Universiteit Antwerpen
Centrum Pieter Gillis

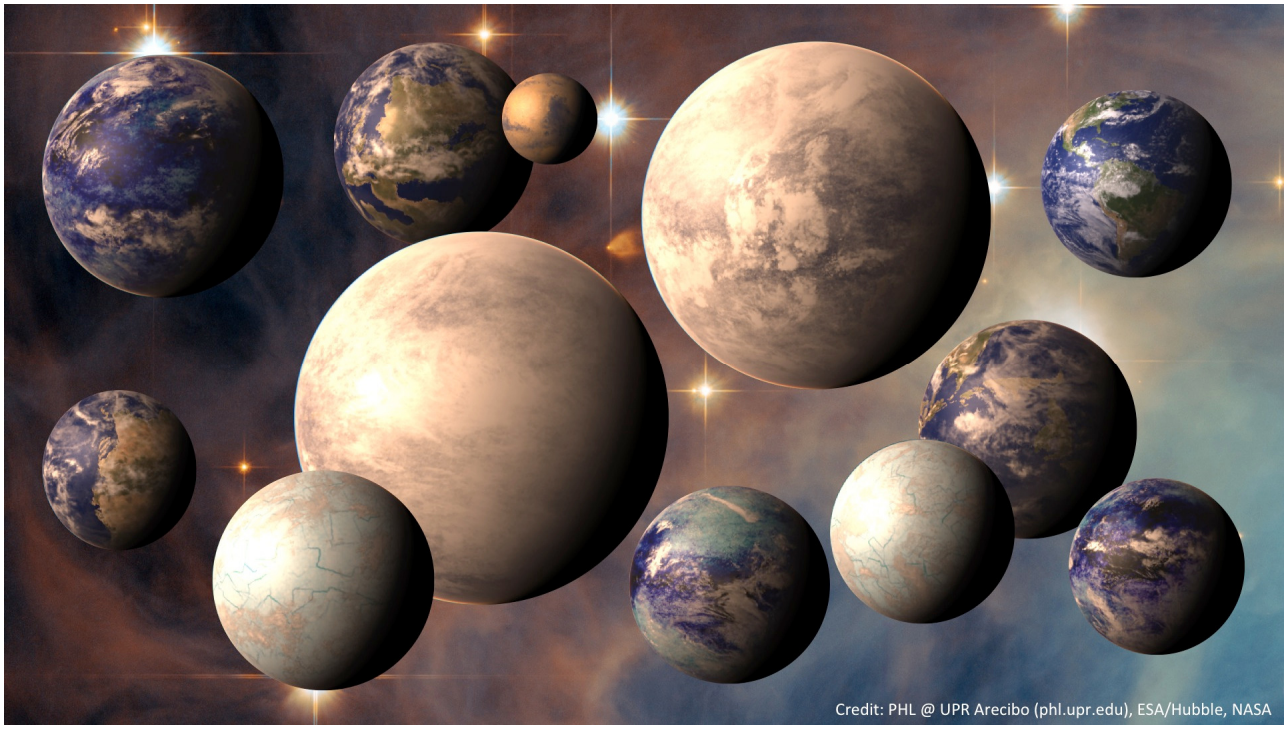
Publieke lezingen najaar 2023 "OORSPRONG"

Over het ontstaan van Planeet Aarde

een planeet die tot leven kwam

Manuel Sintubin
Departement Aard- en Omgevingswetenschappen
KU Leuven

KU LEUVEN




There is
no
Planet B!


Zijn we alleen in het universum?

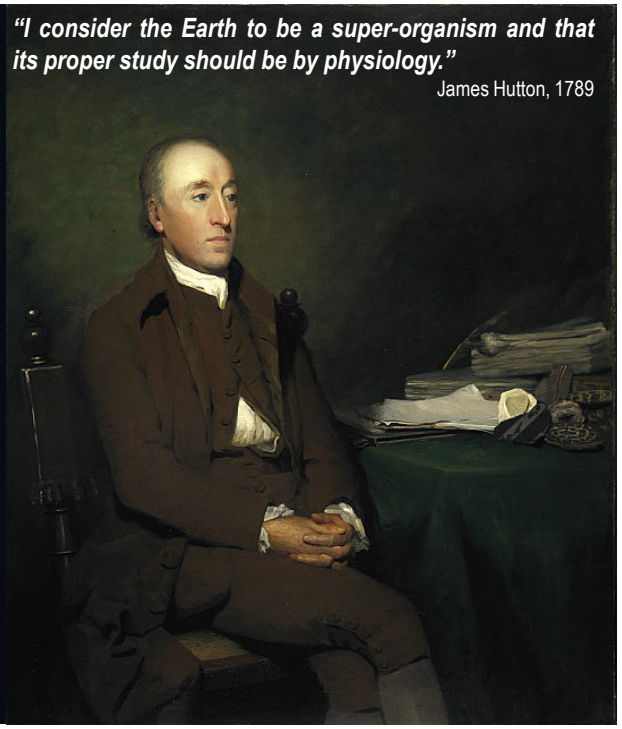
Planeet Aarde …

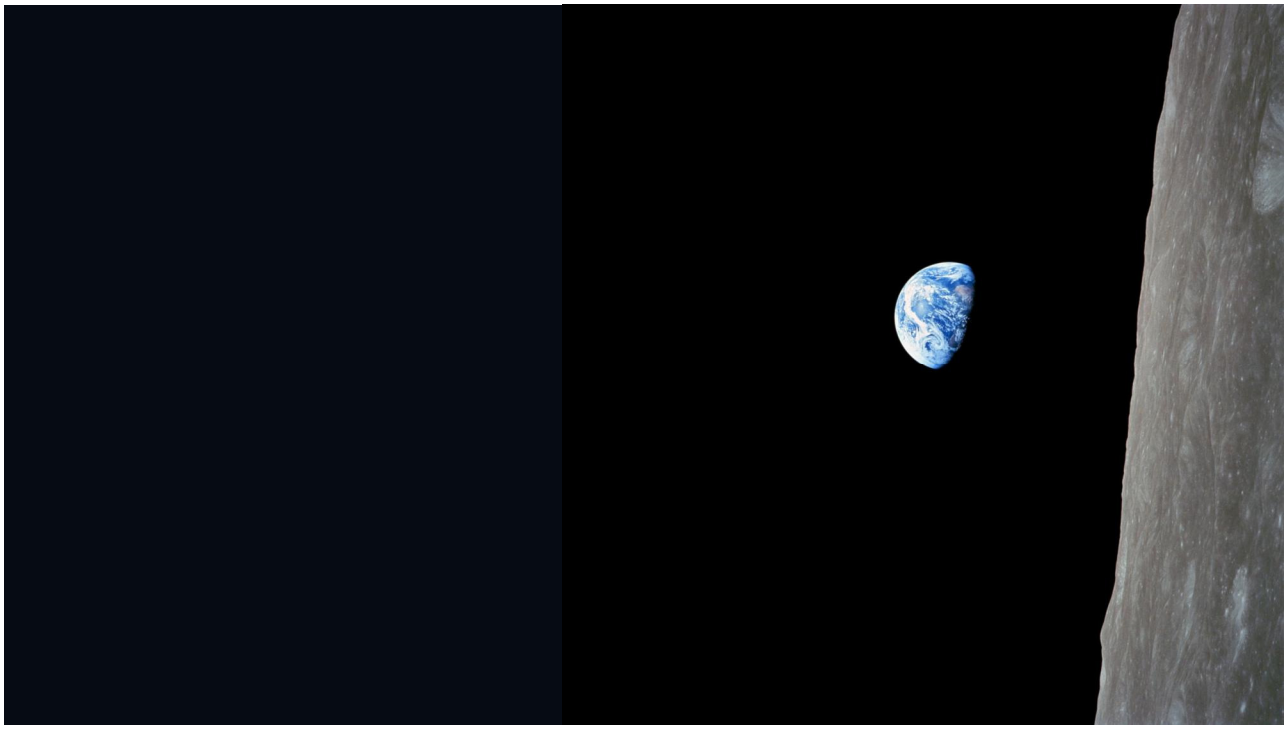
… een planeet die tot leven kwam

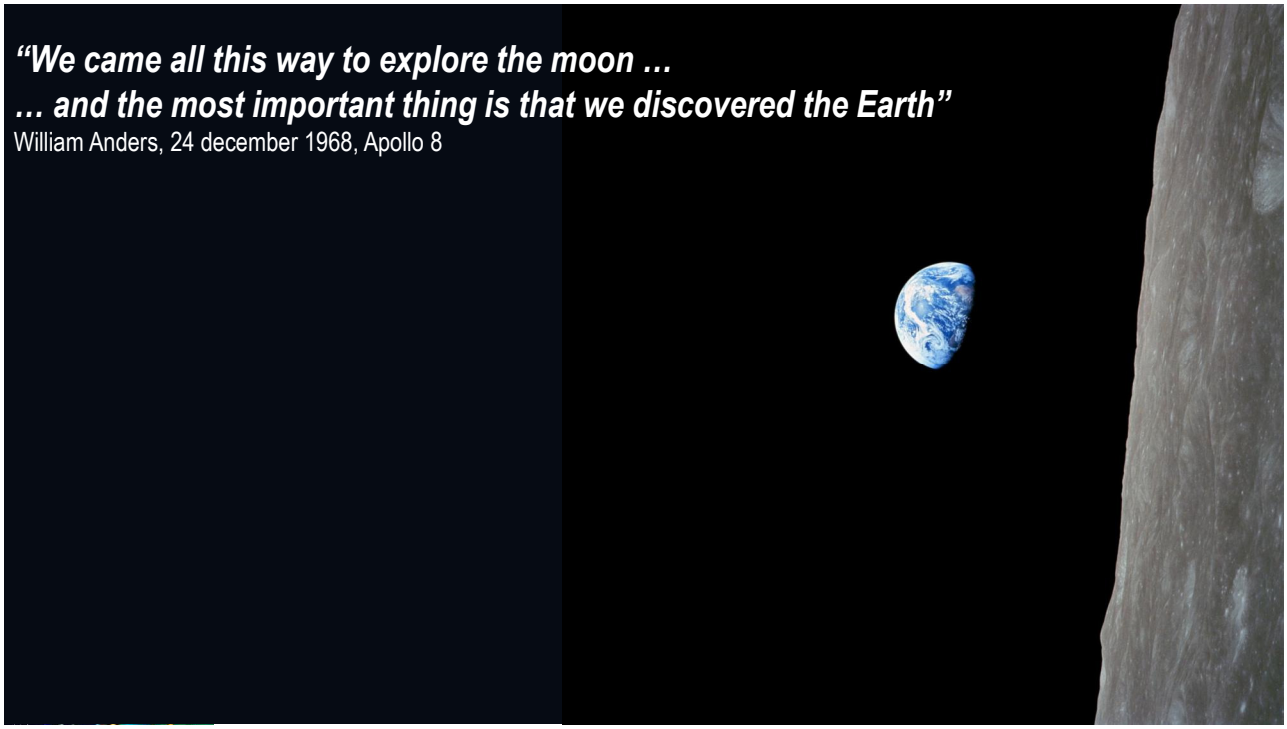
Een levende planeet?

"I consider the Earth to be a super-organism and that its proper study should be by physiology."

James Hutton, 1789





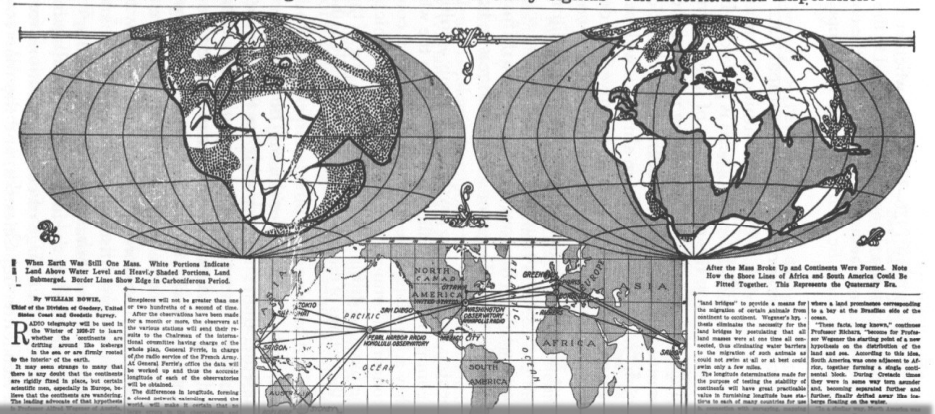

“We came all this way to explore the moon …
… and the most important thing is that we discovered the Earth”
William Anders, 24 december 1968, Apollo 8

"For the first time in my life I saw the horizon as a curved line. It was accentuated by a thin seam of dark blue light—our atmosphere. Obviously this was not the ocean of air I had been told it was so many times in my life. I was terrified by its fragile appearance."
Ulf Merbold

THE NEW YORK TIMES, SUNDAY, SEPTEMBER 6, 1925. XX 5

SCIENTISTS TO TEST 'DRIFT' OF CONTINENTS

Observations of Longitude and Time at Many Points Will Determine After a Period of Years Whether Land Masses Move Like Icebergs in the Sea—Radio to Carry Signals—An International Experiment



When Earth Was Still One Mass. White Portions Indicate Land Above Water Level and Heavily Shaded Portions, Land Submerged. Border Lines Show Edge in Carboniferous Period.

After the Mass Broke Up and Continents Were Formed. Note How the Shore Lines of Africa and South America Could Be Fitted Together. This Represents the Quaternary Era.

By WILLIAM BOWIE,
Chief of the Division of Geodesy, United States Coast and Geodetic Survey.

RADIO telegraphy will be used in the Winter of 1926-27 to learn whether the continents are drifting around like icebergs in the sea, or are firmly rooted to the interior of the earth.

It may seem strange to many that there is any doubt that the continents are rigidly fixed in place, but certain scientific men, especially in Europe, believe that the continents are wandering. The leading advocate of that hypothesis

Unexplored will not be greater than one or two hundredths of a second of time. After the observations have been made for a month or more, the observers at the various stations will send their results to the Chairman of the International committee having charge of the whole plan, General Ferrie, in charge of the radio service of the French Army. At General Ferrie's office the data will be worked up and thus the accurate longitudes of each of the observatories will be obtained.

The differences in longitude, forming a closed network extending around the world, will make it certain that no

"land bridges" to provide a means for the migration of certain animals from one continent to continent, Wegener's hypothesis eliminates the necessity for the land bridges by postulating that all land masses were at one time all connected, thus eliminating water barriers to the migration of such animals as could not swim at all or at best could swim only a few miles.

The longitude determinations made for the purpose of testing the stability of continents will have great practicable value in furnishing longitude base stations to each of many countries for use

where a land prominence corresponding to a bay at the Brazilian side of the ocean.

"These facts, long known," continues Professor Richarz, "become for Professor Wegener the starting point of a new hypothesis on the distribution of the land and sea. According to this idea, South America was once adjacent to Africa, together forming a single continental block. During Cretacic times they were in some way torn asunder and, becoming separated further and further, finally drifted away like icebergs floating on the water.

"if continental drift were true, geologists would have to forget everything which has been learned in the last 70 years and start all over again." –
R.T. Chamberlin 1928

Een levende planeet?

'NEW GLOBAL TECTONICS' – ASILOMAR PENROSE CONFERENCE – 15-20 December 1969

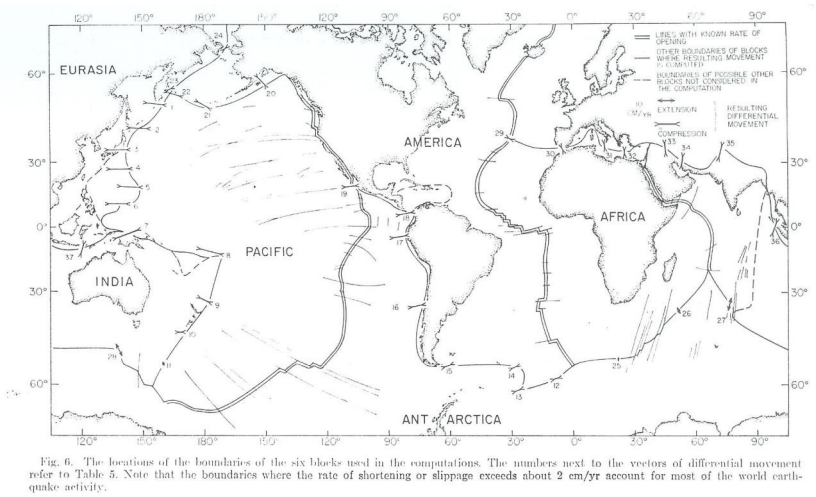


Fig. 6. The locations of the boundaries of the six blocks used in the computations. The numbers next to the vectors of differential movement refer to Table 5. Note that the boundaries where the rate of shortening or slippage exceeds about 2 cm/yr account for most of the world earthquake activity.

Le Pichon, X. 1968. Sea floor spreading and continental drift. *Journal of Geophysical Research 73(12), 3661-3697.*

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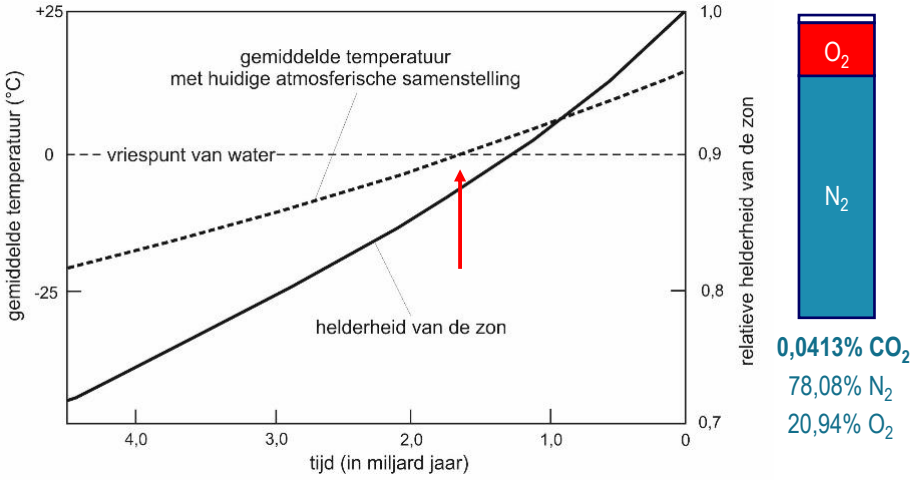
Planeet Aarde, een madeliefjeswereld?

