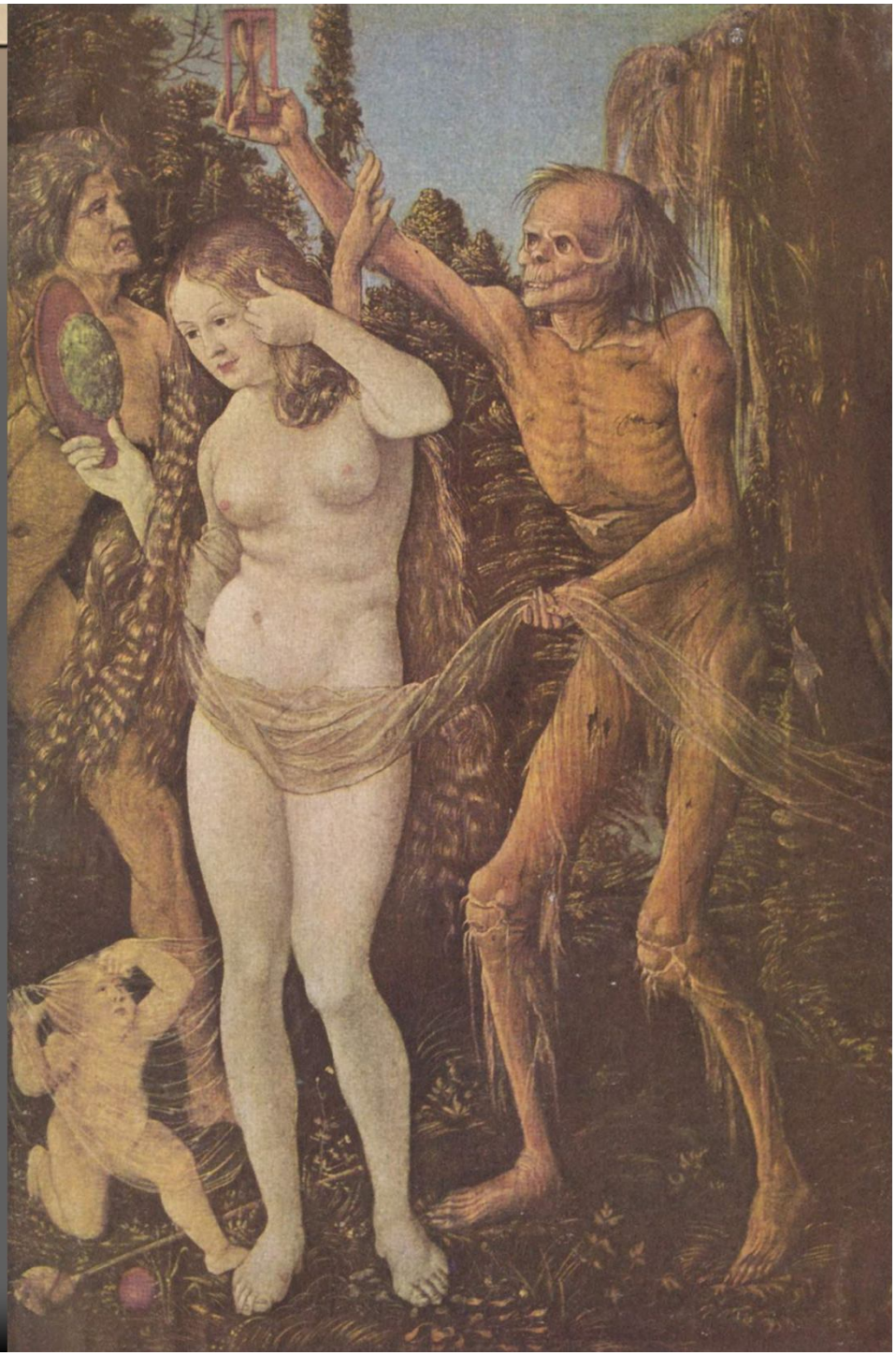
SCENARIO OF THE CHEMICAL AND BIOLOGICAL EVOLUTION OF THE EARTH

Gyvybės apibrėžtis

- **Gyvybė** – organizmo būsena tarp prasidėjimo ir mirties (*Vikipedija*)



Trys gyvenimo amžiai ir mirtis

- Hans Baldung paveikslas

Gyvybės apibrėžtis

- *Pasaulyje yra trys svarbiausi singuliarumai*
  - Stebima Visata
  - Gyvybė žemėje
  - Žmogus

Pagal J. Oro

Gyvybės apibrėžtis

- 1976 NASA siuntė Vikingą į Marsą

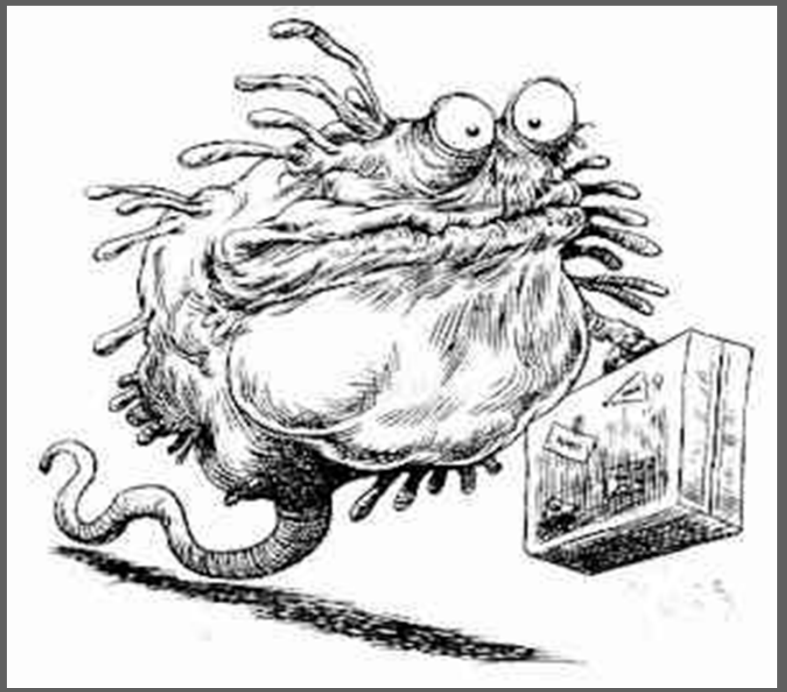
  Carl Sagan

Pagal J. Oro

Gyvas - negyvas

- Kristalas

- Bakterija



Vikipedija

Gyvybės apibrėžtis

Biologijoje organizmas laikomas gyvu, jeigu jo egzistavimo metu vyksta visi šie reiškiniai:

- Augimas
- Medžiagų apykaita - vartojimas, perdirbimas bei energijos saugojimas
- Judėjimas - tiek aplinkoje, tiek vidinis
- Reprodukcija - galimybė kurti organizmus, panašius į save
- Jutimas - galimybė reaguoti į supančią aplinką pagal esamas sąlygas

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Biologai, tiriantys tik Žemės organizmus dažnai prideda papildomus "*gyvo organizmo*" požymius:

- Gyvi organizmai turi šiuos molekulinius komponentus: angliavandenius, lipidus, nukleinines rūgštis ir proteinus (baltymus).
- Gyviems organizmams reikia energijos ir medžiagų gyvybės tąsai
- Gyvi organizmai yra sudaryti bent iš vienos ląstelės.
- Gyvuose organizmuose egzistuoja vidinė medžiagų apykaitos pusiausvyra (homeostazė)
- Gyvų organizmų rūšys vystysis

Gyvybės apibrėžtis

- Gyvosios sistemos yra sudėtingos struktūros, esančios toli nuo pusiausvyros, palaikomos įtekančio energijos srauto.

  Jos yra organinės, homochiralinės, erdvinės struktūros padalintos į skyrius, glaudžiai susijusios ir komunikuojančios su aplinka (taip pat su kitomis gyvosiomis formomis). Tuo pat metu jos yra atsiskyrusios riba (išlikusiuose organizmuose tai lipidų bisluoksnis) ir jų aktyvumas priklauso nuo nuolatinio energijos ir medžiagos srauto iš aplinkos per šią membraną.

  Jos gali dalintis, mutuoti, keistis energija ir medžiaga su aplinka ir vystytis skatinami daugelio organinių katalizatorių.

  Visų šių vyksmų ir molekulių bruožai, kaip rodo jų cheminiai ciklai, savireguliacija, sąveika, papildomumas ir ritmai patvirtina tęstinumo principą.

  Išsivysčiusios iš negyvosios gamtos jos sudaro autokatalitines, besivystančias, teleonomines (siekiančias tikslo) organines sistemas, kurios gali perduoti, saugoti ir apdoroti informaciją, remiantis šabloninėmis ir grandininėmis reakcijomis, - visa tai apibūdina autopoetines būtybes.

Noam Lahav "BIOGENESIS Theories of Life's Origin", Oxford University Press, 1999.

Gyvybės apibrėžtis

- Dauguma enciklopedijų

"*Gyvybė yra organizuotos materijos dinaminė būsena, charakterizuojama pagal jos galimybę adaptuotis ir evoliucionuoti reaguojant į aplinkos pokyčius, bei jos galimybes reprodukuotis duodant augti naujai gyvybei.*

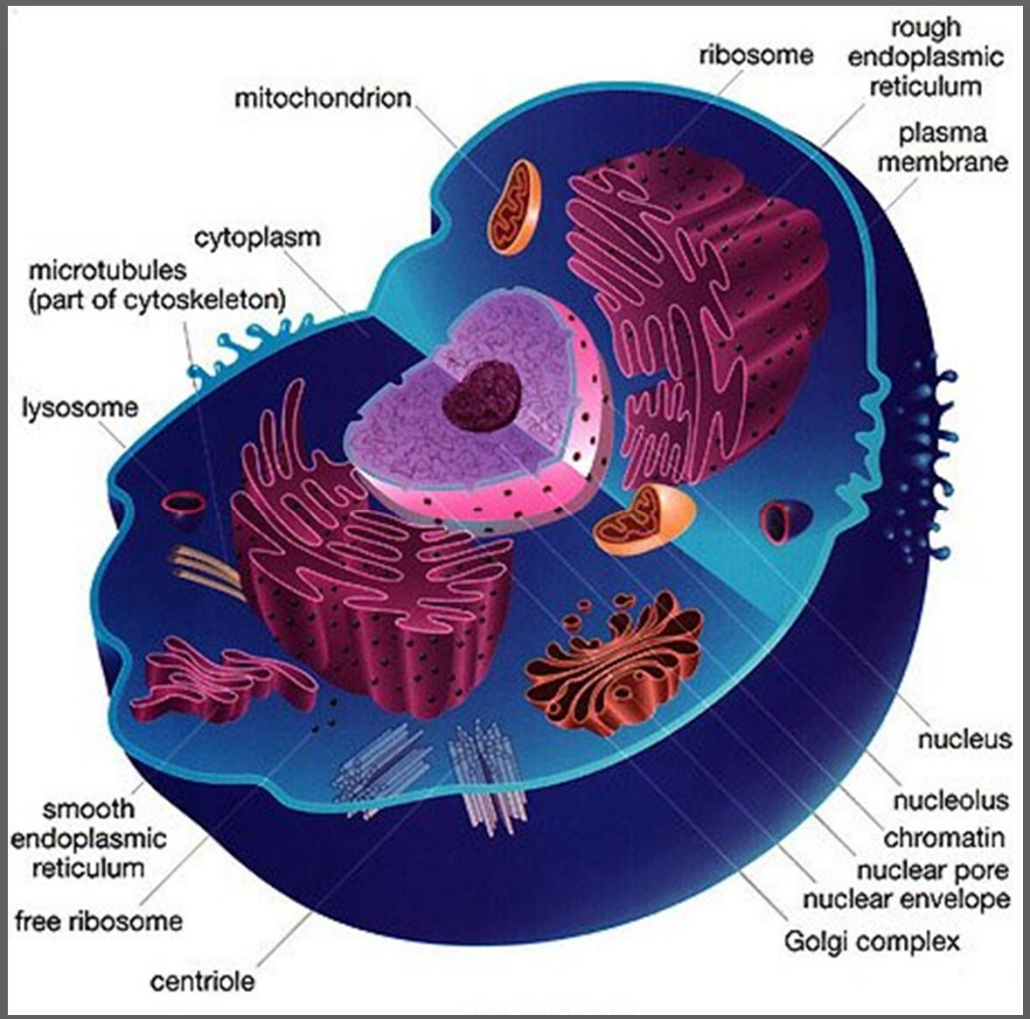
Tokia būsena yra metabolinių katalitinių reakcijų pasekmė, bei gyvojo organizmo sąveikos su kitais organizmais ir aplinka pasekmė."

Pagal J. Oro

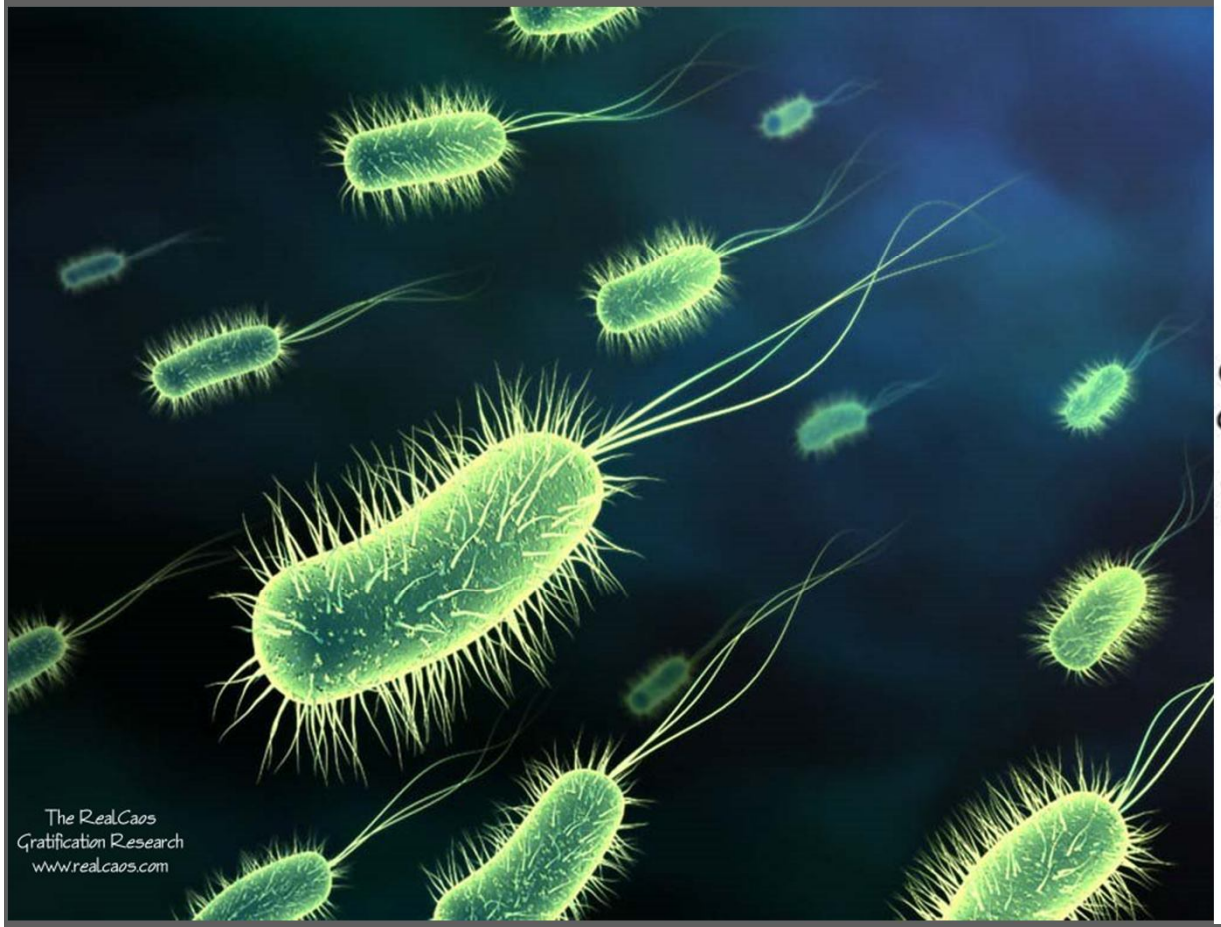
Fizikiniai gyvųjų sistemų bruožai

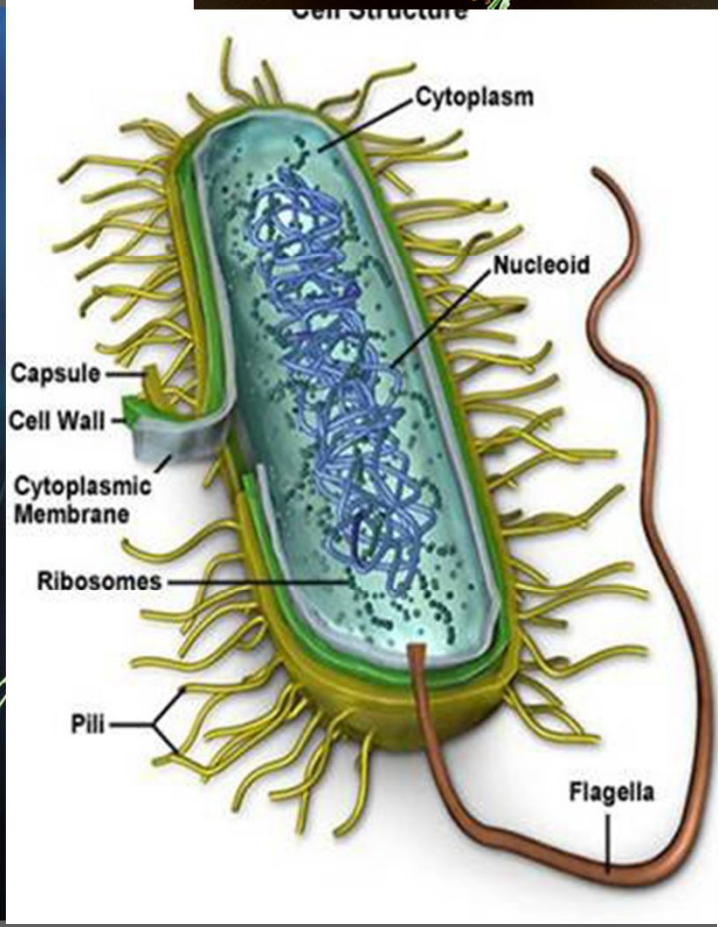
- Nepusiausviroji sistema, veikianti prieš II termodinamikos dėsnį. Sistema, atvira medžiagai ir energijai, tačiau atsiskyrusi nuo aplinkos.
- Paklūstanti netiesinei dinamikai istorinė sistema. Savitvarkė, autopoetinė save atkurianti sistema.
- Chaosinė, fraktalinės dimensijos
- Teigiamų ir neigiamų grįžtamųjų ryšių tinklas (apimantis ir sąveiką su aplinka). Valdymas, teleonominė - siekianti tikslo sistema. Komunikuojanti, kaupianti informaciją sistema
- Pažįstanti sistema, keičianti savo struktūrą sąveikaujant su aplinka. Gyvybės vyksmai – pažinimo vyksmai

Ląstelė

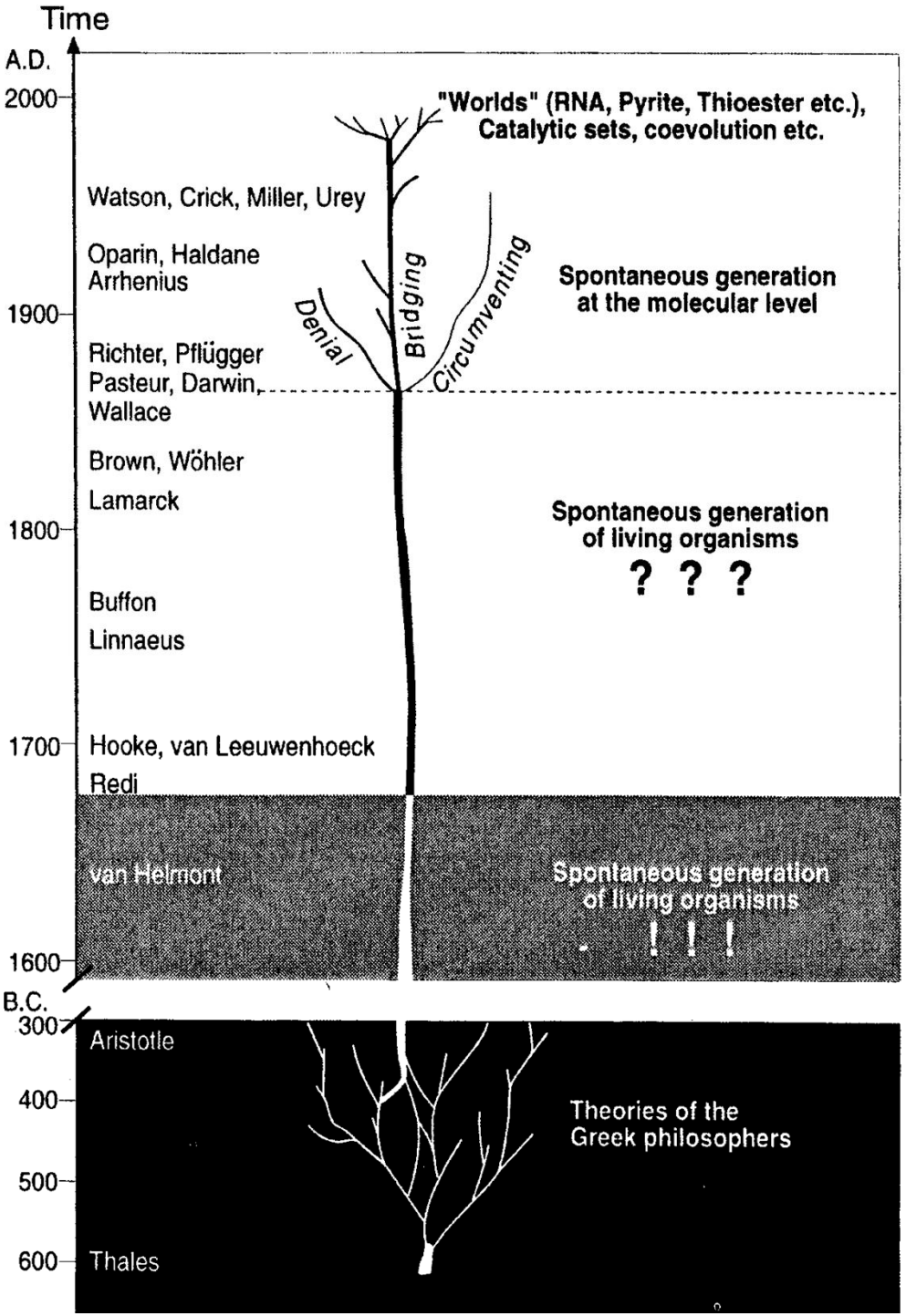

ribosome
rough endoplasmic reticulum
mitochondrion
plasma membrane
cytoplasm
microtubules (part of cytoskeleton)
lysosome
nucleus
nucleolus
chromatin
nuclear pore
nuclear envelope
Golgi complex
smooth endoplasmic reticulum
free ribosome
centriole

Bakterijos


The RealCaos
Gratification Research
www.realcaos.com


Cytoplasm
Nucleoid
Capsule
Cell Wall
Cytoplasmic Membrane
Ribosomes
Pili
Flagella

Istorija


Time
A.D.
2000
1900
1800
1700
1600
B.C.
300
400
500
600
"Worlds" (RNA, Pyrite, Thioester etc.), Catalytic sets, coevolution etc.
Watson, Crick, Miller, Urey
Oparin, Haldane
Arrhenius
Denial
Bridging
Circumventing
Spontaneous generation at the molecular level
Richter, Pflügger
Pasteur, Darwin,
Wallace
Brown, Wöhler
Lamarck
Spontaneous generation of living organisms
? ? ?
Buffon
Linnaeus
Hooke, van Leeuwenhoeck
Redi
van Helmont
Spontaneous generation of living organisms
- ! ! !
Aristotle
Theories of the Greek philosophers
Thales

