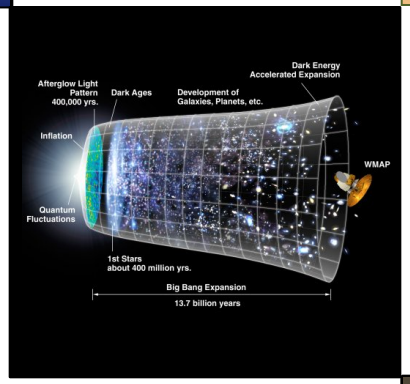
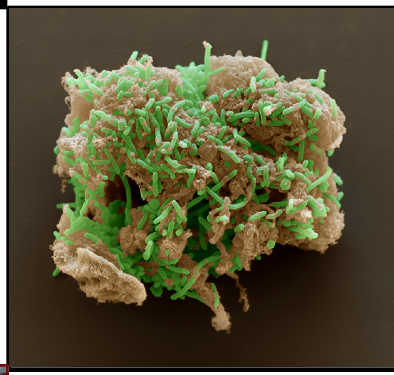
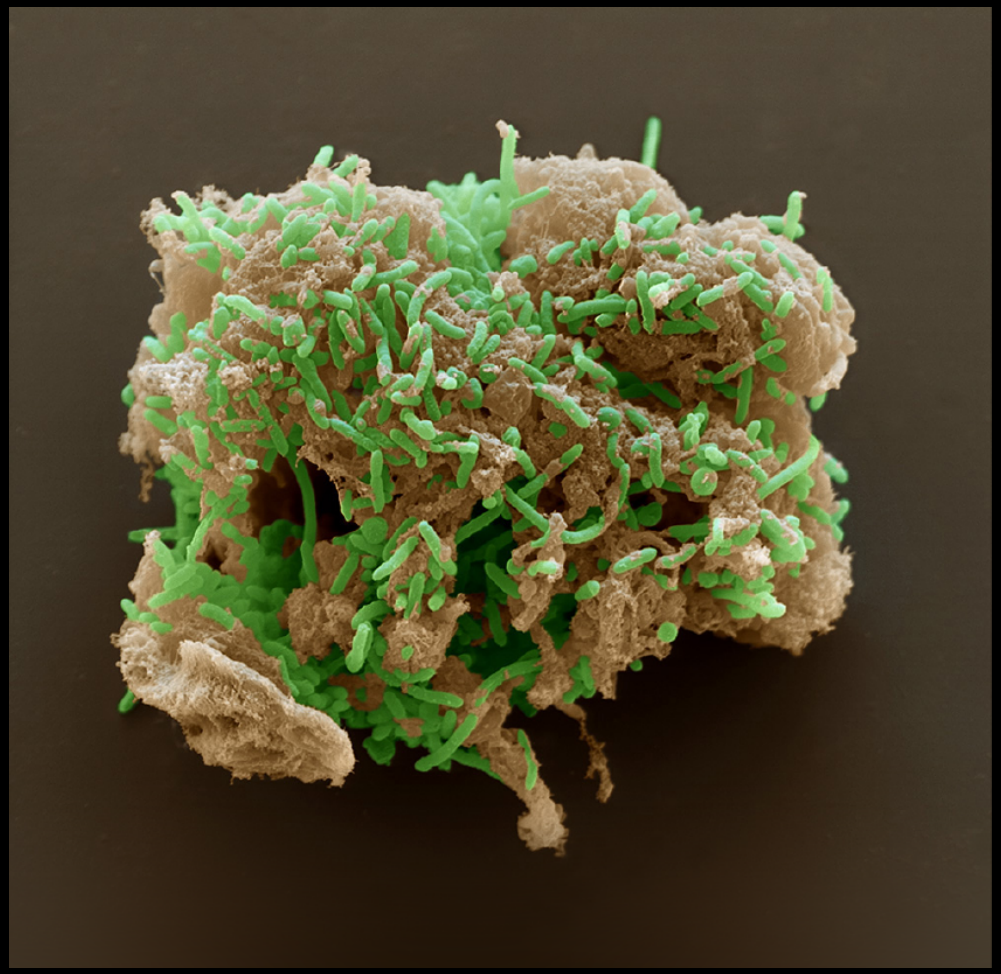


Det Tidligste Liv

Tais W. Dahl
Lektor, Geobiologi
Statens Naturhistoriske Museum
Københavns Universitet



DANMARKS FRIE FORSKNINGSFOND



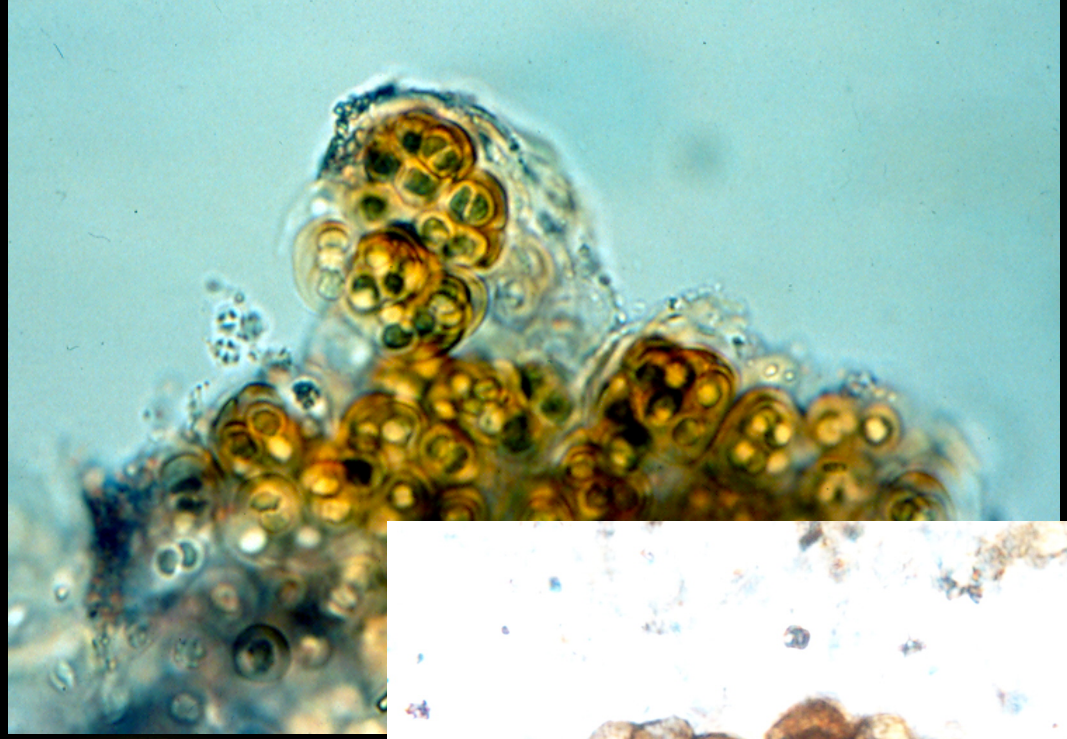
En verden af ~~liv~~ mikrober

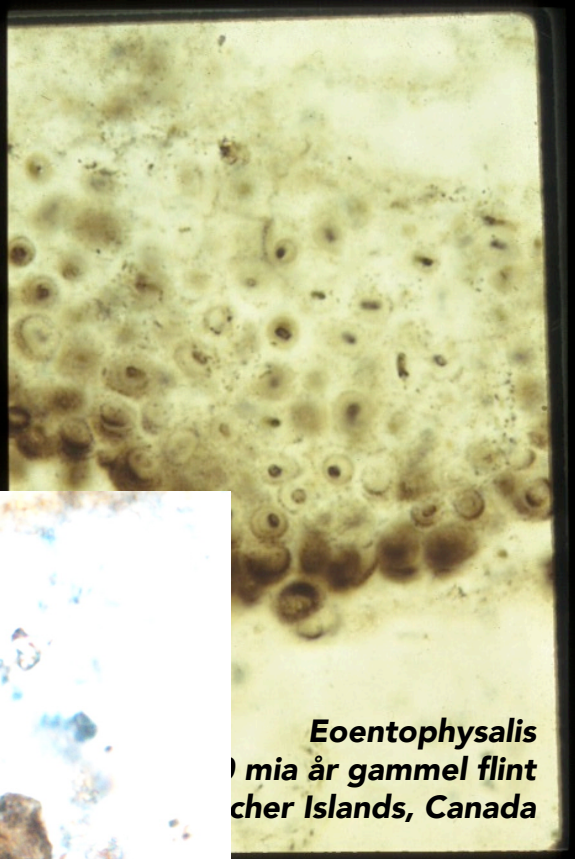
Båndet jernmalm

Ca. 600 millioner år gammel havbund

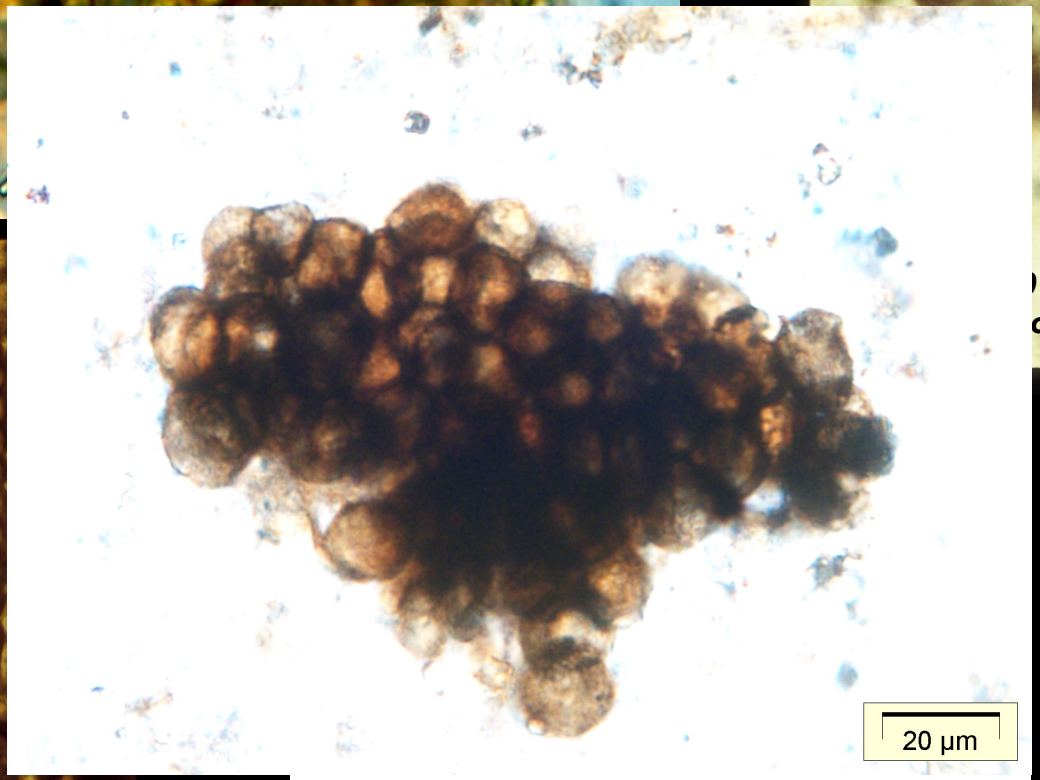
Huqf Supergroup, Oman, 2009


STABILO
OHPen universal
F

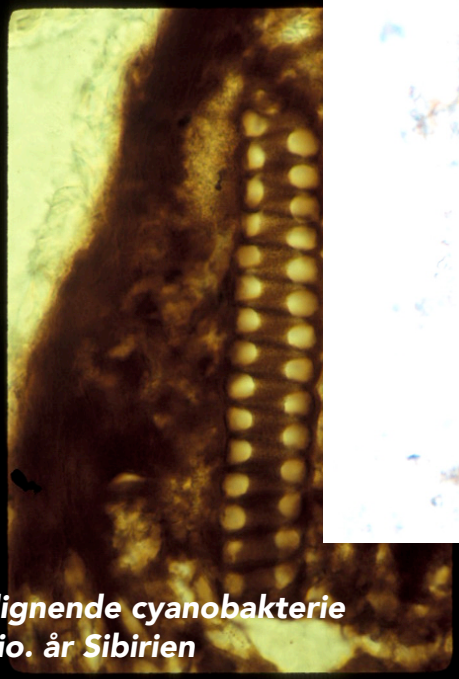




Eoentophysalis
) mia år gammel flint
cher Islands, Canada



Myxococcoides cantabrigiens
Draken Formationen, Svalbard
~800 mio. år gammel



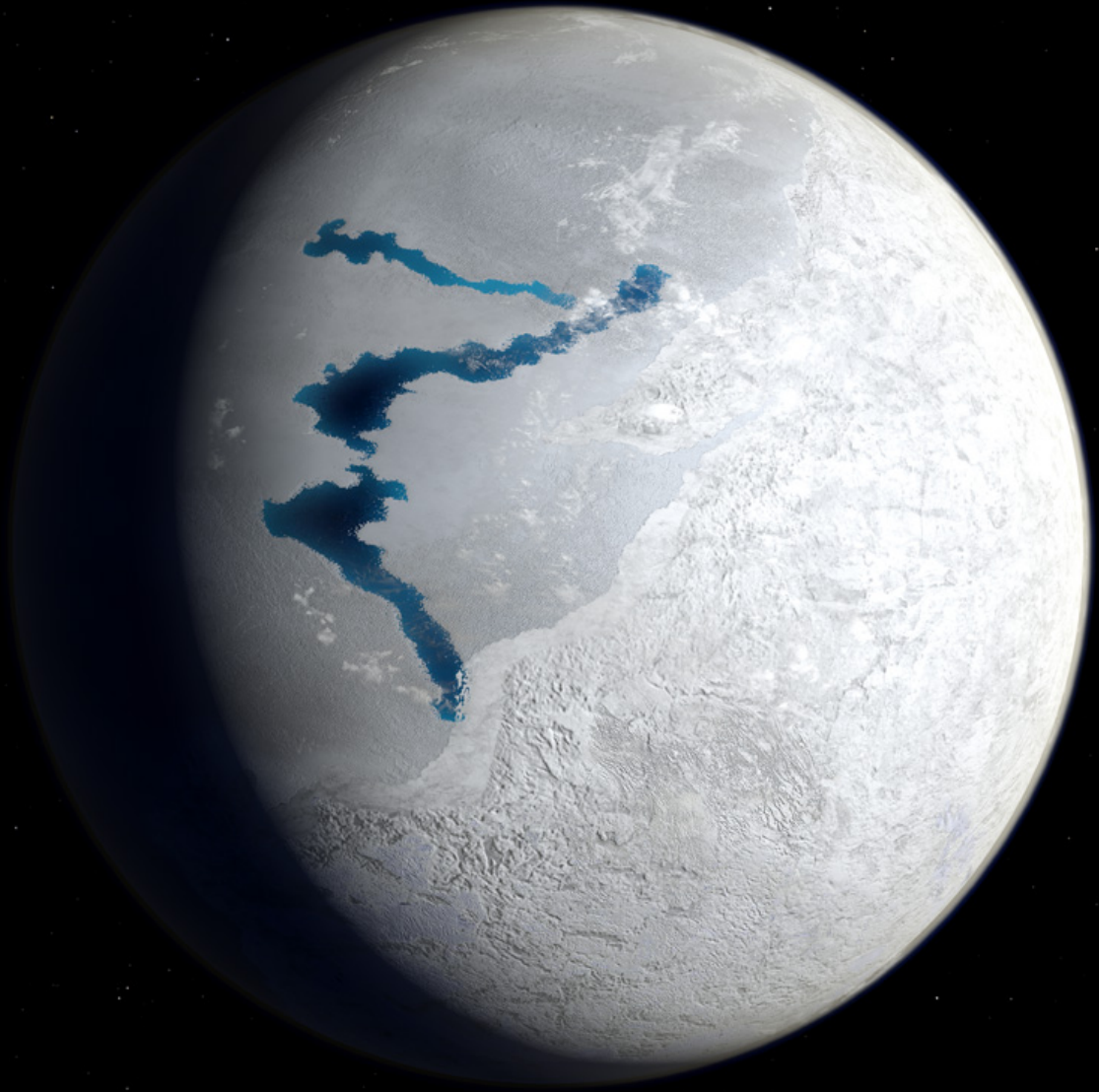
Spirogyra-lignende cyanobakterie
635-542 mio. år Sibirien

