Origin of Life

Lecture 2, Course: GMR-121

Zoology II (Evolution and Ecology)

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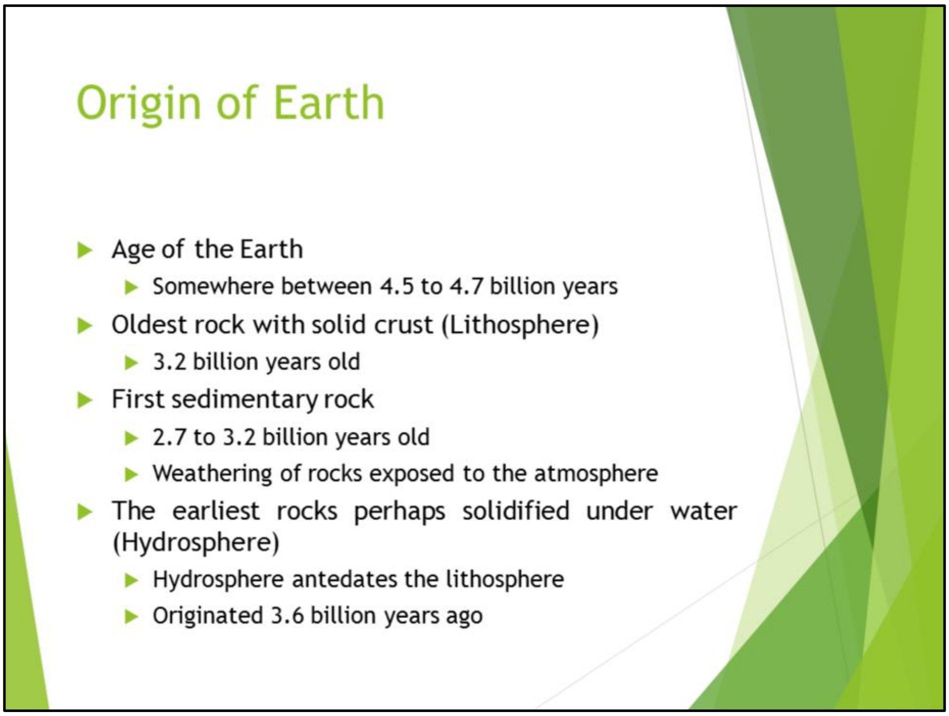
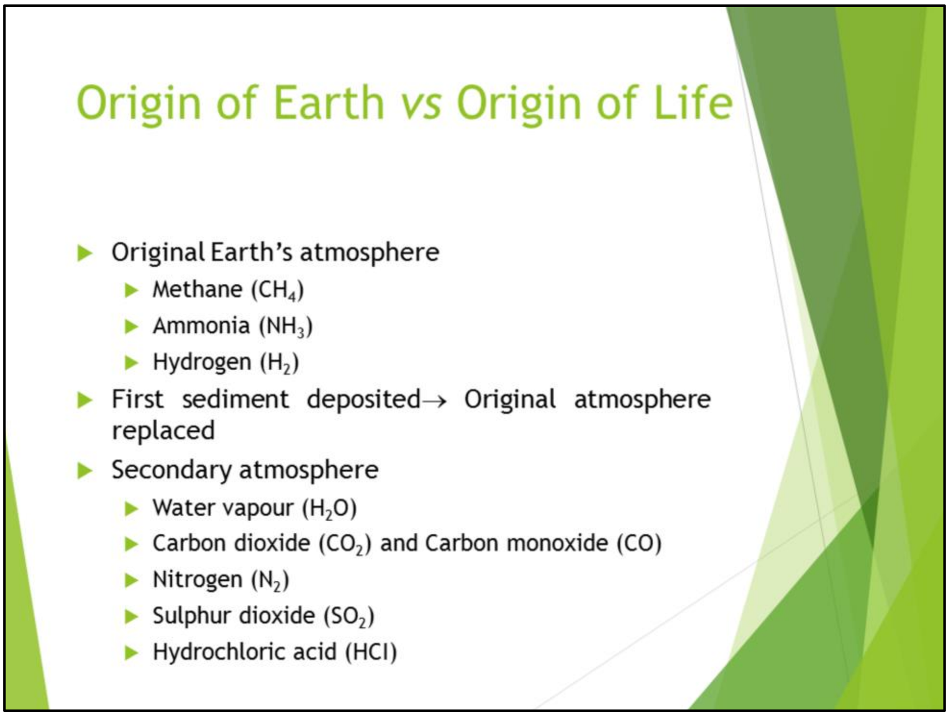
Origin of Earth *vs* Origin of Life

Theories and Hypothesis

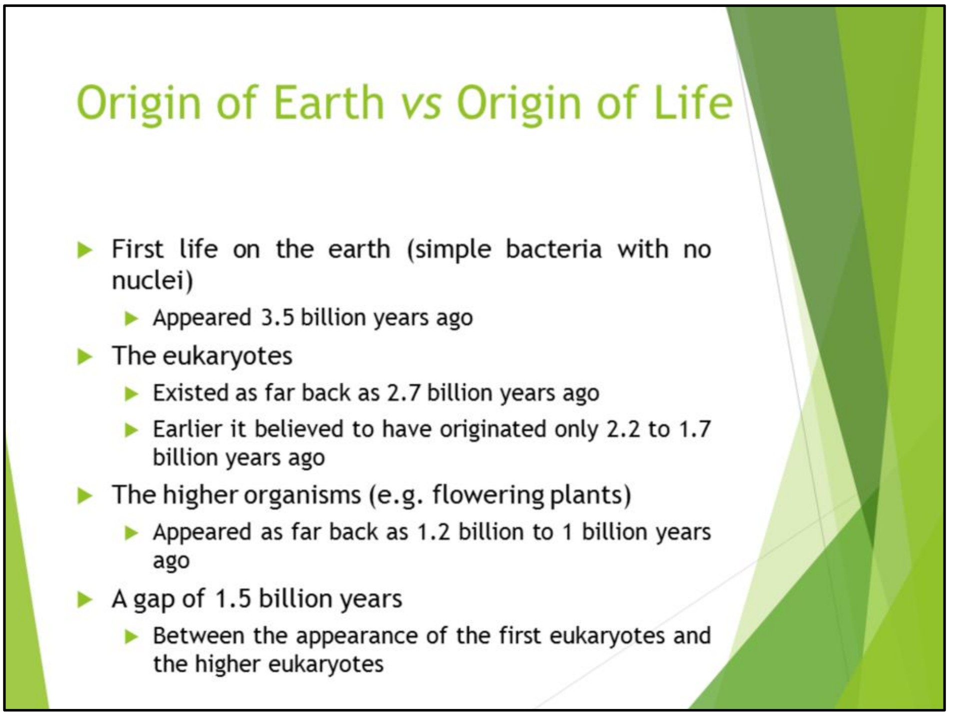


It is estimated that the age of the earth is somewhere between 4.5 to 4.7 billion years. The oldest rocks are believed to be 3.2 billion years old, and must have had a solid crust, 'lithosphere' (according to some other estimates, these are 3.8 billion years old).

The first sedimentary rocks are 2.7 to 3.2 billion years old, suggesting that there was weathering of rocks exposed to the atmosphere. Also there is evidence that the earliest rocks perhaps solidified under water, suggesting that hydrosphere antedates the lithosphere (hydrosphere is believed to have originated 3.6 billion years ago).