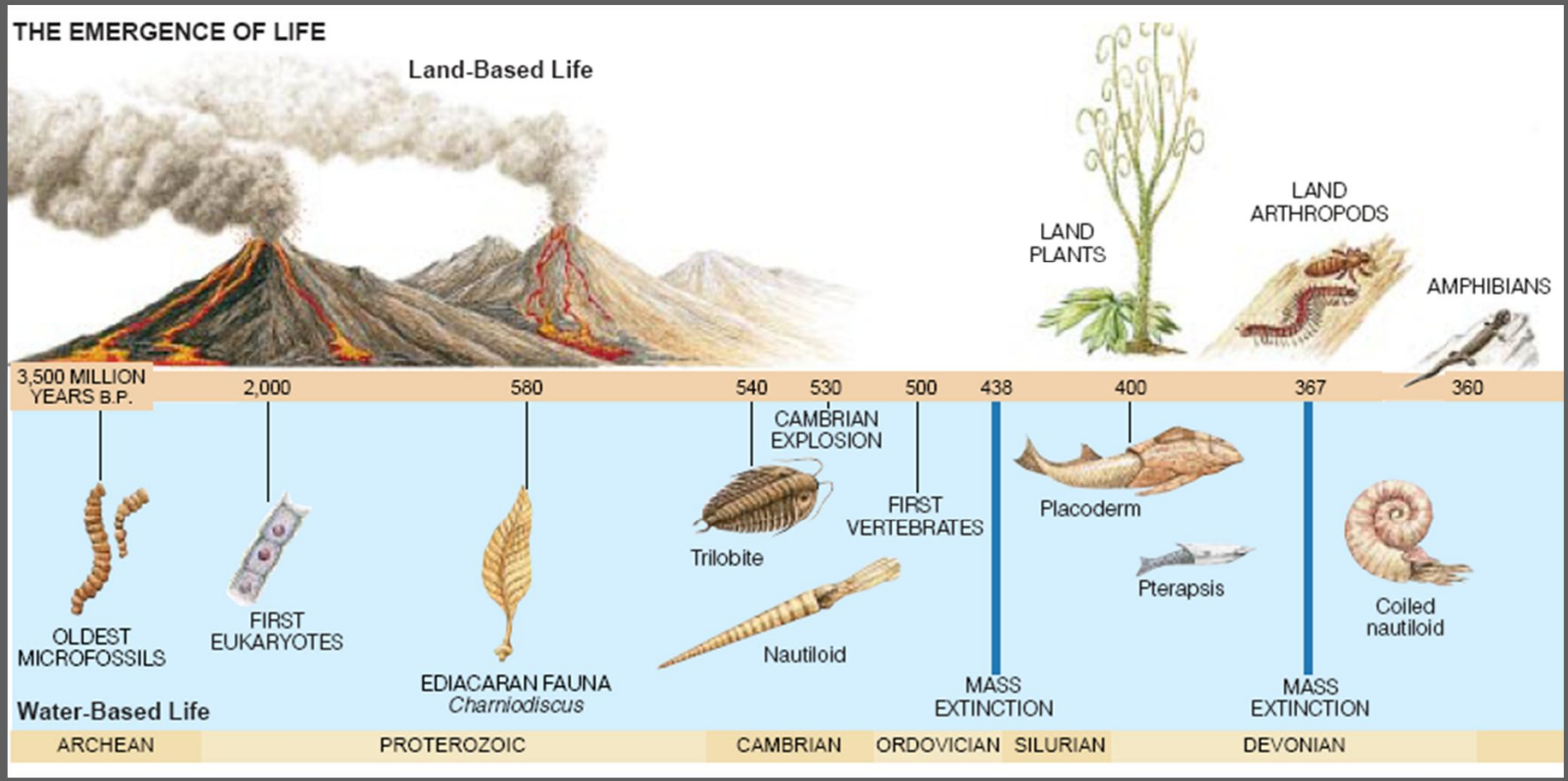
The Creation of Adam by Michelangelo

Gyvybės pradžia, duomenų grupės

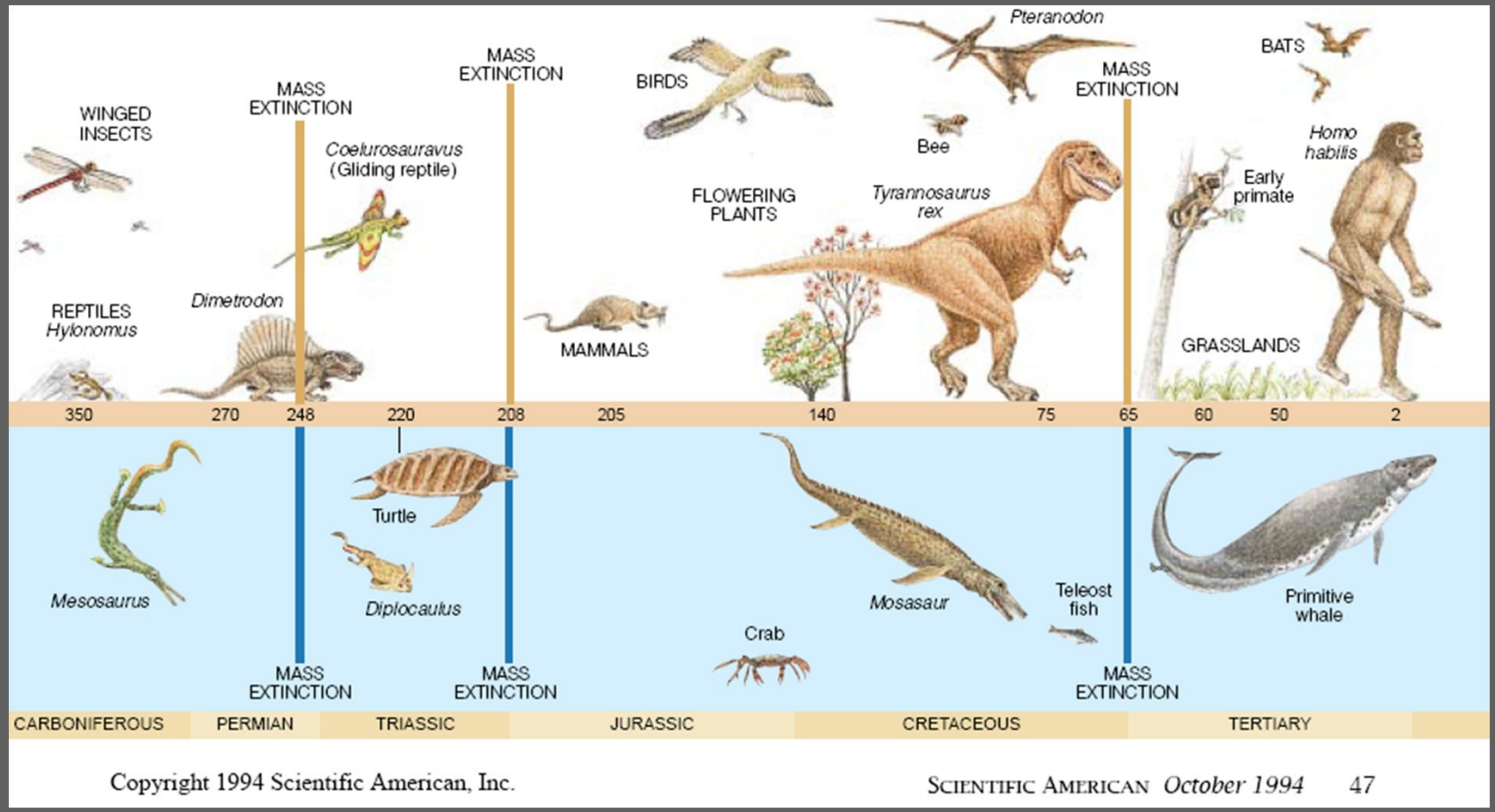
- Primityvių mikroorganizmų analizė
- Gyvųjų organizmų raidos susiejimas su fosilijomis ir biocheminiais įspaudais
- Planetų raidos duomenų susiejimas su pirmykštėmis Žemės sąlygomis
- Kompleksinių dinaminių sistemų tyrimai

Pirmykštė Žemė

The emergence of life (1)



The emergence of life (2)

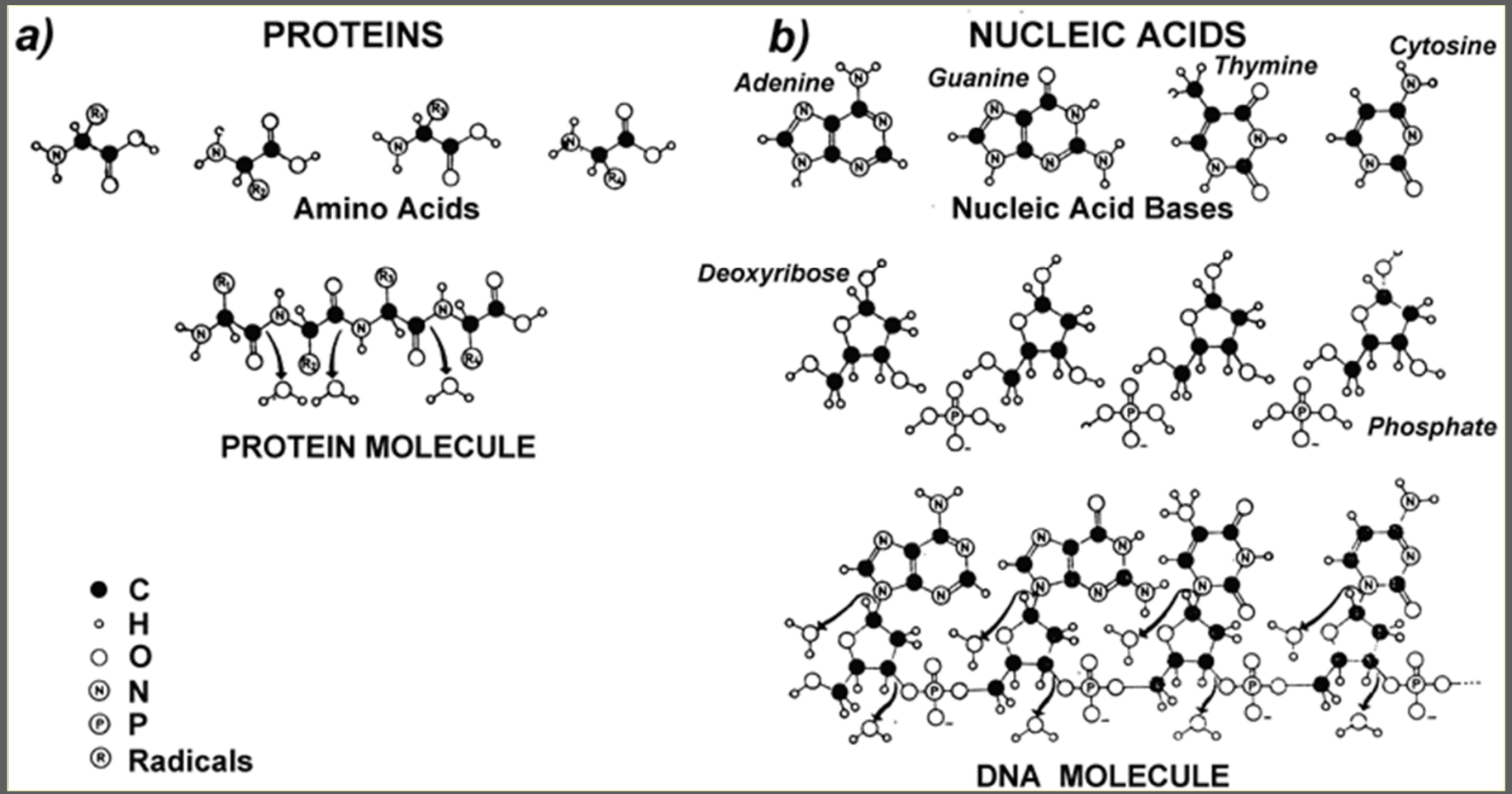


Chemical evolution of the Earth

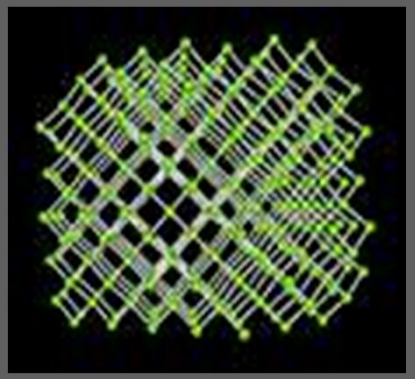
a	**formation of the primary atmosphere** of the Earth, constituting the raw material and the medium for the synthesis of more complex molecules, necessary for life;
b	**synthesis of amino acids and nucleotide molecules** in chemical reactions produced by radiation from the Sun and by electric discharges;
c	**formation of bio-polymers** - macro- molecules of proteins and nucleic acids from amino acid and nucleotide molecules in the waters of the primary oceans;
d	**separation of bio-polymers from the surrounding medium** in form of self-organising primitive "cells", so called protobionts, in which aimed metabolic processes are provided;
e	**formation of a genetic apparatus** which permits the "protobionts" to reproduce through division.

The most essential polymers of life - proteins and nucleic acids

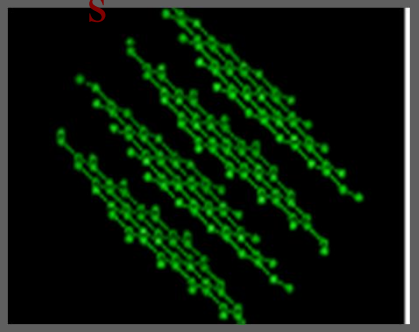
a - formation of protein macro-molecules from amino acids; living organisms contain 20 so called universal amino acids
b - formation of the macro-molecule of desoxyribonucleic acid (DNA) from nucleic acid bases, desoxyribose and phosphate.
The sequence of four nucleic acid bases - adenine (A), guanine (G), thymine (T), and cytosine (C) in a DNA molecule codes genetically the sequence of amino acids in protein molecules; each DNA base triplet (e.g. AGC) codes a definite amino acid



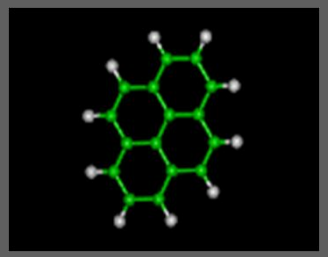
Anglies darinių įvairovė



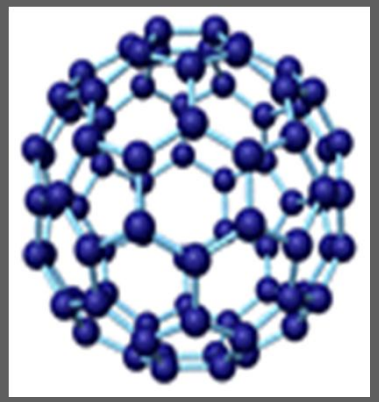
- Deimantas



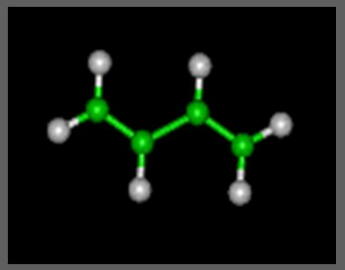
- Grafitas



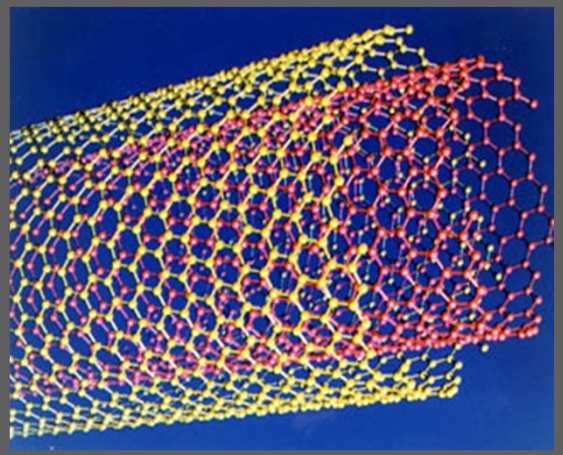
- Policikliniai dariniai



- Fulerenai



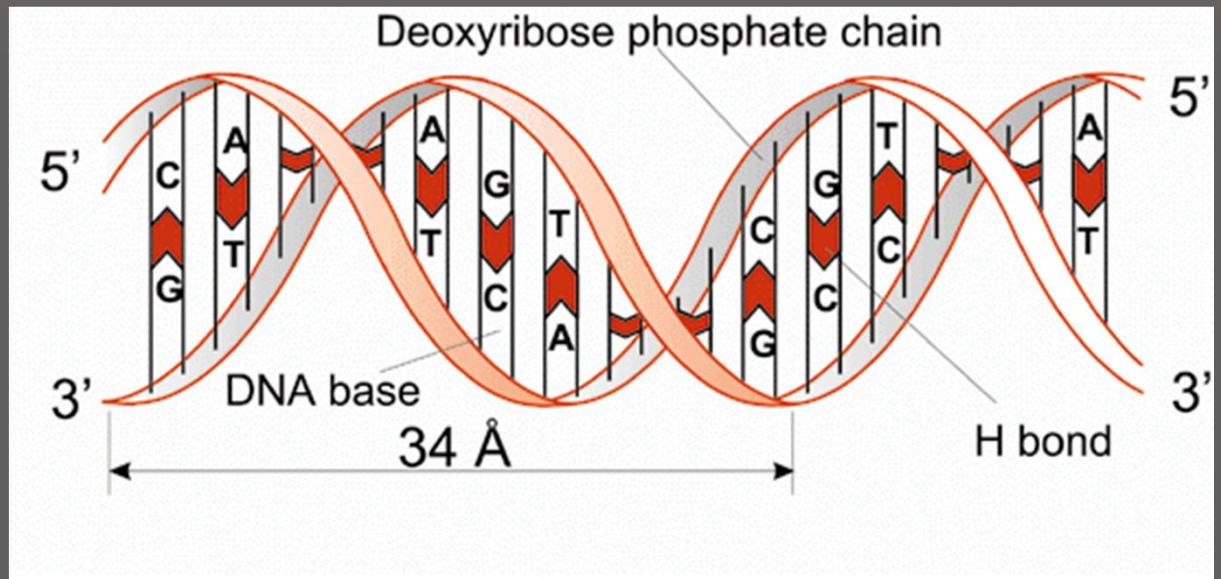
- Polimerai

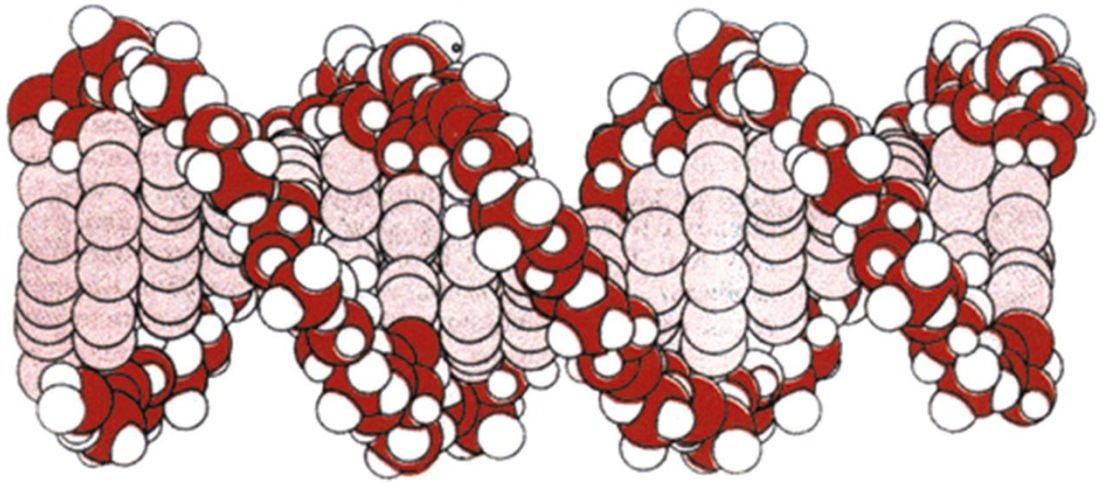


- Anglies nanovamzdeliai

Desoxyribonucleic acid (DNA) macromolecule

Genetic information is inscribed in the four-letter alphabet of DNA bases (A, T, G, C). The basic element - the codon is formed by a triplet of 3 DNA bases. The DNA "alphabet" contains 64 triplet "letters", each triplet coding a definite amino acid and determining their sequence in the synthesis of protein macro-molecules.

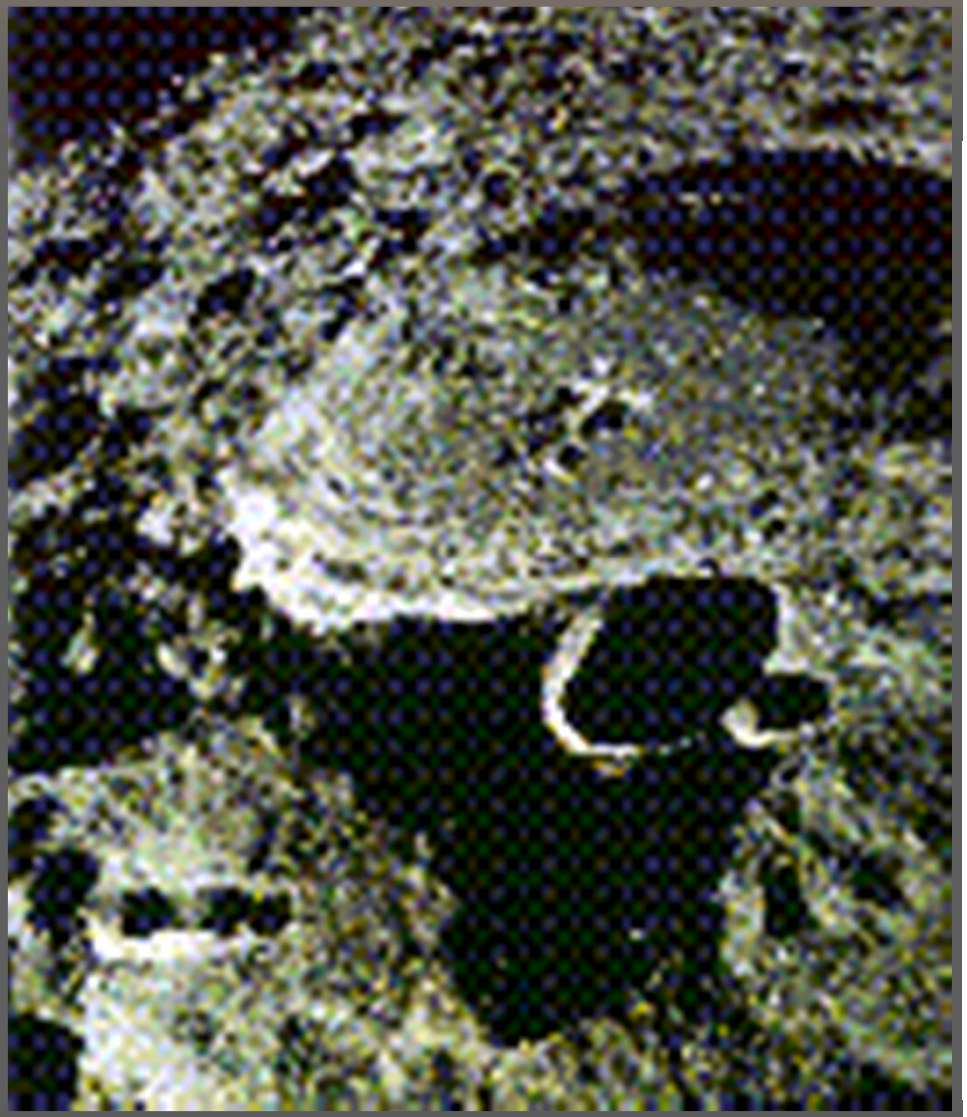




Impact of the Moon

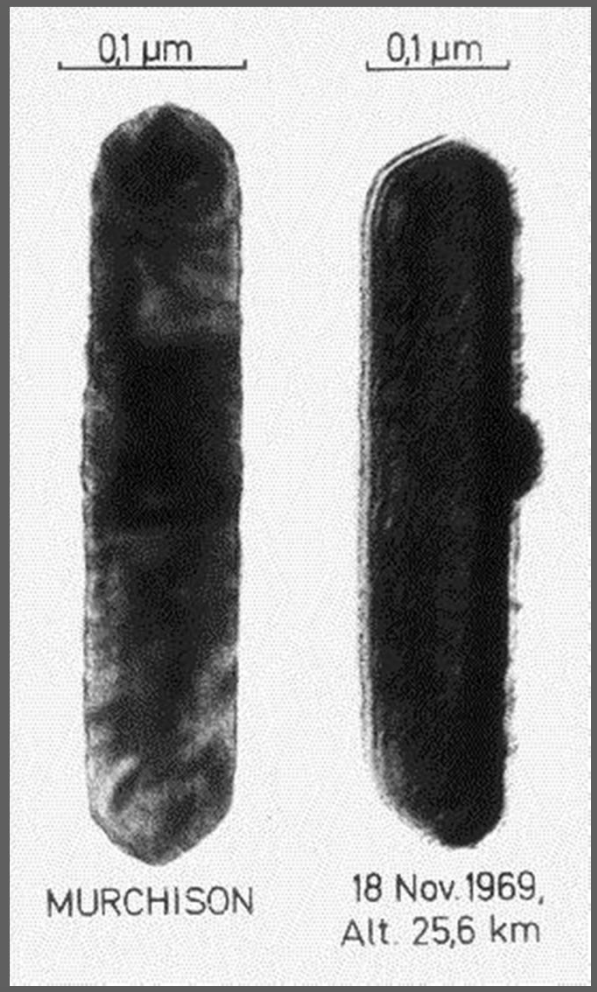
Krateriai

Mėnulis



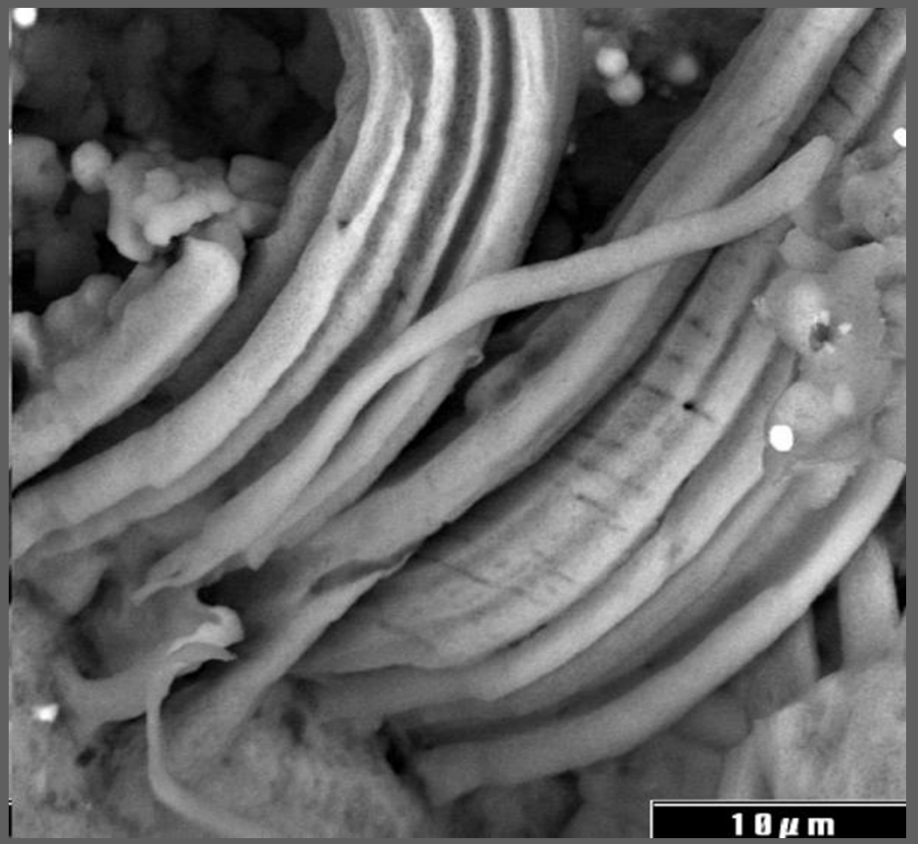
Panspermia

A fossil from the Murchison meteorite and a bacterium recovered in the high atmosphere, by Hans D. Pflug



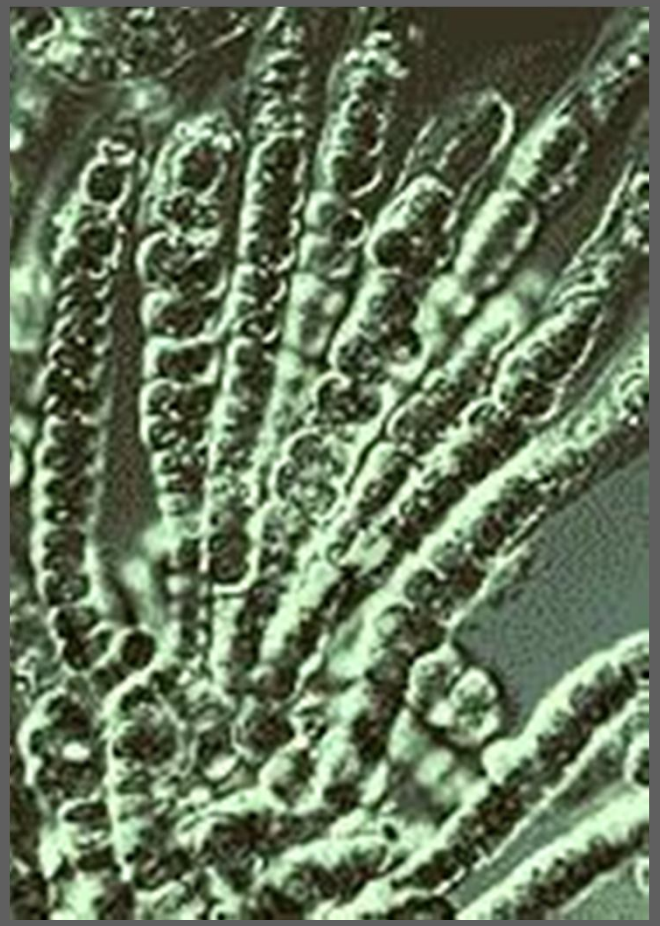
Cosmic ancestry

- **Microfossils in Orgueil**; photo by Richard B. Hoover, NASA/NSSTC, 21-23 July 2004; sample courtesy of Paul Sipiera, the Dupont Meteorite Collection of the Planetary Studies Found ation.