Grypania

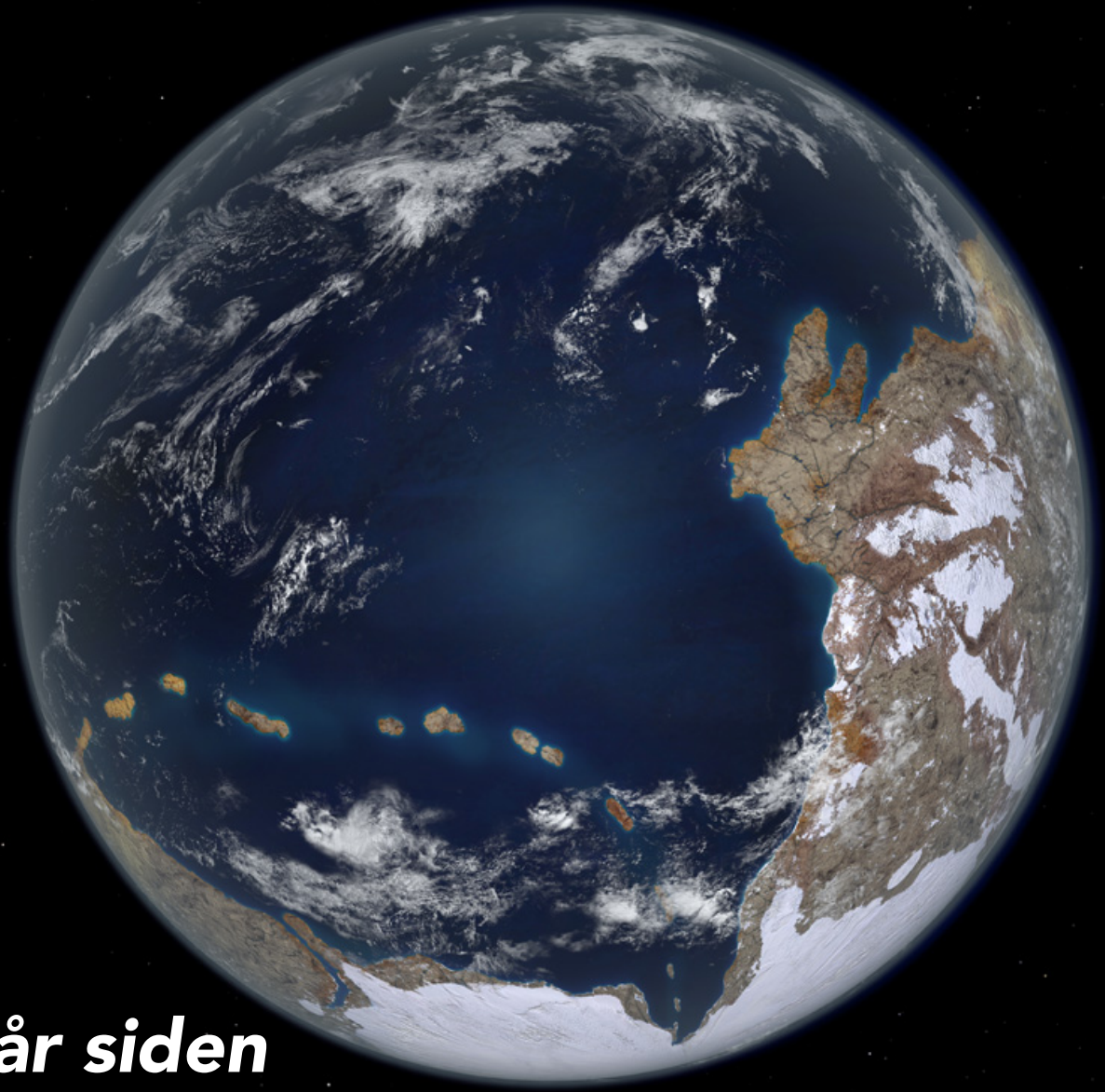
det ældste eukaryote fossil?

1,45 mia. år gammel

1,87 mia år gammel

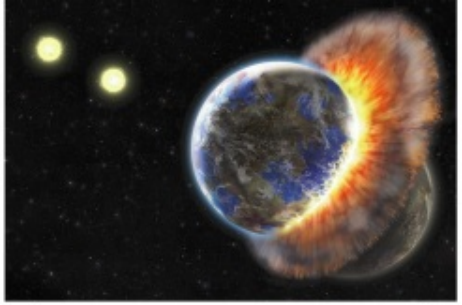


Jorden
635 mio. år siden

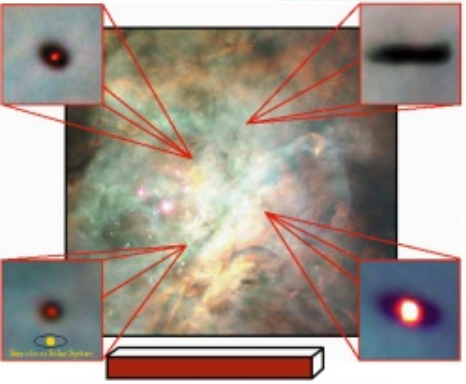


Jorden
600 mio. år siden

Hvornår opstod det første liv?

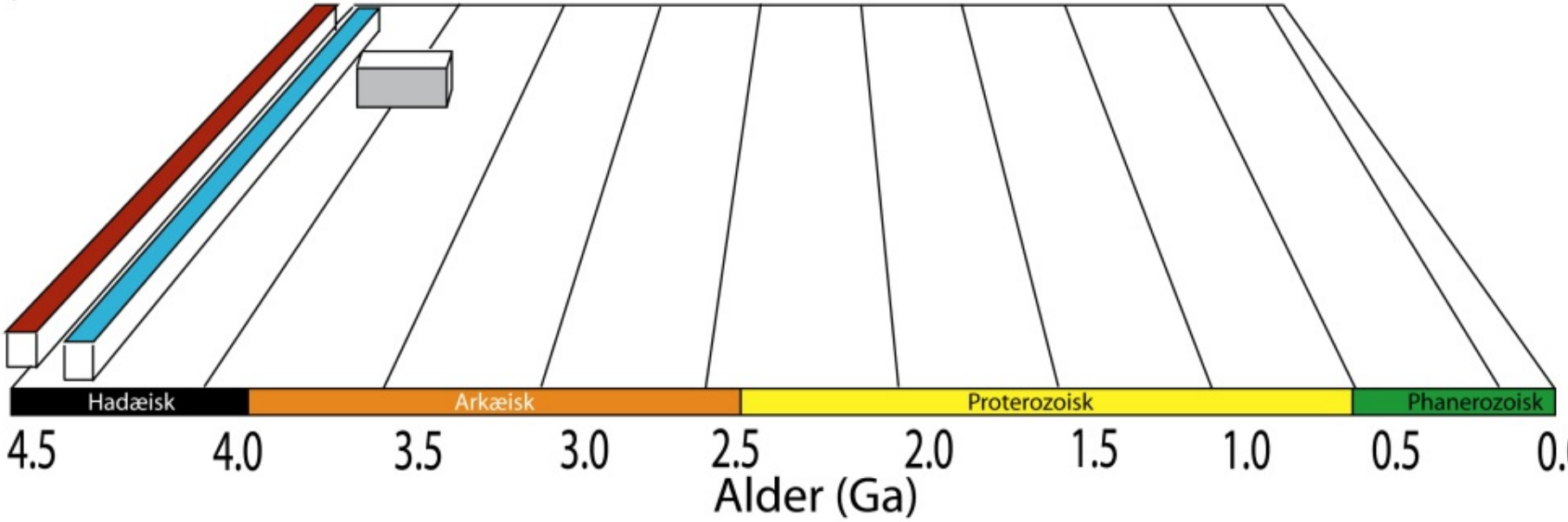


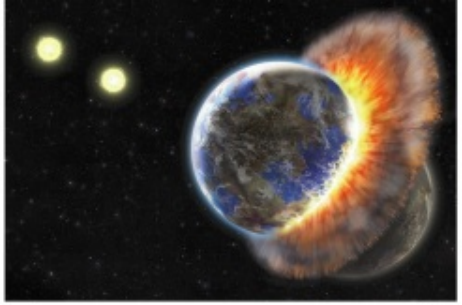
Jorden og Månen dannes, ca. 4.5 Ga



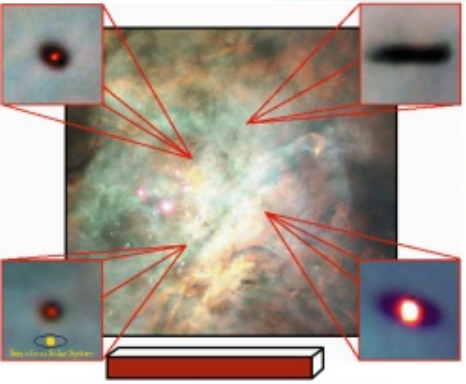
Solsystemet dannes 4.57 Ga

De første bjerge og kontinenter
ca. 4.0-3.5 Ga





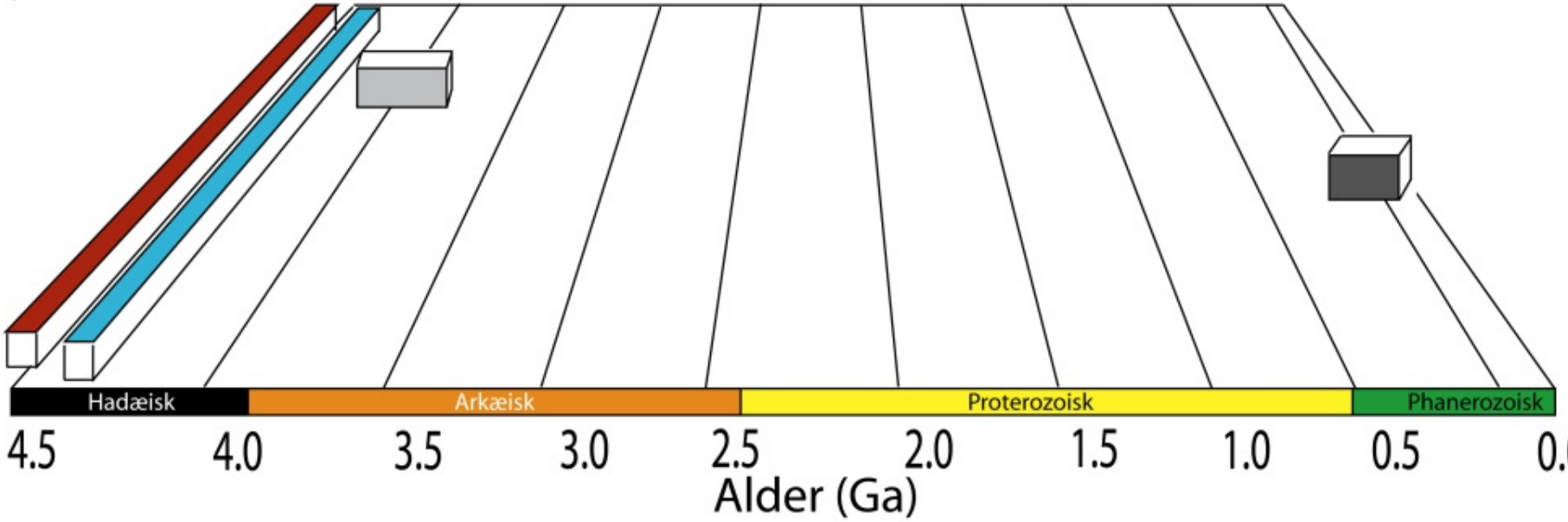
Jorden og Månen dannes, ca. 4.5 Ga

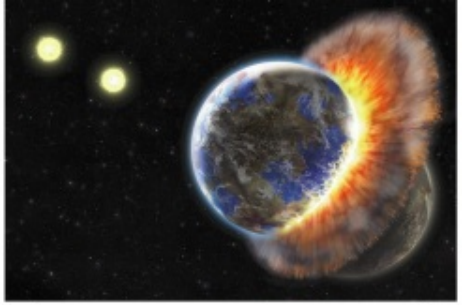


Solsystemet dannes 4.57 Ga

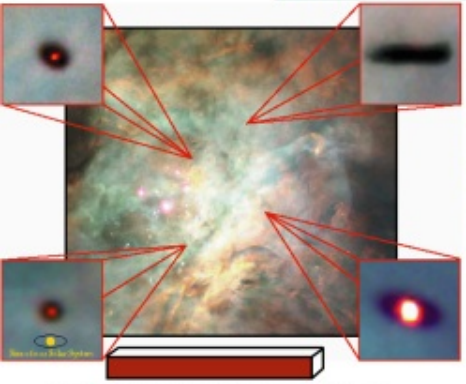
De første bjerge og kontinenter ca. 4.0-3.5 Ga

