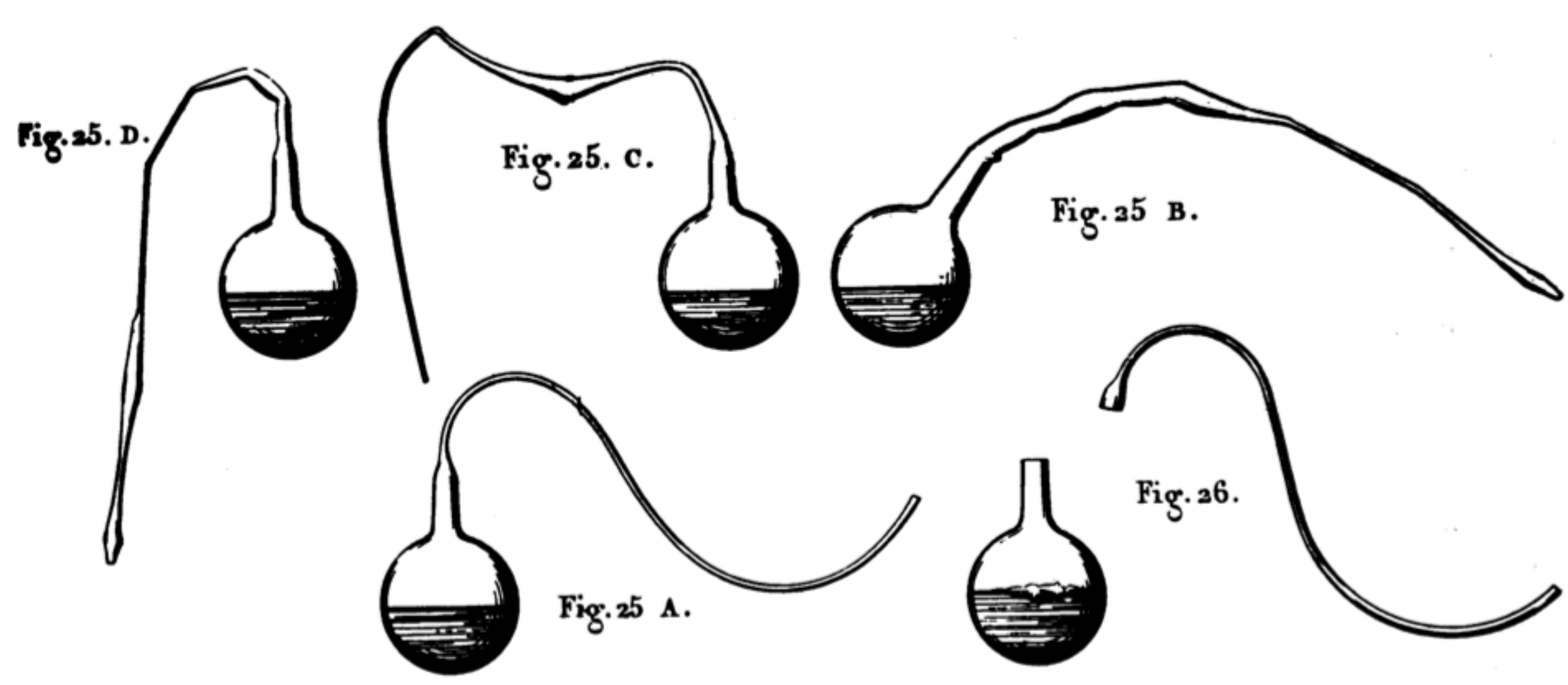
Origin of life, astrobiology, synthetic life

Brian O'Meara

EEB464 Fall 2019

Learning objectives

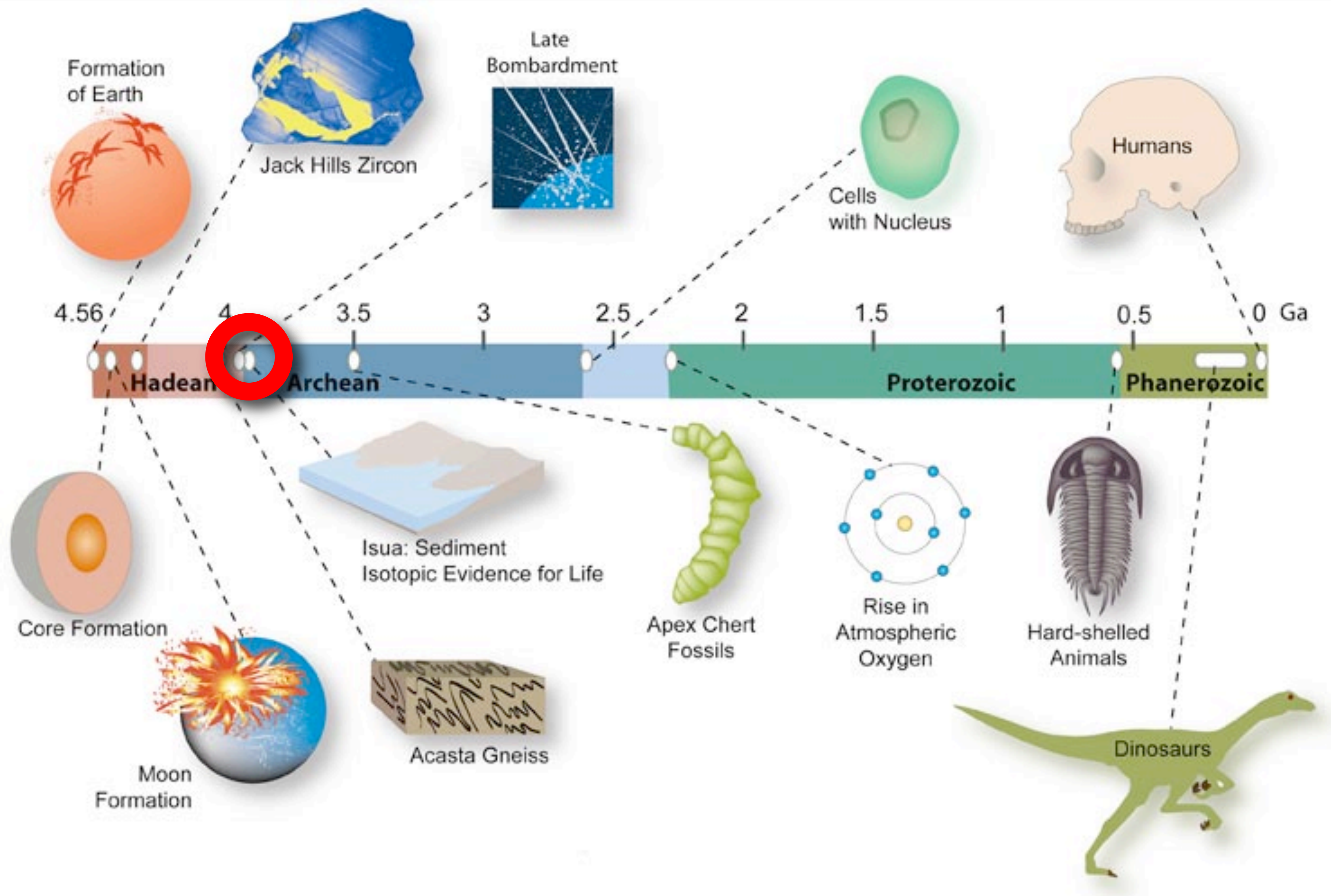
- Aspects requiring explanation about origin of life
- Hypotheses
- Life elsewhere



I place in a glass flask the following liquids or infusions, all very alterable on contact with ordinary air: beer-yeast water, sugar-beer-yeast water, urine, beet juice, and pepper water; then with the aid of a lamp, I draw the necks of the flasks to give different shapes. I then bring the liquid to a boil for a few minutes until the water vapors leave abundantly by the end of the drawn-out neck.... I then let the flasks cool. A strange thing happens that will astonish everyone accustomed to the delicacy of experiments relative to so-called spontaneous generation;... the liquid in the flasks remains indefinitely without alteration.