Cyanobacteria

- It is widely believed that 2000 million years ago the cyanobacteria — oxygen eliminating photosynthetic prokaryotes that used to be called blue-green algae... effected one of the greatest changes this planet has ever known: the increase in concentration of atmospheric oxygen from far less than 1% to about 20%. Without this concentration of oxygen, people and other animals would have never evolved.



Biocheminiai monomerai

TABLE 1.3 BIOCHEMICAL MONOMERS AND PROPERTIES THAT CAN BE DERIVED FROM COMETARY MOLECULES

Cometary Molecules	Formulas and Reactants	Biochemical Monomers and (Properties)
1. Hydrogen	H_2	(Reducing agent)
2. Water	H_2O	(Universal solvent)
3. Ammonia	NH_3	(Amination and catalysis)
4. Carbon monoxide	CO $(+H_2)$	Fatty acids
5a. Formaldehyde	CH_2O	Ribose and glycerol
5b. Aldehydes	$RCHO$ $(+HCN + NH_3)$	Amino acids
6. Hydrogen sulfide	H_2S (+other precursors)	Cysteine and methionine
7. Hydrogen cyanide	HCN	Purines and amino acids
8. Cyanoacetylene	HC_3N (+cyanate)	Pyrimidines
9. Phosphate[a]	PO_4^{3-}	Phosphates and nucleotides
10. Cyanamide[b]	H_2NCN	Oligonucleotides

[a]In interplanetary dust particles.
[b]Not yet detected in comets.

Sterilizacija

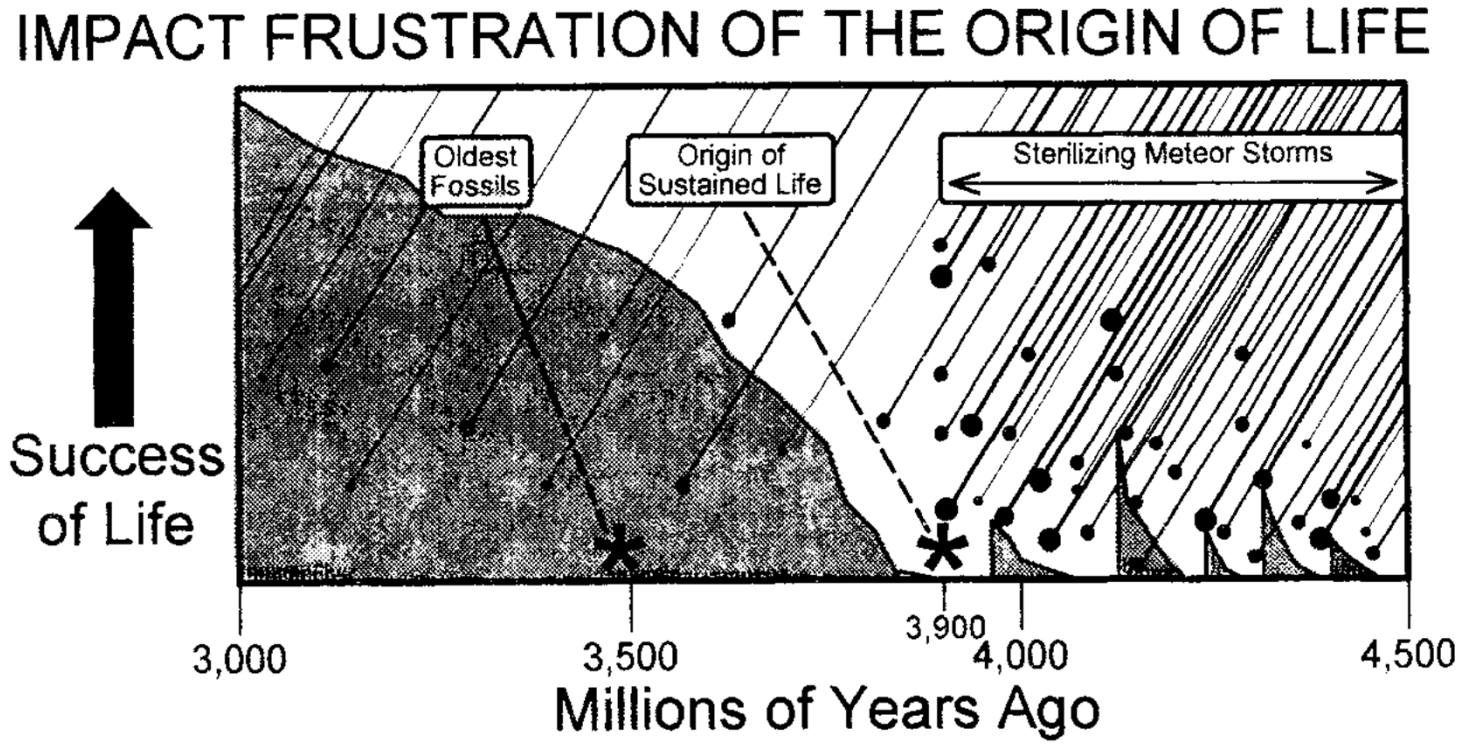


Figure 6.9. The common ancestor of life today could have originated only after the last great planet-sterilizing meteoritic impact.

Rekonstrukcija

“iš apačios “ ir “iš viršaus”

The Creation of Adam by Michelangelo

Geologija

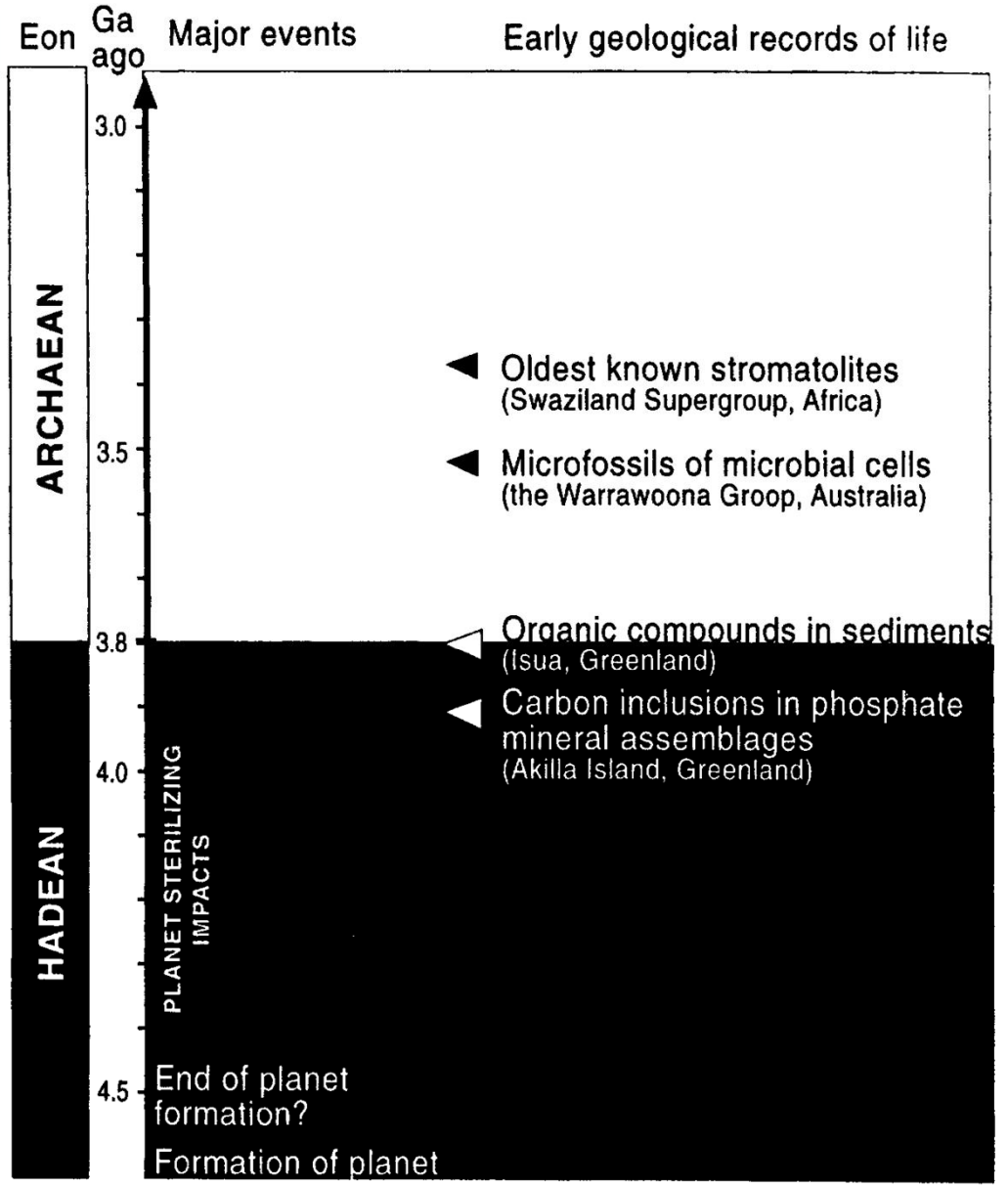
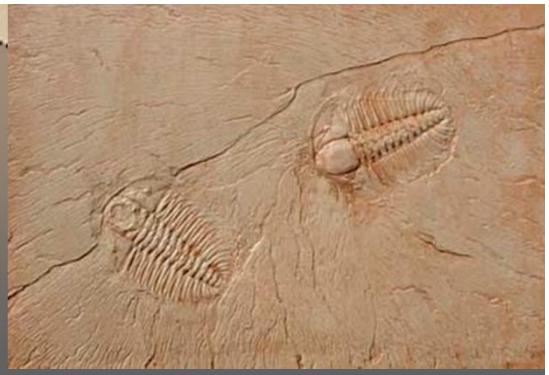


Fig. 13.1. Geochronological eons. The earliest records of fossil cells was reported by Schopf (1992a, 1992b). The earliest chemical records of life were reported by Schidlowski (1988) and Mojzsis et al. (1996), as discussed in chapter 15.

Fosilijos



Pre-Cambrian stromatolites in the Siyeh Formation, Glacier National Park.
In 2002, W.Schopf of UCLA published in *Nature* arguing that geological formations such as this possess 3.5 Ga fossilized cyanobacteria microbes. If true, they would be the earliest known life on earth

Fosilijos

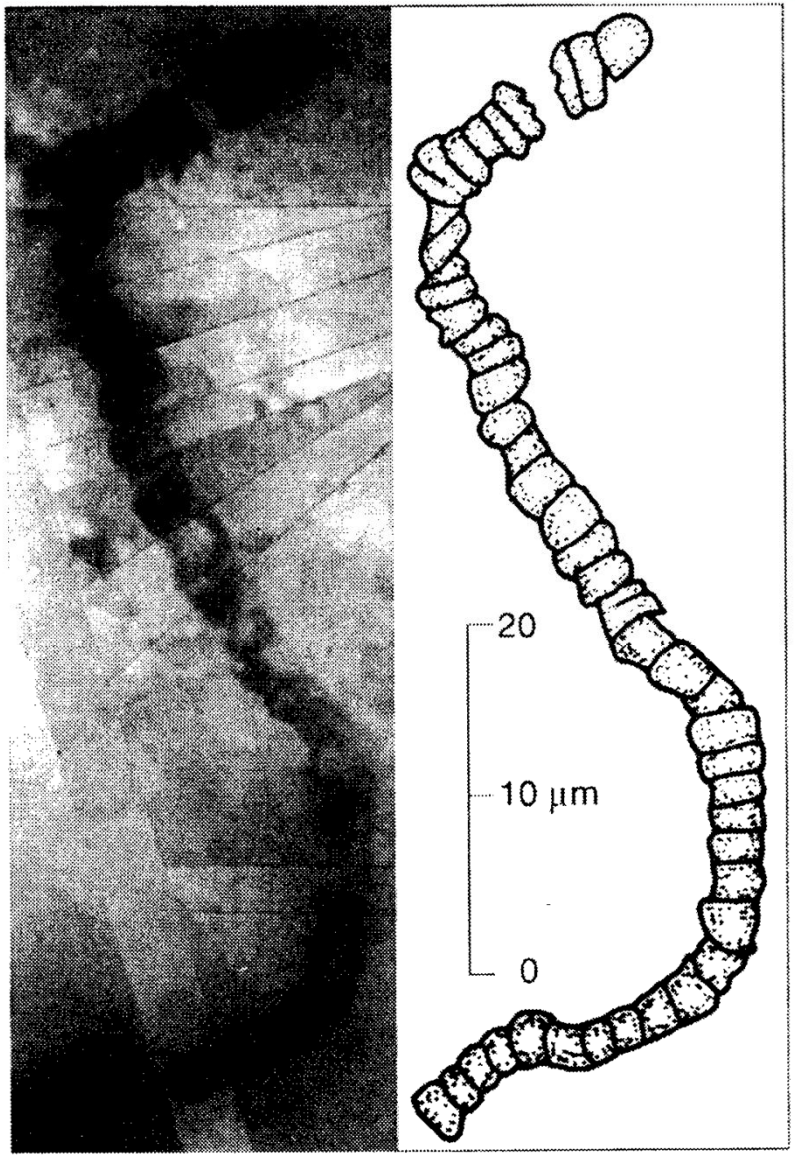


Fig. 15.1. Carbonaceous prokaryotic fossils (with interpretive drawings) shown in petrographic thin sections of the Early Archaean (3,465 million years old) Apex chert of northwestern Western Australia (Schopf, 1993). (Photo courtesy of J. W. Schopf)

Gyvybės atsiradimo langas

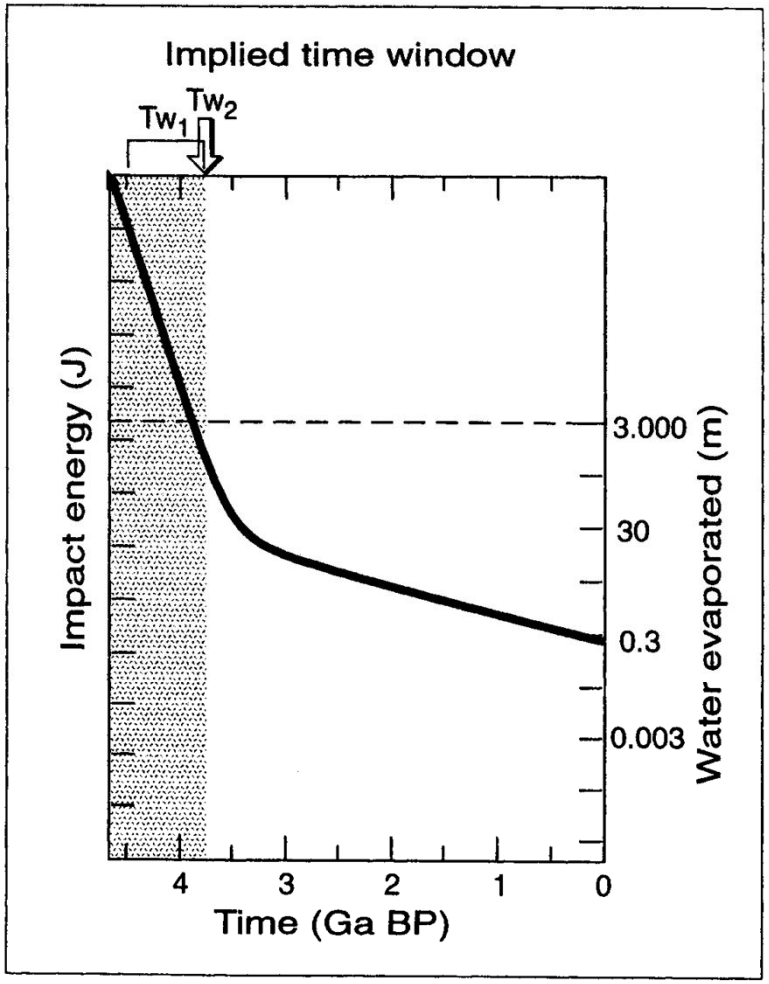
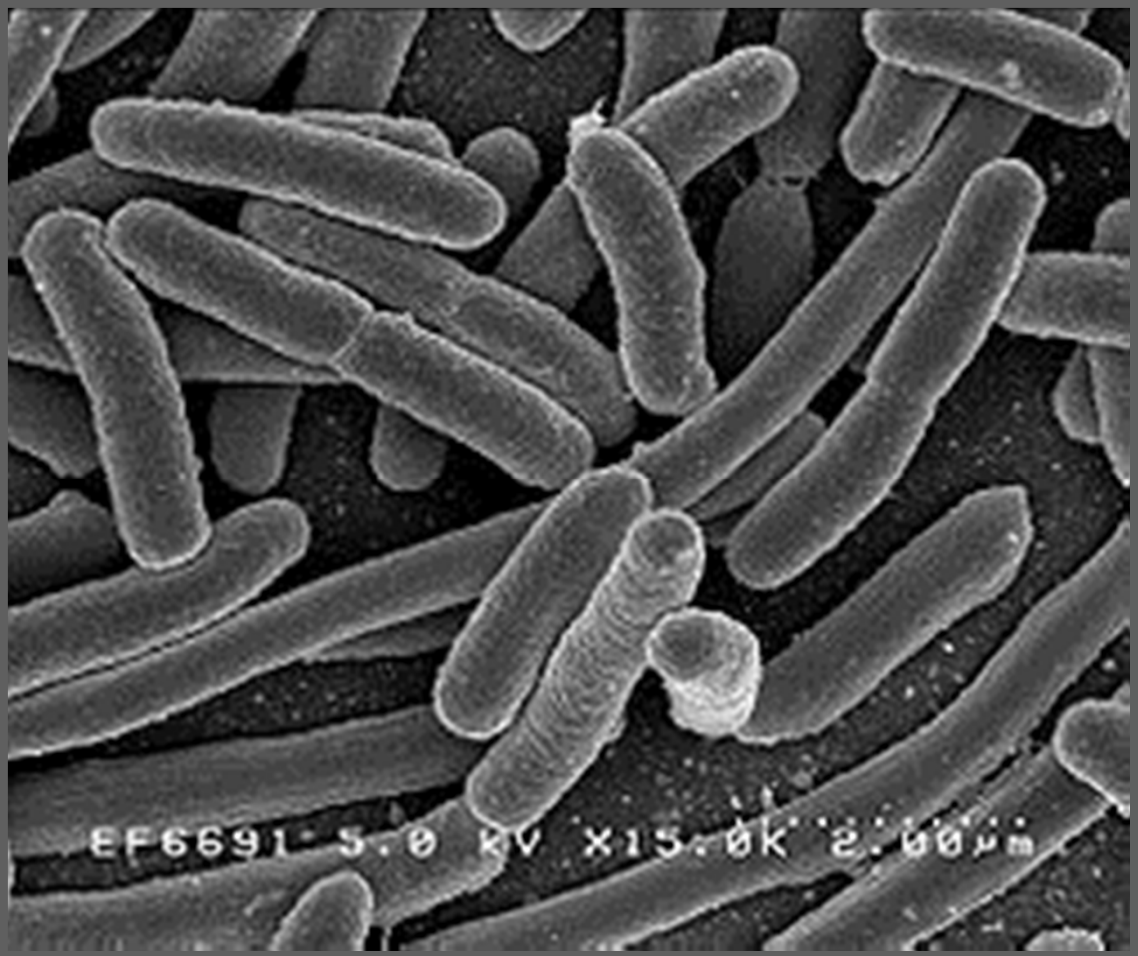


Fig. 15.2. Bolide impact energy on Earth during its early history, depth of the ocean vaporized by the impact, according to Sleep et al. (1989), and the estimated width of the time window for the emergence of life (upper scale). TW_1 is the time window calculated without taking into account the meteorite bombardments. TW_2 represents the narrow time window based on the last sterilizing impact (~3.8 Ga BP) on the one hand, and the geological record of the first living entities according to Schidlowski (1988) and Mojzsis et al. (1996) (i.e., ~3.85 Ga BP), on the other. The uncertainties involved in these estimates result in inaccuracies of the time window. Note that adequate conditions for continuous life characterize the primordial earth since ~3.8 Ga ago. (Adapted from Sleep et al., 1989)

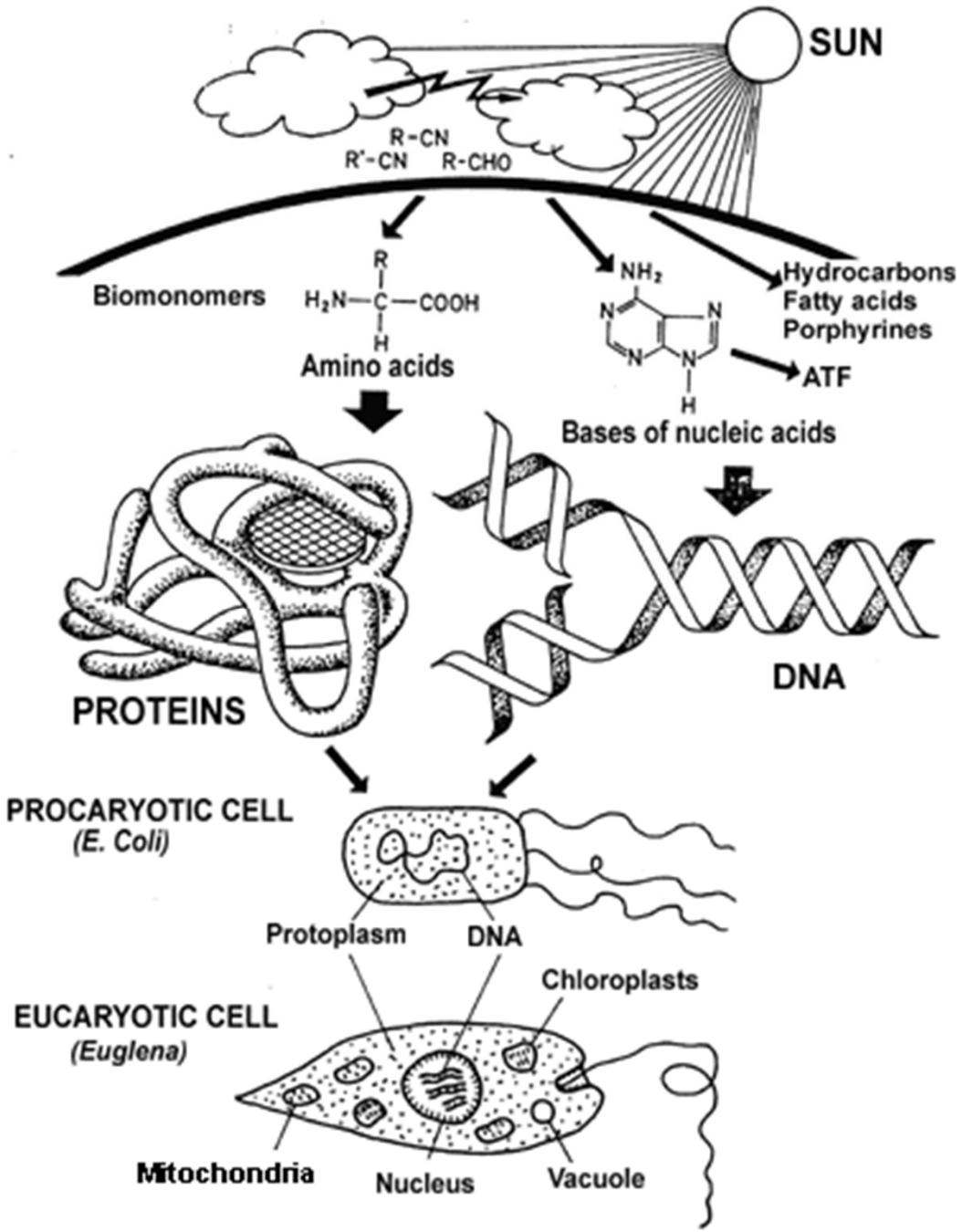
Proteobacteria



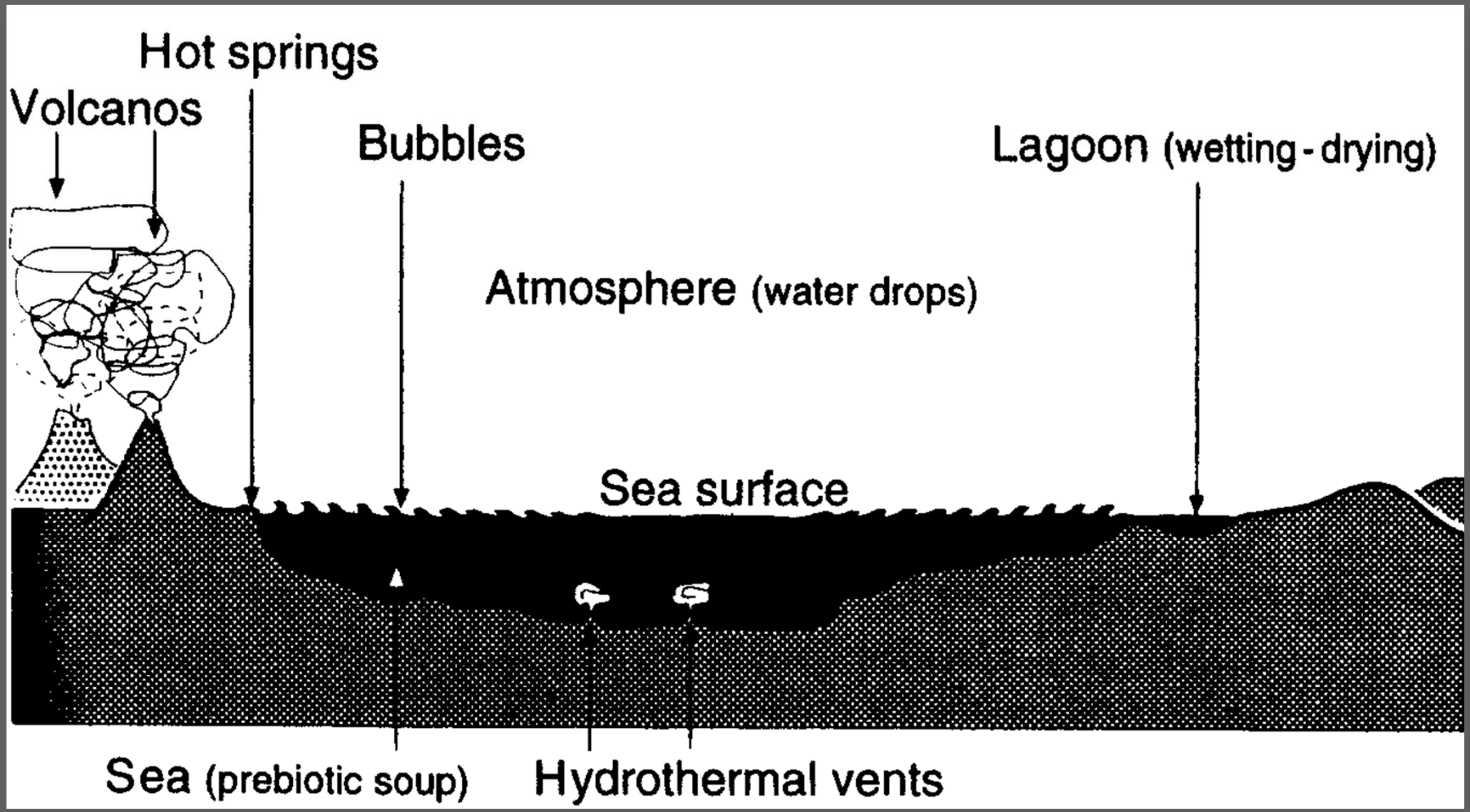
Escherichia coli

Chemical and biological evolution of the Earth

Under action of radiation from the Sun the basic components of bio-systems - amino acids and nucleic acid bases - are formed in photochemical reactions form the primary gases of the Earth's atmosphere. From these bio-monomers bio-polymers - proteins and nucleic acids - were formed in processes of independent evolution, according to the hypothesis of M. Calvin. Out of the "symbiosis" of these two bio-polymer systems the first living bio-systems - unicellular organisms -emerged.



