# Open questions in the origin of life

Purificación López-García

*Unité d'Ecologie, Systématique et Evolution, CNRS UMR8079, Université Paris-Sud, Orsay*

Team *"Microbial diversity and evolution":*

- Molecular and metagenomic approaches / various environments
- Molecular phylogeny and phylogenomics / early evolution

**Origin of life**

Scientific question

Historical question (contingency)

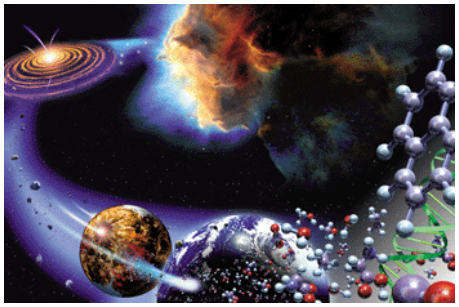
What?

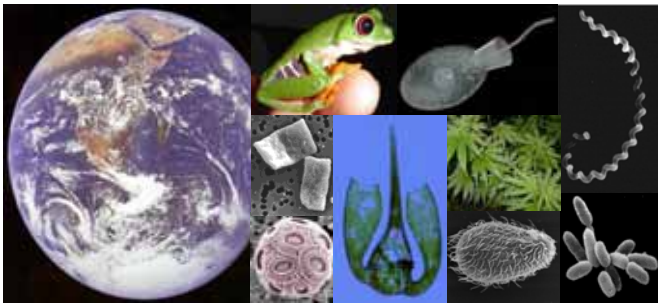
How?

Where?

When?

Elsewhere?





"Bottom-up"

"Top-down"

