6 THE ORIGIN OF TERRESTRIAL LIFE AND THE QUEST OF LIFE IN THE UNIVERSE

1. The first traces of terrestrial life
2. The tree of life and LUCA
3. The selfish gene
4. The search of life in the Universe
5. Where are they?

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6.1 THE FIRST TRACES OF TERRESTRIAL LIFE

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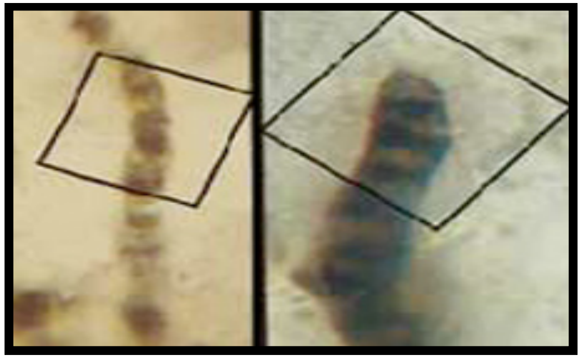
THE OLDEST FOSSILS

6.Origin & quest

6.1 Traces

1- Micro-fossiles of cyanobacteria found in Australia and that date 3.5 billions years



2- Stromatolites that date 3.8-2.5 billions years

PROBLEM: THE DATA INTERPRETATION IS VERY CONTROVERSIAL BECAUSE ENTIRELY BASED ON MORPHOLOGY

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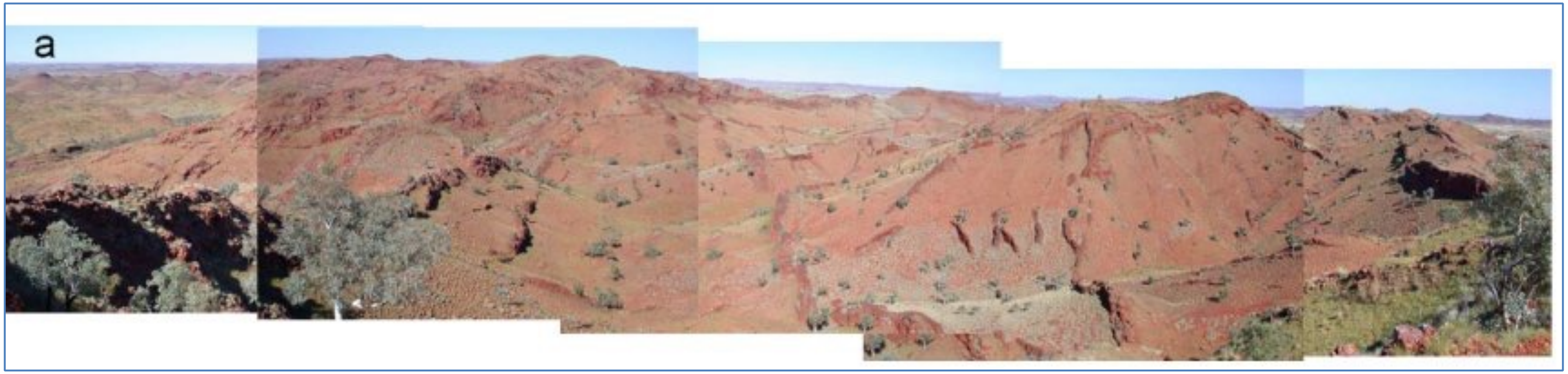
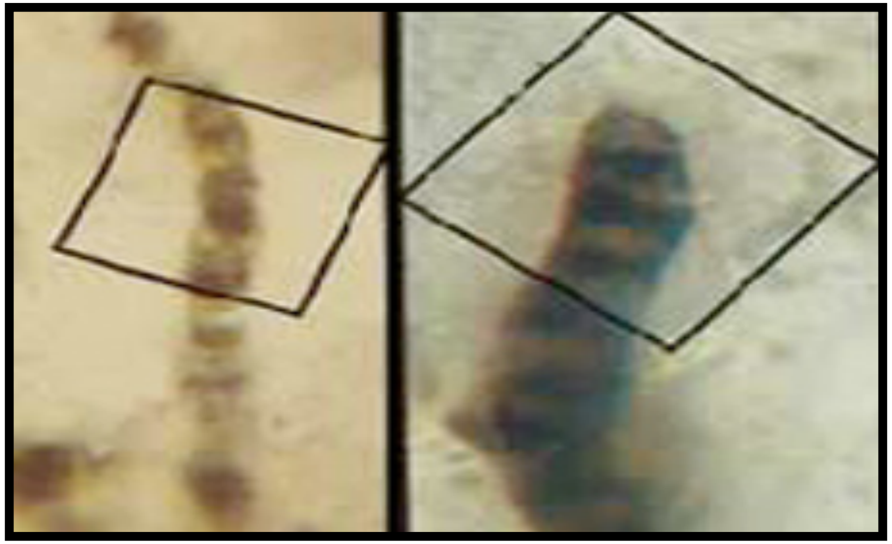
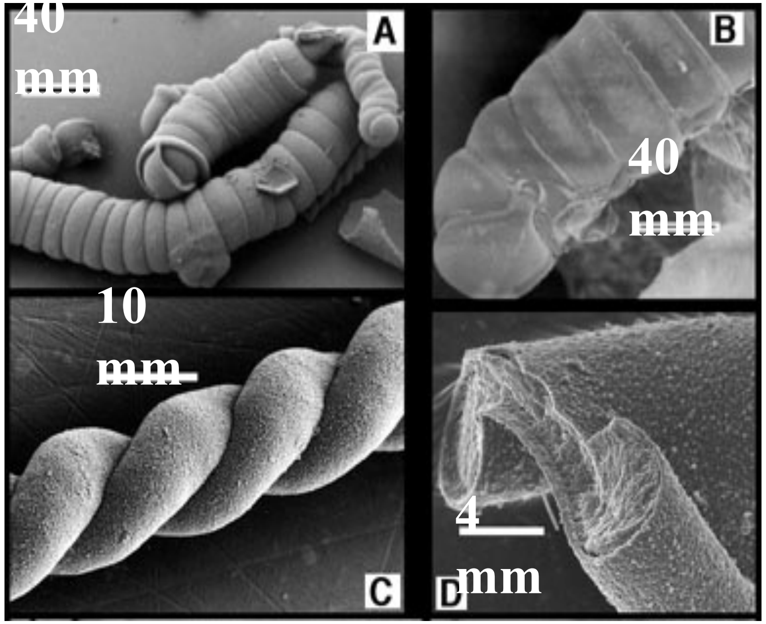
EX: THE CYANOBACTERIA IN AUSTRALIA