ZWAKKE-ZONPARADOX – Carl Sagan & George Mullen (1972)



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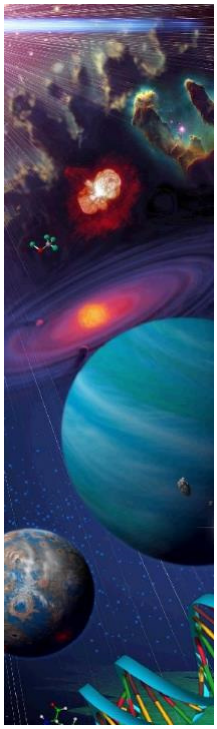
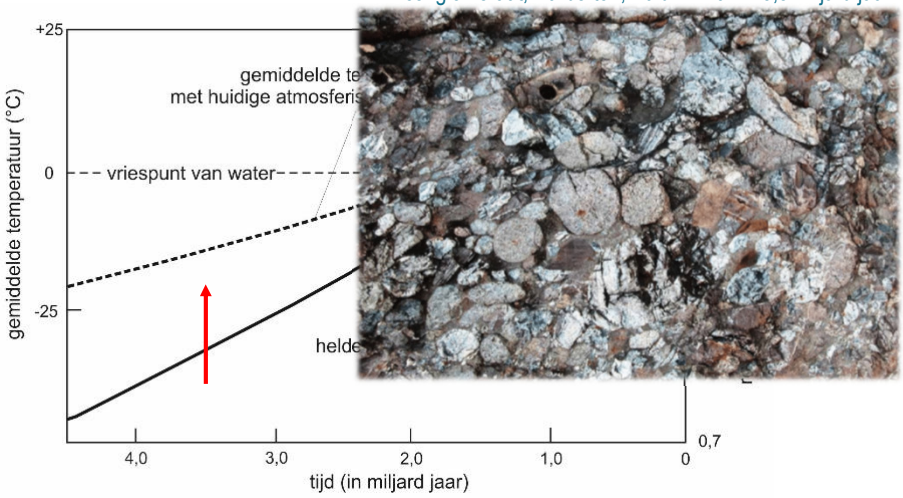


Planeet Aarde, een madeliefjeswereld?

ZWAKKE-ZONPARADOX – Carl Sagan & George Mullen (1972)

conglomeraat, Barberton, Zuid-Afrika - ~3,5 miljard jaar



Sintubin 2011

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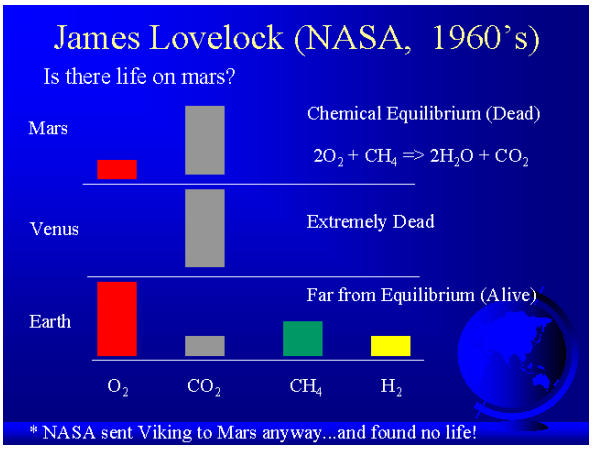
Planeet Aarde, een madeliefjeswereld?

IS ER LEVEN OP MARS? – James Lovelock (1965)
A physical basis for life detection experiments, J. Lovelock, Nature 207, 568-570.

*Hoe herken je een **'levende planeet'**?*
⇨ *'door een dynamische toestand van extreem afwijkend inorganisch chemisch evenwicht'*



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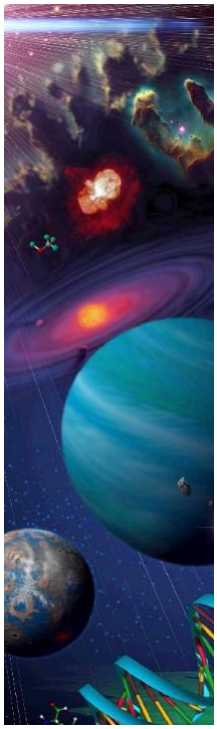

Planeet Aarde, een madeliefjeswereld?

GAIA HYPOTHESE – James Lovelock (1972), Lovelock & Margulis (1973)

⇨ **HOMEOSTATIS**
⇨ 'biosfeer die actief de planetaire omstandigheden controleert en onder 'gewenste' condities houdt'

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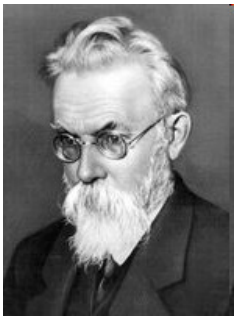
*"de **plaats op het aardoppervlak** waar het leven floreert"*
Eduard Suess (1831-1914) – Das Antlitz der Erde

BIOSFEER

*"een **actieve kracht** die de Aarde vormgeeft"*
Vladimir Ivanovich Vernadsky (1862-1945)



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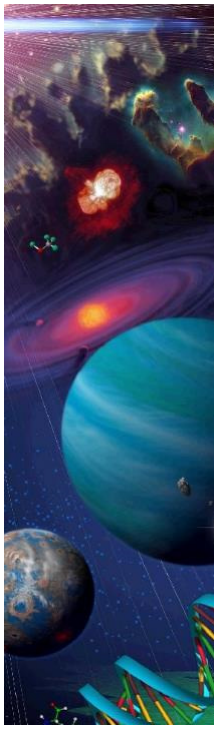
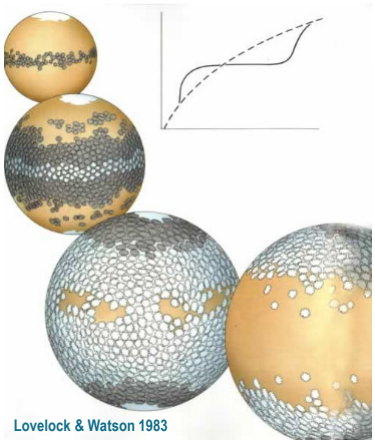
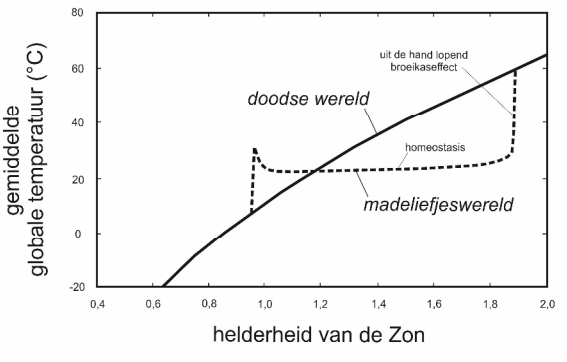


Planeet Aarde, een madeliefjeswereld?

DAISYWORLD – Andrew Watson & James Lovelock (1983)
Biological homeostasis of the global environment: the parable of daisyworld, Tellus 35B,284-289.





Sintubin 2011

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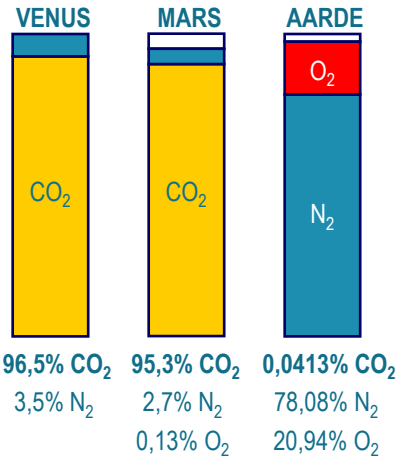
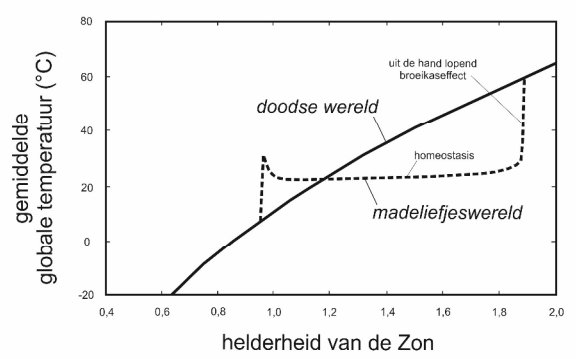
Planeet Aarde, een madeliefjeswereld?

ZWAKKE-ZONPARADOX – Carl Sagan & George Mullen (1972)
⇨ OMVORMING VAN ATMOSFERISCHE SAMENSTELLING
⇨ **vastleggen van CO_2 & aanmaak O_2**





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Shark Bay, Australië - stromatolieten

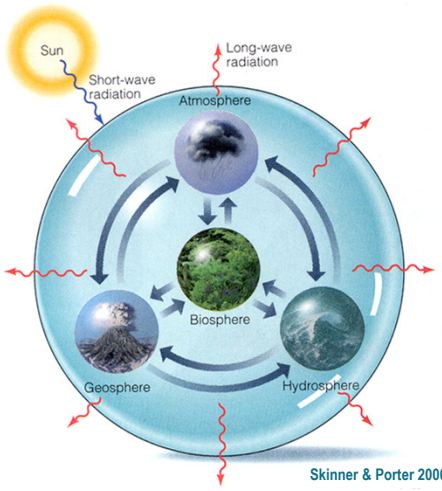

Glacier National Park - stromatolieten


Planeet Aarde, een madeliefjeswereld

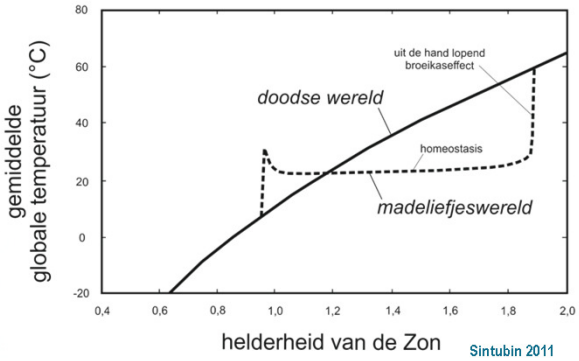
Planeet Aarde, een madeliefjeswereld

HOMEOSTASIS

⇨ actief, **zelfregulerend biogeochemisch systeem** dat de planetaire omstandigheden in een dynamische evenwichtstoestand houdt
= EMERGENTE EIGENSCHAP



Skinner & Porter 2000



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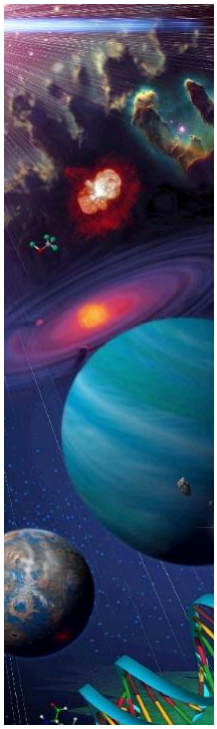
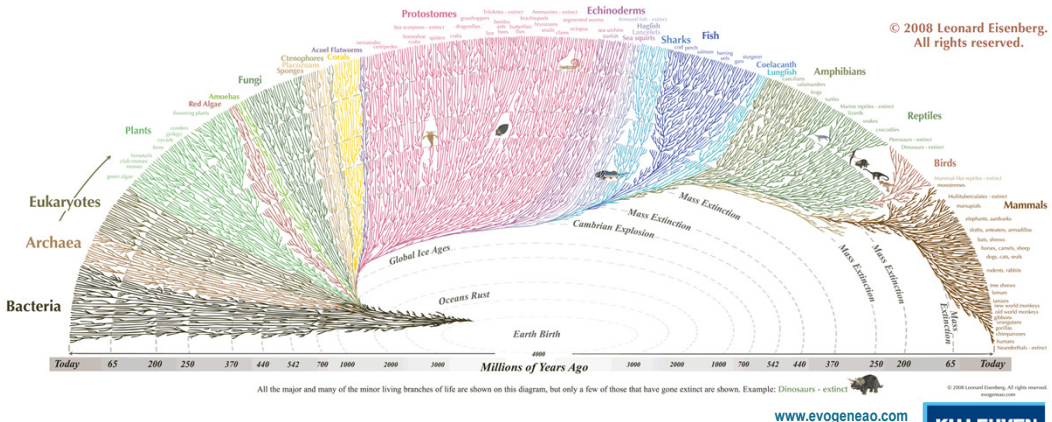


Planeet Aarde, een madeliefjeswereld

'HABITABILITY PROBLEM'?

⇨ 'de planetaire omstandigheden zijn 3 à 4 miljard jaar 'bewoonbaar' gebleven, niettegenstaande het Aardse klimaat aan een delicate balanceeroefening blijkt onderhevig te zijn'



All the major and many of the minor living branches of life are shown on this diagram, but only a few of those that have gone extinct are shown. Example: Dinosaurs - extinct

www.evogeneao.com

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Planeet Aarde, een madeliefjeswereld

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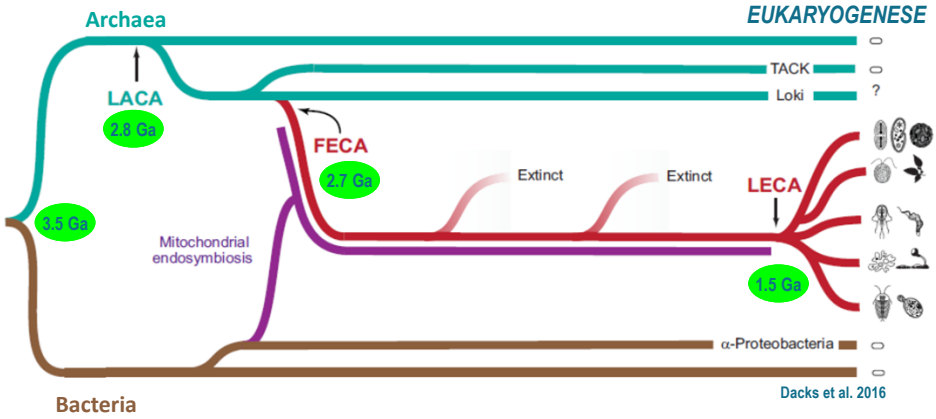

⇨ **LACA** = *Last Archaeal Common Ancestor – ~2.8 Ga (?)*
⇨ **FECA** = *First Eukaryotic Common Ancestor – ~2.7 Ga (?)*
⇨ **LECA** = *Last Eukaryotic Common Ancestor – ~1.5 Ga (?)*

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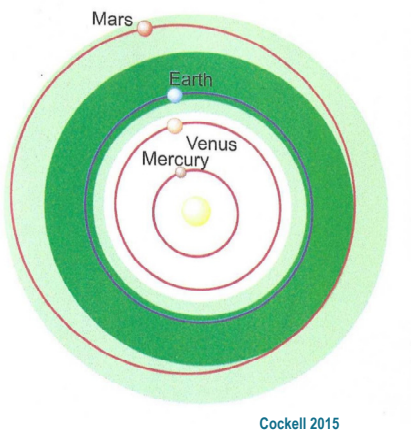
Planeet Aarde, een bewoonde wereld

Planeet Aarde, een bewoonde wereld

BEWOONBARE ZONE – *'CIRCUMSTELLAR HABITABLE ZONE'*

⇨ *schil rond een ster waar de gemiddelde planetaire oppervlaktetemperatuur juist goed is om permanent **vloeibaar water** toe te laten aan het oppervlak'* – Su-Shu Huang, 1959

⇨ tussen **0.99** en **1,688 AU** (Kopparapu et al. 2013)



Cockell 2015

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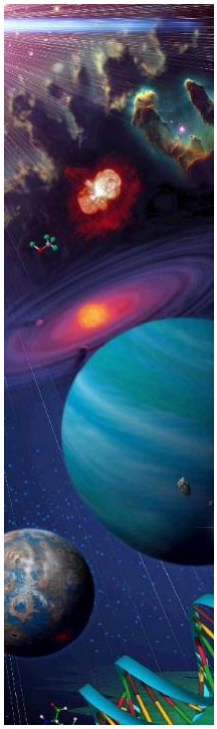

Planeet Aarde, een bewoonde wereld

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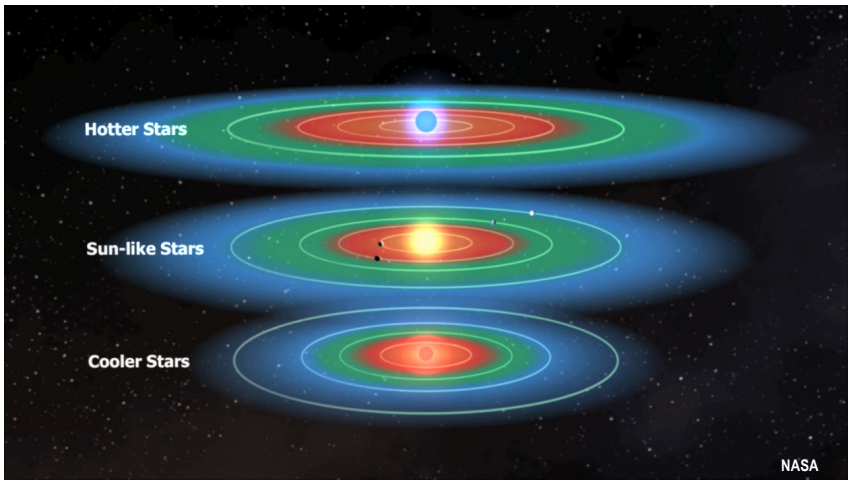

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Planeet Aarde, een bewoonde wereld

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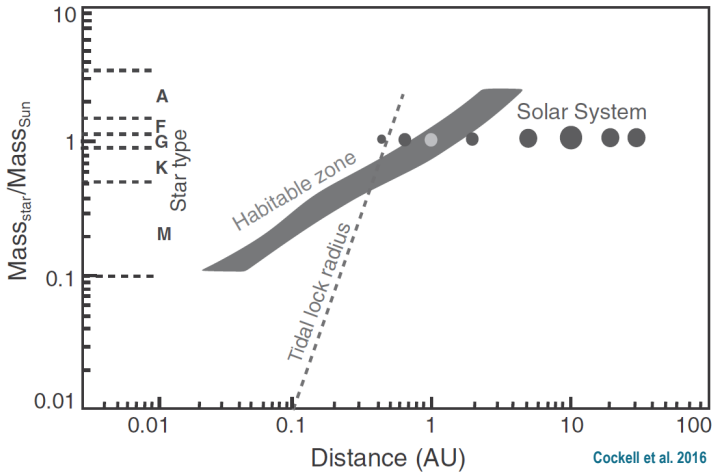

Cockell et al. 2016

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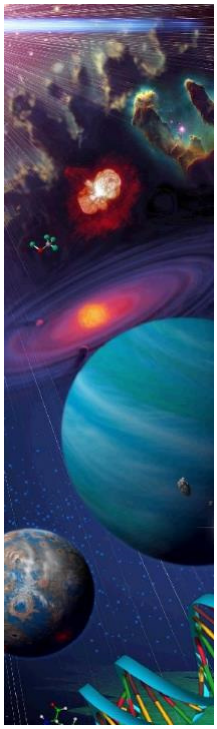

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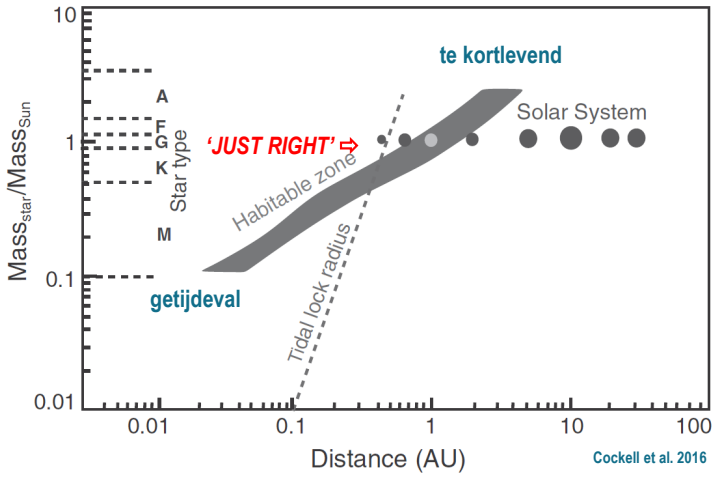
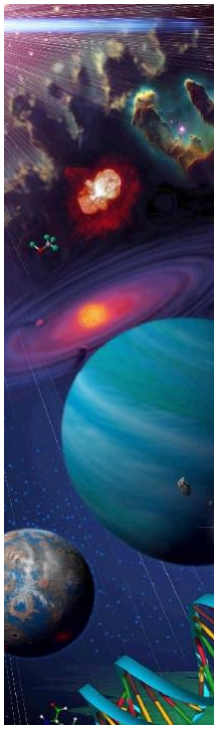


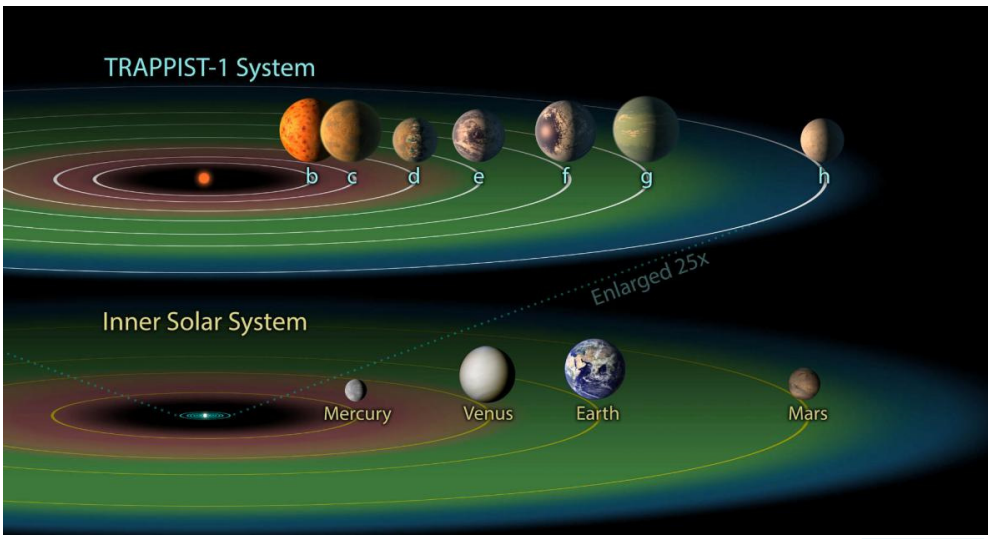
Cockell et al. 2016

KU LEUVEN



Planeet Aarde, een bewoonde wereld

BEWOONBARE EXOPLANETEN?