Dinosaurer, 0.25-0.06 Ga





Jorden og Månen dannes, ca. 4.5 Ga

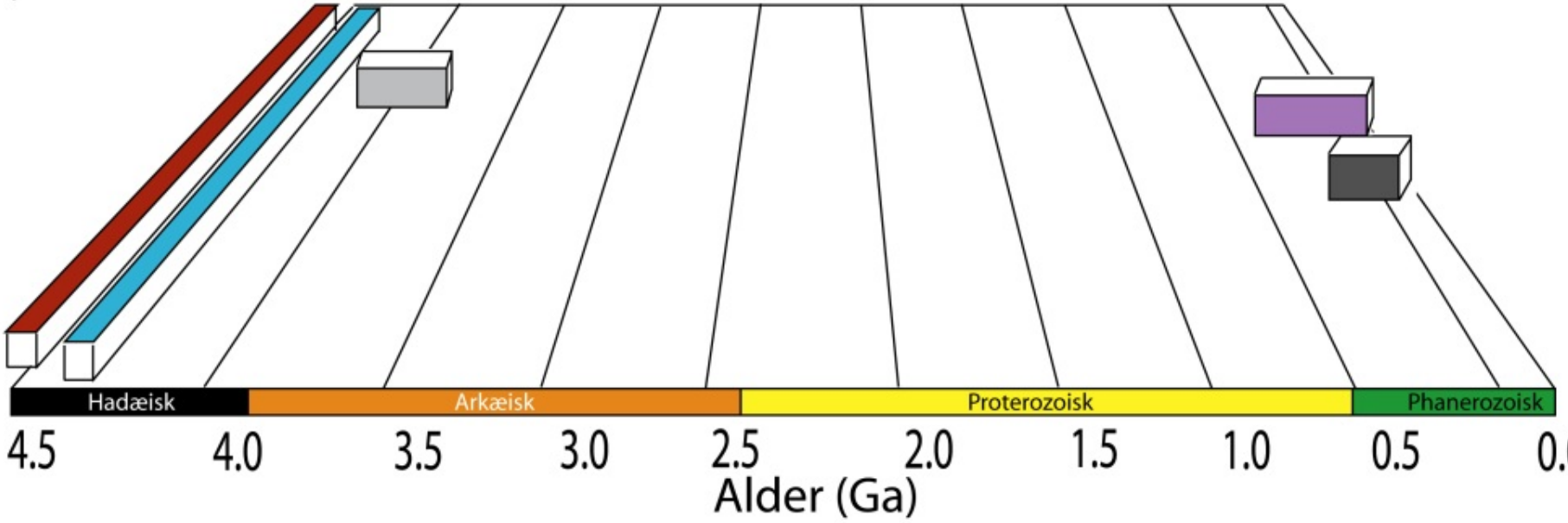


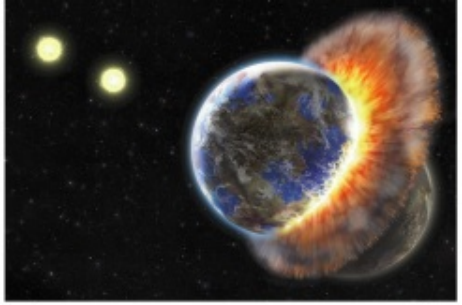
Solsystemet dannes 4.57 Ga

De første bjerge og kontinenter ca. 4.0-3.5 Ga

Landplanter, 0.48-0 Ga

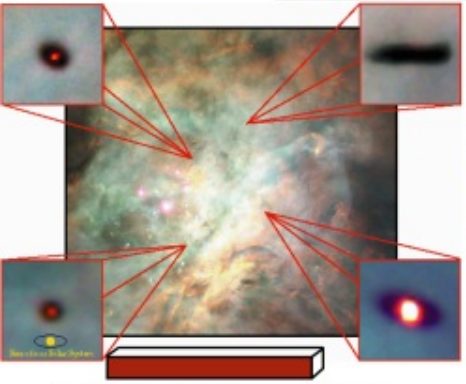
Dinosaurer, 0.25-0.06 Ga





Jorden og Månen dannes, ca. 4.5 Ga

Landplanter, 0.48-0 Ga

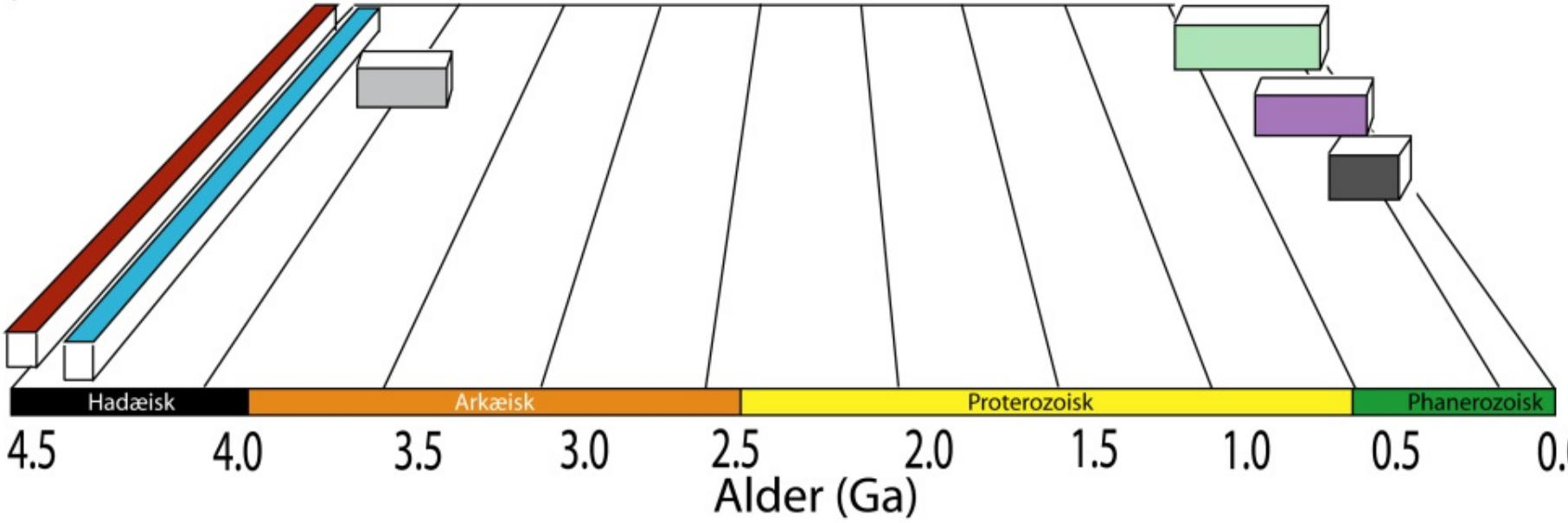


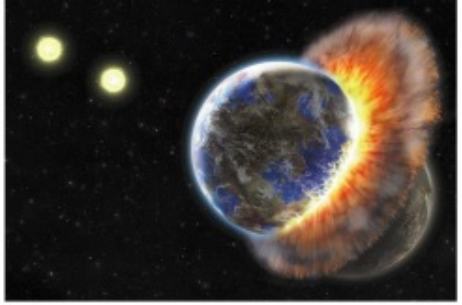
Solsystemet dannes 4.57 Ga

De første bjerge og kontinenter ca. 4.0-3.5 Ga

Dyr, 0.54-0 Ga

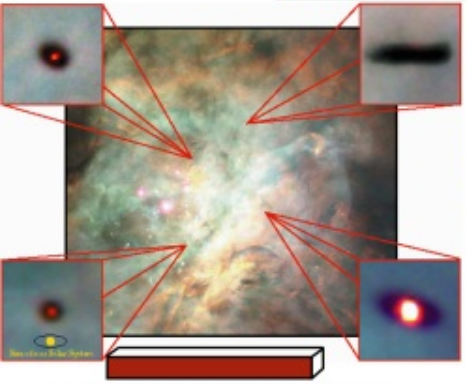
Dinosaurer, 0.25-0.06 Ga





Jorden og Månen dannes, ca. 4.5 Ga

Landplanter, 0.48-0 Ga

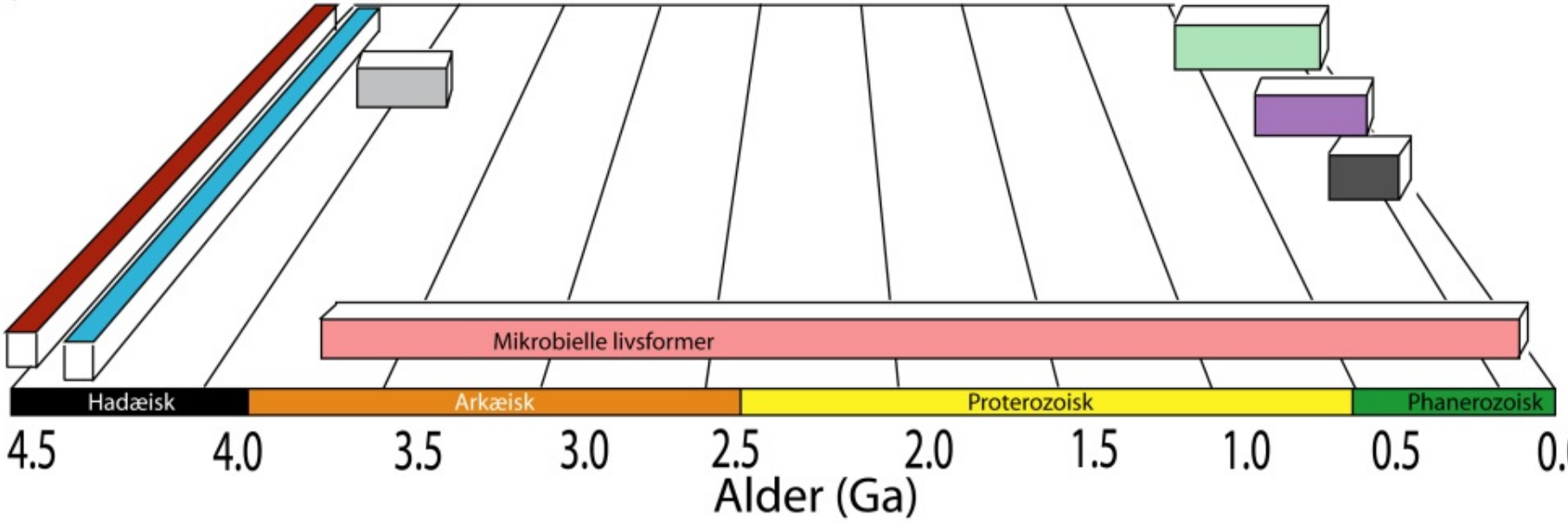


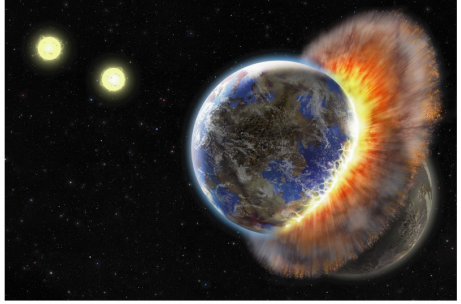
Solsystemet dannes 4.57 Ga

De første bjerge og kontinenter ca. 4.0-3.5 Ga

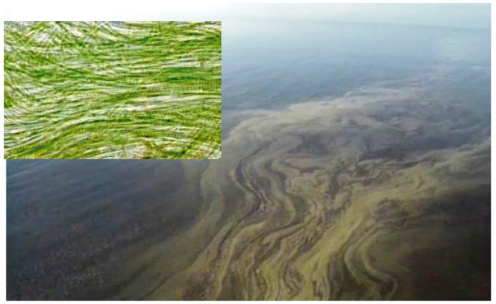
Dyr, 0.54-0 Ga

Dinosaurer, 0.25-0.06 Ga



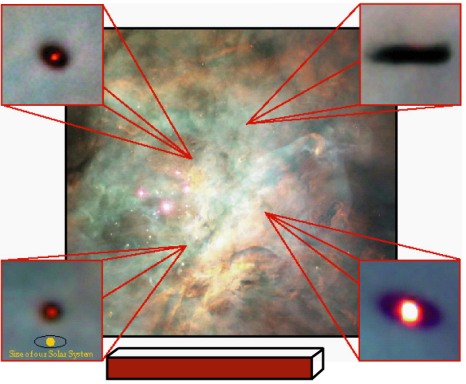


Jorden og Månen dannes, ca. 4.5 Ga



Iltproducerende fotosyntese, 2.5-0 Ga

Landplanter, 0.48-0 Ga

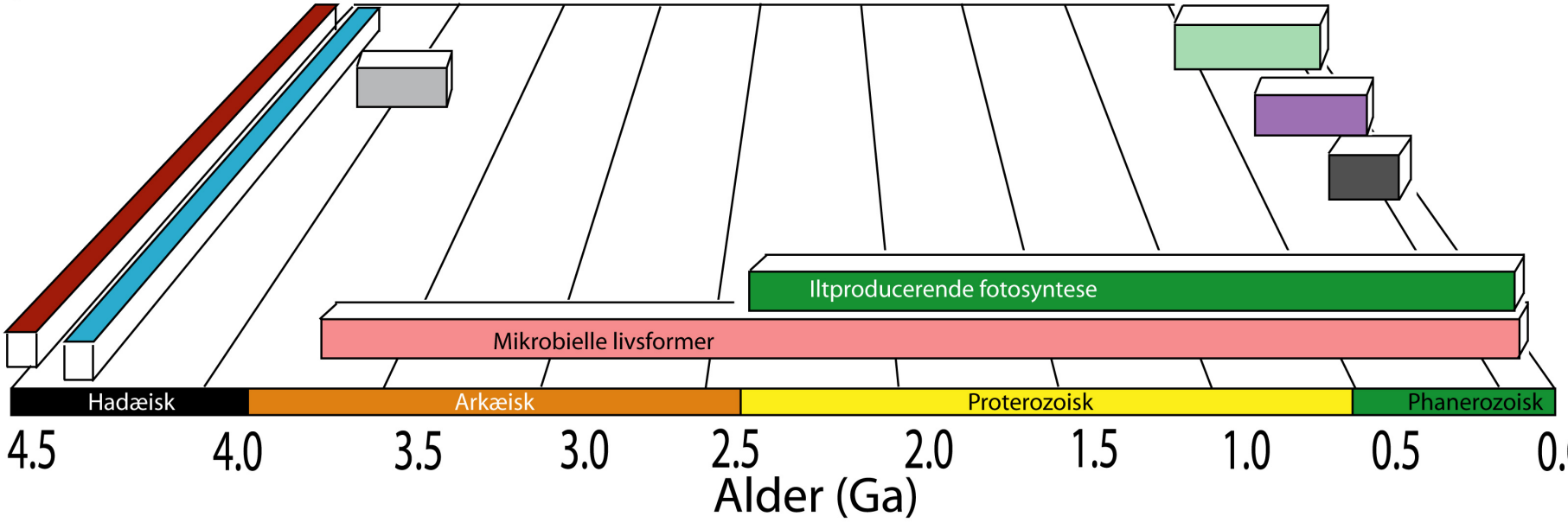


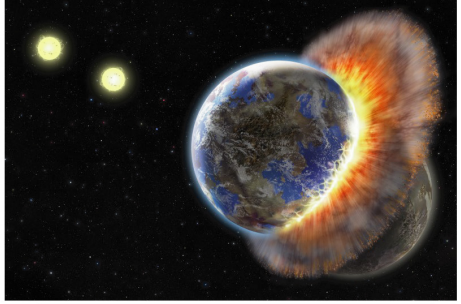
Solsystemet dannes 4.57 Ga

De første bjerge og kontinenter ca. 4.0-3.5 Ga

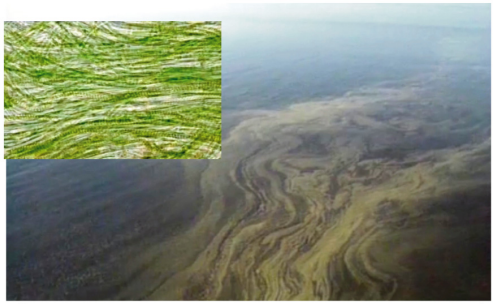
Dyr, 0.54-0 Ga

Dinosaurer, 0.25-0.06 Ga



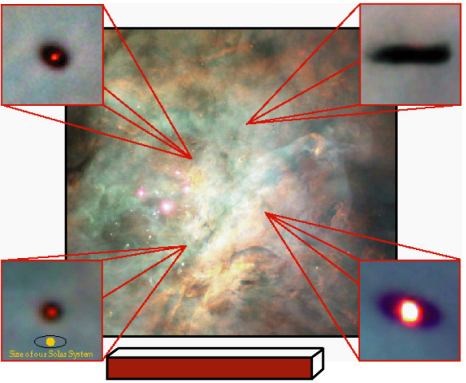


Jorden og Månen dannes, ca. 4.5 Ga



Iltproducerende fotosyntese, 2.5-0 Ga

Landplanter, 0.48-0 Ga

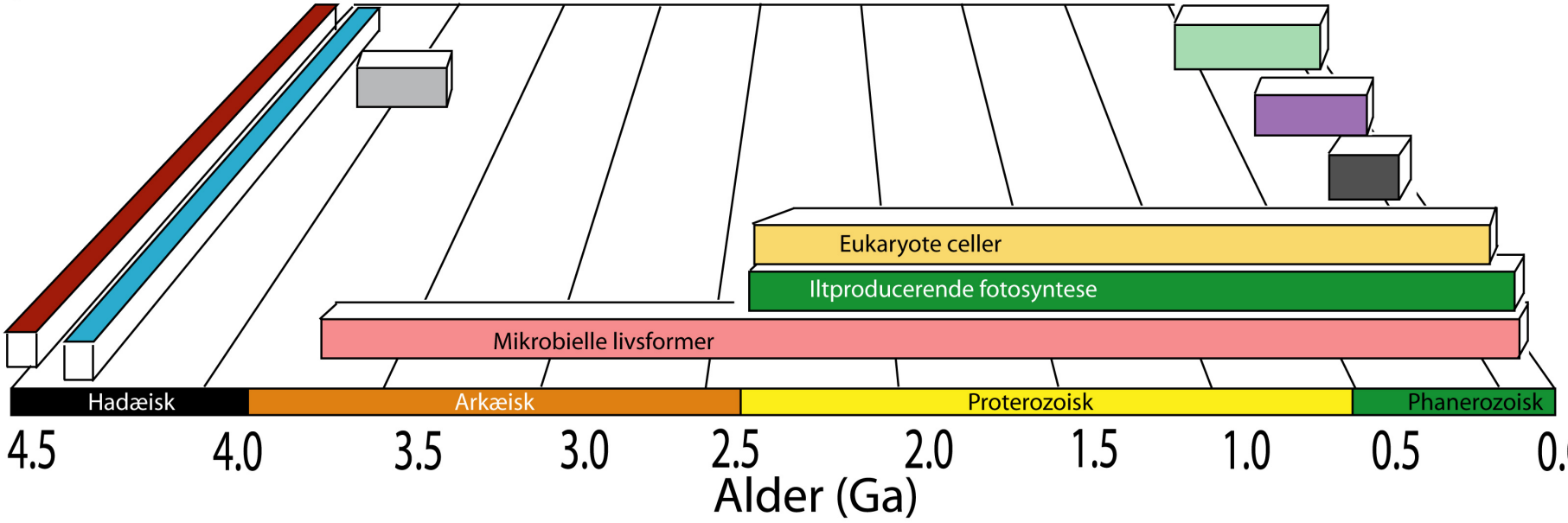


Solsystemet dannes 4.57 Ga

De første bjerge og kontinenter ca. 4.0-3.5 Ga

Dyr, 0.54-0 Ga

Dinosaurer, 0.25-0.06 Ga



Betingelser for Liv

- Flydende vand (H_2O, T = 0-100°C)
- Energikilde (Sollys eller kemisk energi)
- Kulstofkilde (organiske forbindelser, CO_2)