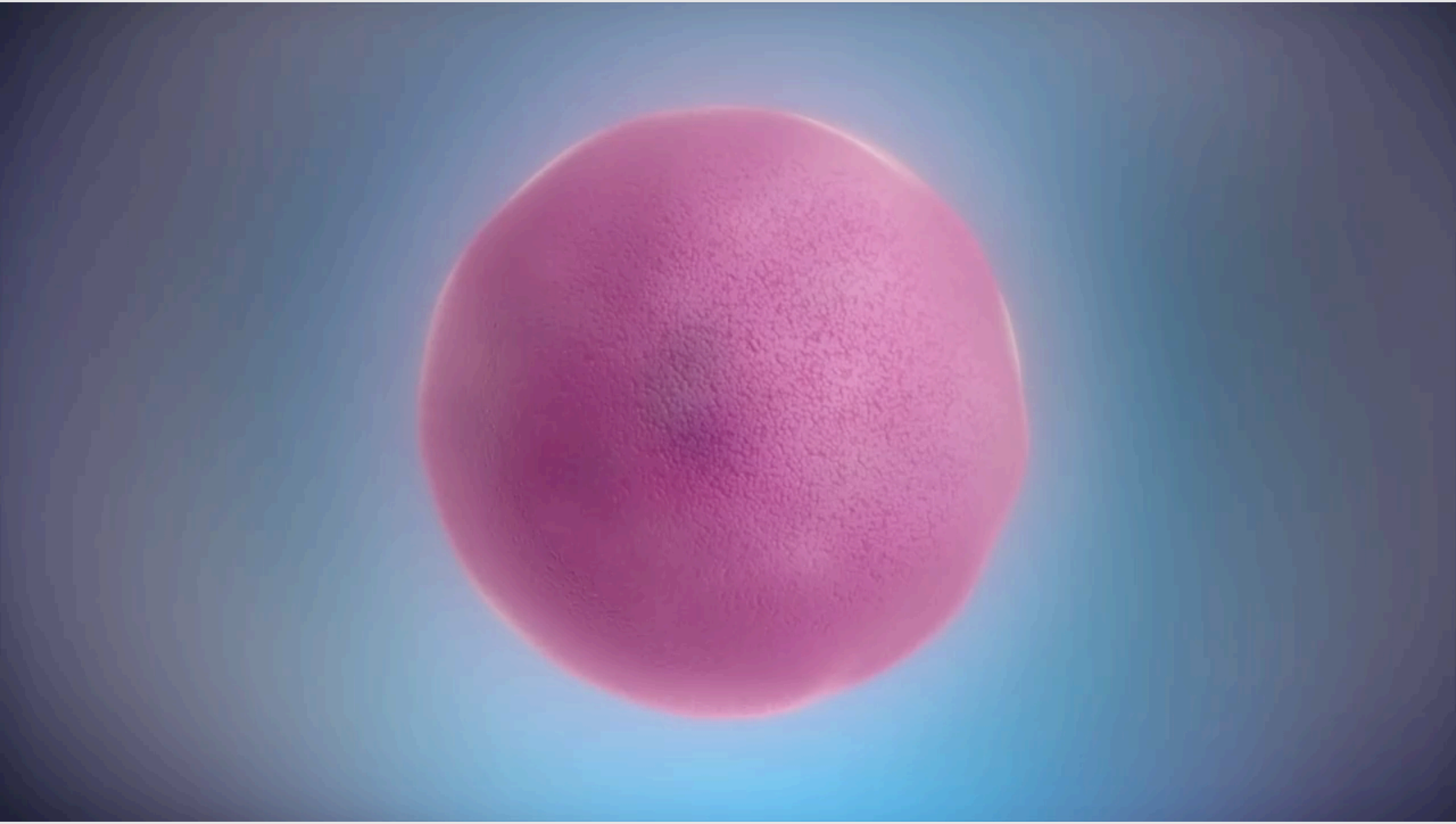
- Louis Pasteur

Porter. LOUIS PASTEUR. ACHIEVEMENTS AND DISAPPOINTMENTS, 1861. Microbiology and Molecular Biology Reviews (1961) vol. 25 (4) pp. 389



Andree Valley

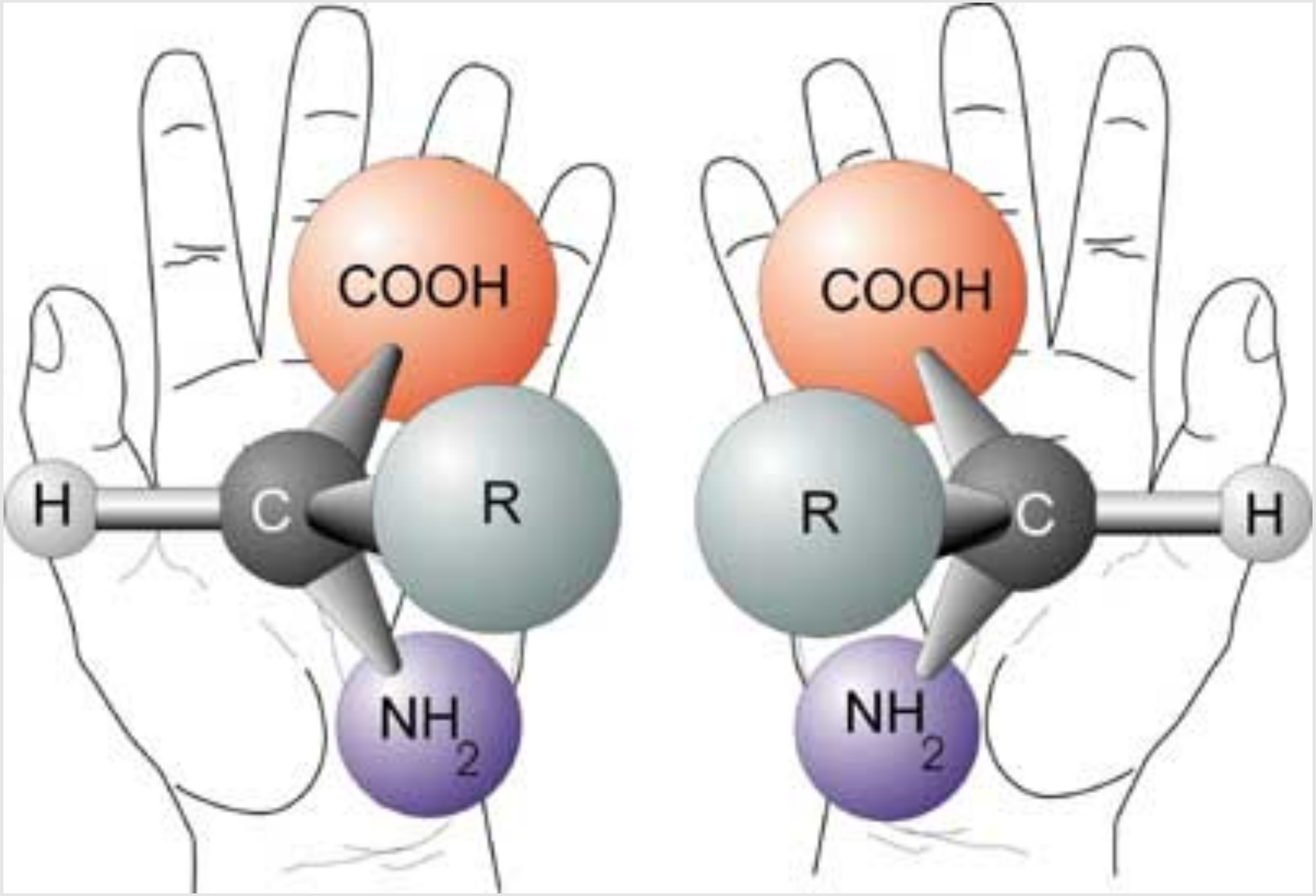
What are characteristics of life to explain?



