1st ELSI International Symposium
2013. 3. 28.

Laboratory Simulation of Formation and Alteration of High Molecular Weight Organics in Space

Kensei Kobayashi
Yokohama National University
kkensei@ynu.ac.jp

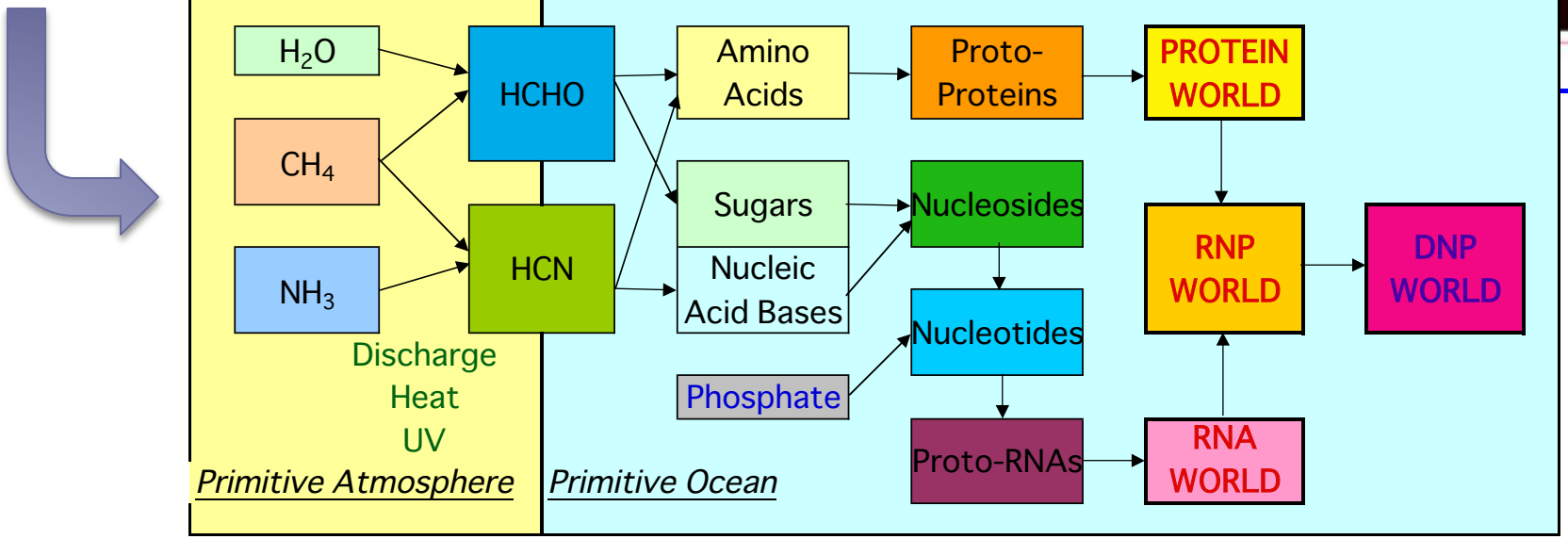
Outline

- Classical Scenario of Chemical Evolution
- Problems in the Classical Scenario
- Extraterrestrial Organics and Origins of Life
- Abiotic Formation of Complex (High Molecular Weight) Organics in Space
- Merits of Complex Amino Acid Precursors
- New Scenario of Chemical Evolution
- Genesis & Evolution of Biochemical Functions

Classical Sinario of Chemical Evolution

- Miller (1953): Amino acid synthesis from strongly reducing atmosphere
- Oro (1960):

  Adenine synthesis from HCN solution
- Orgel et al. (1970s–80s): Abiotic syntheses of oligonucleotides

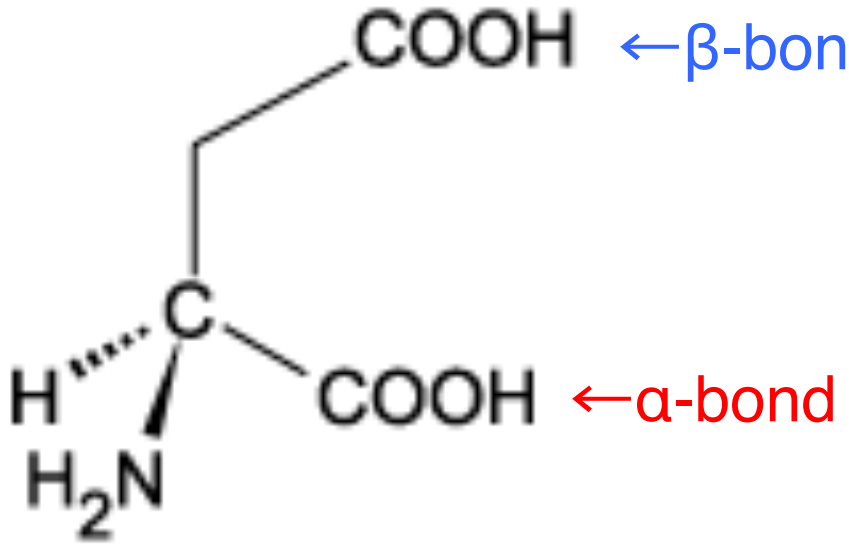


Problems in Classical Scenario (1)
High concentration (～1M) of pure starting meterials are required

- HCN + HCHO + NH_3
  → Amino acids (Strecker Reaction)
- 5 HCN → Adenine
- 5 HCHO → Ribose (Formose Reaction)

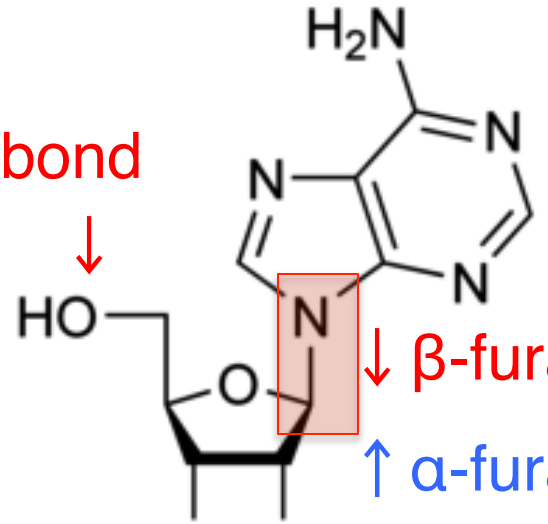
- Inhibitors should not co-exist
  (*eg.* Ammonia in Formose reactions)
- Amino acids and sugars are easily decomposed in aqueous solution by heat or radiation

Problems in Classical Scenario (2)
Regio- and Stereoselectivity



Aspartic acid (amino acid)

Adenosine (nucleoside)