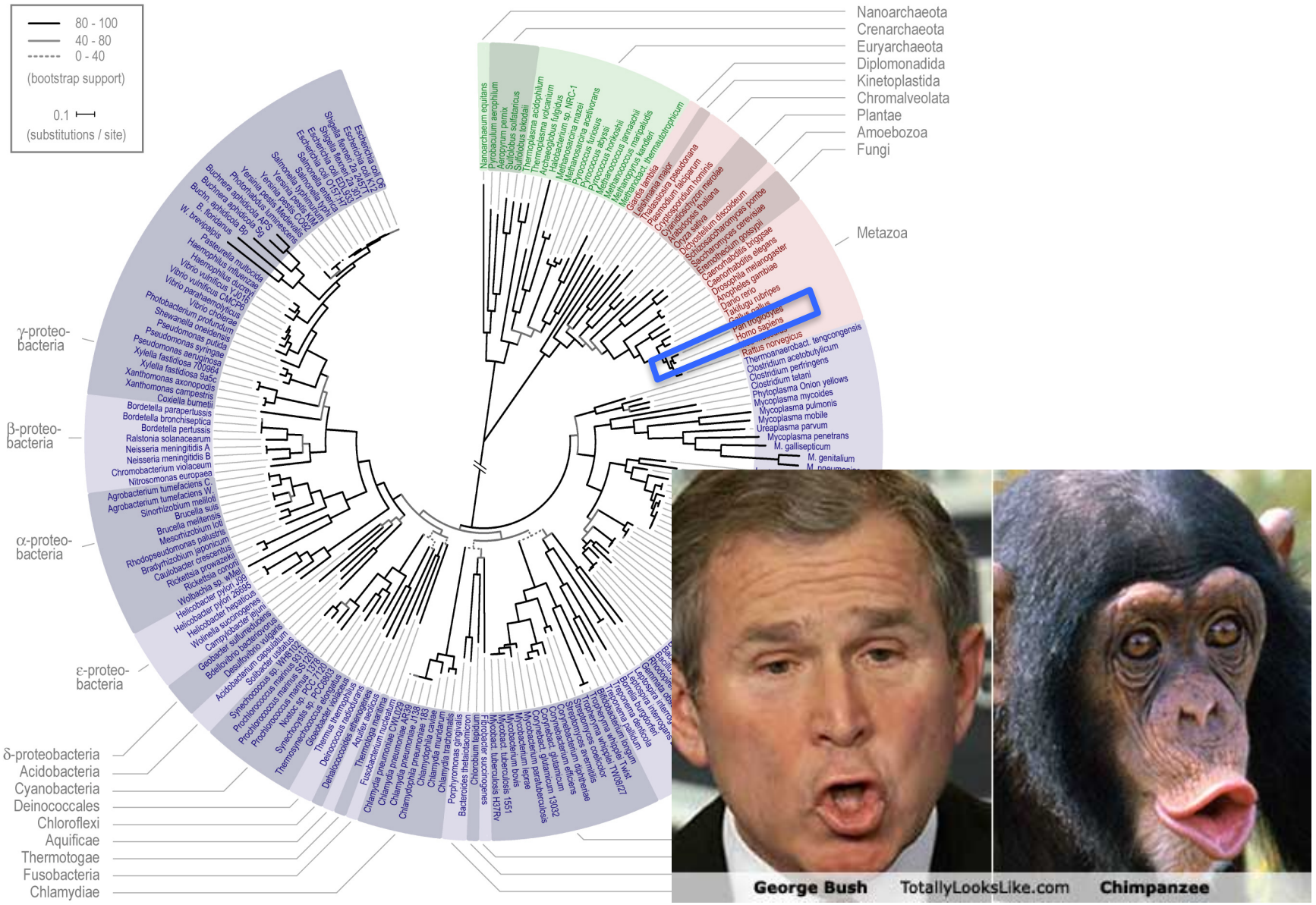
Båndet jernmalm

Hvad er liv?

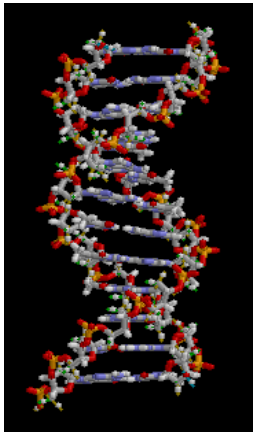
Liv = stofskifte + hukommelse

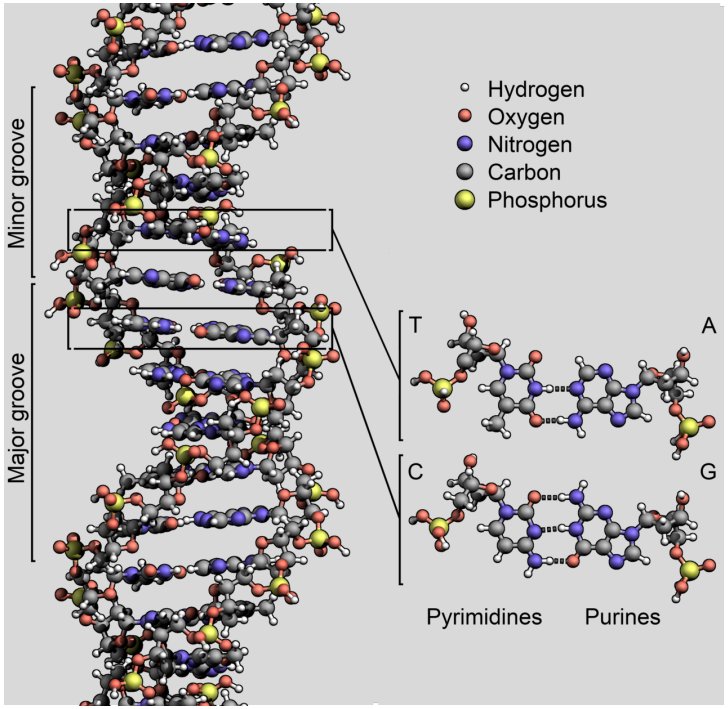
(omsætning af energi) (opskrift til den næste generation)

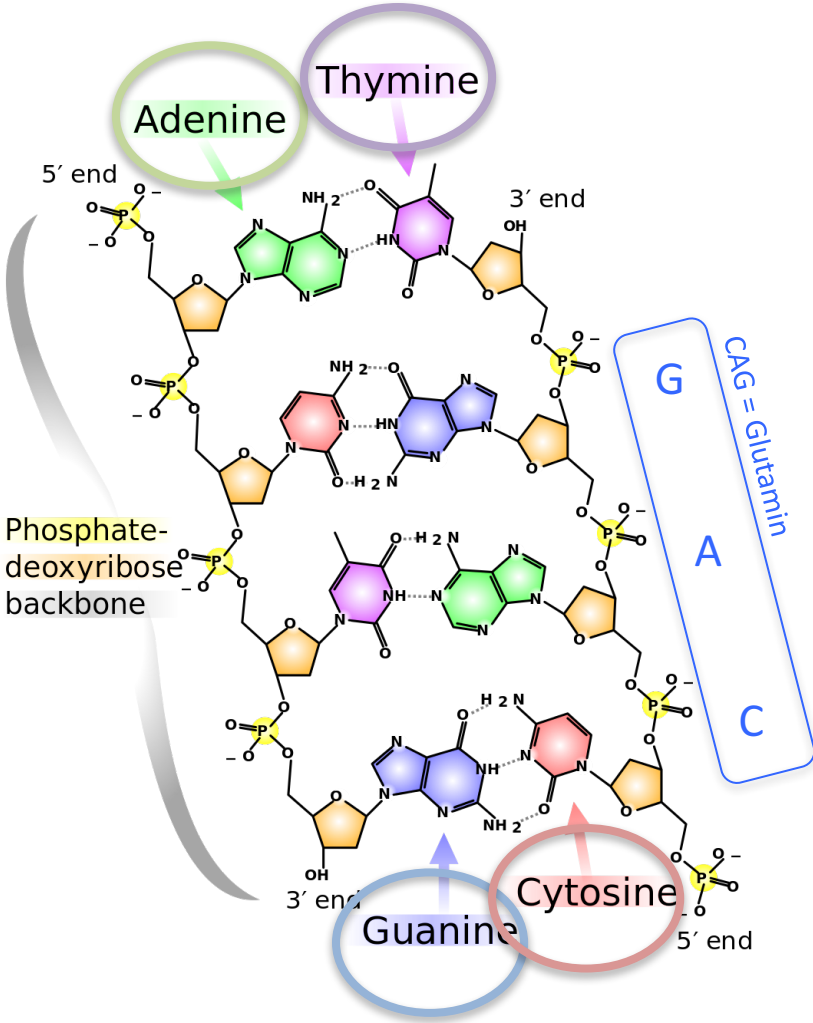
Hukommelse (den genetiske kode)



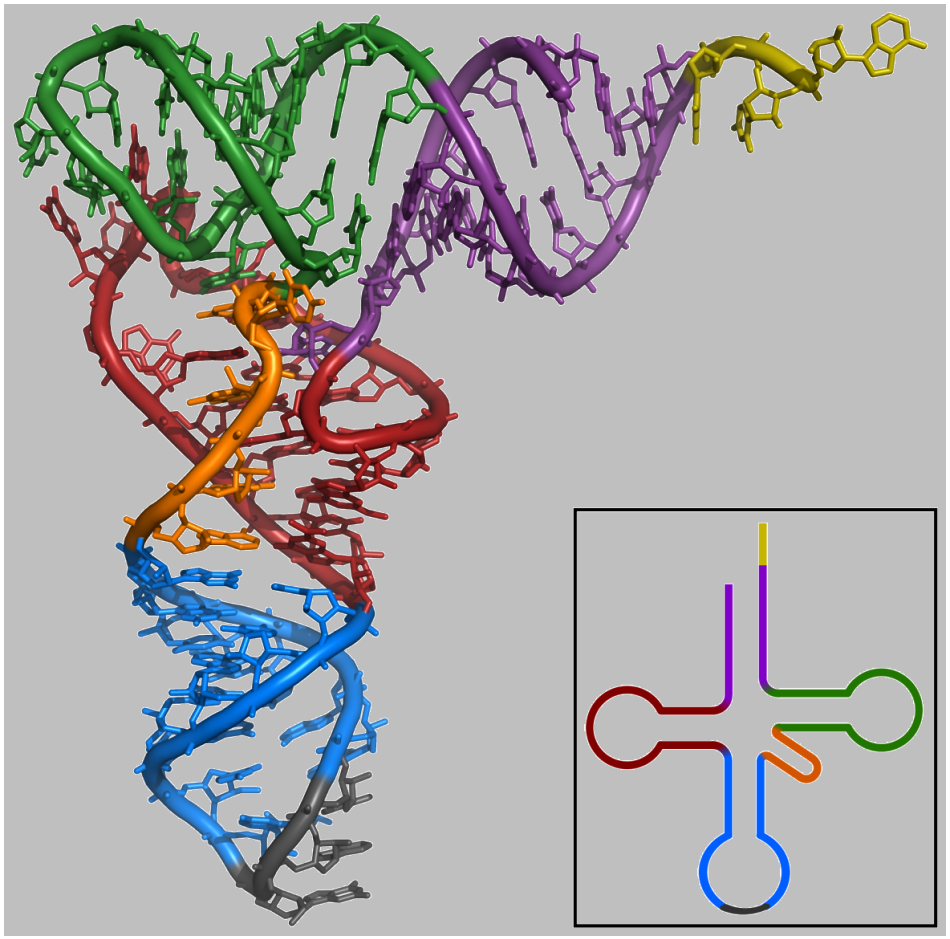
Fælles kode: DNA

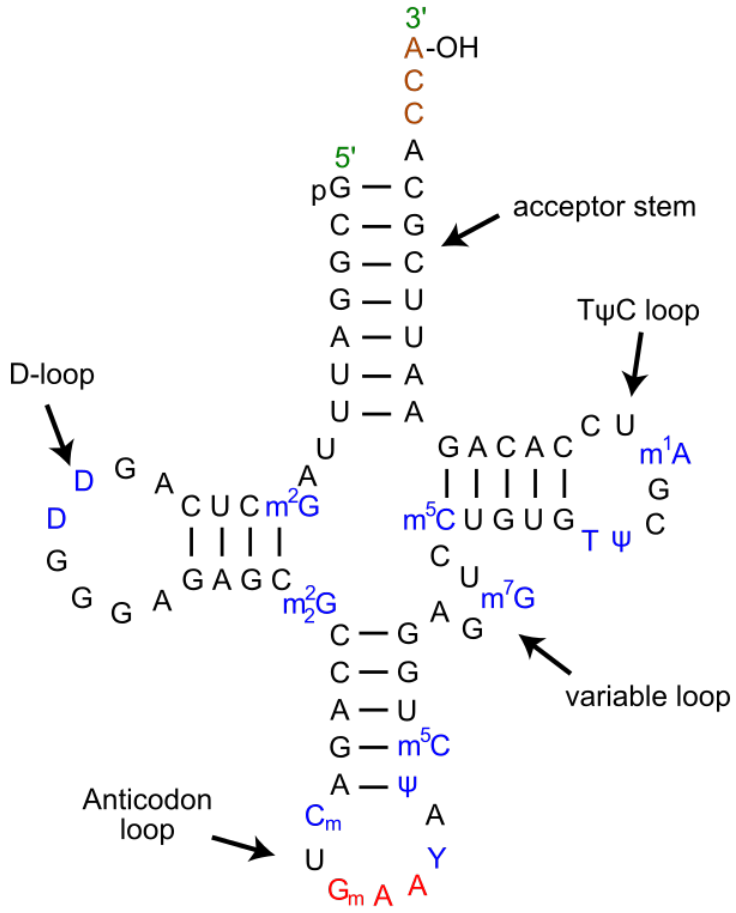






RNA (Ribonucleic Acid)





RNA kan både bære og omsætte genetisk information

(DNA) (enzym)

Stofskifte – Hvad er det?

