

Trapp Research Group

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SCOUTING CHEMICAL NETWORKS

Origin of Life Research in the Group of
Prof. Dr. Oliver Trapp



Table of Contents

1. The Multiplicities of possible Origin(s) of Life
2. Central Open Questions
3. Targeting Complexity
 1. *Light induced Redox Chemistry*
 2. *Phosphorylation Reactions*
 3. *Carbohydrate Chemistry*
 4. *Nucleotide Synthesis and Catalysis*
 5. *Miller Type Reactions*
4. Summary

Defining Terms and Conditions

LIFE

1. Homeostasis – *Regulation*
2. Organization – *Compartments*
3. Metabolism – *Energy Transformation*
4. Growth – *Dynamic Behavior*
5. Adaption – *Darwinian Evolution*
6. Response – *Feedback Loops*
7. Reproduction – *Information*

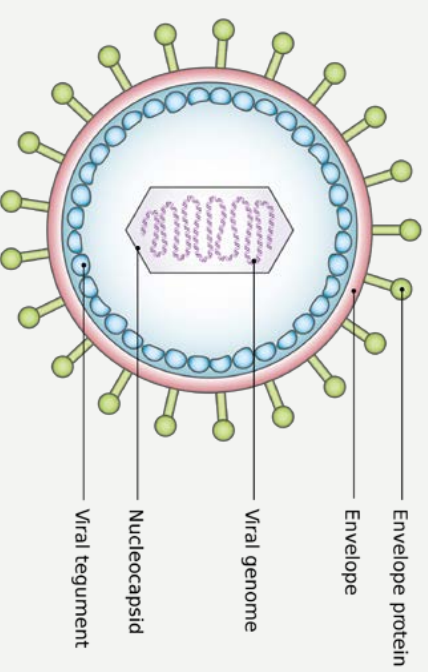
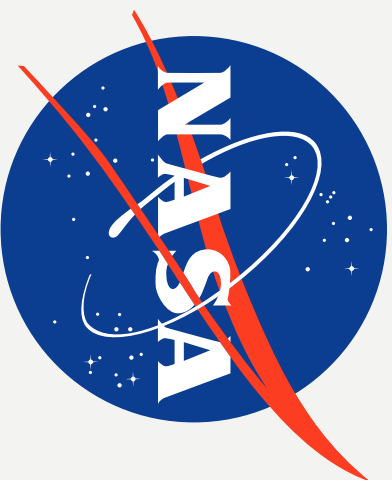


D. E. Koshland, *Science* **2002**, 295, 2215-2216; C. P. McKay, *PLoS Biol.* **2004**, 2, e302;
S. A. Benner, *Astrobiology* **2010**, 10, 1021-1030.

Defining Terms and Conditions

LIFE

Gerald Joyce: “Life is a self-sustaining system capable of Darwinian evolution.”

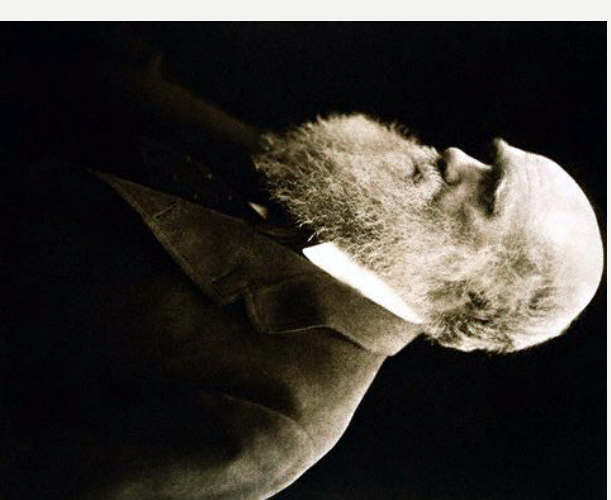


<http://www.astrobio.net/origin-and-evolution-of-life/forming-a-definition-for-life-interview-with-gerald-joyce/>