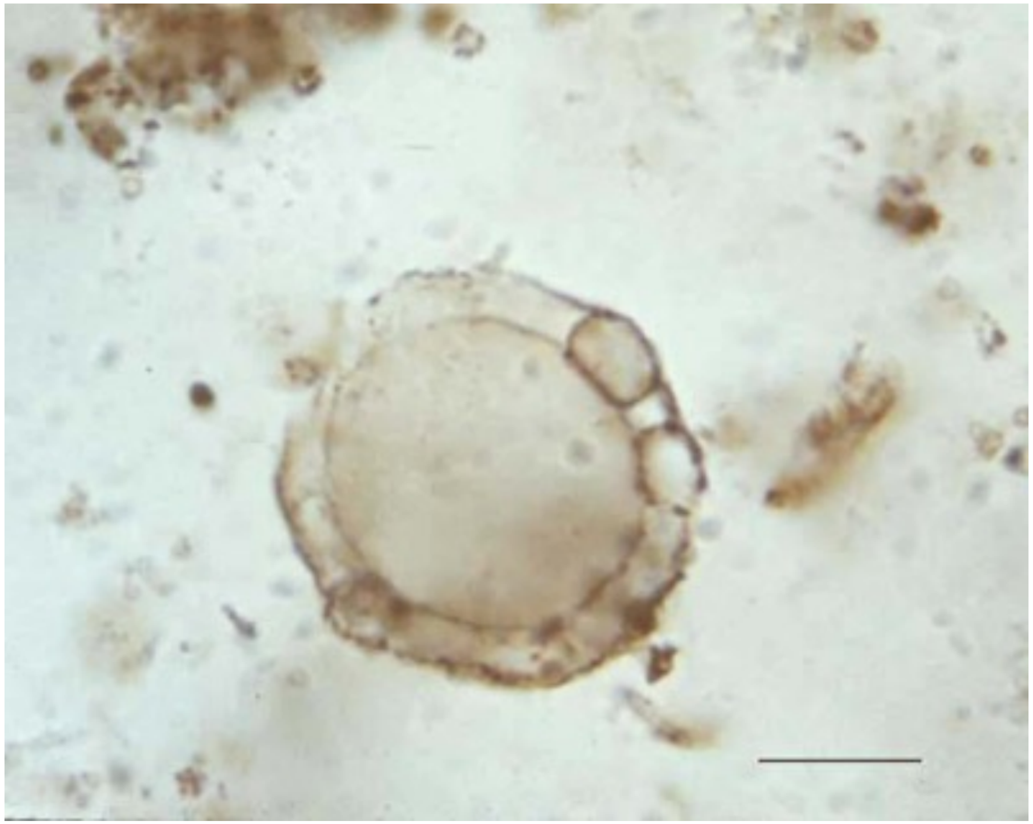


Microcrystals of carbonates

THE UNCONTESTED OLDEST FOSSILS

STROMATOLITES OF 2 BILLIONS YEARS AGE IN MINNESOTA AND ONTARIO, IN THE LAKE SUPERIOR

THE AGE CORRESPONDS ALSO TO THE JUMP IN THE ATMOSPHERE OF THE MOLECULAR OXYGEN



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6.2 THE TREE OF LIFE AND LUCA

6.Origin & quest

6.2 Life tree & LUCA

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MOLECULAR PHYLOGENETICS

The method is based on the comparison of RNA (or DNA or proteins) sequence of the different organisms. **The number of differences between sequences of two organisms is considered a measure of the evolutive distance between the two organisms.** This implicitly assumes that all organisms start from a single common point.

Exon 2 Sequences Aligned [Clustal W] and % Identity

```
U29186 mouse     GACTCCTGAGTATATTTCAGAACTGAACCATTTCAACCGAGCTGAAGCAT 50
D50092 rat       GACTCCTGAATATATTTCAAAACTGAACCATTTCAACCCAACTGAAGTAT 50
U78769 hamster   GACTCCTGAATATATTCCAAAACTGAACAATTTCAACTGAGCTGAAGTAC 50
Consensus        GACTCCTGAATATATTTCAAAACTGAACAATTTCAACCAAGCTGAAGCAT 50
D26150 cow       GACTTCTGAATATATTTGAAAACTGAACAGTTTCAACCAAGCCGAAGCAT 50
U67922 sheep     GACTTCTGAATATATTTGAAAACTGAACAGTTTCAACCAAGCTGAAGCAT 50
U29185 human     GACTCCTGAATATTTTTCAAAACTGAACAATTTCAGCCATGTCTGAGCTT 50
                 **** **** *** **   * ********  ***** *         **
                                 51 Conserved Residues

U29186 mouse     TCTGCCTTCCTAGTGGTACCAGTCCAATTT-AGGAGAGCCA-AGCAGACT 98
D50092 rat       TCTGCCTTCTTAGCGGTACCAGTCCGGTTT-AGGAGAGCCA-AGCCGACT 98
U78769 hamster   TCTGTTTTTCTAGAGGTACCAGTTCAGTTT-AGGAGAGTCACAGCAGATC 99
Consensus        TCTGTCTTCCTAGAGGTACCAGTCCAGTTT-AGGAGAGCCACAGCAGATT 99
D26150 cow       -CTGTCTTCCCAGAGACACAAATCCAACTTGAGCTGAATCACAGCAGAT- 98
U67922 sheep     -CTGTCTTCCCAGAGACACAGATCCAACTTGAGCTGAATCACAGCAGAT- 98
U29185 human     TCCGTCTTCCTGGAGGCACAAATCTAGTTT-AGCTGAACCACAACAGATT 99
                  * *  **     * *  **    *     ** **  **  ** * * **
```

	Consensus	human	cow	sheep	mouse	rat	hamster
Consensus	Ave:85%	81	81	81	90	88	89
human		-	77	76	72	66	71
cow			-	97	73	58	75
sheep				-	73	58	76
mouse					-	89	82
rat						-	81
hamster							-