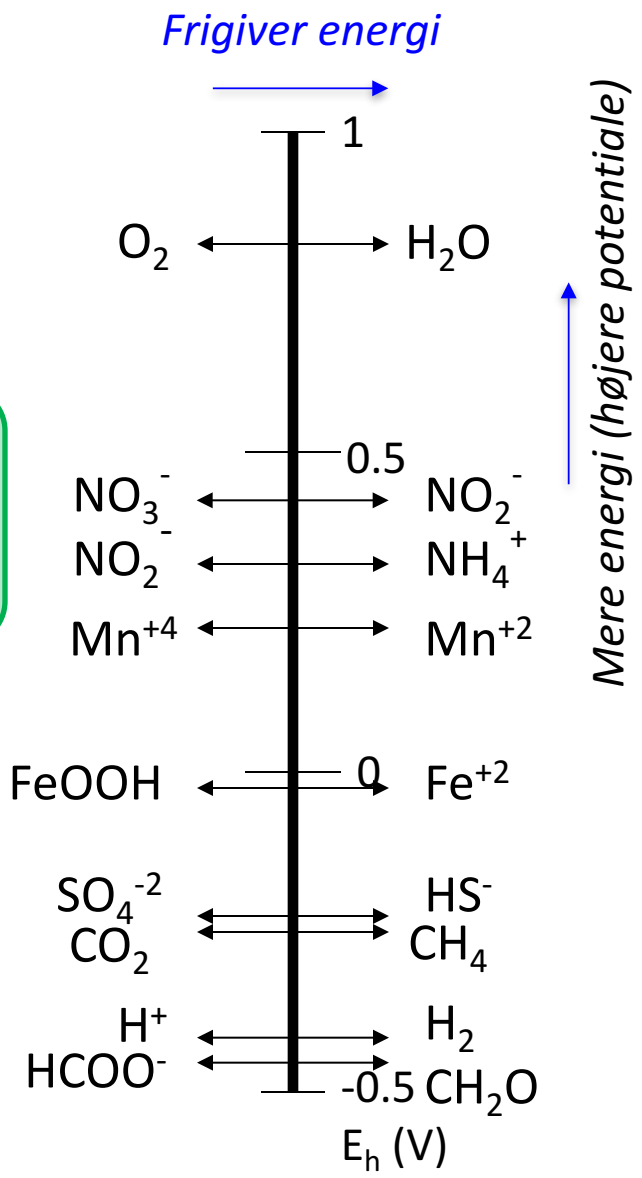
To eksempler:

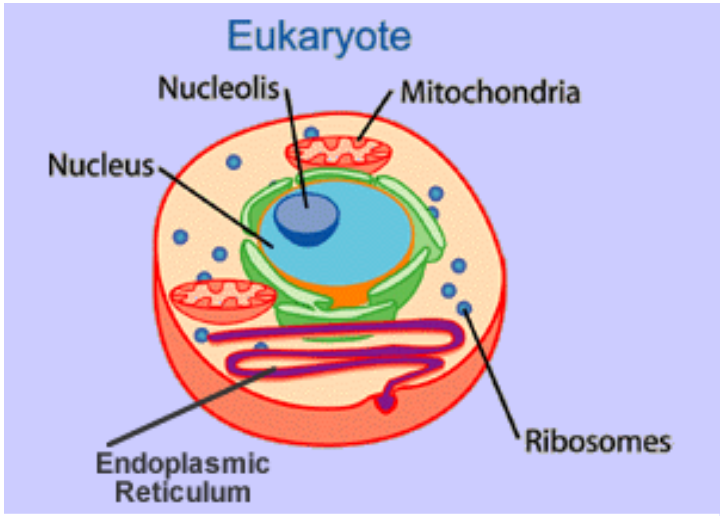
Aerob fotosyntese (med ilt)

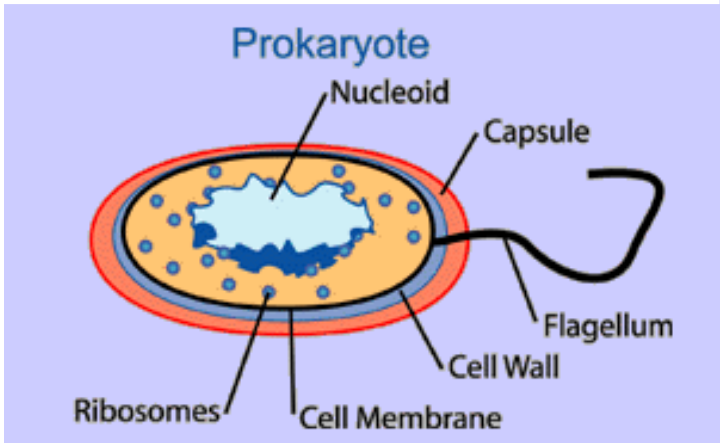
$CO_2 + H_2O + lys \rightarrow CH_2O + O_2$

Aerob forbrænding (med ilt)

$CH_2O + O_2 \rightarrow CO_2 + H_2O$

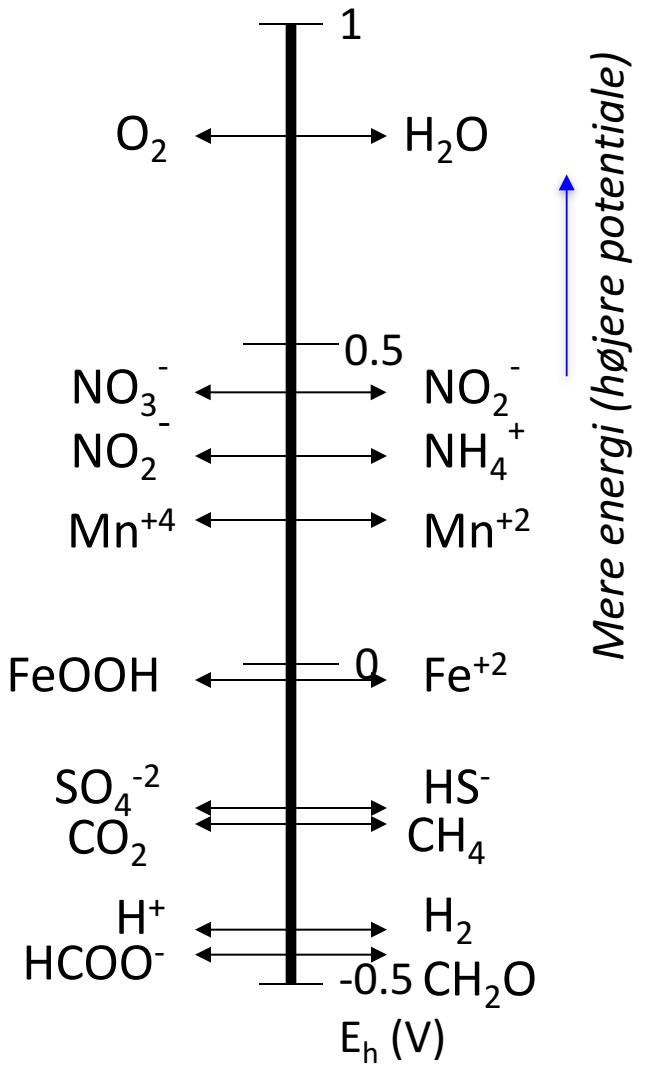






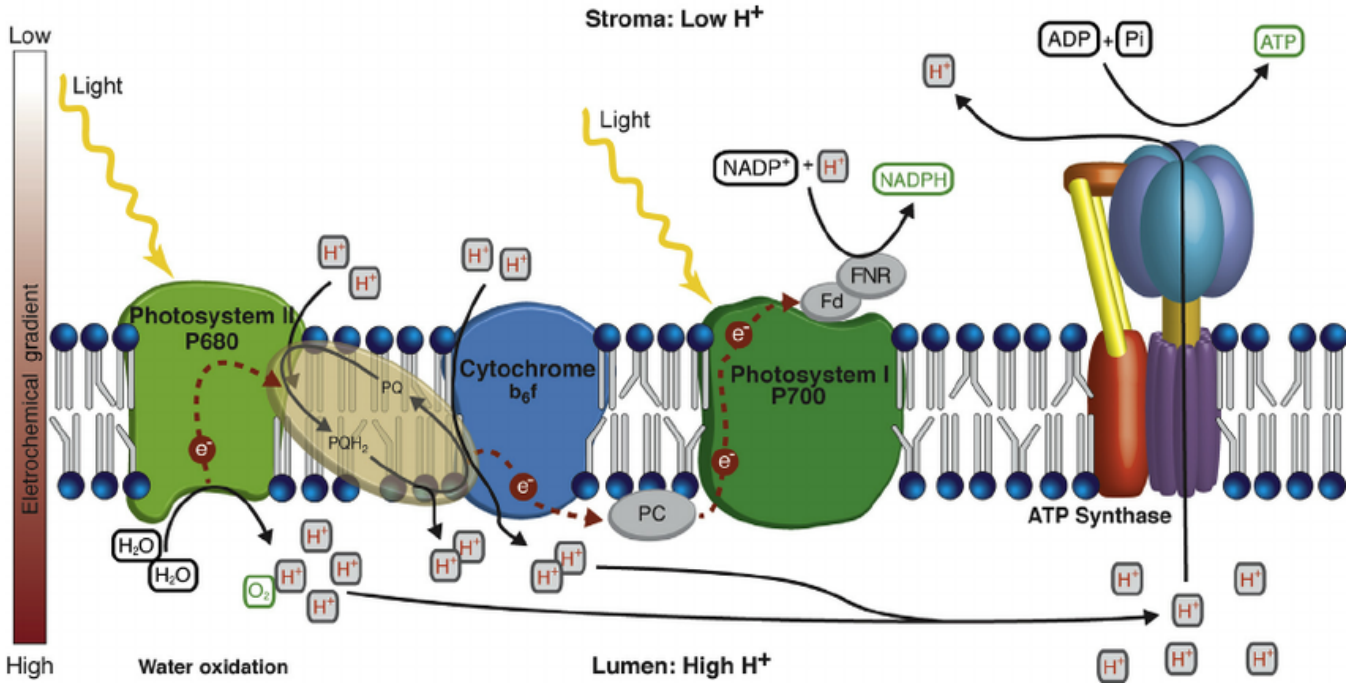
Aerob forbrænding (med ilt)

$$CH_2O + O_2 \Rightarrow CO_2 + H_2O$$



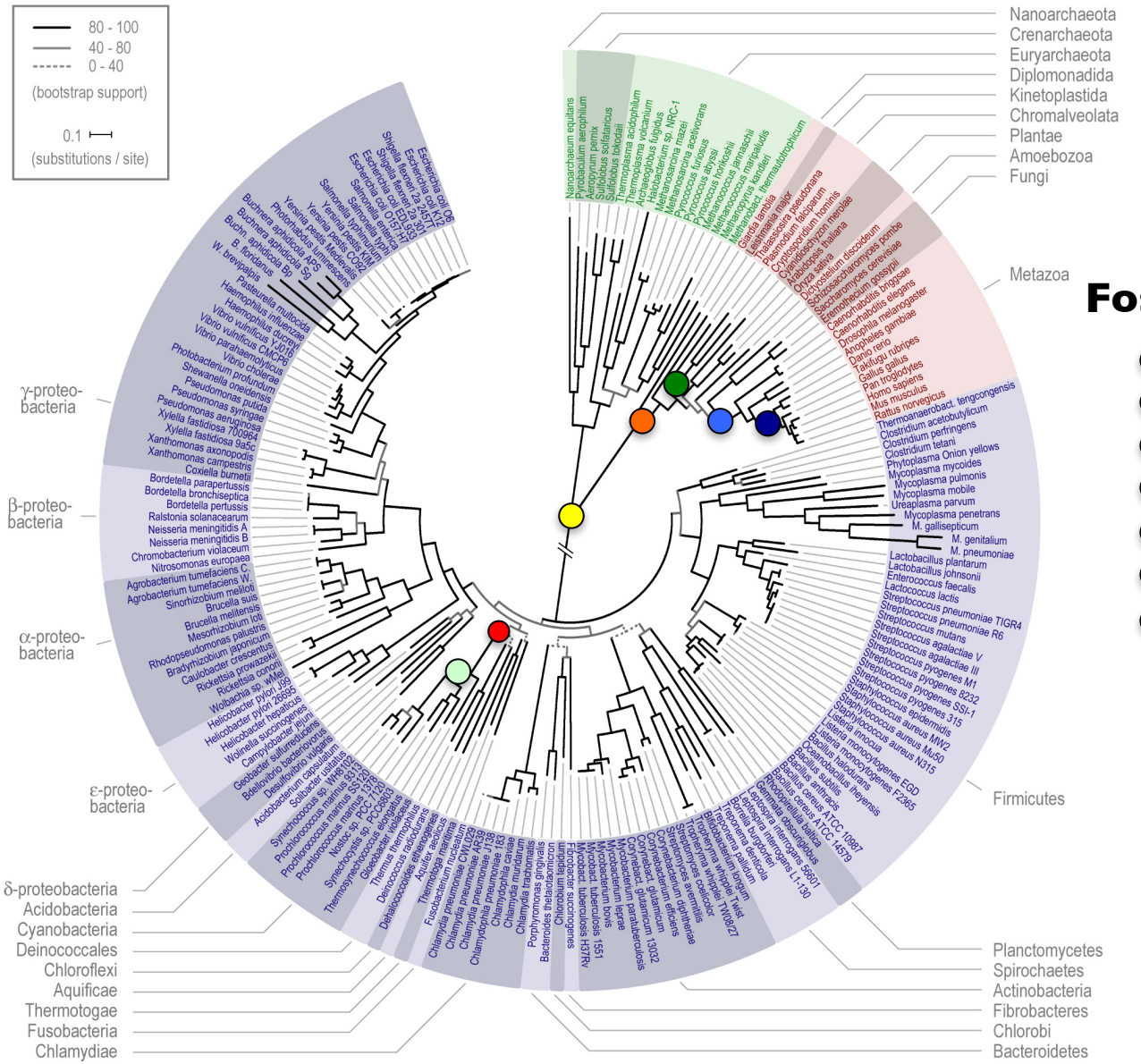
Aerob fotosyntese (med ilt)

$CO_2 + H_2O + lys \rightarrow CH_2O + O_2$



Hvad var det første liv?