Animations from yourgenome, https://www.youtube.com/watch?v=gG7uCskUOrA

What are characteristics of life to explain?

- DNA for storage
- DNA $\rightarrow$ RNA
- RNA $\rightarrow$ protein
- genetic code
- tRNA, mRNA, rRNA
- chirality
- membrane
- mitosis


COOH
H
C
R
NH_2
COOH
R
C
H
NH_2

http://www.zcars.com.au/images/2010-toyota-prius22.jpg

DAUERTEST TOYOTA PRIUS

Nichts ist unmöglich: Rost am Toyota-Blech

■ Im DEKRA-Technology-Center in Klettwitz blickten wir dem Prius tief in die Eingeweide. Resultat: Die ebenso aufwendige wie kompakte Hybridtechnik zeigt sich makellos. Also alles bestens? Nicht ganz. Es gibt kleine Überraschungen. In der Klimaanlage findet sich nur noch ein Viertel der Kältemittelfüllung. Eingeschränkte Kühlleistung, schlimmstenfalls ein Kompressorschaden hätte den nächsten Sommer getrübt. An den Nockenwellenrädern sind Laufspuren der Kette feststellbar, ein Folgeschaden ist aber nicht zu befürchten. Erstaunlich: ein völlig vergammelter Blechhalter am Prius-Heck. Er trägt den Taster zur Heckklappenöffnung, der baldige Abfall des Elektrokontakts ist programmiert. Ebenso unfein: leichter Rostansatz unter der Dichtung im Rahmen der Fahrertür.

Geprüft und für gut befunden: DEKRA-Sachverständiger Günther Schiele bei der Hohlraumuntersuchung

1 Die Inverter/Konvertereinheit (oben) wirkt innen wie frisch aus der Produktion. Keinerlei Schäden an Steckern und Leitungen

2 Der Elektromotor hat den Einsatz ohne Blessuren bewältigt. Keine thermischen Spuren, Kontakte wie neu

3 Lediglich Laufspuren an den druckbelasteten Seiten der Zylinderwände zeugen vom 100 000-Kilometer-Stress

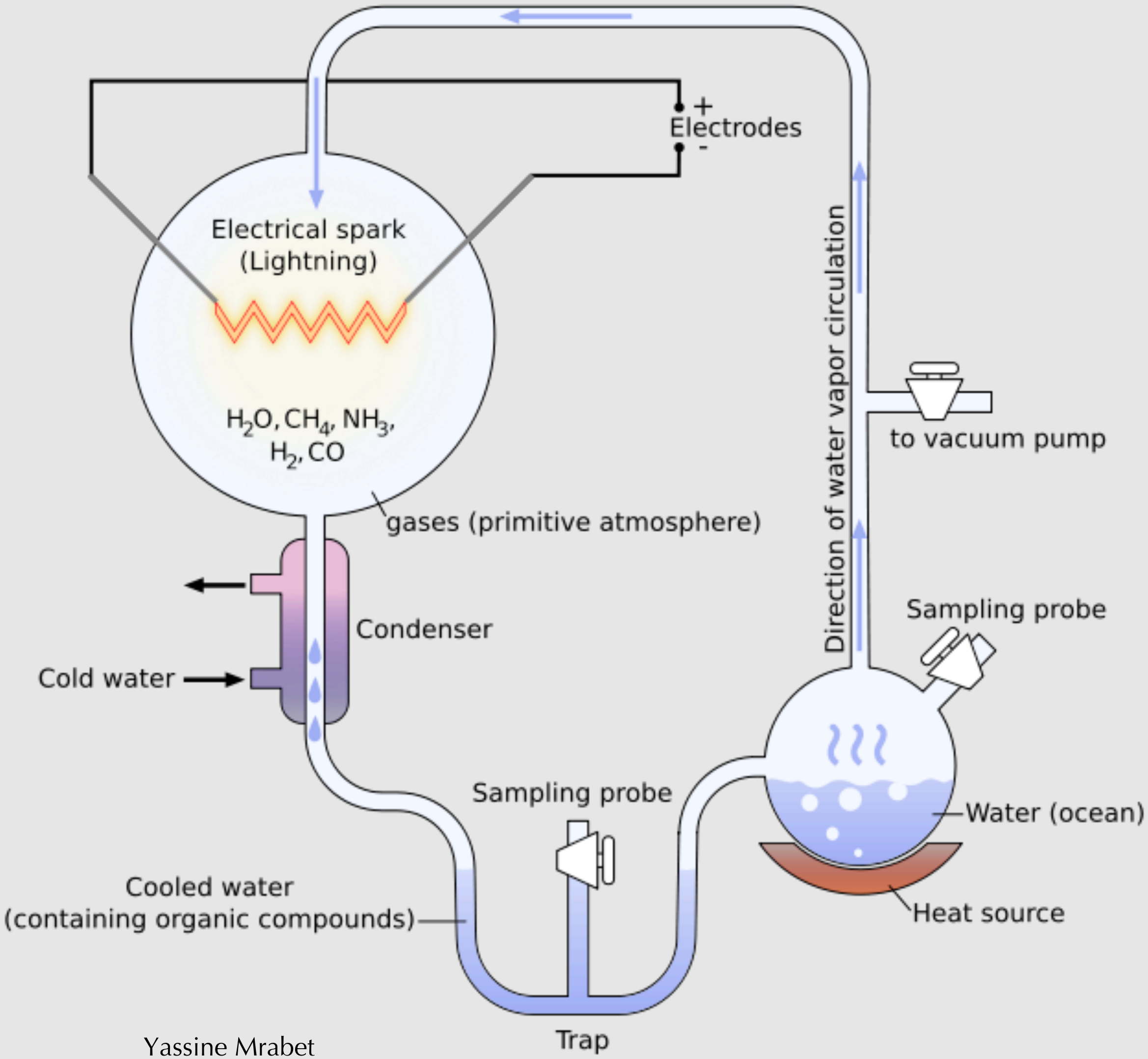
4 Dieser Halter fällt (bald) aus dem Rahmen. Rost greift an den Kontaktpunkten schon auf die Karosserie über

http://www.kollewin.com/blog/performance-parts/

It is often said that all the conditions for the first production of a living organism are present, which could ever have been present. But if (and Oh! what a big if!) we could conceive in some warm little pond, with all sorts of ammonia and phosphoric salts, light, heat, electricity, etc., present, that a protein compound was chemically formed ready to undergo still more complex changes, at the present day such matter would be instantly devoured or absorbed, which would not have been the case before living creatures were formed.

