15th Annual Seven Pines Symposium: Origins of Life

The recent history of the origin of life: the ghosts in the soup

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May 2011

ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

By CHARLES DARWIN, M.A.,

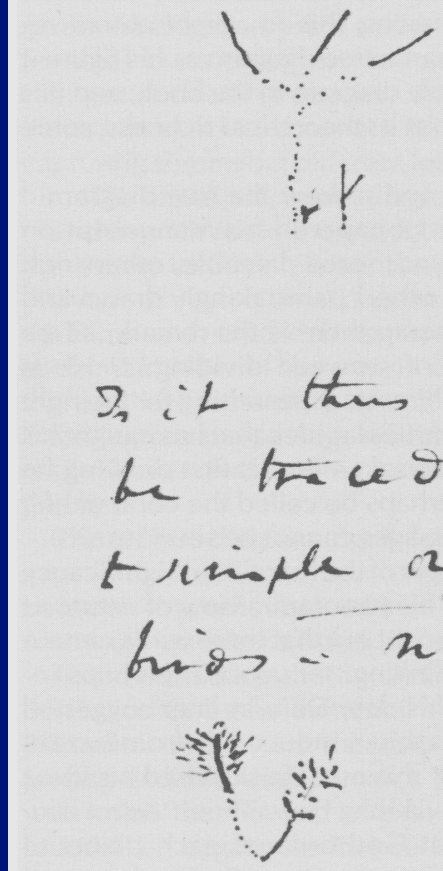
FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;

AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

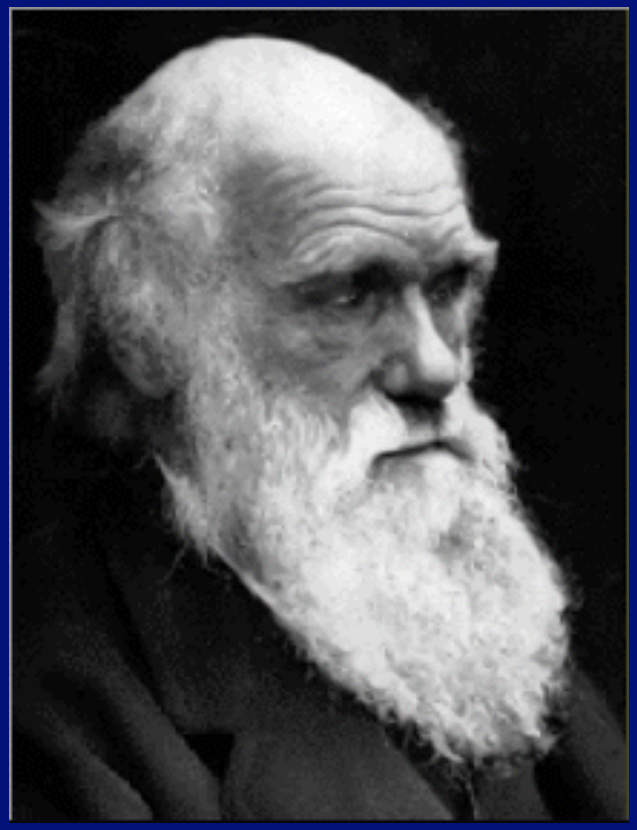
LONDON:

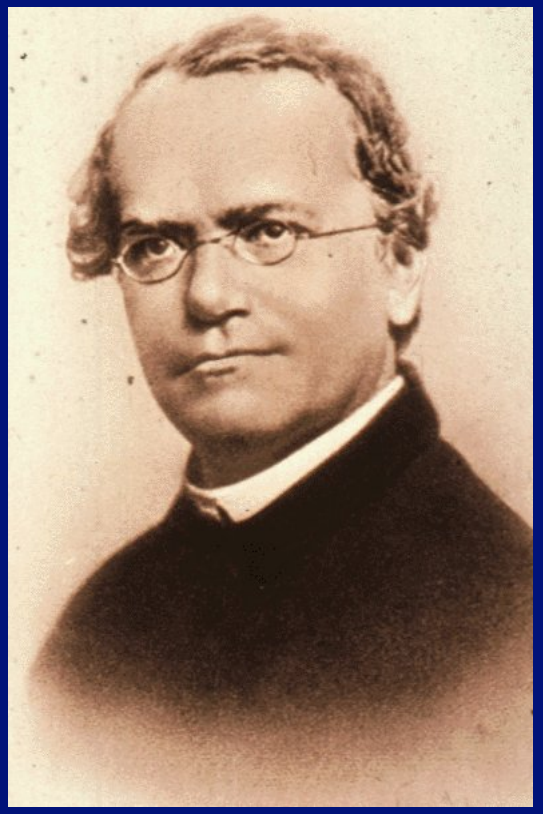
JOHN MURRAY, ALBEMARLE STREET.

1859.



Darwin vs. Mendel?





Following the “rediscovery” of Mendel’s work, genetic mutations were considered as the fundamental source of evolutionary novelties in opposition to Darwin’s natural selection.

H. J. Muller joined Morgan's Fly Room at Columbia University, and became a committed neoMendelian --as shown by his single gene theory of the origin of life (later "DNA first")

1. The first living being was a gene that appeared by chance in the primitive oceans;

2. The primordial gene was endowed with:

    a) autocatalysis (replication)

    b) heterocatalysis (metabolism)

    c) mutation properties (evolvability)

3. The primordial gene was endowed with autotrophic abilities

Muller, 1926

Some important traits of Russian/Soviet Darwinism

1. Starting in 1865, Arkady K. Tymiriazev started to promote Darwin's ideas, an effort that rapidly attracted scientists, philosophers, writers and, of course, left-wing politicians. This lead a number of conservative thinkers, including several staunch supporters of monarchic absolutism, to campaign against Darwin's views.

3. The "rediscovery" of Mendel's ideas and the role of mutation was seen by many as an attack against Darwinism.

   This lead Tymiriazev (1912) to state that "Mendelists and mutationists are the principal enemies in the struggle against anti-darwinists"

Tymiriazev, A. (1912) Sochineniia 8: 63

BERKELEY, CALIFORNIA

SPECIAL ARTICLES

ENZYMES OF THERMAL ALGAE

THE algae of the hot springs in Yellowstone National Park offer good opportunity for a study of the distribution of enzymes in relation to the temperatures at which the organisms live. There is a complete series of thermal springs ranging in temperature from the boiling point (about 91° C) down to ordinary temperatures. Algae are found growing at a great many different temperatures within this range. One species of Phormidium was found growing at 89° C in Beryl Spring.

The action of some enzymes has been shown to be destroyed at temperatures much below the normal temperature range of some of these thermal algae. It seems of interest to determine at what range of temperature the thermolabile enzymes are present in the algae, and how the algae are able to conduct their metabolic processes at temperatures above the maximum for the activity of several important enzymes.

Phormidium laminosum was found growing in pure culture in Hymen Terrace spring at 73° C. to 65° C. Its range did not extend below 65° C. Possibly other factors than the temperature were concerned in this distribution, since the carbon dioxide and hydrogen sulfide used by this organism are quickly liberated from the water after it escapes. Possibly the temperatures below this range do not allow metabolic processes to proceed normally in the absence of certain enzymes.