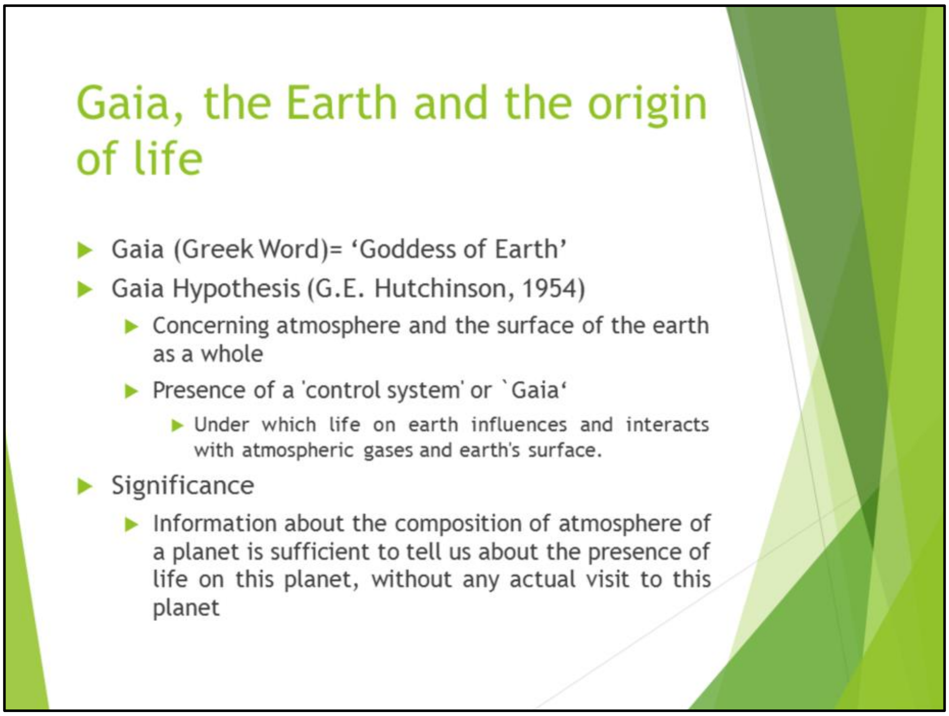


By the time the first sediments were being deposited, the original atmosphere consisting of methane (CH_4), ammonia (NH_3) and hydrogen (H_2) disappeared and was replaced by a secondary atmosphere consisting of water vapour (H_2O), carbon dioxide (CO_2), carbon monoxide (CO), nitrogen (N_2), sulphur dioxide (SO_2) and hydrochloric acid (HCl). Whatever ammonia remained was dissolved in the sea.



It is believed that the first life (simple bacteria with no nuclei) on this Earth appeared some 3.5 billion years ago. According to some recent studies conducted in Australia (reported in a 1999 issue of the journal Science, published from USA), the eukaryotes existed on this earth as far back as 2.7 billion years ago (earlier these were believed to have originated only 2.2 to 1.7 billion years ago).

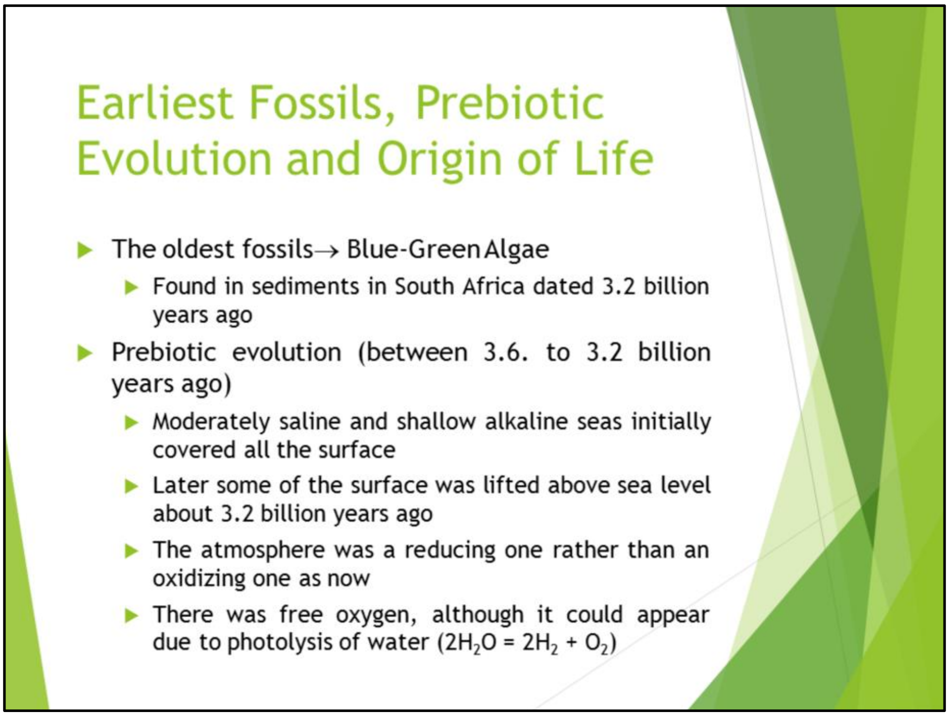
The higher organisms (e.g. flowering plants) appeared as far back as 1.2 billion to 1 billion years ago, so that there is a gap of 1.5 billion years between the appearance of the first eukaryotes and the higher eukaryotes.



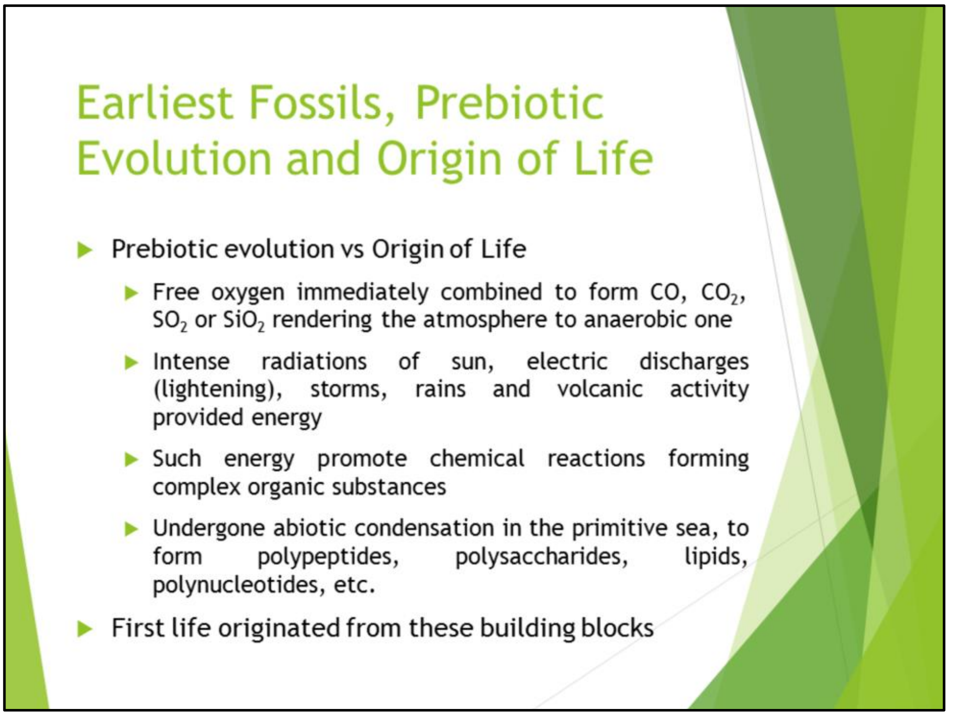
Gaia is a Greek name of the 'Goddess Earth', and is associated with a hypothesis concerning atmosphere and the surface of the earth as a whole. `Gala hypothesis', initiated in 1954, by G.E. Hutchinson (later progressively established by the efforts of Lovelock, Hitchcock and Margulis) assumes that there is a 'control system' or `Gaia' under which life on earth influences and interacts with atmospheric gases and earth's surface.