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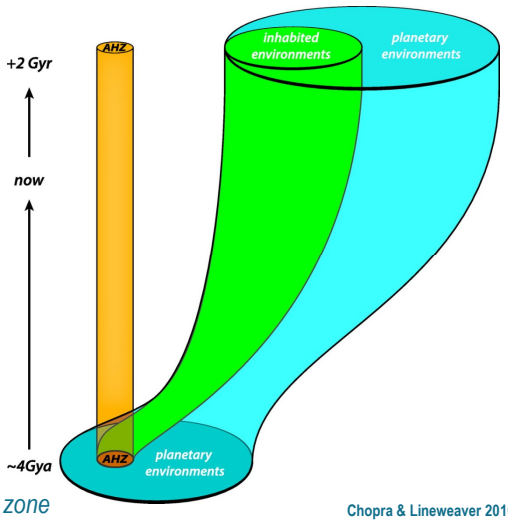
Planeet Aarde, een bewoonde wereld

ABIOGENESIS HABITABLE ZONE – AHZ

⇨ de *'goudlokje'* **planetaire omstandigheden** waarbinnen leven kan ontstaan



AHZ = *abiogenesis habitable zone*

Chopra & Lineweaver 2016

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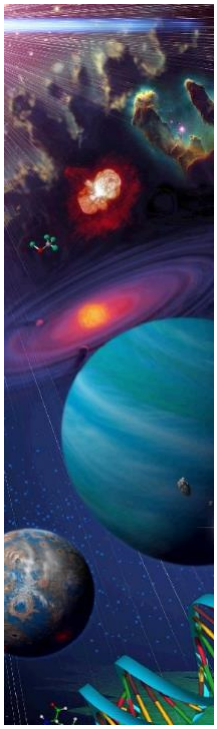
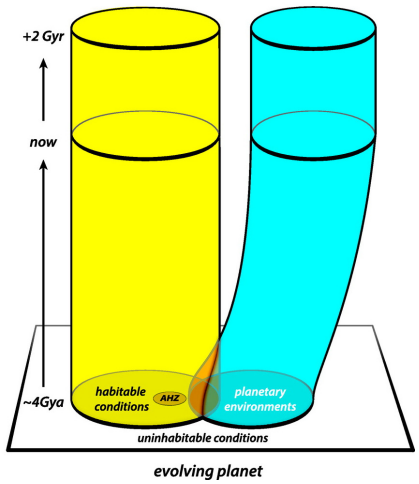


Planeet Aarde, een bewoonde wereld

EMERGENTIE FLESSENHALS – *EMERGENCE BOTTLENECK*

⇨ AHZ buiten planetaire omstandigheden



Chopra & Lineweaver 2016

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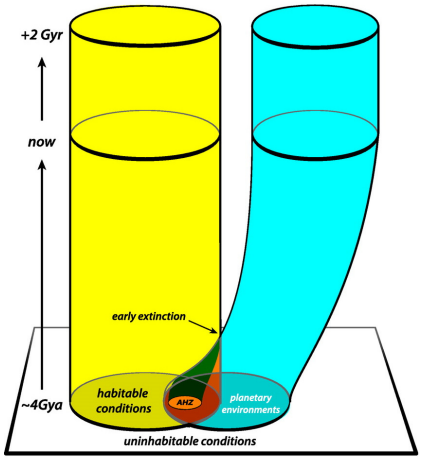
Planeet Aarde, een bewoonde wereld

GAIAANSE FLESSENHALS – *GAIAN BOTTLENECK*

- ⇨ AHZ binnen planetaire omstandigheden
- ⇨ geen *'terraforming'* biosfeer



Gaian Bottleneck: Early Extinction

Chopra & Lineweaver 2016

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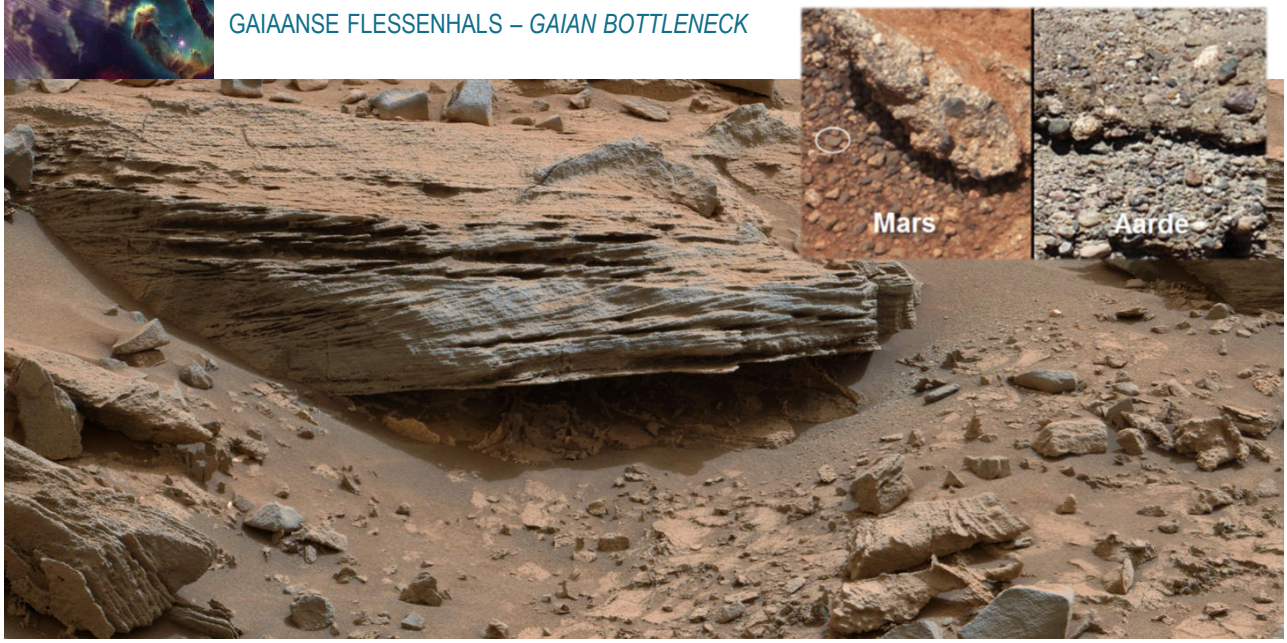
Planeet Aarde, een bewoonde wereld

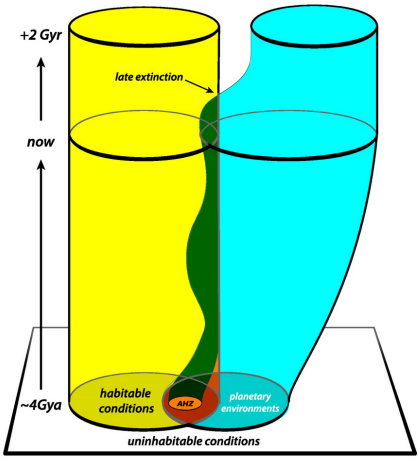
GAIAANSE FLESSENHALS – *GAIAN BOTTLENECK*



Planeet Aarde, een bewoonde wereld

GAIAANSE REGULERING – *GAIAN REGULATION*

⇨ ***'terraforming'* biosfeer**



Gaian Regulation: Late Extinction

Chopra & Lineweaver 2016

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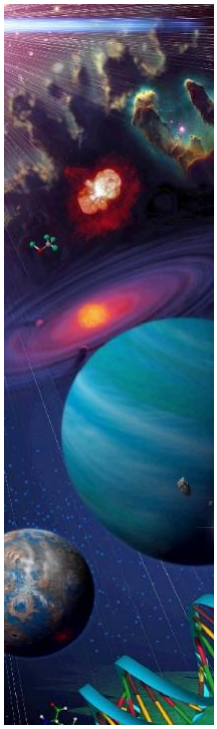
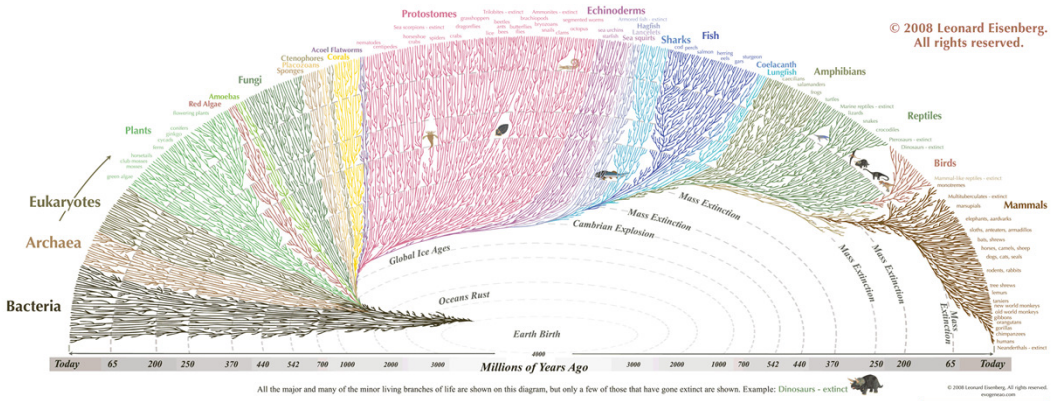


Planeet Aarde, een bewoonde wereld

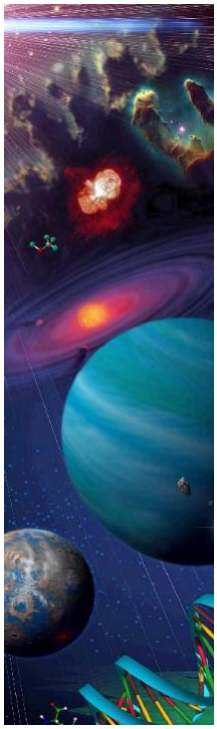
GAIAANSE REGULERING – *GAIAN REGULATION*

⇨ 'de planetaire omstandigheden zijn 3 à 4 miljard jaar 'bewoonbaar' gebleven, niettegenstaande het Aardse klimaat aan een delicate balanceeroefening blijkt onderhevig te zijn'



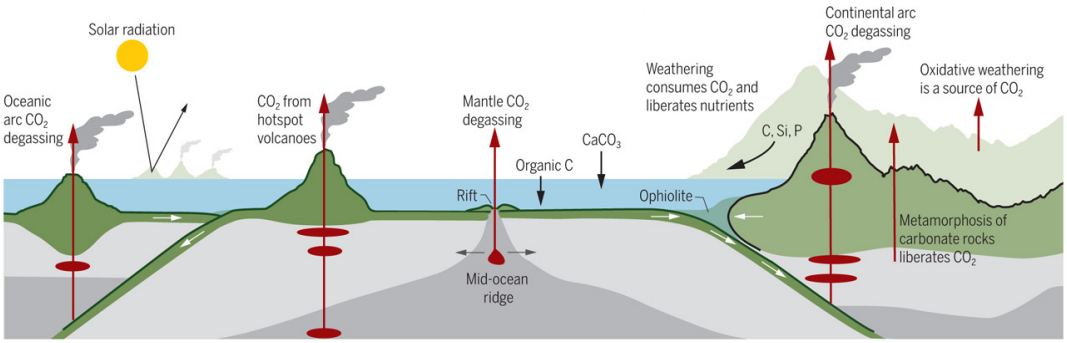
www.evogeneao.com

KU LEUVEN



Aardse thermostaat

CARBONAAT-SILICAATCYCLUS



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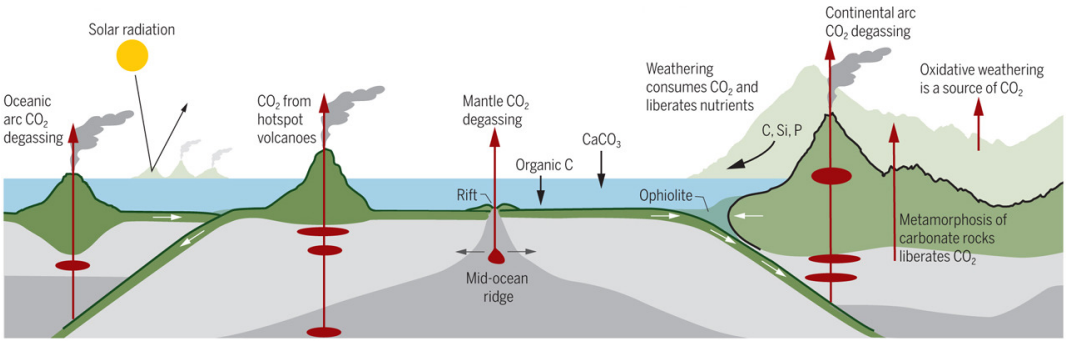
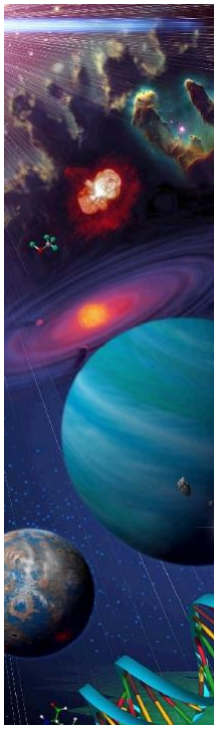
Aardse thermostaat

CARBONAAT-SILICAATCYCLUS

- ⇨ VRIJGEVEN van CO_2
  - ⇨ vulkanisme & gebergtevorming (geosfeer)
  - ⇨ celademhaling / verrotting organisch materiaal (biosfeer)



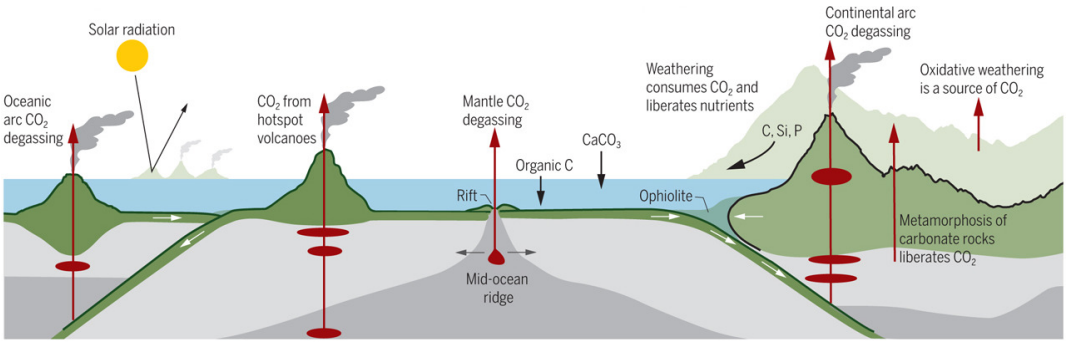
KU LEUVEN



Aardse thermostaat

CARBONAAT-SILICAATCYCLUS

- ⇨ VASTLEGGEN van CO_2
  - ⇨ **continentale silicaatverwering** (geosfeer)
  - ⇨ fotosynthese / begraving organisch materiaal (biosfeer)
  - ⇨ oplossing (hydrosfeer)



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Aardse thermostaat

CARBONAAT-SILICAATCYCLUS

⇨ AFVANGEN van CO_2

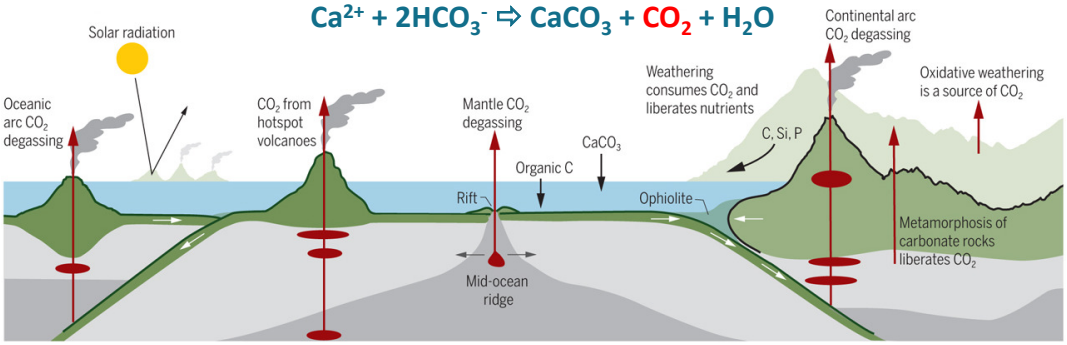
⇨ chemische verwering van continentale silicaatgesteenten