Darwin to Hooker, 1871

http://www.totalwallpapers.com/wallpapers.asp?number_id=1500



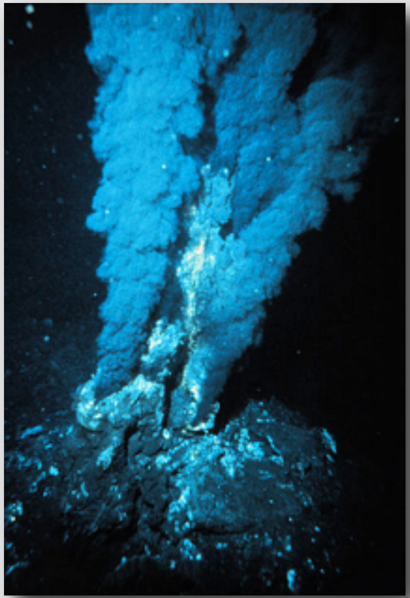
Yassine Mrabet

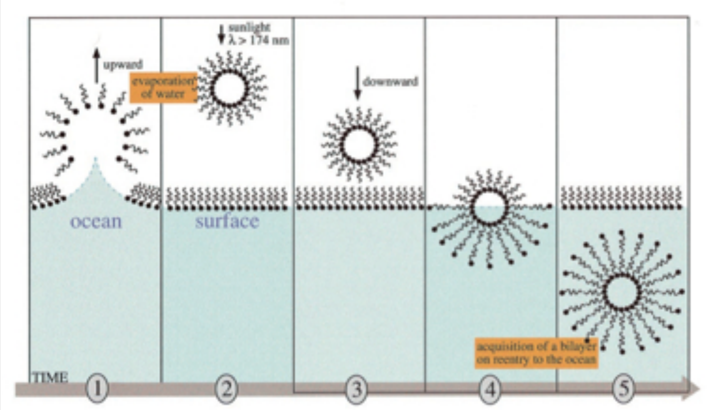
Miller. A Production of Amino Acids Under Possible Primitive Earth Conditions. Science (1953) vol. 117 (3046) pp. 528-529

Prebiotic phosphorylation of (pre)biological substrates under aqueous conditions is a critical step in the origins of life. Previous investigations have had limited success and/or require unique environments that are incompatible with subsequent generation of the corresponding oligomers or higher-order structures. Here, we demonstrate that diamidophosphate (DAP)—a plausible prebiotic agent produced from trimetaphosphate—efficiently (amido)phosphorylates a wide variety of (pre)biological building blocks (nucleosides/tides, amino acids and lipid precursors) under aqueous (solution/paste) conditions, without the need for a condensing agent. Significantly, higher-order structures (oligonucleotides, peptides and liposomes) are formed under the same phosphorylation reaction conditions. This plausible prebiotic phosphorylation process under similar reaction conditions could enable the systems chemistry of the three classes of (pre)biologically relevant molecules and their oligomers, in a single-pot aqueous environment.

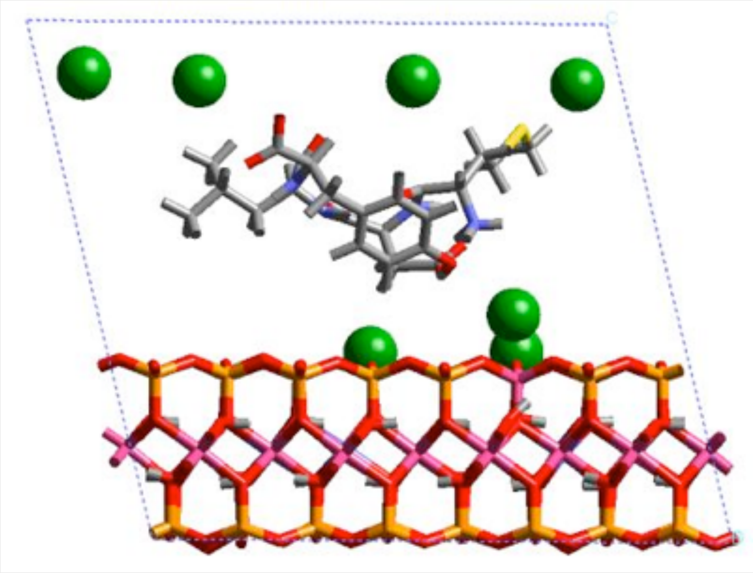
Gibard et al., Nov 6, 2017, *Nature Chemistry*

Where?

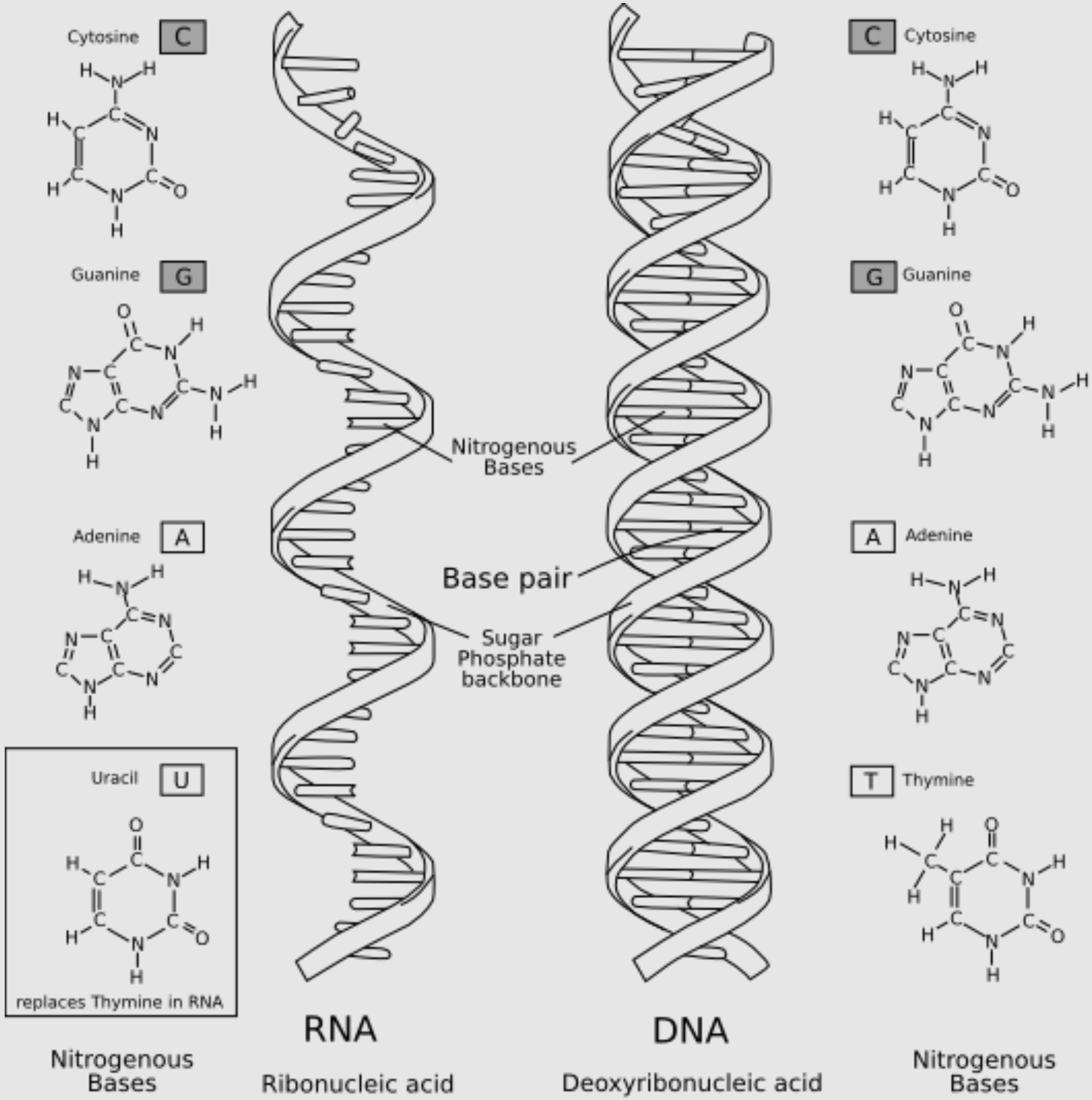




Dobson et al. Atmospheric aerosols as prebiotic chemical reactors. PNAS (2000) vol. 97 (22) pp. 11864