A certain set of environmental characters and their interaction, actually led to the organization of life or the `prebiotic evolution' on Earth

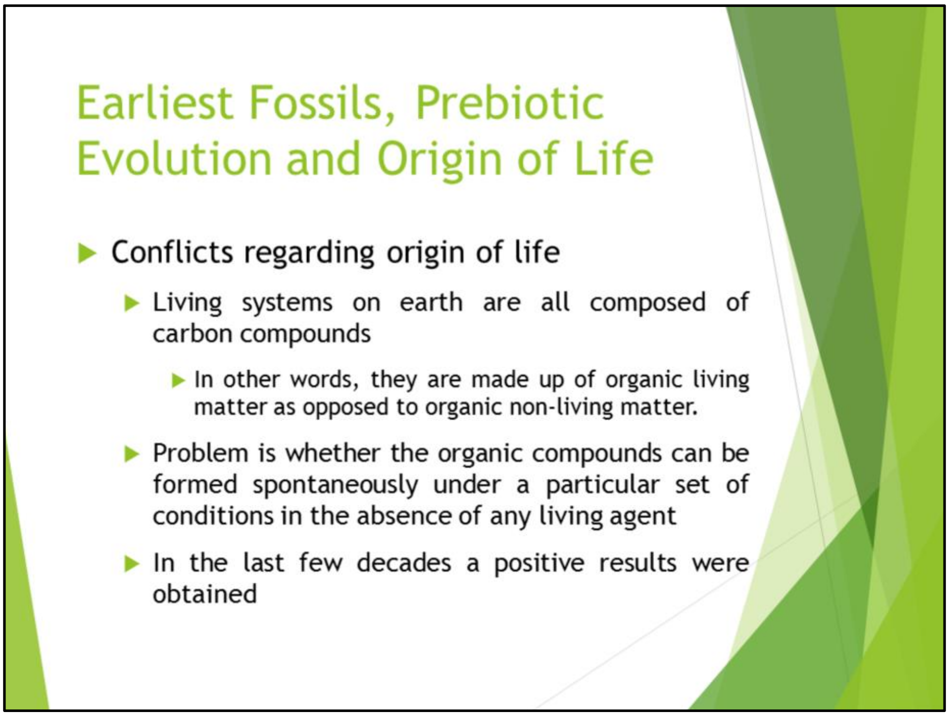
According to 'Gaia hypothesis', an information about the composition of atmosphere of a planet is sufficient to tell us about the presence of life on this planet, without any actual visit to this planet. For instance the near-equilibrium state (as the compositions shown above) and the absence of fluid medium or open bodies of water (as known for Venus and Mars) suggest absence of life.



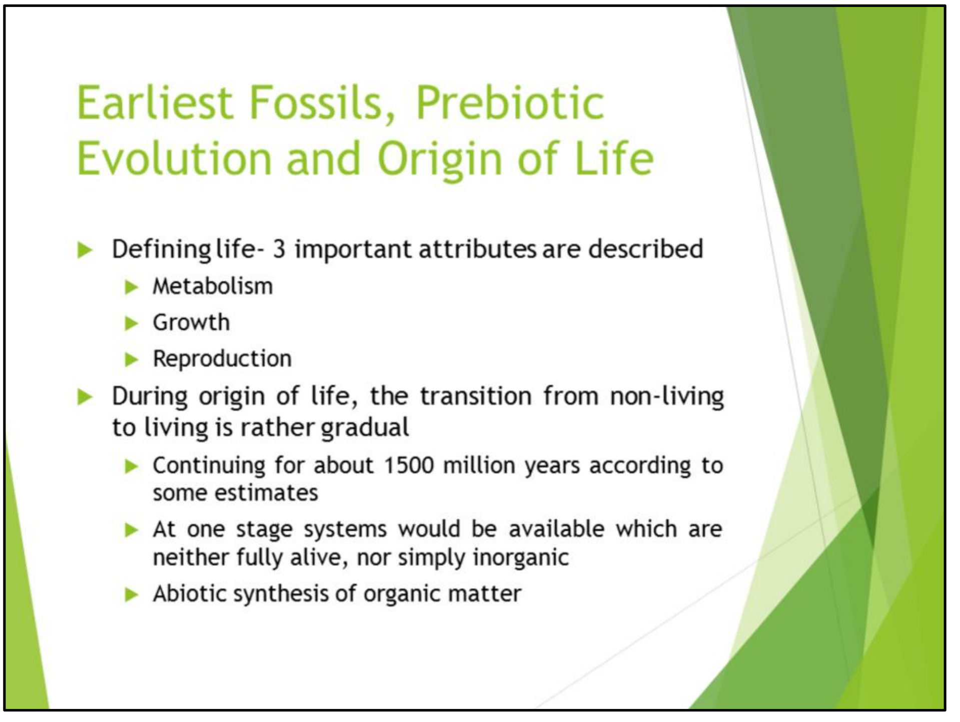
The oldest fossils belonging to the blue-green algae were found in sediments in South Africa dated 3.2 billion years ago. Between these times i.e. from 3.6. to 3.2 billion years ago (a period of 400 million years) the general conditions on the earth were supposed to be as follows : moderately saline and shallow alkaline seas initially covered all the surface, but later some of the surface was lifted above sea level about 3.2 billion years ago. The atmosphere was a reducing one (mainly containing methane, ammonia, water vapour, hydrogen and very little oxygen) rather than an oxidising one as now. There was free oxygen, although it could appear due to photolysis of water ($2H_2O = 2H_2 + O_2$).



Such free oxygen immediately combined to form CO, CO_2, SO_2 or SiO_2 rendering the atmosphere an anaerobic one. Radiations from sun were more intense. There were also common electric discharges (lightening), storms, rains and volcanic activity which provided energy to sponsor chemical reactions forming complex organic substances, which might have undergone abiotic condensation in the primitive sea, to form polypeptides, polysaccharides lipids, polynucleotides, etc.