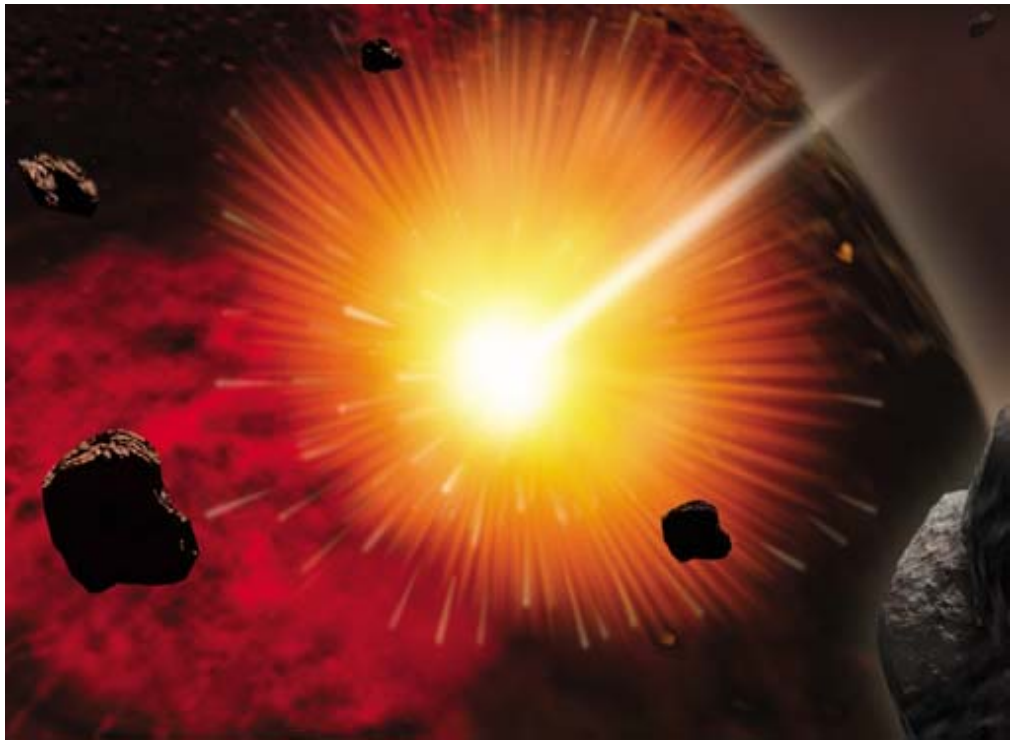


Cyclic 2', 3'-bond ↑

Correct and Wrong Bonds

α-pyranoside, β-pyranoside….

Problems in Classical Scenario (3) Primitive Earth Atmosphere was not Strongly-Reducing



- Primitive atmosphere was only slightly-reducing
- Amino acids are hardly formed from slightly-reducing gas mixtures by UV, heat and spark discharges

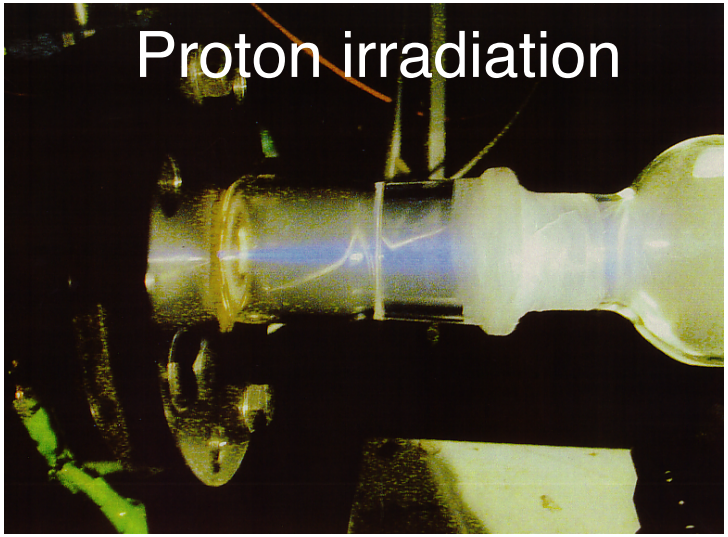
http://www.newtonpress.co.jp/search2/e_book/ebook/2002_02/mmsolarsys_0502.html

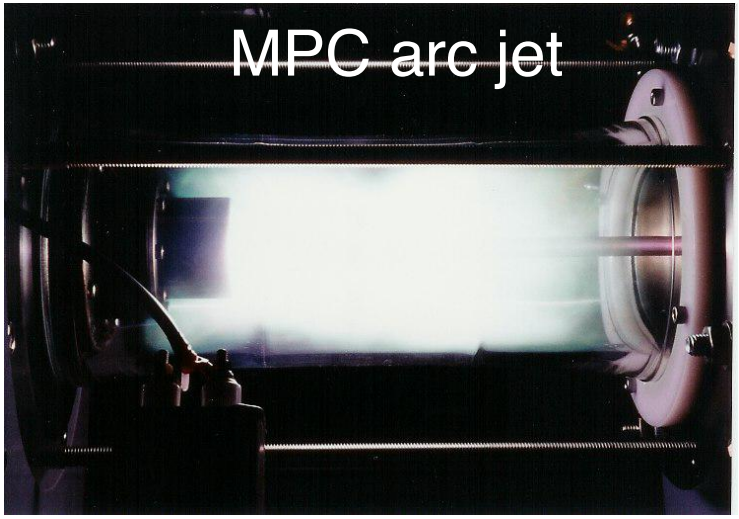
New Insight 1:
Reevaluated Energies for Prebiotic Syntheses

Materials :
Weakly-reducing gas mixtures
(CO_2, CO, N_2, H_2O)
(N_2, CH_4 (tr.), H_2O)

Energies:
Cosmic rays (Proton irradiation)
Bolide impacts (MPD arc jet)

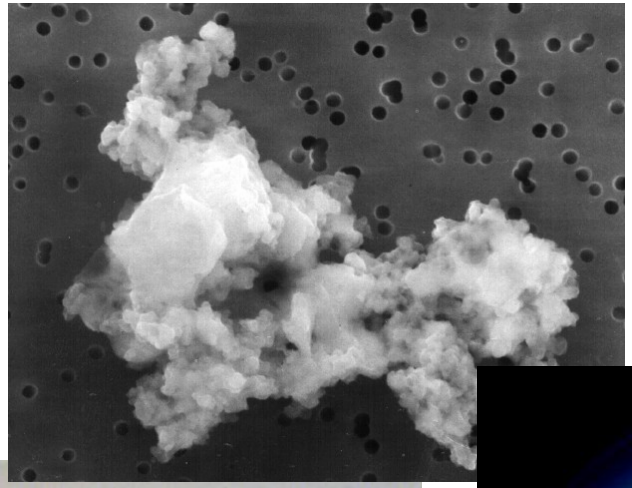
Amino acid precursors with high molecular weights are produced