http://www.sandia.gov/geobio/randy.html



Users Antilived, Fabiolib, Turnstep, Westcairo on en.wikipedia

UUU [F] Phe	UCU [S] Ser	UAU [Y] Tyr	UGU [C] Cys
UUC [F] Phe	UCC [S] Ser	UAC [Y] Tyr	UGC [C] Cys
UUA [L] Leu	UCA [S] Ser	UAA [ ] Ter	UGA [ ] Ter
UUG [L] Leu	UCG [S] Ser	UAG [ ] Ter	UGG [W] Trp
CUU [L] Leu	CCU [P] Pro	CAU [H] His	CGU [R] Arg
CUC [L] Leu	CCC [P] Pro	CAC [H] His	CGC [R] Arg
CUA [L] Leu	CCA [P] Pro	CAA [Q] Gln	CGA [R] Arg
CUG [L] Leu	CCG [P] Pro	CAG [Q] Gln	CGG [R] Arg
AUU [I] Ile	ACU [T] Thr	AAU [N] Asn	AGU [S] Ser
AUC [I] Ile	ACC [T] Thr	AAC [N] Asn	AGC [S] Ser
AUA [I] Ile	ACA [T] Thr	AAA [K] Lys	AGA [R] Arg
AUG [M] Met	ACG [T] Thr	AAG [K] Lys	AGG [R] Arg
GUU [V] Val	GCU [A] Ala	GAU [D] Asp	GGU [G] Gly
GUC [V] Val	GCC [A] Ala	GAC [D] Asp	GGC [G] Gly
GUA [V] Val	GCA [A] Ala	GAA [E] Glu	GGA [G] Gly
GUG [V] Val	GCG [A] Ala	GAG [E] Glu	GGG [G] Gly

Figure 1. The standard genetic code. The codon series are shaded in accordance with the polar requirement scale values (*4*), which is a measure of an amino acid's hydrophobicity: the greater hydrophobicity the darker the shading (the stop codons are shaded black).

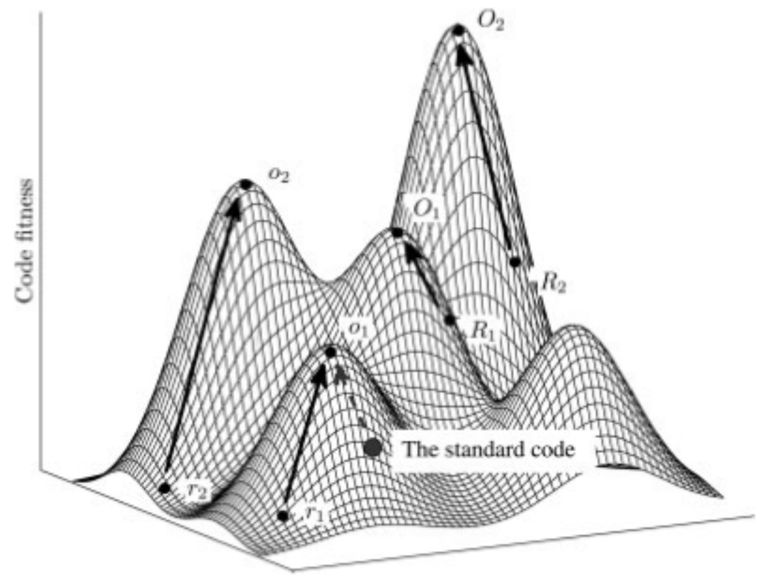


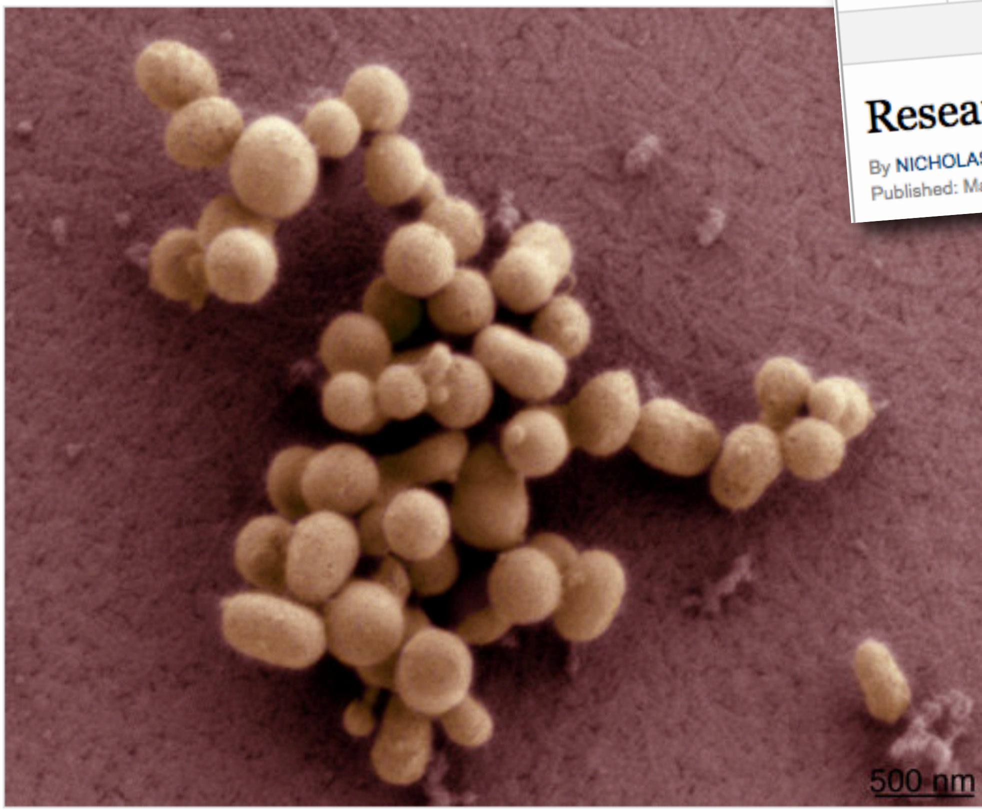
Figure 3. Evolution of codes in a rugged fitness landscape (a cartoon illustration). $r_1,r_2 \in \mathbf{r}$ random codes with the same block structure as the standard code, $o_1,o_2 \in \mathbf{o}$: codes obtained from $r_1,r_2 \in \mathbf{r}$ after optimization, $R_1,R_2 \in \mathbf{R}$: random codes with fitness values greater than the fitness of the standard code, $O_1,O_2 \in \mathbf{O}$: codes obtained from $R_1,R_2 \in \mathbf{R}$ after optimization. The figure is modified from (*86*).

Koonin and Novozhilov. Origin and evolution of the genetic code: The universal enigma. IUBMB life (2009) vol. 61 (2) pp. 99-111

Researchers Create the World's First Fully Synthetic, Self-Replicating Living Cell

Scientists call it 'the first self-replicating species we've had on the plane[t ...]
parent is a computer'

By Clay Dillow Posted 05.20.2010 at 1:15 pm 100 Comments



M. mycoides JCVI-syn1.0 *JCVI*

The New York Times **Science**

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | S[...]

ENVIRONMENT SPA[...]

Researchers Say They Created a 'Synthetic Cel[l'

By NICHOLAS WADE
Published: May 20, 2010

[...]anics

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[...]epage / Science / Health / Breakthroughs / Craig Venter Boots up First Synthetic Cell

Craig Venter Boots up First Synthetic Cel[l]

Craig Venter and his team have created the first self-replicating synthetic cell, blazing the
a new era in synthetic biology and bringing scientists ever-closer to creating synthetic life.