% Identities

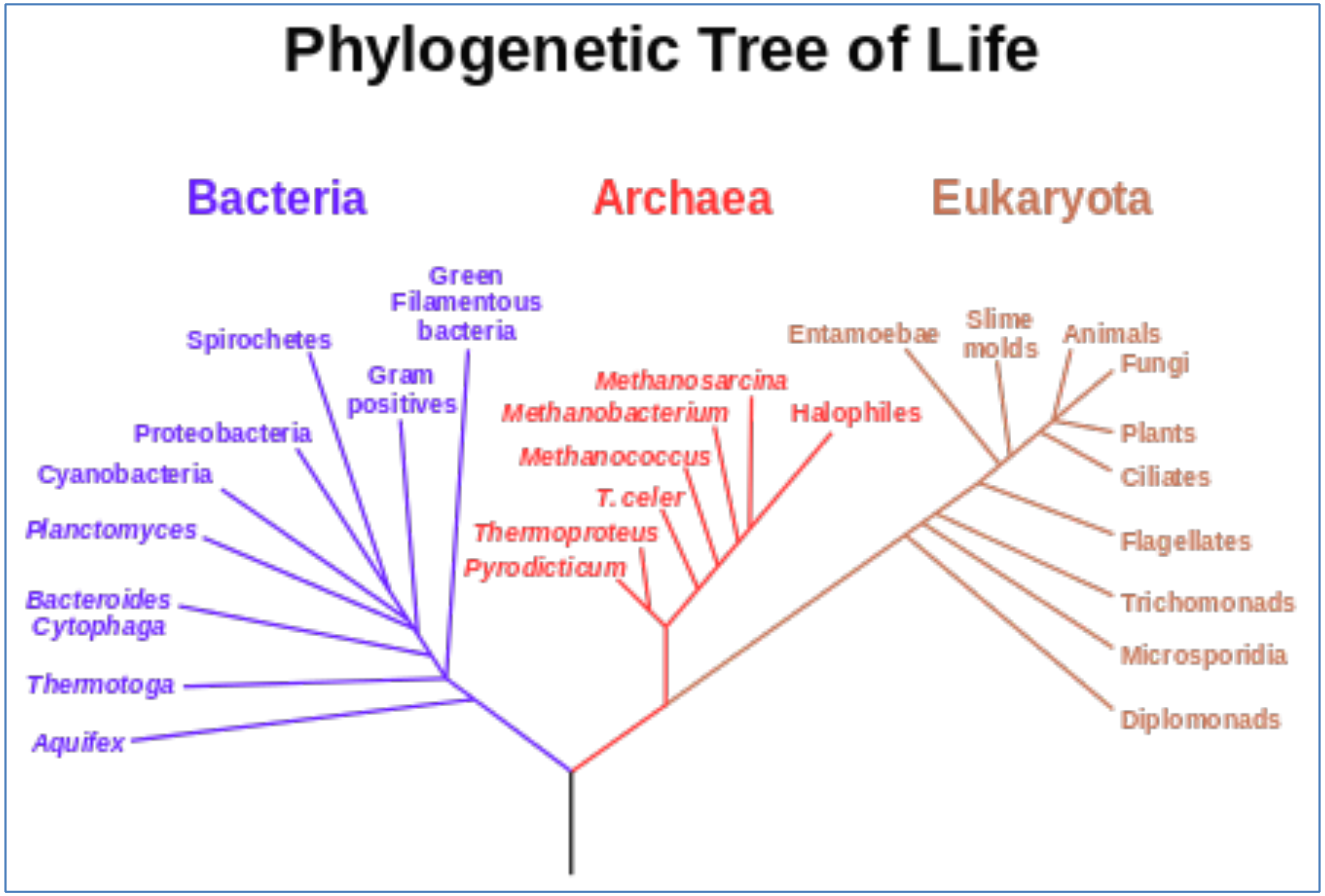
Average:74.9%

NOTE: in order to apply the method the genetic data "pass through" various numerical models (e.g. to align the sequences, etc)

Exemples of RNA sequences

THE PHYLOGENETIC TREE OF LIFE

THE PHYLOGENETIC TREE OF LIFE HAS BEEN DERIVED USING THE MOLECULAR PHYLOGENETIC METHOD



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THE DIFFICULTIES

ASSUMPTIONS:
1) THE DIFFERENCE BETWEEN TWO SEQUENCES CORRESPONDS TO THEIR EVOLUTIVE DISTANCE.
2) THE GENES CHANGE/ARE TRANSMITTED FROM A GENERATION TO THE NEXT ONE, NAMELY VERTICALLY.
ARE THESE ASSUMPTIONS ALWAYS CORRECTS?

THE USE OF DIFFERENT SEQUENCES OF RNA, DNA OR PROTEINS LEADS TO DIFFERENT BASES OF THE TREE
WHAT SHOULD ONE CHOSE AND WHY?

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THE HORIZONTAL GENE TRANSFER

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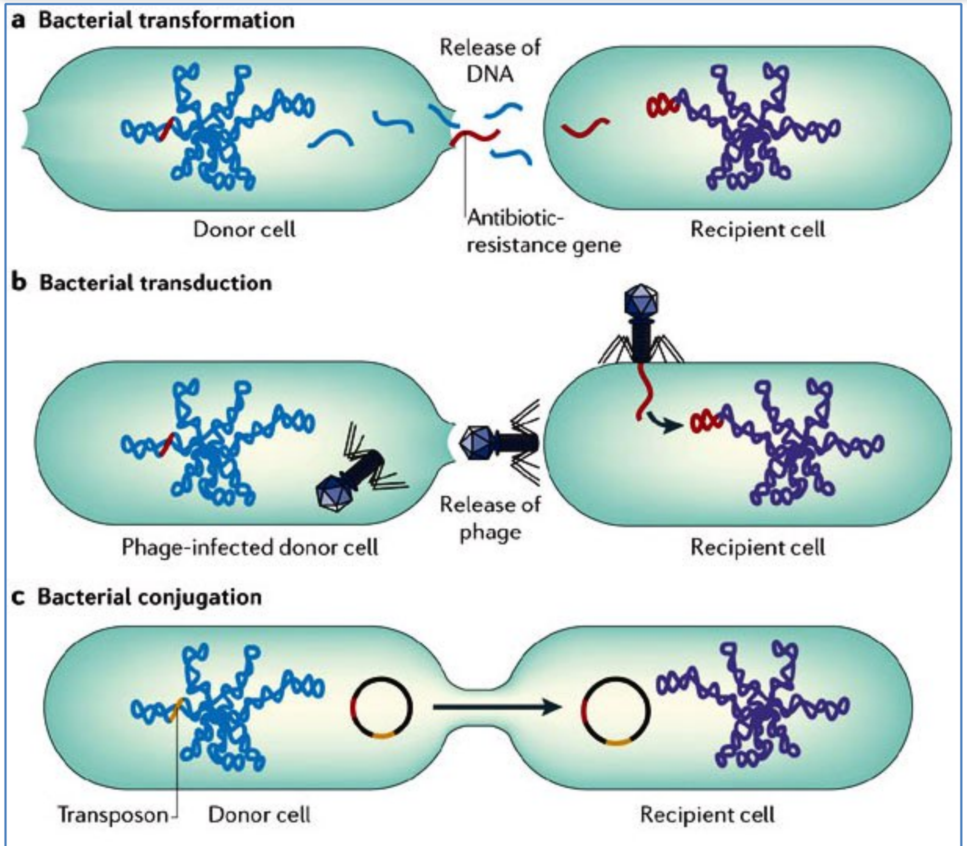
SINCE ABOUT 10 YEARS WE KNOW THAT THE SECOND ASSUMPTION IS WRONG: WHILE ANIMALS AND PLANT TRANSMIT THE GENE FROM ONE GENERATION TO THE NEXT ONE, THIS IS NOT NECESSARILY THE CASE FOR ALL MICROORGANISMS
=> BACTERIA AND ARCHEA EXCHANGE GENES HORIZONTALLY



Nature Reviews | Microbiology

ABOUT 80% OF BACTERIA AND ARCHEA HAVE EXCHANGED GENES VIA HGT AT LEAST ONCE IN THEIR LIFE

(BTW, THIS CAUSES THE BACTERIA RESISTANCE)