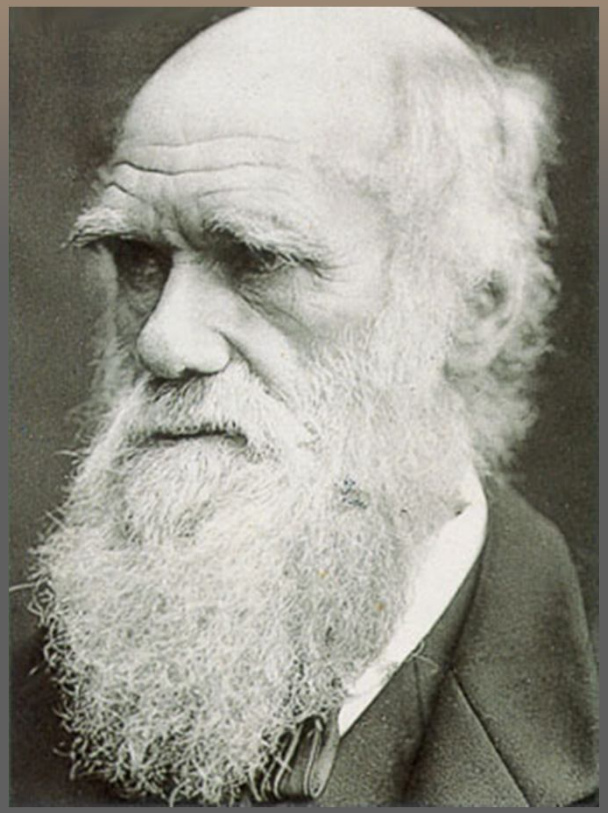
Kur atsirado gyvybė?



Kur atsirado gyvybė?

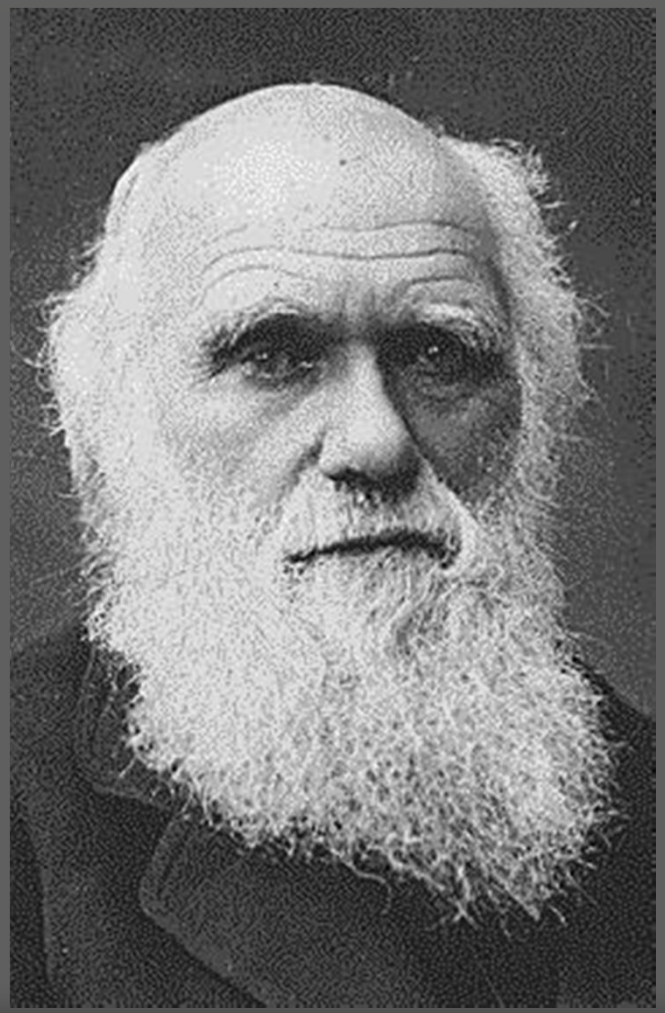
- Jūros vanduo ir jo ribos
  - Jūros paviršius – protocelės
  - Burbuliukai –aerozolio lašeliai, vandens paviršiaus ir atmosferos riba
- Karšti vulkaniniai šaltiniai
  - Amino rūgščių gausa – RNR pasaulis
  - Redukuotos geležies, sieros ir molio gausa
- Jūros dugnas
  - Hidroterminiai šaltiniai
- Balos – hidratacijos dehidratacijos ciklai
- Atmosfera
  - Vandens lašeliai
  - Vulkaninių pelenų ir dujų debesys

C.Darvinas



- Jis tikėjo pirminiu pradėjimu, bet jo požiūris kito
- 1871
  - Jei (O! Koks didelis jei!) įsivaizduotume mažą šiltą puodelį, kur įdėti visos reikalingos fosforo ir amonio druskos, šviesa, šiluma, elektra ir kt., kad susidarytų cheminiai baltymų dariniai ir būtų sąlygos jų tolesnei sudėtingėjimo raidai ...šiomis dienomis galėtų išsivystyti gyvos būtybės
  - Cheminės evoliucijos idėja

Charles Darwin



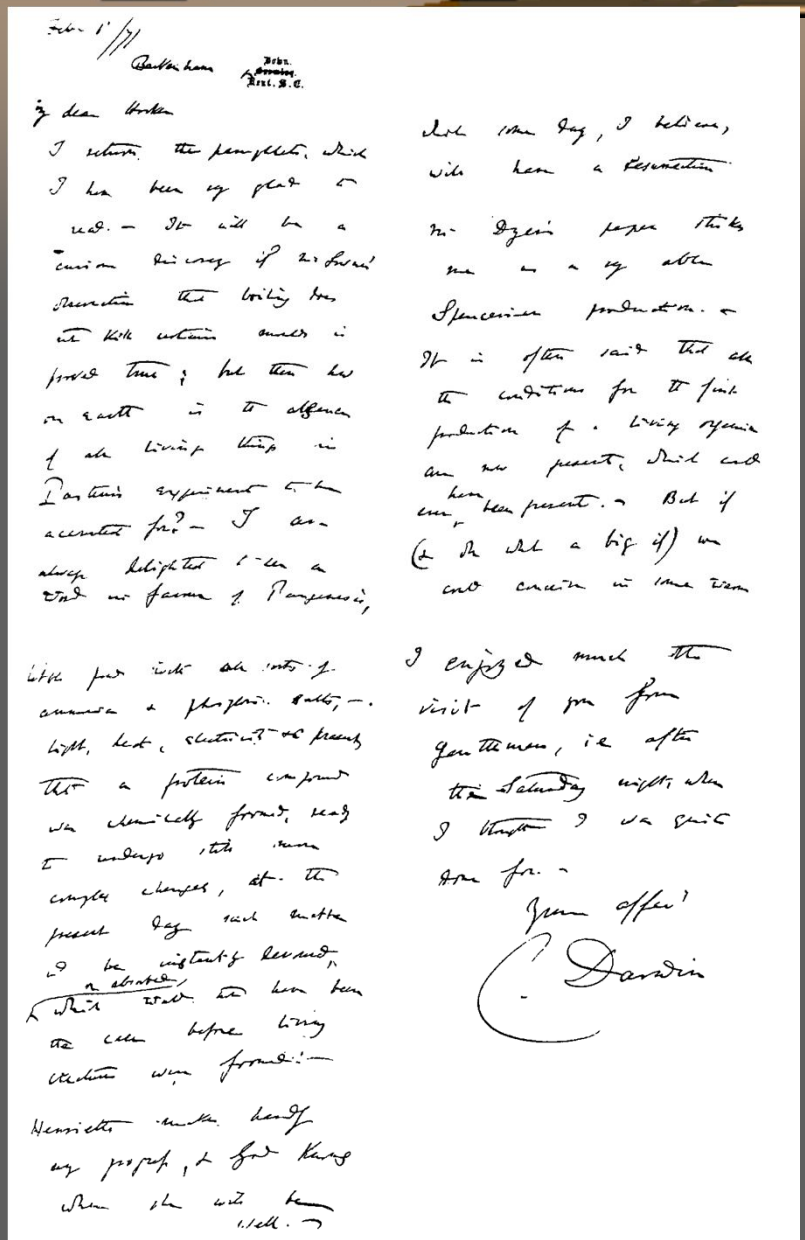
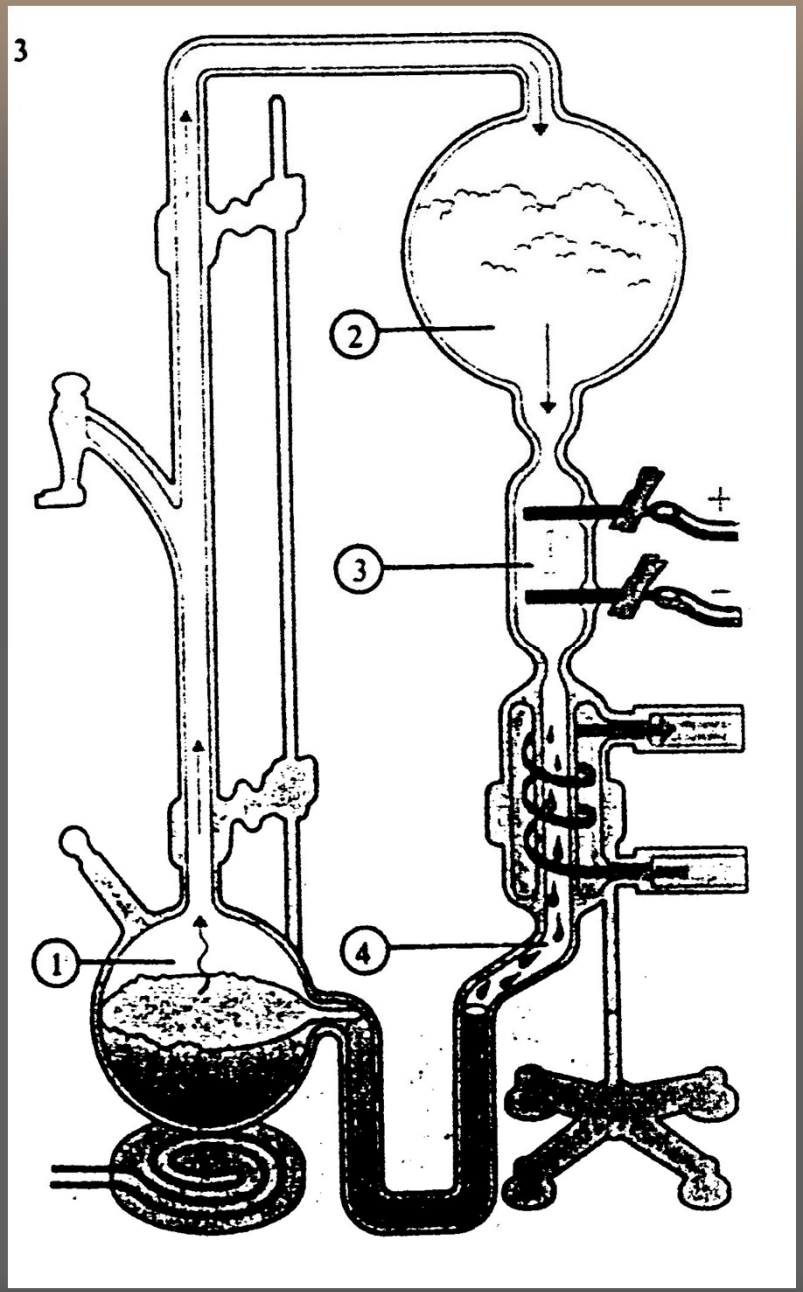


Figure 3.1. Charles Darwin's letter to Joseph Hooker, dated February 1, 1871. In spite of the handwriting, Darwin's ideas on a "warm little pond" are readable. Adapted from Calvin 1969.

H.Urey's and L.Miller's experiment

- The primary atmosphere of the Earth did not contain any oxygen, consisting only of non-oxidising and relatively inert gases, such as ammonia (NH_3), methane (CH_4), hydrogen (H_2), nitrogen (N_2), and carbon dioxide (CO_2).

- Various complex organic molecules may appear in such a mixture of gases in photo- or electrochemical reactions caused by radiation or electric discharges, among which amino acids and nucleic acid bases, such as pyrimidines and purines, which exist in living organisms.



Atmosferos rūšys

TABLE 3.3 TYPES OF PLANETARY ATMOSPHERES

Atmosphere	Composition(s)
Reducing	CH_4, NH_3, N_2, H_2O, H_2
	CO_2, N_2, H_2O, H_2
	CO_2, H_2, H_2O
Neutral	CO_2, N_2, H_2O
Oxidizing	CO_2, N_2, H_2O, O_2

Organikos produkcija

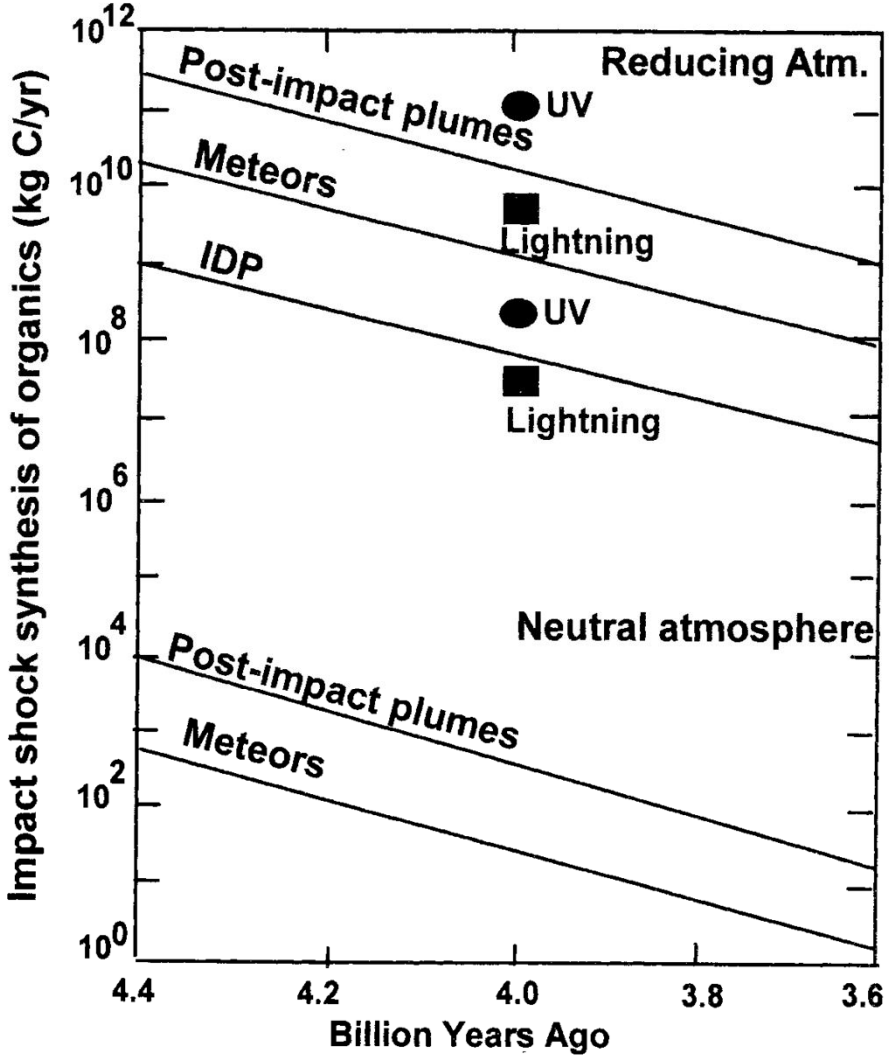
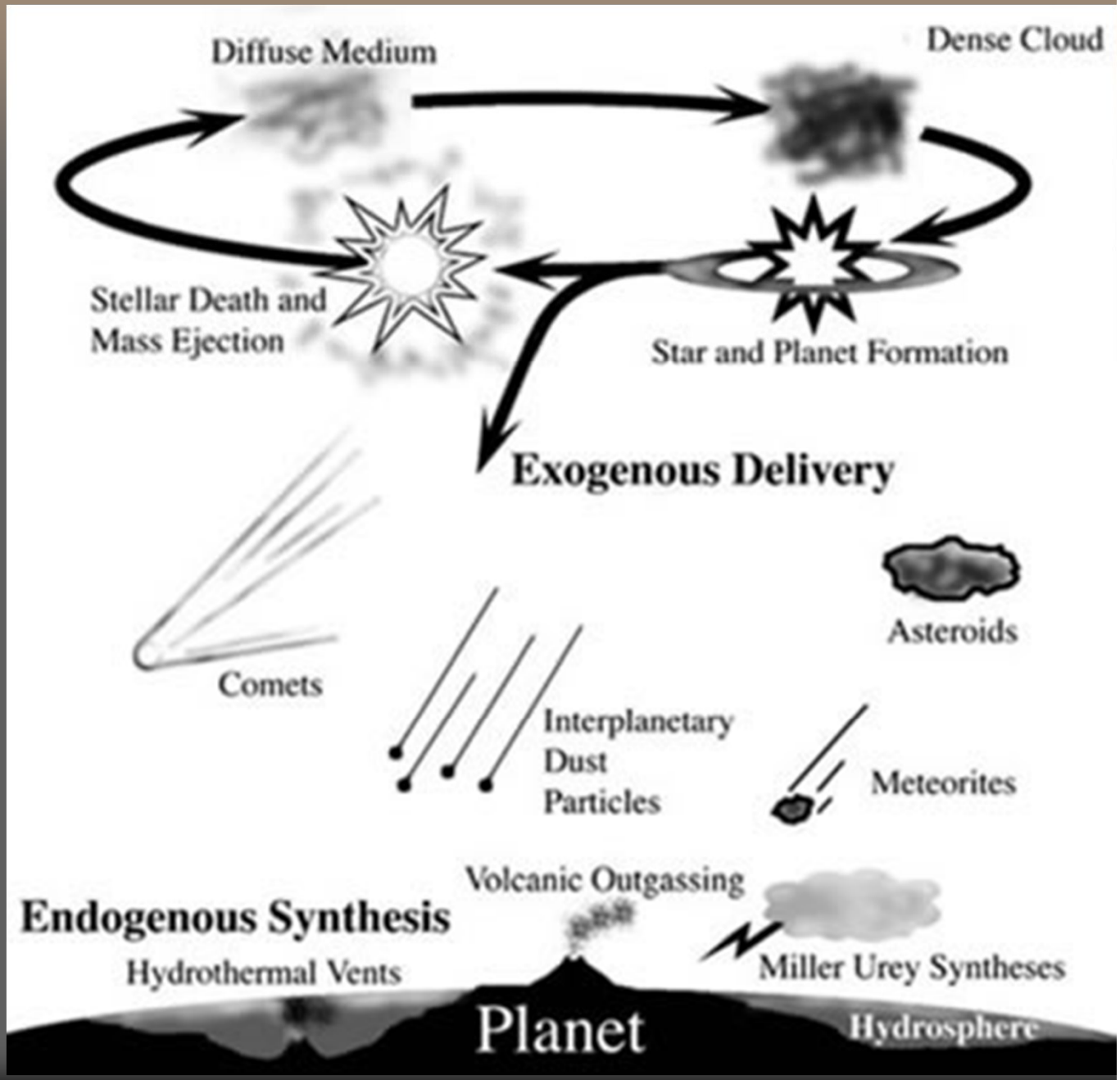


Figure 2.6. Estimated production rates (in kilograms per year) of organic carbon compounds from meteor shockwaves, high-temperature chemical reactions in impact plumes, and in-fall of interplanetary dust particles (IDPs) compared with such production from ultraviolet light and electric discharges. Two sets of data are shown: The lower for a "neutral" (CO_2–N_2–H_2O) atmosphere; the higher for a "reducing" (CH_4–N_2–H_2O) atmosphere. The IDP flux is independent of atmospheric composition. Overall, productivity decreases logarithmically over time as the frequency and size of impactors decreases. (Adapted from Chyba and Sagan 1992.)

Organikos kilmė



Elementų proporcijos

TABLE 1.1 PERCENTAGES OF ELEMENTS IN LIFE COMPARED WITH THOSE IN INTERSTELLAR FROST AND COMETS

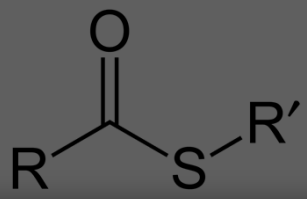
Elements	Bacteria	Mammals	Interstellar Frost	Volatiles in Comets
Hydrogen	63.1	61.0	55	56
Oxygen	29.0	26.0	30	31
Carbon	6.4	10.5	13	10
Nitrogen	1.4	2.4	1	2.7
Sulfur	0.06	0.13	0.8	0.3
Phosphorus	0.12	0.13	—	0.08
Calcium	—	0.23	—	—

Adapted from Delsemme (2000).