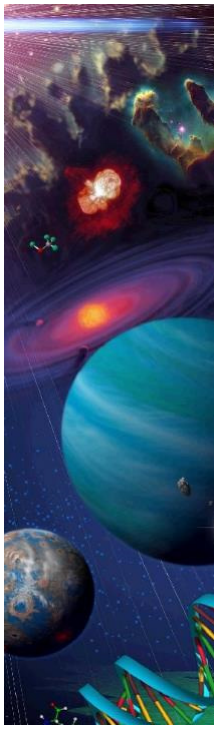
$$CaSiO_3 + 2CO_2 + H_2O \Rightarrow Ca^{2+} + 2HCO_3^- + SiO_2$$

⇨ VASTLEGGEN van CO_2

⇨ biogene neerslag van kalkgesteenten

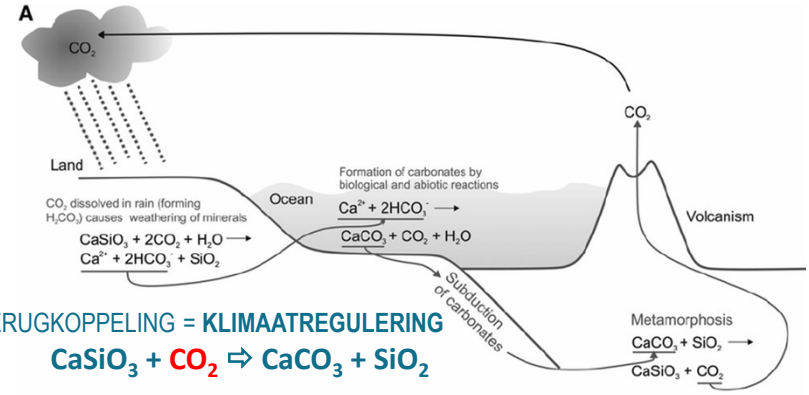
$$Ca^{2+} + 2HCO_3^- \Rightarrow CaCO_3 + CO_2 + H_2O$$





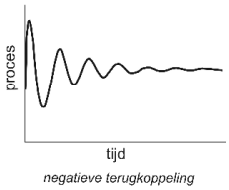
Aardse thermostaat

CARBONAAT-SILICAATCYCLUS

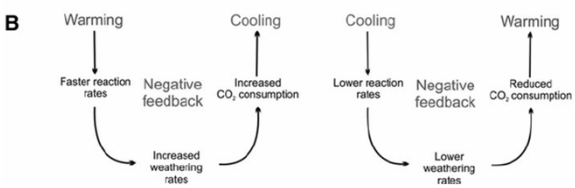


⇨ NEGATIEVE TERUGKOPPELING = **KLIMAATREGULERING**

$$CaSiO_3 + CO_2 \Rightarrow CaCO_3 + SiO_2$$



negatieve terugkoppeling



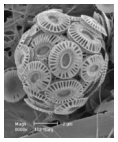
Cockell 2015

Aardse thermostaat

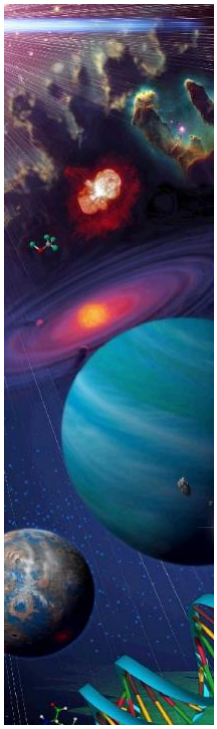
CARBONAAT-SILICAATCYCLUS

⇨ VASTLEGGEN van CO_2

⇨ biogene neerslag van kalkgesteenten



KU LEUVEN

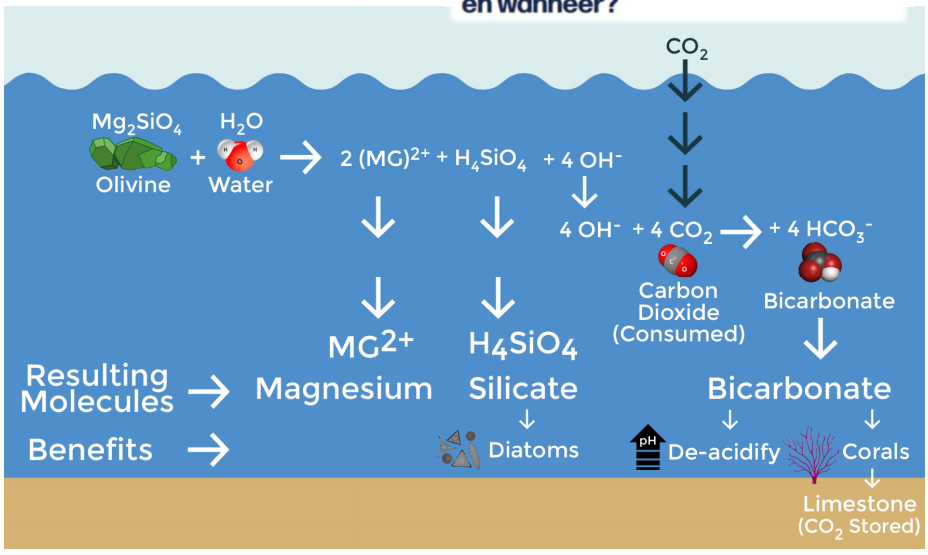


Aardse thermostaat

'ENHNACED WEATHERING'

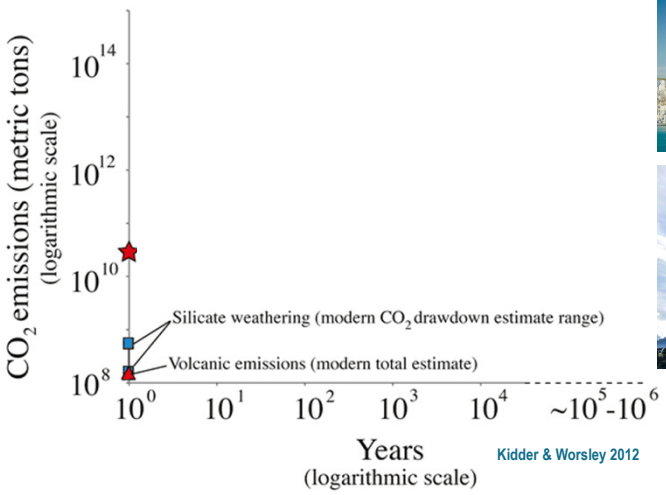
⇨ VASTLEGGEN van CO_2

Olivijn in zee strooien om CO2 uit de lucht te halen: geen sciencefiction meer, maar op welke schaal kan het en wanneer?



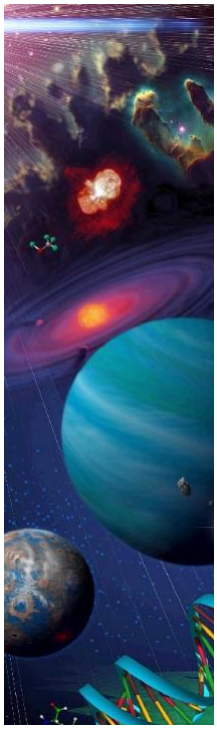
Aardse thermostaat

CARBONAAT-SILICAATCYCLUS



Kidder & Worsley 2012

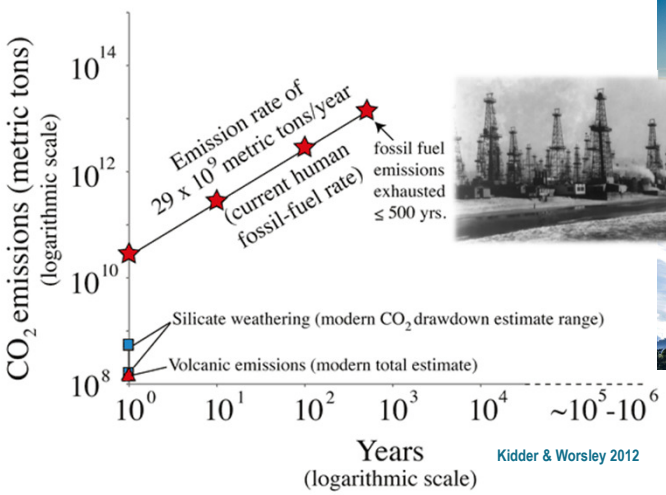
KU LEUVEN



Aardse thermostaat

CARBONAAT-SILICAATCYCLUS

⇨ **ANTROPOGENE *'CARBON BURP'***



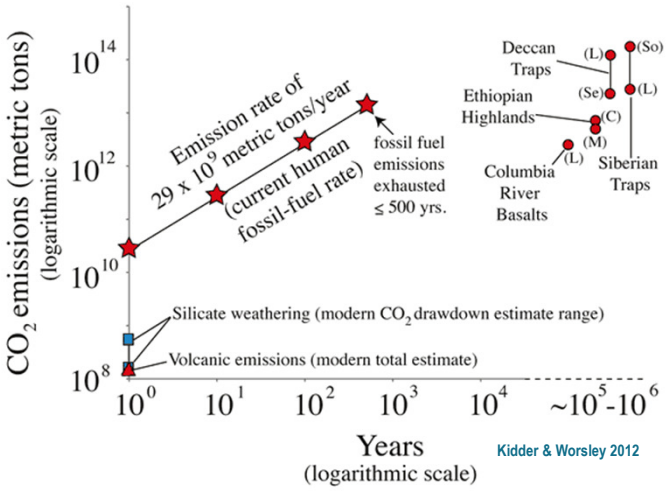
Kidder & Worsley 2012

KU LEUVEN

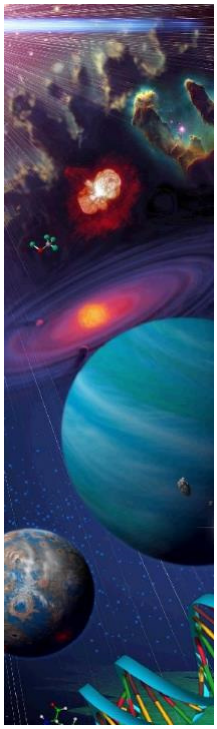
Aardse thermostaat

CARBONAAT-SILICAATCYCLUS

⇨ **ANTROPOGENE *'CARBON BURP'***



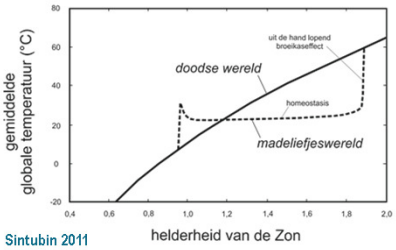
Kidder & Worsley 2012



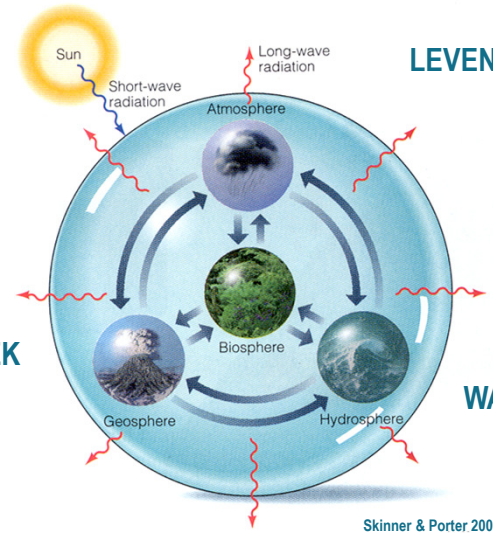
Aardse thermostaat

HOMEOSTASIS

⇨ *wat zijn de hoofdrolspelers in het onderhouden van homeostasis voor bijna 4 miljard jaar?*



Sintubin 2011



LEVEN

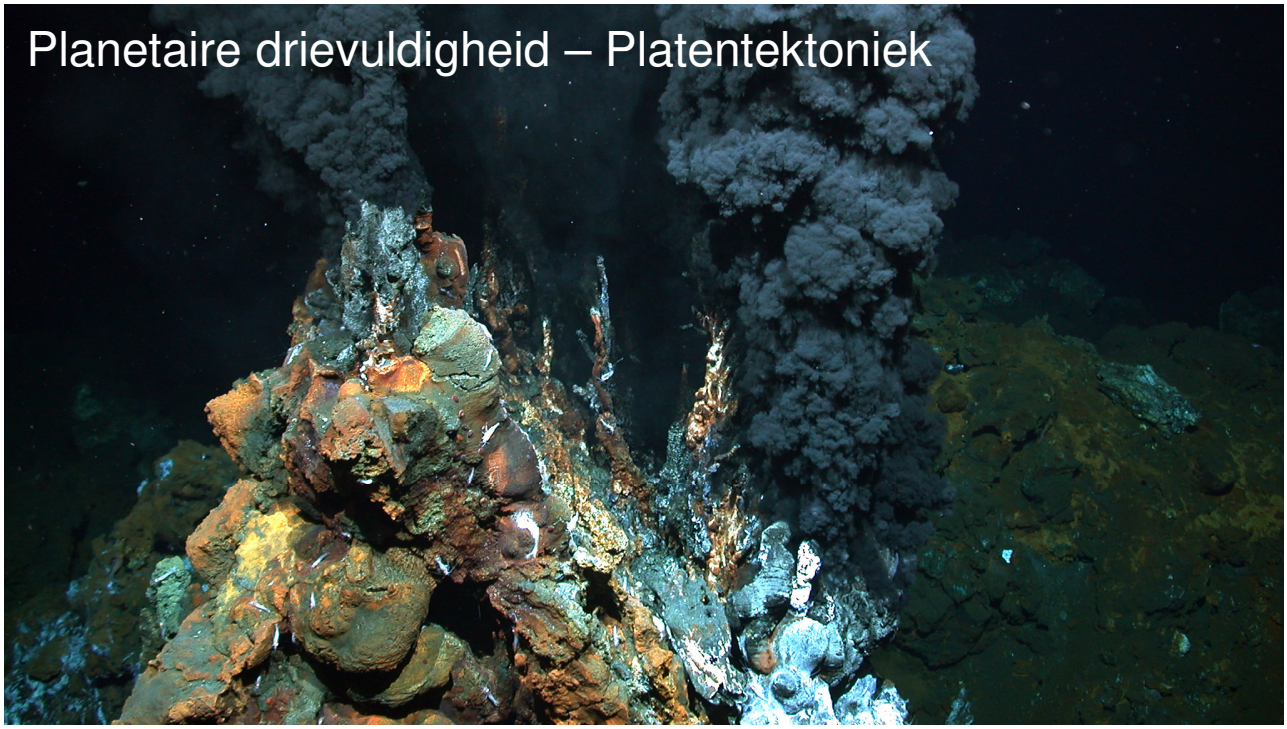
PLATENTEKTONIEK

WATER

Skinner & Porter 2000

KU LEUVEN

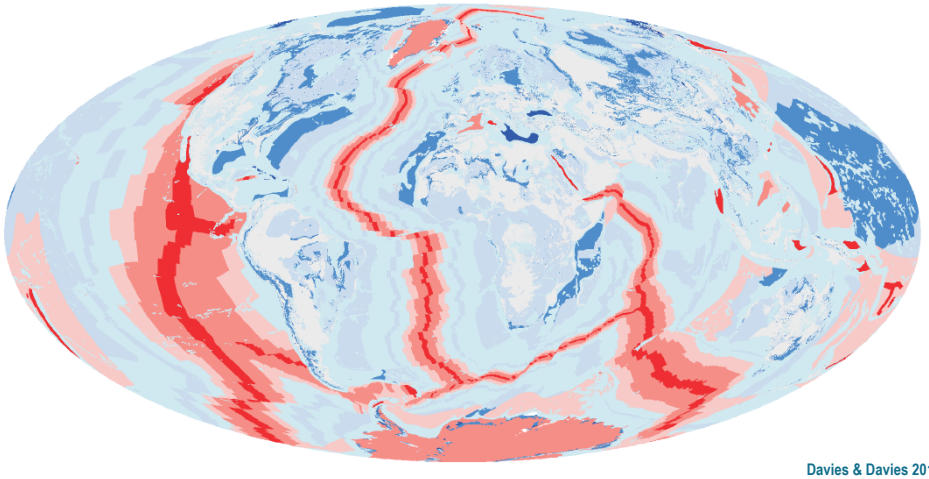

Planetaire drievuldigheid


Planetaire drievuldigheid – Platentektoniek

Platentektoniek

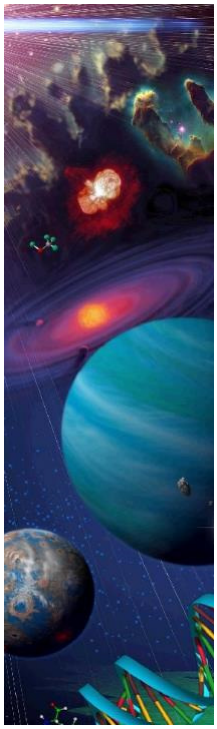
UNIEK AFKOELINGSMECHANISME

⇨ warmteoverdracht **~92 mW/m²**



Davies & Davies 2010

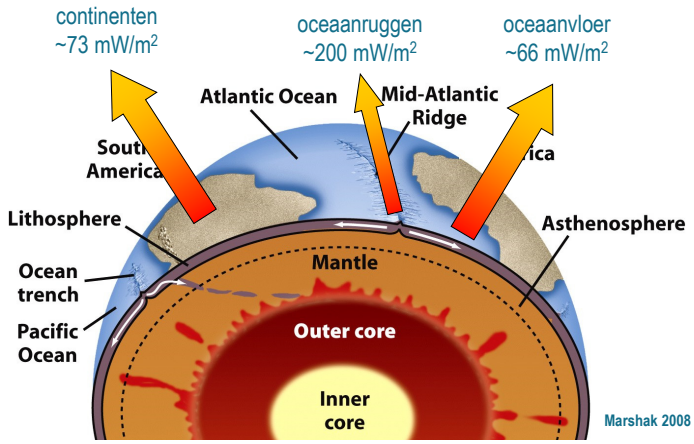
KU LEUVEN



Platentektoniek

UNIEK AFKOELINGSMECHANISME

⇨ warmteoverdracht **~92 mW/m²**



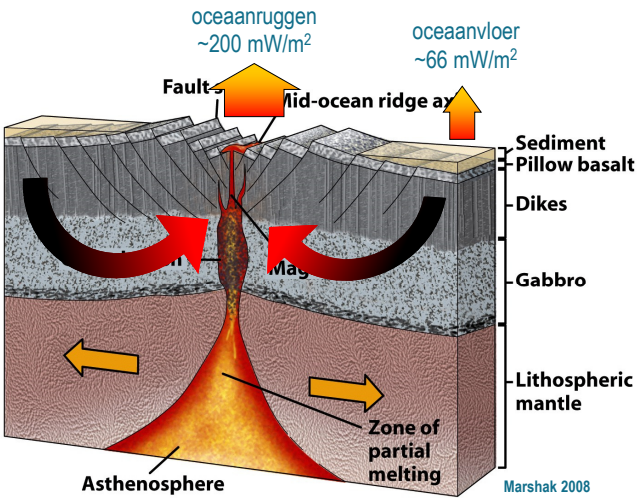
Marshak 2008

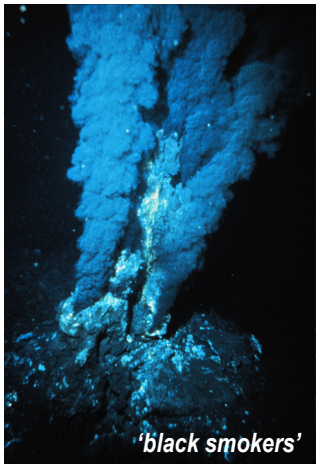
KU LEUVEN

Platentektoniek

UNIEK AFKOELINGSMECHANISME

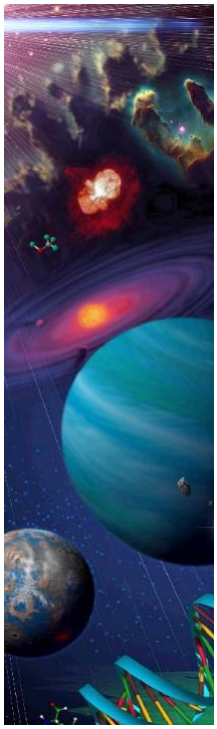
⇨ warmteoverdracht **~92 mW/m²**





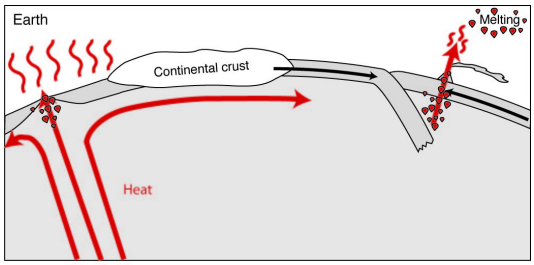
WATER !