[...]WARD

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Negatively stained transmission electron micrographs of dividing M. mycoides JCVI-syn1. Micrographs provided by Tom Deerinck and Mark Ellisman of the National Center for Microscopy and Imaging Researc

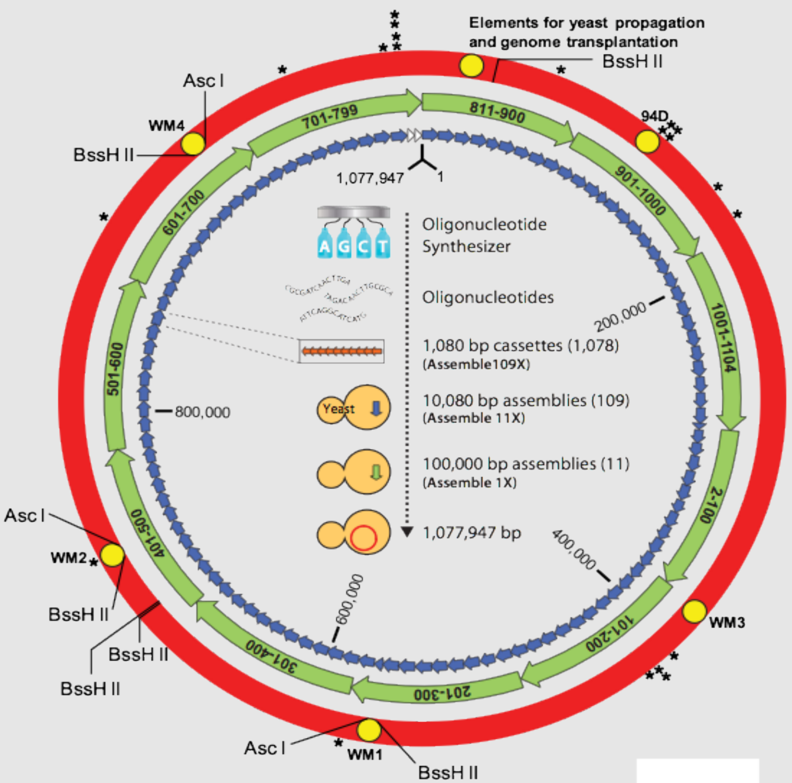
May 20, 2010 3:57 PM

TEXT SIZE: A . [...]

"We're here today to announce the first synthetic cell," said genetic pioneer Craig Venter at a press conference held on Thursday Washington, D.C.'s Newseum. "This is the first self-replicating cell we've had on the planet whose parent is a computer."

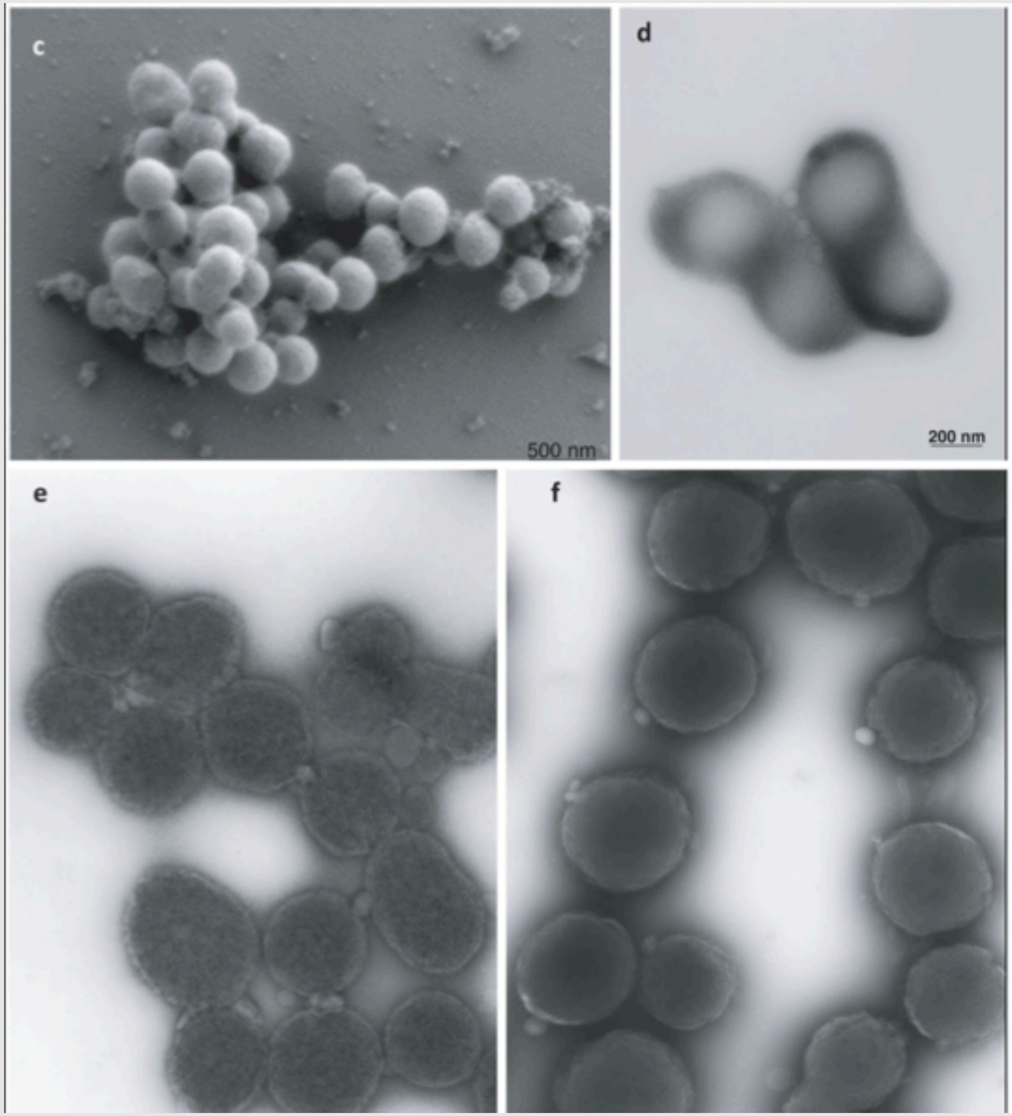
Venter called his work the culmination of a "15-year quest." He was flanked by a team of scientists from the Maryland-based J. Craig Venter Institute, including Daniel Gibson, Clyde Hutchinson and Nobel laureate Hamilton Smith. Venter is best known for his work in mapping the human genome a decade ago. Details of this breakthrough, the last in a three-step process, will be published in the journal *Science*. Two years ago, the team chemically synthesized a bacterial genome. Next, they successfully transplanted the genome of one bacterium in[to] another bacterium. Now, th[...] those two st[...]

The assembly of a synthetic *M. mycoides* genome in yeast



Gibson, D. G., J. I. Glass, C. Lartigue, V. N. Noskov, R.-Y. Chuang, M. A. Algire, G. A. Benders, M. G. Montague, L. Ma, M. M. Moodie, C. Merryman, S. Vashee, R. Krishnakumar, N. Assad-Garcia, C. Andrews-Pfannkoch, E. A. Denisova, L. Young, Z.-Q. Qi, T. H. Segall-Shapiro, C. H. Calvey, P. P. Parmar, C. A. Hutchison III, H. O. Smith, and J. C. Venter. 2010. Creation of a bacterial cell controlled by a chemically synthesized genome. Science, Published online May 20 2010.

J. Craig Venter INSTITUTE



Gibson et al. Creation of a bacterial cell controlled by a chemically synthesized genome. Science (2010) vol. 329 (5987) pp. 52

Drake equation

$$N = R^* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

Where,

N = The number of civilizations in The Milky Way Galaxy whose electromagnetic emissions are detectable.

R^* =The rate of formation of stars suitable for the development of intelligent life.

f_p = The fraction of those stars with planetary systems.

n_e = The number of planets, per solar system, with an environment suitable for life.