Gyvybės hipotezės

TABLE 3.7 CURRENT HYPOTHESES ON THE ORIGIN OF LIFE (EXCLUDING PANSPERMIA)

1. Abiotic Synthesis and Heterotrophic Origin	
Oparin (1936)	Primitive soup and primordial fermentation
Corliss et al. (1981)	Submarine hot spring thermophilic heterotroph
Gilbert (1986)	RNA World
De Duve (1991)	Thioester World
Kauffman (1993)	Self-organization and complexity theory
2. Primordial CO_2 Fixation and Autotrophic Origin	
Wächterhäuser (1988)	Pyrite-based chemolithotrophic metabolic networks



Thioester

FeS_2

Pyrite

DNR gyvybė

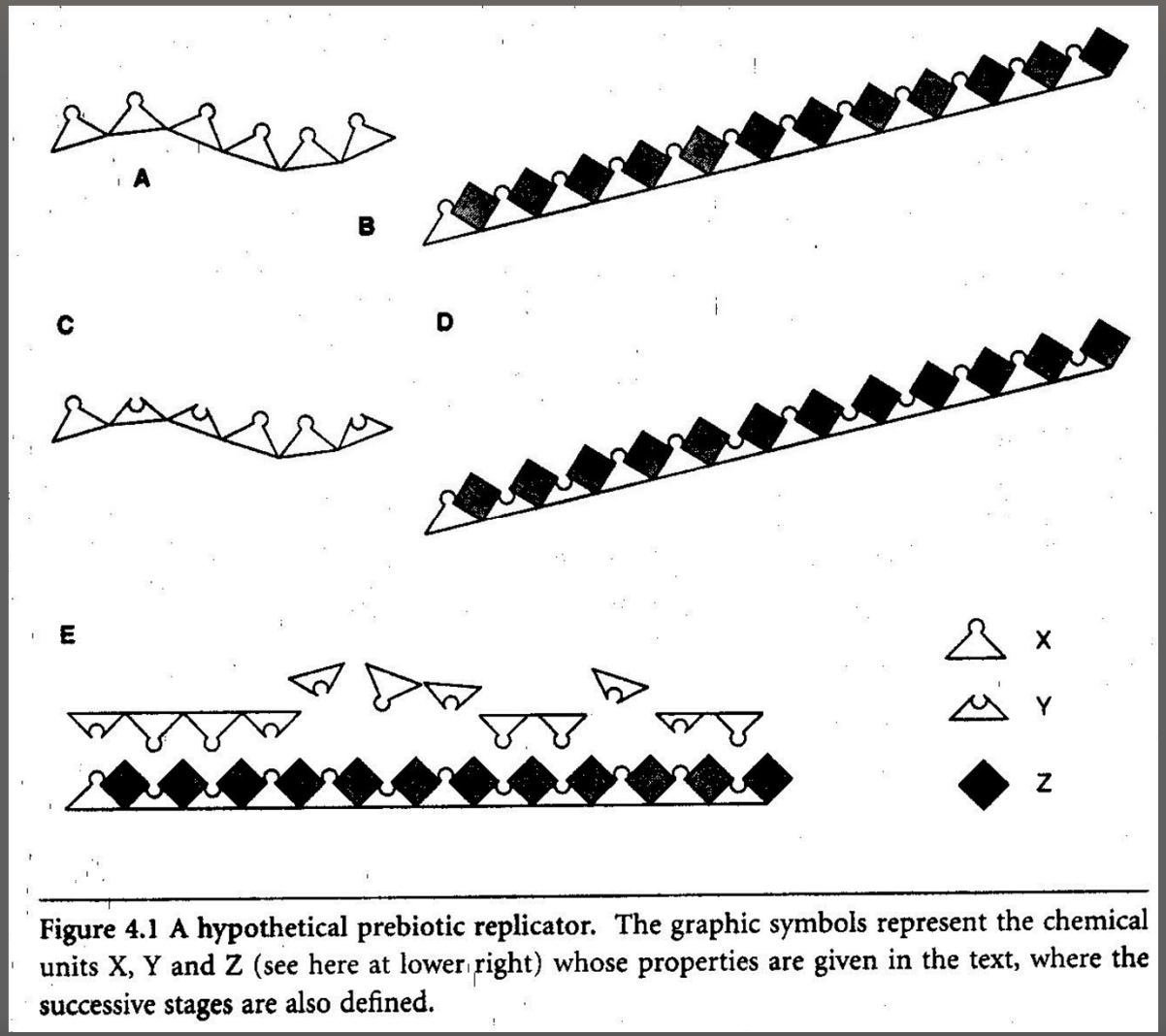


Figure 4.1 A hypothetical prebiotic replicator. The graphic symbols represent the chemical units X, Y and Z (see here at lower right) whose properties are given in the text, where the successive stages are also defined.

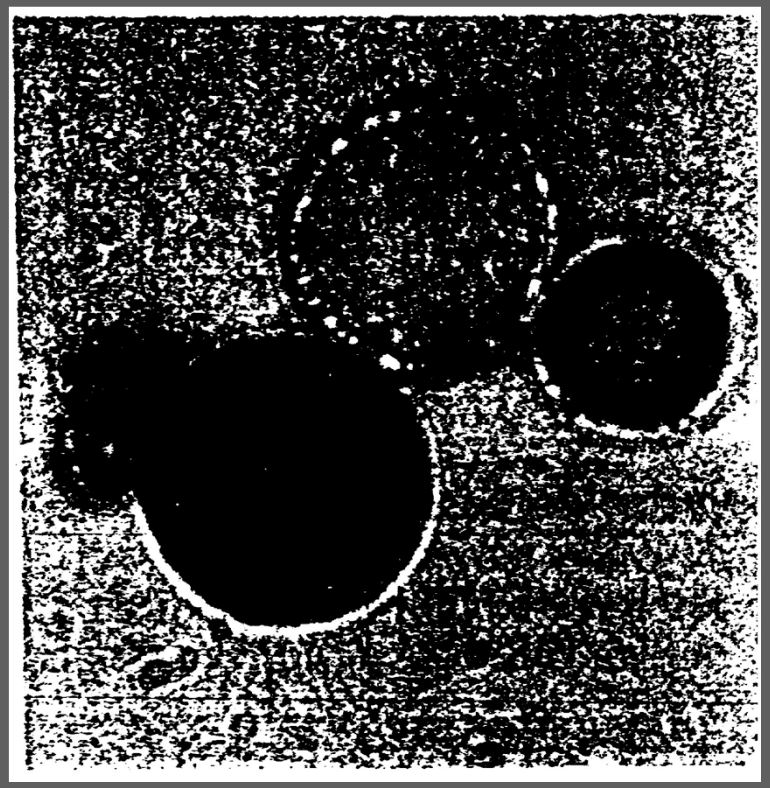
Biopoiesis

J. B. S. Haldane suggested that the Earth's pre-biotic oceans–very different from their modern counterparts–would have formed a "hot dilute soup" in which organic compounds could have formed. This idea was called *biopoiesis*, the process of living matter evolving from self-replicating but nonliving molecules

J. B. S. Haldane

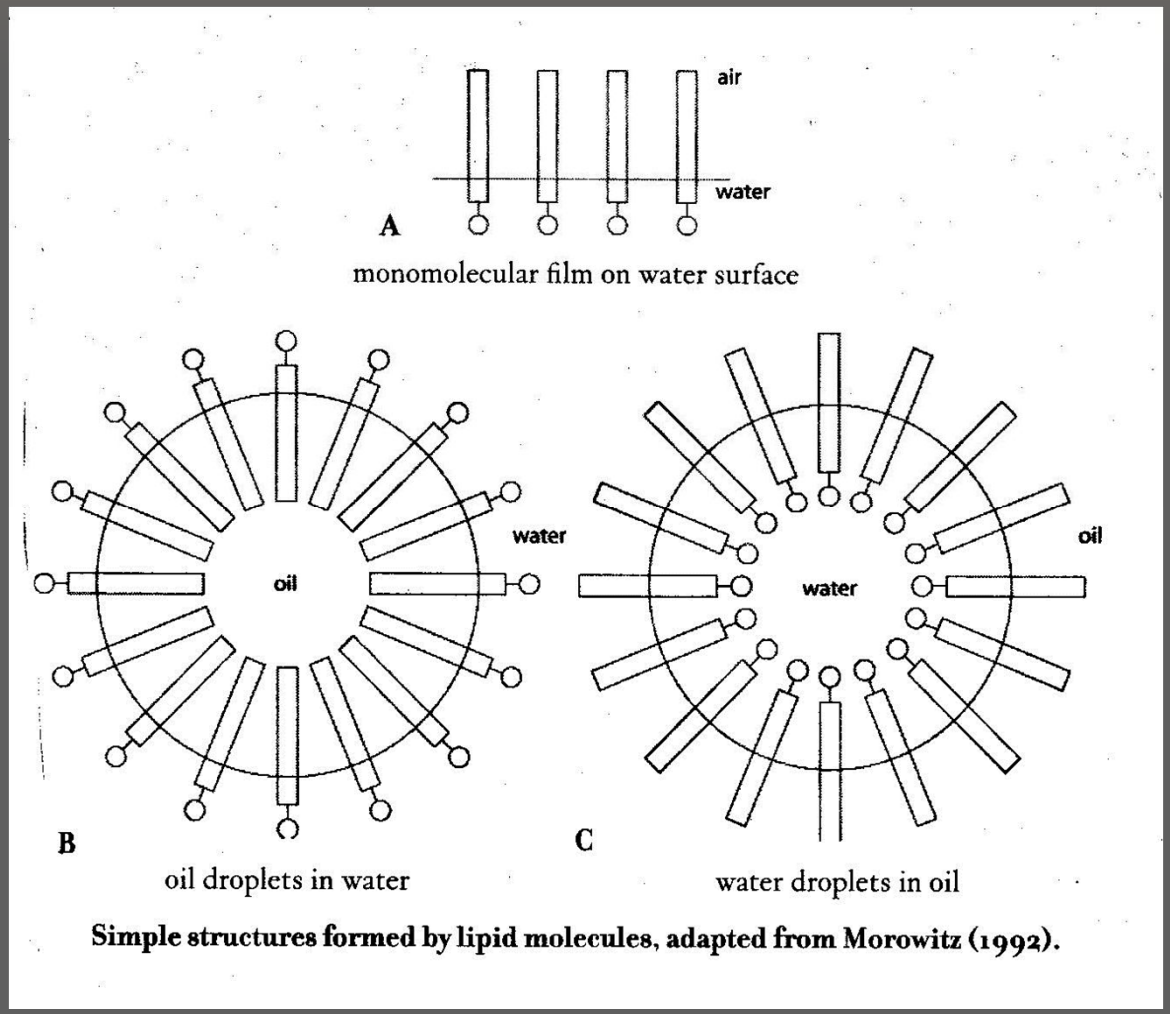
A.Oparins experiment

Protobionts,
the most simple
metabolical bio-system

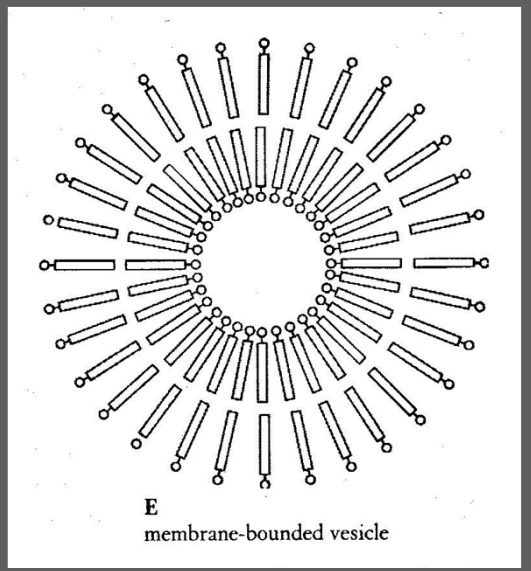


1924 Alexander Oparin
(right) at the laboratory

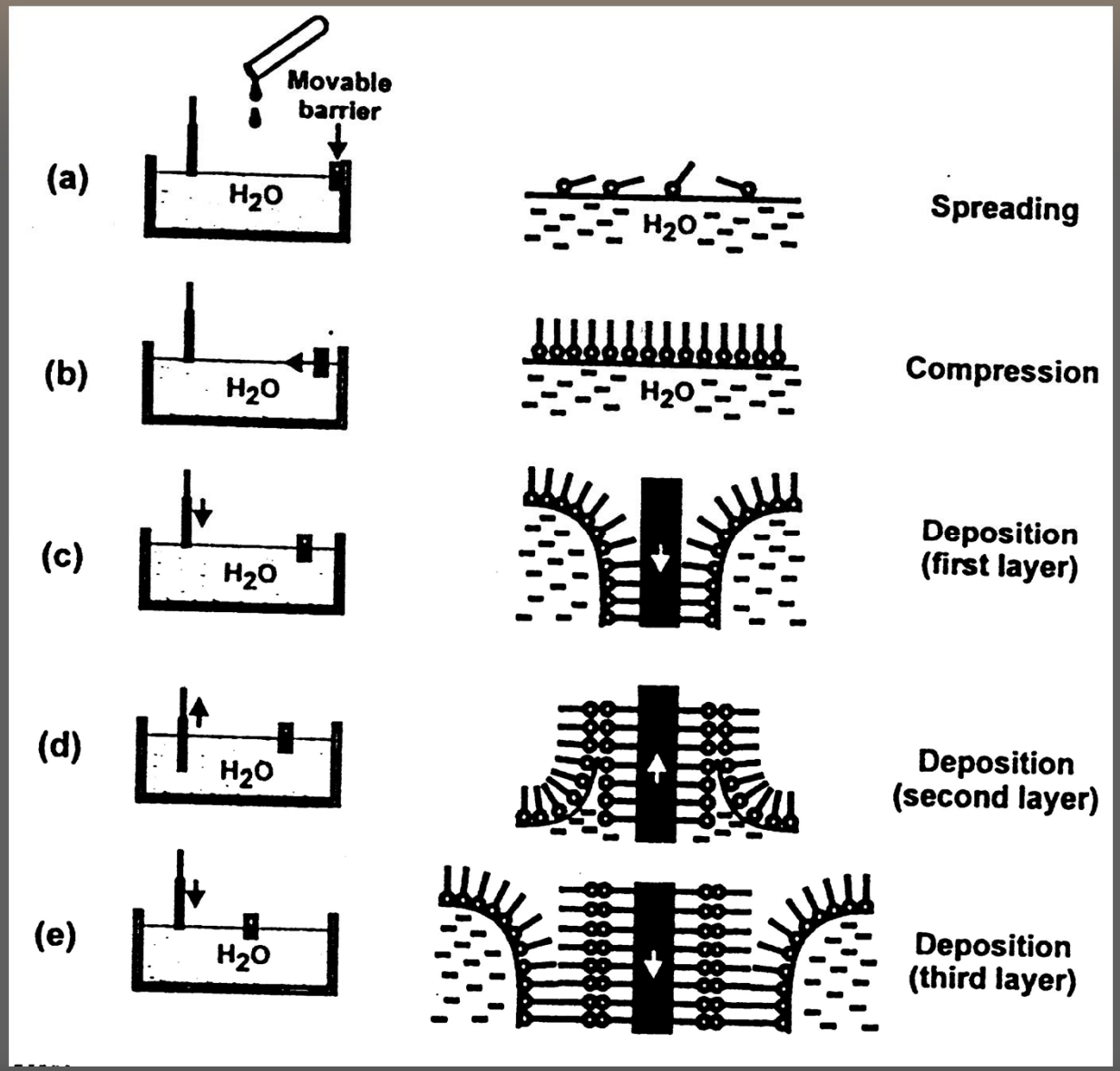
Lipidų struktūros



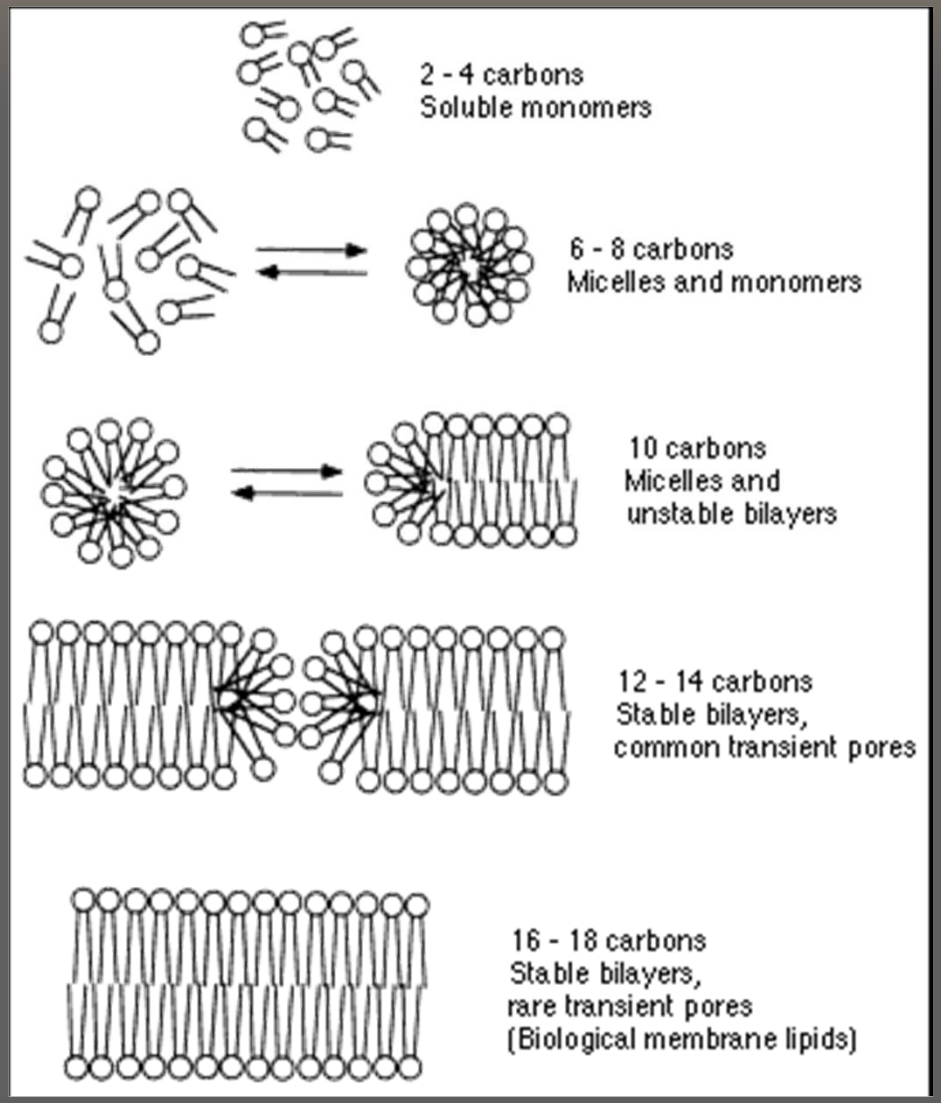
Simple structures formed by lipid molecules, adapted from Morowitz (1992).



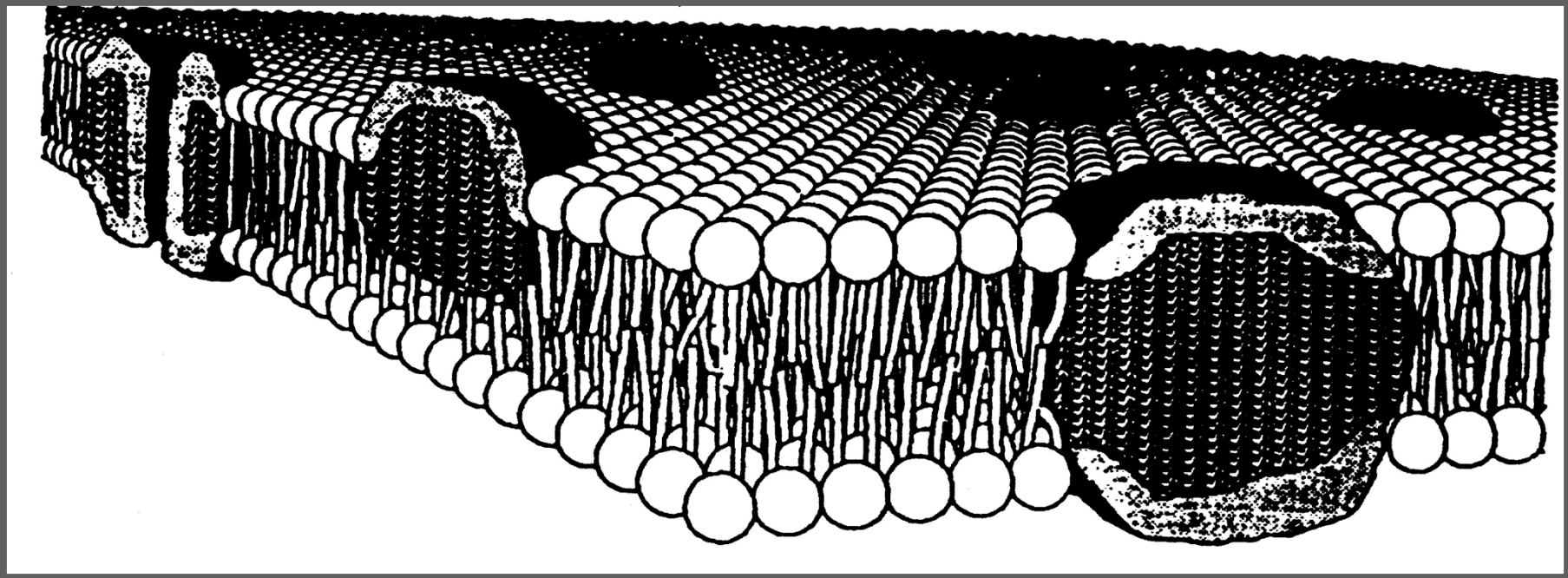
Langmuir-Blogett (LB) films



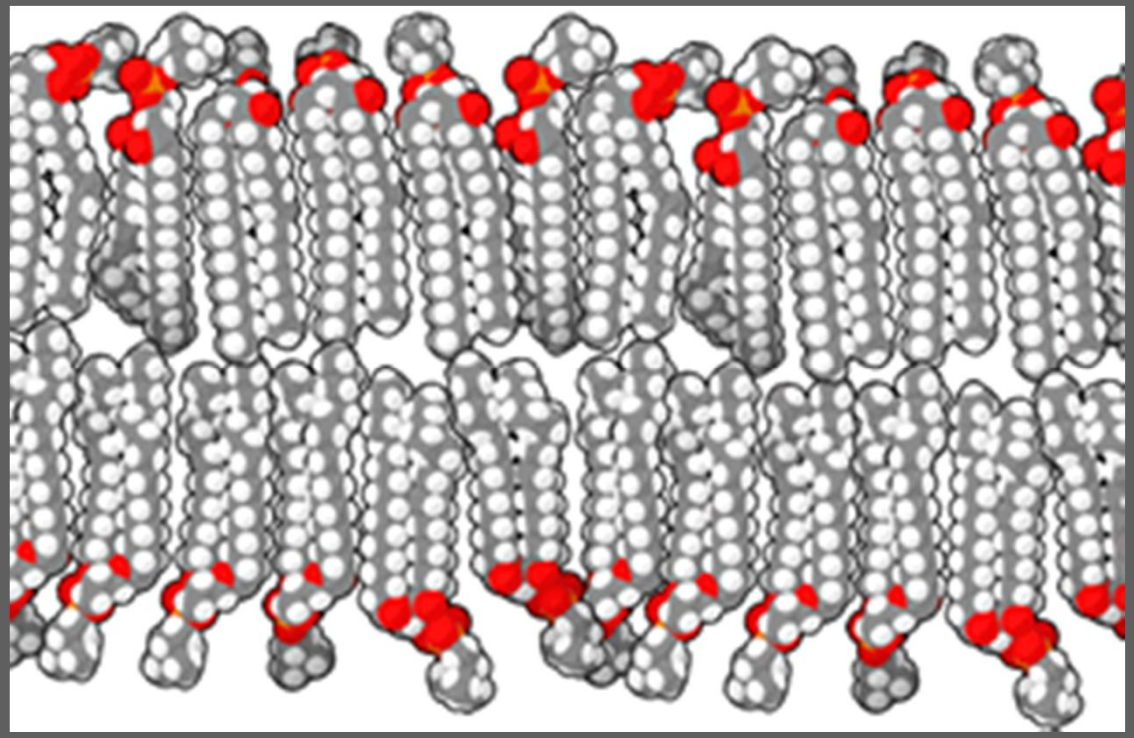
Self-assembly of amphilic molecules



Singer-Nicholson model of the cell membrane



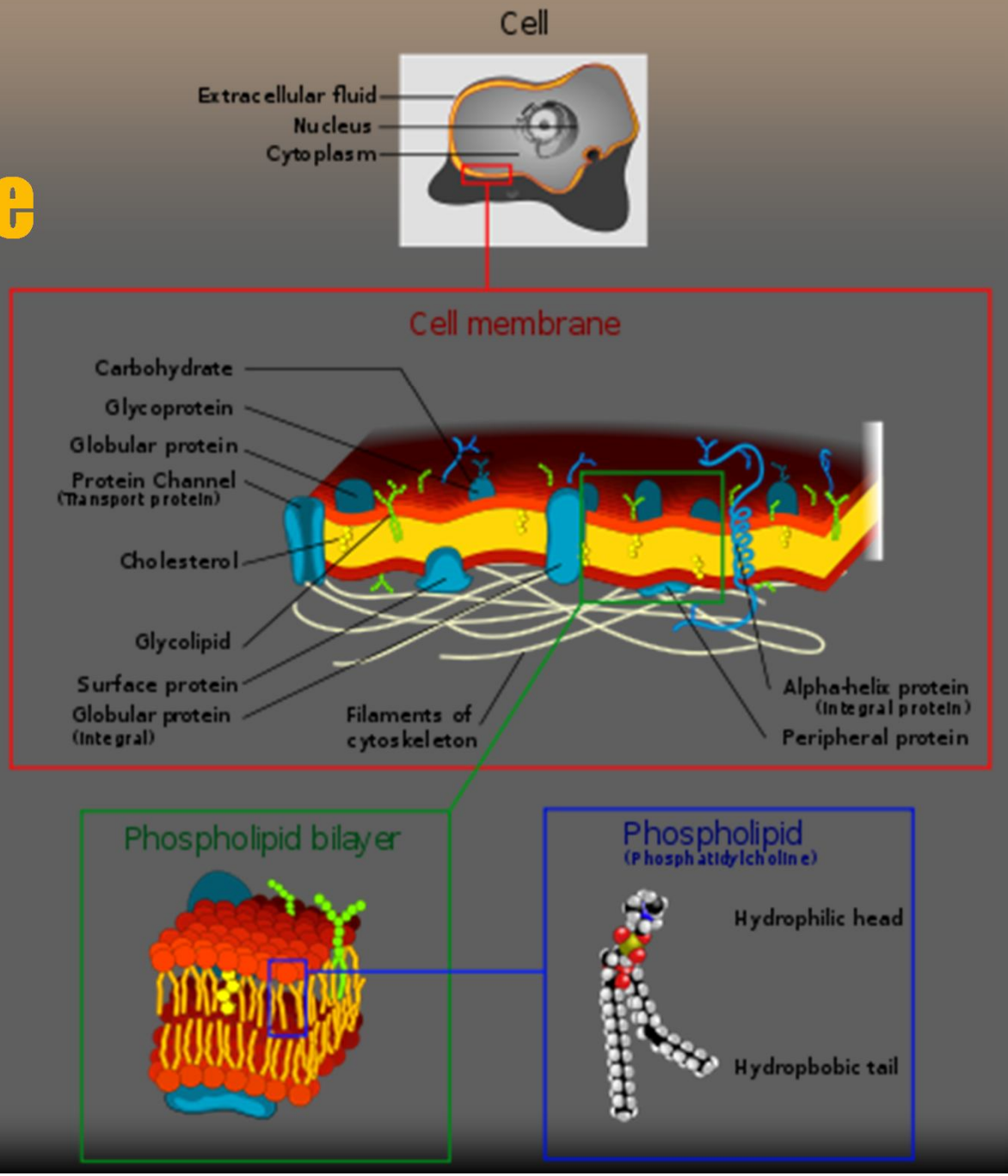
Lipid bilayer



- This fluid lipid bilayer cross section is made up entirely of phosphatidylcholine.