KU LEUVEN

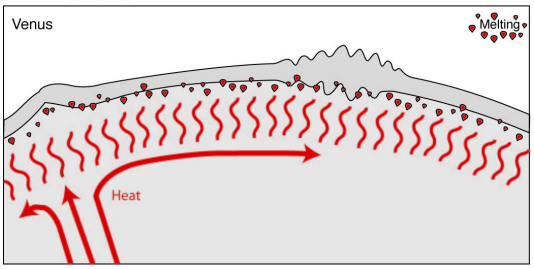


Platentektoniek

UNIEK AFKOELINGSMECHANISME



⇨ 'mobiel' plaattektonisch regime



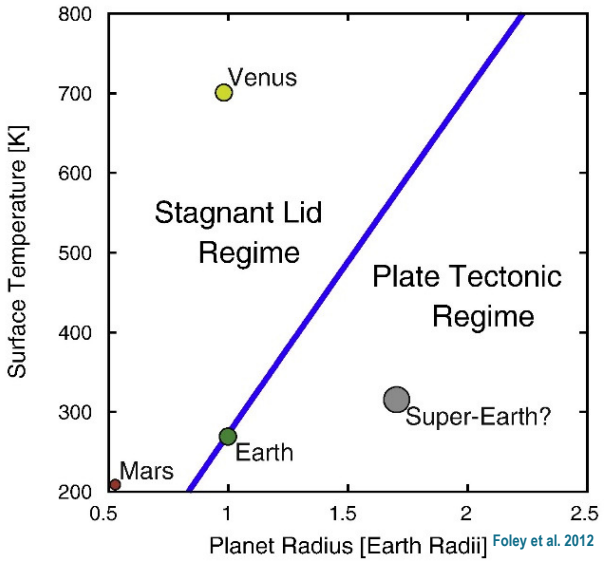
⇨ '*stagnant lid*' regime

KU LEUVEN

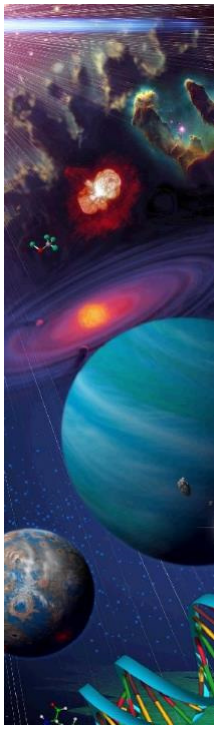
Platentektoniek

UNIEK AFKOELINGSMECHANISME

⇨ **SUPERAARDES ?**



KU LEUVEN



Platentektoniek

CONTINENTALE KORST

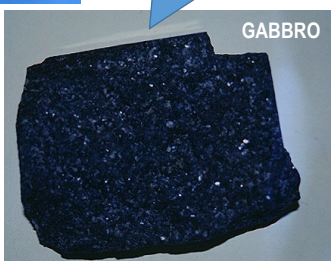
⇨ gefractioneerde kristallisatie

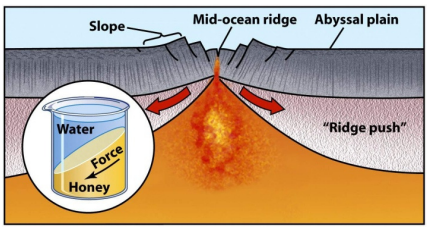
⇨ vorming van **basaltische oceanische korst**

PERIDOTIET

mantel

oceanische korst





Marshak 2008

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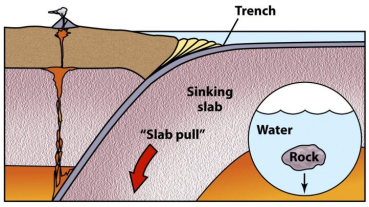
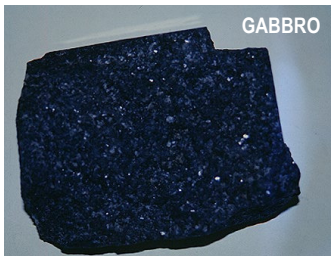
Platentektoniek

CONTINENTALE KORST
- ⇨ partiële opsmelting
- ⇨ vorming van **granodioritische continentale korst**



Marshak 2008

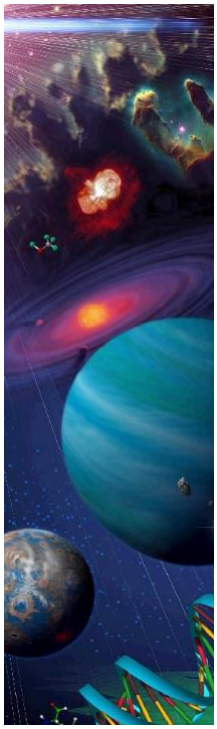
oceanische korst



continentale korst

DIORIET

KU LEUVEN



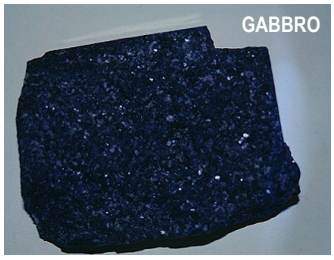
Platentektoniek

CONTINENTALE KORST
- ⇨ **uniek product van platentektoniek!**

PERIDOTIET

mantel

oceanische korst



continentale korst

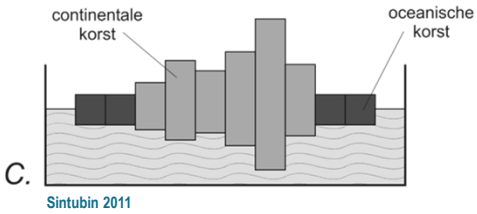
DIORIET

KU LEUVEN

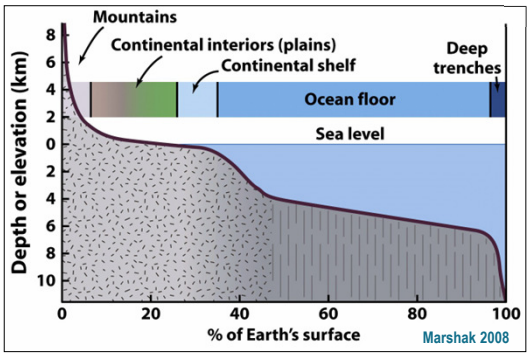
Platentektoniek

CONTINENTALE KORST

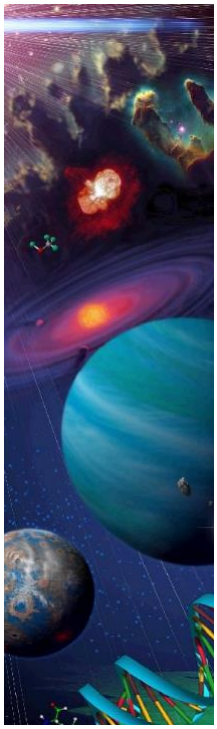
⇨ **lage dichtheid!**



isostasisch evenwicht
tussen oceanische en continentale korst



KU LEUVEN

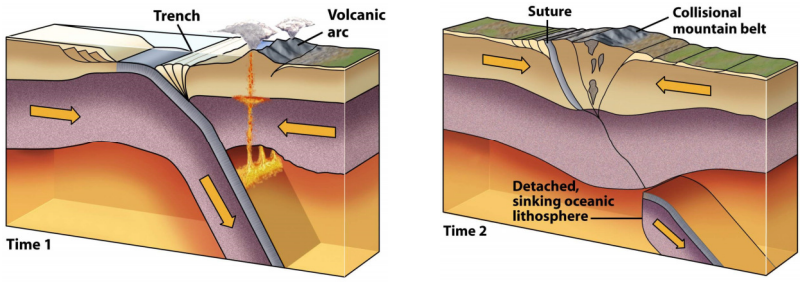


Platentektoniek

CONTINENTALE KORST

⇨ lage dichtheid!

⇨ niet gerecycleerd bij subductie ⇔ **gebergtevorming**



Marshak 2008

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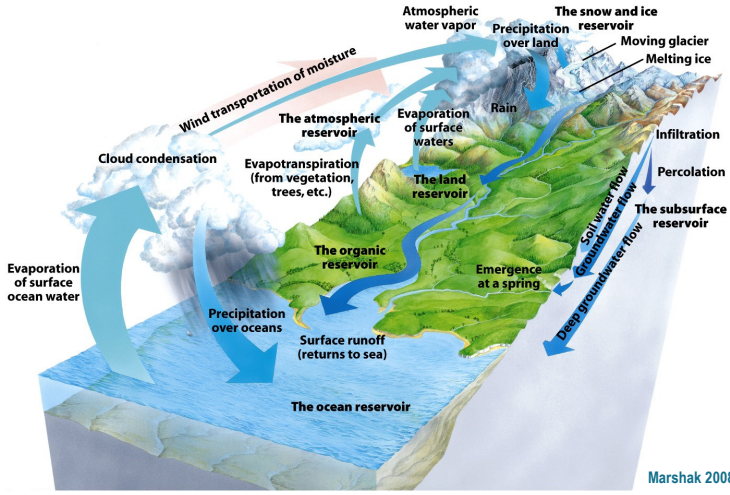
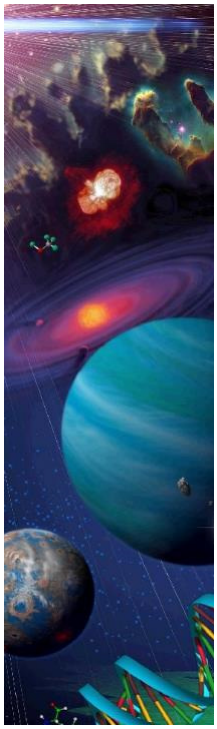
Platentektoniek

CONTINENTALE KORST
- ⇨ lage dichtheid!
- ⇨ niet gerecycleerd bij subductie ⇔ gebergtevorming
  - ⇨ fluxen van chemische elementen ⇔ **biogeochemische cycli**



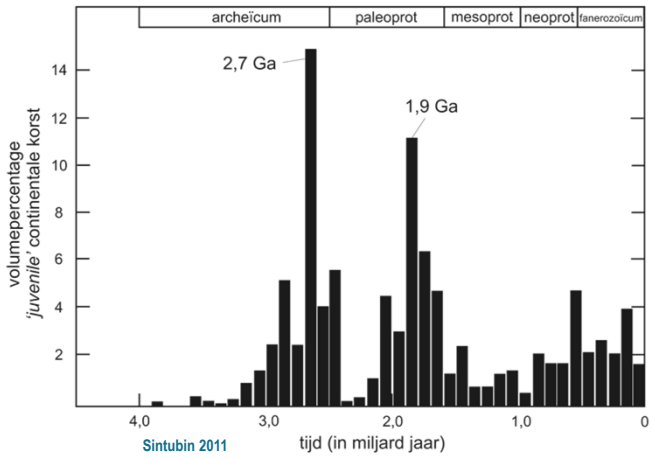
Marshak 2008

KU LEUVEN



Platentektoniek

CONTINENTALE KORST
- ⇨ lage dichtheid!
- ⇨ niet gerecycleerd bij subductie ⇔ gebergtevorming
- ⇨ **aangroei** van globale continentale massa (~1.67 km^3/jaar over aardse geschiedenis)



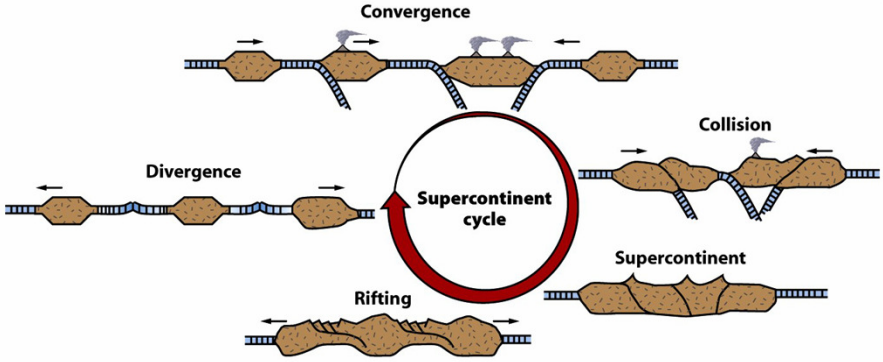
Sintubin 2011

KU LEUVEN

Platentektoniek

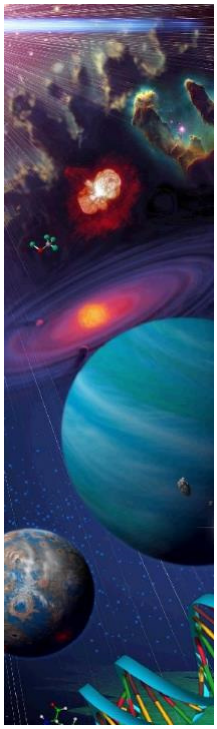
CONTINENTALE KORST

- ⇨ lage dichtheid!
- ⇨ niet gerecycleerd bij subductie ⇔ gebergtevorming
- ⇨ aangroei van globale continentale massa (~1.67 km^3/jaar over aardse geschiedenis)
- ⇨ **supercontinentcyclus**



Marshak 2008

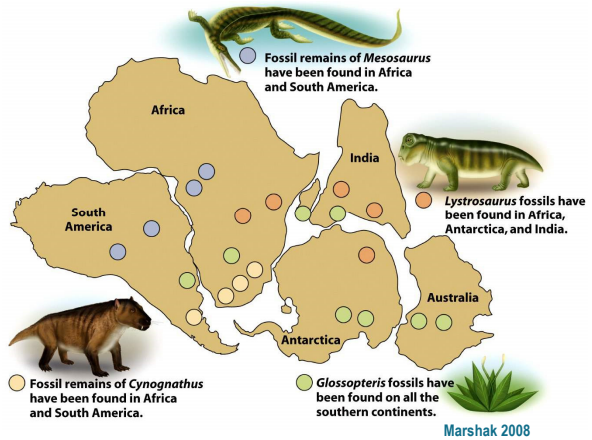
KU LEUVEN



Platentektoniek

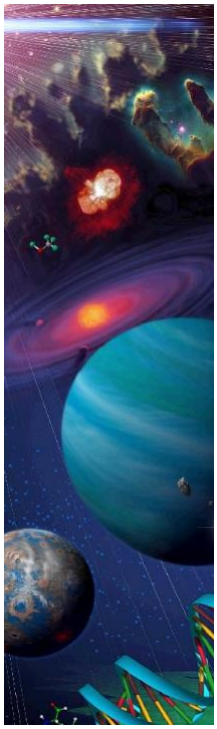
CONTINENTALE KORST

- ⇨ lage dichtheid!
- ⇨ niet gerecycleerd bij subductie ⇔ gebergtevorming
- ⇨ aangroei van globale continentale massa (~1.67 km^3/jaar over aardse geschiedenis)
- ⇨ supercontinentcyclus
- ⇨ **continentendrift**



Marshak 2008

KU LEUVEN



Water

WATERWERELD?

'How inappropriate to call this planet Earth, when clearly it is Ocean' – Arthur C. Clarke (1917-2008)

Water

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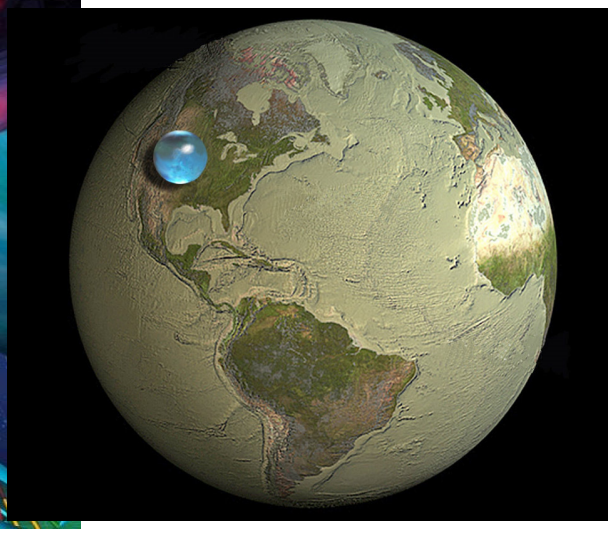