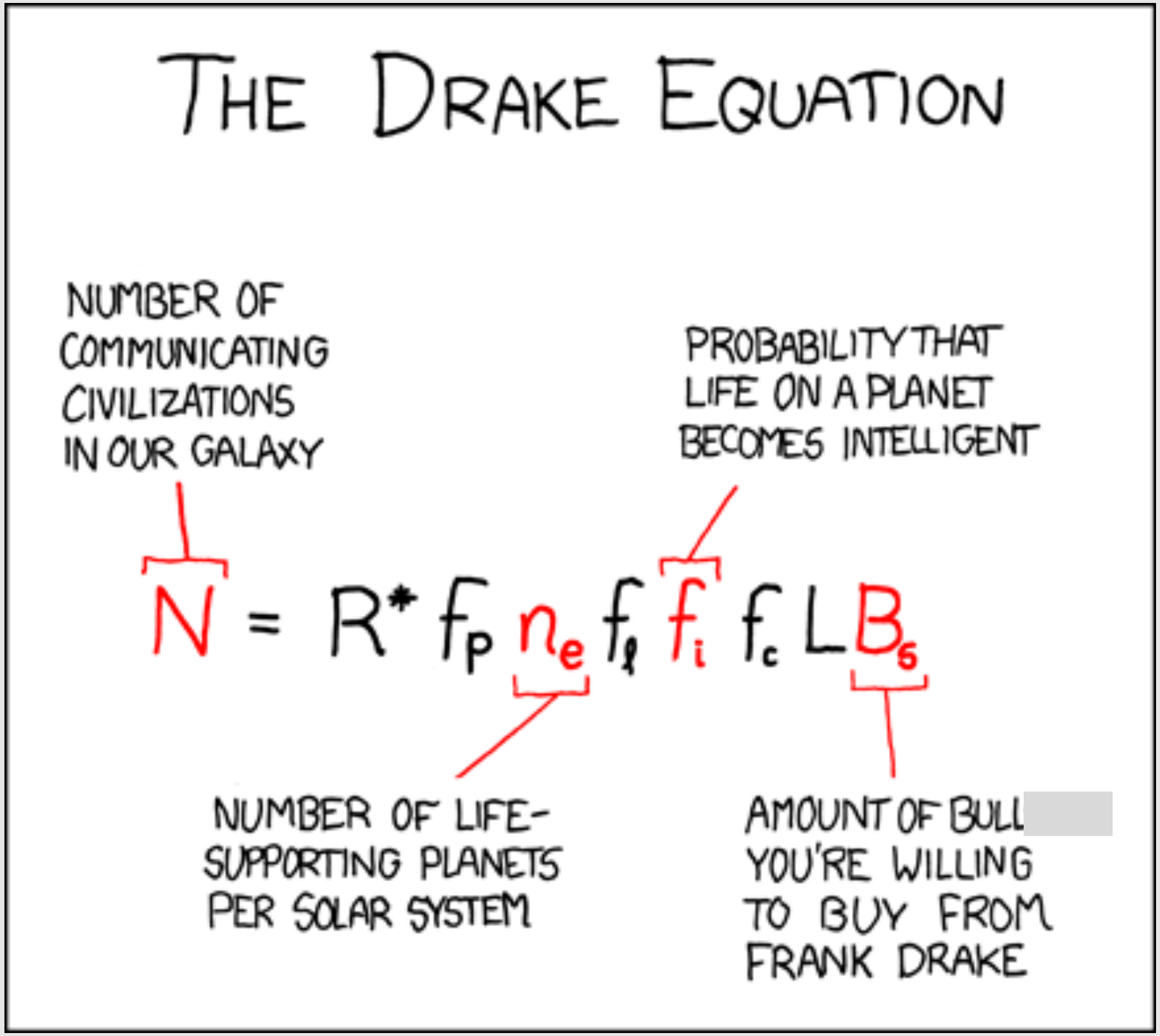
f_l = The fraction of suitable planets on which life actually appears.

f_i = The fraction of life bearing planets on which intelligent life emerges.

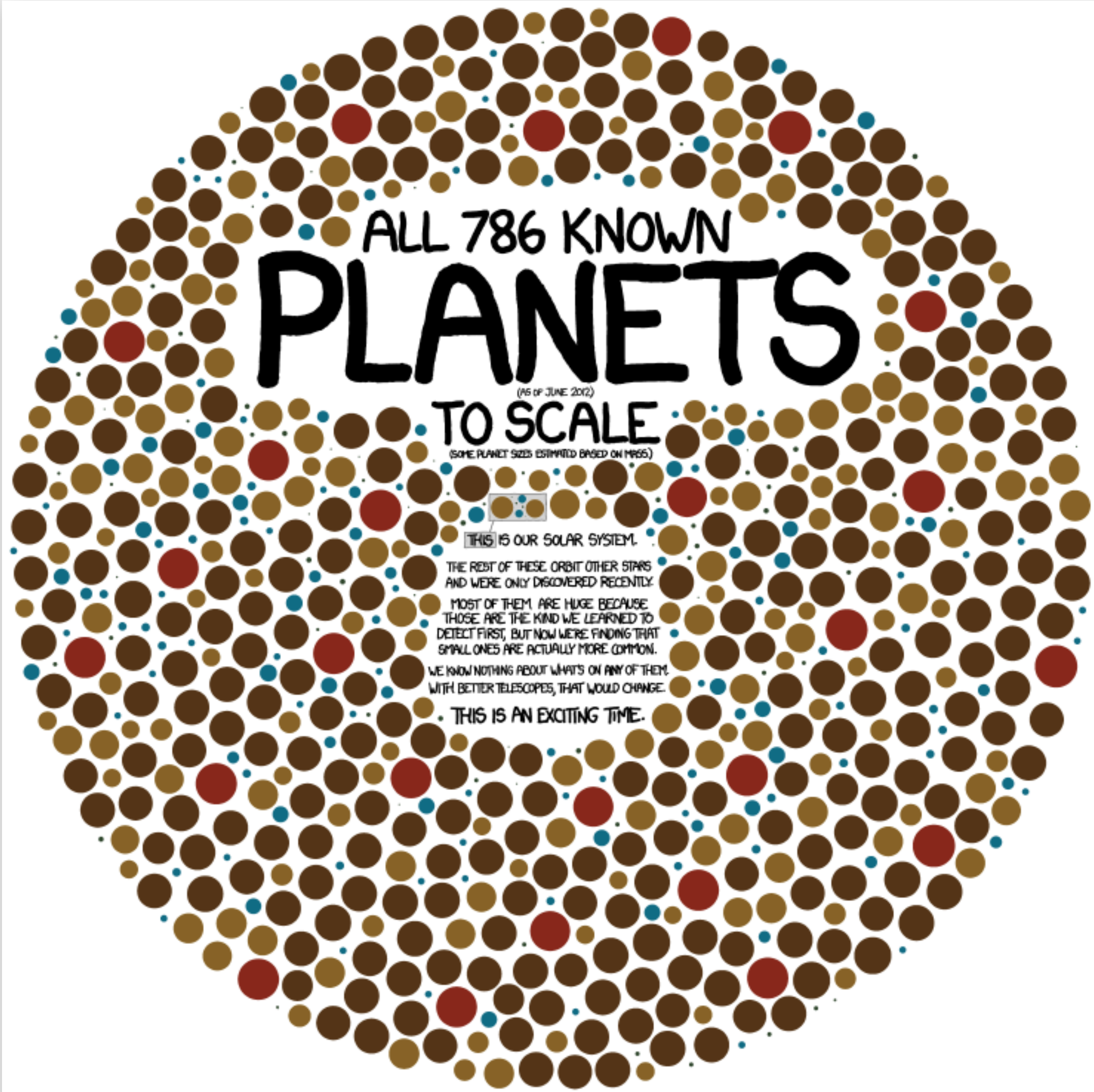
f_c = The fraction of civilizations that develop a technology that releases detectable signs of their existence into space.