MORE THAN A TREE A NETWORK

THE CONSEQUENCE IS THAT AT THE BASE THE TREE IS NOT A TREE BUT RATHER A NETWORK

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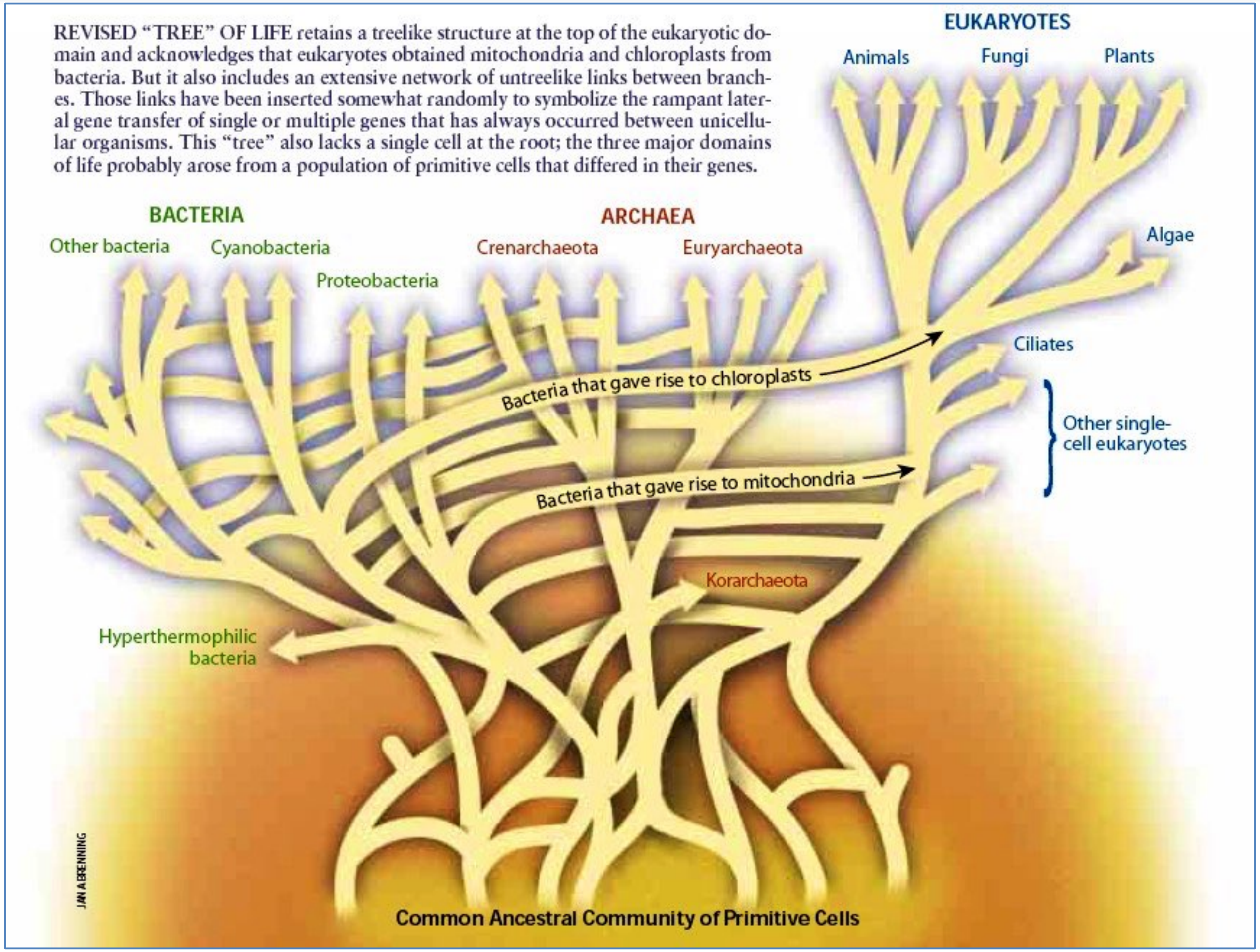
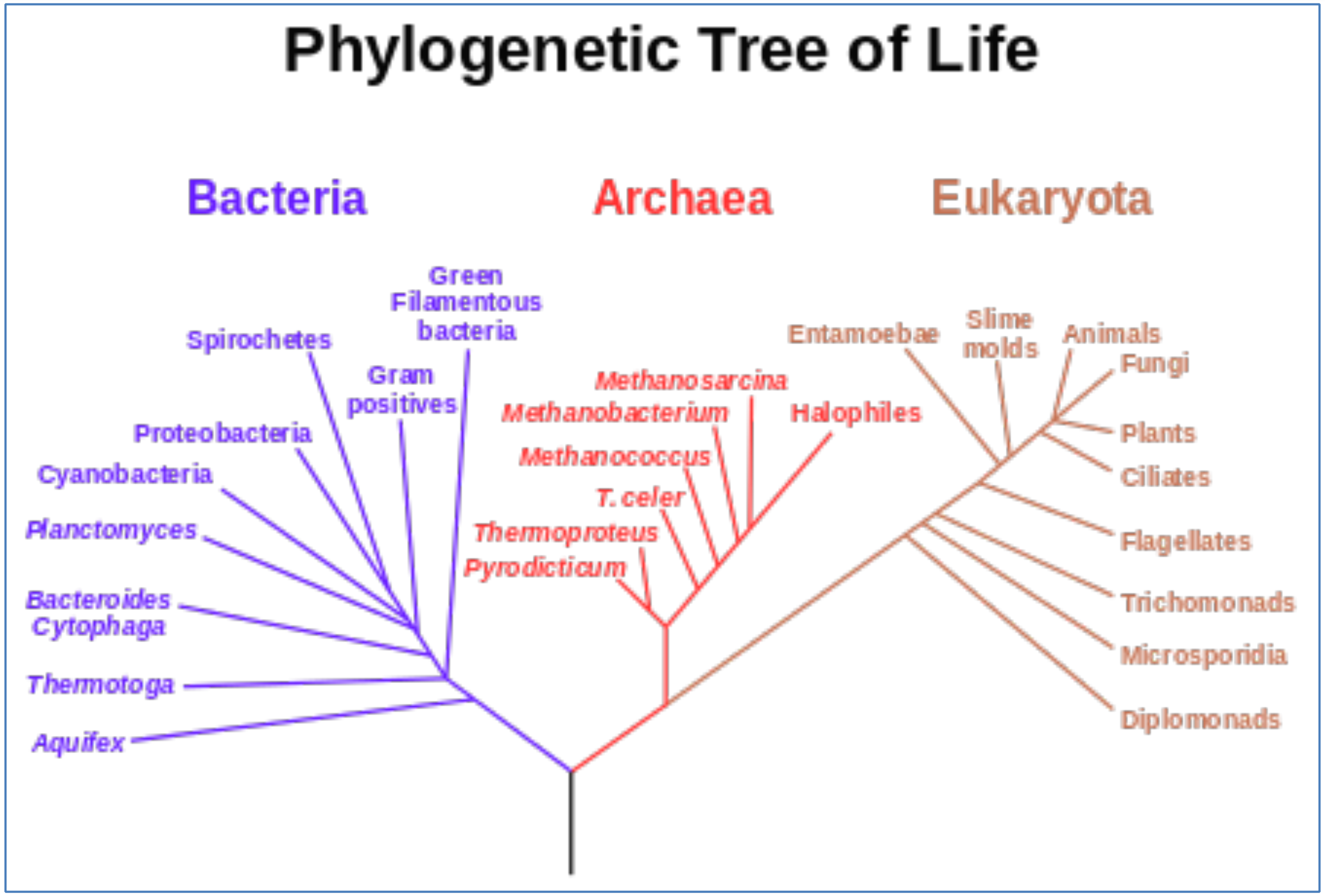


LUCA

IF ONE DOES NOT CONSIDER THE HGT AND THE NETWORK-LIKE ROOT, THE TREE DEPARTS FROM A SINGLE POINT:

LUCA: Last Universal Common Ancestor



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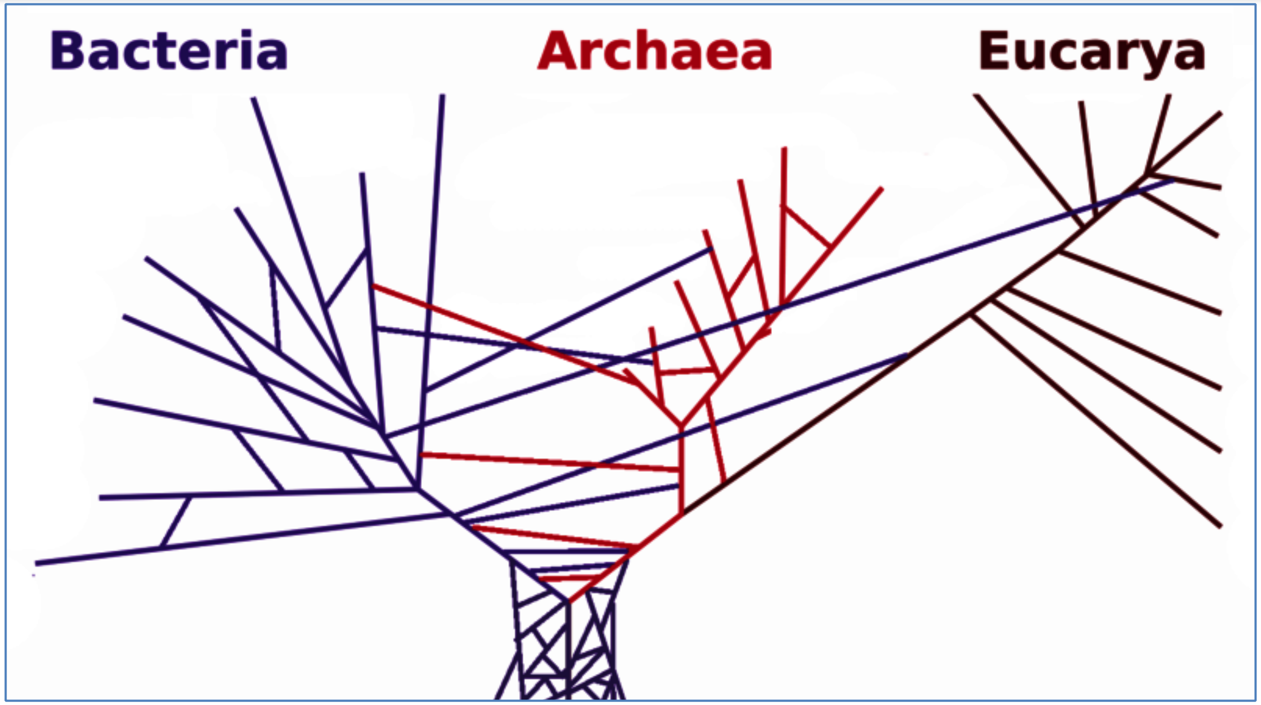
DID LUCA EXIST?

DIFFICULT TO ANSWER, EVEN THOUGH THE HGT WOULD CHALLENGE THE CONCEPT



INDEED THE QUESTION MIGHT BE TRANSLATED INTO:

DID LIFE START ONCE AND ONLY ONCE?

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DID LIFE START ONCE AND ONLY ONCE?

DIFFICULT TO ANSWER

WE KNOW SO LITTLE OF THE BIOSPHERE -MOSTLY MADE UP OF MICROORGANISMS WHICH HAVE NOT BEEN CULTURED OR CHARACTERISED, OR GENETICALLY SEQUENCED

THE SHADOW BIOSPHERE

IT IS POSSIBLE THAT THERE WERE OTHER STARTS OF LIFE AND THAT THEY ARE STILL PRESENT IN THE BIOSPHERE, JUST WAITING FOR BEING DISCOVERED

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6.3 THE SELFISH GENE or the evolutionism from the genes point of view

(R.Dawkins 1976 and later)

METABOLISM OR GENETIC FIRST?
THE POSSIBLE KEY ROLE OF FORMAMIDE

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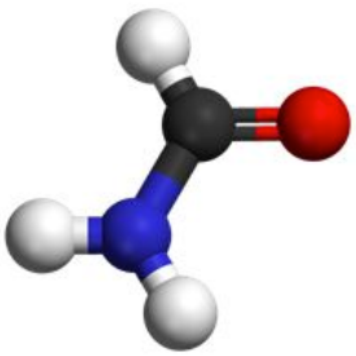
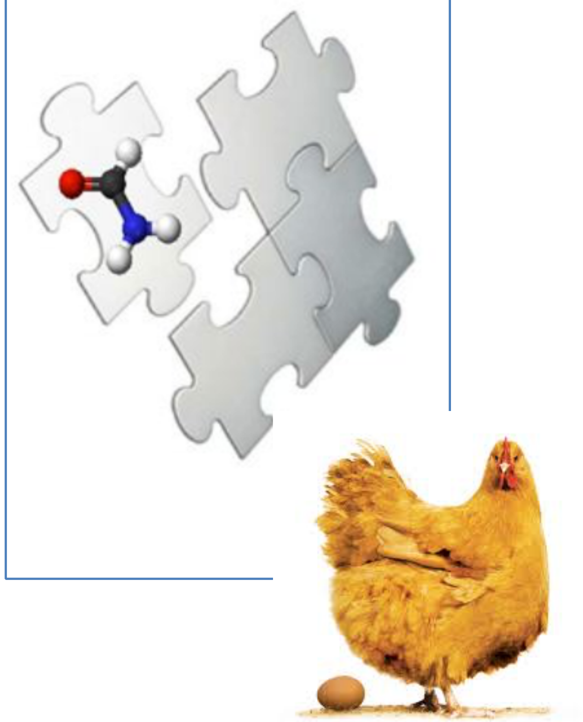
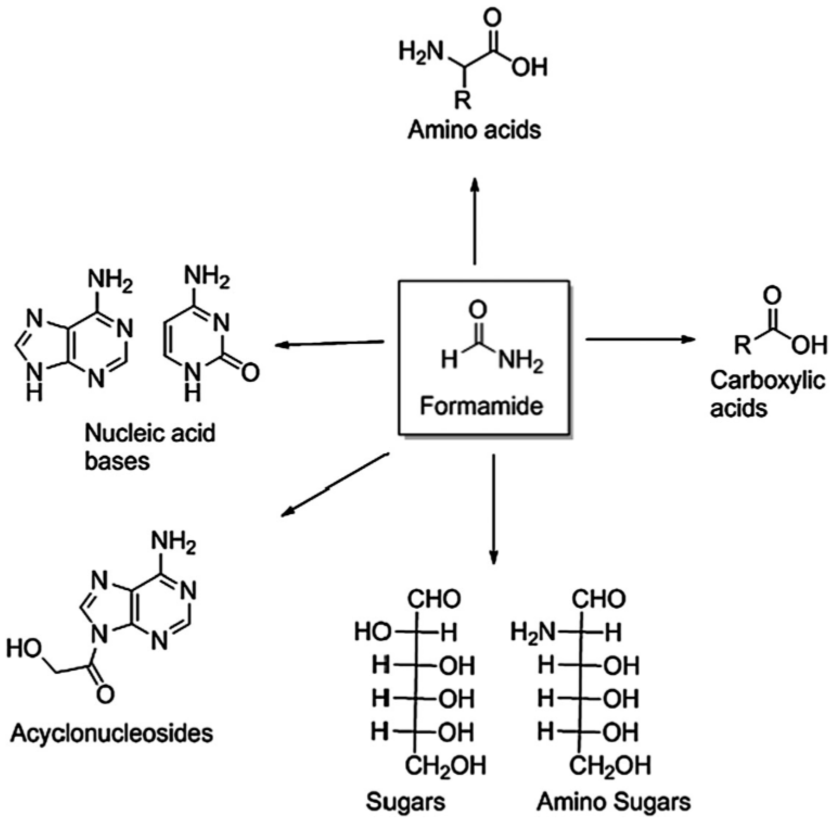
NH_2CHO



= **starting point** for the prebiotic synthesis of **both metabolic and genetic species:** amino acids, nucleic acid bases, acyclonucleosides, sugars, amino sugars and carboxylic acids.
(Saladino et al. 2012, Ferus et al. 2015.)





