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Societat Catalana de Física

Prebiotic chemistry and the origin of life: the legacy of Joan Oró

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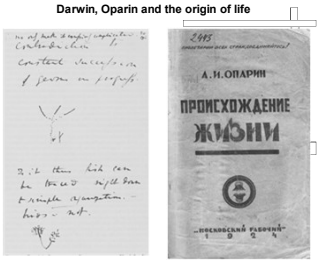
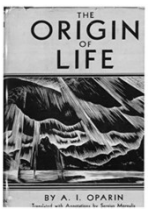
Darwin, Oparin and the origin of life



A. Lazcano (1998) *Journal of Molecular Evolution* **53**: 284.

Oparin's heterotrophic origin of life



reducing atmosphere
↓
synthesis of organic compounds (formation of the prebiotic soup)
↓
coacervates
↓
heterotrophic anaerobic bacteria

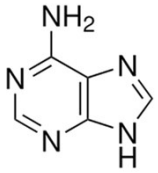
Oparin's heterotrophic scheme

1. set the question of the origin of life within a Darwinian framework;
2. proposed a multi- and interdisciplinary research program;
3. reinterpreted many isolated facts & observations within an evolutionary sequence leading to the first organisms;
4. interpreted chemical data and phenomena within an evolutionary context, bridging the gap between the non-living and the living worlds;
5. separated the idea of spontaneous generation of organisms from the chemical and biochemical origins of life; and
6. based on pre-Mendelian genetics, he rejected the idea of a "living molecule" and suggested life as a property of systems of molecules.

Lazcano (2010) In Deamer & Szostak (eds) *Cold Spring Harbor Perspectives in Biology: The Origins of Life*

June Linsdey (1922 -2021)

Adenine



Urey's reducing primitive atmosphere

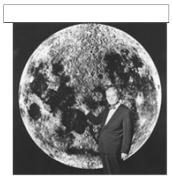
$C + 2H_2 \rightarrow CH_4$

$N_2 + 3H_2 \rightarrow NH_3$

$O_2 + 2H_2 \rightarrow H_2O$

$S + H_2 \rightarrow H_2S$

$CO_2 + 6H_2 \rightarrow CH_4 + 2H_2O$

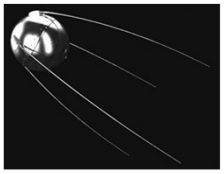


The harvest of '53

Watson & Crick and the double helix model of DNA

Stanley L. Miller and the prebiotic synthesis of amino acids

A Cold War technological feat with major political impact: the launching of the Sputnik on October 1957



In the wake of the launching of the Sputnik, and as a result of a complex mixture of social, political, military and scientific interests, "on July 29, 1958 President Eisenhower signed the National Aeronautics and Space Act, creating NASA as the US space agency…." *

NASA soon became committed to exobiology, which was seen as the study the origin, evolution and distribution of life in the Universe. It is difficult to picture the current development of the studies on the origin of life with its support.

Strick (2004) *J. Hist. Biol.* 37: 131

The National Defense Education Act (1958)

Definition:

- A law passed by the United States Congress to grant federal funds to American high schools to support mathematical, science, and foreign language education programs.

The 1960s: the intellectual and scientific atmosphere in the USA

a) Major improvement in scientific research financing policies

b) Growth of the scientific and educational apparatus

c) Thanks to NASA, new emphasis in planetary sciences

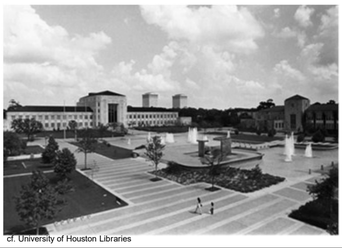
cf. Lazcano & Peretó (2017) *J Theoret Biol* **434**: 80