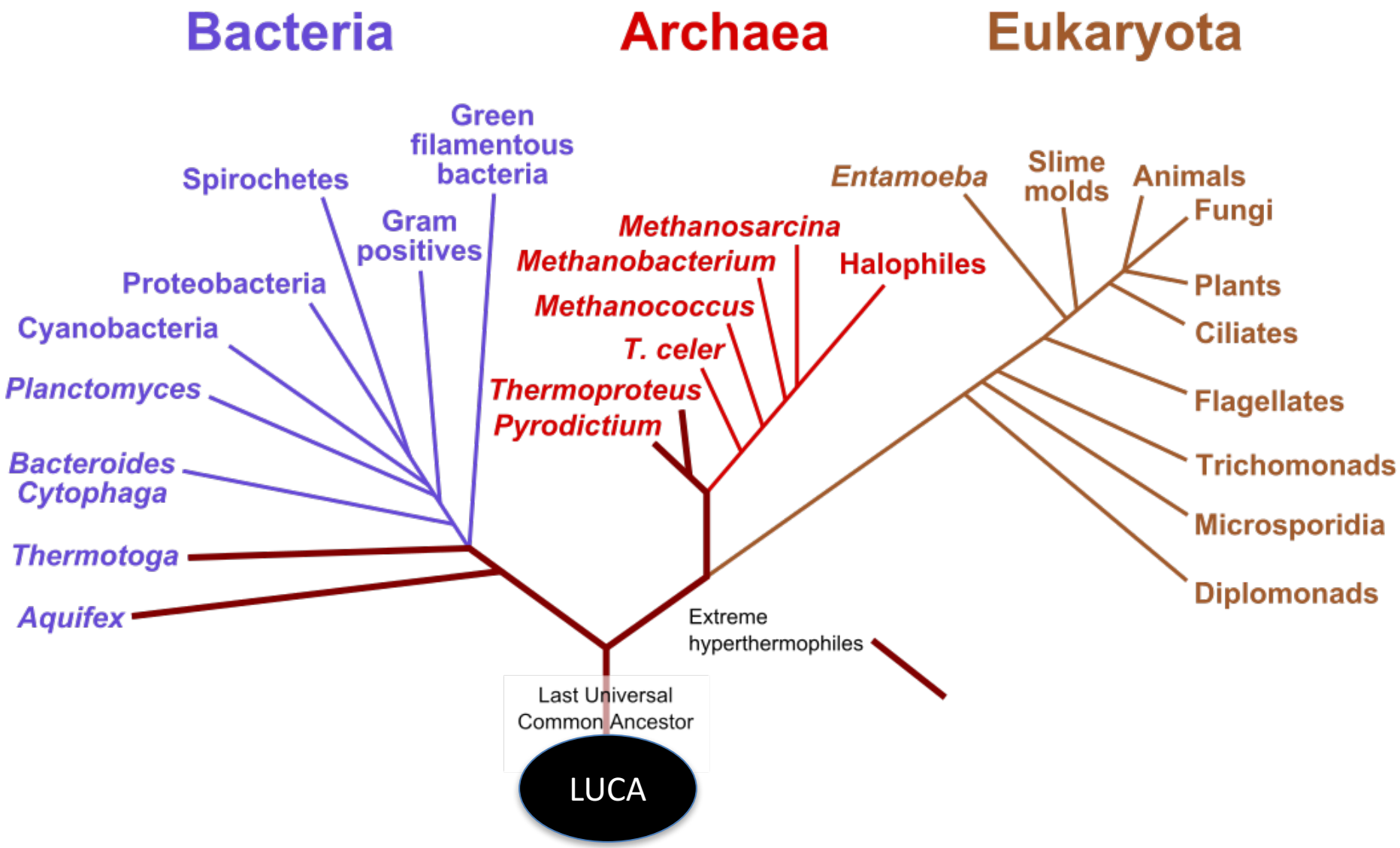
Livets træ

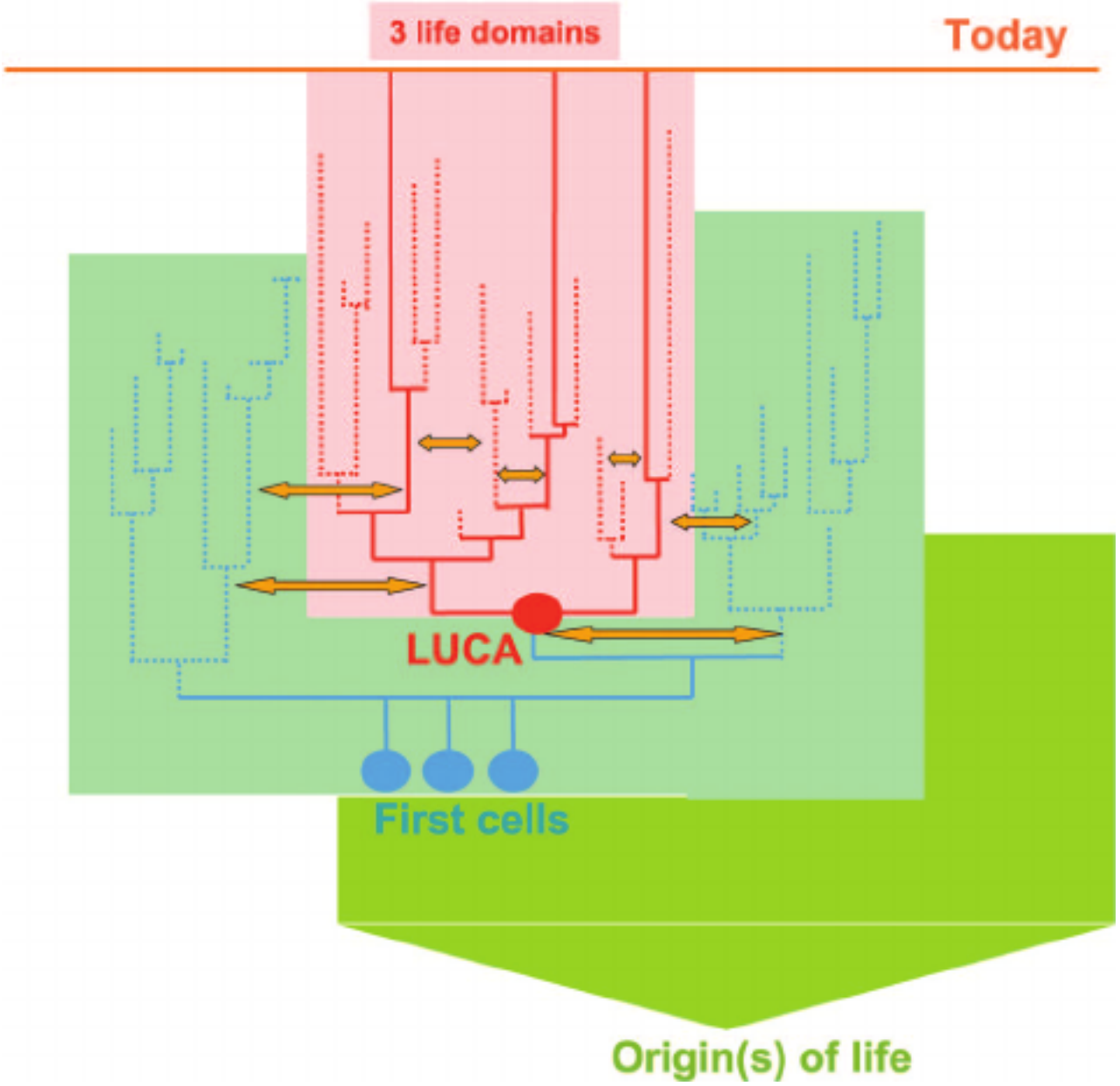


Fossilerne fortæller os

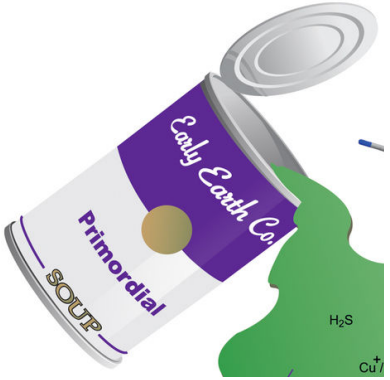
- >3800 Ma Første celler
- >2500 Ma Cyanobakterier
- >2670 Ma Eukaryote celler
- >1500 Ma
- >1200 Ma Akvatiske planter
- > 635 Ma Dyr
- ~ 410 Ma Tetrapoder

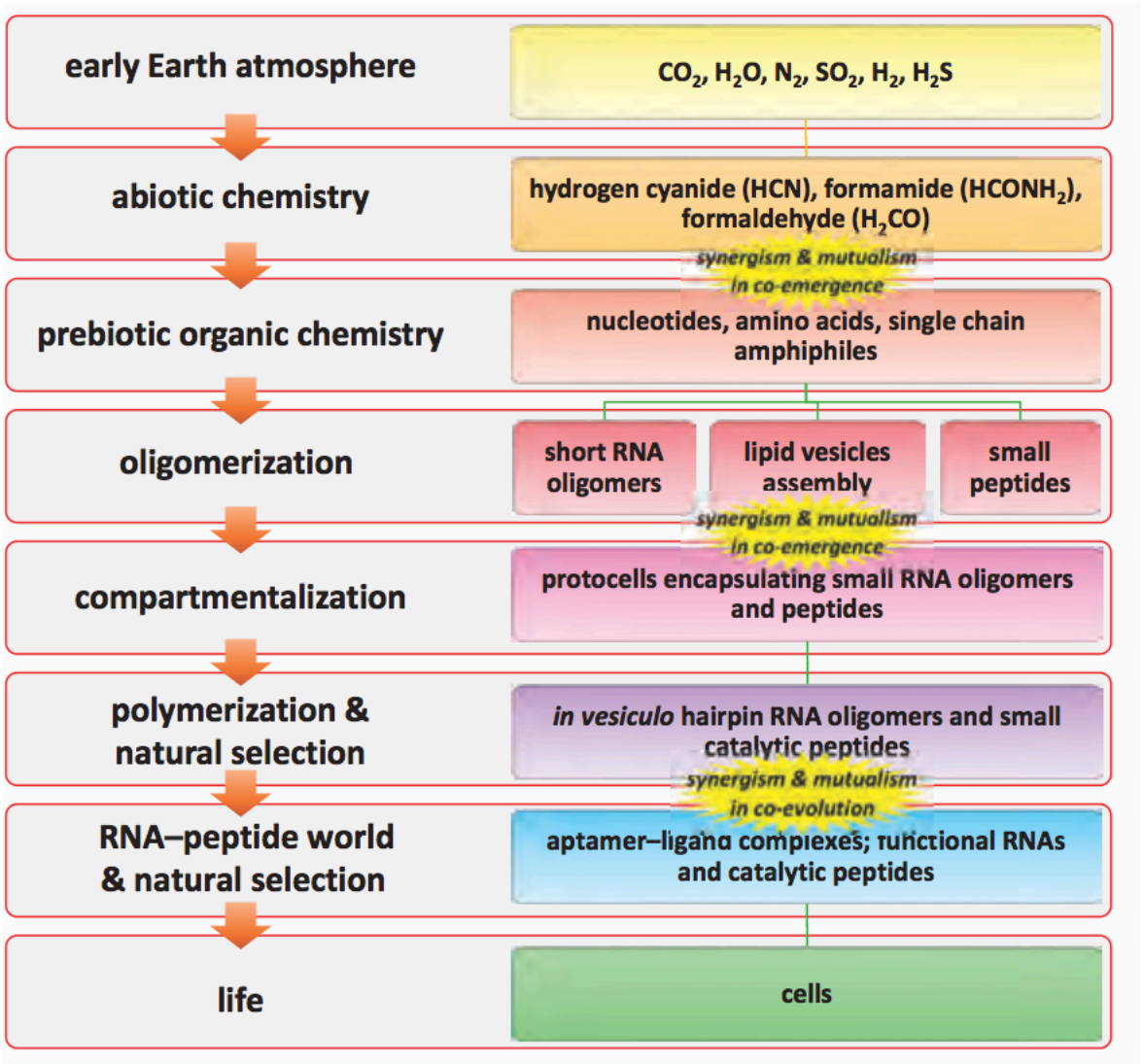
Livets træ (slægtskab)

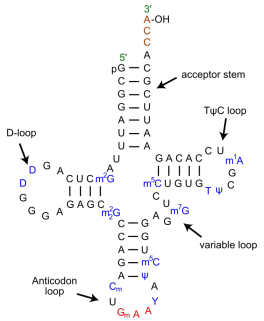



3 life domains
Today
LUCA
First cells
Origin(s) of life

Livets opståen

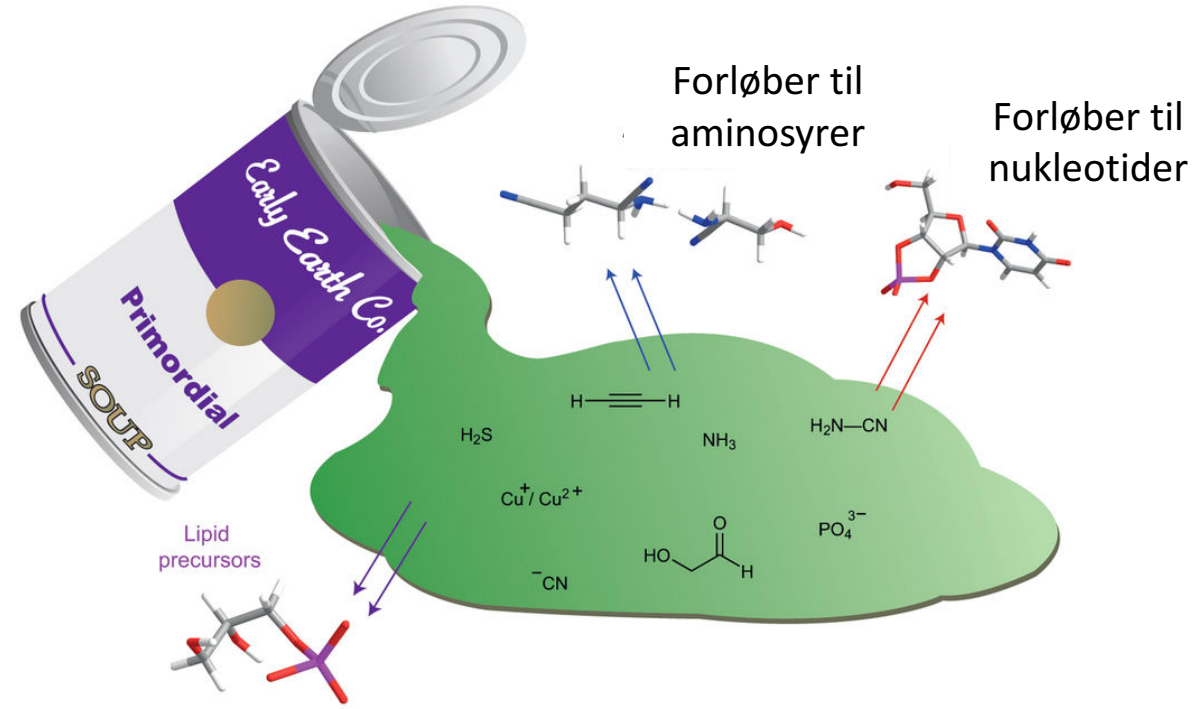






LUCA

Hvor kommer livets byggesten fra?