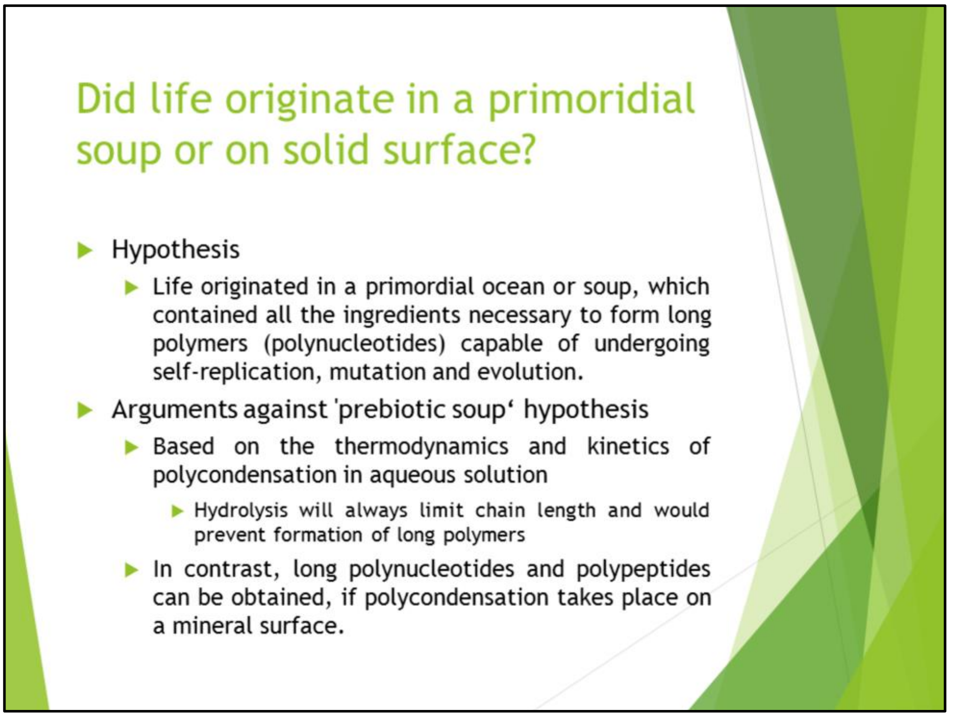


Living systems on earth are all composed of carbon compounds. In other words, they are made up of organic living matter as opposed to organic non-living matter. However, the important question is whether the organic compounds can be formed spontaneously under a particular set of conditions in the absence of any living agent. Answer to this question has been sought in the last few decades and positive results were obtained.



However, while defining life, three important attributes are described. These are metabolism, growth and reproduction.

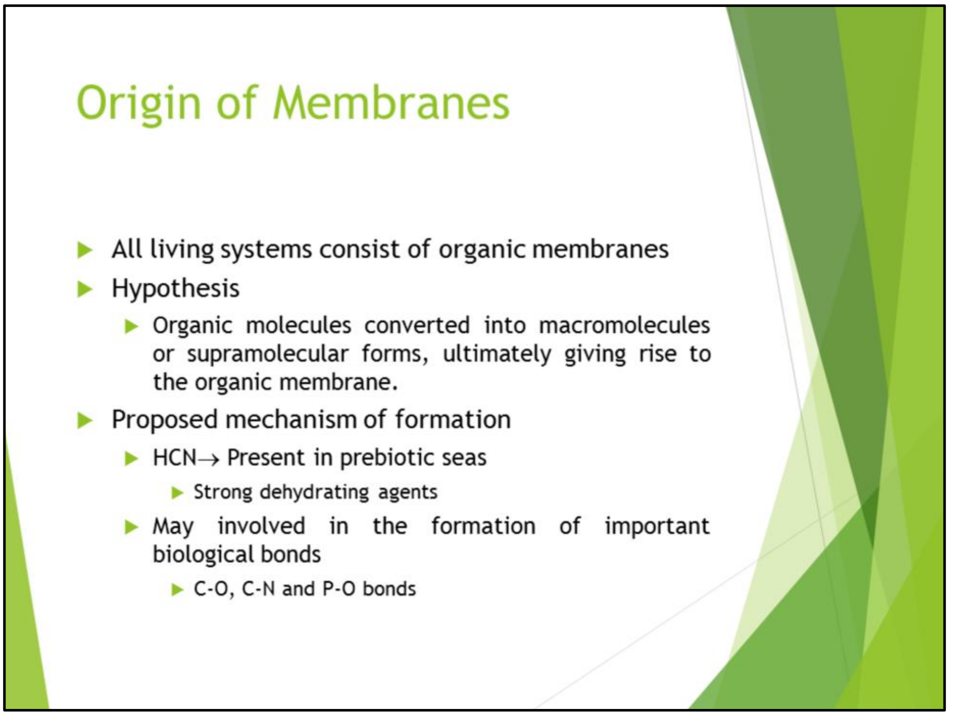
In any case, during origin of life, the transition from non-living to living should have been rather gradual (continuing for about 1500 million years according to some estimates). Therefore, at one stage systems would be available which are neither fully alive, nor simply inorganic. Whether we call them alive or non-living would not matter, as long, as we can find out how life having the three attributes described above originated.



According to most of the current ideas, life originated in a primordial ocean, which contained all the ingredients necessary to form long polymers (polynucleotides) capable of undergoing self-replication, mutation and evolution. It is also believed that subsequent to abiotic synthesis of matter, seas were converted into 'hot dilute soup' (as described by Haldance) or 'cold dilute soup' (as described by Abelson), which provided medium for origin of life.

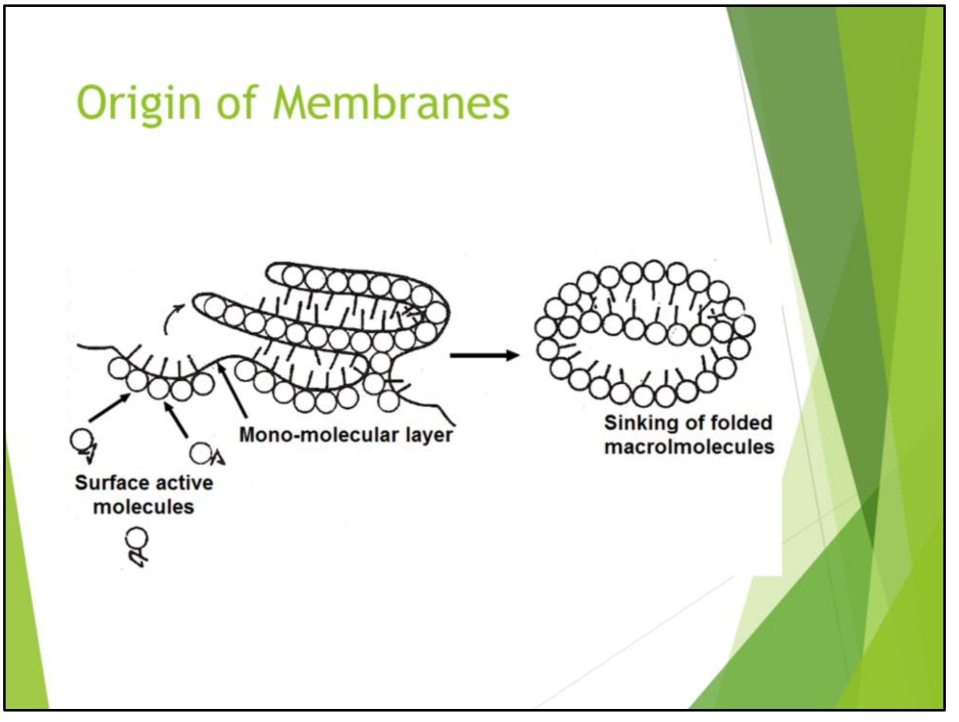
There are arguments, however, against the above hypothesis of 'prebiotic soup'. One of these arguments is based on the thermodynamics and kinetics of polycondensation in aqueous solution. Because hydrolysis will always limit chain length. It would prevent formation of long polymers, necessary to set up a genetic system. In contrast, long polynucleotides and polypeptides can be obtained, if polycondensation takes place on a mineral surface.