METABOLISM OR GENETIC FIRST?
THE POSSIBLE KEY ROLE OF FORMAMIDE

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6.3 Selfish gene

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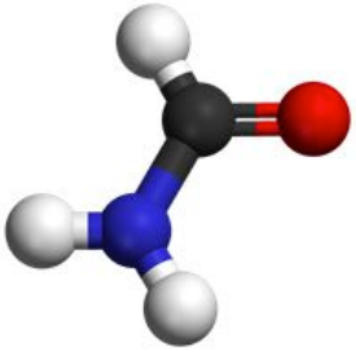
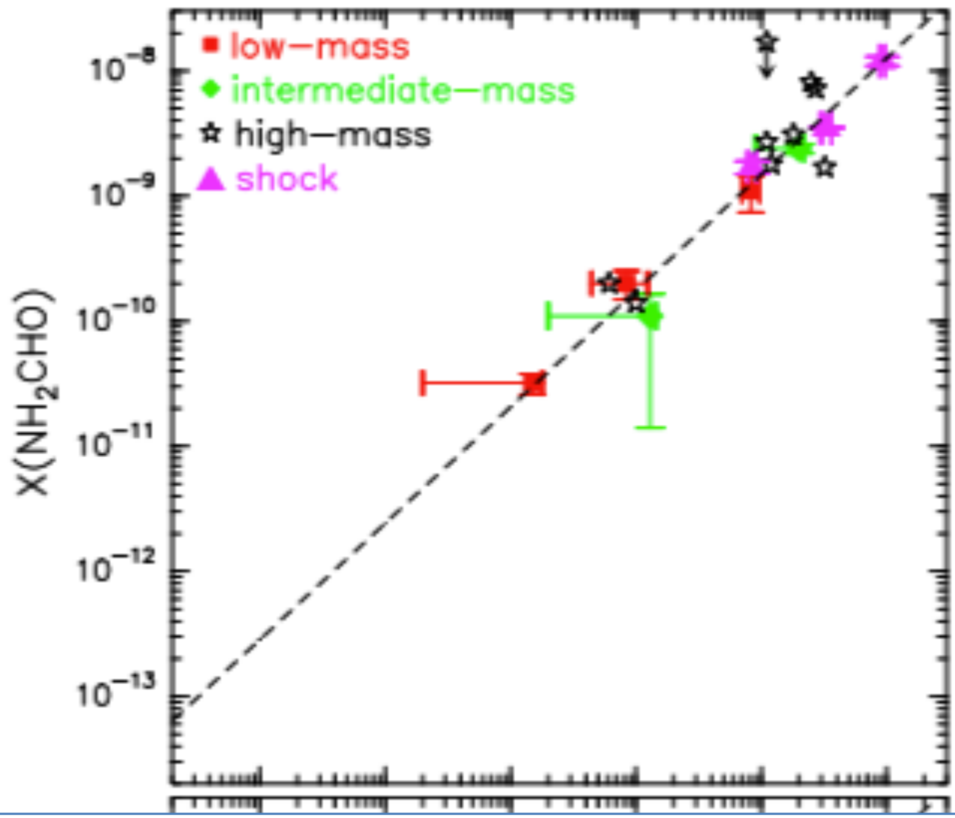
NH_2CHO



Kahane et al. 2013; Mendoza et al. 2014;
Lopez-Sepulcre et al. 2015



FORMAMIDE IS ABUNDANT, $>10^{-11}$ wrt H_2, IN STAR FORMING REGIONS

THE REPLICATOR APPEARANCE

Matter of fact: the Univers is populated by stable entities.

- If a group of atoms form a stable molecule, the molecule tend to remain in that state. => The first form of selection is the selection of stable molecules wrt unstable molecules.

- It is possible that in the Primitive Earth several stable complex organic molecules formed or ended up in the oceans, for example, or in the mud etc These first molecules formed more complex molecules, again stable.

- The process goes on until one of these molecules is capable of duplicate. This is the appearance of the first "REPLICATOR".

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THE REPLICATOR EVOLUTION

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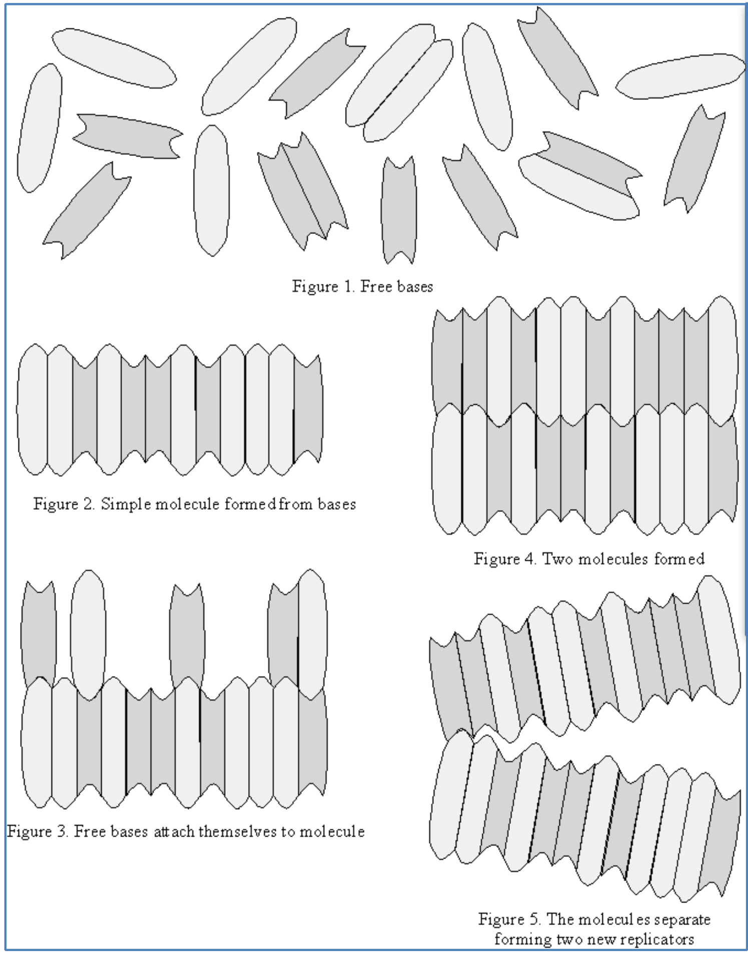
6.3 Selfish gene



From this moment on, the Replicator reproduces itself, in association with other molecules and/or replicators. Sometimes, it commits a mistake of copy and, sometimes, this ends up into more complex Replicators. Those Replicators which are more efficient and stable survive better.

Up to the day that the Replicator reaches the form of a **gene**, the most stable and efficient form of replication.

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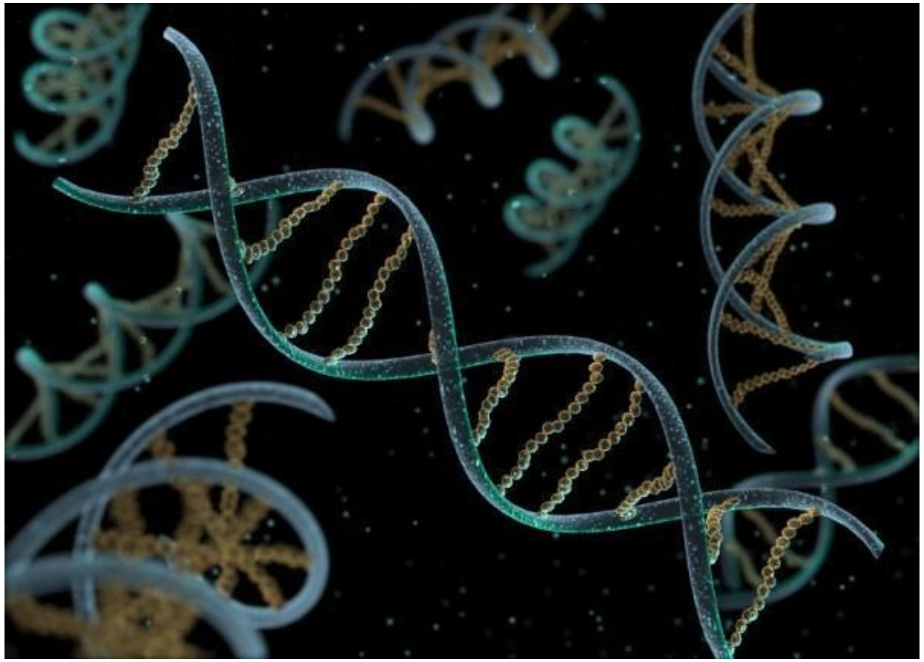
THE REPLICATOR DOMINION



The process of complexification continues: several genes are formed. Again, the most stable and efficient genes reproduce themselves in larger copies: the genes that use the ressources and that adapt to the environment at best.