Prebiotic chemistry

First life forms

Astrophysics

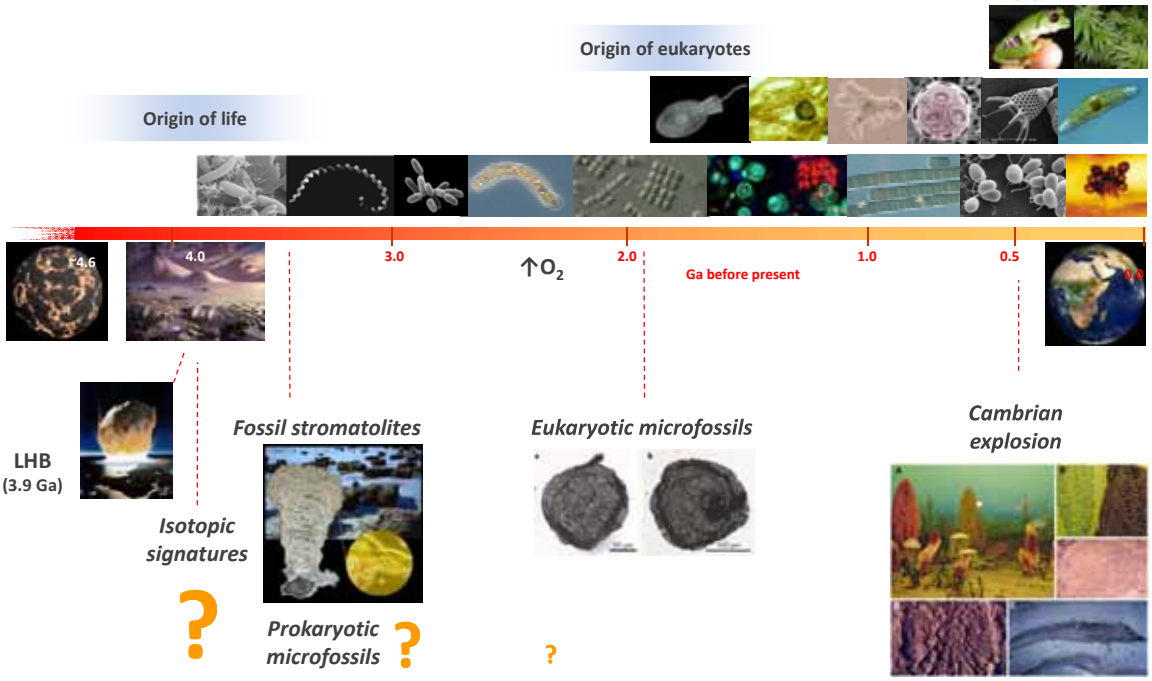
Chemistry

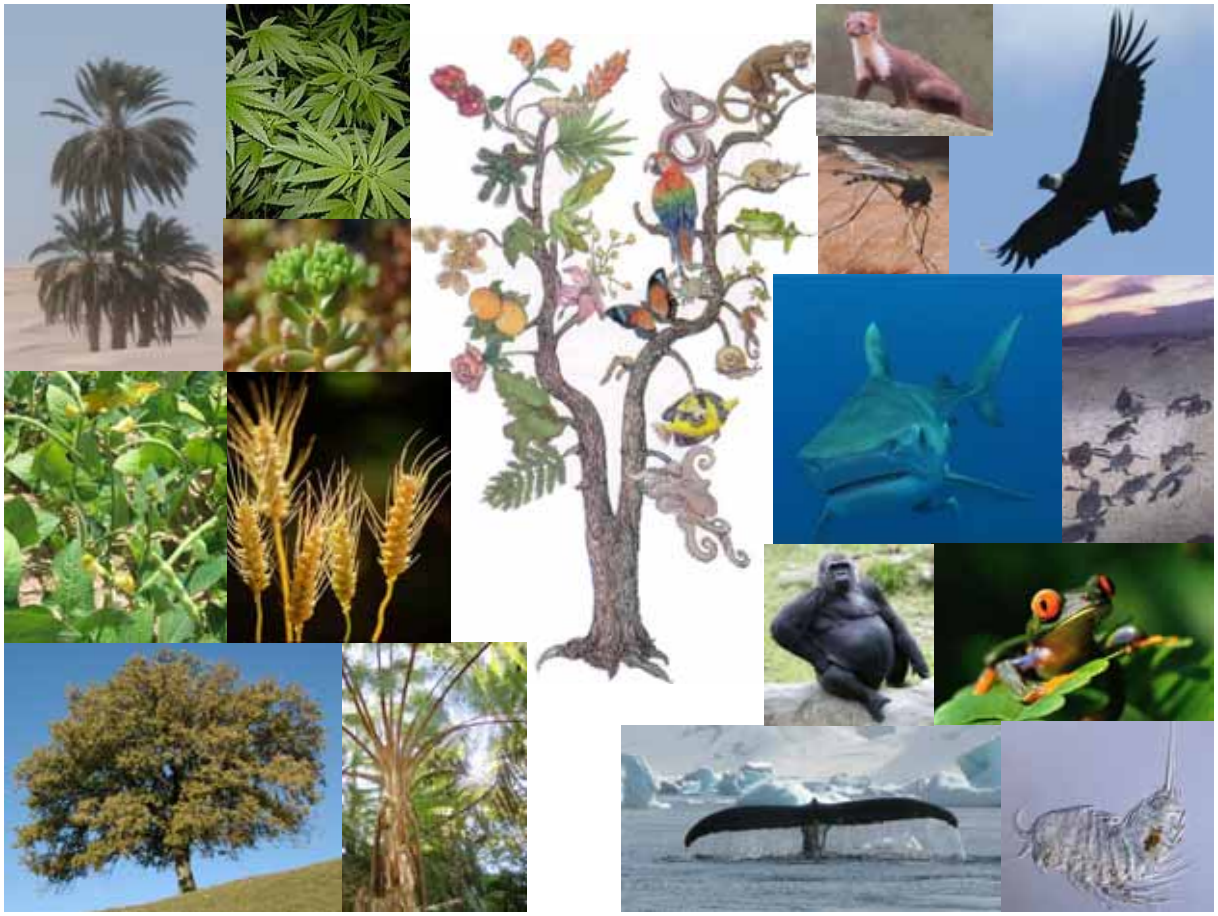
Origin of life

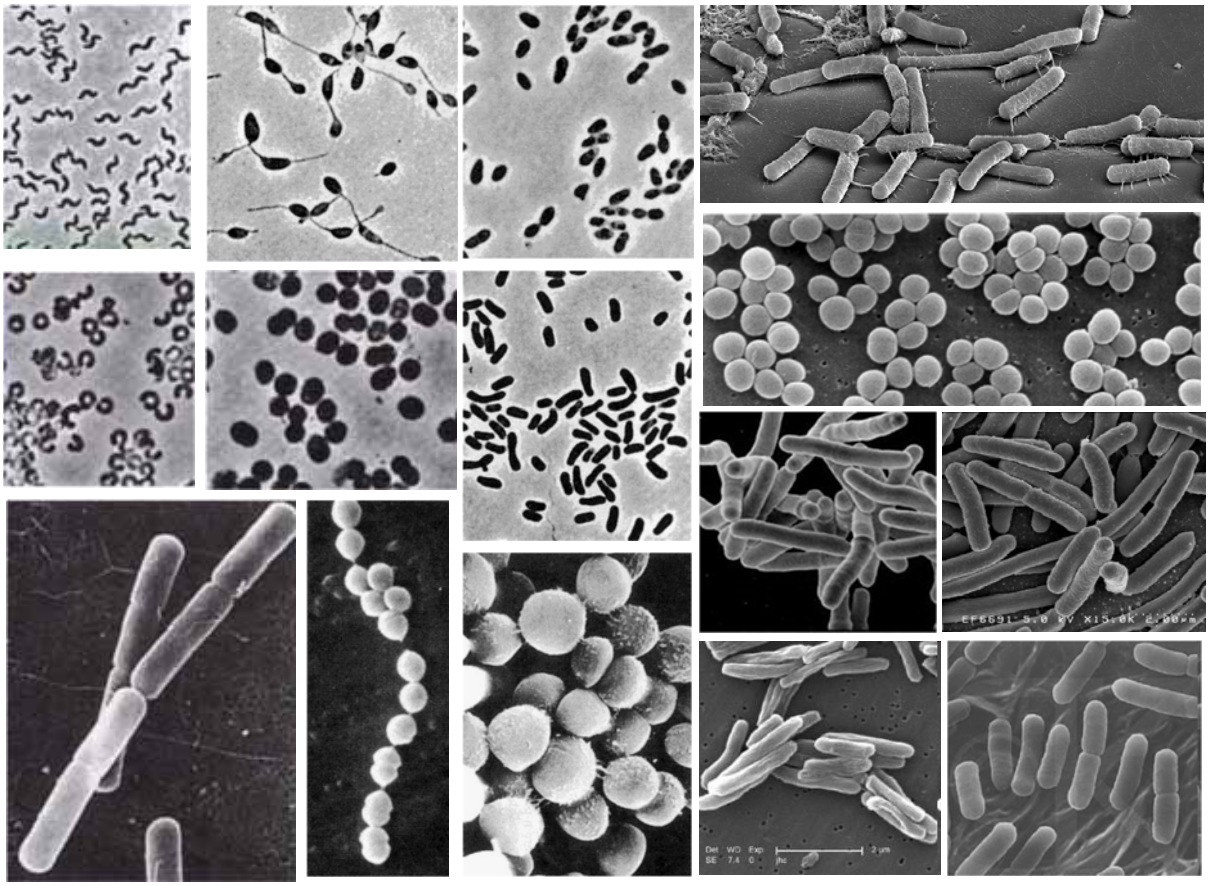
Biology

Geology

# A time framework for life evolution



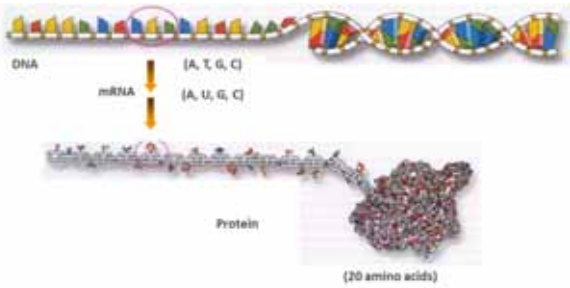





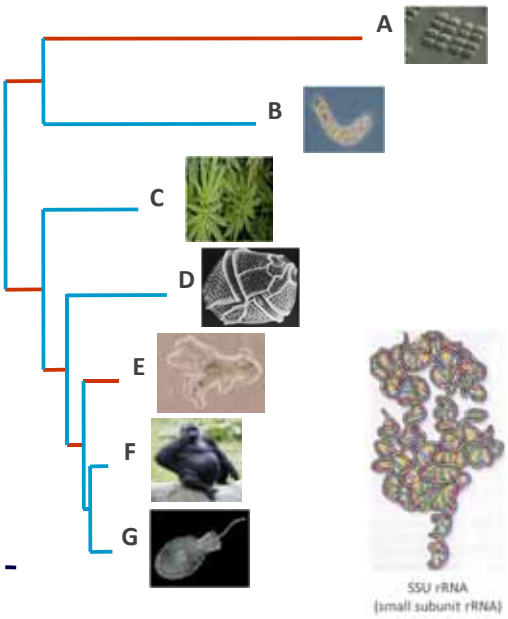
# Molecular phylogeny and natural classification