In view of this, it was concluded once in 1996, that polymers of life were more likely baked like `prebiotic crepes' rather than cooked in a ‘prebiotic soup' (French Crepes are prepared by pouring liquid dough over a hot stone plate, causing the dough to dehydrate and solidify; this dehydration corresponds to polycondensation).



As we know, all living systems consist of organic membranes. Therefore, a mechanism should be known, which in the past converted the organic molecules into macromolecules or supramolecular forms, ultimately giving rise to the organic membrane.

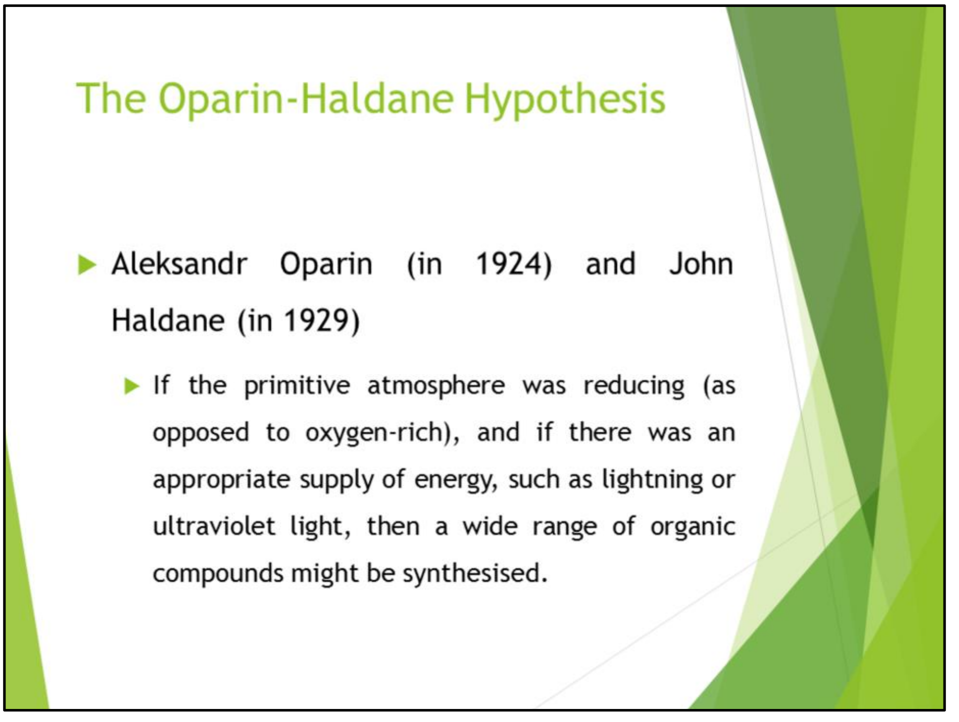
Since compounds like HCN are known to have been present in prebiotic seas and since these are strong dehydrating agents, a mechanism for the formation of biologically important C-0, C-N and P-0 bonds could be proposed.



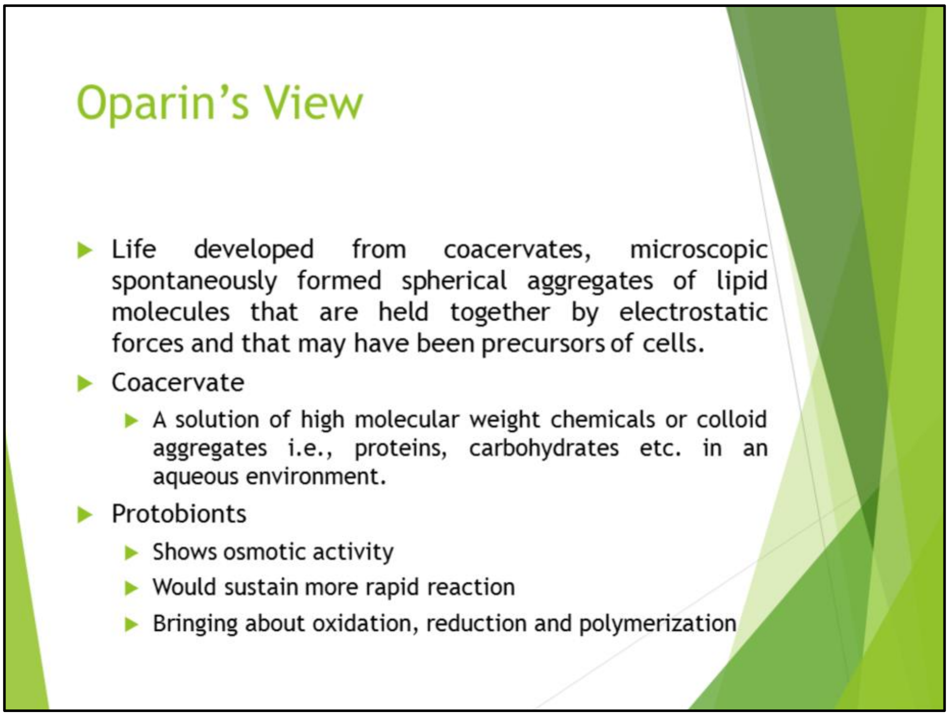
Removal of a molecule of water from two molecules of an organ compound like amino acids will bring about polymerization. These macromolecules would then aggregate on water surface to give rise monomolecular layer. The monomolecular layer becomes folded and after attaining certain weight, this material sinks. In this manner, perhaps phospholipids were formed

Next Class

- Oparin's coacervate model
- Theory of Panspermia
- Early Life and the 'RNA World'
- Origin of the Genetic Code

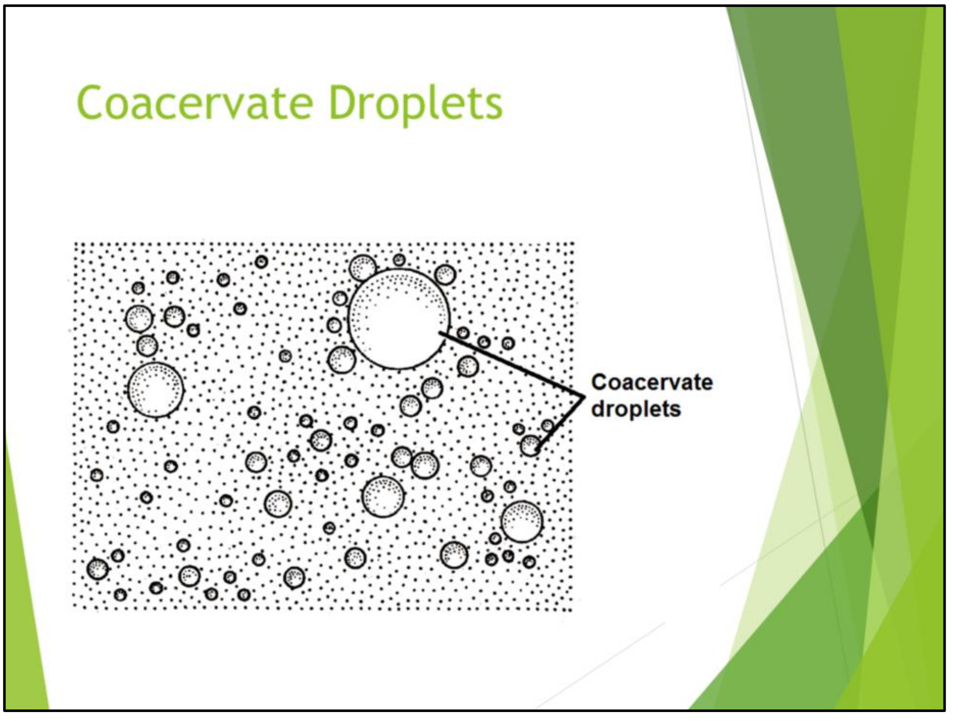


In the early decades of the 20th century, Aleksandr Oparin (in 1924), and John Haldane (in 1929, before Oparin's first book was translated into English), independently suggested that if the primitive atmosphere was reducing (as opposed to oxygen-rich), and if there was an appropriate supply of energy, such as lightning or ultraviolet light, then a wide range of organic compounds might be synthesised.
A coacervate is a solution of high molecular weight chemicals i.e., proteins, carbohydrates etc.