The **living organisms become the gene containers**, the machines to protect and replicate them. Those machines that permit the genes to better replicate themselves survive more numerous: this is the principle of the selection and Darwinian evolution.

THE GENES DOMINATE THE WORLD, WE ARE THERE TO PROTECT THEM.

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6.4 THE SEARCH OF LIFE IN THE UNIVERSE

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THE DRAKE EQUATION

DRAKE EQUATION

$$N = R \times f_s \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

- R average rate of star formation
- f_s fraction of good stars that have planetary systems
- n_e number of planets aound these stars within an "ecoshell"
- f_l fraction of those planets where life develops
- f_i fraction of living species that develop intelligence
- f_c fraction of intelligent species with communications technology
- L lifetime of the "communicative phase"

Sir Drake, 1960

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THE DRAKE EQUATION

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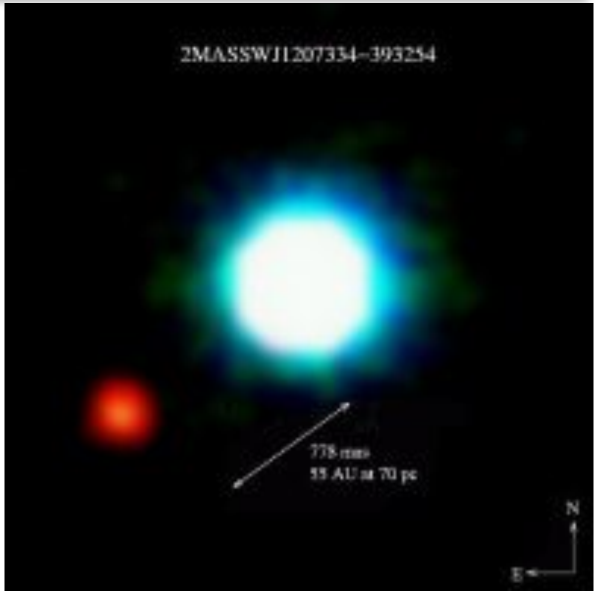
DRAKE EQUATION

$$N = R \times f_s \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Since 1960, almost 2000 extrasolar planet candidates have been discovered (http://exoplanet.eu), so start to have an estimate of the number of planet per star.



Obviously we do nota have any idea of the fraction of planets with life, those with an intelligent life and the duration of a civilisation.

THE SETI EXPERIMENT

6.Origin & quest

6.4 Search of life

The SETI (Search for Extra-Terrestrial Intelligence) experiment consists in searching intelligent signals in the radio (in the minimum of the Galaxy emission frequency), using the Arecibo-305mt telescope.

In 1974, the same telescope was used to send intelligent signal to the globular cluster M13, showing that the principle was valid.

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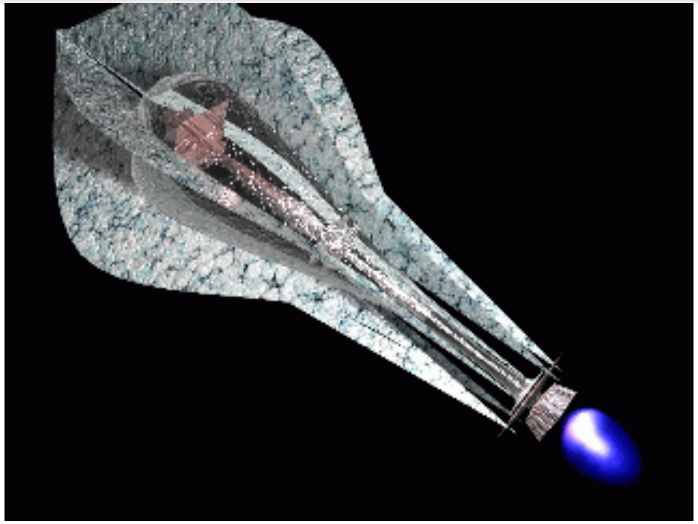
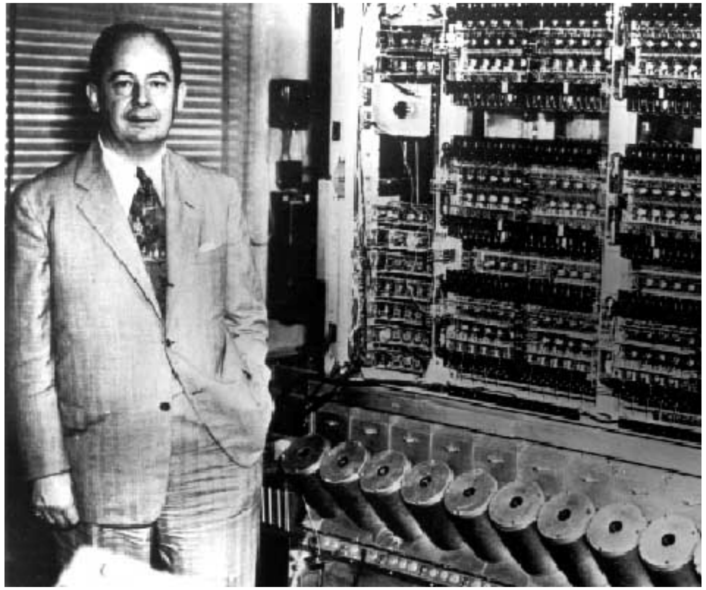
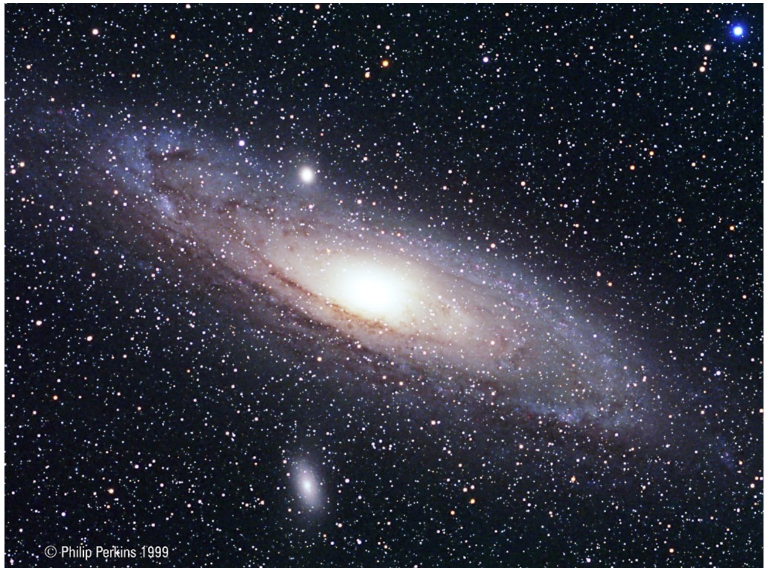
THE von NEUMANN PROBE



In the 40s, the mathematic and physicist J. von Neunmann proposed a project for a machine capable of building another machine, as itself, using the material present in the environment of an asteroid. Such a machine would colonise the entire Galaxy in less than one million year.