**E. Zuckerkandl & L. Pauling**

*Molecules as documents of evolutionary history (1965)*

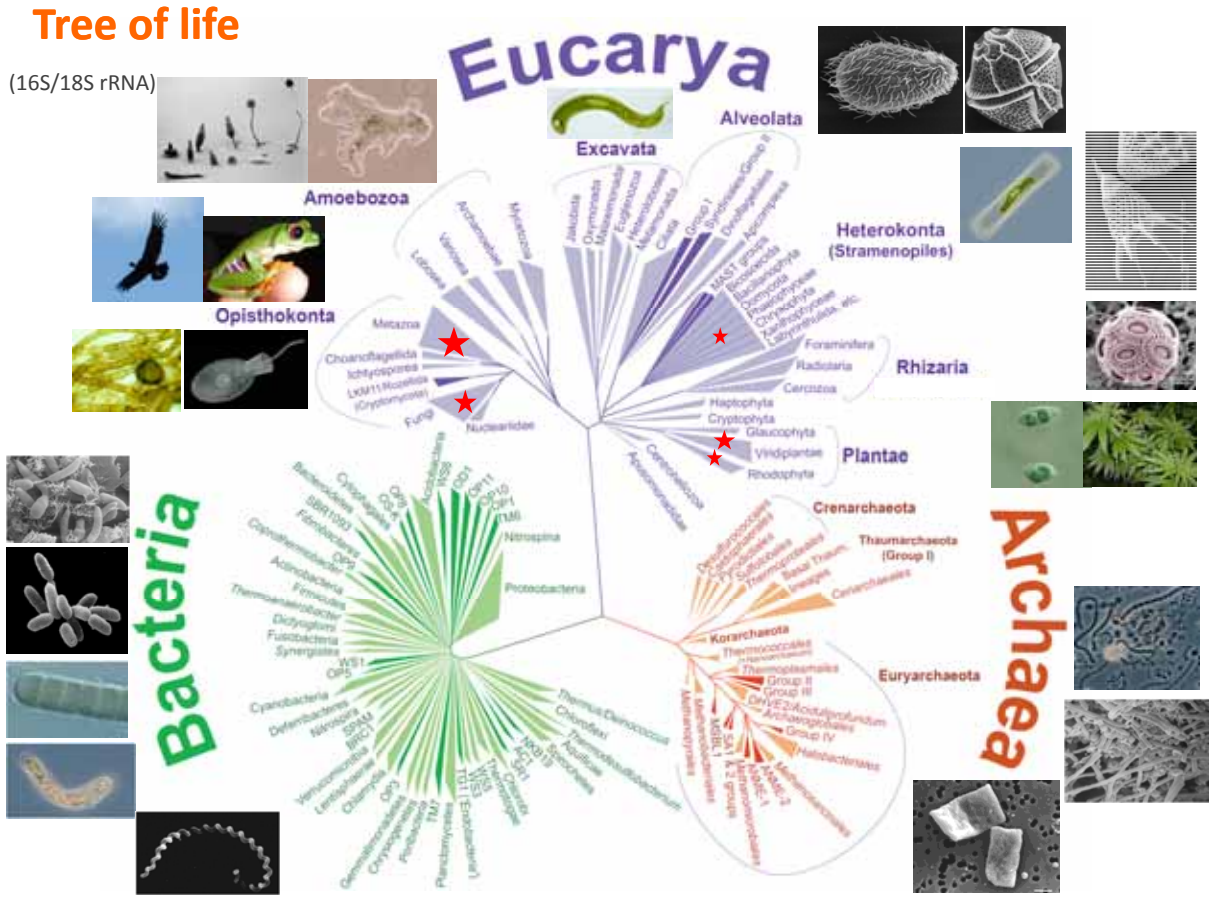



Phylogenetic trees based on universal genes

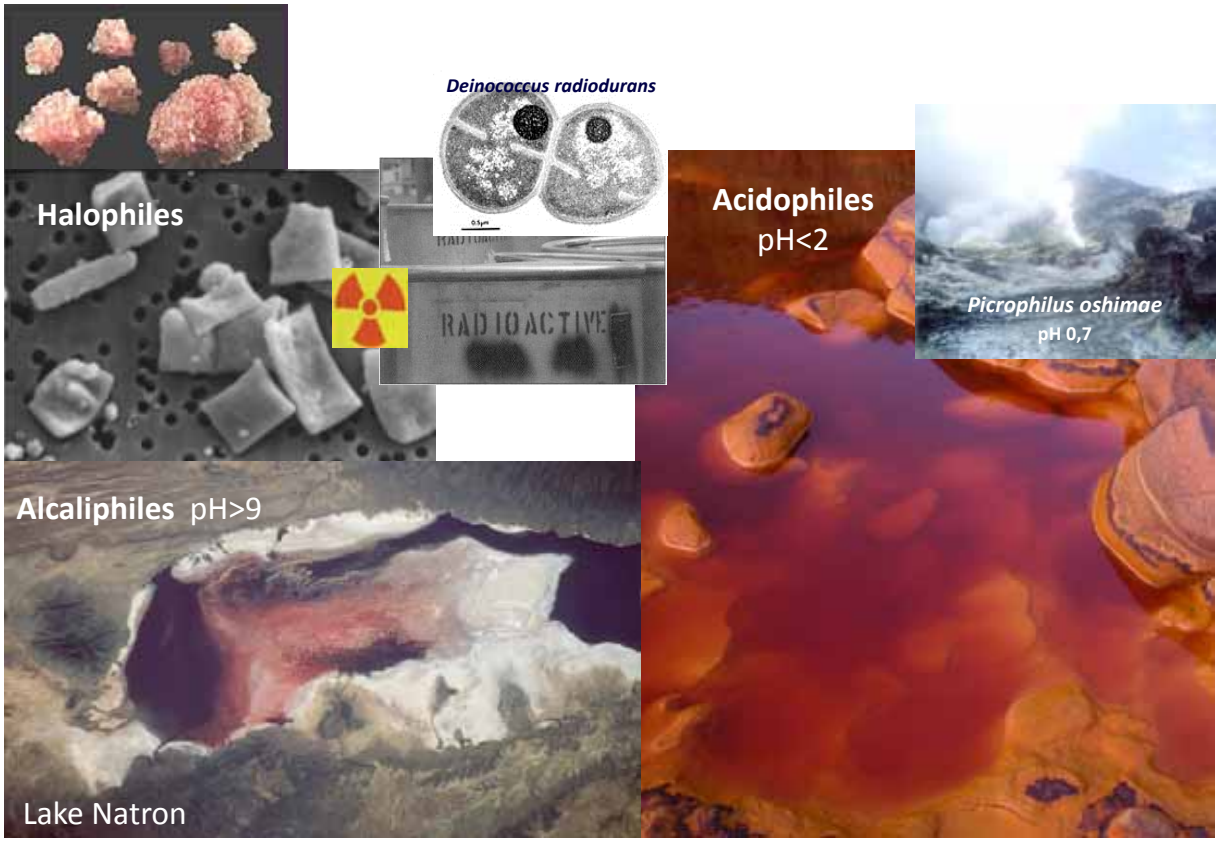


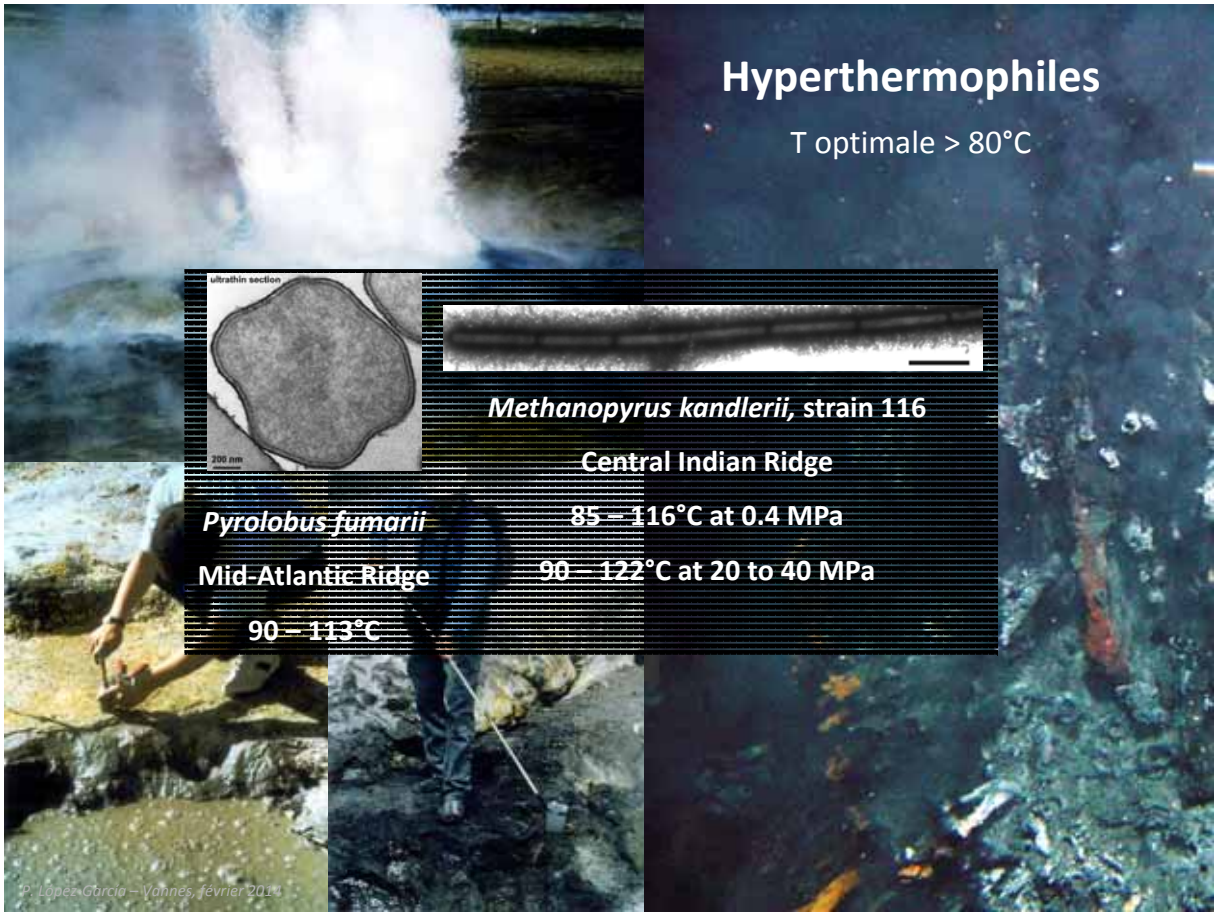
# Tree of life

(16S/18S rRNA)