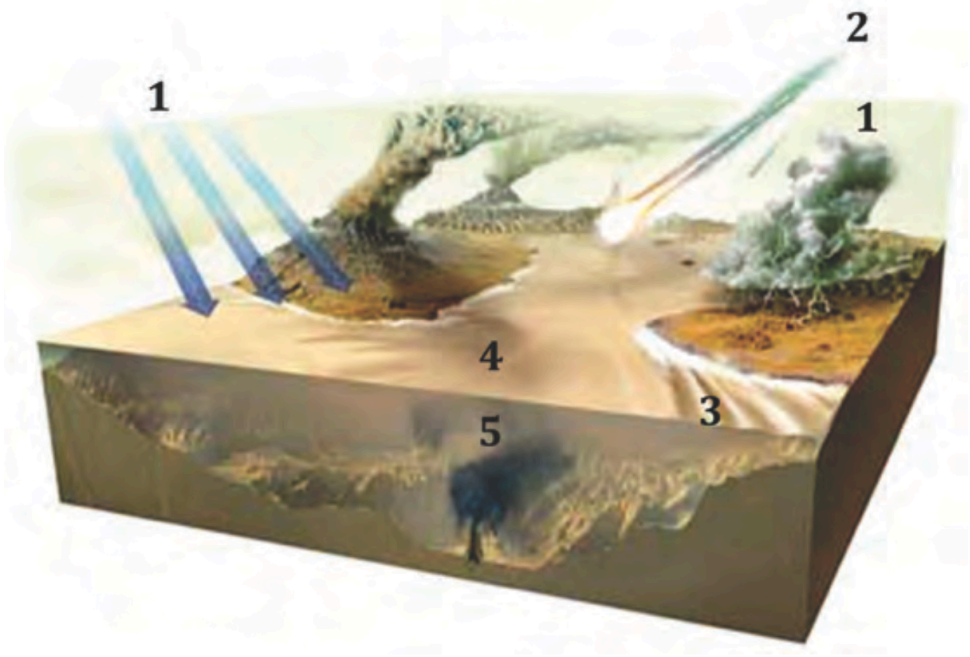


Forløber til aminosyrer

Forløber til nukleotider

Forløber til fedtsyrer

5 miljøer hvor præbiotiske organiske molekyler kunne komme fra

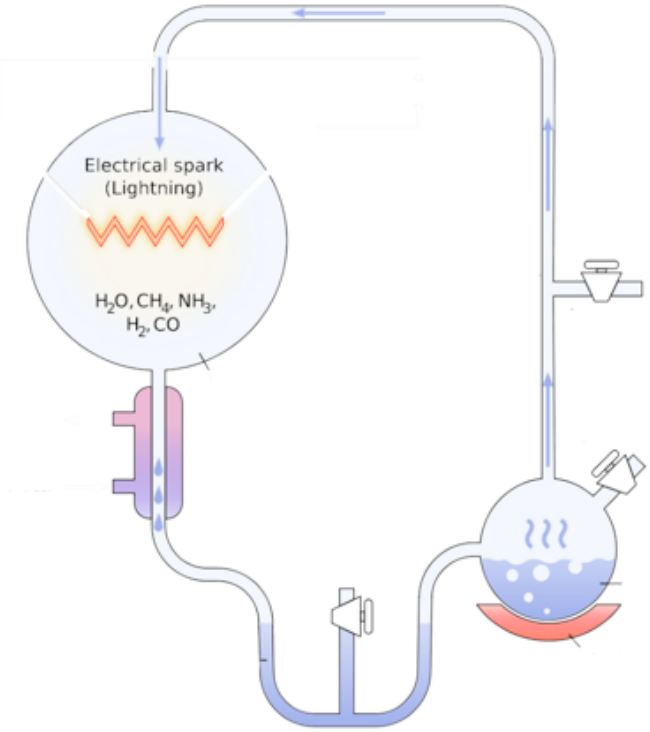


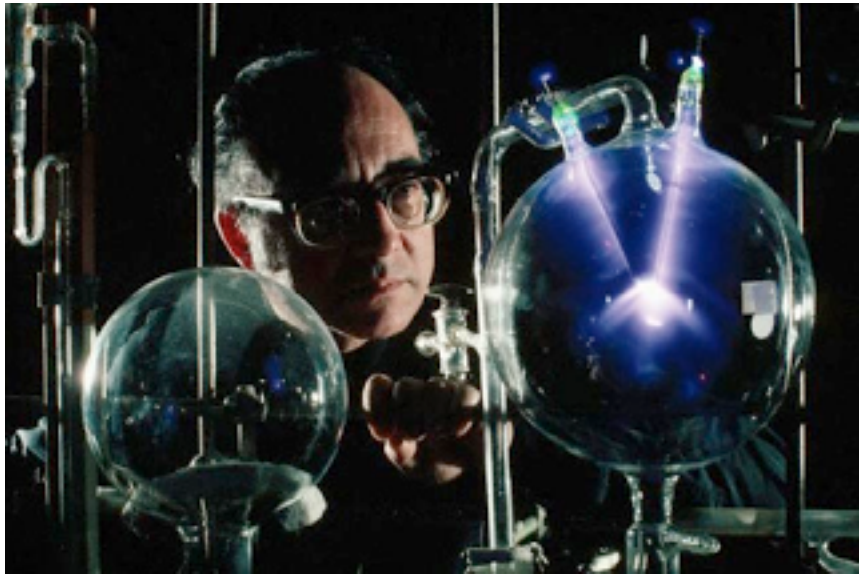
1 Atmosfæren
2 Meteoritter og kometer
3 Overflader mellem mineraler og vandig opløsning (med sollys)
4 Overflader mellem mineraler og vandig opløsning (uden sollys)

5 Varme kilder og under overfladen

Urey-Miller experimentet

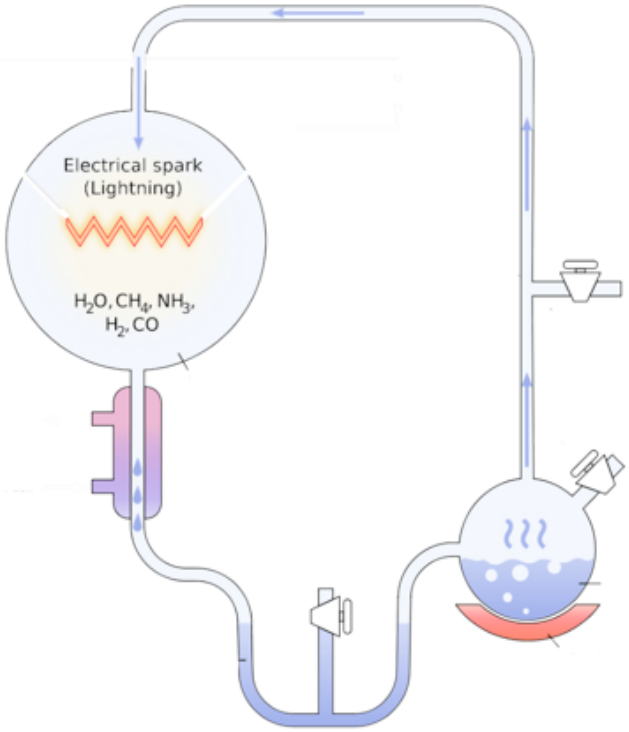
University of Chicago 1953

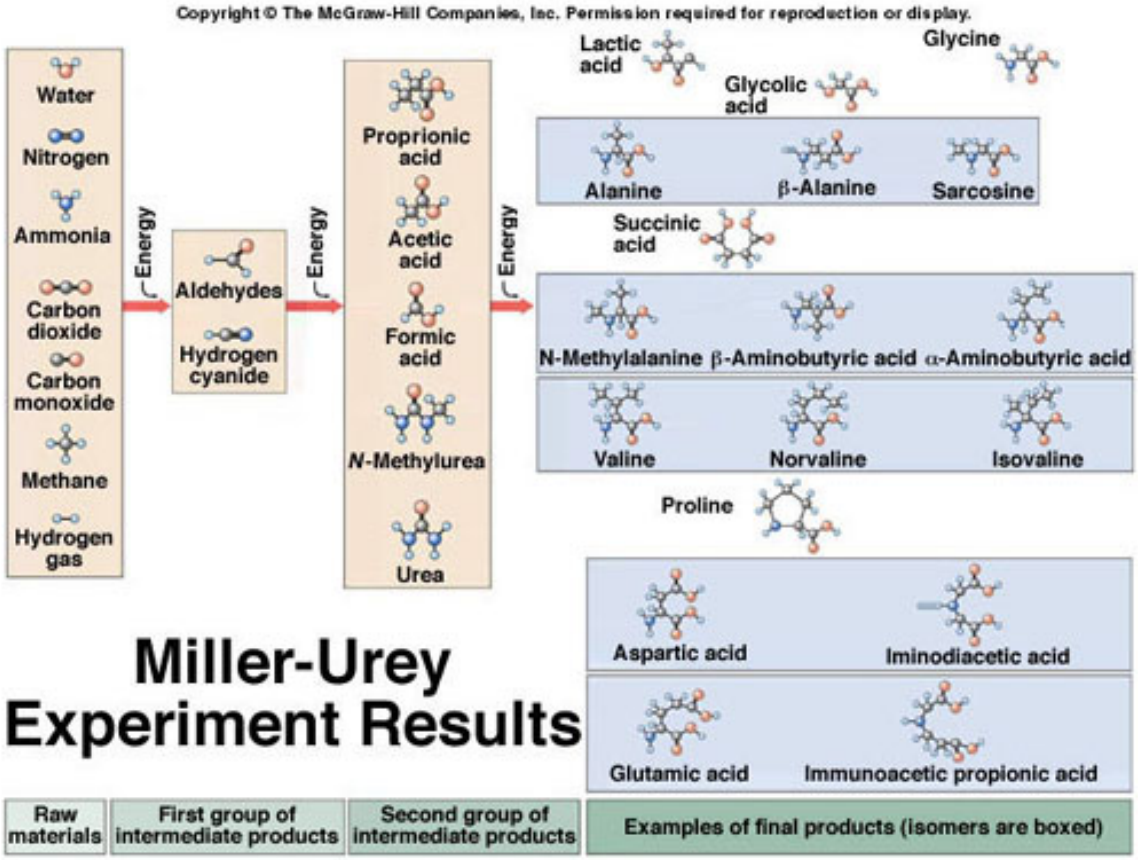


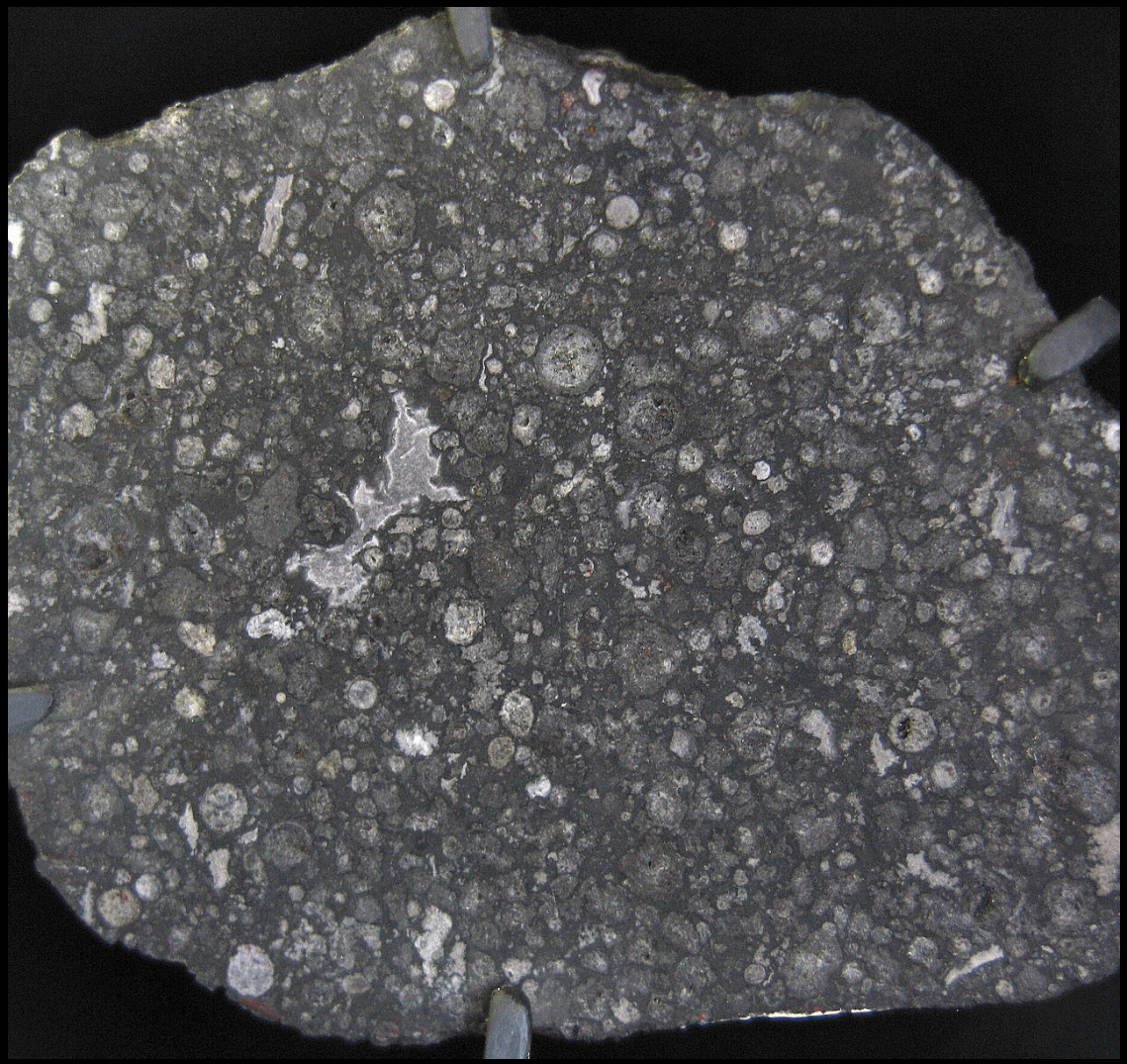


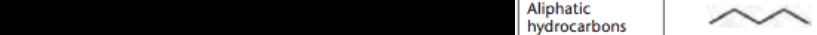
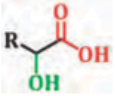
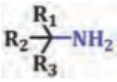
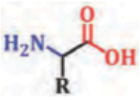
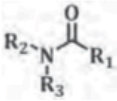
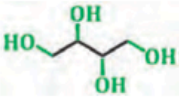
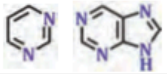
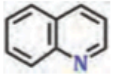
Urey-Miller experimentet

University of Chicago 1953



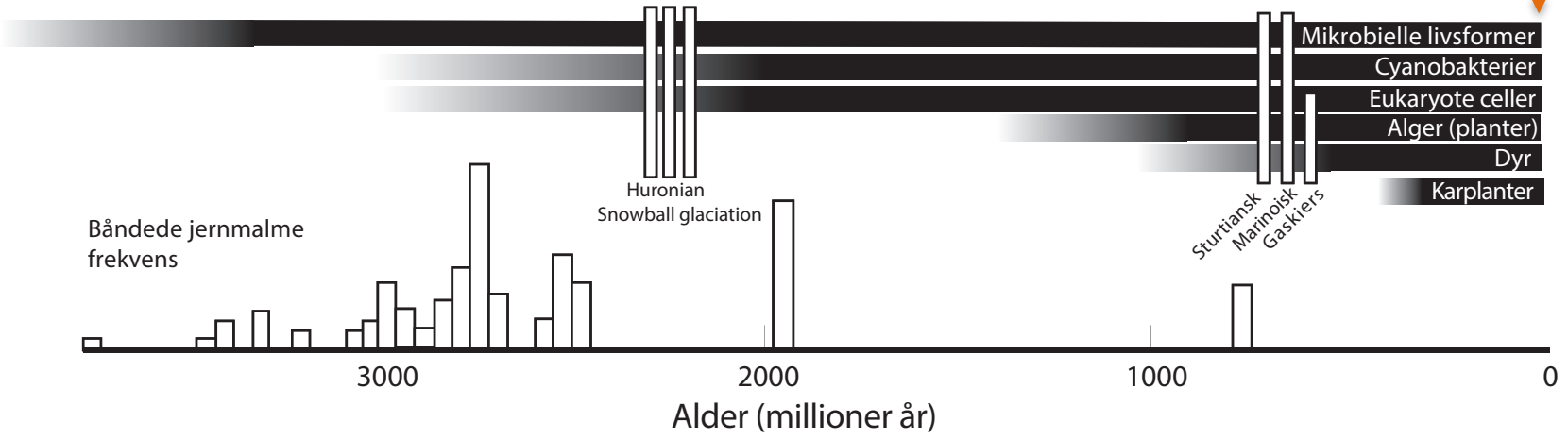




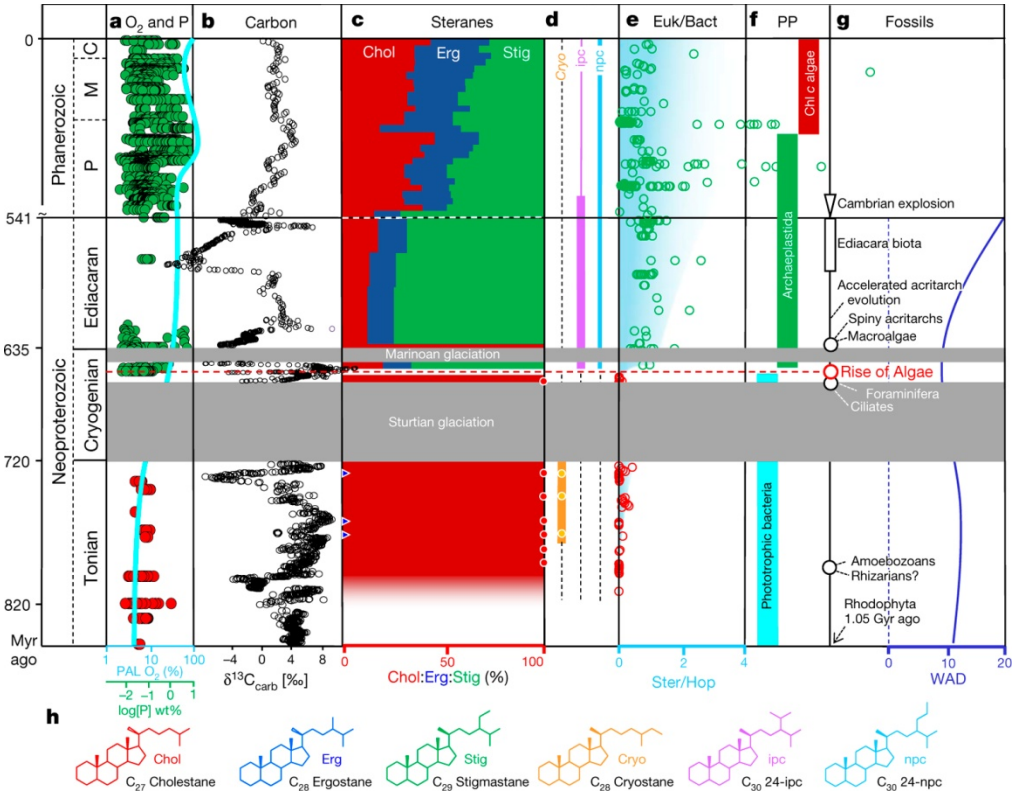
Compounds	Structure	Concentration (ppm)	Carbon Chain Length
Aliphatic hydrocarbons		12–35	C1–C30
Aromatic hydrocarbons		15–28	C6–C20
Carboxylic acids		>350	C1–C12
α-Hydroxy carboxylic acids		15	C2–C8
Alcohols		11	C1–C4
Aldehydes		11	C1–C5
Ketones		16	C1–C5
Amines		8	C1–C4
Amino acids		60	C2–C9
Amides		62	C1–C3
Sugar-related (sugar alcohols, sugar acids)		60	C3–C6
Purines and Pyrimidines		2	C4–C5
Basic N-heterocycles		0.05–0.5	C4–C5
Sulfonic acids		67	C1–C4
Phosphonic acids		1.5	C1–C4
Polymers (macromolecular compounds)	—	>14,300	C>100

After Sephton (2002) and Llorca (2004).