The 1960s: a new perspective of the Earth

1. Recognition of the role of microorganisms as agents of geological change (Berkner & Marshall)
2. Extension of the paleontological record to the early Precambrian (Barghoorn, Cloud)
3. Increased interest in the formation and characteristics of the primitive Earth

cf. Lazcano & Peretó (2017) *J Theoret Biol* **434**: 80

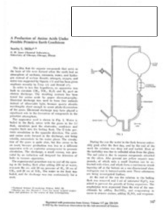
Cullen Family Plaza, University of Houston



cf. University of Houston Libraries

Joan Oró, en la Universidad de Houston, hacia 1963

Prebiotic syntheses of amino acids



Amino Acid Synthesis from Formaldehyde and Hydroxylamine

J. Oro', A. Kimball, R. Fritz and F. Master

From the Department of Chemistry, University of Houston, Houston, Texas

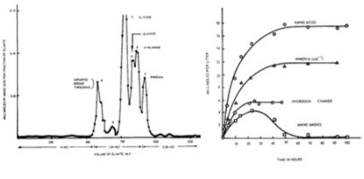
Received March 30, 1959

INTRODUCTION

The synthesis of amino acids, in one-step processes, by reaction of simple compounds of carbon (C_1 and C_2) with simple nitrogen compounds has been accomplished by several investigators using highly activating forms of energy such as electric discharges, ultraviolet light, and ionizing radiation (1-23).

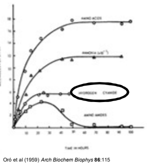
In particular, Loeb (1), Miller (2-6), Abelson (7, 8), and Heyns *et al.* (9) used the action of silent and spark discharges upon aqueous mixtures of totally reduced or partially oxidized carbon and nitrogen compounds.

Photochemical syntheses of amino acids in aqueous systems were claimed some time ago by Baudisch (10) from potassium nitrite, carbon monoxide, and ferric chloride, by Baly *et al.* (11) from formhydroxamic acid and formaldehyde, and by Dhar and Mukherjee (12) from nitrates, simple carbon compounds such as glycol, and titanium dioxide. More recently, Bahadur and his associates (13-16) have observed the formation of amino acids by the action of light upon aqueous solutions of potassium nitrate, paraformaldehyde, and ferric chloride, and upon aqueous mixtures of paraformaldehyde and molybdic oxide in the presence of air. Also, recently Groth and von Weyssenhoff (17, 18) and Miller (6) have reported amino acid syntheses by irradiating with ultraviolet light aqueous mixtures containing ammonia as a nitrogen source, and ethane and methane, respectively, as a carbon source.



Oró et al (1959) *Arch Biochem Biophys* **86**:115

Hydrogen cyanide as a key prebiotic reactant



Oró et al (1959) *Arch Biochem Biophys* **86**:115

$$RCHO + NH_3 + HCN \underset{}{\overset{K}{\rightleftharpoons}} RCH(NH_2)CN + H_2O$$

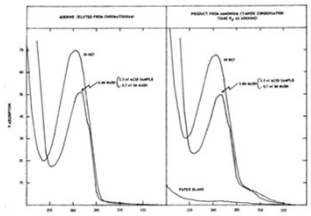
$$RCH(NH_2)CN + 2H_2O \xrightarrow{k} RCH(NH_2)COOH + NH_3$$

$$RCHO + HCN \overset{H}{\rightleftharpoons} RCH(OH)CN$$

$$RCH(OH)CN + 2H_2O \xrightarrow{h} RCH(OH)COOH + NH_3$$

Miller 1959

Oró (1960) *Biochem Biophys Res Comm* **2**: 407



Oró (1960) *Biochem Biophys Res Comm* **2**: 407

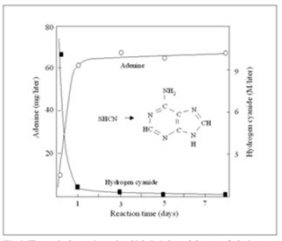
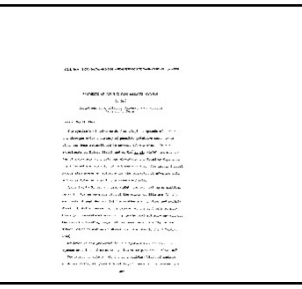
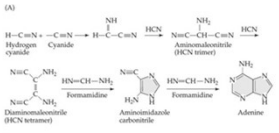


Fig. 2. The seminal experiment in which Oró showed the rate of adenine synthesis from ammonium cyanide at 90°C.