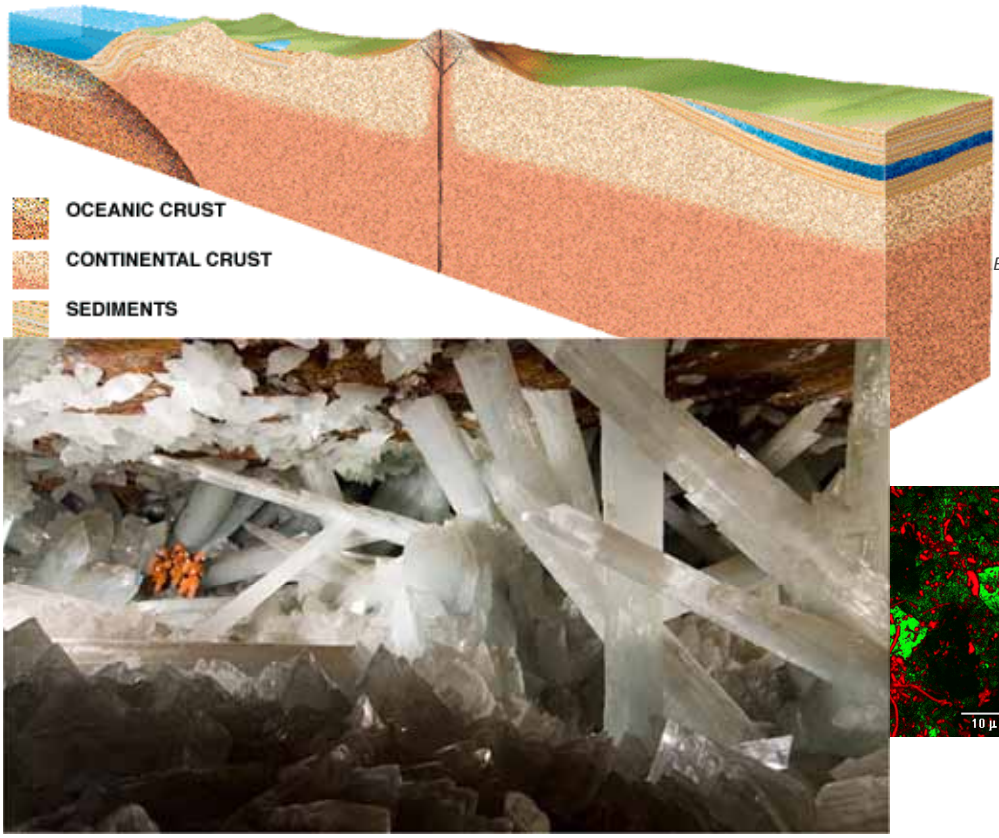


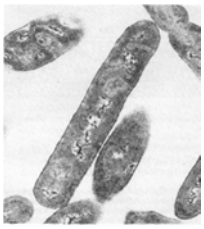
# Extreme environments



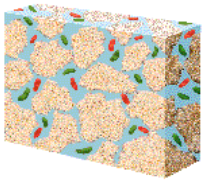



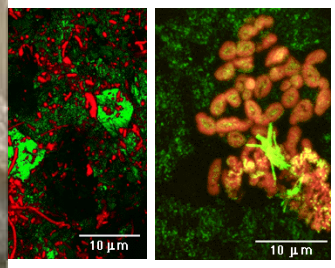
# The deep subsurface



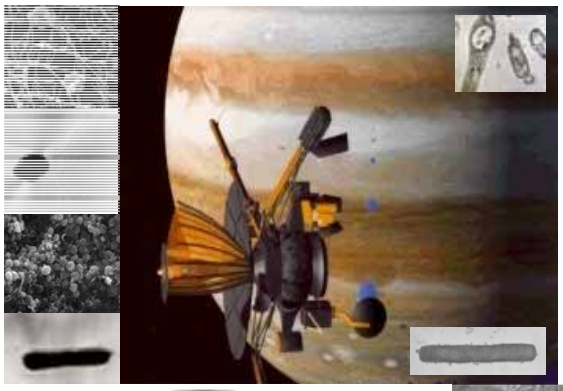



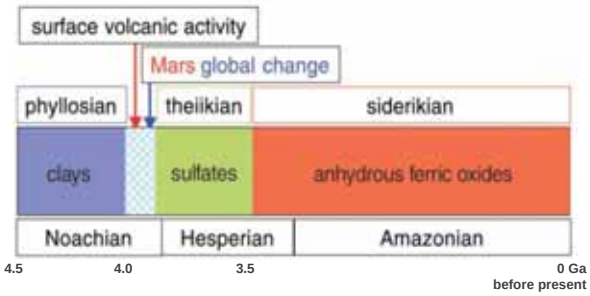
*Bacillus infernus* (2.7 Km)