Determinations on the catalase, oxidase, oxydoreductase and peroxidase action of this Phormidium were made immediately at the spring. For oxydoreductase activity the reduction of methylene blue in the presence of acetone was used. Strong reduction was shown by the preparation, some of which was probably due to the reducing substances present in

the water which can not be eliminated. For oxidase activity, the oxidation of tetra methyl para phenylene diamine showed a slight activity. On the addition of hydrogen peroxide to this reagent a very active peroxidase action was shown. Catalase was determined by means of the Van Slyke apparatus commonly used for the determination of amino acids, the oxygen being liberated in the reaction vessel and measured in the burette. The material was collected from pure culture and the determinations were completed within a few minutes. No catalase activity was shown by the Phormidium filaments either suspended in water or after grinding for a long time in a mortar with fine quartz sand and calcium carbonate. The failure to decompose hydrogen peroxide was not due to any defect in the experiment or to poisonous substances in the spring water, since leaves of Iva xanthifolia treated in exactly the same manner with spring water showed high catalase activity at room temperature. It must be concluded, then, that this Phormidium possesses no catalase and little oxidase activity but shows a strong peroxidase and probably oxydo-reductase action.

Catalase previously has been found to be of universal distribution in living organisms. Czapek in his "Biochemie der Pflanzen" gives a bibliography of its distribution in various groups of plants and animals. Oscar Loew concluded that catalase was universally distributed, occurring in every organism and necessary in every living cell. This is the first instance of its absence from an organism having been demonstrated. G. B. Reed reported catalase activity in ripe and half ripe pineapples but found no activity in very green pineapples. No mention was made of controlling the acidity, so it seems probable that the catalase present in the green fruits was destroyed in the preparation. This enzyme, therefore, can not be required for the life activities of all organisms as has been suggested. The maximum temperature for the activity of catalase is low. Catalase derived from leaves of Iva xanthifolia was destroyed at the temperature of the spring water of Hymen Terrace (73° C.) by exposure for less than one minute. Oxydo-reductase is known to have a rather high optimum (57° C.) for its activity, and peroxidase activity is shown at the boiling temperature since it is thermostable, in fact, to such a degree that there is doubt that it should be included in the class of enzymes.

The fact that an organism can live at the temperature at which water boils at high altitudes demands that by some means it shall be able to carry on the hydrolytic cleavages or other chemical activities required for its metabolism. As the altitude increases there would be found a level at which water would maintain a constant temperature by boiling at a tem-

THE ORIGIN OF LIFE

By Professor CHARLES B. LIPMAN
UNIVERSITY OF CALIFORNIA

AT the remotest frontiers of man's most penetrating and imaginative thought there has always lingered the dream—perhaps the hope—that the age-old mystery of the origin of life would some day be solved. The remarkable forward strides that have been taken in the physical sciences in the last two decades, replete with significance for the progress of biological thought and study, have strengthened rather than weakened that hope. It is my purpose in this brief paper to recall to your minds, among other things, some of the theories, or at least speculative hypotheses, which have been put forward in the past to account for the origin of life on our planet, but chiefly to review critically some of the consequences of these hypotheses in order to test the soundness of the latter and to propose a view of my own relative to the problem in hand. To the interested reader, it is probably superfluous to enter into a disquisition on the difficulties of the task in question. Needless to say, finality of judgment in the premises is proscribed and I do not seek to be dogmatic in any part of my discussion. Inconclusive indeed I must be, but I venture to hope that my analysis of the problem may contribute to progress, or at least to clarification of our thought.

The Aristotelian conception of the origin of many forms of animal life from de
during the greater
man. In fact, the th
its death-blow until
arrived. But befor
Pasteur had put th
generation, many inv
Before the last third
strated that maggots
from flies, and that o
in the meat were m
were challenged by
by the high authority
to be specious by the
of Cagniard de la To
the solid foundation

The Editor of "The Rationalist Annual" desires it to be understood that each contributor is alone responsible for the opinions he expresses, and that he in no way commits the R. P. A. or any of the other contributors to an endorsement of his views. The aim of the Editor is to provide a platform for all liberal thinkers in general agreement with Rationalism as defined in the Memorandum of the R. P. A.

THE ORIGIN OF LIFE

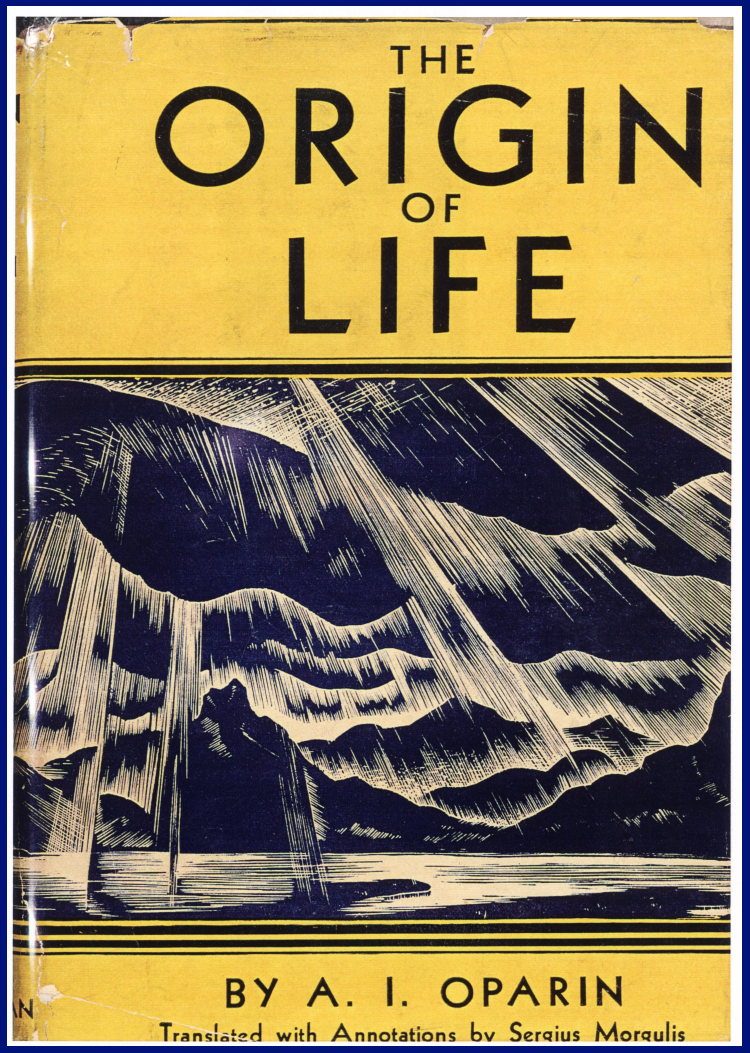
By J. B. S. HALDANE

UNTIL about 150 years ago it was generally believed that living beings were constantly arising out of dead matter. Maggots were supposed to be generated spontaneously in decaying meat. In 1668 Redi showed that this did not happen provided insects were carefully excluded. And in 1860 Pasteur extended the proof to the bacteria which he had shown were the cause of putrefaction. It seemed fairly clear that all the living beings known to us originate from other living beings. At the same time Darwin gave a new emotional interest to the problem. It had appeared unimportant that a few worms should originate from mud. But if man was descended from worms such spontaneous generation acquired a new significance. The origin of life on the earth would have been as casual an affair as the evolution of monkeys into man. Even if the latter stages of man's history were due to natural causes, pride clung to a supernatural, or at least surprising, mode of origin for his ultimate ancestors. So it was with a sigh of relief that a good many men, whom Darwin's arguments had convinced, accepted the conclusion of Pasteur that life can originate only from life. It was possible either to suppose that life had been supernaturally created on earth some millions of years ago, or that it had been brought to earth by a meteorite or by micro-organisms floating through interstellar space. But a large number, perhaps the majority, of biologists, believed, in spite of Pasteur, that at some time in the remote past life had originated on earth from dead matter as the result of natural processes.

The more ardent materialists tried to fill in the details of this process, but without complete success. Oddly enough, the few scientific men who professed idealism agreed with them. For if one can find evidences of mind (in religious terminology the finger of God) in the most ordinary events, even those which go on in the chemical laboratory, one can

Bada & Lazcano, 2003

Heterotrophic origin of life



reducing atmosphere

↓

synthesis of organic compounds & formation of the primitive soup

↓

coacervates

↓

primordial heterotrophs

It is surprising that Oparin's proposal did not include genes or nucleic acids?