Wikipedia

Eukaryotic cell membrane



Įkapsuliacija

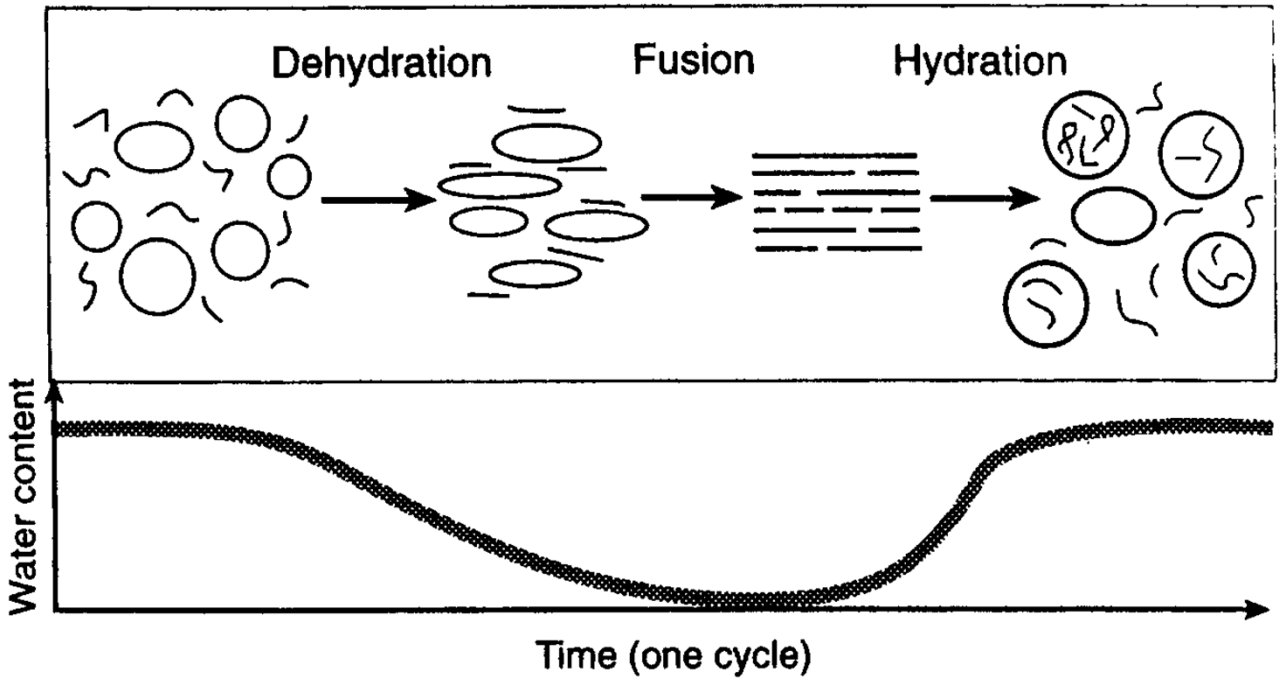


Fig. 19.4. Encapsulation of molecules according to the hydration-dehydration method. (Adapted from Deamer et al., 1994)

Protocelė

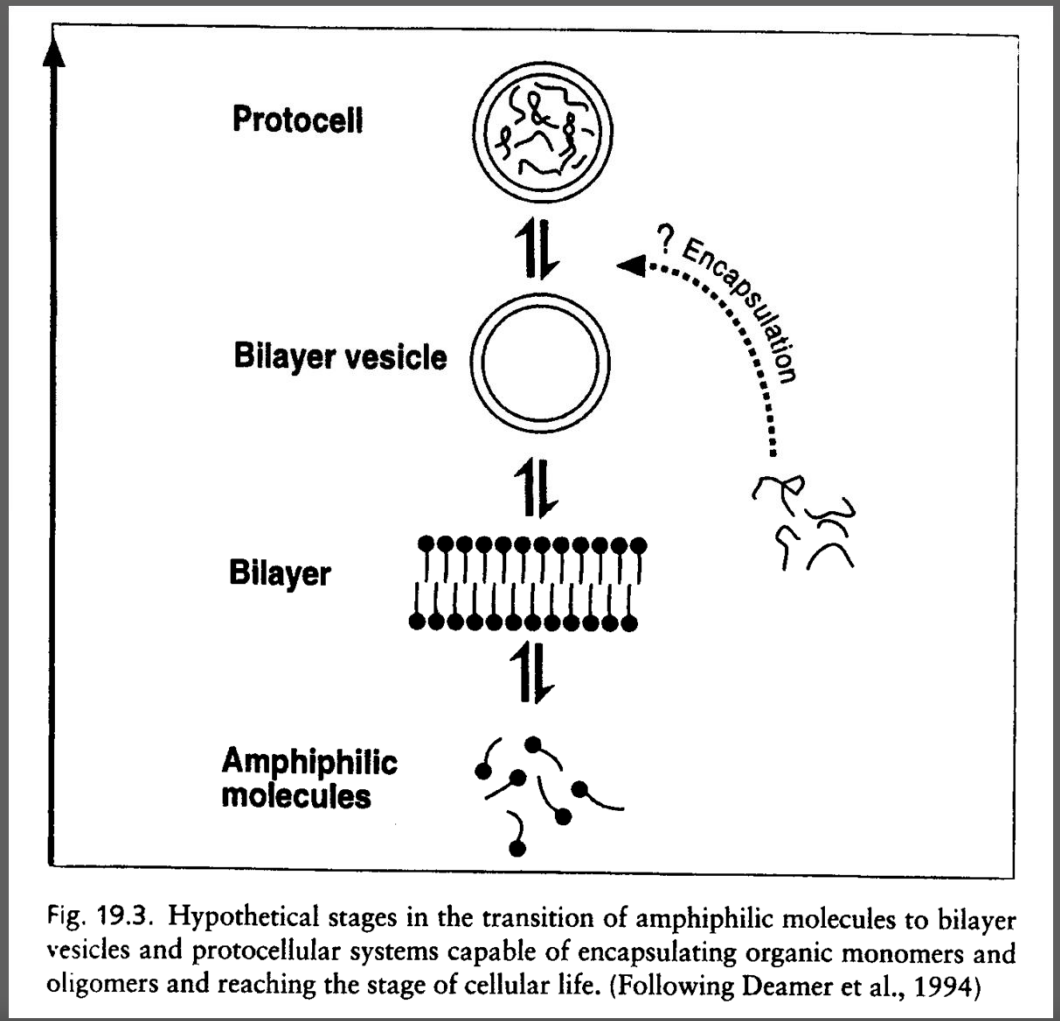
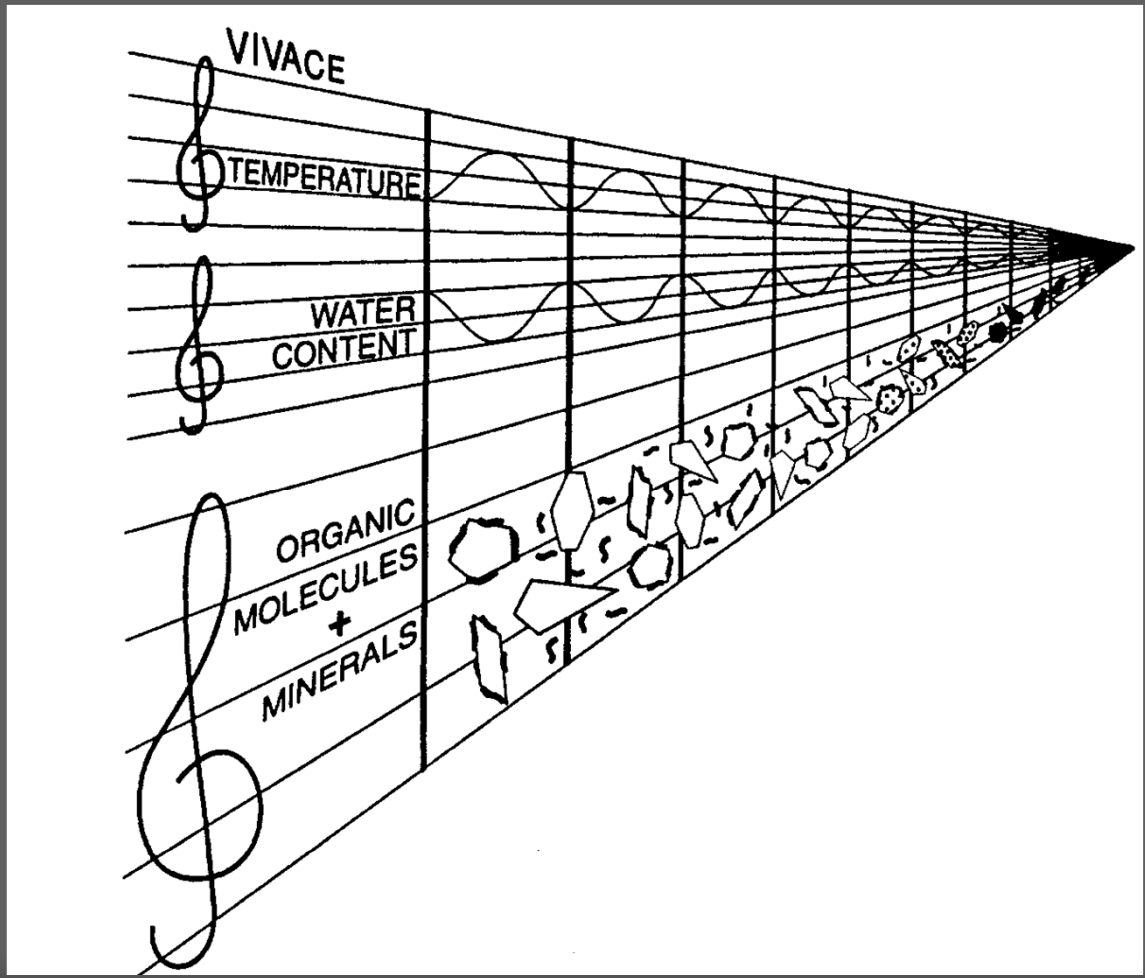
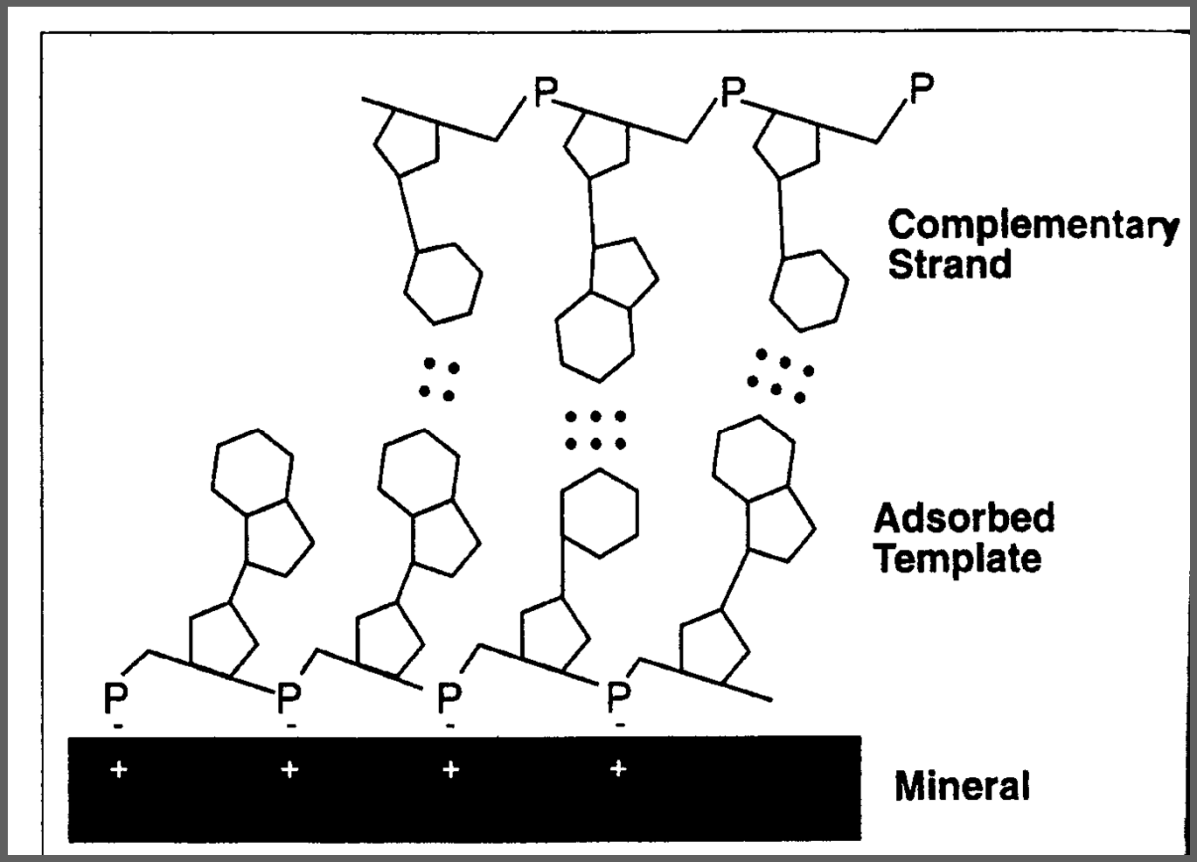


Fig. 19.3. Hypothetical stages in the transition of amphiphilic molecules to bilayer vesicles and protocellular systems capable of encapsulating organic monomers and oligomers and reaching the stage of cellular life. (Following Deamer et al., 1994)

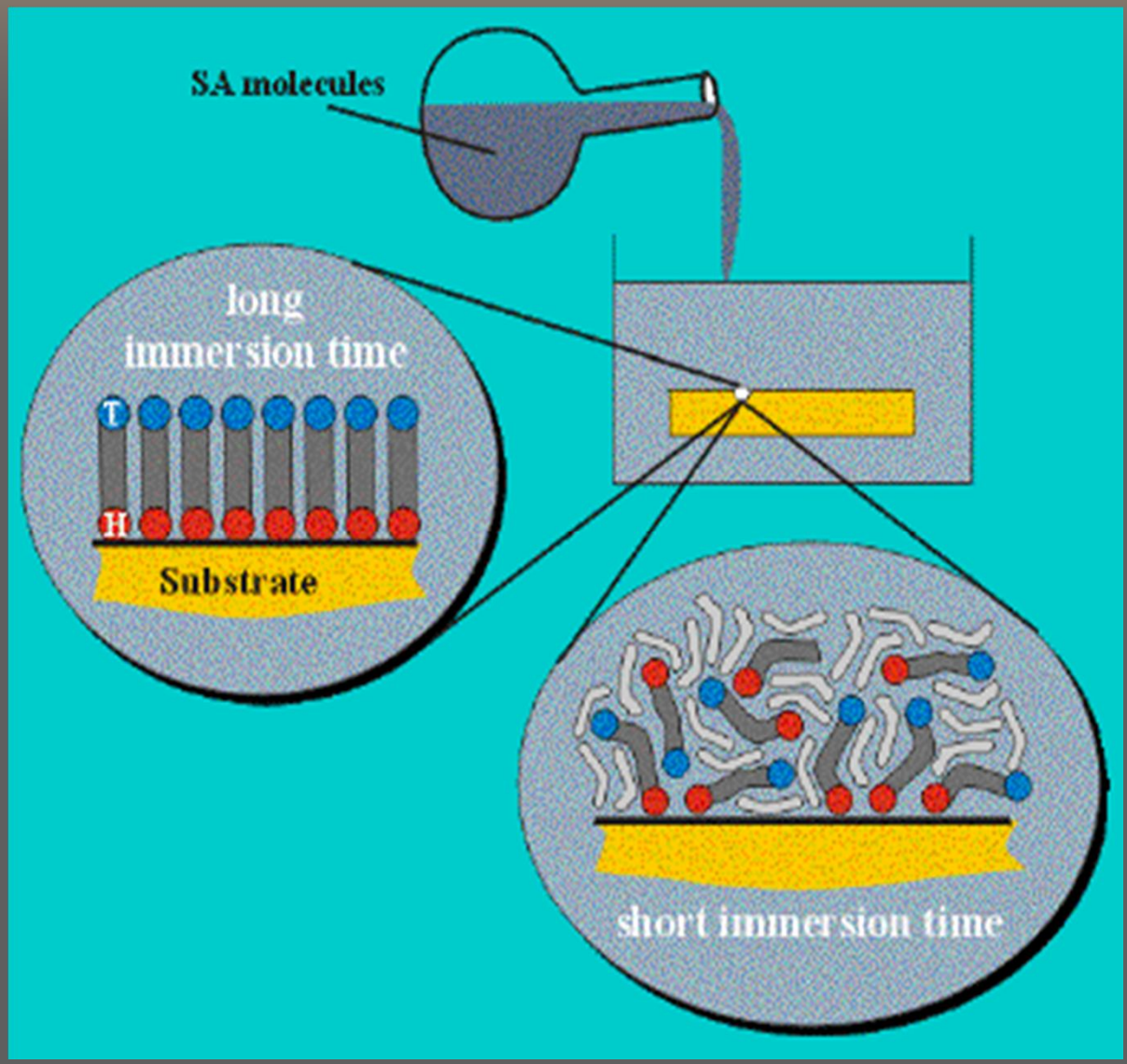
Vandens fluktuacijos



Šablonai



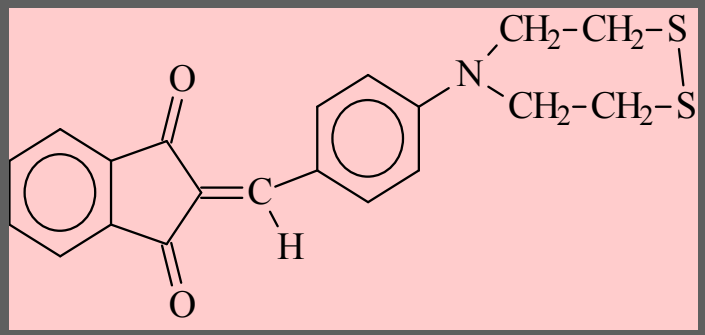
SAM

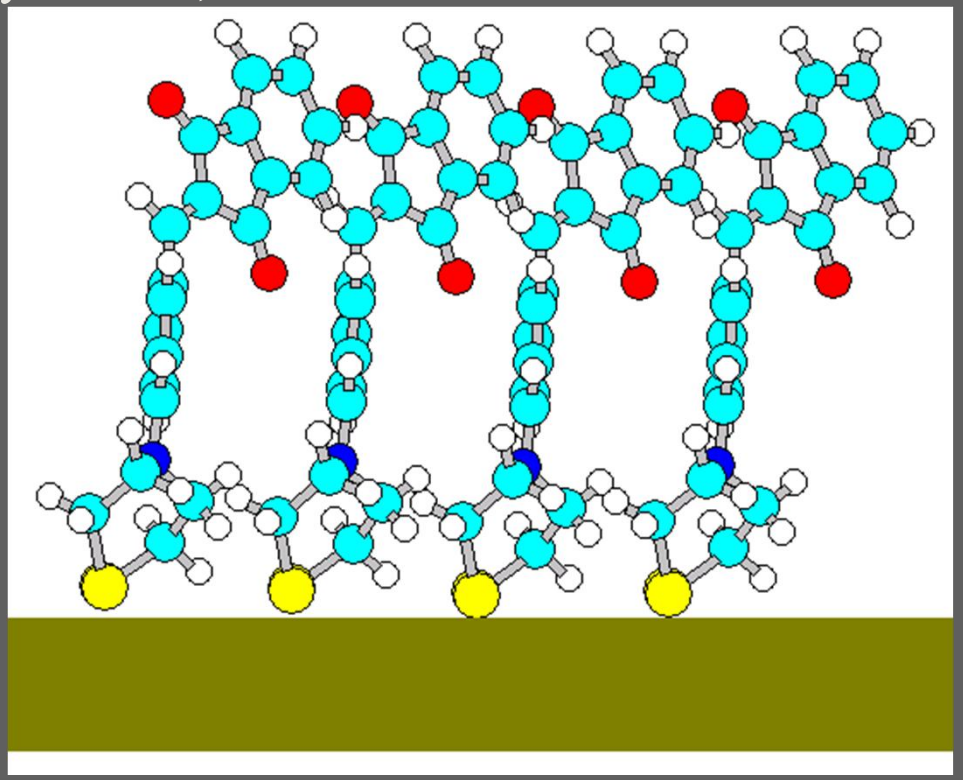

SA molecules
long
immersion time
T
H
Substrate
short immersion time

Savitvarkiai molekuliniai sluoksniai

DMABI-2S SAMs

4’-(3H-1,2,5 dithiazepan-5-yl) benzylidene 1,3- indandione





Molis

Table 20.1 Various fundamental characteristics of living organisms compared to corresponding attributes of Cairns-Smith's "clay organisms"

Feature	Living organisms	"Clay organisms"
Information storage	One-dimensional sequence of polynucleotides	Three-dimensional array of crystal lattice defects*
Recognition mechanism	Hydrogen bonding between purines or pyrimidines moieties of nucleotides	Mainly electrostatic forces that affect crystal lattice growth and formation.**
Stages in self-replication process	Information is read twice in self-replication processes by formation of acomplementary strand	Information is read once, by direct transfer of crystal lattice information from a "mother" lamella to its "daughter" lamella**
Compartmentation	Lipid membrane with embedded proteins	Clay lamellae and their adsorption characteristics

Source: Adapted from Lahav, 1994.

*Established experimentally. The stability of these defects and their exact pattern known only partially.

**Implied. No experimental data.

RNR world

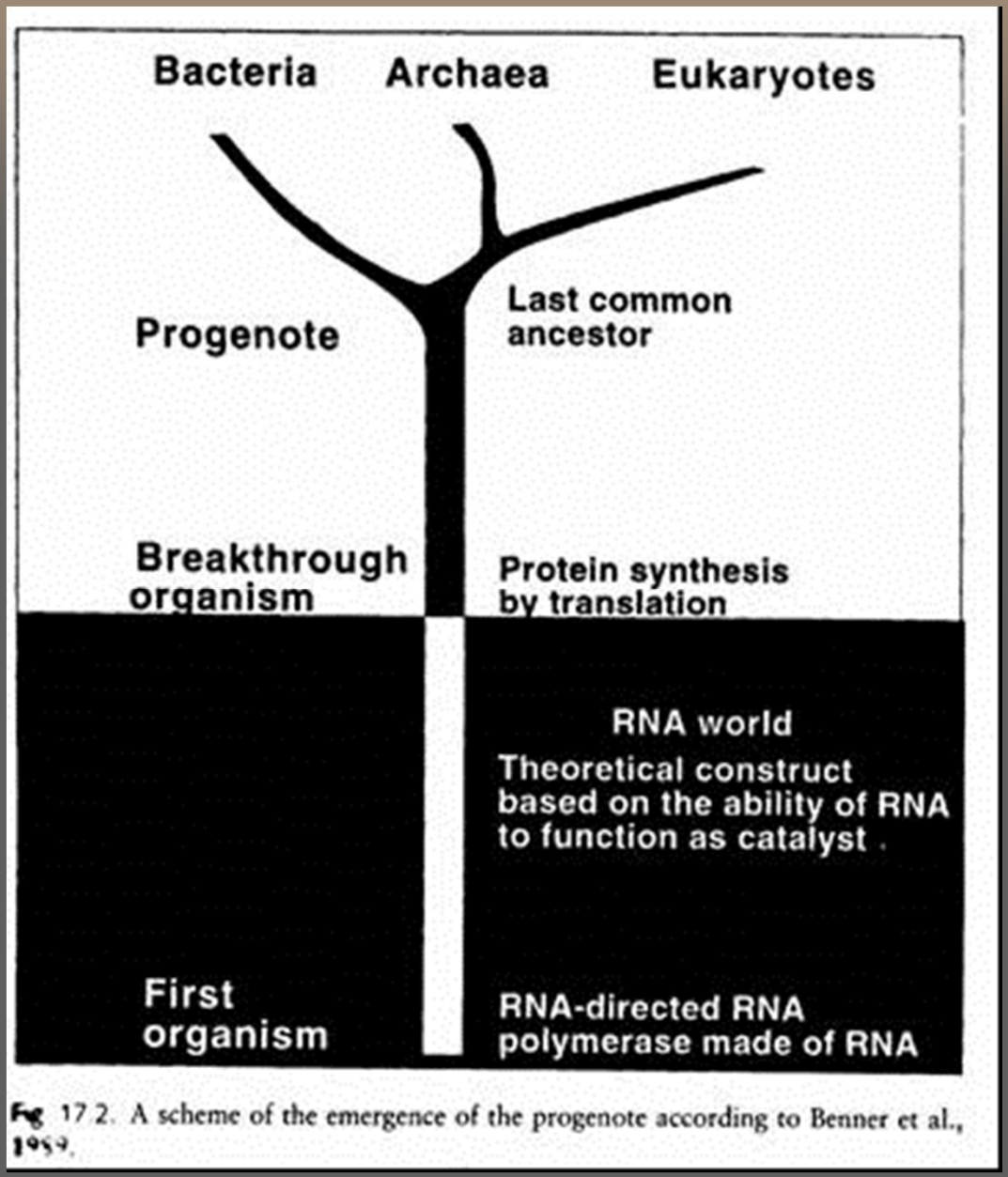
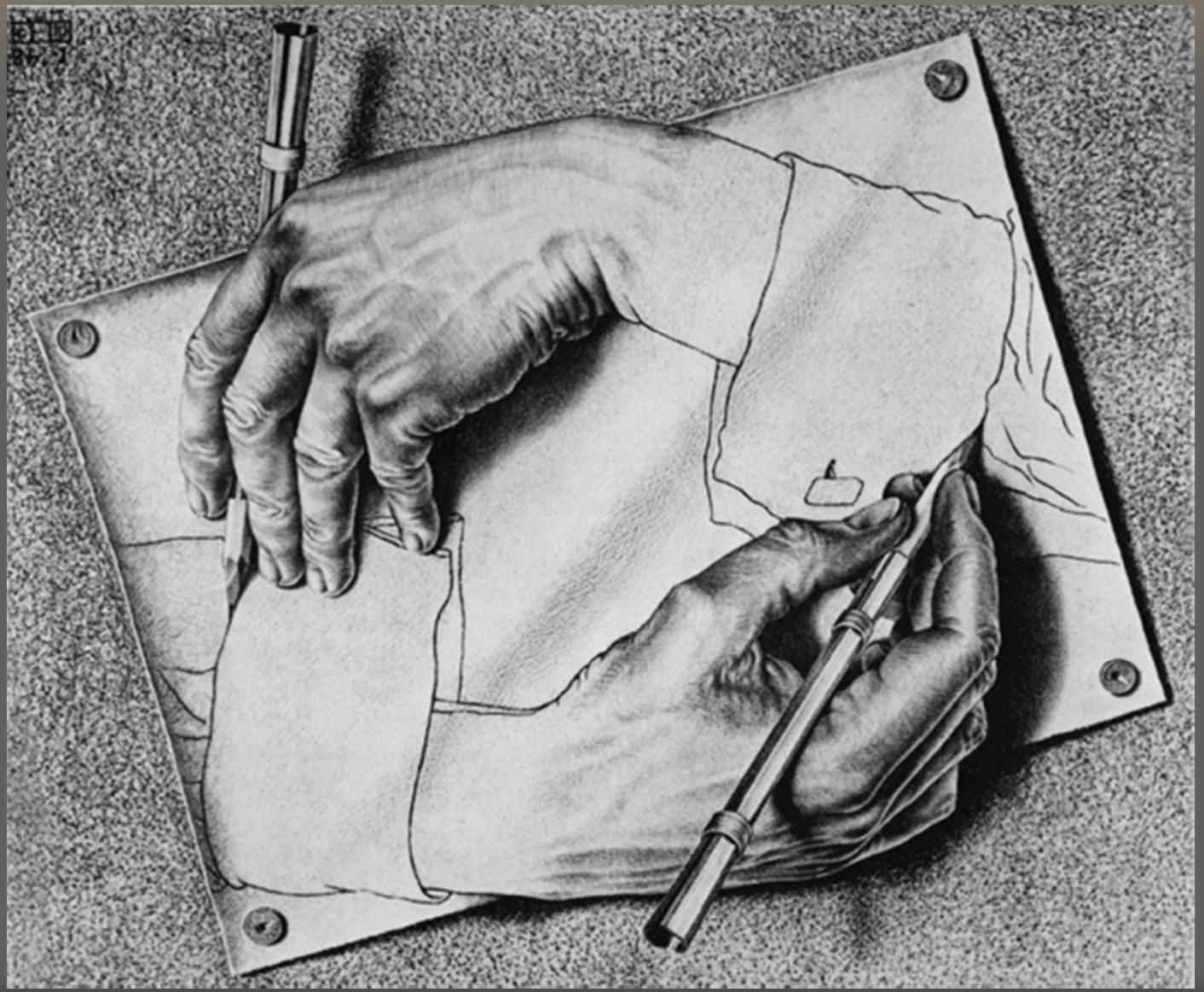