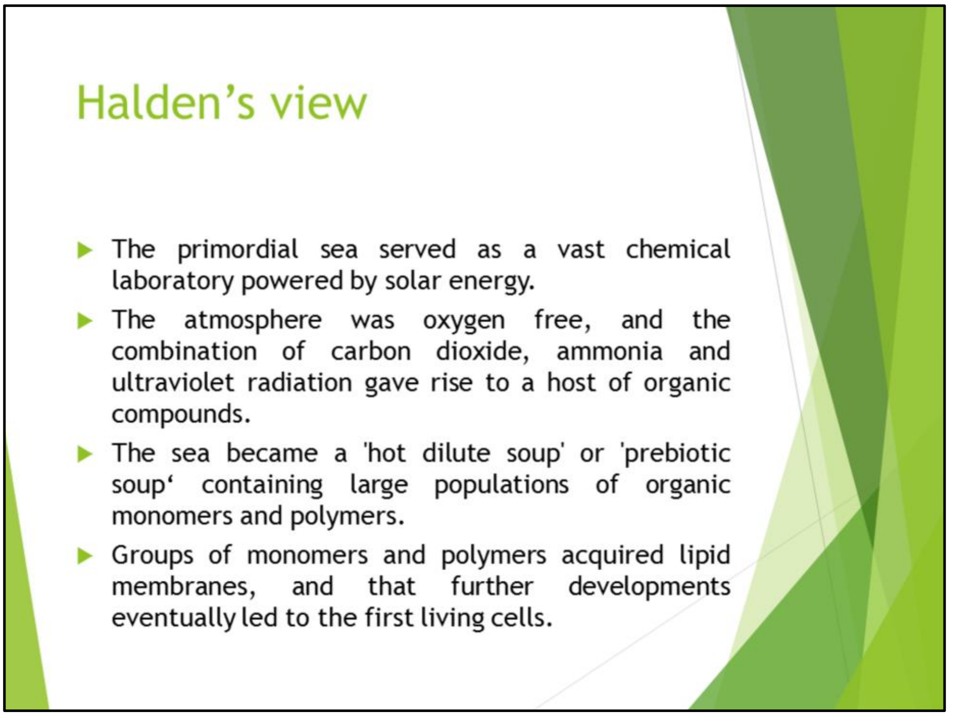


Oparin believed that life developed from coacervates, microscopic spontaneously formed spherical aggregates of lipid molecules that are held together by electrostatic forces and that may have been precursors of cells.

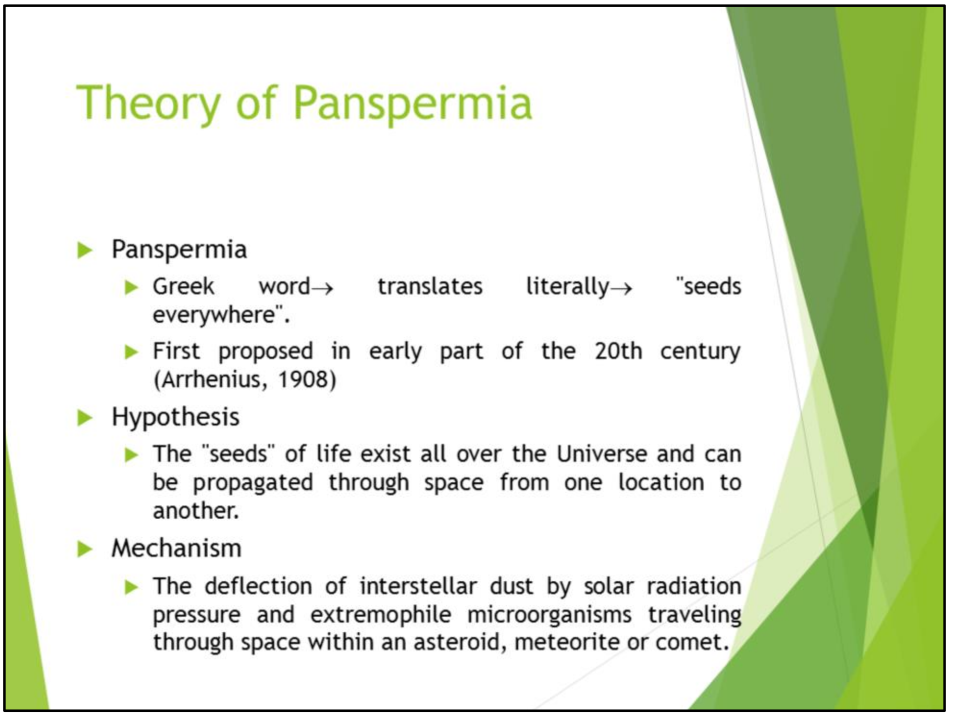
The organic molecules once becoming concentrated should have become organized into supramolecular structures of some kind. In order to explain this, A.I. Oparin, a Soviet biologist of great fame, proposed his coavervate model (Fig. 37.3). A coacervate is a solution of high molecular weight chemicals i.e., proteins, carbohydrates etc. Under certain conditions this coacervate separates into two phases, the sol phase and the gel phase. On contact with an aqueous solution, the gel phase shows osmotic activity and would sustain more rapid reaction bringing about oxidation, reduction and polymerization. Such systems are called `protobionts' by Oparin.



The coacervates were able to absorb and assimilate organic compounds from the environment in a way reminiscent of metabolism. They would have taken part in evolutionary processes, eventually leading to the first lifeforms.



Haldane proposed that the primordial sea served as a vast chemical laboratory powered by solar energy. The atmosphere was oxygen free, and the combination of carbon dioxide, ammonia and ultraviolet radiation gave rise to a host of organic compounds. The sea became a 'hot dilute soup' containing large populations of organic monomers and polymers. Haldane envisaged that groups of monomers and polymers aquired lipid membranes, and that further developments eventually led to the first living cells.
Haldane coined the term 'prebiotic soup', and this became a powerful symbol of the Oparin-Haldane view of the origin of life.



An extremophile (from Latin extremus meaning "extreme" and Greek philiā (φιλία) meaning "love") is an organism that thrives in and even may require physically or geochemically extreme conditions that are detrimental to the majority of life on Earth.