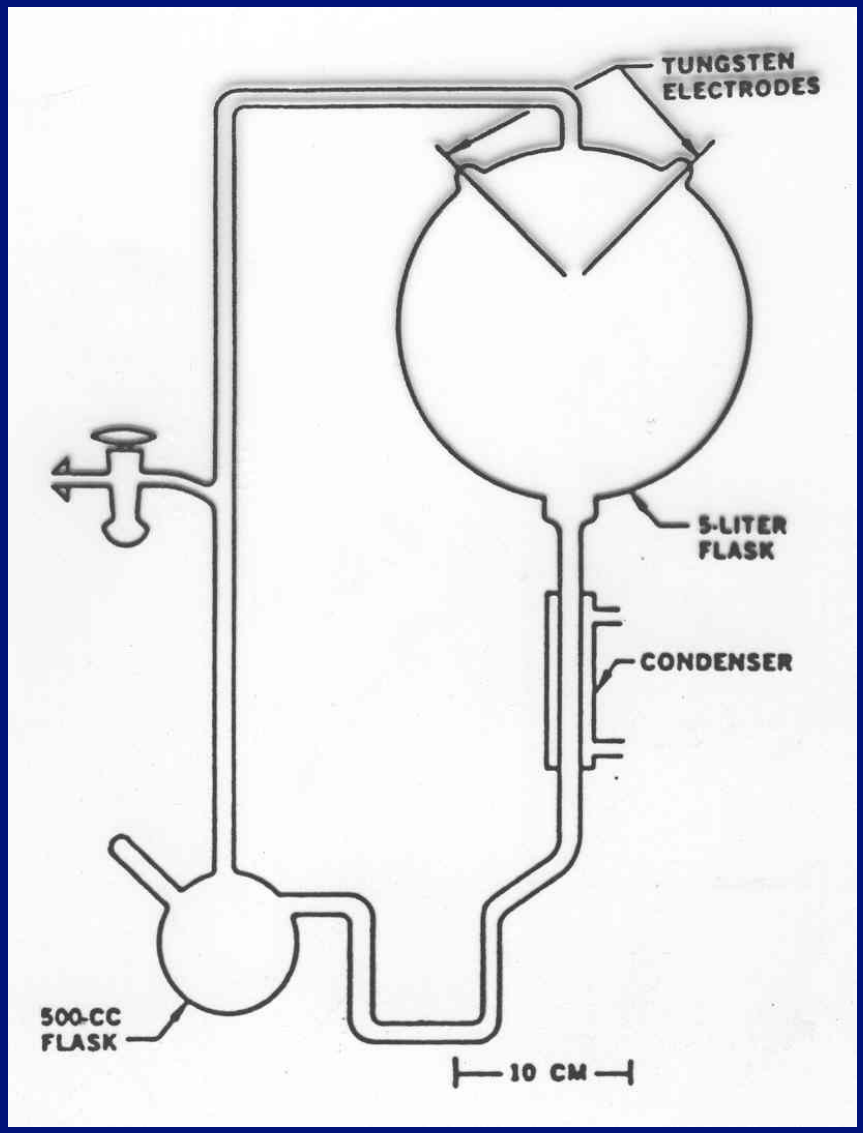
1. Ernst Haeckel, who was a major influence in Oparin's work, had assumed that Monera lacked all traces of the hereditary substances of other organisms

   E. Haeckel (1904) *The Wonders of Life*

2. "… bacteria have no genes in the sense of accurately quantized portions of hereditary substances; and therefore have no need for accurate division of the genetic system which is accomplished by mitosis."

   Julian Huxley (1942) *Evolution: the modern synthesis*

The 1953 Miller-Urey experiment



During the first twenty years following the 1953 Miller experiment, attempts to understand the origin of life were shaped to a considerable extent,

1) scientifically,

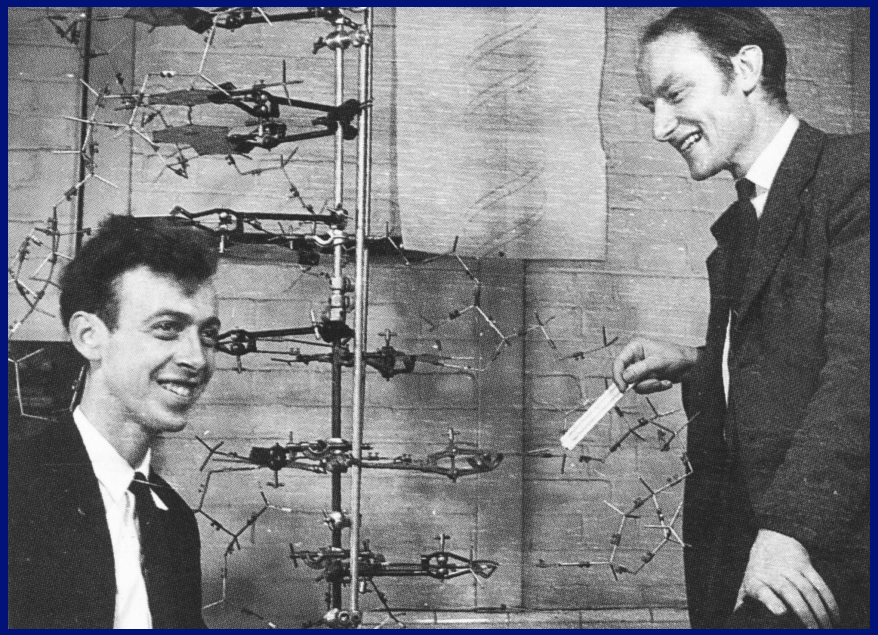
* by the fact that since the late 1940´s, evolutionary biology became an established field of research;

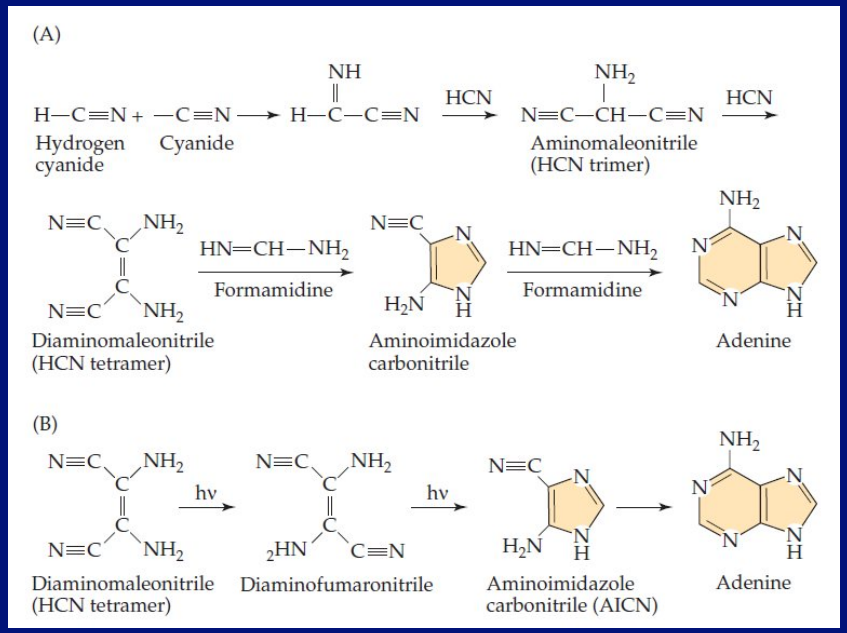
* the unraveling of the details of DNA replication & protein biosynthesis; and

* the development of space programs

2) in socio-political terms, by the atmosphere created by Cold War tensions.