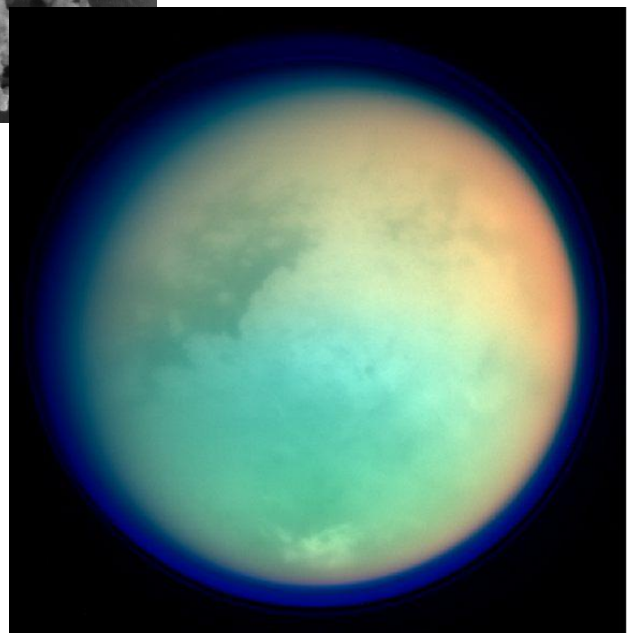
New Insight 2:
Complex Organics in Space

Comets



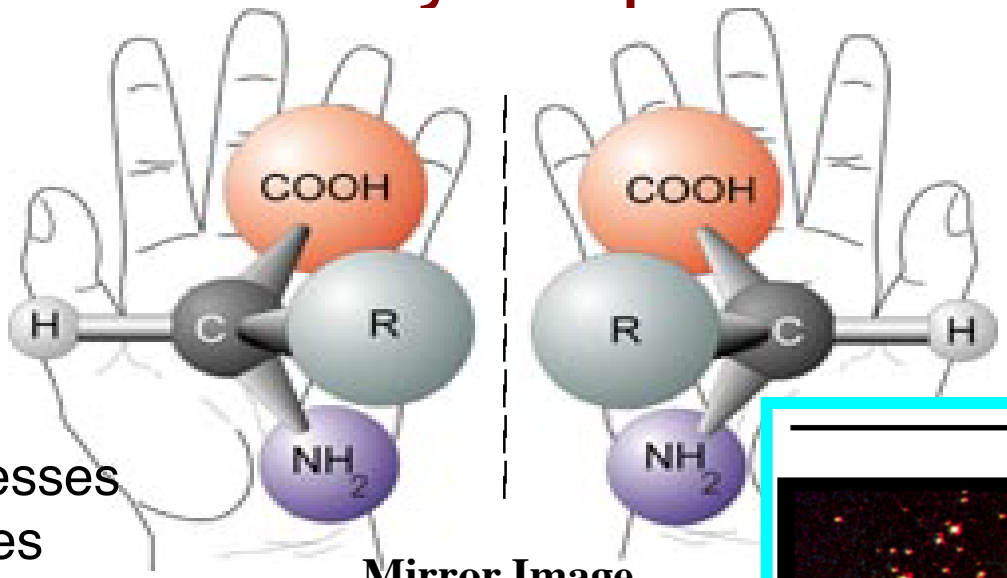
Interplanetary dust particles

Titan



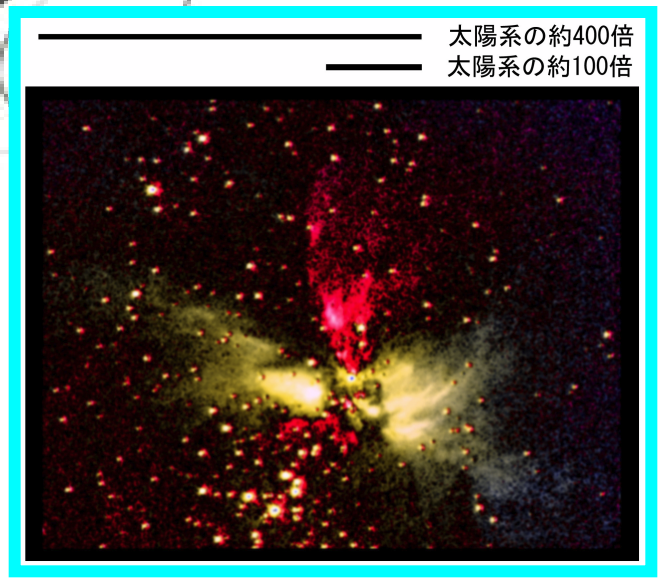
Carbonaceous chondrites

New Insight 3:
Seeds of homochirality in Space



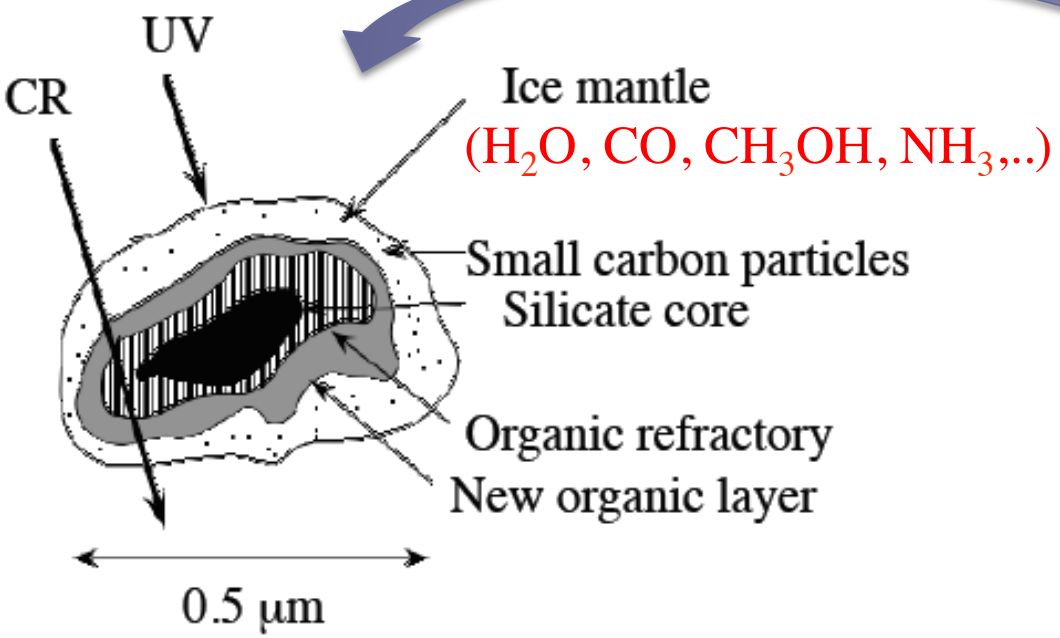
Mirror Image

Enantiomeric excesses
Found in meteorites



Extended Circularly-polarized light in the Orion massive star forming region (Fukue et al., 2011)

Origin of Organics in Comets and Meteorites: Formation in Molecular Clouds?



