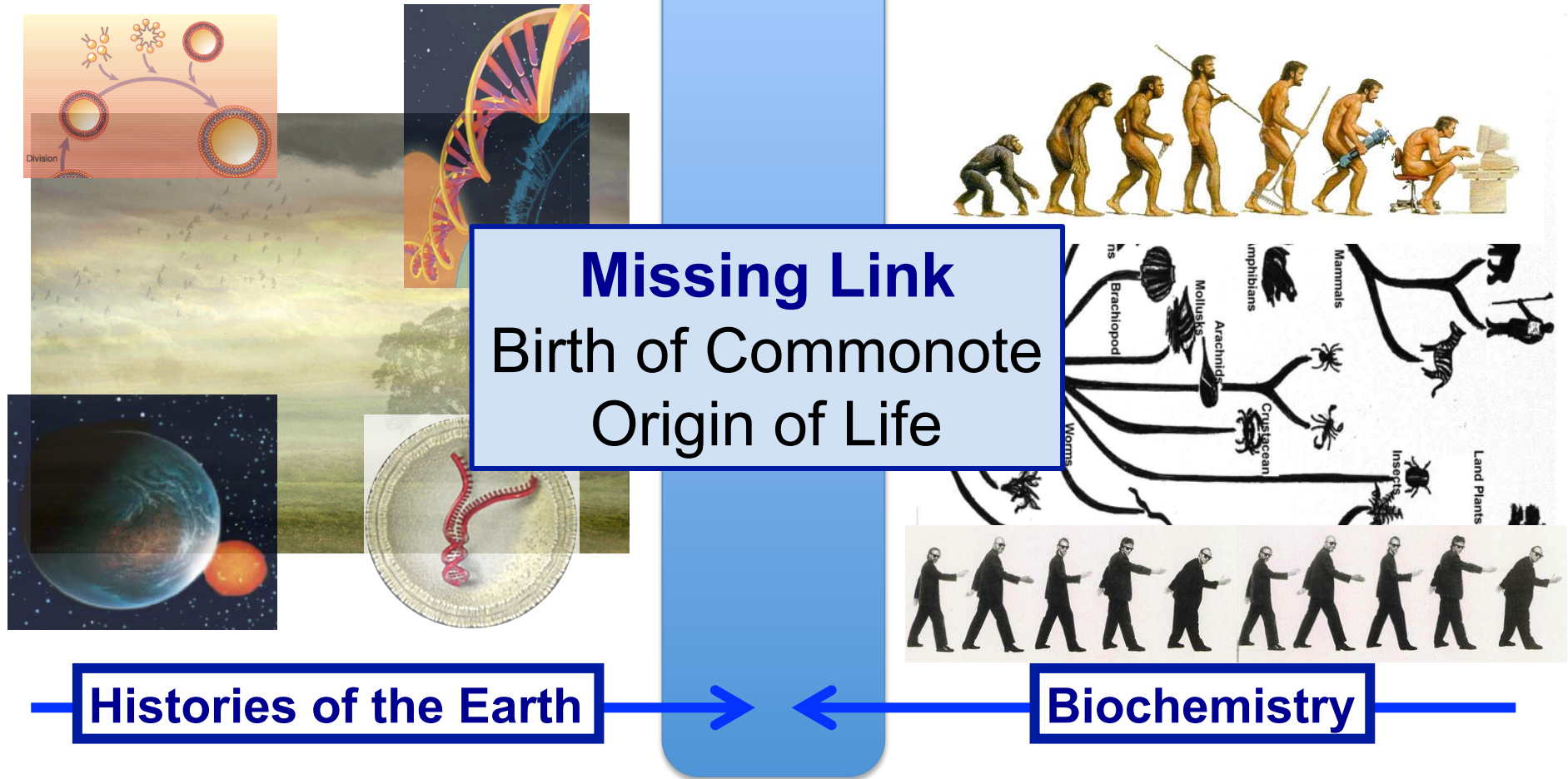


Experimental System to bridge over Histories of the Earth and Life

Chemical Evolution Experiments with Early Earth Materials

Chemical Evolution

Evolution of Life



Histories of the Earth

Biochemistry

Thank you for your attention.

A misty landscape with a large tree and birds flying in the sky. The scene is hazy and atmospheric, with a large, leafy tree on the right side and many small birds scattered across the sky. The ground is a grassy field, and the overall tone is soft and ethereal.

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to Connect the Dots Looking Backwards
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