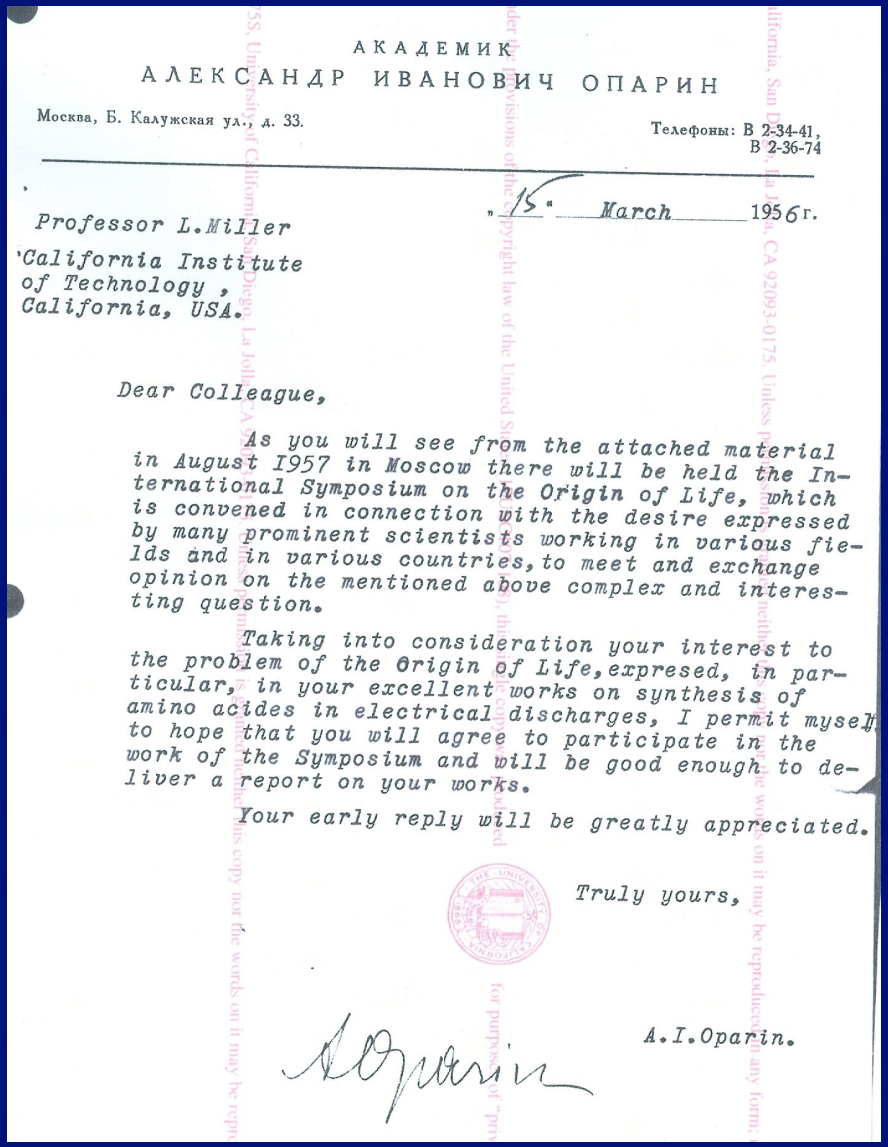
Molecular biology and prebiotic chemistry: did DNA molecules form in the primitive soup?





a) Oró 1960; b) Ferris & Orgel 1966

In sociopolitical terms…



АКАДЕМИК
АЛЕКСАНДР ИВАНОВИЧ ОПАРИН

Москва, Б. Калужская ул., д. 33.

Телефоны: В 2-34-41,
В 2-36-74

"15" March 1956 г.

Professor L.Miller
'California Institute
of Technology ,
California, USA.

Dear Colleague,

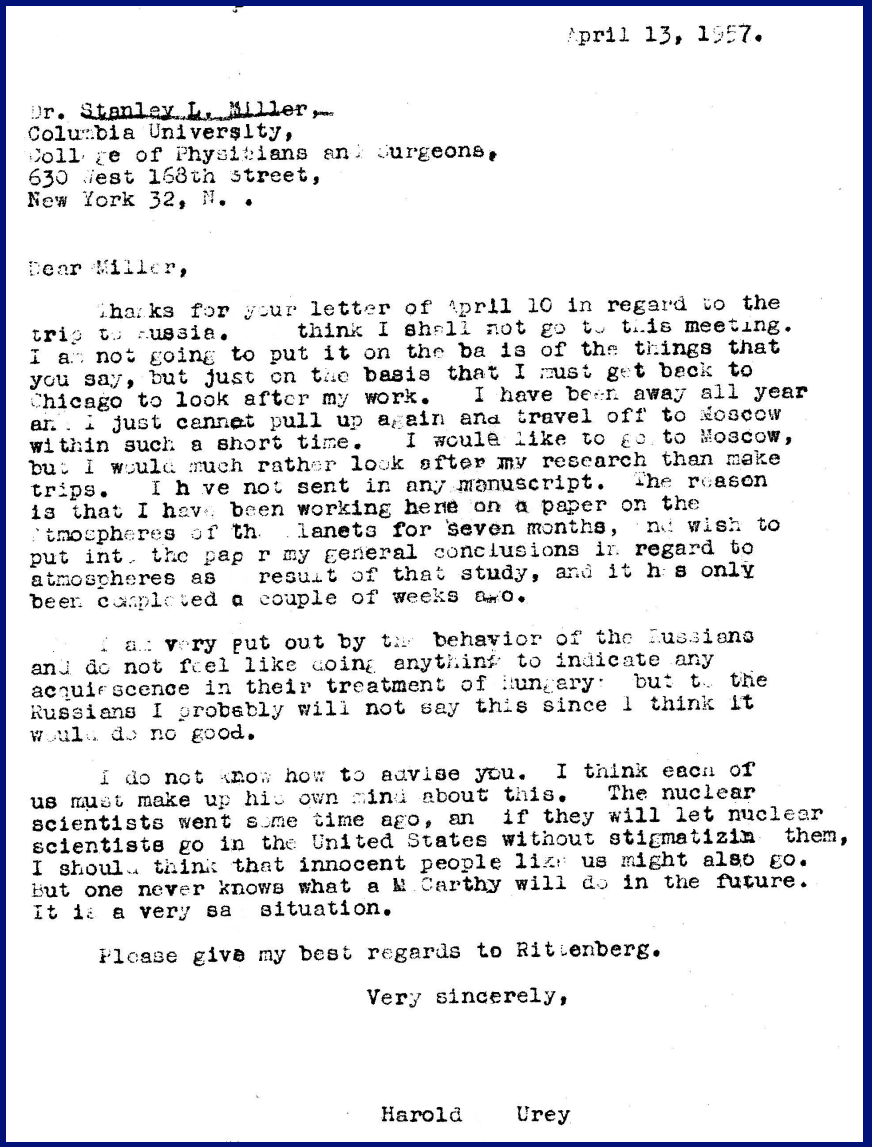
As you will see from the attached material in August 1957 in Moscow there will be held the International Symposium on the Origin of Life, which is convened in connection with the desire expressed by many prominent scientists working in various fields and in various countries, to meet and exchange opinion on the mentioned above complex and interesting question.

Taking into consideration your interest to the problem of the Origin of Life, expresed, in particular, in your excellent works on synthesis of amino acides in electrical discharges, I permit myself to hope that you will agree to participate in the work of the Symposium and will be good enough to deliver a report on your works.

Your early reply will be greatly appreciated.

Truly yours,

A.I.Oparin.



April 13, 1957.