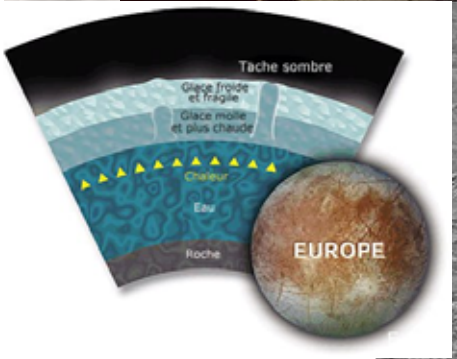




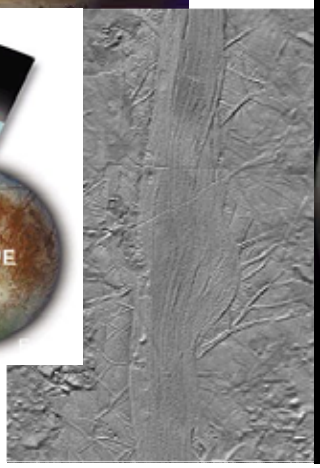

# Extremophiles and astrobiology





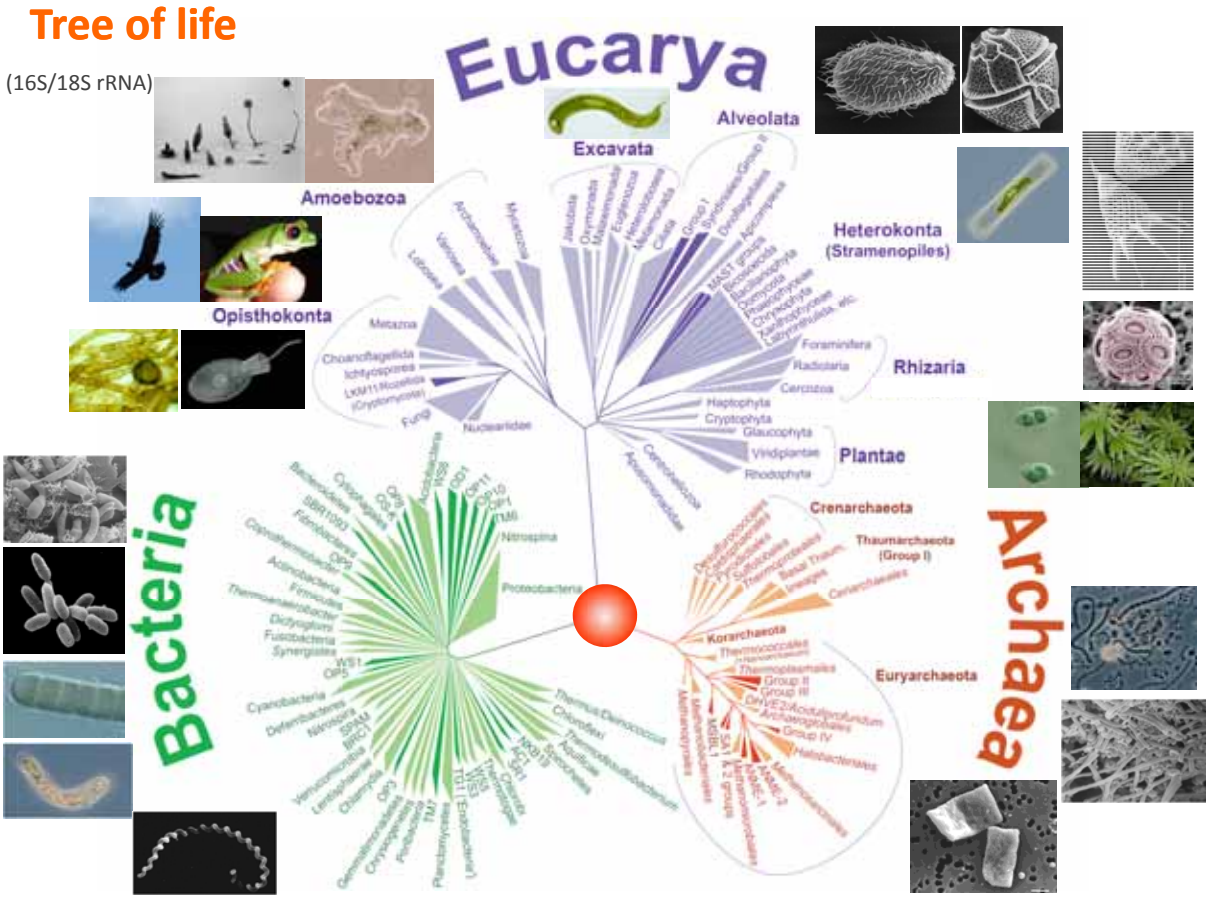

Europa?

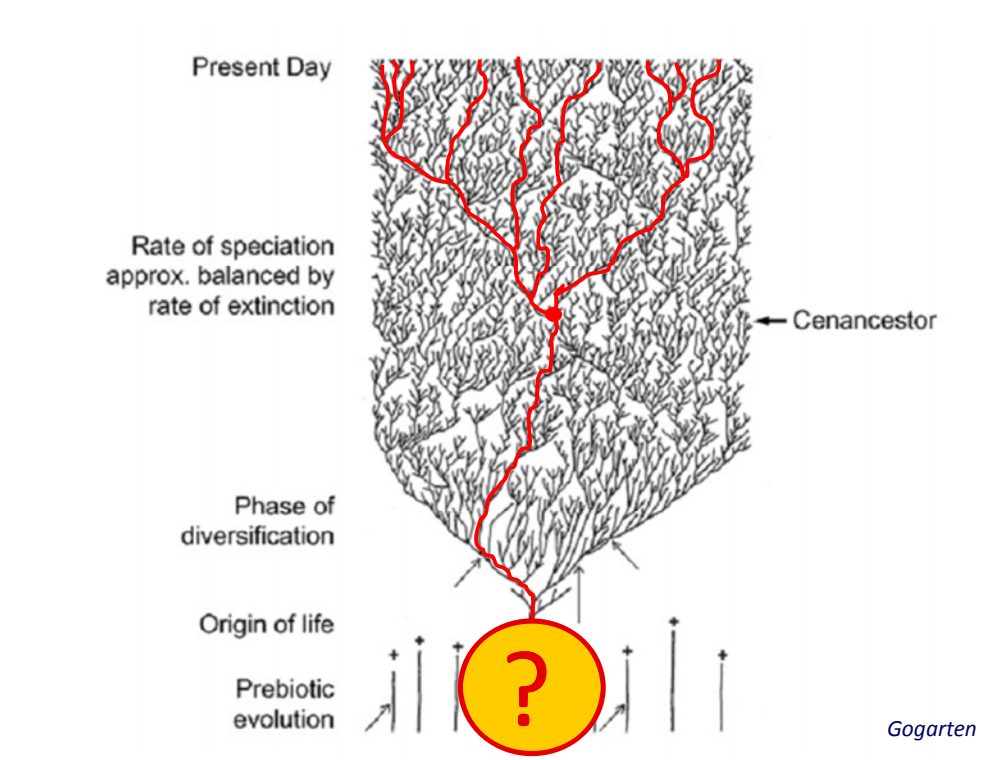


Mars?