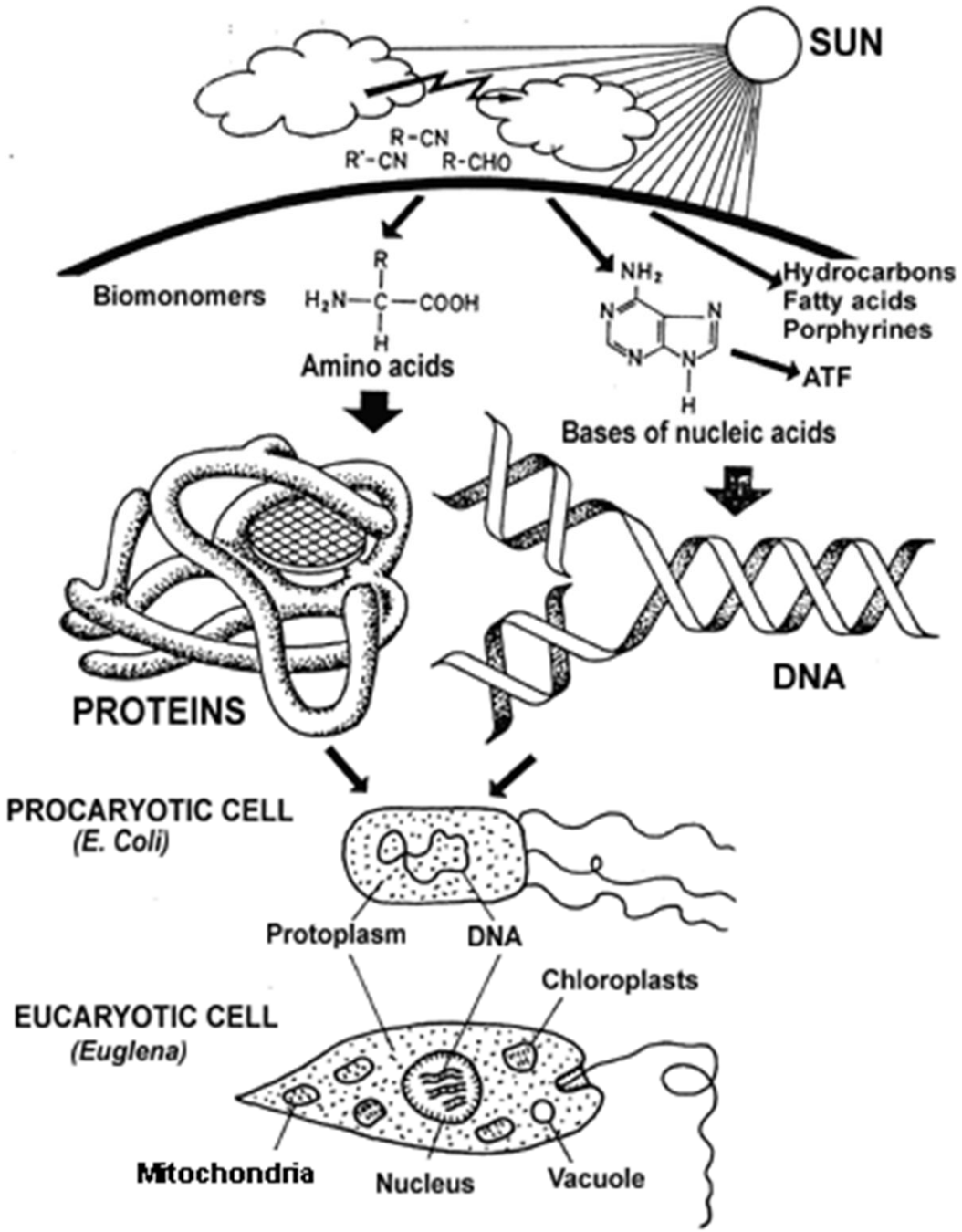
Fig 17 2. A scheme of the emergence of the progenote according to Benner et al., 1989.

M.C. Escher's "Drawing Hands"

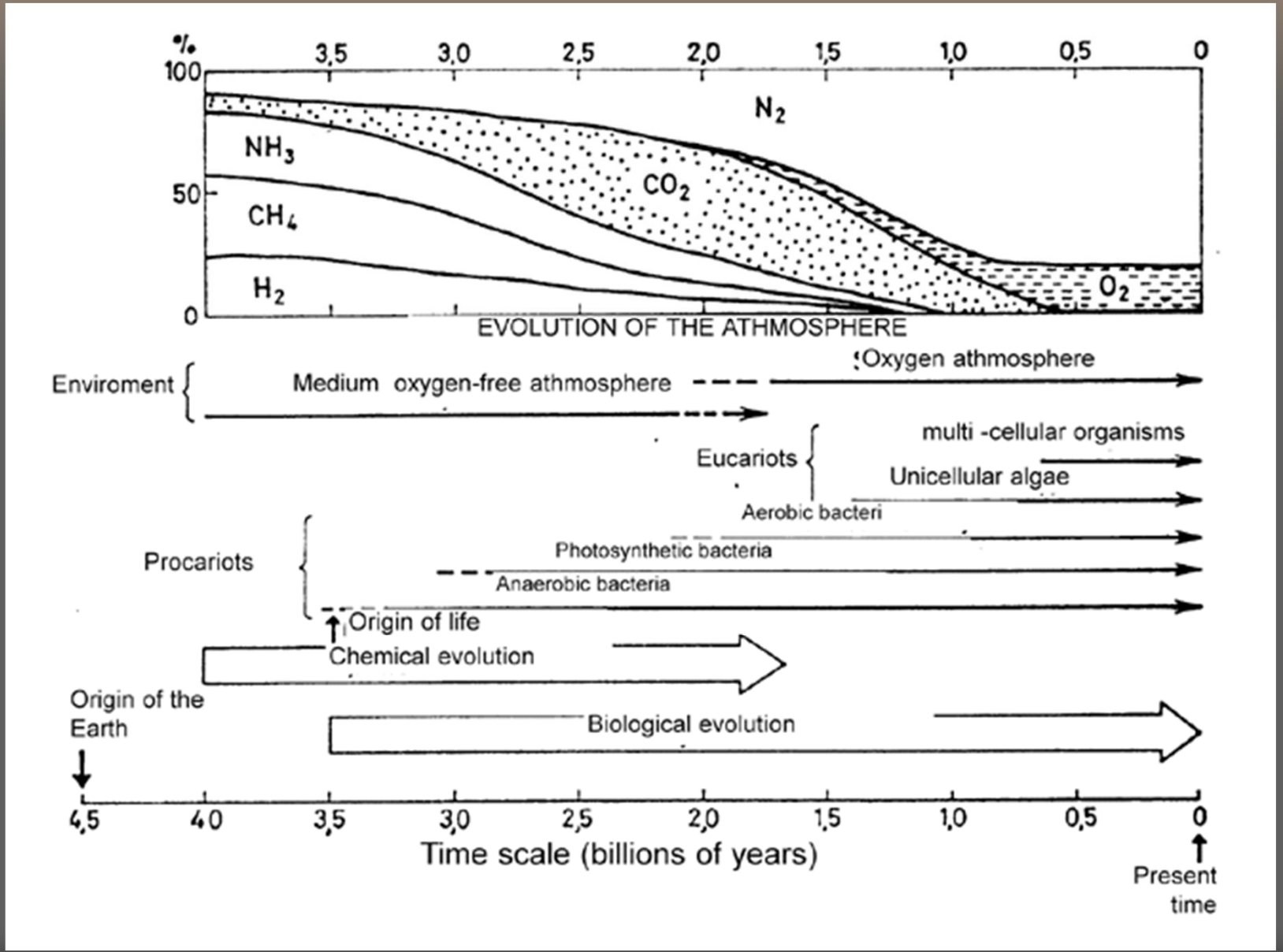


Chemical and biological evolution of the Earth

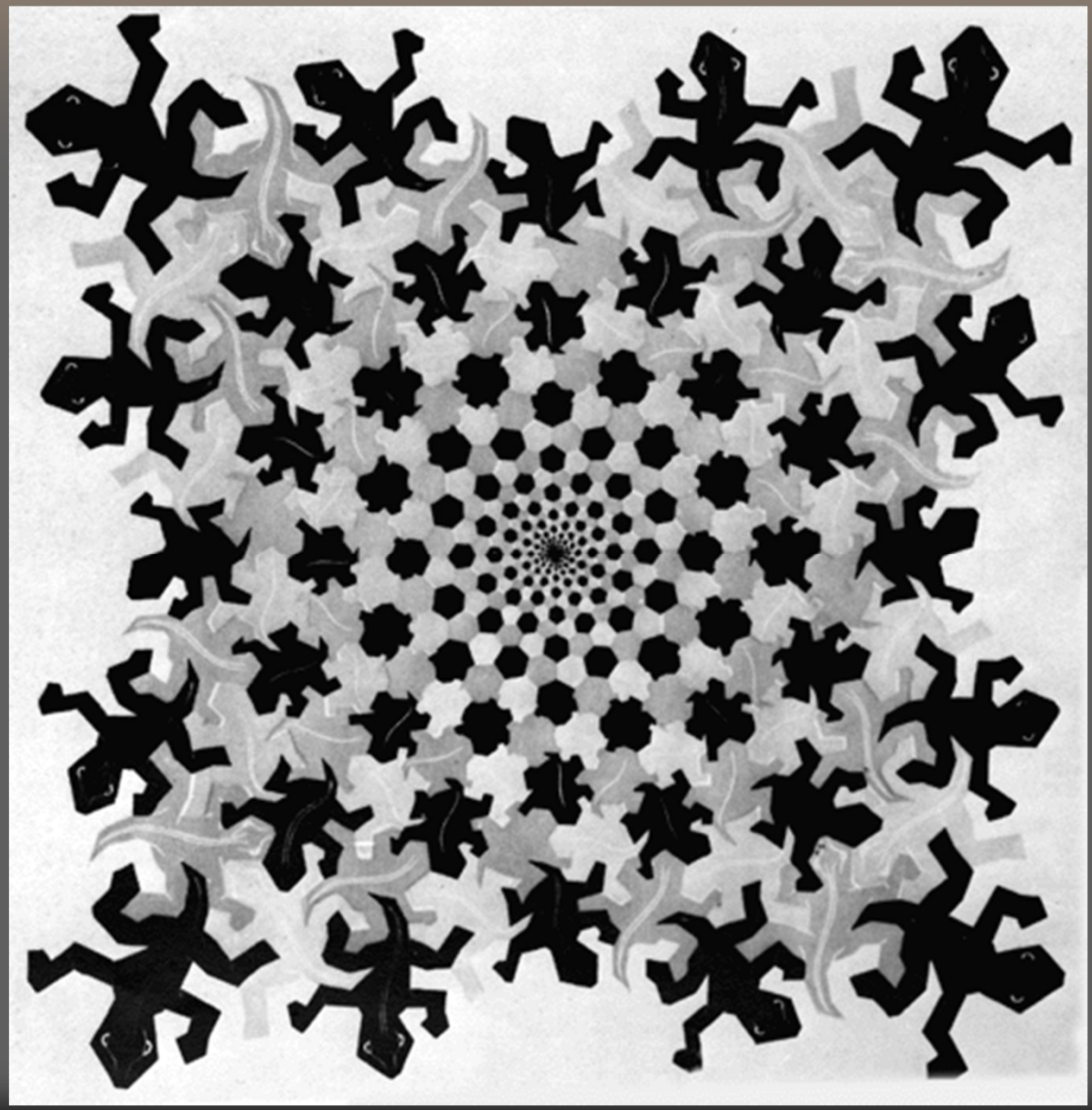
Under action of radiation from the Sun the basic components of bio-systems - amino acids and nucleic acid bases - are formed in photochemical reactions form the primary gases of the Earth's atmosphere. From these bio-monomers bio-polymers - proteins and nucleic acids - were formed in processes of independent evolution, according to the hypothesis of M. Calvin. Out of the "symbiosis" of these two bio-polymer systems the first living bio-systems - unicellular organisms -emerged.



Time scale of the Earth's chemical and biological evolution

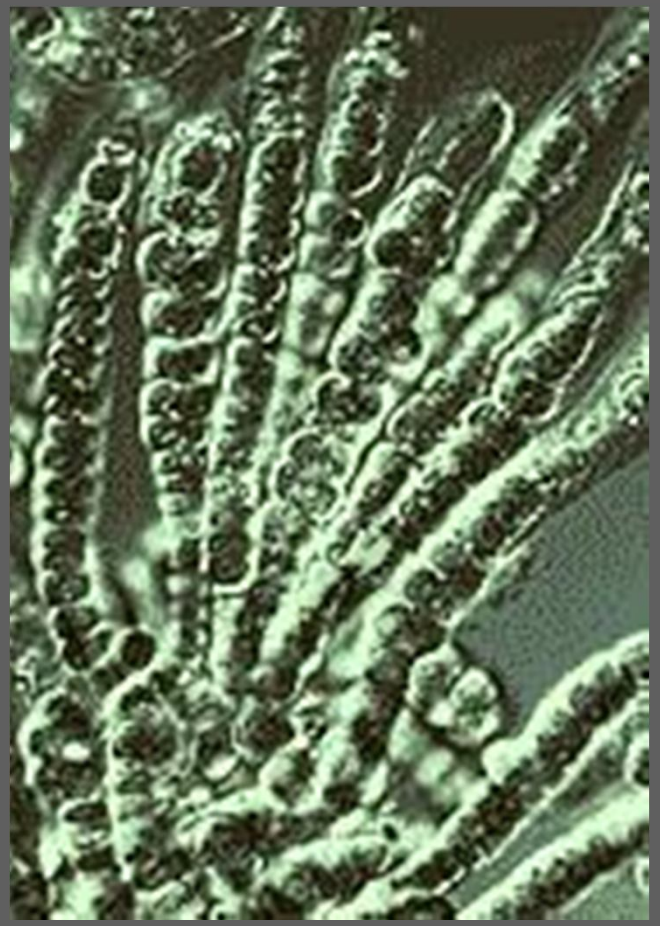


M.C. Escher's "Development"

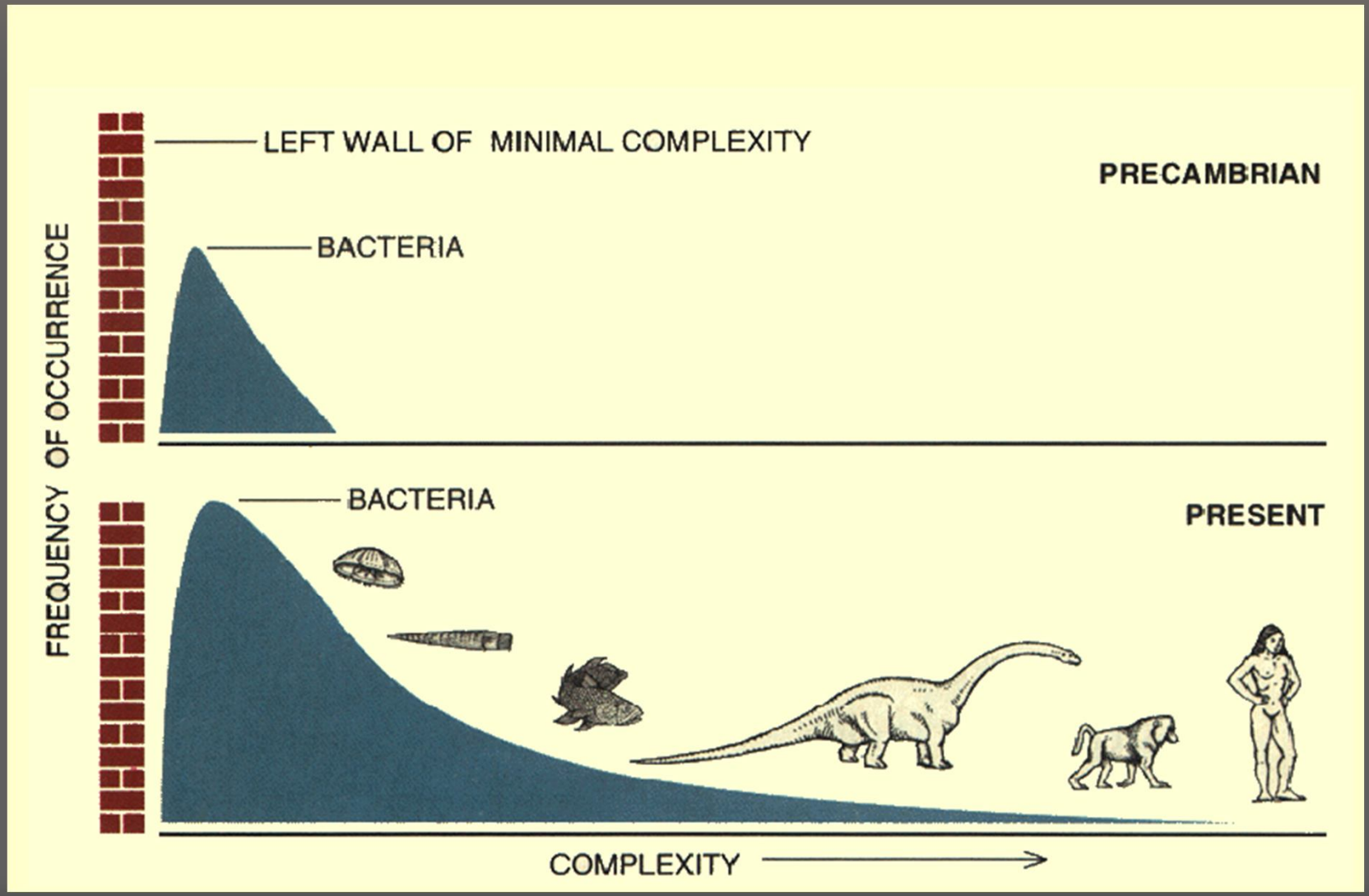


Cyanobacteria

- It is widely believed that 2000 million years ago the cyanobacteria — oxygen eliminating photosynthetic prokaryotes that used to be called blue-green algae... effected one of the greatest changes this planet has ever known: the increase in concentration of atmospheric oxygen from far less than 1% to about 20%. Without this concentration of oxygen, people and other animals would have never evolved.

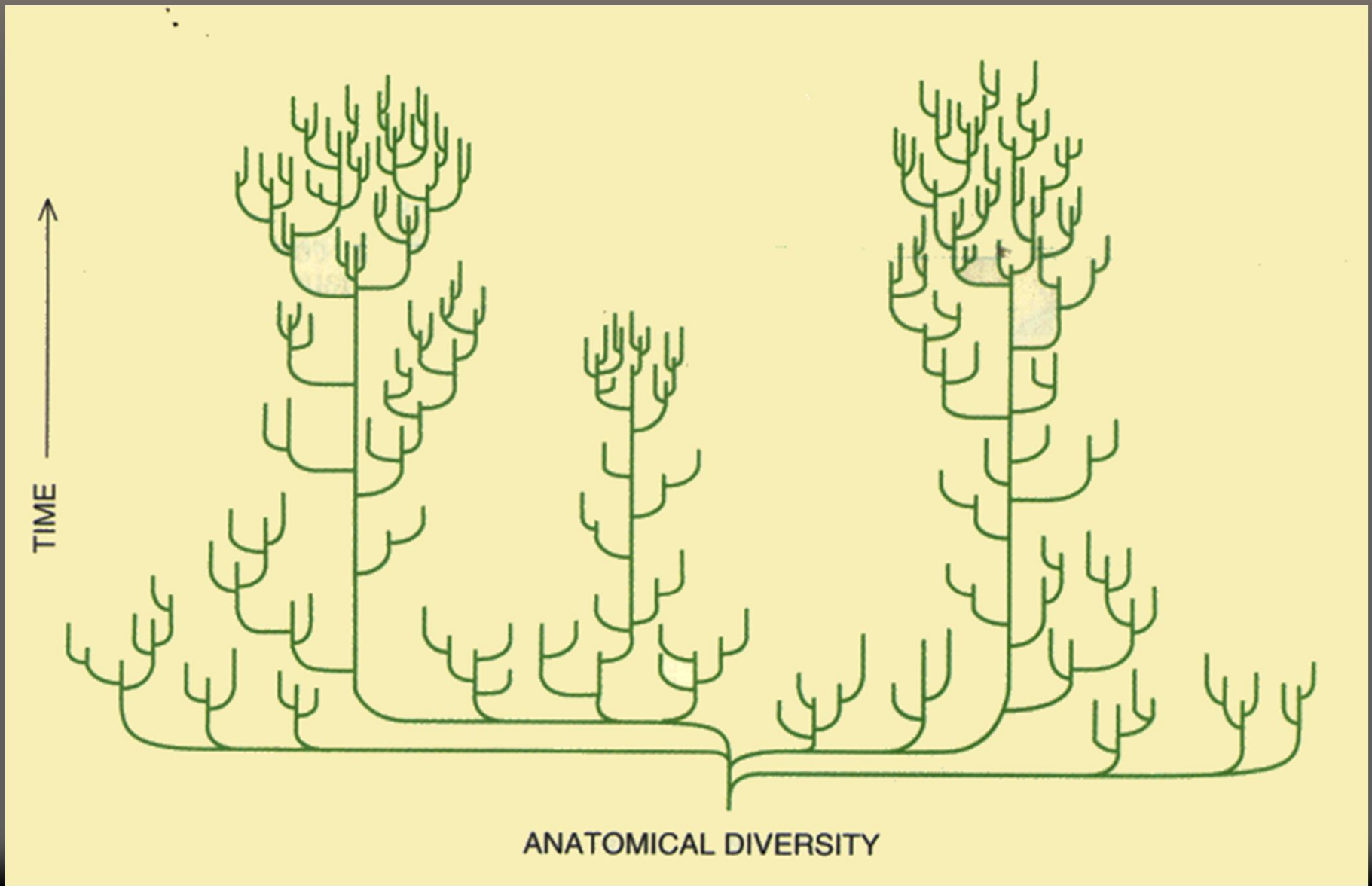


Appearance of different organisms, as dependent on their degree of complexity

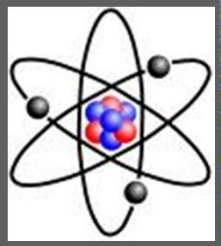


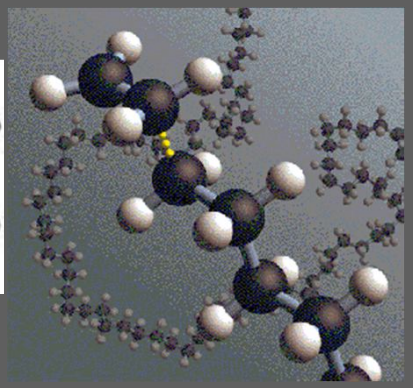
Evolutionary iconogram of the tree of life

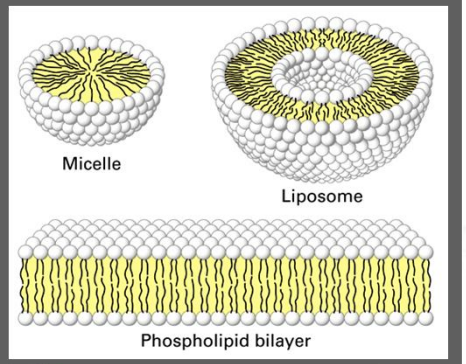
It shows the anatomical diversity of organisms in the process of evolution

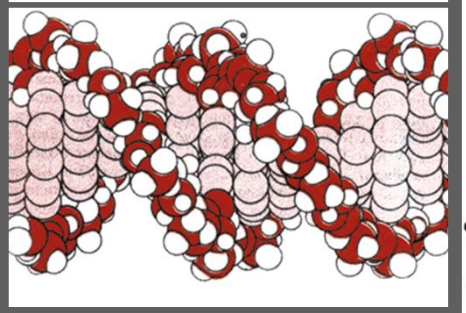


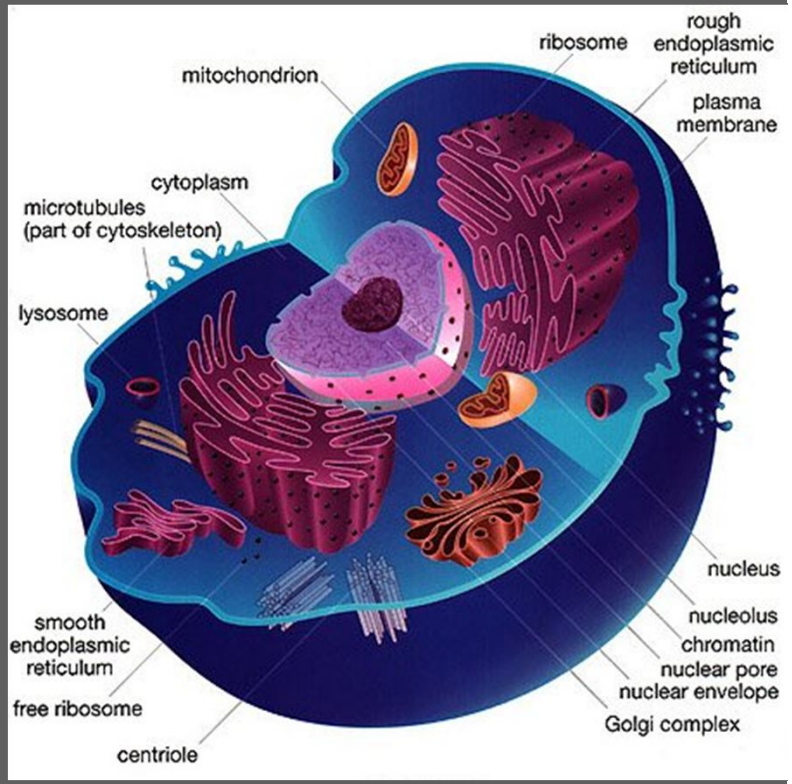
Sudėtingumo skalės



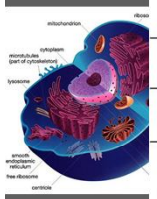








Sudėtingumo skalės



Gaia

Goddess of the Earth

Gaia

- **Gaia** is the primal Greek goddess personifying the Earth.
- Gaia is a primordial deity in the Ancient Greek pantheon and considered a Mother Goddess or *Great Goddess*.
- Her equivalent in the Roman Pantheon was Terra Mater
- Lietuvių mitologijoje, Gaja – Žemė, Saulės ir Mėnulio dukra

Wikipedia

Gaja

James Lovelock

Gaia hypothesis

According to this holistic theory the whole of our planet, its biosphere and atmosphere form one total living self-organising system.