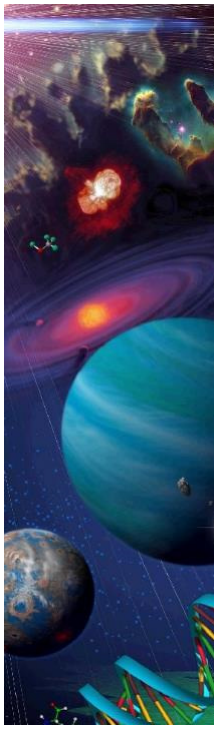

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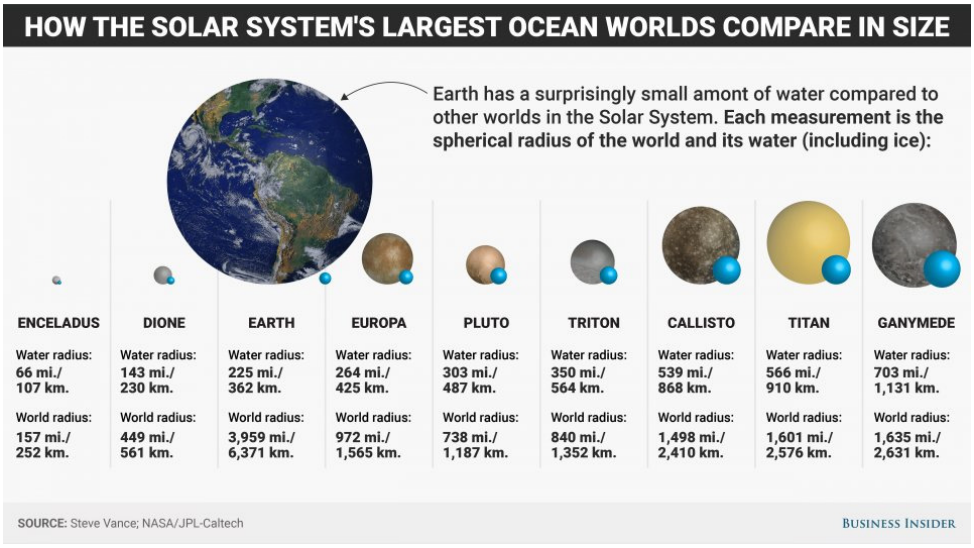
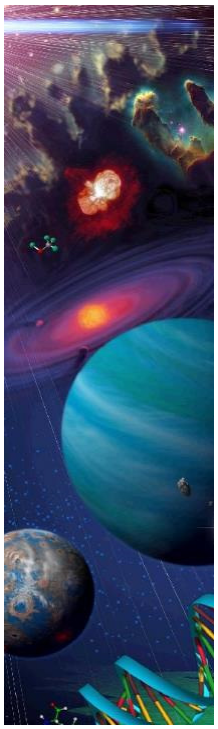
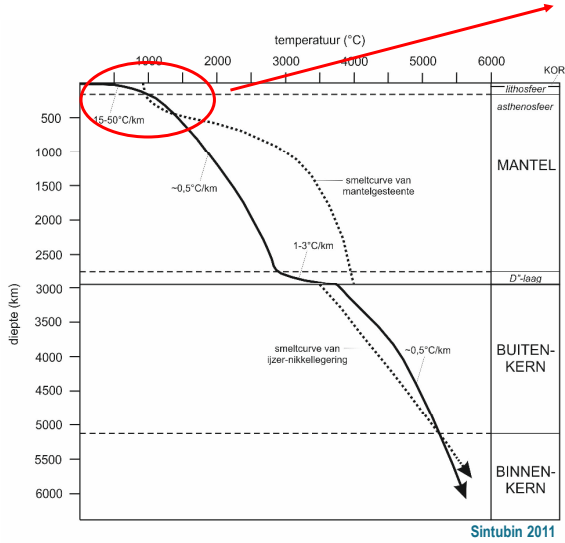


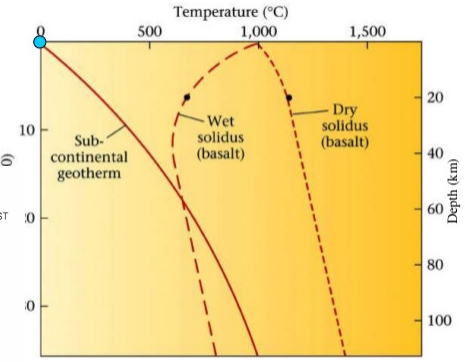


Water

PLATENTEKTONIEK

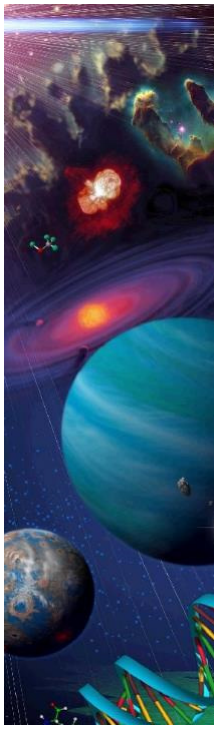
⇨ **magmatisme**





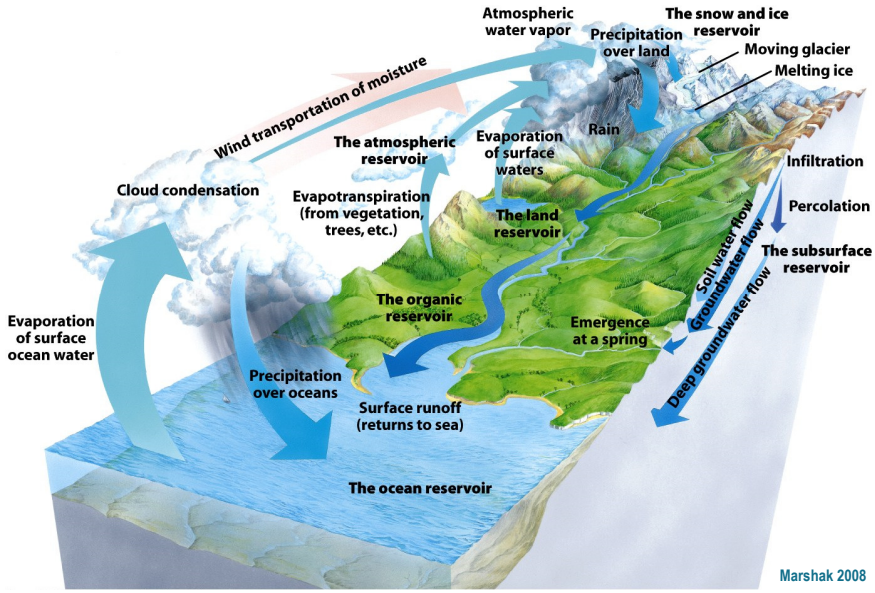
Sintubin 2011

KU LEUVEN



Water

HYDROLOGISCHE CYCLUS

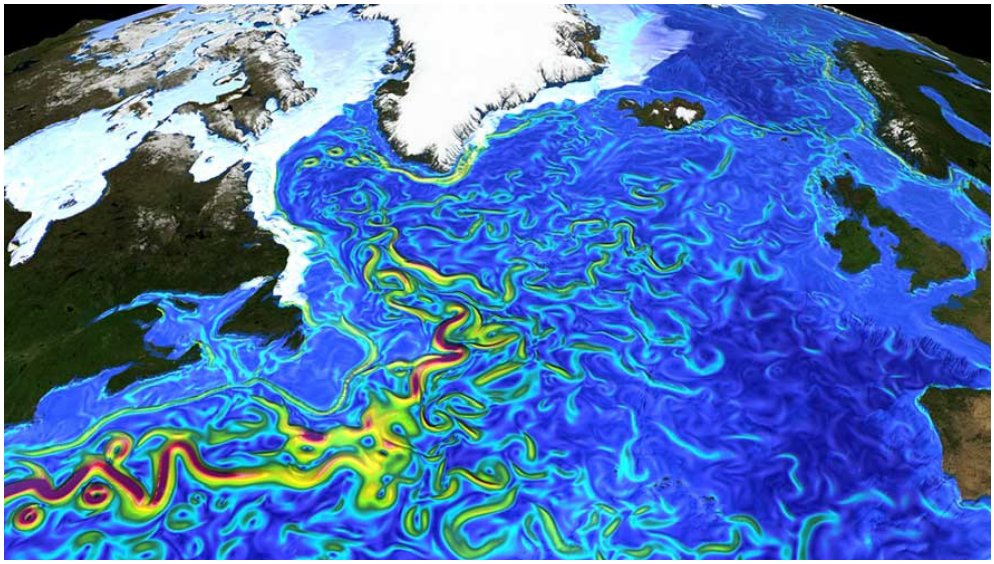


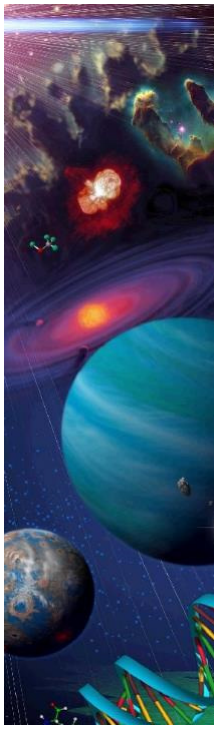
Marshak 2008

KU LEUVEN

Water

OCEAANCIRCULATIE





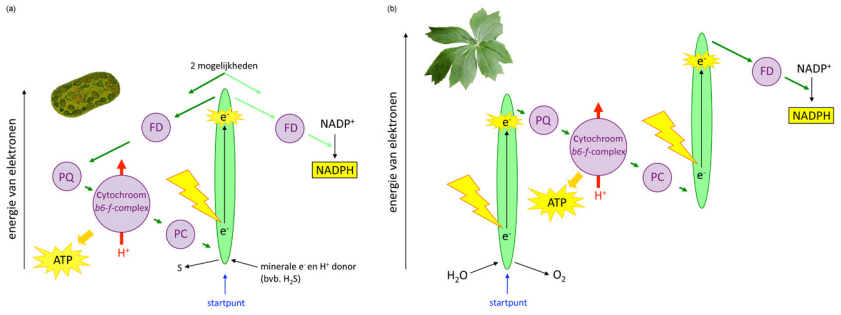
Water

IJS – CRYOSFEER

Water

FOTOSYNTHESE

ANOXYGENE versus OXYGENE FOTOSYNTHESE



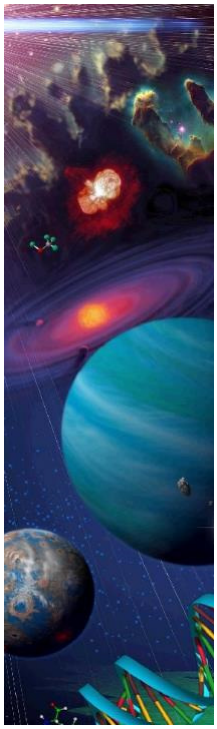
⇨ H_2S als electronendonor

⇨ **H_2O als electronendonor**

⇨ O_2 als afvalproduct

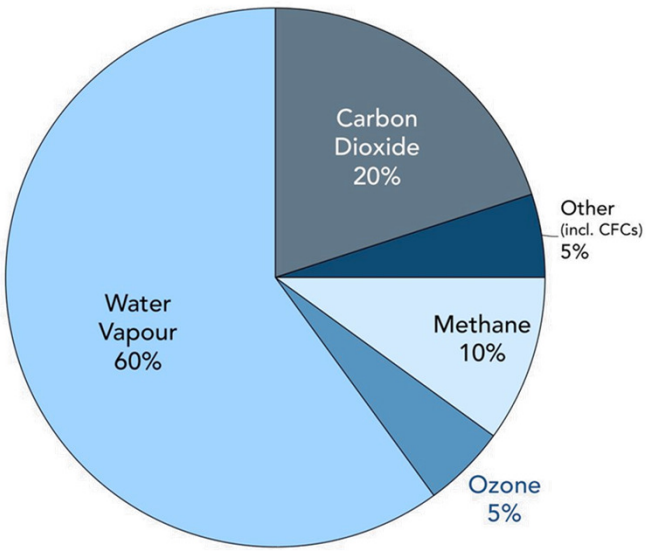
De Groef & Roels 2009

KU LEUVEN



Water

BROEIKASEFFECT

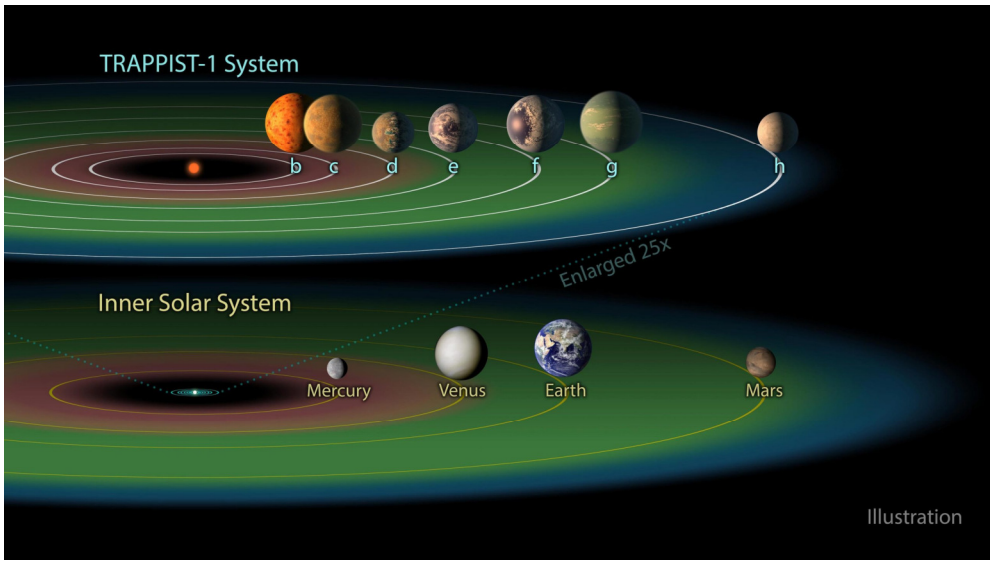


KU LEUVEN

Water

BEWOONBARE ZONE

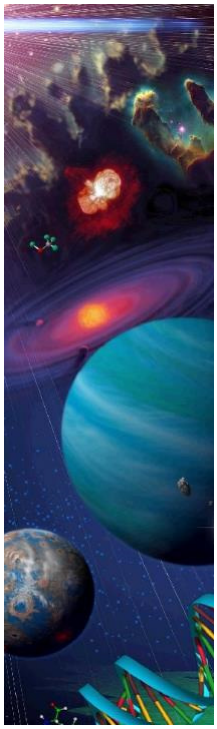
⇨ voorwaarde voor leven ⇔ *'Carbon-Water Chauvinism'?*



Leven

TERRAFORMING

⇨ vastleggen van atmosferisch CO_2



Leven

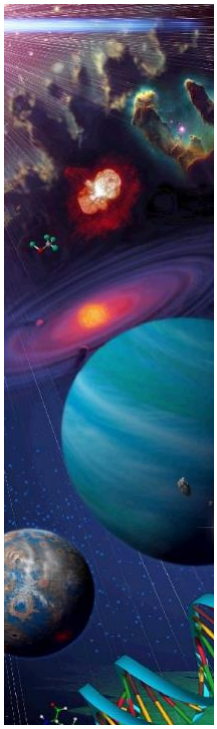
TERRAFORMING

⇨ vrijgave van O_2

Leven

TERRAFORMING

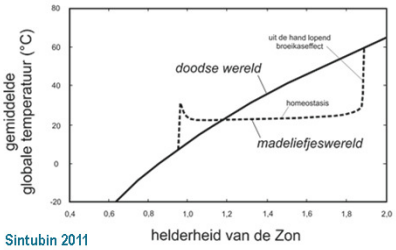
⇨ bodemontwikkeling ⇔ verwering continenten!

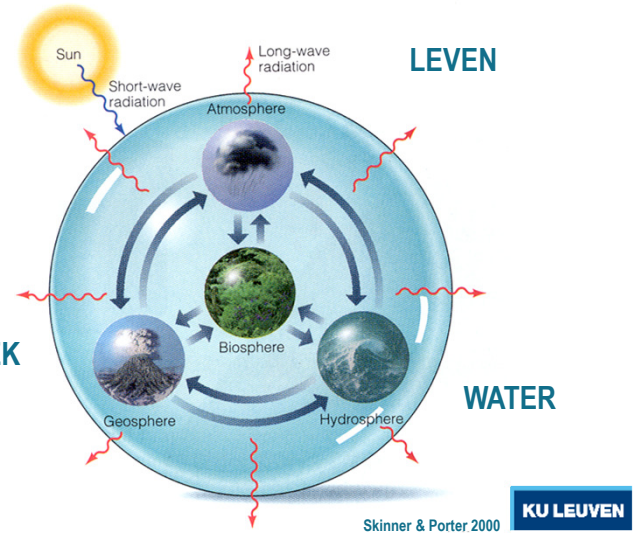


Planetaire drievuldigheid

HOMEOSTASIS

⇨ *wanneer verschenen de hoofdrolspelers op het aardse toneel?*



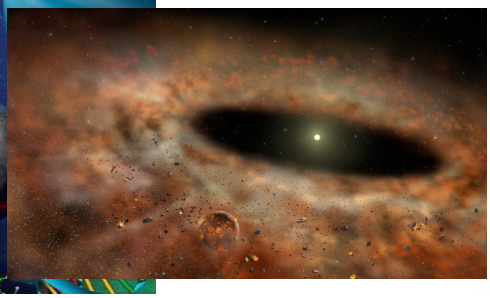


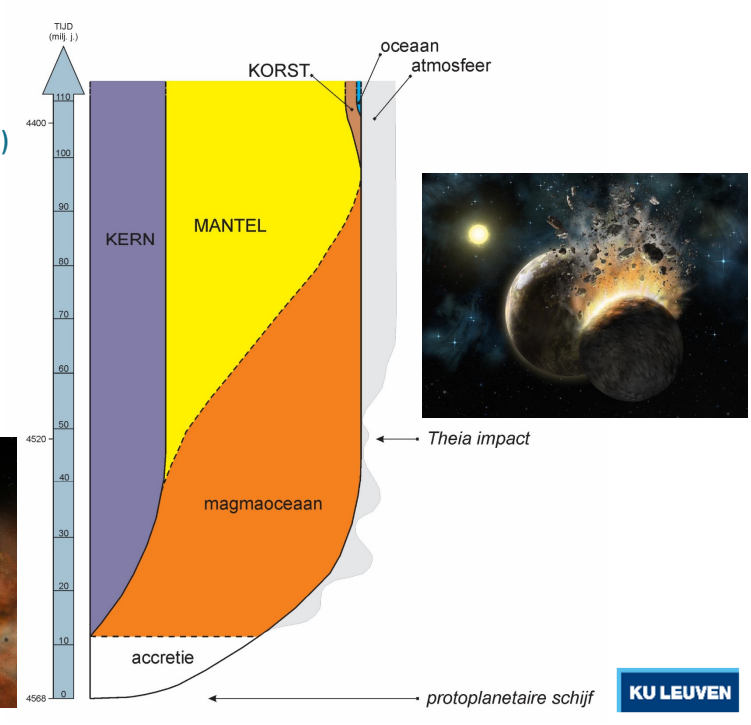
'Origins'?

'HABITABILITY BOUNDARY'

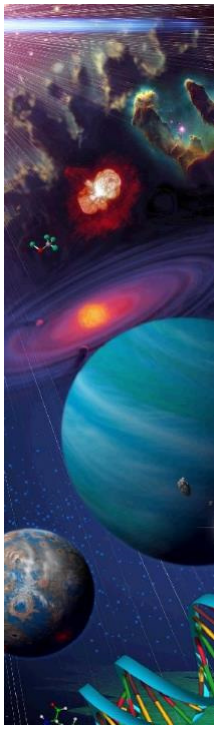
⇨ **~4.400 miljoen jaar (?)**

⇔ vorming van de Aarde





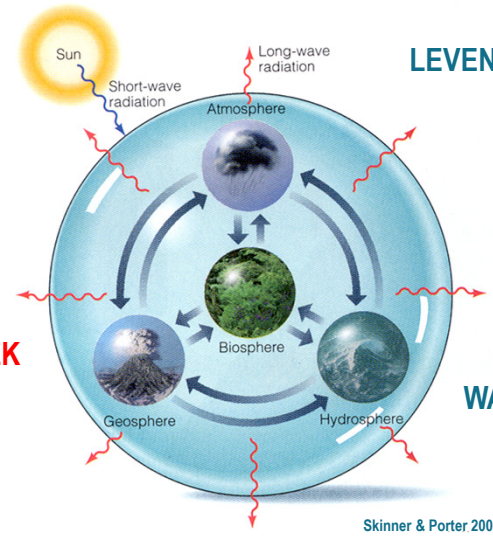
KU LEUVEN



'Origins'?

WANNEER BEGON PLATENTEKTONIEK?