Molecular cloud

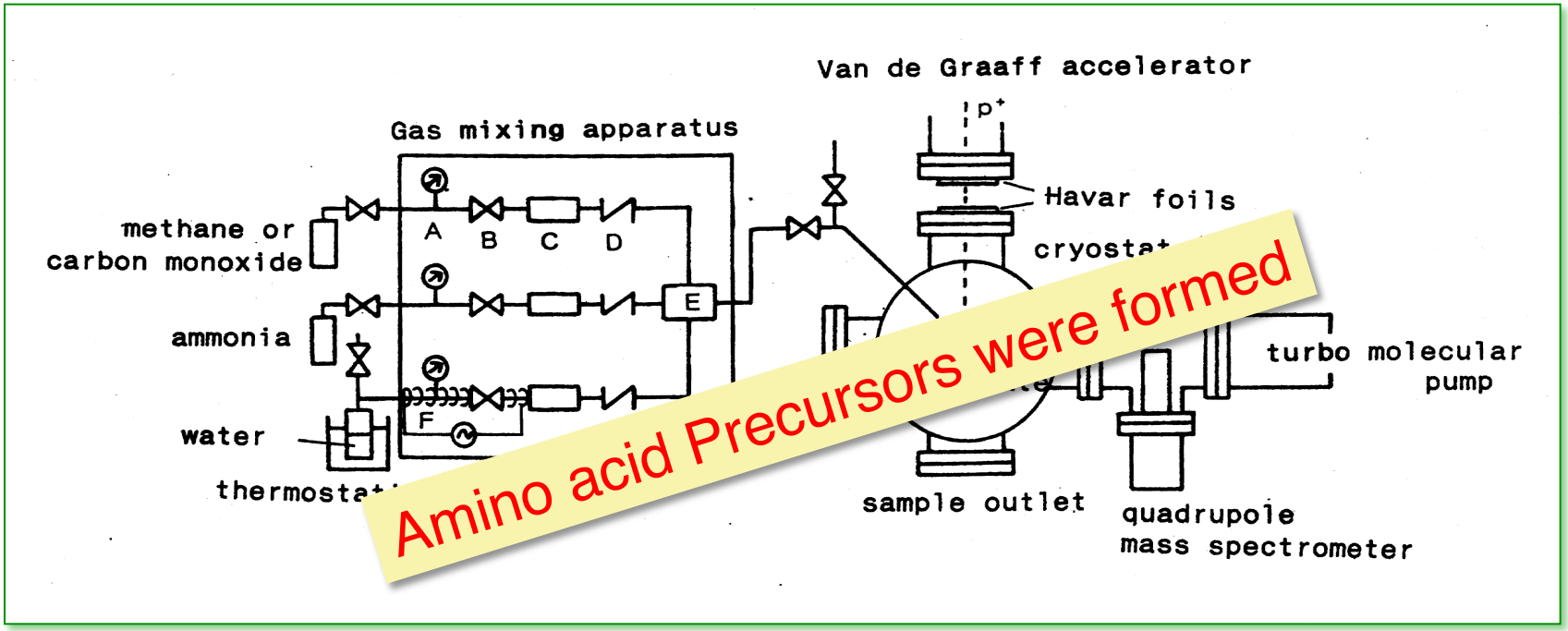
Greenberg Model:

Complex organics are formed in ice mantles of interstellar dust particles in molecular clouds

Irradiation of Simulated ISD Ices

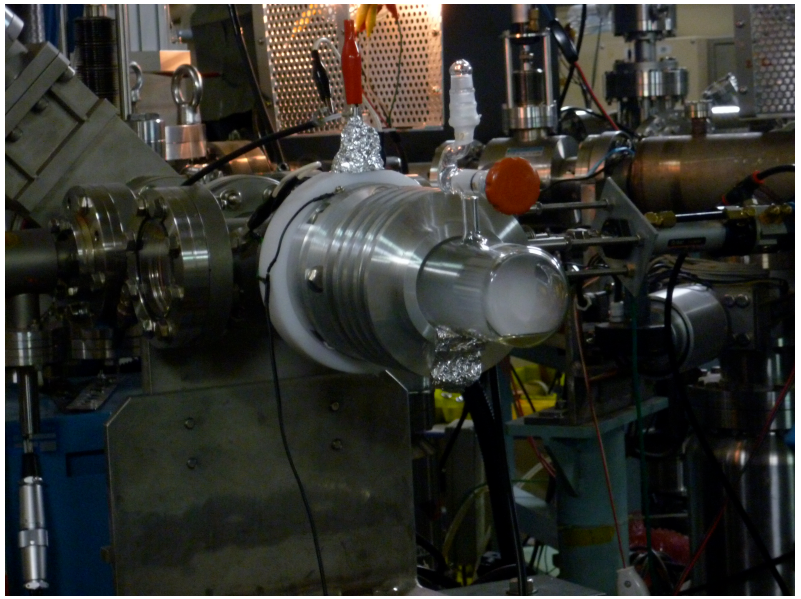
Charged Particles
- Kobayashi et al., 1995
- Kasamatsu et al., 1997
- Kobayashi et al., 2007

Ultraviolet Light
- Munos Caro et al., 2002
- Bernstein et al., 2002
- Takano et al., 2003