Dr. Stanley L. Miller,
Columbia University,
College of Physicians and Surgeons,
630 West 168th Street,
New York 32, N. Y.

Dear Miller,

Thanks for your letter of April 10 in regard to the trip to Russia. I think I shall not go to this meeting. I am not going to put it on the basis of the things that you say, but just on the basis that I must get back to Chicago to look after my work. I have been away all year and I just cannot pull up again and travel off to Moscow within such a short time. I would like to go to Moscow, but I would much rather look after my research than make trips. I have not sent in any manuscript. The reason is that I have been working here on a paper on the atmospheres of the planets for seven months, and wish to put into the paper my general conclusions in regard to atmospheres as a result of that study, and it has only been completed a couple of weeks ago.

I am very put out by the behavior of the Russians and do not feel like doing anything to indicate any acquiescence in their treatment of Hungary. But to the Russians I probably will not say this since I think it would do no good.

I do not know how to advise you. I think each of us must make up his own mind about this. The nuclear scientists went some time ago, and if they will let nuclear scientists go in the United States without stigmatizing them, I should think that innocent people like us might also go. But one never knows what a McCarthy will do in the future. It is a very sad situation.

Please give my best regards to Rittenberg.

Very sincerely,

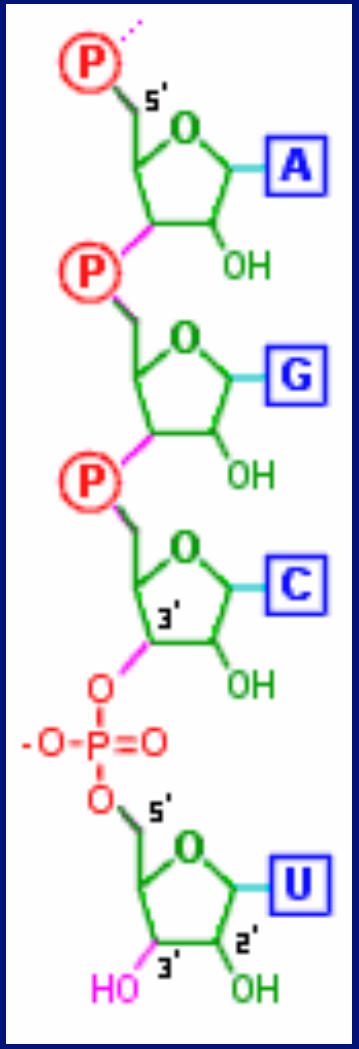
Harold Urey

In sociopolitical terms….

"I do not know how to advise you. I think each of us must make his own mind about this. The nuclear scientists went some time ago, and if they will let the nuclear scientists go in the United States without stigmatizing them, I should think that innocent people like us might also go, but one never knows how what a McCarthy will do in the future. It is a very sad situation."

Harold C. Urey to Stanley L. Miller, April 13, 1957

What's in a name?

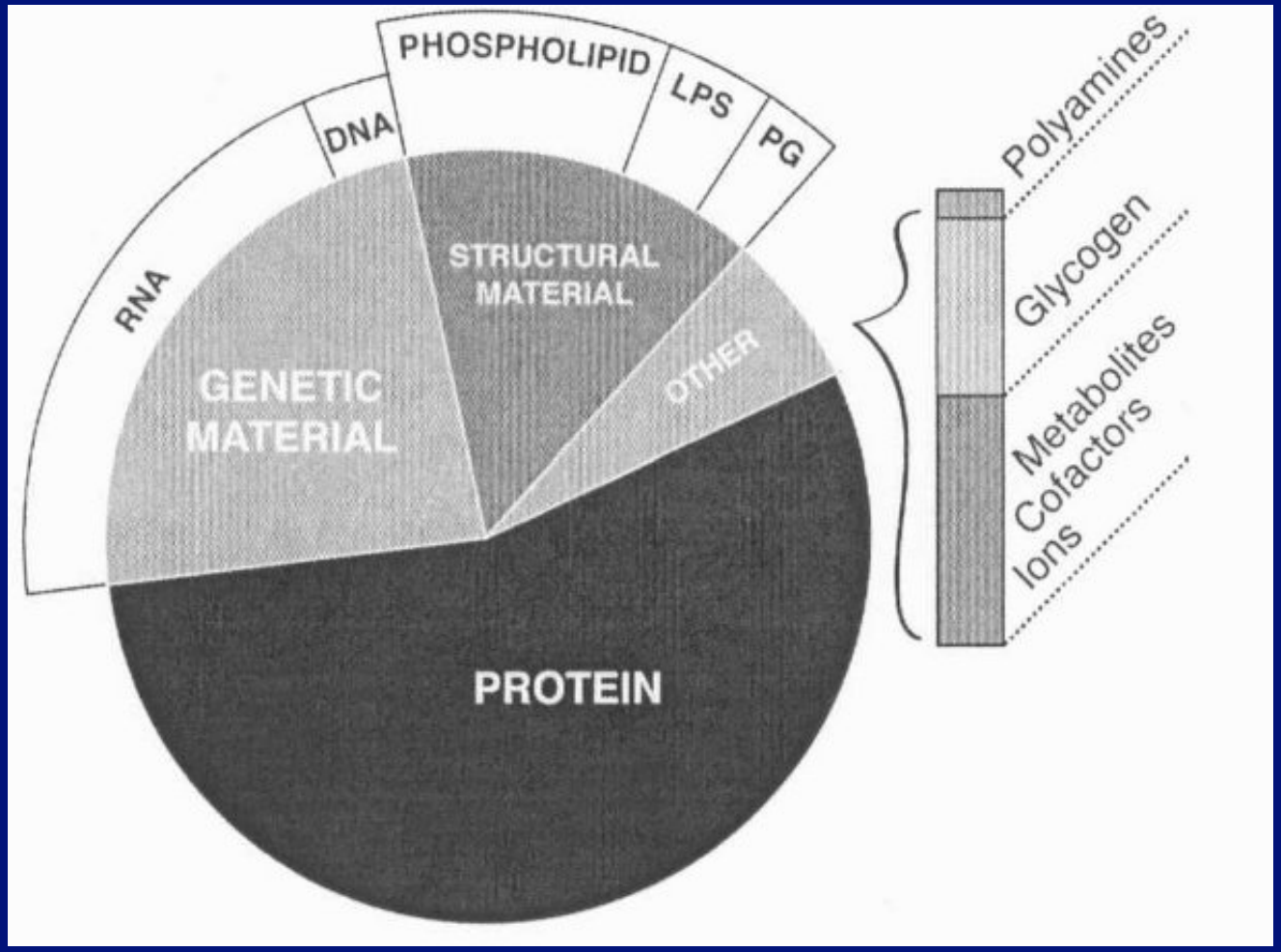


RNA is a nucleic acid with a RIBOSE-PHOSPHATE backbone

-ose is for sugars, and RIB for the Rockefeller Institute of Biochemistry

Ettienne-Decant, J. (1988) *Genetic Biochemistry: from gene to protein* (Ellis Horwood Ltd)

By the time the 1957 Moscow meeting took place, the genetic roles of both DNA and RNA had been firmly established



Neidhart, Ingraham & Schaechter (1990)