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THE INTERSTELLAR VOYAGES

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6.4 Search of life

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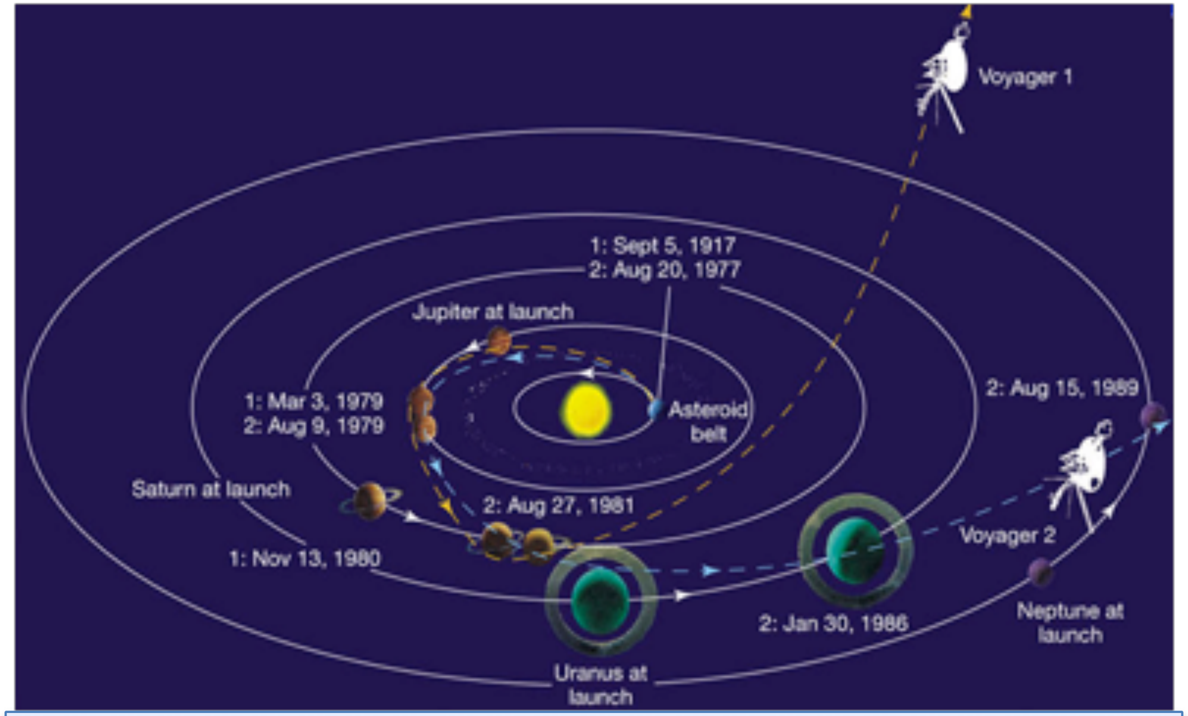
ACTUALLY, WE, THE MANKIND, HAVE ALREADY STARTED THE INTERSTELLAR VOYAGES



In 1977, we launched the 2 Voyager probes which are now outside the Solar System. They contain the "Gold disk" with sounds and images of the terrestrial life, from music of Beethoven and Stravinski to the songs of birds, images of the Solar System, mathematical formulae…

THE INTERSTELLAR VOYAGES

6.Origin & quest

6.4 Search of life

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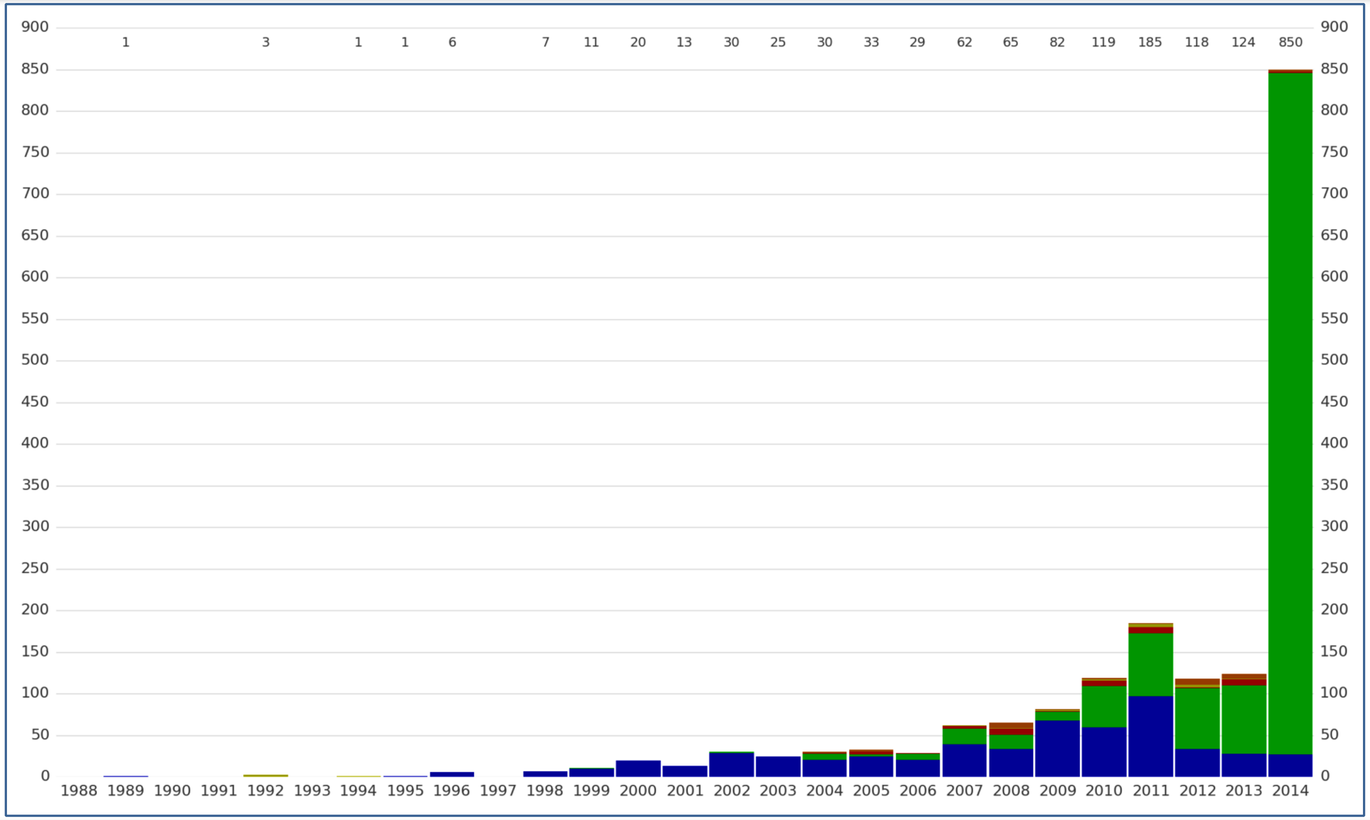
The number of planets discovered every year increases exponentially with time (e.g.http://exoplanet.eu/catalog-RV.php), and the future projects, including PLATO, will certainly discover nearby Earth-like planets.



WILL NOT SEND PROBES TOWARDS THOSE PLANETS TO VERIFY THE PRESENCE OF LIFE?

WHERE ARE THEY?

In 1950 Fermi formulate the question which became famous as **the Fermi's paradox.**

If there were extraterrestrial civilisations, their representatives should already be among us.

Where are they?

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