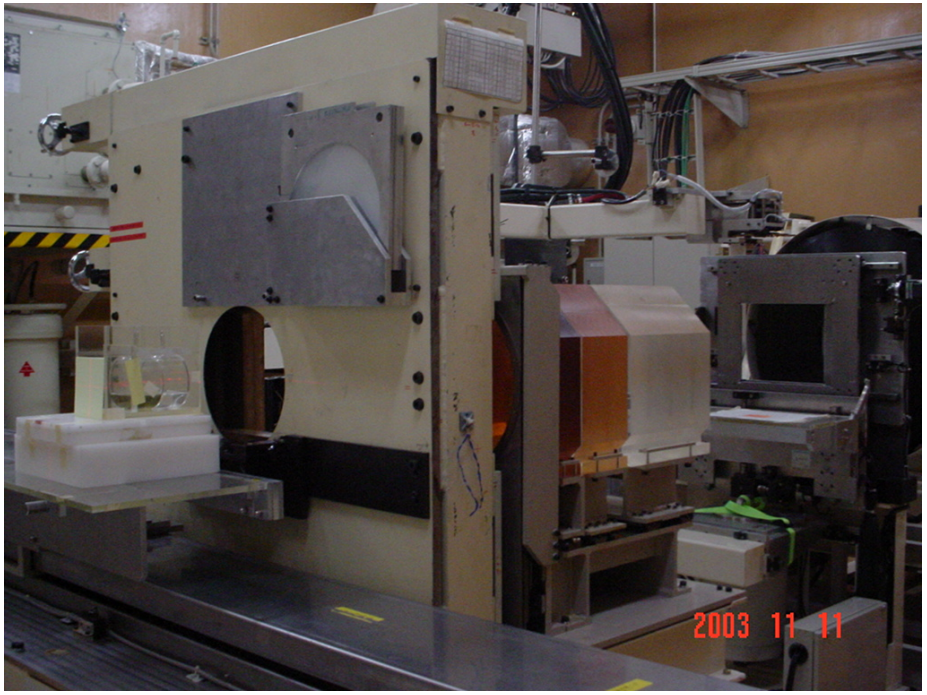


Particles Irradiation of Simulated Interstellar Media

Protons@Tandem Accelerator(TIT)→



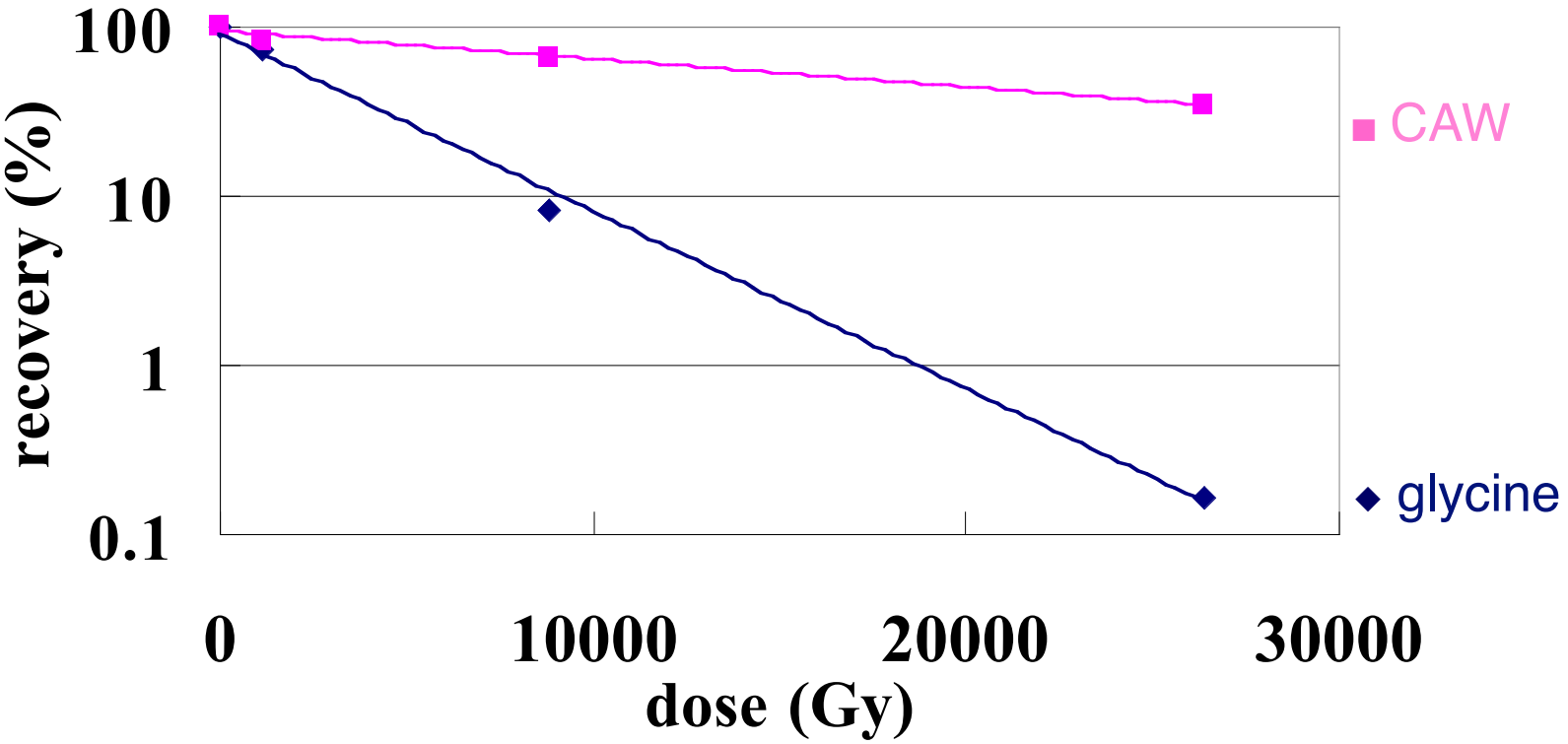
Heavy ions@HIMAC(NIRS)↓



- ✓ Molecular weights: Some thousands
- ✓ Amino acids were yielded after hydrolysis
- ✓ Catalytic activities

Merits of Complex Amino Acid Precursors (1)

Stability of Free Glycine and Complex Glycine Precursors* against γ-rays irradiation