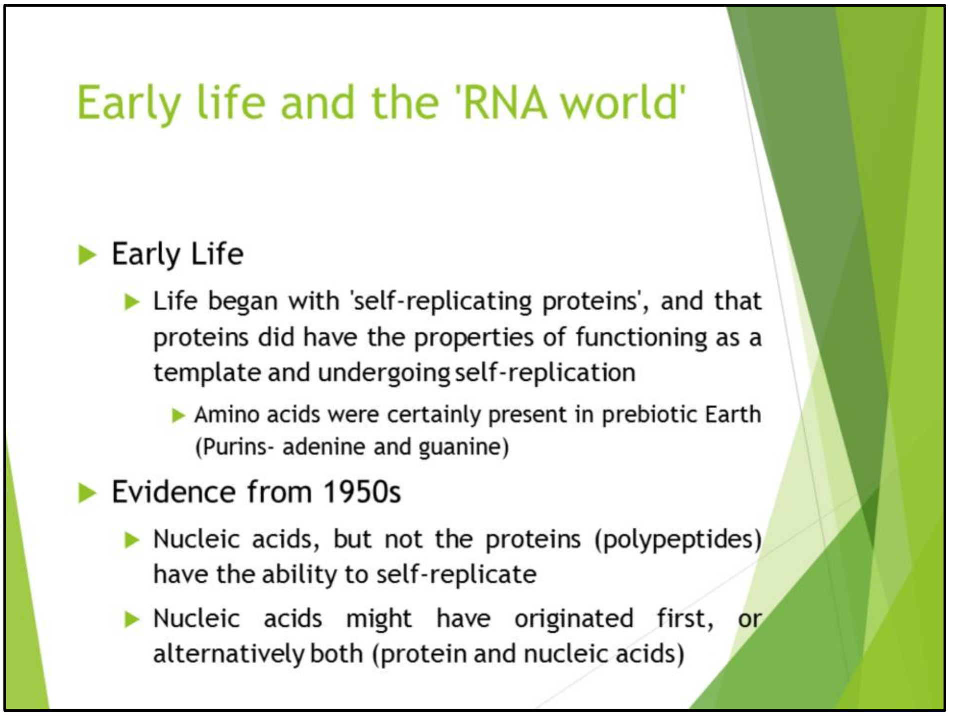
Most known extremophiles are microbes. The domain Archaea contains renowned examples, but extremophiles are present in numerous and diverse genetic lineages of both bacteria and archaeans.

Variations of Panspermia Theory

- Lithopanspermia (interstellar panspermia)
  - Impact-expelled rocks from a planet's surface serve as transfer vehicles for spreading biological material from one solar system to another.
- Ballistic panspermia (interplanetary panspermia)
  - Impact-expelled rocks from a planet's surface serve as transfer vehicles for spreading biological material from one planet to another within the same solar system
- Radiopanspermia
  - Dissemination of organisms by starlight (star's radiation pressure propels microorganisms into interstellar space)
- Directed panspermia
  - The intentional spreading of the seeds of life to other planets by an advanced extraterrestrial civilization

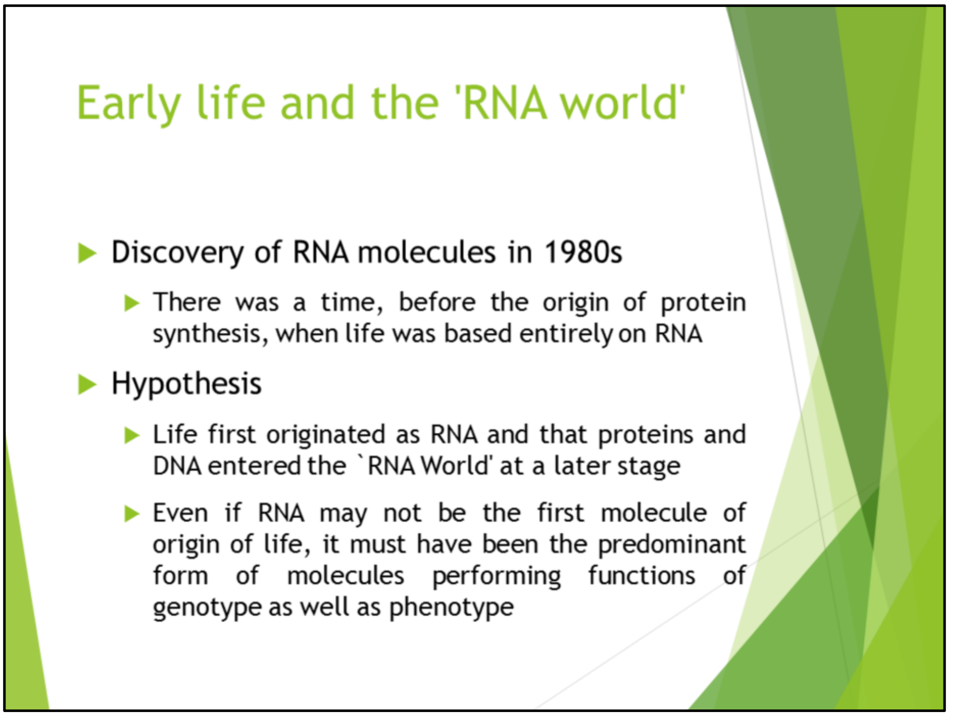
Panspermia

CO
ETHANE
POLYYNES
PAHs
FORMIC-ACID
ACETO-NITRILE
DIMETHYL ETHER
FULLERENES
AMINO ACIDS
RNA
ACETYLENE

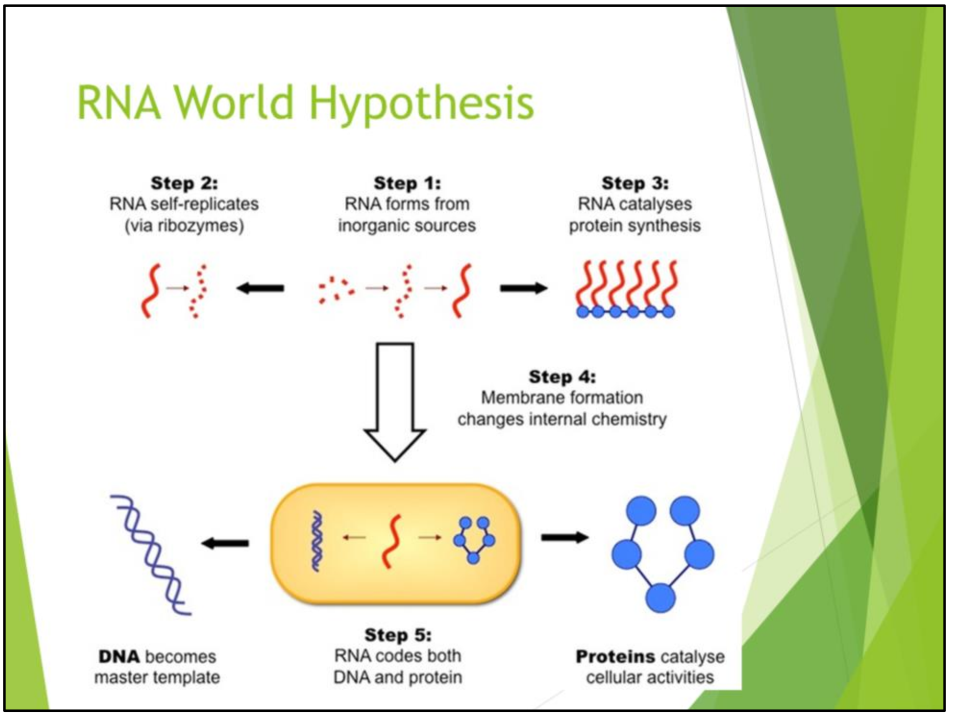


There was a time, when it was widely believed that life began with 'self-replicating proteins', and that proteins did have the properties of functioning as a template and undergoing self-replication. Although, there is no doubt that amino acids were certainly present in prebiotic Earth, purines (adenine and guanine as building blocks of nucleic acids) were perhaps also synthesized by polymerization of HCN.