PLATENTEKTONIEK



LEVEN

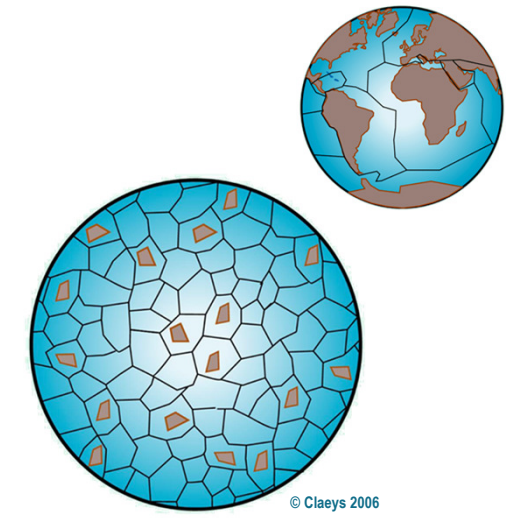
WATER

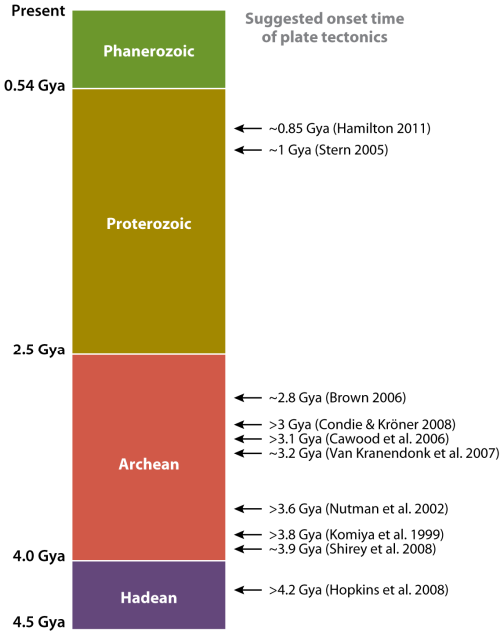
Skinner & Porter 2000

KU LEUVEN

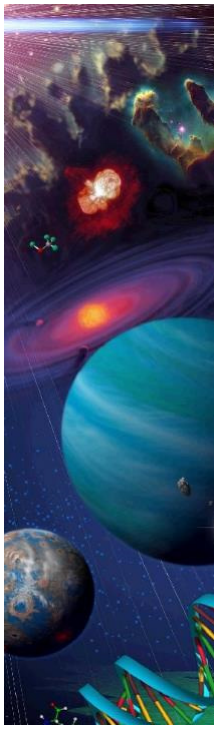
'Origins'?

WANNEER BEGON PLATENTEKTONIEK?





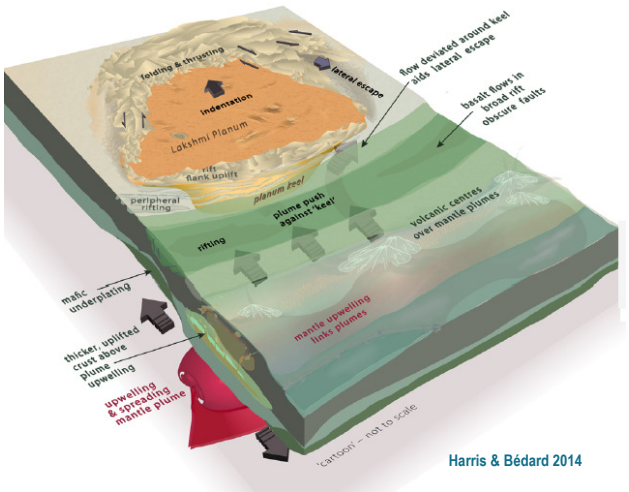
Korenaga J. 2013.
Annu. Rev. Earth Planet. Sci. 41:117–51

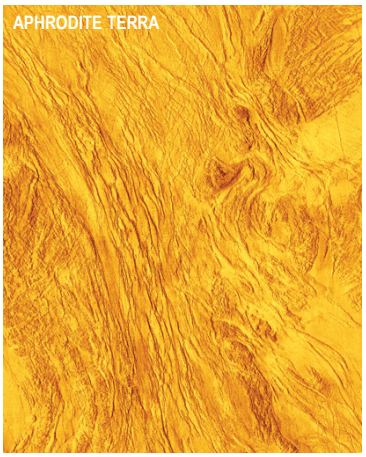


'Origins'?

WANNEER BEGON PLATENTEKTONIEK?

⇨ embryonale platentektoniek op Venus?

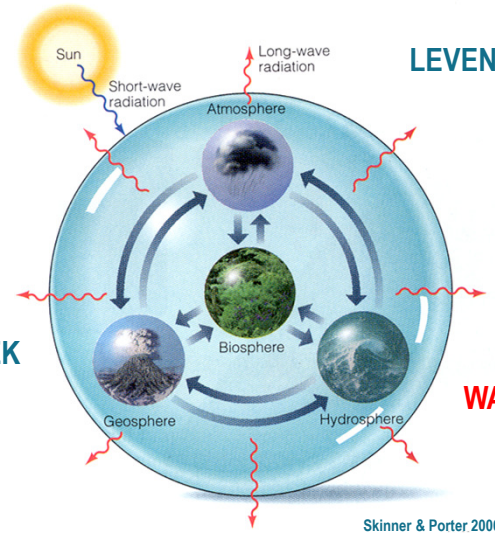




KU LEUVEN

'Origins'?

WANNEER ONTSTONDEN DE OCEANEN?



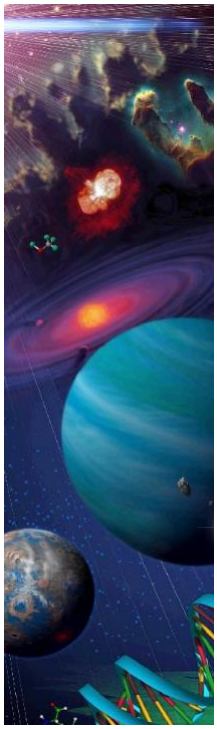
LEVEN

PLATENTEKTONIEK

WATER

Skinner & Porter 2000

KU LEUVEN



'Origins'?

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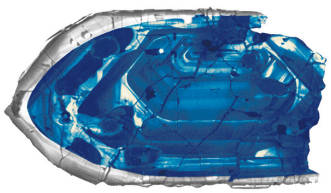
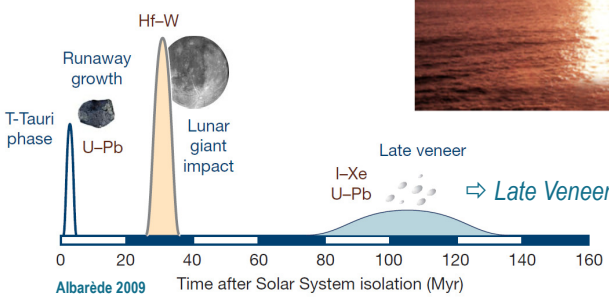


⇨ oudste zirkoon – ~4.374 Ma

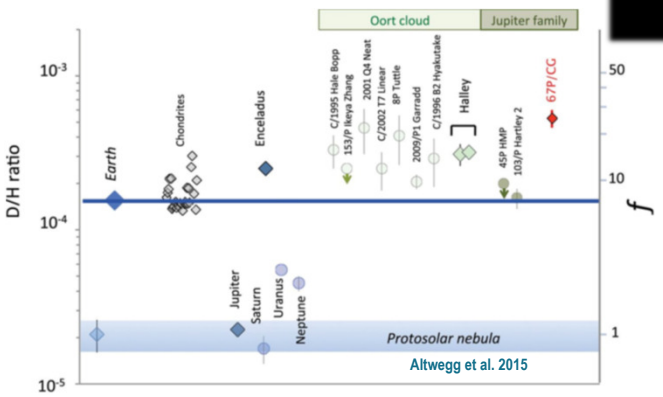


⇨ *Late Veneer hypothesis* – ~4.400 à 4.000 Ma

KU LEUVEN

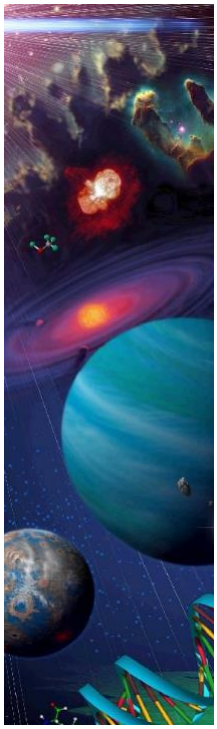
'Origins'?

VANWAAR KOMT HET WATER IN DE AARDE?



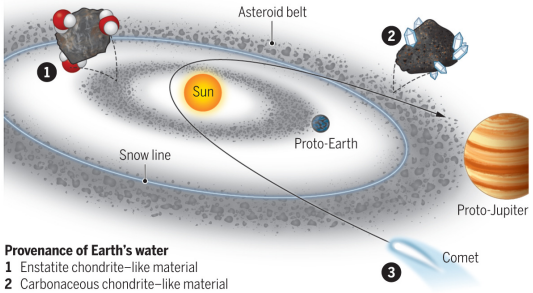
⇨ *interstellar 'old' water?*

KU LEUVEN



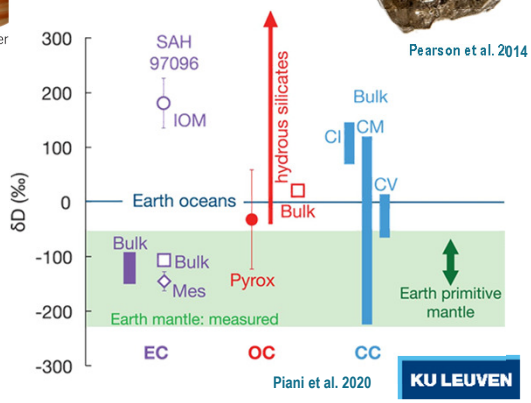
'Origins'?

VANWAAR KOMT HET WATER IN DE AARDE?



Provenance of Earth's water
1 Enstatite chondrite–like material
2 Carbonaceous chondrite–like material
3 Comets contributing to the atmosphere's composition

Pearson et al. 2014



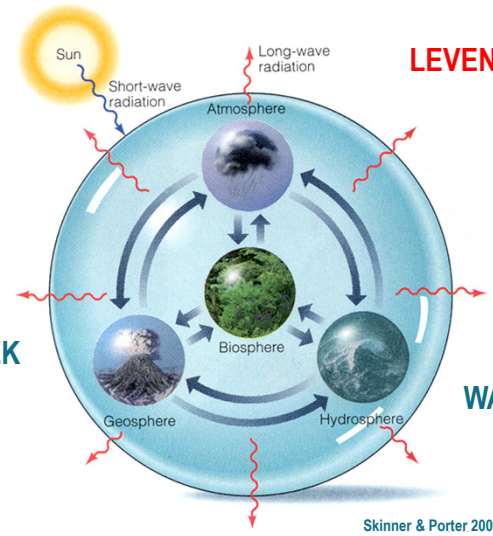
Piani et al. 2020

KU LEUVEN

'Origins'?

WANNEER ONTSTOND HET LEVEN?

⇨ ***'biosignature boundary'?***

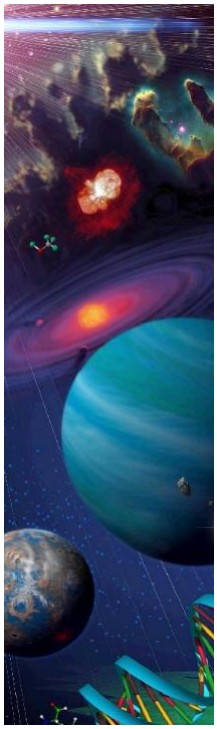


LEVEN

PLATENTEKTONIEK

WATER

KU LEUVEN



'Origins'?

WANNEER ONTSTOND HET LEVEN?

⇨ ***'biosignature boundary'?***

⇨ oudste geïdentificeerde stromatolieten ⇨ **~3.500 miljoen jaar**

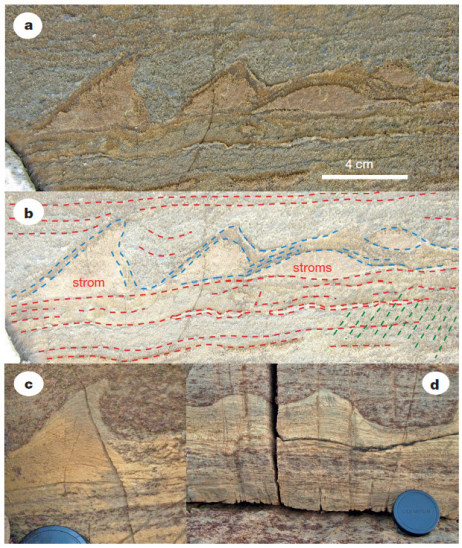
'Origins'?

WANNEER ONTSTOND HET LEVEN?

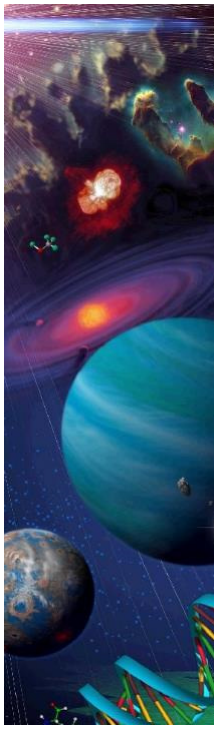
⇨ ***'biosignature boundary'?***

⇨ oudste geïdentificeerde stromatolieten?

⇨ **~3.700 miljoen jaar**



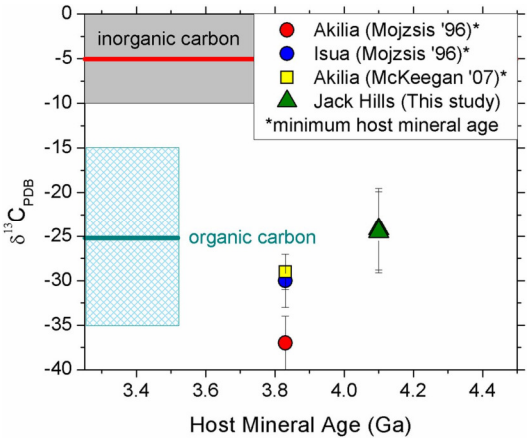
Nutman et al. 2016

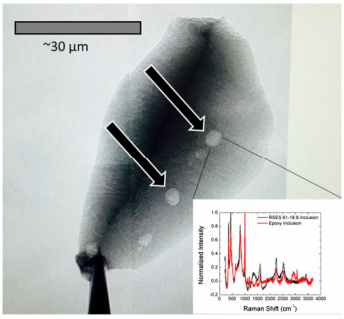


'Origins'?

WANNEER ONTSTOND HET LEVEN?

⇨ ***'biosignature boundary'?***





Evidence of life on Earth is manifestly preserved in the rock record. However, the microfossil record only extends to ~3.5 billion years (Ga), the chemofossil record arguably to ~3.8 Ga, and the rock record to 4.0 Ga. Detrital zircons from Jack Hills, Western Australia range in age up to nearly 4.4 Ga. From a population of over 10,000 Jack Hills zircons, we identified one >3.8-Ga zircon that contains primary graphite inclusions. Here, we report carbon isotopic measurements on these inclusions in a concordant, 4.10 ± 0.01-Ga zircon. We interpret these inclusions as primary due to their enclosure in a crack-free host as shown by transmission X-ray microscopy and their crystal habit. Their $\delta^{13}C_{PDB}$ of −24 ± 5‰ is consistent with a biogenic origin and may be evidence that a terrestrial biosphere had emerged by 4.1 Ga, or ~300 My earlier than has been previously proposed.

Bell et al. 2015

Potentially biogenic carbon preserved in a 4.1 billion-year-old zircon

KU LEUVEN

'Origins'?

WANNEER ONTSTOND HET LEVEN?

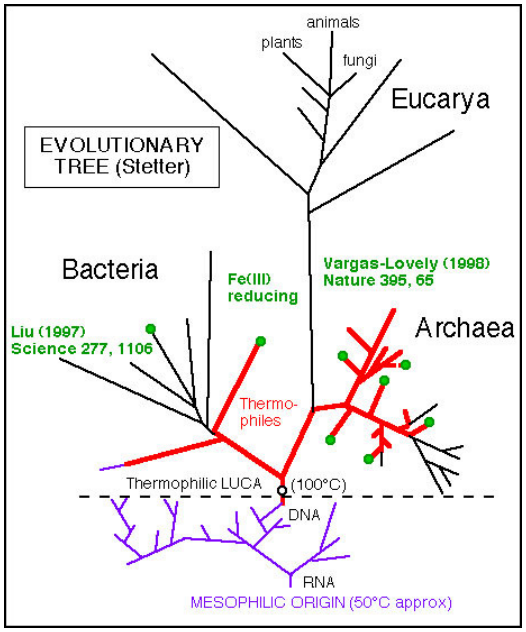
⇨ ***'biosignature boundary'?***

Origin of the RNA world: The fate of nucleobases in warm little ponds

Ben K. D. Pearce[a,b,1], Ralph E. Pudritz[a,b,c,d], Dmitry A. Semenov[c], and Thomas K. Henning[c]

Pearce et al. 2017

dust particles. Ponds appeared as continents rose out of the early global ocean, but this increasing availability of "targets" for meteorites was offset by declining meteorite bombardment rates. Moreover, the rapid losses of nucleobases to pond seepage during wet periods, and to UV photodissociation during dry periods, mean that the synthesis of nucleotides and their polymerization into RNA occurred in just one to a few wet–dry cycles. Under these conditions, RNA polymers likely appeared before 4.17 billion years ago.

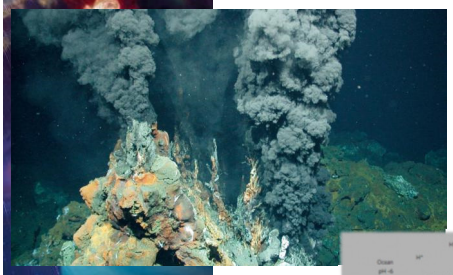


KU LEUVEN

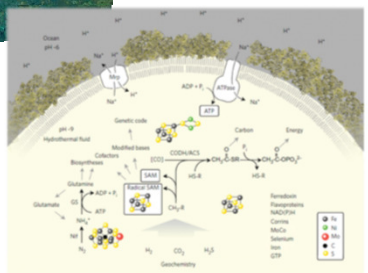
'Origins'?

WANNEER ONTSTOND HET LEVEN?