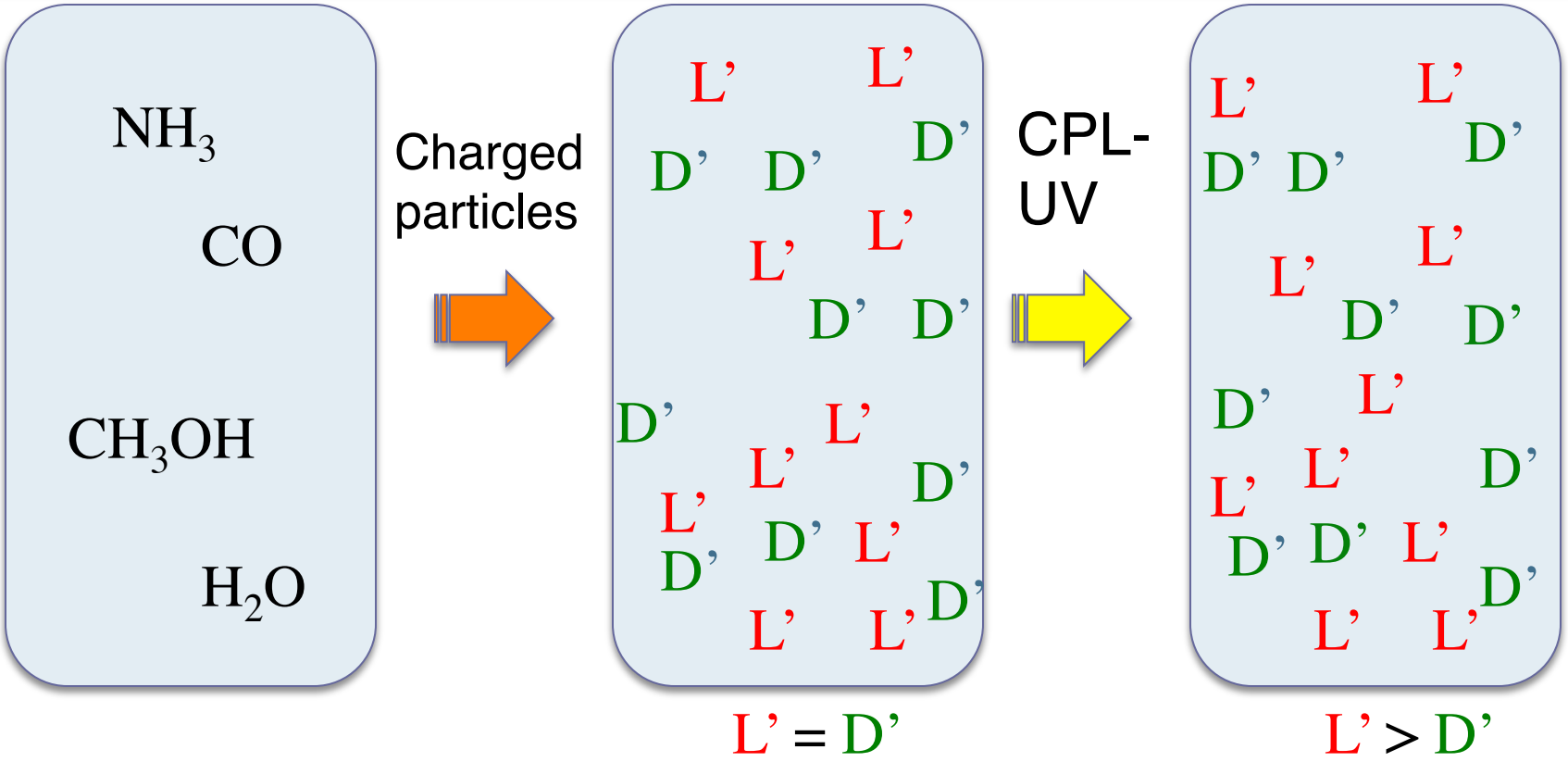


•CAW: Product when a mixture of CO, NH_3 and H_2O was irradiated with High Energy Protons.