Defining Terms and Conditions

DARWINIAN EVOLUTION – *Survival of the Fittest*

1. Overpopulation
2. Heritable phenotypic variations
3. Environmental pressure
4. Isolation leads to new species

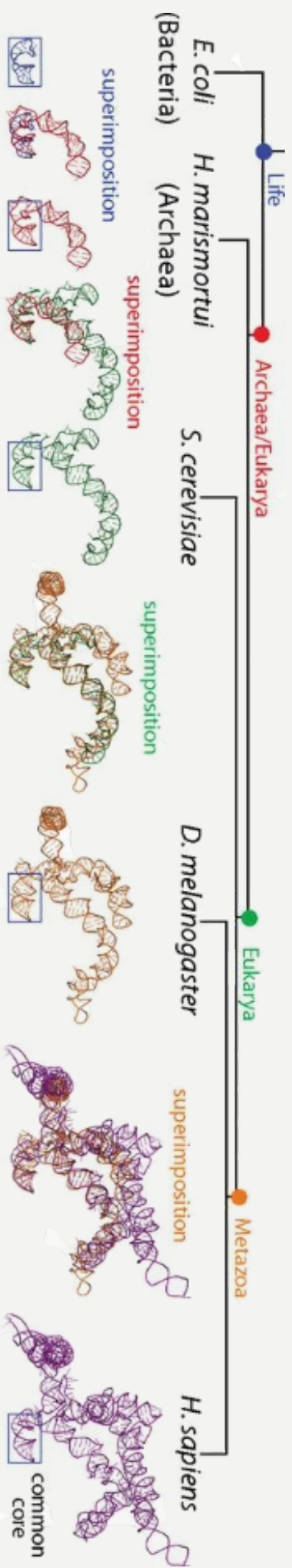