However, when in 1950s, it became evident that nucleic acids and not the proteins have the ability to self-replicate, it was accepted that nucleic acids rather than polypeptides might have originated first, or alternatively both (protein and nucleic acids) must have originated simultaneously.



In the 1980s, discovery of RNA molecules with catalytic activity, which earned the 1989 Nobel Prize in Chemistry to Sidney Altman and Thomas Cech, generated interest in an idea, which assumed that there was a time, before the origin of protein synthesis, when life was based entirely on RNA. This hypothesis for origin of life assumed that life first originated as RNA and that proteins and DNA entered the `RNA World' at a later stage. Even if RNA may not be the first molecule that developed in the history of origin of life, there is strong evidence that at some stage, soon after the origin of life, RNA must have been the predominant form of molecules performing functions of genotype as well as phenotype.

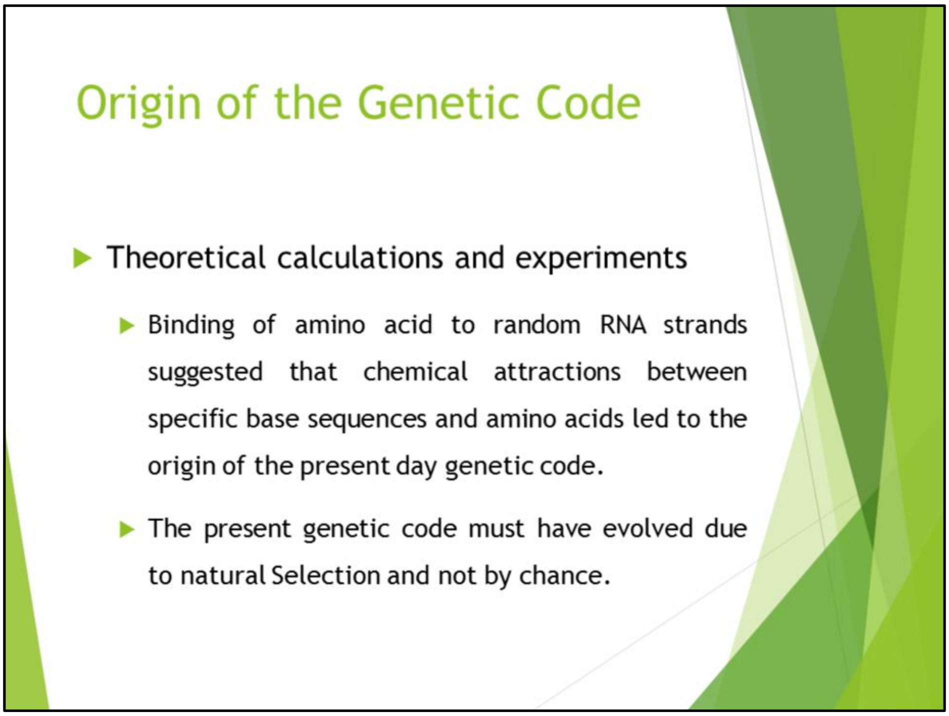


The RNA world hypothesis is an idea of how early life on Earth transmitted information and carried out functions. RNA did everything, stored info., replicated itself, and carried out enzymatic activity. A – E represent a possible sequence, although no times can be assigned yet. According to this theory – the last thing that developed was enzymatic proteins – but new evidence suggests that proteins were important for the development of tRNAs so they must have been around earlier. Step B is an area of interest,

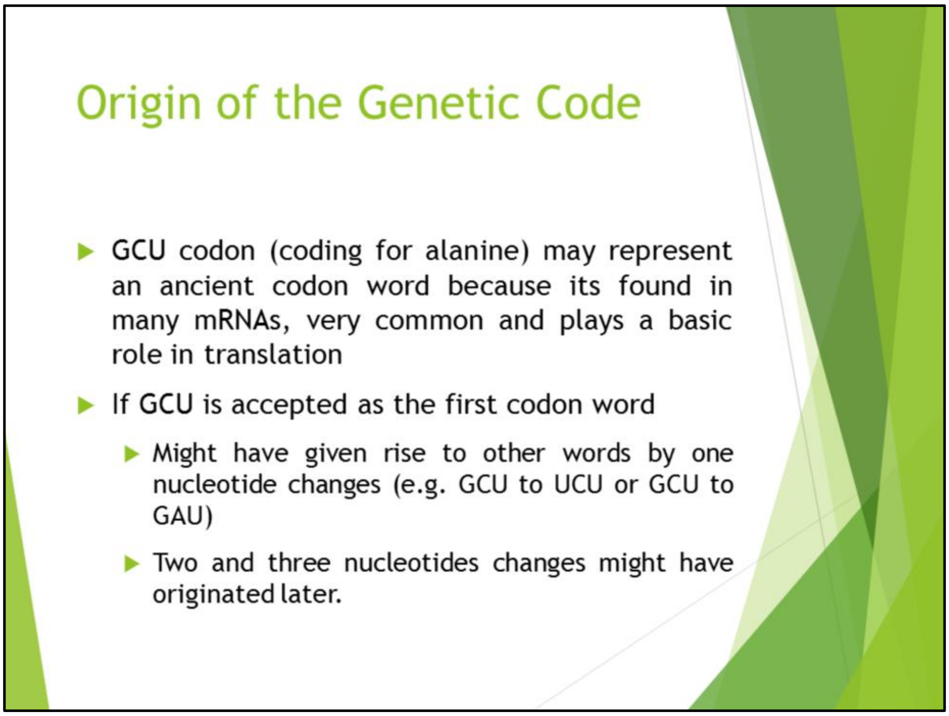
as scientists are trying to make an RNA that could replicate any RNA, even itself.

Supporting Evidence- RNA World

- Template properties of RNA simplify the task of self-replication
- RNA genomes are known to exist in some viruses (e.g. TMV)
- RNA has catalytic properties, as exemplified by self-splicing activity of some group I and group II introns
- RNA is used as RNA primers in DNA synthesis
- RNA functions, during protein synthesis, as mRNA, tRNA and ribosomal RNA (rRNA)
- RNA is an essential component of ribonucleoprotein enzyme (telomerase) that directs telomere synthesis



Recently (1998-99), both theoretical calculations and experiments involving binding of amino acid to random RNA strands suggested that chemical attractions between specific base sequences and amino acids perhaps led to the origin of the present day genetic code.



According to one theoretical study, GCU codon (coding for alanine) is so spaced in many mRNAs that the mRNA will have extensive base pairing with ribosomal RNA. Since GCU is so common and plays such a basic role in translation, this may represent an ancient codon word. During evolution, if GCU is accepted as the first codon word, in the first step, this might have given rise to other words by one nucleotide changes (e.g. GCU to UCU or GCU to GAU); two and three nucleotides changes might have originated later.


Have a Nice Day
Thank You