Merits of Complex Amino Acid Precursors (2)Origin of Bio-homochilarity

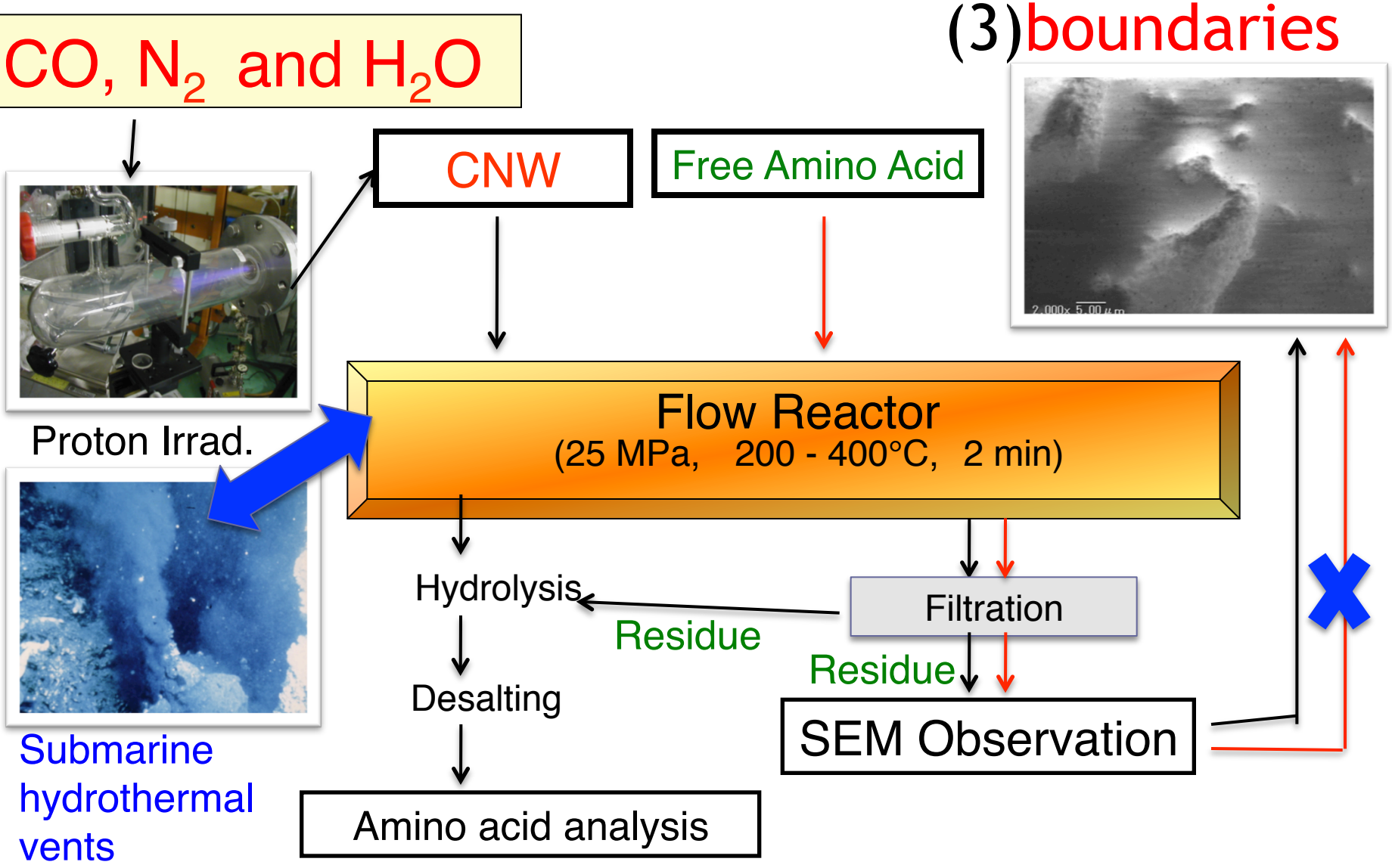
L', D': Amino acid precursors

Enantiomeric excesses formed without assymetric destruction

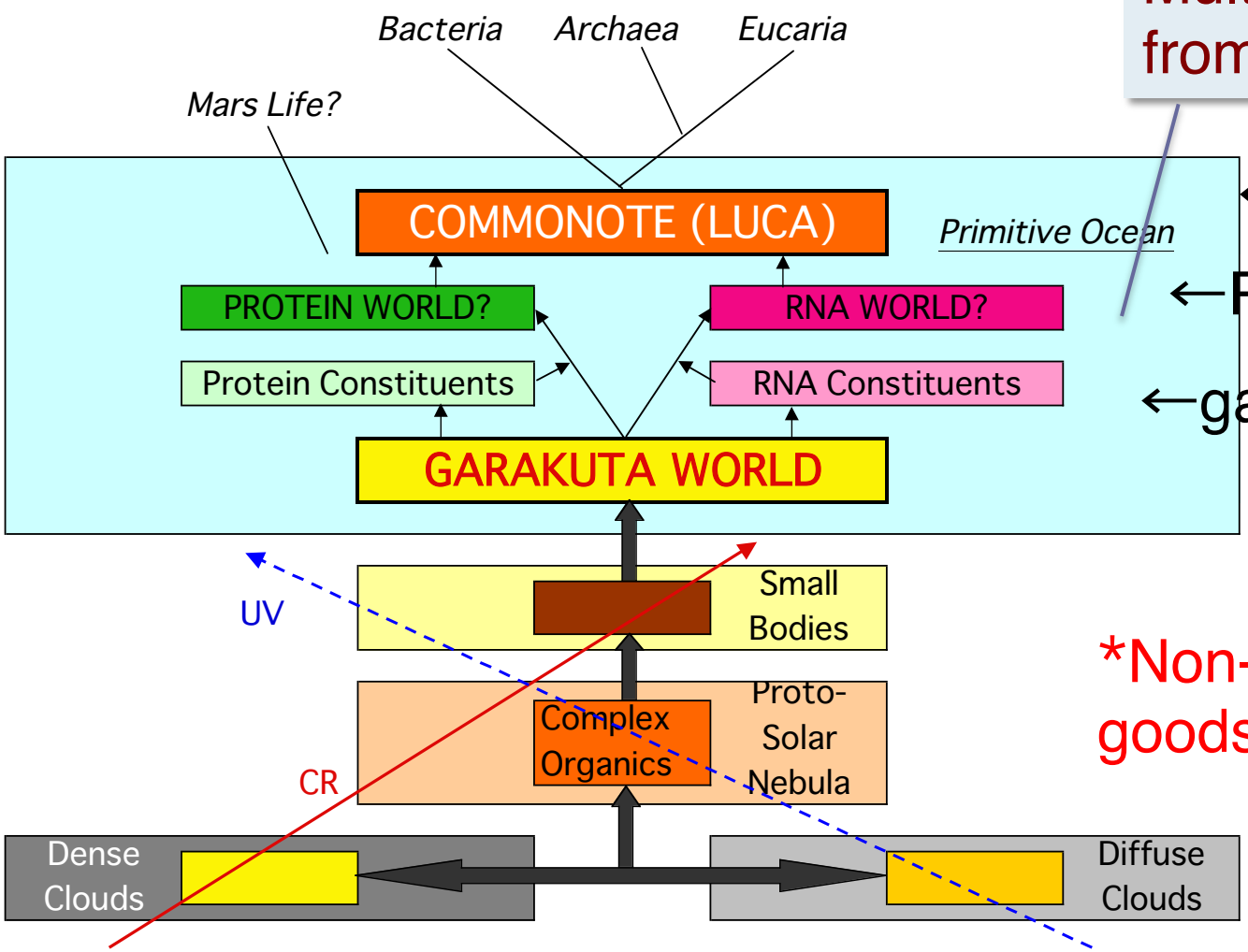


Merits of Complex Amino Acid Precursors

(3)boundaries



New Senario of Origins of Life:
The Garakuta * World



Multiple exits from this World

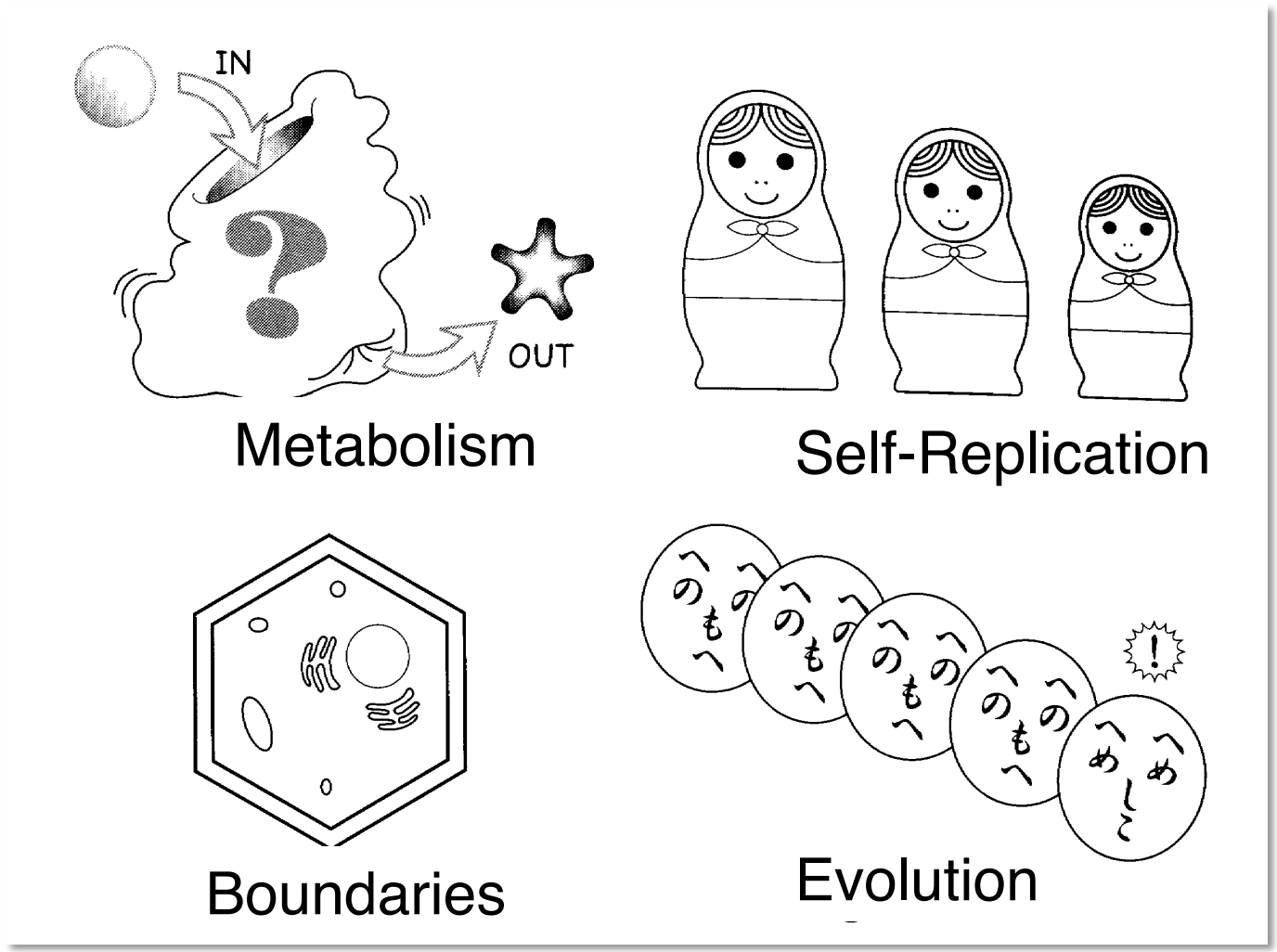
←Solid LIFE

←Pseudo-LIFE

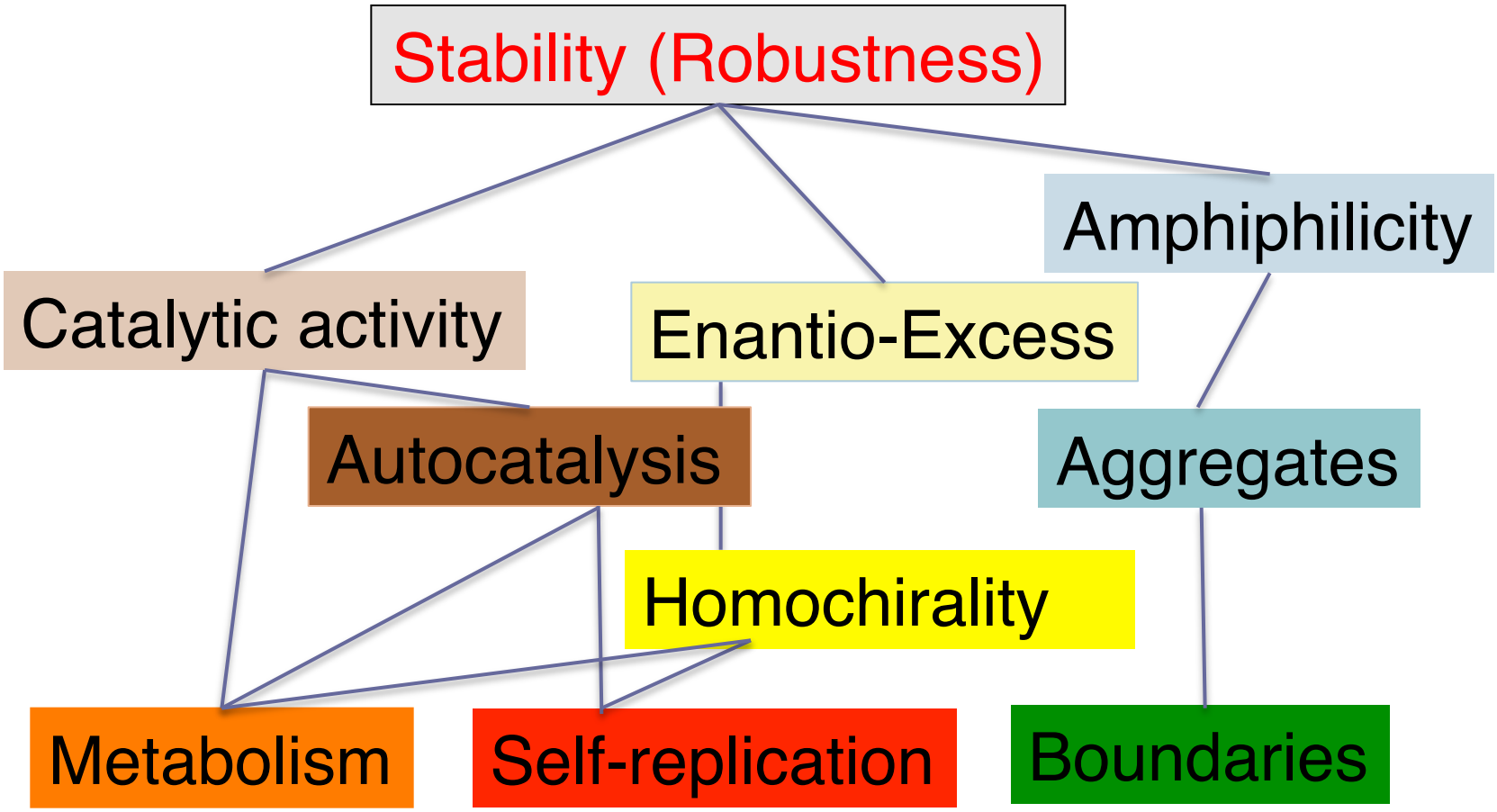
←garakuta LIFE