C. Darwin, *On the Origin of Species* 1859, Down, Bromley, Kent *London*.

Starting from what is Factual

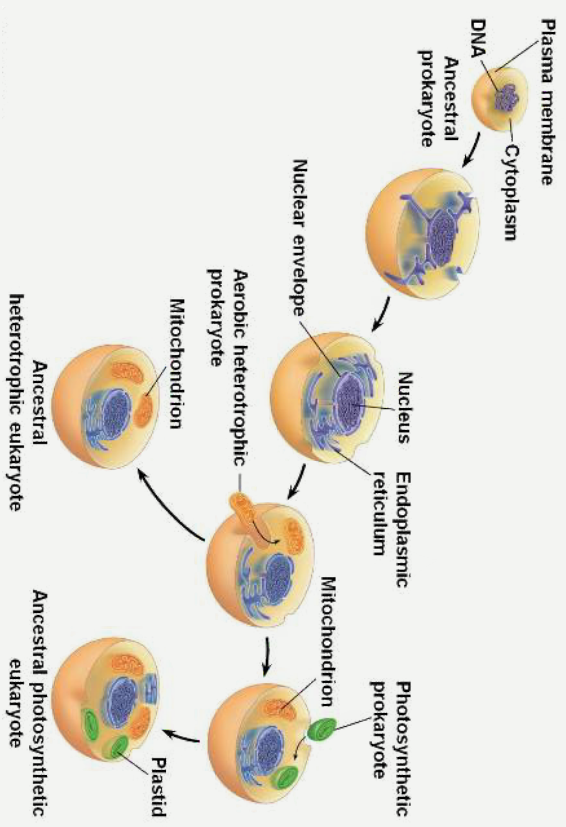
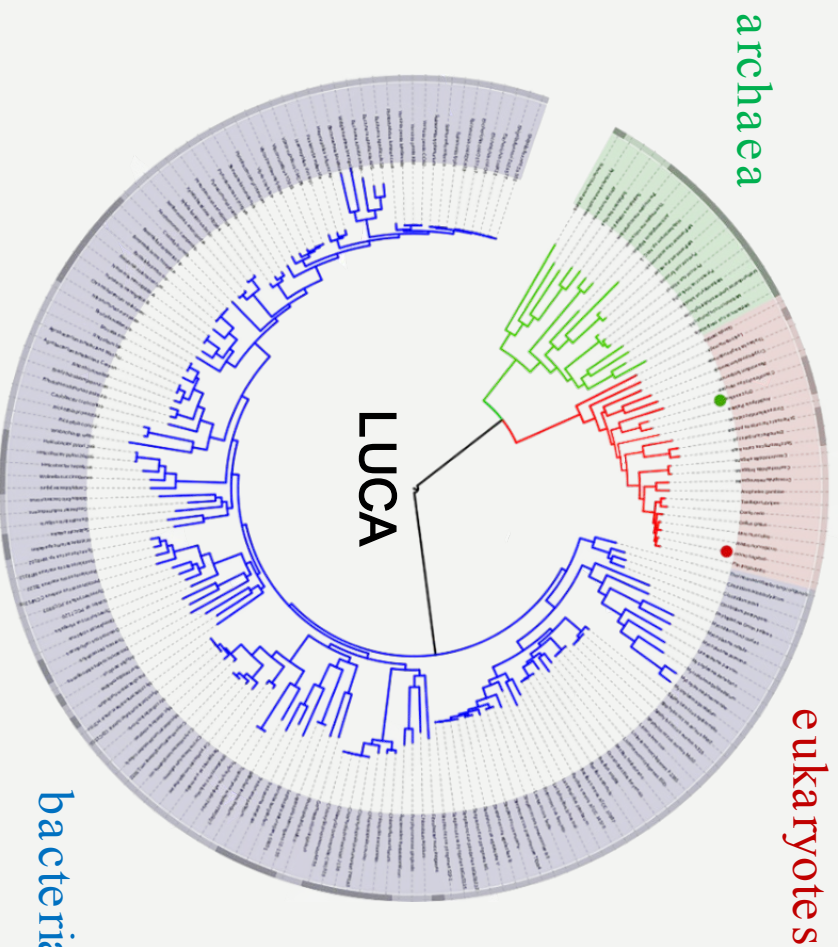
LUCA – *last universal common ancestor*