RNA is abundant and functionally interesting: the value of intuition

J. L. A. Brachet (1909-1998)

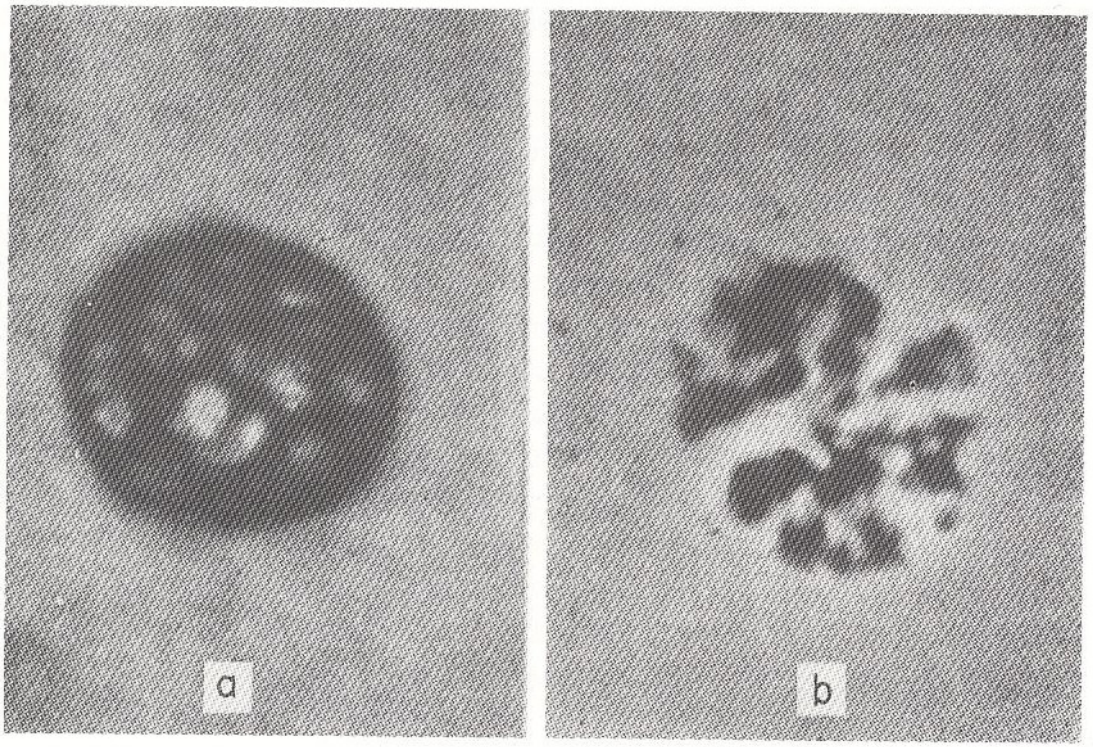
A. N. Belozersky (1905–1972)

"…There is no doubt that nucleic acids played an important role in the evolution of the organic world and metabolic reactions. Yet both RNA and DNA could hardly arise simultaneously in the early evolution of life. It rather seems that ribonucleotides, and then RNA, originated first. DNA came into existence far more recently, as the protoplasm became more differentiated and its functions grew in complexity.

"It seems that RNA, being associated with the most general processes of life, was formed at an earlier evolutionary stage, while the origin of DNA was associated with the development of more specialized and phylogenetically later features of organisms"

A.N. Belozersky, 1957 (1959)

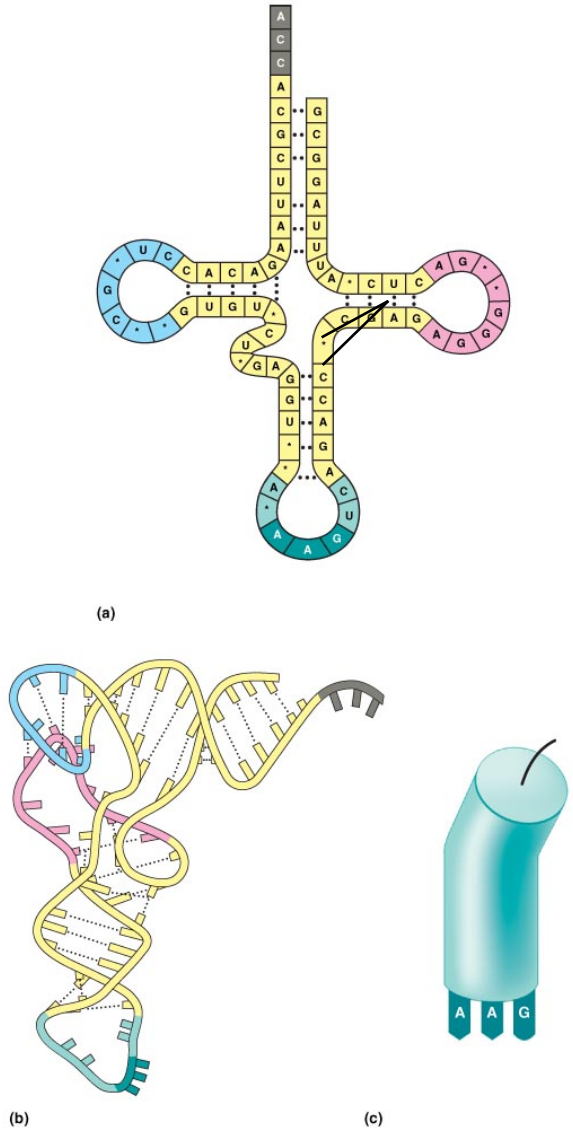
By the early 1960s, Haldane, Oparin and others were convinced that RNA had preceded DNA as genetic material during early cell evolution. In fact, Oparin had worked on coacervates with RNA since 1947, which was, if not an act of defiance of Lysenko's influence in Soviet science, at least a sympton of independence

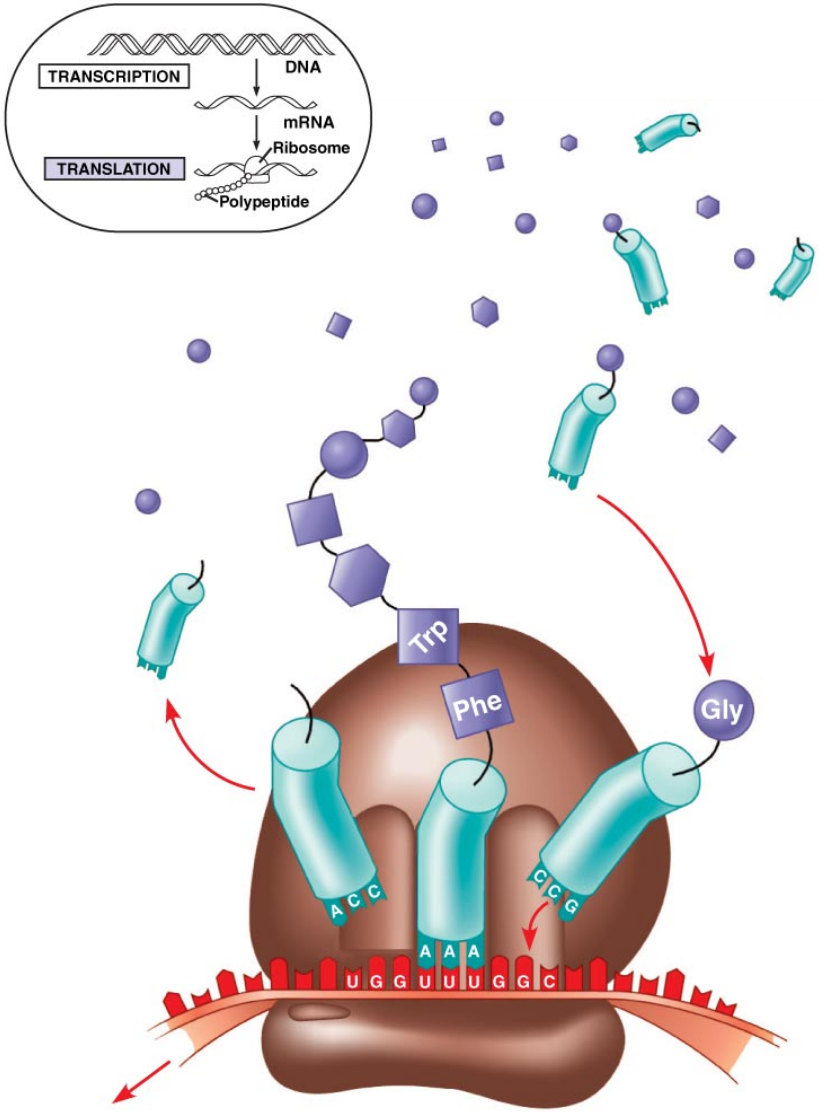


Coacervate droplet of serum albumin + gum arabic + RNA and the enzyme ribonuclease under the electron microscope. a. Before the beginning of breakdown. b. After a 15-minute breakdown period.