# Tree of life

(16S/18S rRNA)



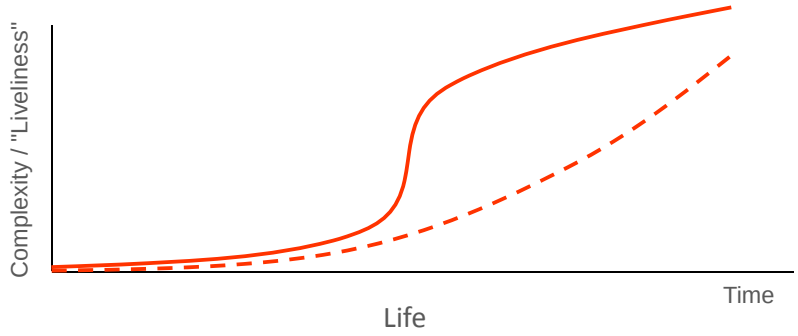




*Gogarten*

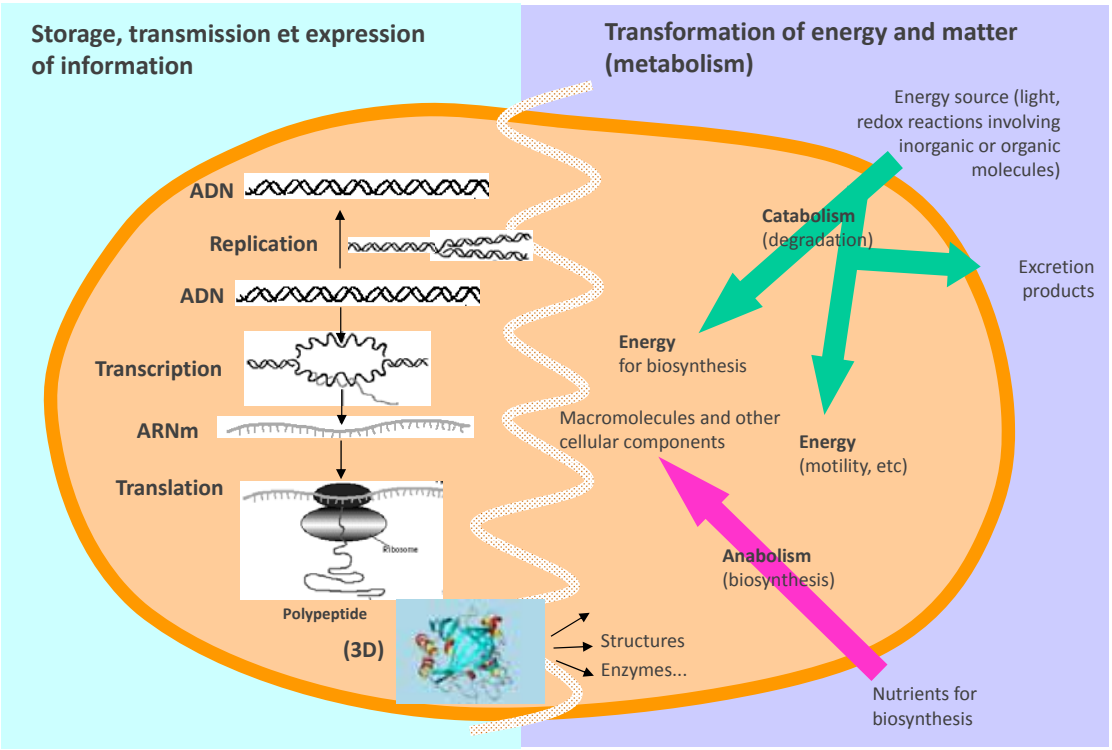
**Origin of life & last common ancestor are two separate events**

# Origin of life

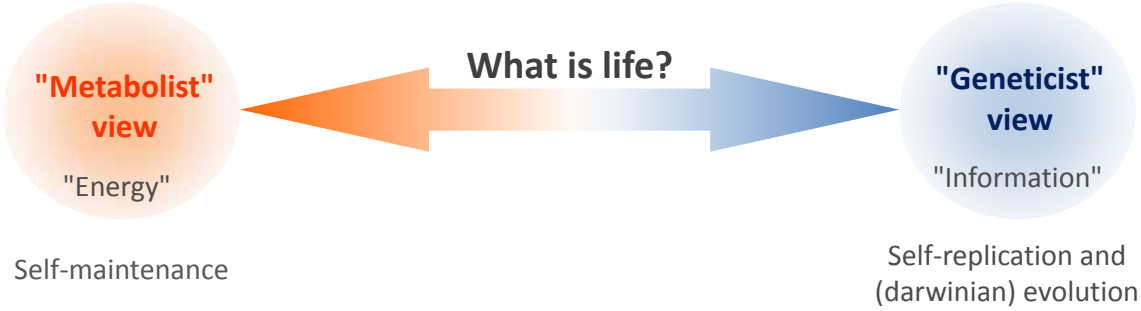
Transition from non-life to life




# The dual nature of the cell



## Origin and definition of life: two opposed views

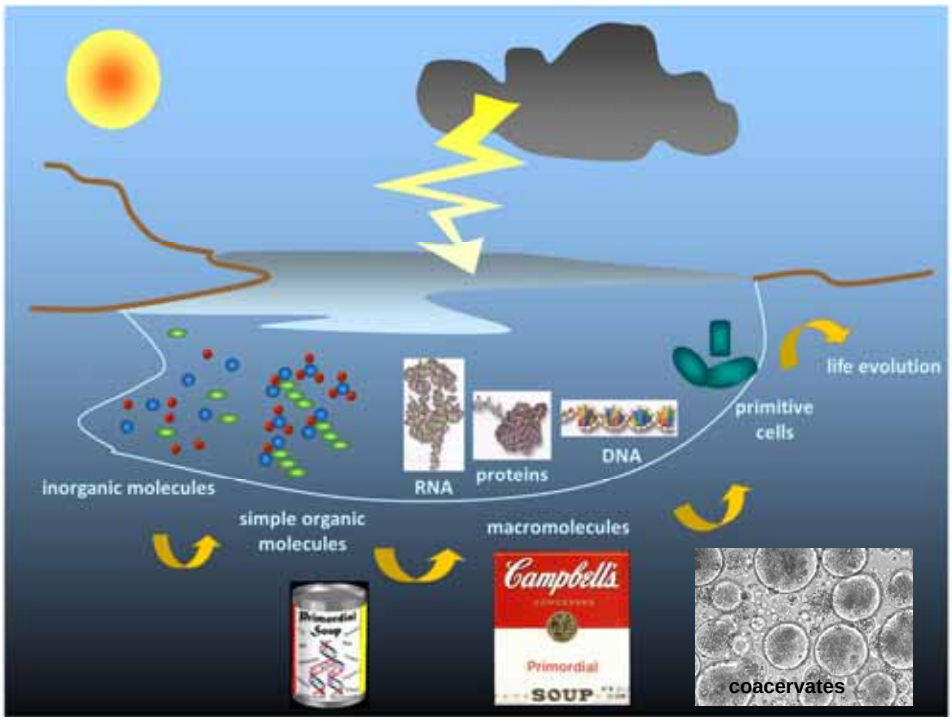



## "Metabolism" versus "genetics"-first models

## A cold, "heterotrophic" origin of life

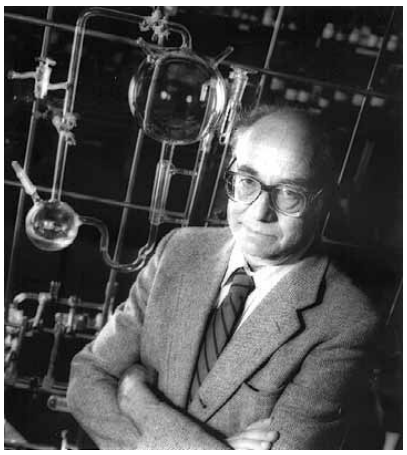
- Alexander I. Oparin (1924): life from a "colloidal chemistry" perspective
- John Haldane (1929): "primordial soup"