Comparison of 25/ES 7 of large subunit rRNA



L. Hays, L. Archenbach, J. Bailey, R. Barnes, J. Barros, C. Bertka, P. Boston, E. Boyd, M. Cable, I. Chen, *Astrobiology Strategy* 2015.

Starting from what is Factual



L. Hays, L. Archenbach, J. Bailey, R. Barnes, J. Barros, C. Bertka, P. Boston, E. Boyd, M. Cable, I. Chen, *Astrobiology Strategy 2015*.

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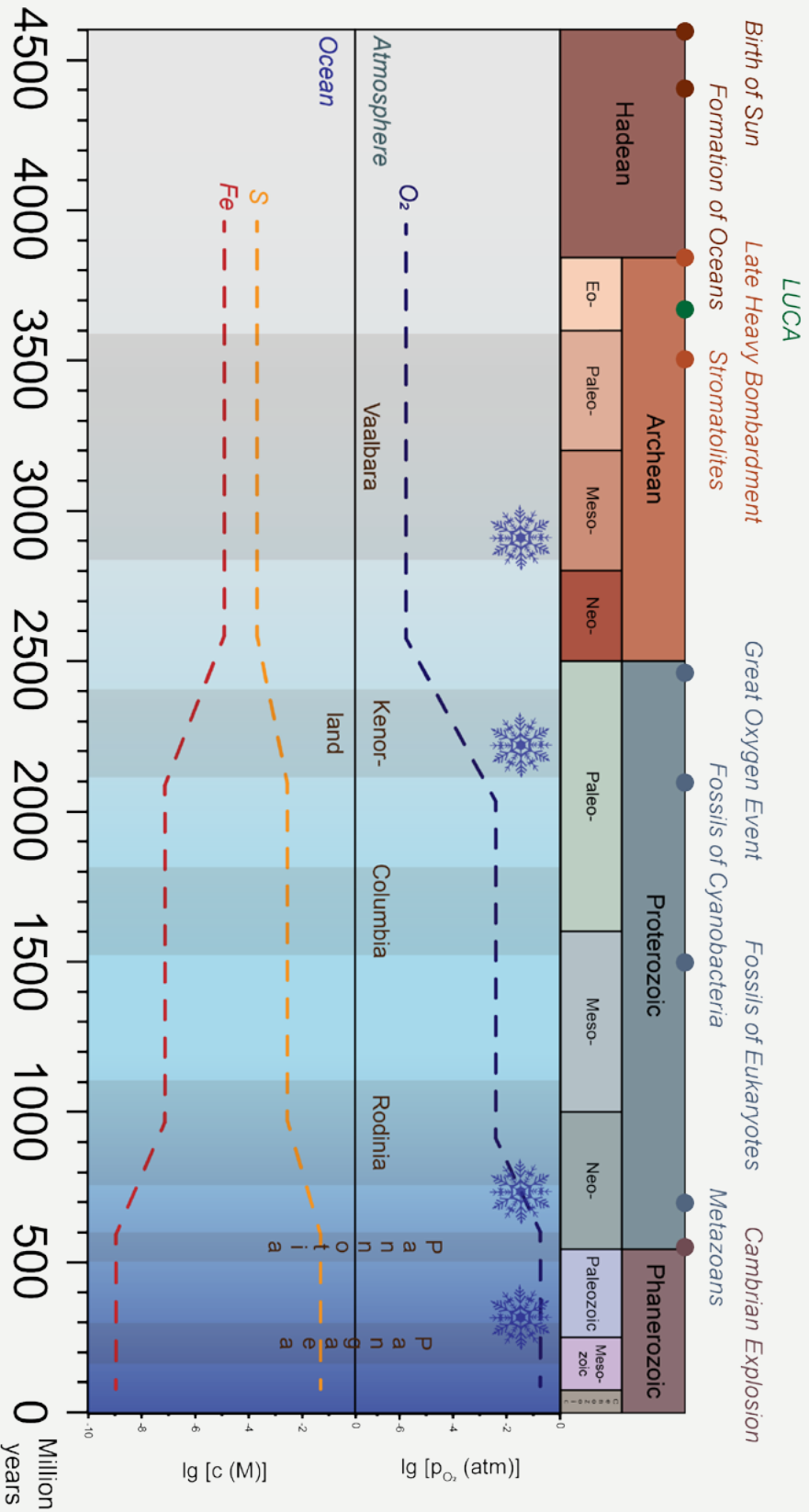
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(1) MULTIPLICITIES OF POSSIBLE ORIGIN(S) OF LIFE