Oparin (1968) *Genesis and Evolutionary Development of Life* (Academic Press, New York)

The extraordinary plasticity of RNA molecules





During early evolutionary stages RNA molecules played a major role in heredity and metabolism

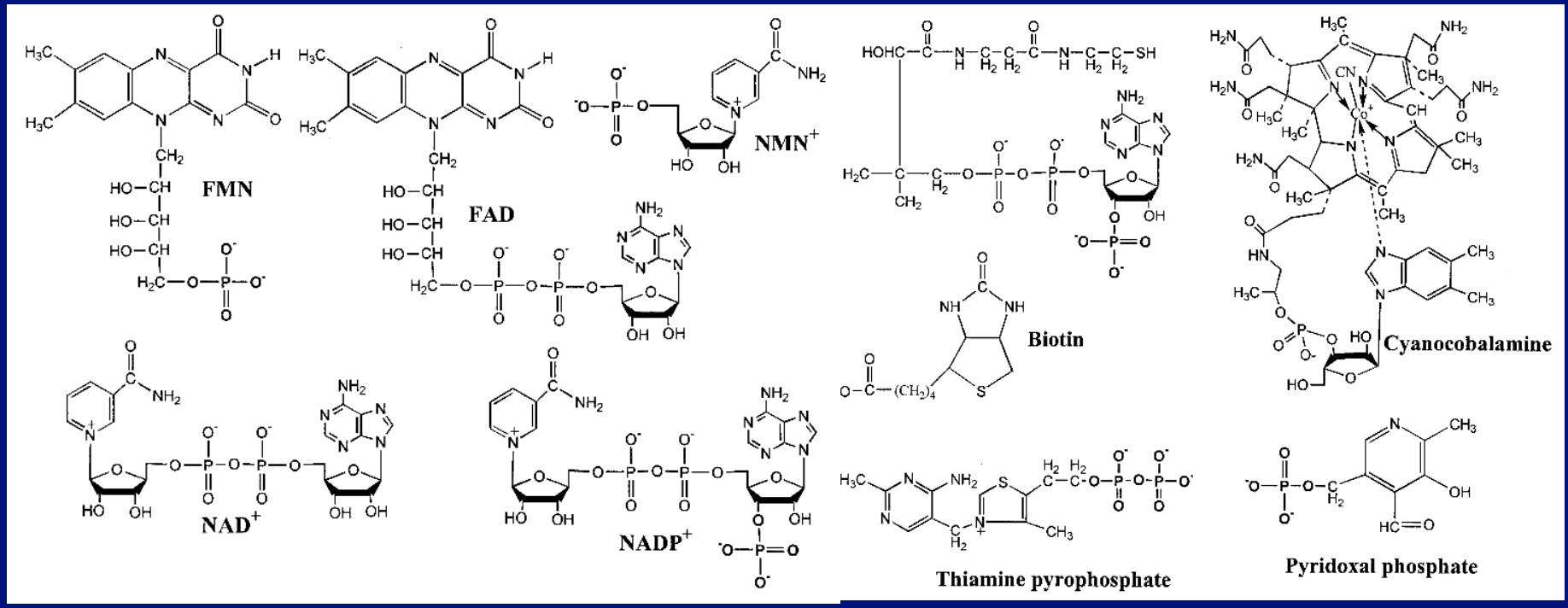
Woese (1967)

Orgel (1968) & Crick (1968)

replicative RNA

catalytic RNA

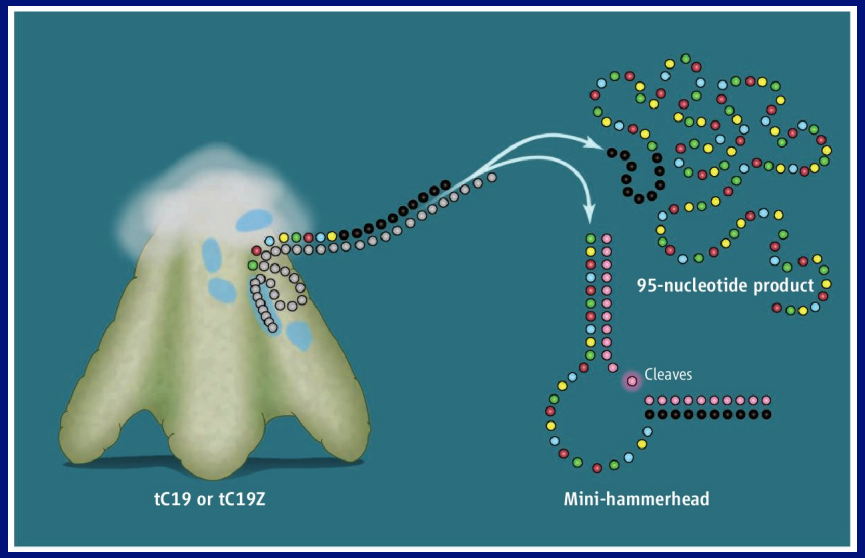
Coenzymes as fossils of the RNA world

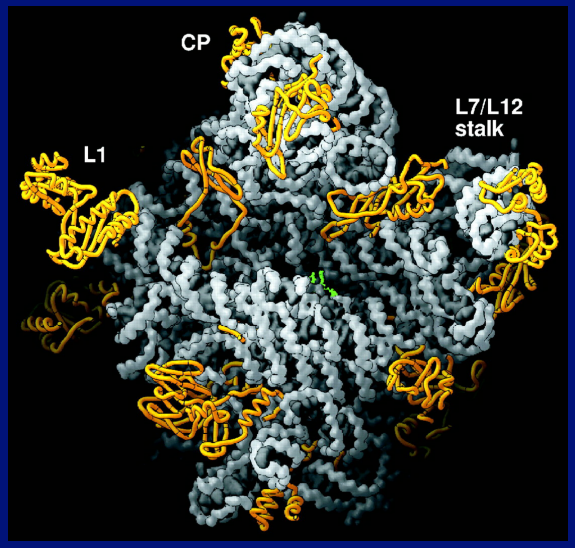


- Most enzymes require coenzymes, without which catalysis is not observed
- Many coenzymes are ribonucleotide derivatives