Life itself prepared the medium and the atmosphere on Earth for its further development. At the beginning the fermentation processes, effected by anaerobic bacteria, increased the amount of carbon dioxide in the atmosphere. After that photo-synthesising bacteria "produced" oxygen - that atmospheric medium which made the development of the vegetable and animal world possible.

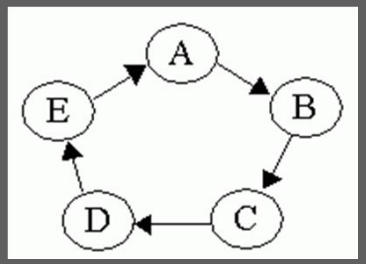
James Lovelock in 1965 named this hypothesis after Gaia, the Greek goddess of the Earth

Theory of the Chemical Hypercycle

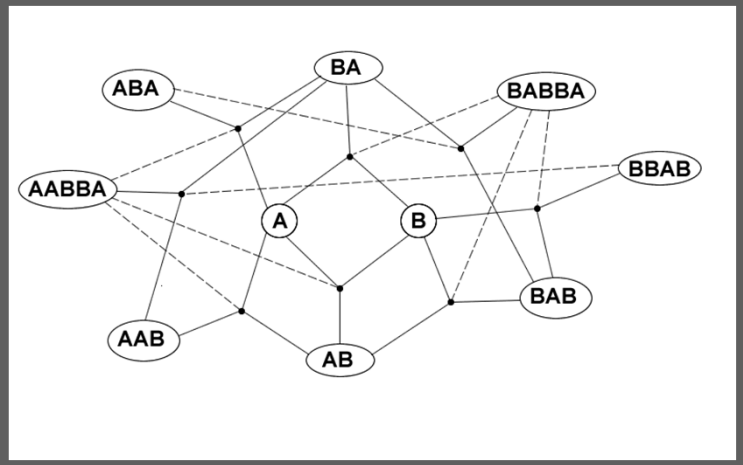
- Manfred Eigen

NP 1967

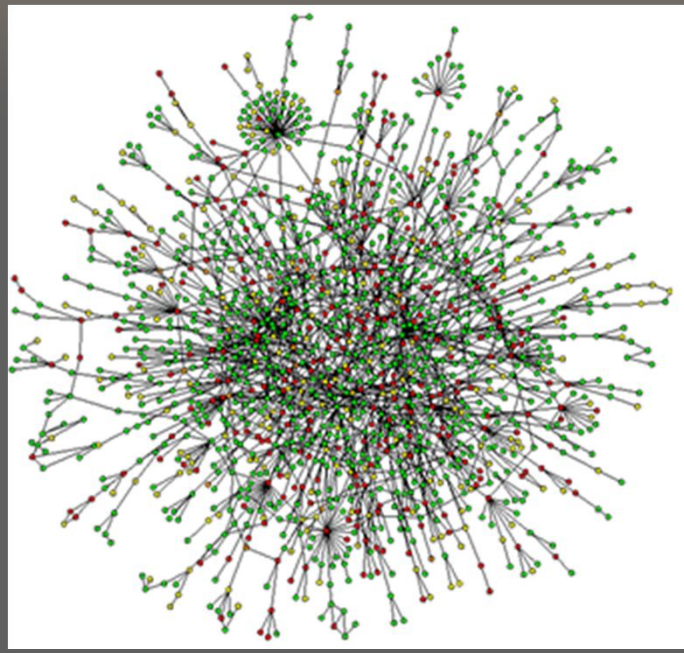
1979



Autocatalytic loop



A very simple autocatalytic set. Each node represents a ligation/cleavage reaction comprising three elements.



Map of protein-protein interactions.

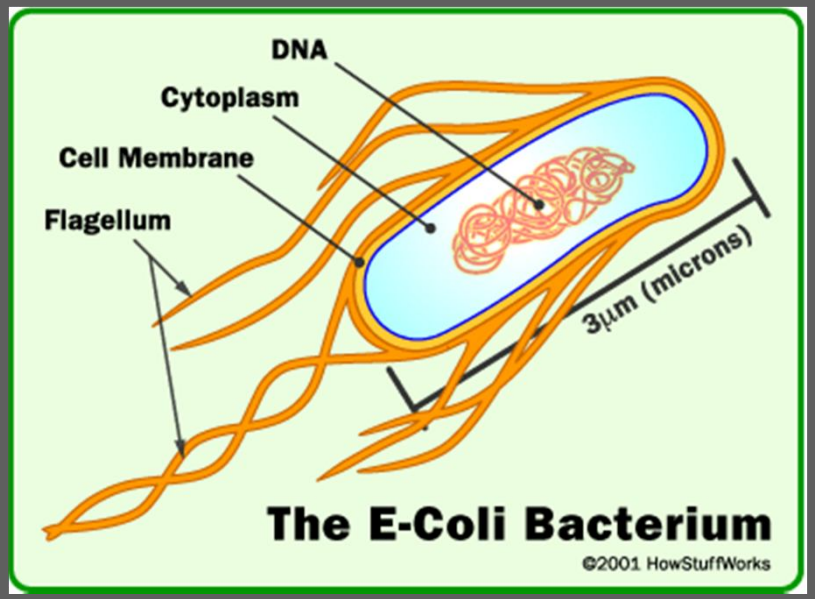
- With sufficient time and continuing flow of energy, catalytic cycles tend to interlock to form closed loops in which the enzymes produced in one cycle act as catalysts in the subsequent cycle and forming hypercycles. They are remarkably stabile and can persist under a wide range of conditions.

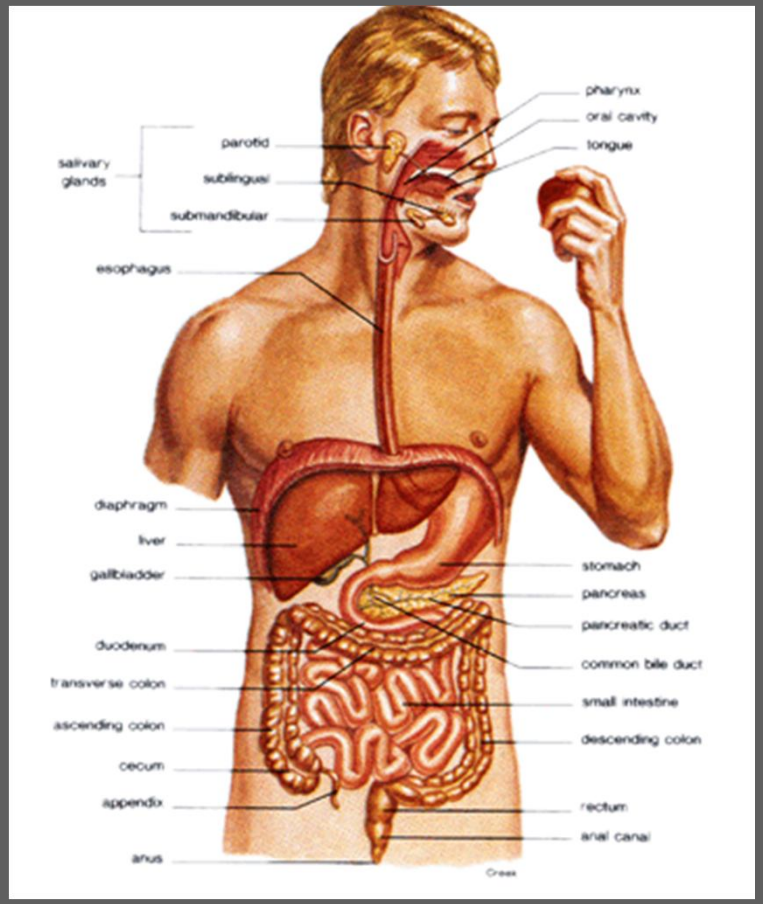
Superorganism

Symbiosis

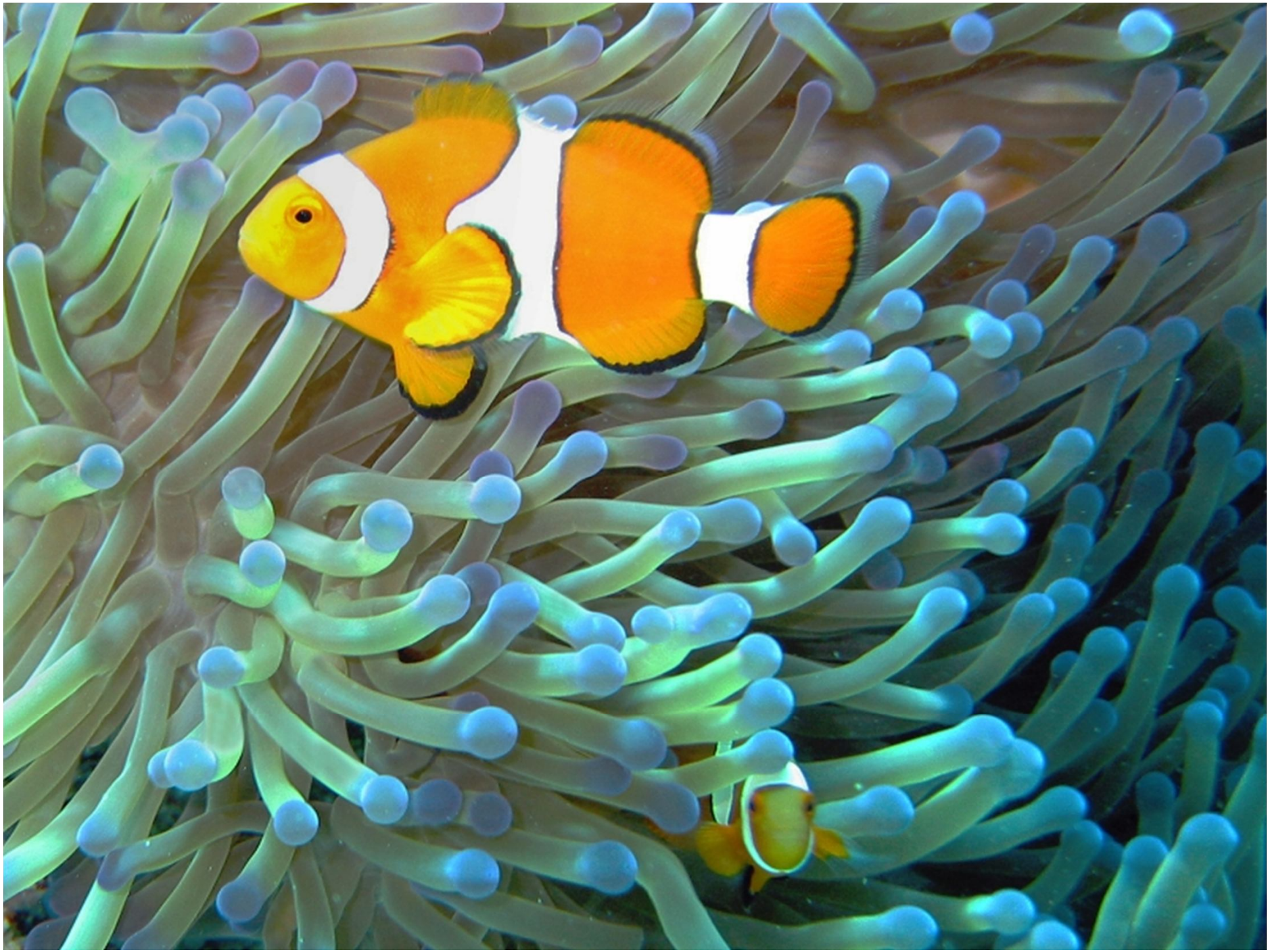
The term was first used in 1879 by the German mycologist Heinrich Anton de Bary, who defined it as "the living together of unlike organisms.“ The definition of symbiosis is in flux, and the term has been applied to a wide range of biological interactions.

E-Coli


DNA
Cytoplasm
Cell Membrane
Flagellum
3µm (microns)
The E-Coli Bacterium
©2001 HowStuffWorks

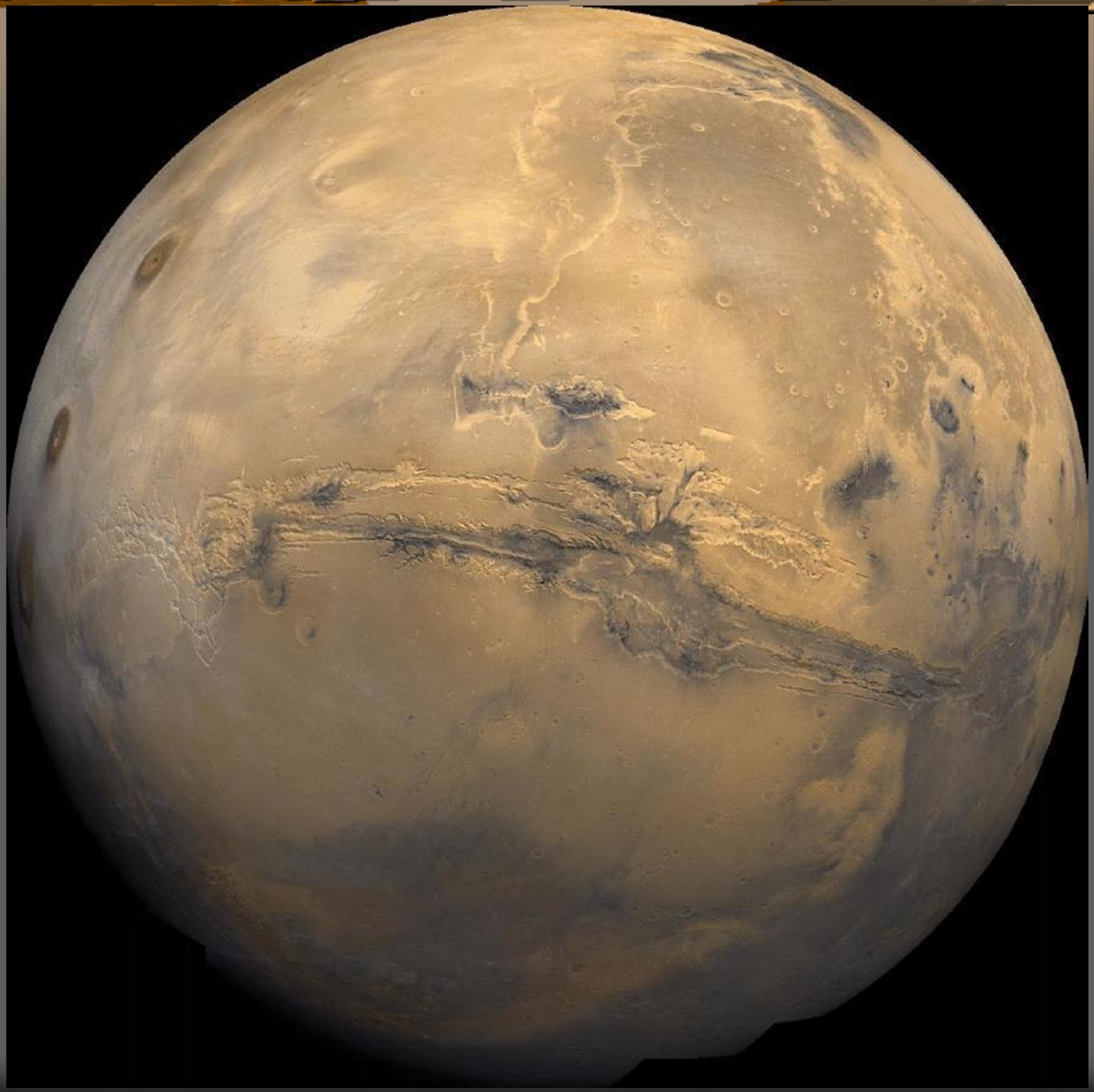

pharynx
oral cavity
tongue
salivary glands
parotid
sublingual
submandibular
esophagus
diaphragm
liver
gallbladder
duodenum
transverse colon
ascending colon
cecum
appendix
anus
stomach
pancreas
pancreatic duct
common bile duct
small intestine
descending colon
rectum
anal canal

Symbiosis



Gaia

Mars

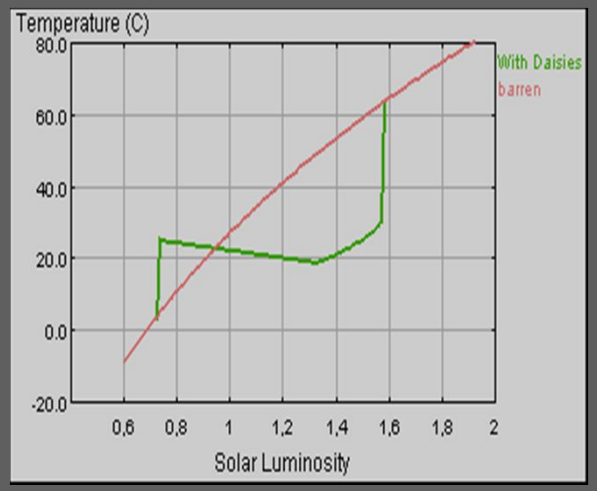


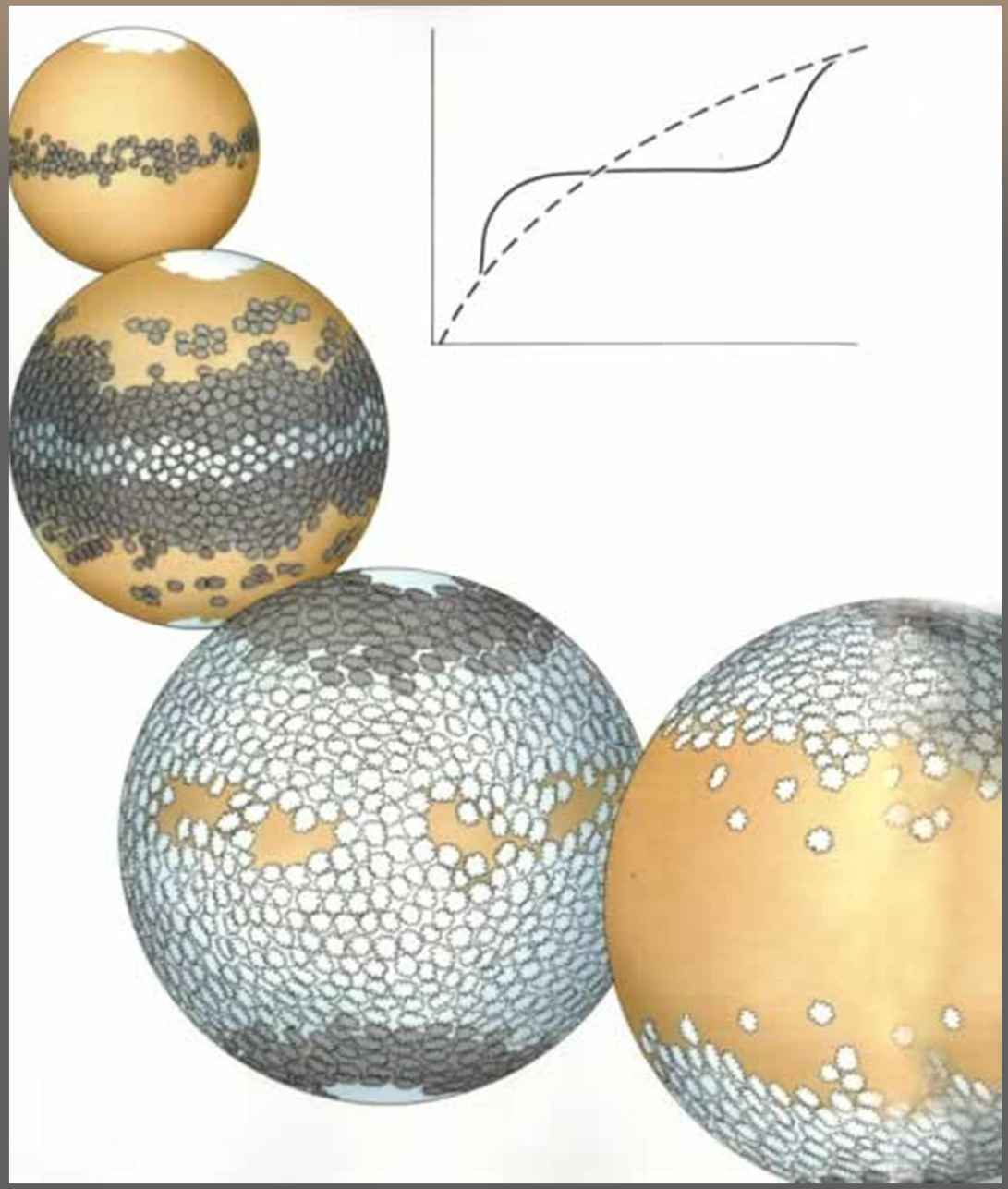
CO_2 ciklas Žemėje

- Ugnikalnių veikla
- Uolų erozija, mikrobai
- Dumbliai
- Nuosėdos
- Lava

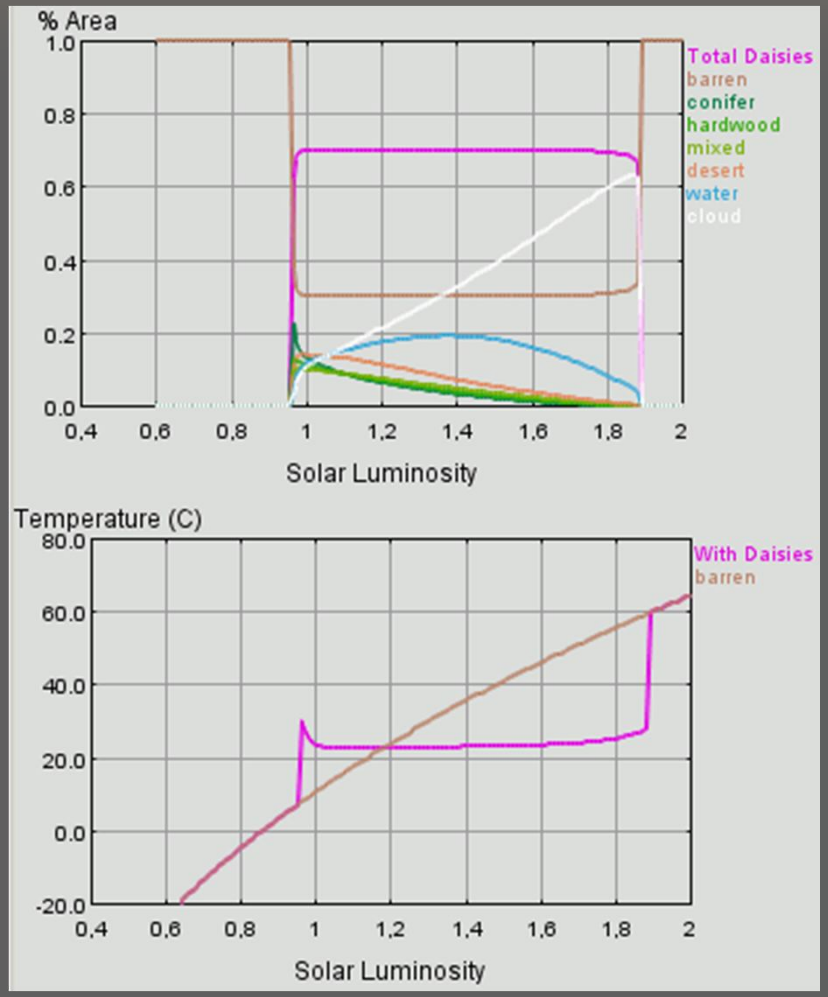
Oceanic alga (coccolithophore) with chalk shell(Capra)

Daisyworld


Temperature (C)
80.0
60.0
40.0
20.0
0.0
-20.0
0,6
0,8
1
1,2
1,4
1,6
1,8
2
Solar Luminosity
With Daisies
barren



Daisyworld


% Area
1.0
0.8
0.6
0.4
0.2
0.0
0,4
0,6
0,8
1
1,2
1,4
1,6
1,8
2
Solar Luminosity
Total Daisies
barren
conifer
hardwood
mixed
desert
water
cloud
Temperature (C)
80.0
60.0
40.0
20.0
0.0
-20.0
0,4
0,6
0,8
1
1,2
1,4
1,6
1,8
2
Solar Luminosity
With Daisies
barren

Gaia