Starting from what is Factual

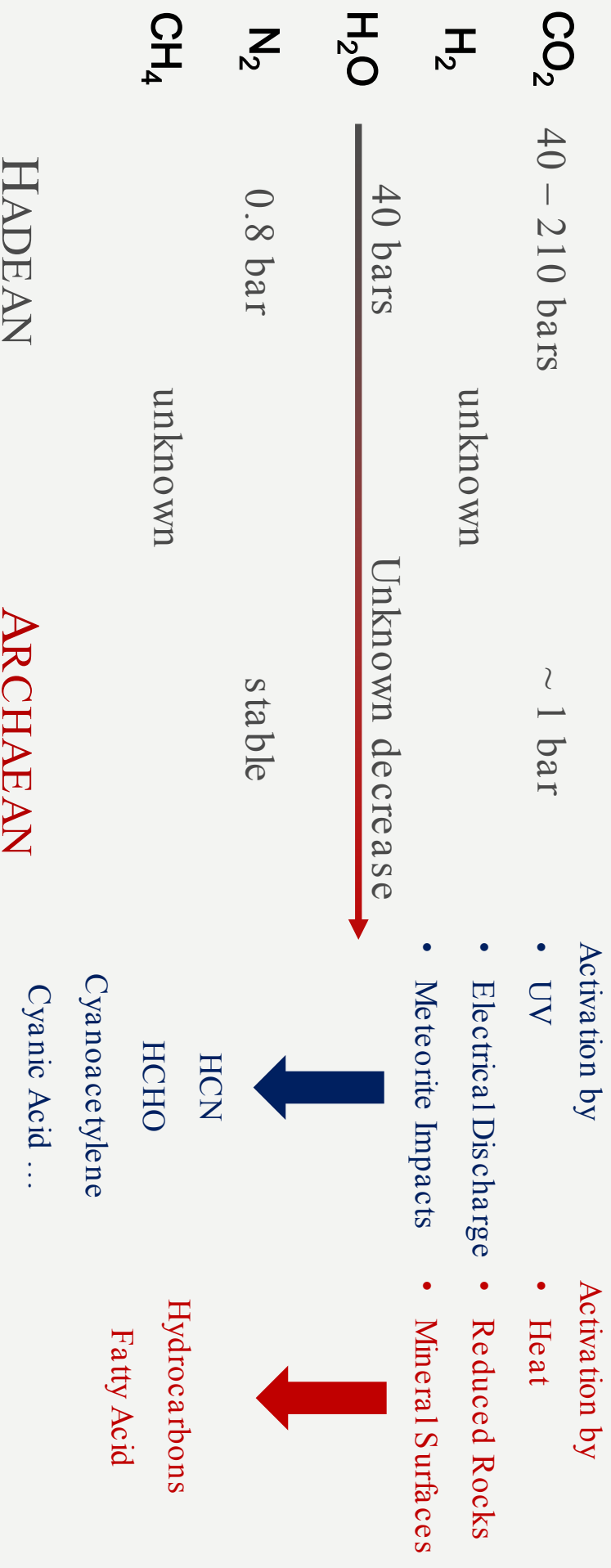


L. Hays, L. Archenbach, J. Bailey, R. Barnes, J. Barros, C. Bertka, P. Boston, E. Boyd, M. Cable, I. Chen, *Astrobiology Strategy 2015*.

Consequences:

- Earth at time of origin of life highly dynamic system:
out of equilibrium
- **Atmosphere:** Changing composition
volcanic out-gassing: CO_2 , H_2O , H_2S , N_2 , NH_3
reductive atmosphere: N_2 , H_2O , CH_4 , NH_3
- **Hydrosphere:** Acid leach of basaltic rocks; thousand of
years of continuous rain; salification; tides by moon
- **Lithosphere:** Crust formation, tectonic movement thermal
vents and volcanism
- Young sun irradiation flux; day and night cycles

Starting from what is Factual



Starting from what is Factual

Table 1. The 16 molecules used to fit the COSAC mass spectrum.

Name	Formula	Molar mass (u)	MS fraction	Relative to water
Water	H ₂ O	18	80.92	100
Methane	CH ₄	16	0.70	0.5
Methanenitrile (hydrogen cyanide)	HCN	27	1.06	0.9
Carbon monoxide	CO	28	1.09	1.2
Methylamine	CH ₃ NH ₂	31	1.19	0.6
Ethanenitrile (acetonitrile)	CH ₃ CN	41	0.55	0.3
Isocyanic acid	HNCO	43	0.47	0.3
Ethanal (acetaldehyde)	CH ₃ CHO	44	1.01	0.5
Methanamide (formamide)	HCONH ₂	45	3.73	1.8
Ethylamine	C ₂ H ₅ NH ₂	45	0.72	0.3
Isocyanomethane (methyl isocyanate)	CH ₃ NCO	57	3.13	1.3
Propanone (acetone)	CH ₃ COCH ₃	58	1.02	0.3
Propanal (propionaldehyde)	C ₂ H ₅ CHO	58	0.44	0.1
Ethanamide (acetamide)	CH ₃ CONH ₂	59	2.20	0.7
2-Hydroxyethanal (glycolaldehyde)	CH ₂ OHCHO	60	0.98	0.4
1,2-Ethanediol (ethylene glycol)	CH ₂ (OH)CH ₂ (OH)	62	0.79	0.2

<https://www.astro.uni-koe.ln.de/cdms/molecules>

Starting from what is Not Factual

Uncertainty of:

- Temperature range
- Pressure range
- Feedstock molecules
- Characteristics of reaction sites
- Cyclic dependence of environmental parameters
- Irradiation flux