Molecular biology and the origins of life:
The prebiotic synthesis of adenine

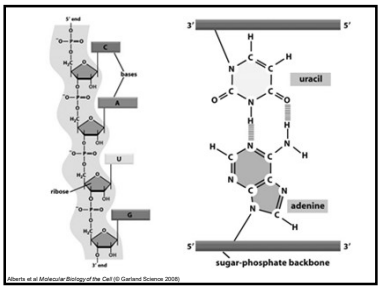


"In the area of prebiotic chemistry, Orgel explored the synthesis of purines and pyrimidines from simple building blocks that are likely to have been available on the primitive Earth.

As early as 1957, he was thinking about these problems. In a February morning walk through Kensington Gardens with Jack Dunitz, the two discussed the occurrence of adenine in the key molecules of genetics and metabolism. Orgel remarked that what makes adenine so special is that it is the first insoluble polymer of hydrogen cyanide.

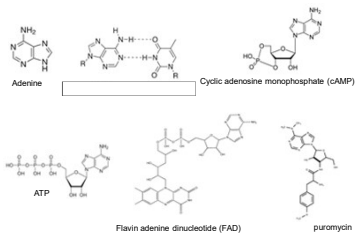
Four years later, Joan Oró showed that adenine can be formed in remarkably high yield from ammonia and hydrogen cyanide…"

Jack Dunitz & Gerald F. Joyce, Leslie E. Orgel (1927-2007), *Biographical Memories, National Academy of Sciences*



Alberts et al *Molecular Biology of the Cell* (© Garland Science 2008)

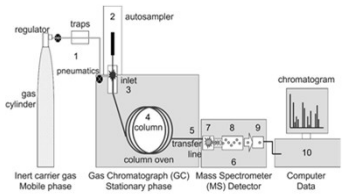
Adenine: a key component of genetic and biochemical processes



COMETS AND THE FORMATION OF BIOCHEMICAL COMPOUNDS ON THE PRIMITIVE EARTH

Carl Sagan to Juan Oró, June 1961

Freeman Quimby, Life Sciences Department, NASA
(cf. Strick, 2004)

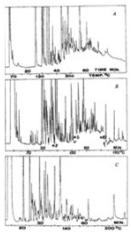


cf. Technology Networks

Meteorito Murchison (Australia, September 1969)

Deamer 2011

Oró et al (1971) Amino acids, aliphatic and aromatic hydrocarbons in the Murchison Meteorite. *Nature* **230**: 105



cf. Flickr

"Dr. Oró's systematic work on the synthesis of the small molecules out of which the key biochemical macromolecules were formed, has marked a notable advance. Previous work had shown that it was sufficient, starting with almost any gaseous sources of hydrogen, carbon, nitrogen and oxygen to form bases and amino acids.

What Dr. Oró has done is to show the actual chemical steps by which this synthesis takes place, beginning with the very small molecules detected spectroscopically in carbon stars and cometary tails. His greatest contribution here seems to have been somewhat on the side, the discovery that it was possible from hydrogen cyanide to synthesize the bases, particularly adenine.

John D. Bernal (1965) in Sidney W. Fox (ed) *The Origins of Prebiological Systems and their molecular matrices* (Academic Press, New York and London)

Joan/Juan/John/J. Oró's scientific legacy

1. His work on prebiotic syntheses linked the field of the origins of life with molecular biology, helping to introduce an evolutionary perspective to the latter;
2. Linked the geochemical history of early Earth with its astronomical context and the appearance of life; and
3. Helped to define the chemical history of the Solar System.

5 HCN ⟶ adenine

Joan Oró

5 HCN ⟶ adenine

Joan d' Oró