L = The length of time such civilizations release detectable signals into space.

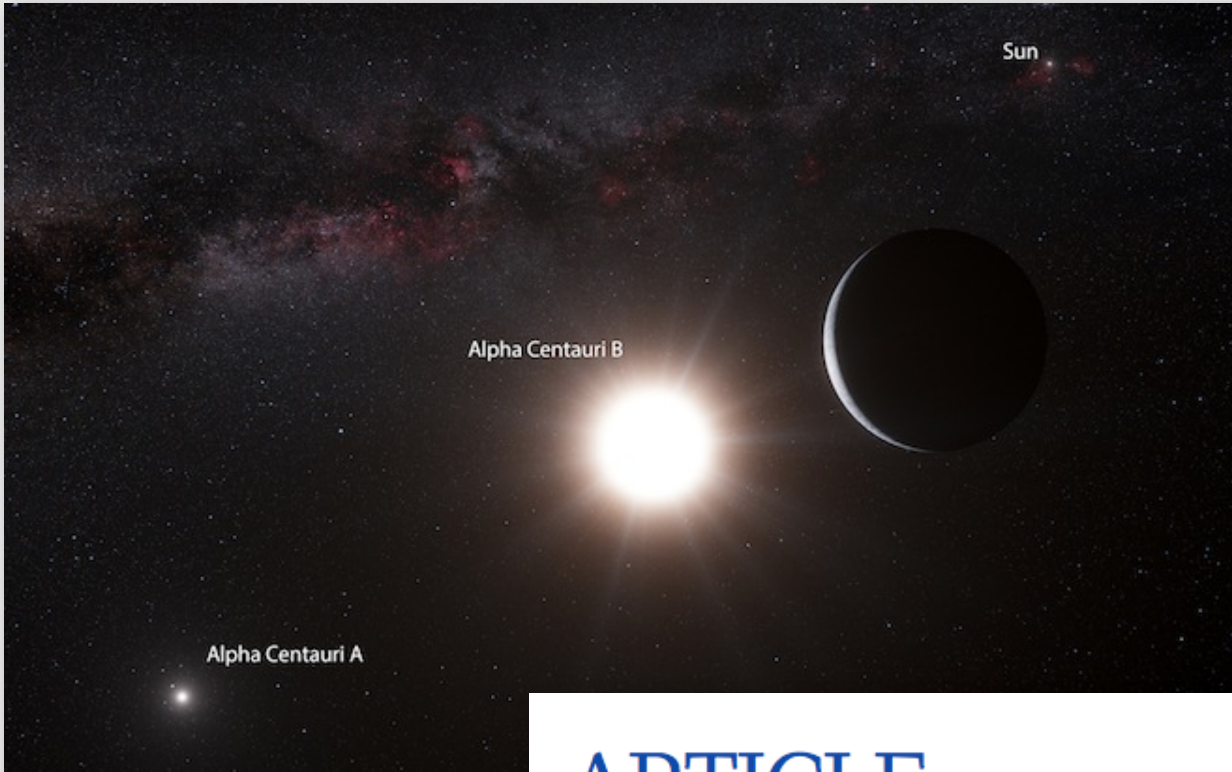
Drake equation



https://xkcd.com/384/



http://xkcd.com/1071/



ARTICLE

doi:10.1038/nature11572

An Earth-mass planet orbiting α Centauri B

Xavier Dumusque[1,2], Francesco Pepe[1], Christophe Lovis[1], Damien Ségransan[1], Johannes Sahlmann[1], Willy Benz[3], François Bouchy[1,4], Michel Mayor[1], Didier Queloz[1], Nuno Santos[2,5] & Stéphane Udry[1]

Exoplanets down to the size of Earth have been found, but not in the habitable zone—that is, at a distance from the parent star at which water, if present, would be liquid. There are planets in the habitable zone of stars cooler than our Sun, but for reasons such as tidal locking and strong stellar activity, they are unlikely to harbour water–carbon life as we know it. The detection of a habitable Earth-mass planet orbiting a star similar to our Sun is extremely difficult, because such a signal is overwhelmed by stellar perturbations. Here we report the detection of an Earth-mass planet orbiting our neighbour star α Centauri B, a member of the closest stellar system to the Sun. The planet has an orbital period of 3.236 days and is about 0.04 astronomical units from the star (one astronomical unit is the Earth–Sun distance).

Dumusque et al. 2012 [published today!]

"The State of Astrobiology, 2009" A report from Mary A. Voytek, Senior Scientist for Astrobiology (Interim), NASA Headquarters

March 27, 2009 – The Astrobiology Program is in good health for program year 2009, with a budget of **$49.5 million dollars** and a full slate of ongoing and new initiatives promising a continuing stream of discoveries. We have two 50th anniversaries to celebrate over the next year: NASA funding of its first exobiology experiment in 1959, and the establishment of the Agency's Exobiology Program – progenitor of the Astrobiology Program – in 1960.

Planetary protection is the term given to the practice of protecting solar system bodies (i.e., planets, moons, comets, and asteroids) from contamination by Earth life, and protecting Earth from possible life forms that may be returned from other solar system bodies. Planetary protection is essential for several important reasons: to preserve our ability to study other worlds as they exist in their natural states; to avoid contamination that would obscure our ability to find life elsewhere — if it exists; and to ensure that we take prudent precautions to protect Earth's biosphere in case it does.

Table 1. Summary of the average serpentine blank-corrected amino acid concentrations in the 6 M HCl acid-hydrolyzed hot-water extracts of the CI-type carbonaceous chondrites Orgueil and Ivuna and the CM chondrites Murray and Murchison

	CI		CM	
Type	Orgueil	Ivuna	Murray	Murchison
D-Asp	28 ± 16	30 ± 2	51 ± 31*	100 ± 15
L-Asp	54 ± 18	146 ± 8	65 ± 16	342 ± 103
D-Glu	15 ± 6	8 ± 1	135 ± 50	537 ± 117
L-Glu	61 ± 31	372 ± 11	261 ± 15	801 ± 200
Gly	707 ± 80	617 ± 83	2,110 ± 144	2,919 ± 433
D-Ala	69 ± 9	82 ± 22	617 ± 79	720 ± 95
L-Ala	69 ± 9	157 ± 14	647 ± 58	956 ± 171
β-Ala	2,052 ± 311	1,401 ± 146	1,063 ± 268	1,269 ± 202
D,L-α-ABA†	13 ± 11*	12 ± 7*	463 ± 68	914 ± 189
D,L-β-ABA‡	332 ± 99	438 ± 142	424 ± 18	708 ± 171
γ-ABA	628 ± 294	≈600	717 ± 192	1,331 ± 472
AIB	39 ± 37*	46 ± 33*	1,968 ± 350	2,901 ± 328
D,L-β-AIB†	148 ± 70	84 ± 12	147 ± 88	343 ± 102
D,L-Iva†	<194 ± 230*	<163 ± 119*	2,834 ± 780	3,359 ± 534
Total	4,200	4,000	11,500	17,200

All values are reported in ppb on a bulk-sample basis. The uncertainties are based on the standard deviation of the average value of between two and five separate measurements.

*These concentrations were very similar to blank levels and therefore must be considered to be maximum values.

†Enantiomers could not be separated under the chromatographic conditions.

‡Optically pure standard not available for enantiomeric identification.

Ehrenfreund et al. Extraterrestrial amino acids in Orgueil and Ivuna: Tracing the parent body of CI type carbonaceous chondrites. Proceedings of the National Academy of Sciences of the United States of America (2001) vol. 98 (5) pp. 2138