(2) CENTRAL OPEN QUESTIONS



Astrophysics



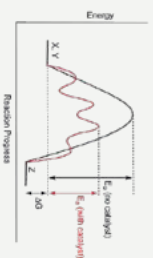
Geochemistry



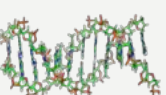
Analytical Chem



Organochemistry



Biochemistry



Synthetic Biology



Evolutionary Bio



organic free
Earth

- pyrolyse of all organic matter

geochemistry
exo. supply

- atmospheric, hydrospheric, litospheric chemistry
- extraterrestrial supply of organics

reaction
networks

- complex reaction paths
- changing conditions
- continuous drive away from equilibrium
- temperature/ pressure/irradiation

(organo)-
catalysts

- coenzymes
- nucleotides
- redox potent molecules
- chromophores
- metall ions/cluster
- amphiphiles
- surfaces

functional
polymers

- DNA
- RNA
- proteins
- lipids
- polysaccharides

protocells

- compartmentalization
- metabolism
- enzyme evolution
- signaling/feedback

LUCA

- Ribosomes
- ATPase
- cell membrane
- cell wall
- cytoplasm, cytoskeleton

Selfamplification

Homochirality

Selfassembly

Chemical Evolution

Darwinian Evolution

Defining Terms and Conditions

Darwinian Evolution

Chemical Evolution

Overpopulation

Multiple reaction sides

Heritable phenotypic variations

Concentration variations
Additives

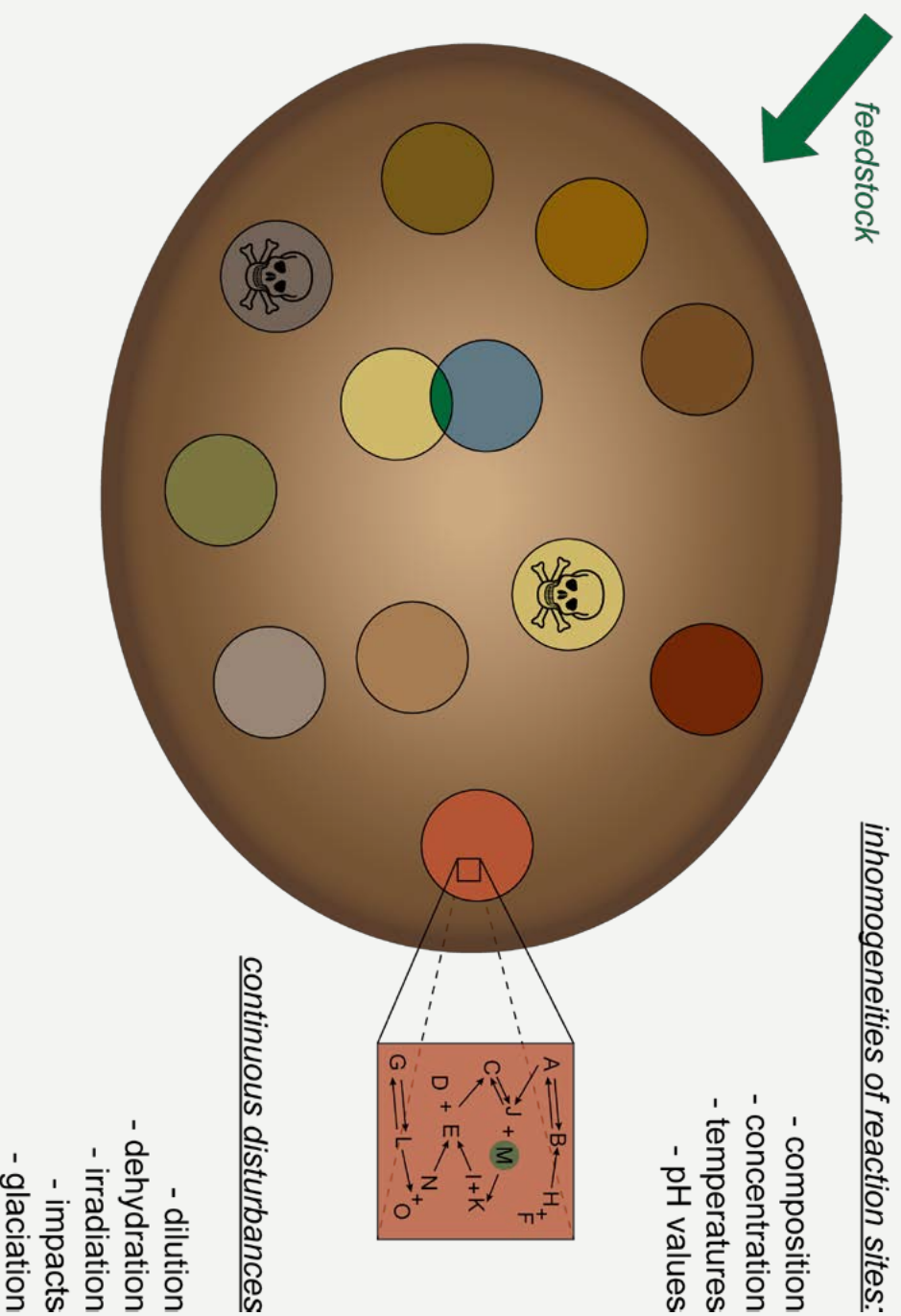
Environmental pressure

Changing environmental
conditions

Isolation

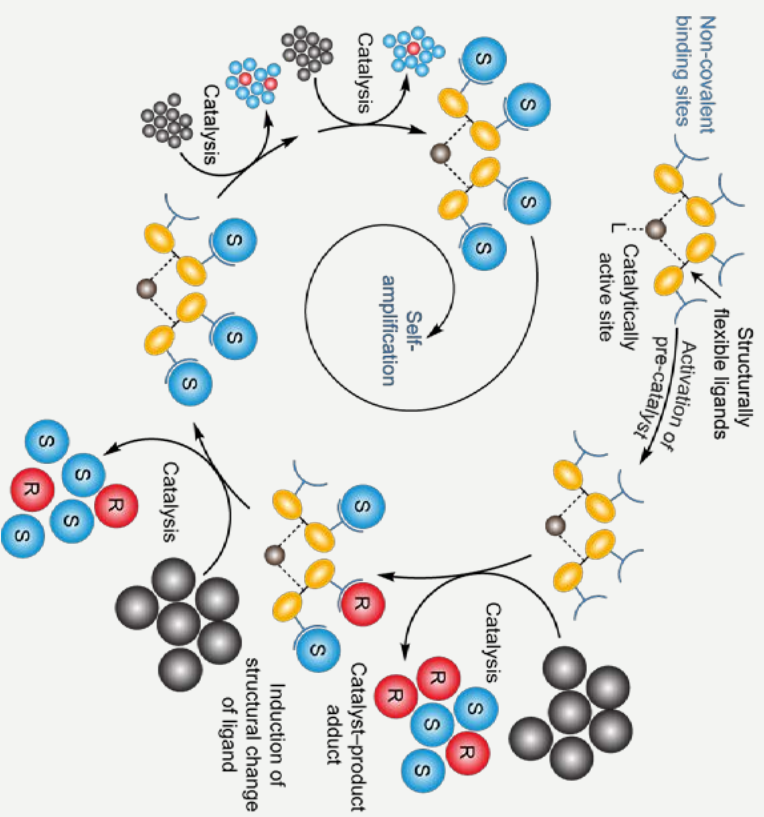
Separation by geophysical
processes or by encapsulation
in micelles or bilayers