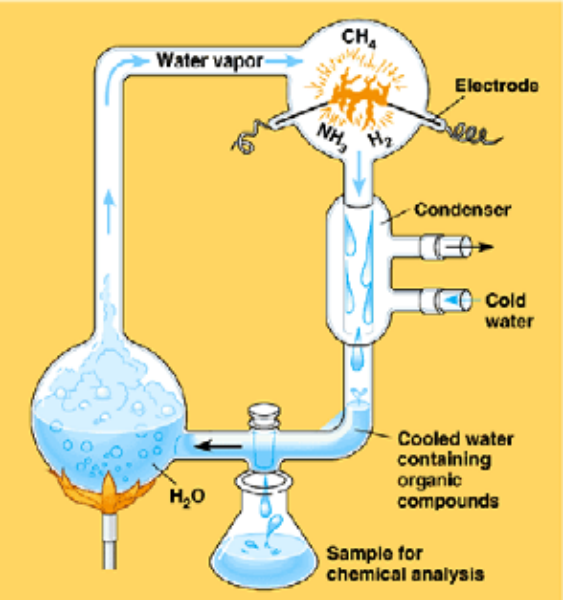
Aleksandr Ivanovitch Oparin (1894-1980)



# Stanley Miller's experiment

1953



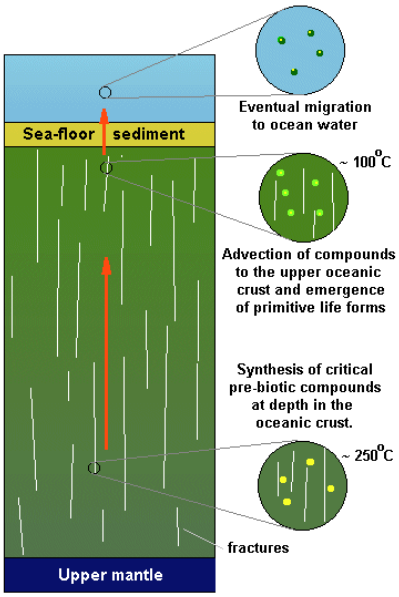



**Reducing gaz mixture**

**$H_2$, $CH_4$, $NH_3$, $H_2O$**

# A hot, "autotrophic" origin of life

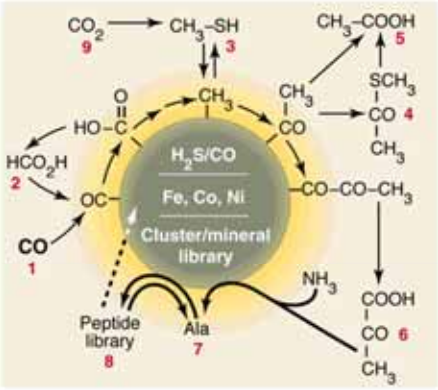
The iron-sulfur world, G. Wächtershäusser, 1988




**1st. Autocatalytic metabolic network**

Redox reactions

C fixation



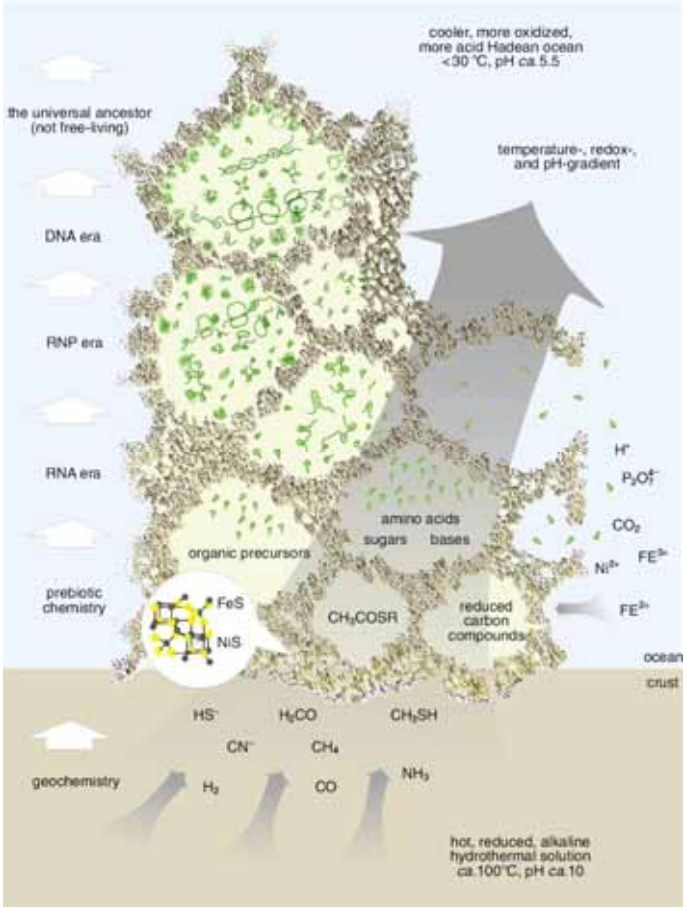

**2nd. Co-evolution of genetic machinery & cellularization**

Nucleic acids – catalysts for peptide formation

Co-evolution of replication & translation (contrary to soup models)

Membrane development based on phospholipids

Chemosmosis & pyrophosphate (ATP later)




**Martin & Russell, 2003**

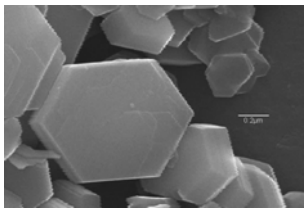
# "Genetics-first" models

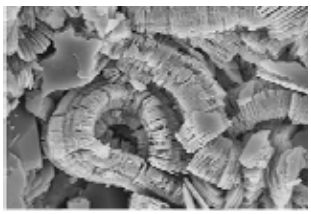
**Herman Müller**:
The first life form might have been a "gene" (1922)

Potential precursors of DNA polymers:

**Graham Cairns-Smith:** clays (formed from suspended silicates)
[life as a self replicative system capable of evolving]

Seven Clues to the Origins of Life 1985

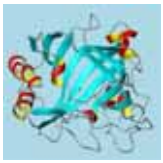




## Protein or DNA?

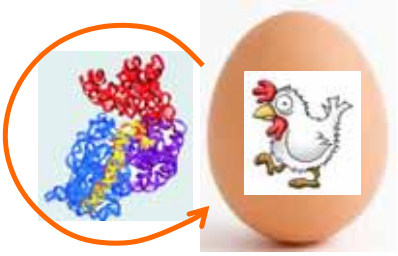
catalysis

genetic information



## ... RNA: the RNA world

Catalysis and genetic information
in the same molecule



## Hypothesis of an RNA world: difficulties

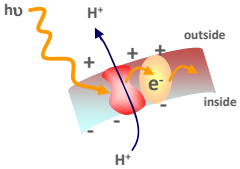
Many "RNA worlds" in the "RNA world" (now we need the details!)