Hvorfor opstod mennesker og dyr så sent?



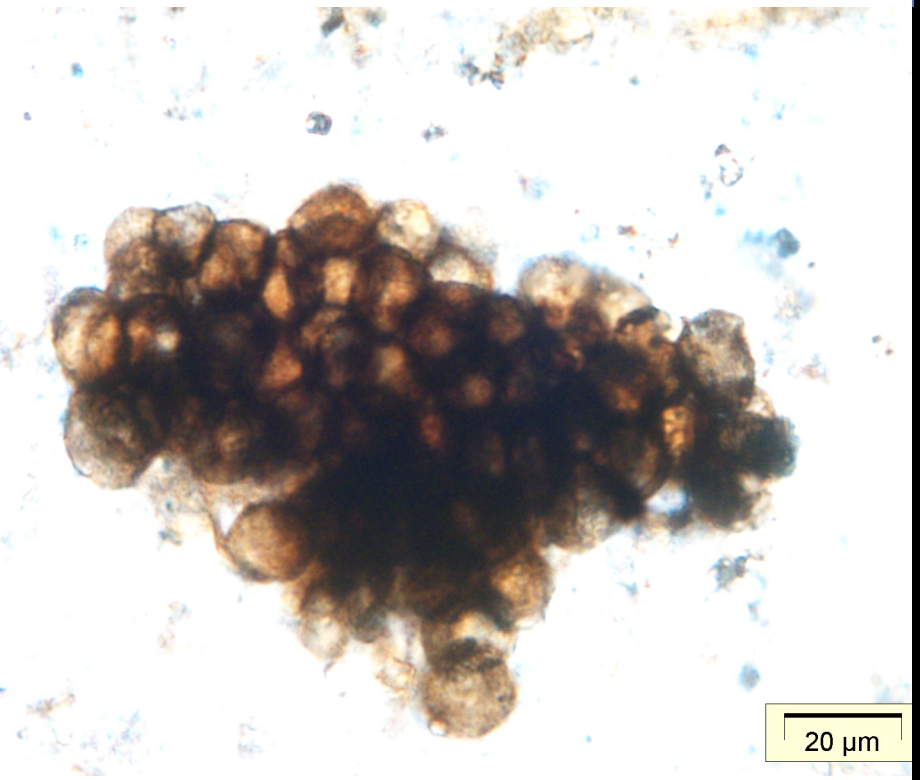
Time chart from 850 Myr ago to the present summarizing environmental, biomarker and fossil data and highlighting the position of the rise of algae



J J Brocks *et al. Nature* 1–4 (2017) doi:10.1038/nature23457

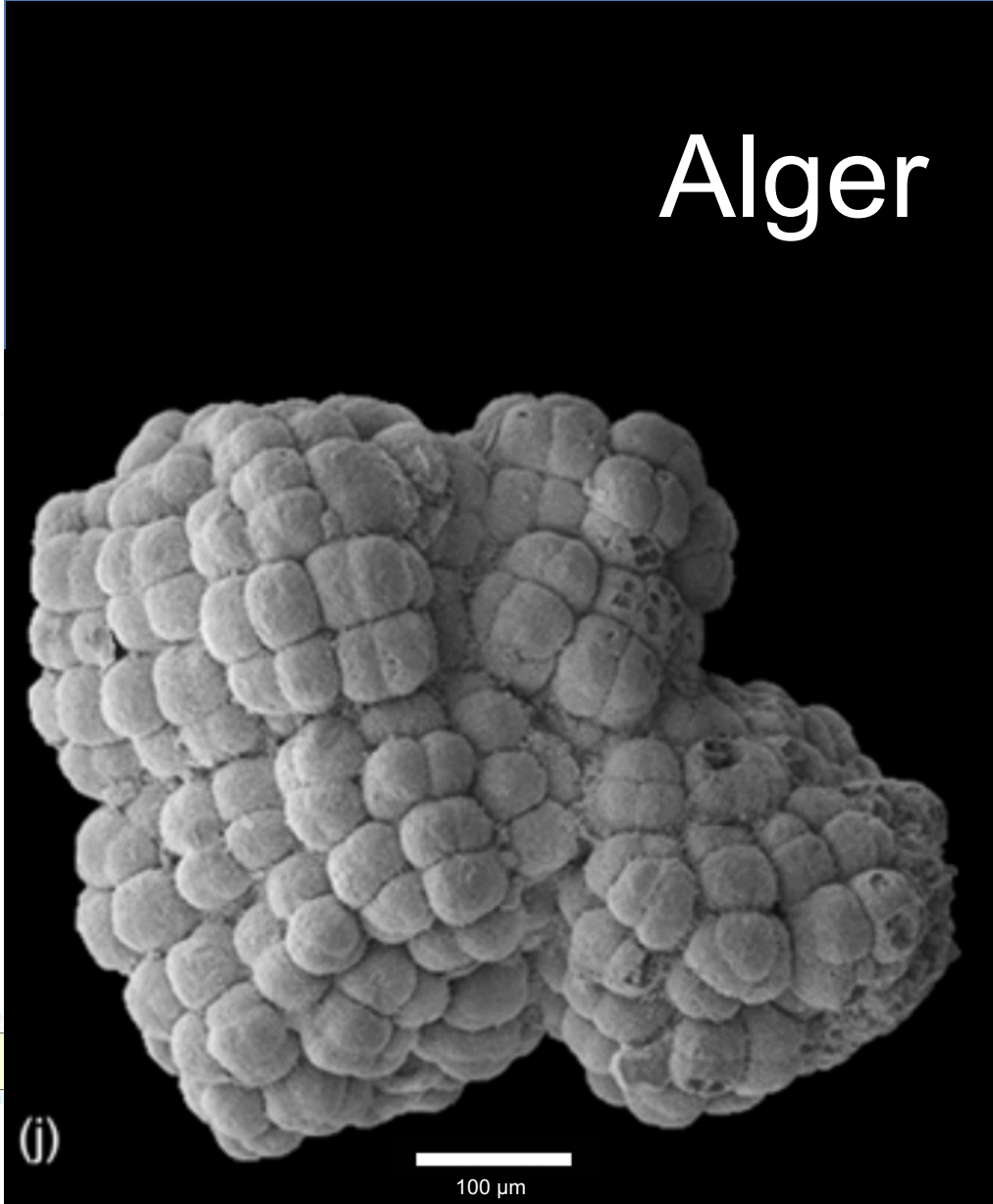
nature

Cyanobakterier



Myxococcoides cantabrigiens
cyanobakterier
Draken Formationen, Svalbard
~800 mio. år gammel
Foto: T. W. Dahl

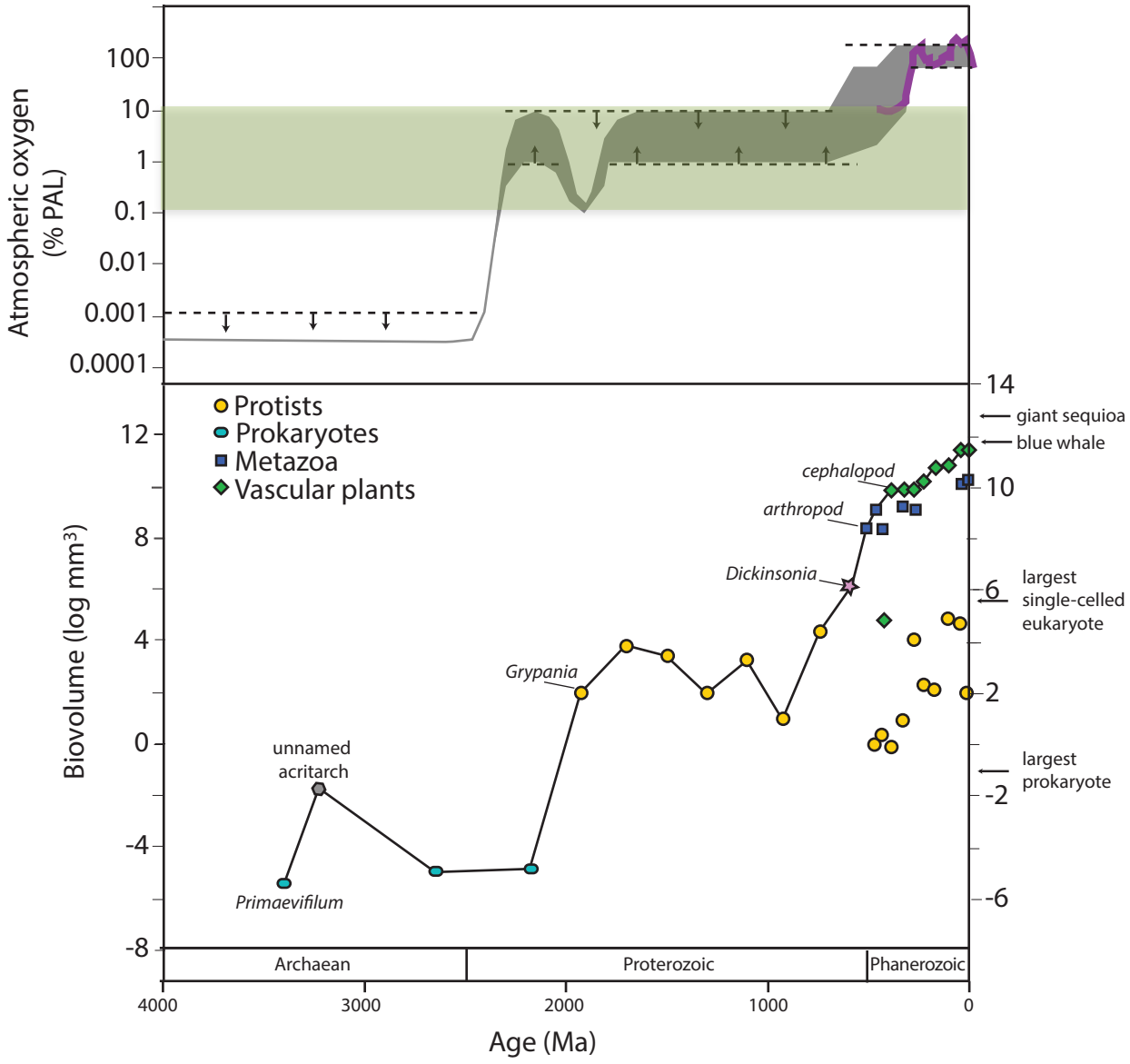
Alger



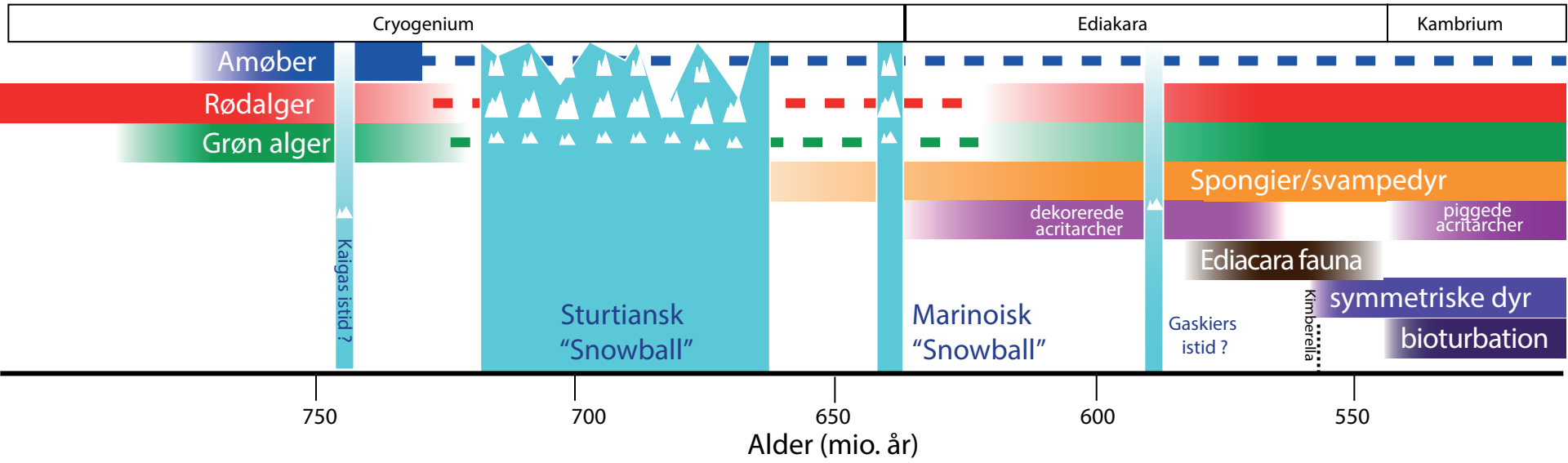
Archaeophycus
Mulig rødalge
Weng'an Biota, Kina· 609-570 mio år gammel
Cunningham et al. 2017

Livets udvikling er tæt knyttet til fri ilt

O_2


Atmospheric oxygen
(% PAL)
100
10
1
0.1
0.01
0.001
0.0001
Protists
Prokaryotes
Metazoa
Vascular plants
Biovolume (log mm³)
12
8
4
0
-4
-8
14
10
6
2
-2
-6
giant sequioa
blue whale
largest
single-celled
eukaryote
largest
prokaryote
cephalopod
arthropod
Dickinsonia
Grypania
unnamed
acritarch
Primaevifilum
Archaean
Proterozoic
Phanerozoic
4000
3000
2000
1000
0
Age (Ma)

Dyrenes tidlige udviklingshistorie



tid

Sammenfatning

- Livet har udviklet sig på Jorden igennem mere end 3,5 mia. år
- Alt liv har en fælles stamfader: LUCA
- Det første liv var mikrobielt.
- Disse celler kunne både replikere og omsætte energi
- Energien fandtes allerede i form af geokemiske reaktioner, der alligevel foregik i miljøet, men cellerne havde enzymer og kunne få reaktionerne til at gå hurtigere.
- Mikrobiel vækst er eksponentiel. Livets kraft er overvældende!
- Affaldsprodukter påvirker nærmiljøet og evolutionen.
- Cyanobakterierne påvirkede endda det globale miljø. De frigav O_2 til havet og atmosfæren.
- Iltniveauet forblev dog lavt og/eller for ustabilt.
- For 0,55 mia. år siden opstod bevægelige dyr.
- Dyrs graven og deres tarmsystem har en effekt på kulstofkredsløbet på Jorden. Det kan have stabiliseret iltniveauet og dermed betingelserne for alt højerestående liv.

Tak for jeres opmærksomhed!

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Danmarks Grundforskningsfond
Danish National Research Foundation

VILLUM FONDEN

Carlsberg
CARLSBERG FOUNDATION

NSF