Out of Equilibrium – *Cyclic Disturbances*



Recognition-Interaction-Principle

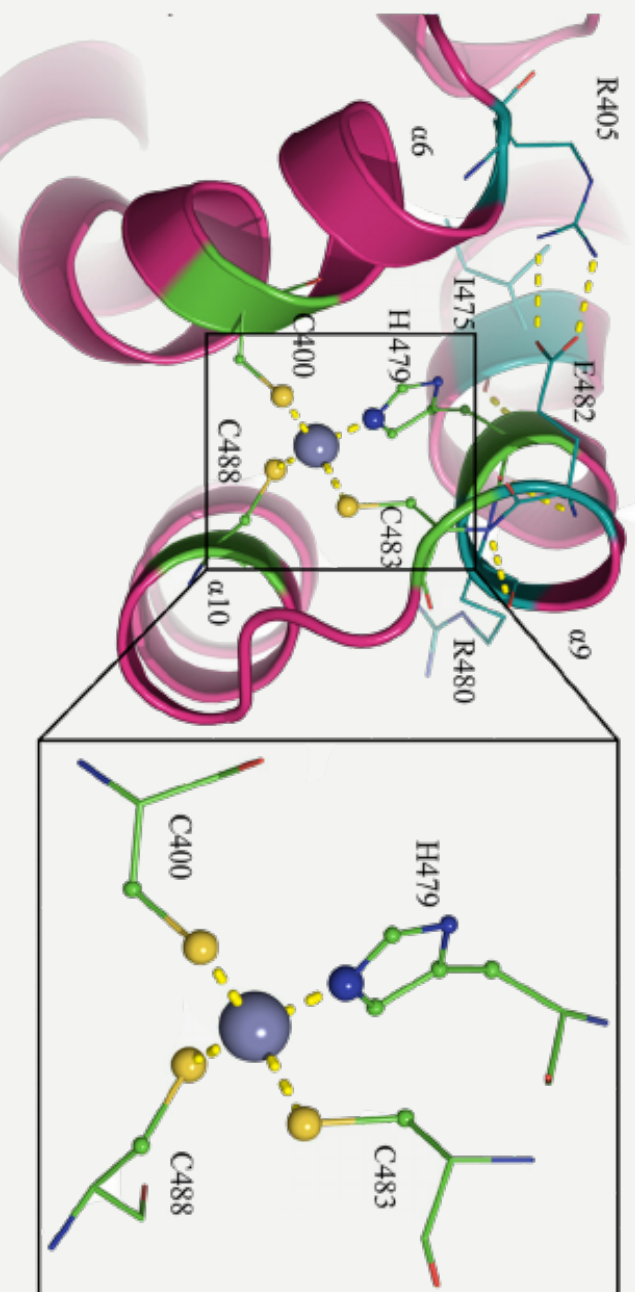
Research into Autocatalysis



G. Storch, O. Trapp, *Nat Chem* **2017**, *9*, 179-187.

Interaction-prone molecules

Amino acids



Pictures:

- [https://www.google.de/search?q=Life&source=lnms&tbm=isch&sa=X&ved=0ahUKEwIV5JzatkVAhXC7hokKHcO8AiYQ_AUIBiqB&biw=1922&bih=971#tbm=isch&q=gr](https://www.google.de/search?q=Life&source=lnms&tbm=isch&sa=X&ved=0ahUKEwIV5JzatkVAhXC7hokKHcO8AiYQ_AUIBiqB&biw=1922&bih=971#tbm=isch&q=growing+plant&imgsrc=tucYZqOffL1woM:)
<https://www.nasa.gov/>
<https://www.colourbox.de/vektor/struktur-des-humanen-immundefizienz-virus-vektor-6886573>
[https://m.blog.naver.com/PostView.nhn?blogId=ohryan77&logNo=60201568634&proxyReferer=https%3A%2F%2Fwww.google.de%2F](https://m.blog.naver.com/PostView.nhn?blogId=ohryan77&logNo=60201568634&proxyReferer=https%3A%2F%2Fwww.google.de%2FxyReferer=https%3A%2F%2Fwww.google.de%2F)
http://www.chem.wisc.edu/~cui/gallery_2.html
<https://upload.wikimedia.org/wikipedia/commons/b/bc/Butlerov.png>
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<https://www.emaze.com/@AQQCTOQZW/meteoroids>
http://web2.mendelu.cz/af_291_projekt2/vseo/files/26/1000.png