Orgel 1968; Orgel & Sulston 1971; White, 1976

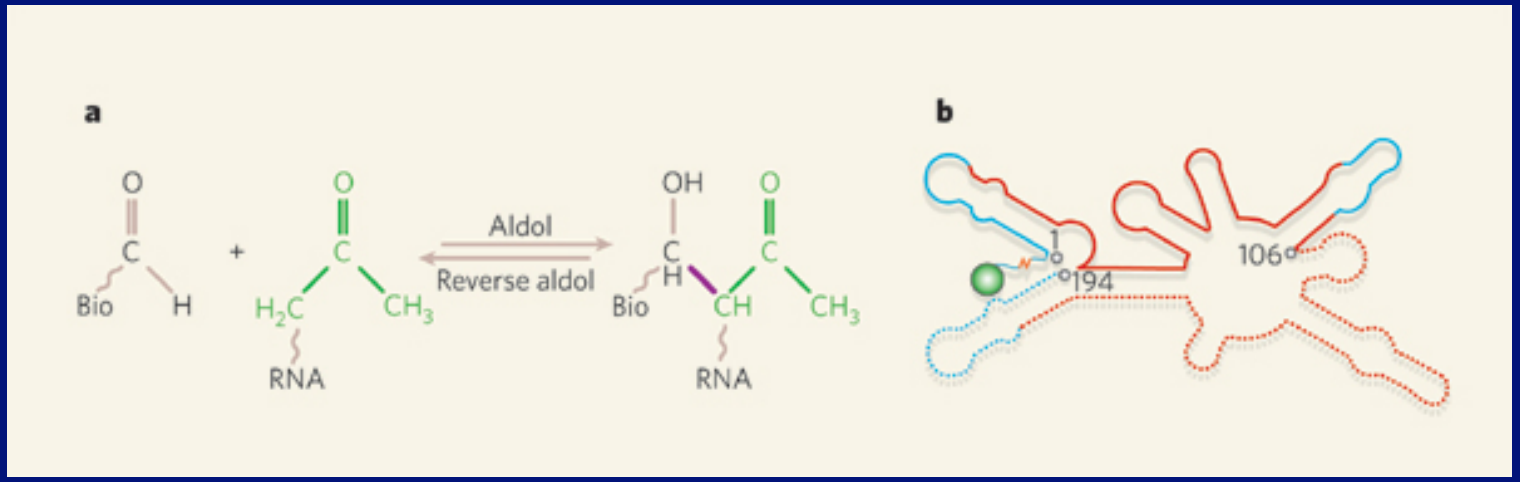
The robustness of the RNA world hypothesis



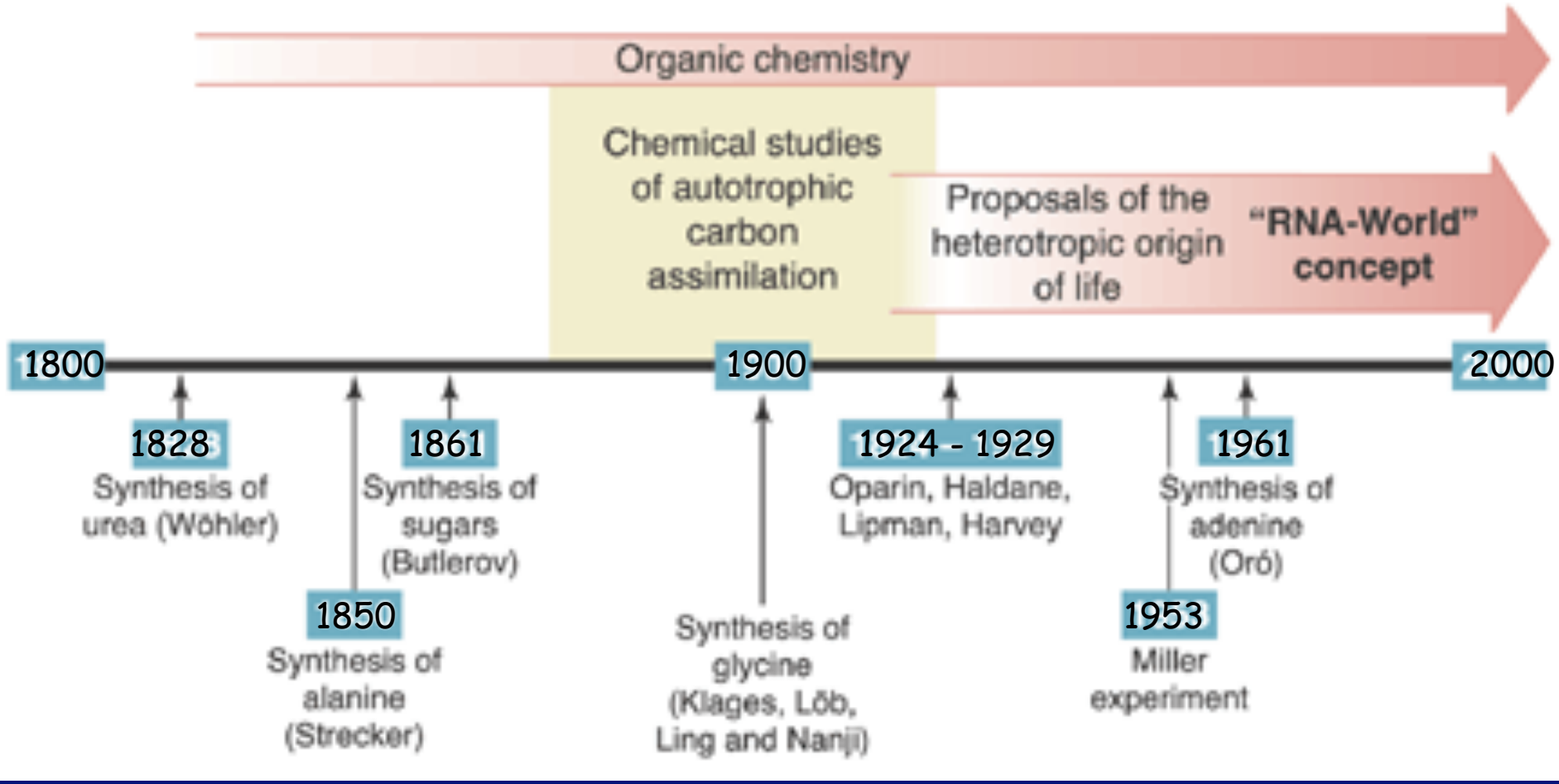


Self-sustained replication of RNA molecules
Wochner et al. (2011)

RNA ribosomal catalyzes peptide-bond formation (Moore & Steitz, 2002)



Ribozymes catalyze metabolic reactions (Fusz *et al*, 2005, *Chem. Biol.* **12**: 941)



Bada & Lazcano (2003) *Science* **300**: 745

RNA World

Unknown prebiotic chemical processes?

Evolutionary outcome of pre-RNA worlds?

“Thought there is no guarantee, of course, that the first-reproducing genetic materials formed in the primordial soup of ancient oceans were nucleic acid, or any polymers even resembling polynucleotides, it has now become clear at least that probing into the origin of the genetic code –into ways in which it could have arisen without, like Athena, having sprung full-blown from Zeus’ head –is likely to be a most profitable attack on this problem.”

Stent (1968) Science 160: 390

For several years, attempts to understand the origin of life were shaped to a considerable extent,

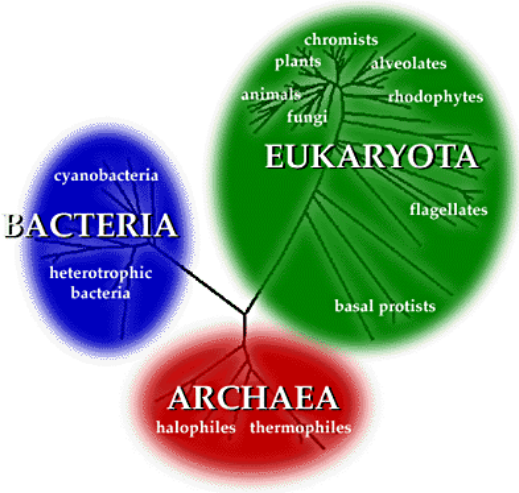
* by the unraveling of the details of DNA replication, protein biosynthesis and the key role of RNA in manifold biological processes;

* the molecularization of life sciences

During the past 15 years, this situation has changed, due in part to

* a strong reaction against molecular biology reductionism (e.g., structuralists);

* the search for all-encompassing theories (e.g., catastrophe theory, chaos, fractals, and now complexity theory…)



DNA, RNA & proteins

RNA + protein biosynthesis

RNA World

?