*Non-sophisticated goods

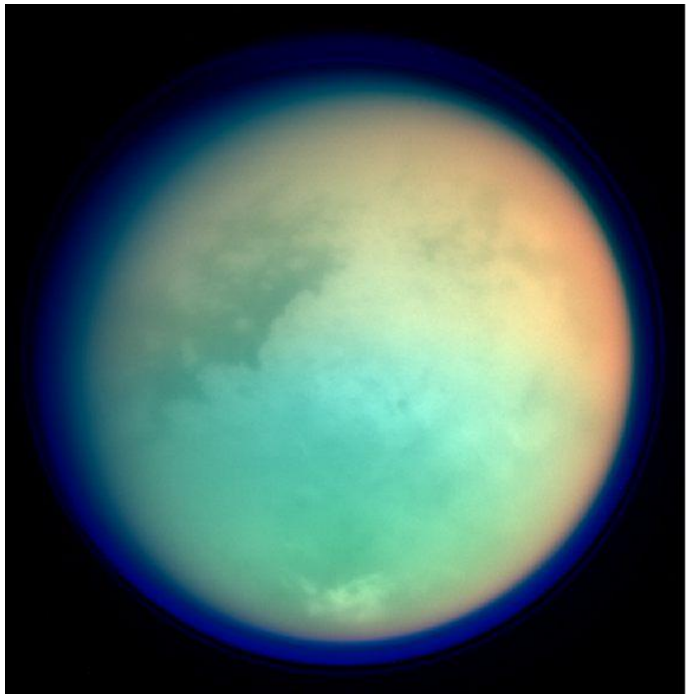
Features of LIFE



Evolution of Biochemical Features



We will be able to Find Garakuta Molecules and Garakuta Life in:



Thank you for your attention!

Acknowledgement

Dr. Satoshi Yoshida & HIMAC Staff（NIRS）
Dr. Katsunori Kawasaki（TIT Van de Graaff）
Dr. Hitoshi Fukuda & Dr. Yoshiyuki Oguri (TIT Tandem)
Dr. Kazuhiro Kanda & NewSUBARU Staff（Univ. Hyogo）
Dr. Jun-ichi Takahashi (NTT)
Dr. Yoshinori Takano (JAMSTEC)
Members of Kobayashi Lab（YNU）