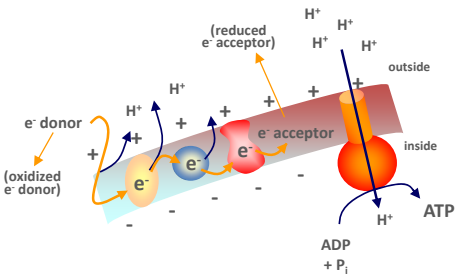
RNA-only world → RNA-peptide world → RNA-peptide-membranes

Problems with potential (efficient) prebiotic synthesis

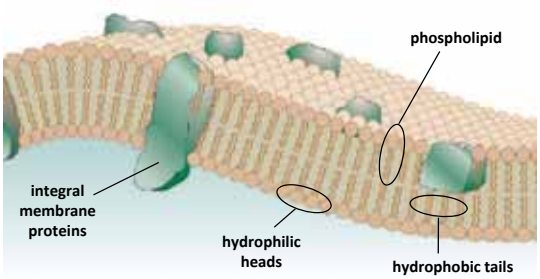
(oligo)peptides RNA

Does not resolve the origin of energetic metabolism

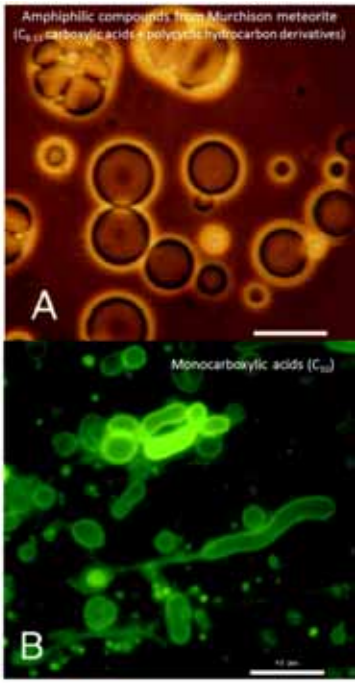


# Cell compartments




Vesicles = chemical reactors

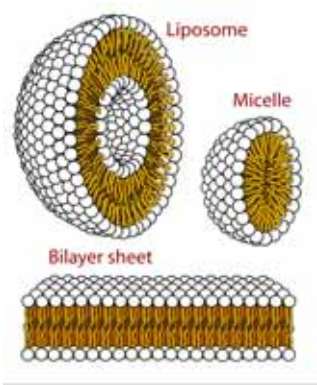



Monnar & Deamer, 2002

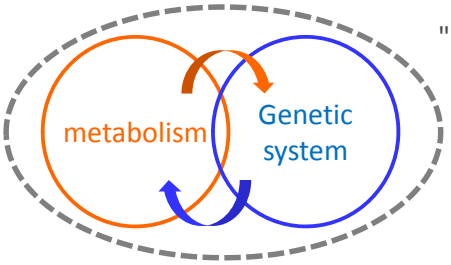
**Amphiphilic molecules auto-assemble**

Fatty acids
Isoprenoids

Bilayers

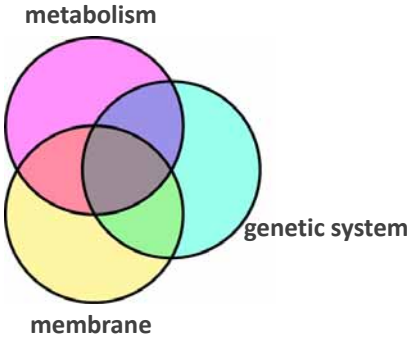


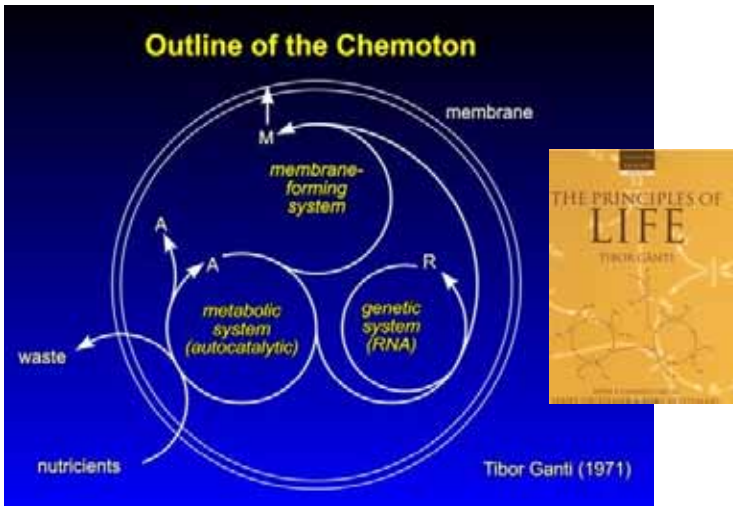

# The origin of life: a co-evolutionary process?

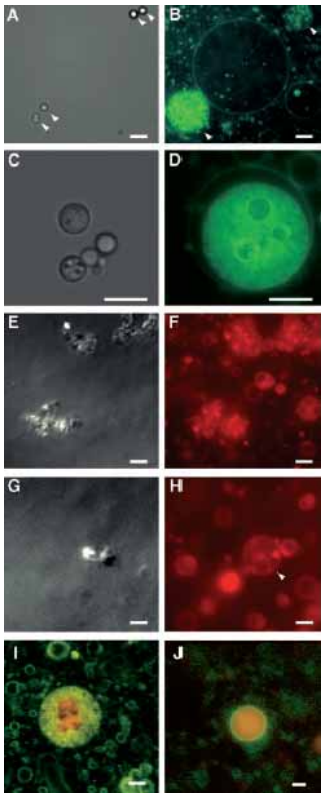



"Proto-cell"

The pragmatic approach of synthetic biology



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## Experimental Models of Primitive Cellular Compartments: Encapsulation, Growth, and Division

Martin M. Hanczyc,* Shelly M. Fujikawa,* Jack W. Szostak†

Montmorillonite accelerates conversion fatty acid micelles into vesicles

Such vesicles can grow and divide

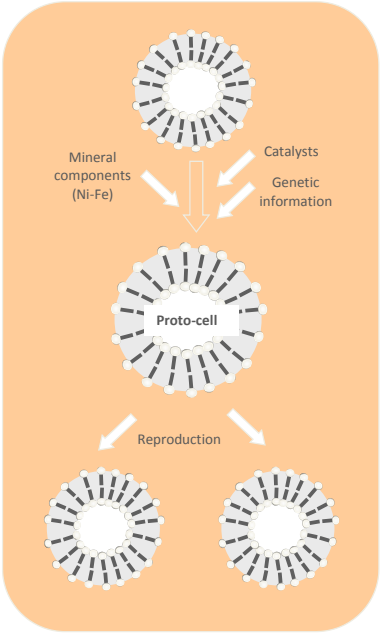
RNA adsorbed to clays is incorporated

Growing vesicles – incipient ion gradients

Chen & Szostak 2004

Cross-replication of two ribozymes in vesicles

Voytek SB, Joyce GF (2009)




# Thank you

# спасибо