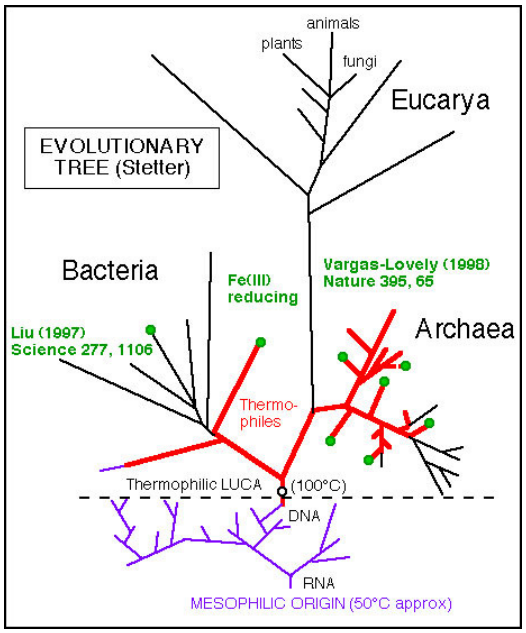
⇨ ***'biosignature boundary'?***



Weiss et al 2016



Last Universal Common Ancestor **(LUCA)**



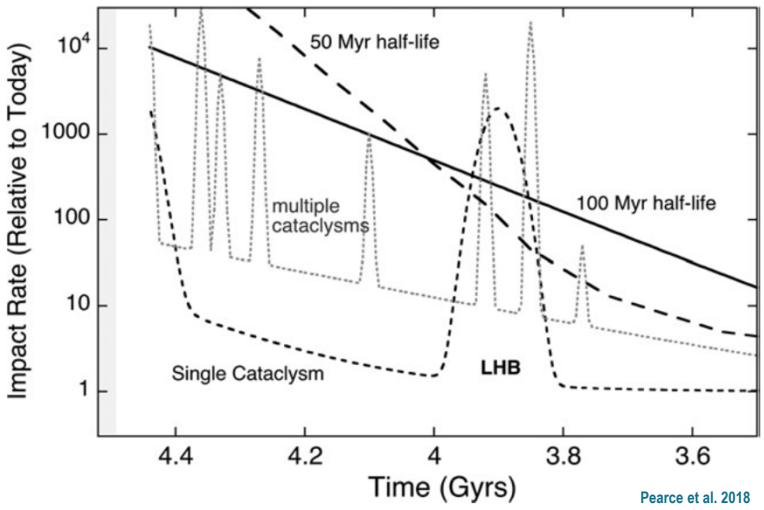
KU LEUVEN

'Origins'?

WANNEER ONTSTOND HET LEVEN?

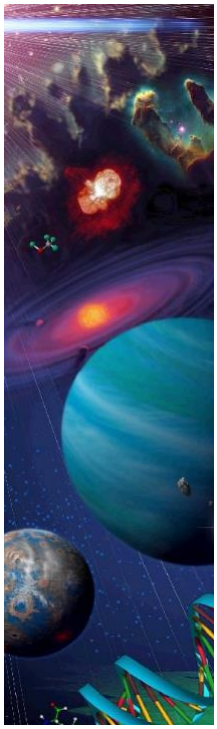
⇨ ***'biosignature boundary'?***

⇨ ***'Late Heavy Bombardment' – ~3.900 miljoen jaar***



Pearce et al. 2018

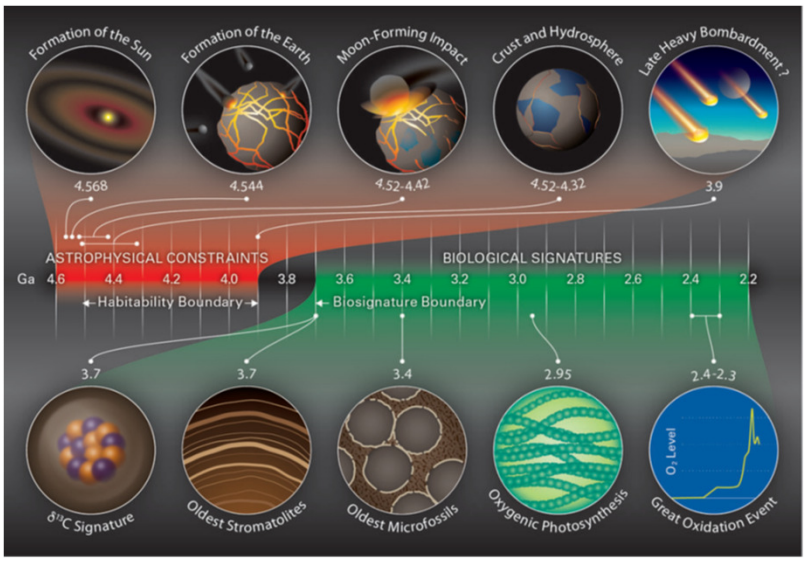
KU LEUVEN



'Origins'?

WANNEER ONTSTOND HET LEVEN?

⇨ ***'habitability boundary'*** *versus* ***'biosignature boundary'***

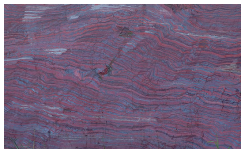


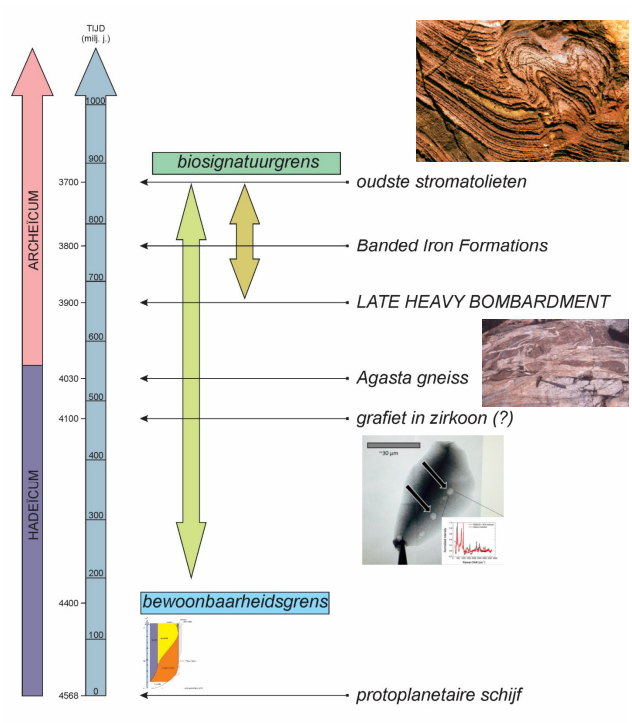
Pearce et al. 2018

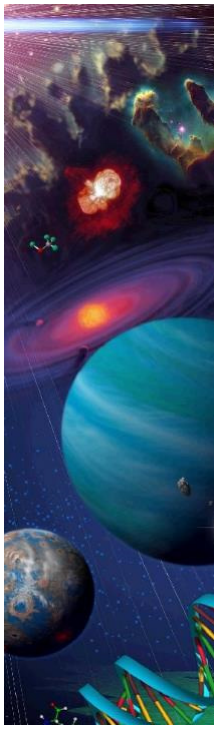
KU LEUVEN

'Origins'?

WANNEER ONTSTOND HET LEVEN?



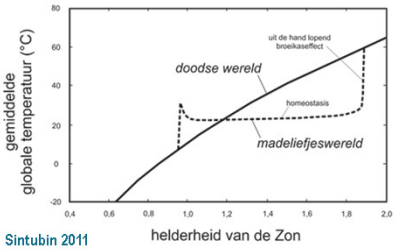


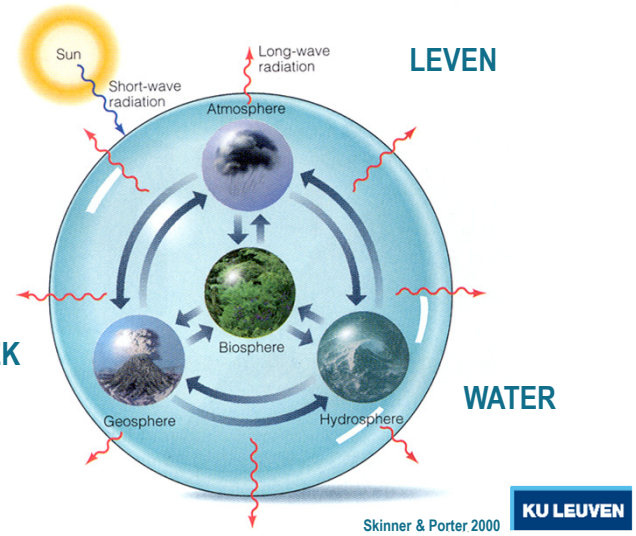


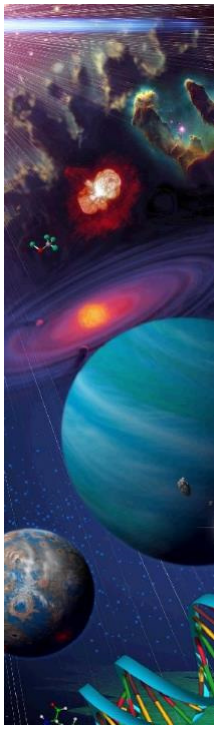
Planetaire drievuldigheid

HOMEOSTASIS

⇨ *wanneer verschenen de hoofdrolspelers op het aardse toneel?*







Planeet Aarde, een goudlokjeplaneet?

'GOLDILOCKS AND THE THREE BEARS' – Robert Southey (1837)

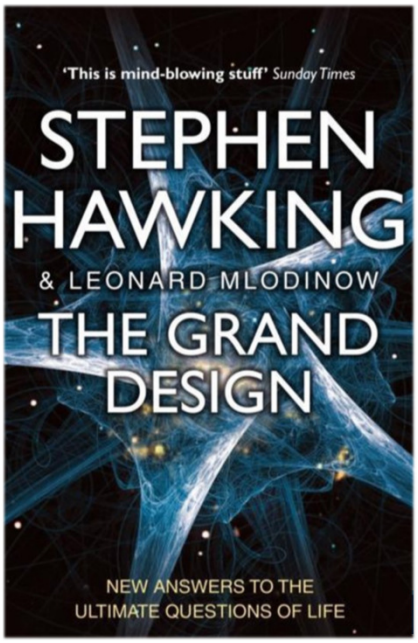
*At the table in the kitchen, there were three bowls of porridge. Goldilocks was hungry. She tasted the porridge from the first bowl. "This porridge is **too hot**!" she exclaimed. So, she tasted the porridge from the second bowl. "This porridge is **too cold**" she said. So, she tasted the last bowl of porridge. "Ahhh, this porridge is **just right**" she said happily and she ate it all up.*

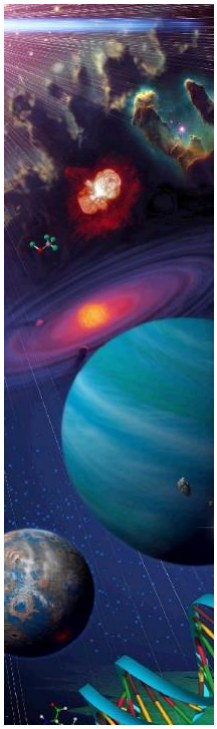
Robert Southey (1774-1843)

Planeet Aarde, een goudlokjeplaneet?

'THE GRAND DESIGN' – Stephen Hawking (2011)

*"like **Goldilocks**, the development of intelligent life requires that planetary temperatures be 'just right'"*

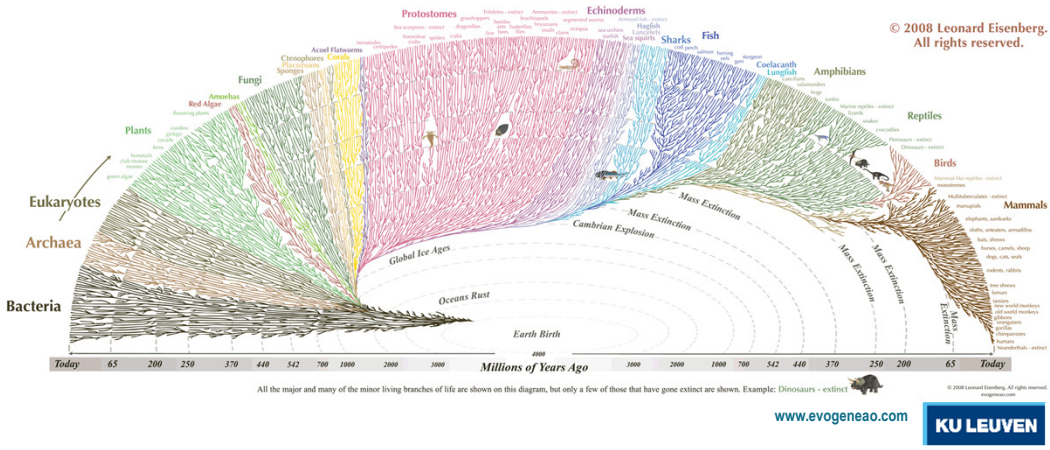




Planeet Aarde, een goudlokjeplaneet?

'HABITABILITY PROBLEM'?

⇨ 'de planetaire omstandigheden zijn 3 à 4 miljard jaar 'bewoonbaar' gebleven, niettegenstaande het Aardse klimaat aan een delicate balanceeroefening blijkt onderhevig te zijn'



Planeet Aarde, een goudlokjeplaneet?

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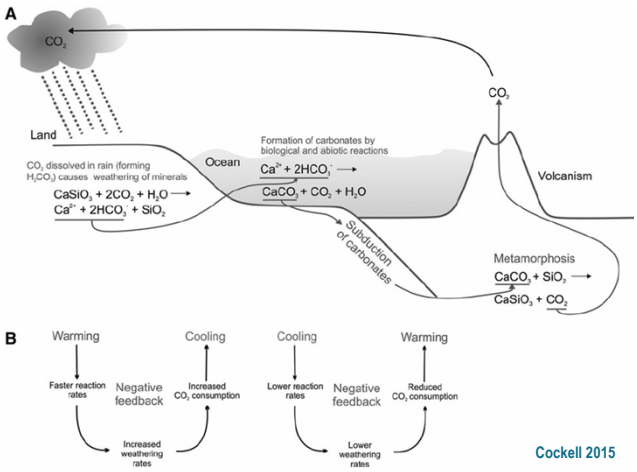
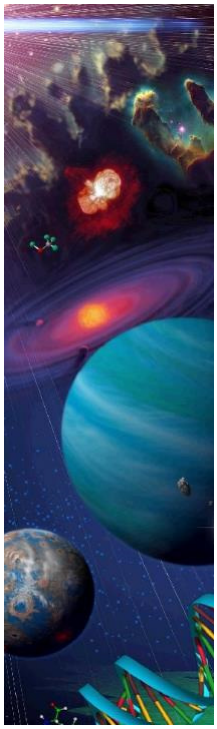
GAIA

⇨ robuste klimaatregulering

⇔ *uniformitarianisme*





Planeet Aarde, een goudlokjeplaneet

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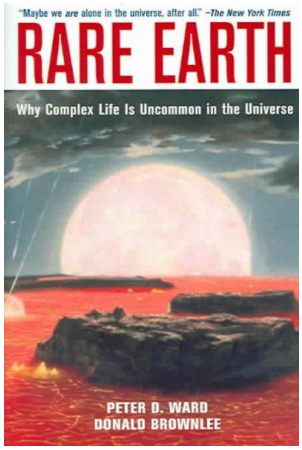
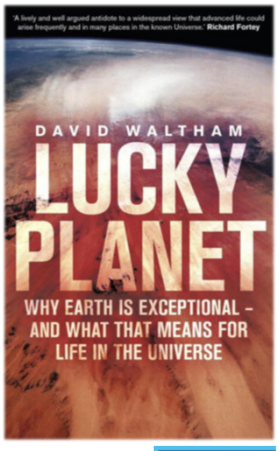
'LUCKY PLANET'

⇨ toeval – ***contingency!***

⇔ *catastrofisme*





KU LEUVEN


Planeet Aarde …
… een planeet die tot leven kwam


Zijn we alleen in het universum?


Terraforming biosfeer


Mens en Aarde

‘Het echte virus op de planeet aarde, dat is de mens. Die koloniseert en vernietigt de aarde. Het lijkt haast alsof het coronavirus de antilichamen vormt van de aarde, die nu op de mens worden afgevuurd, omdat de mens nutteloos en zelfs schadelijk is voor de planeet. In plaats van zich aan te passen aan de natuur, past de mens de natuur aan zijn eigen behoeften aan.’

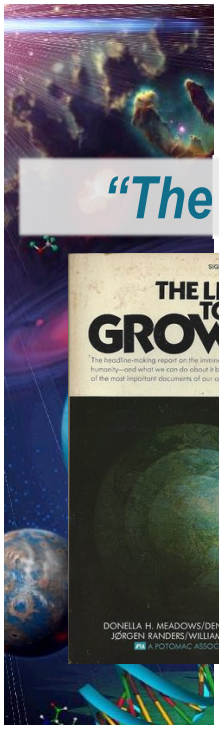
‘De wetenschap, de politiek en dat waanzinnige idee van alles te moeten controleren, hebben van de mens een ge

betert en er zwemmen weer dolfijnen rond in de havens. De natuur heeft de mens afgeremd.’

Sandro Veronesi, De Standaard, 3 april 2020

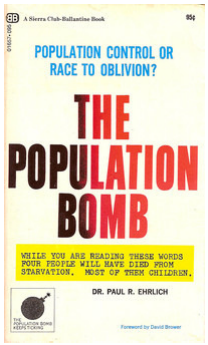
“Het echte virus op de planeet aarde, dat is de mens!”

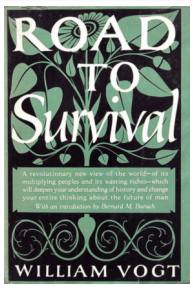
KU LEUVEN



“The Earth has a cancer and the cancer is man!”

Alan Gregg, 1955





Humanity is waging war on nature.

This is suicidal.

Nature always strikes back – and it is already doing so with growing force and fury.

Antonio Guterres, 2020

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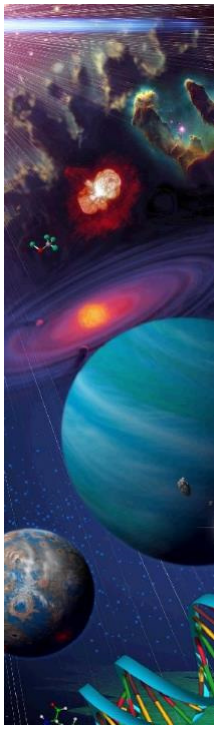
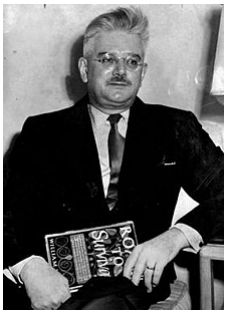
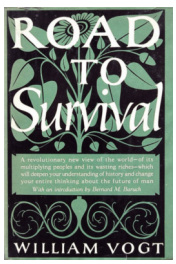
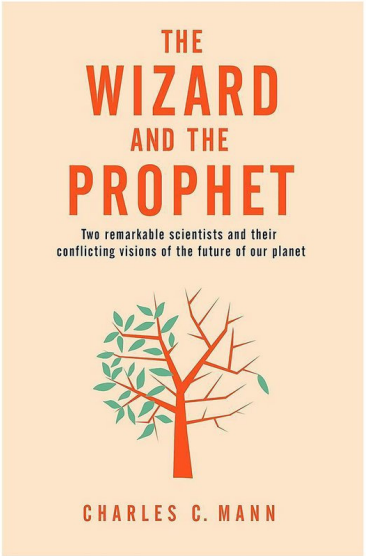


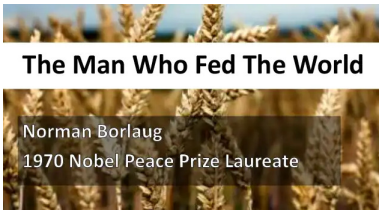


William Vogt (1902-1968)





Norman Borlaug (1914-2009)



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Mens als geologische kracht


Good Anthropocene
Bad Anthropocene


"The Earth is a fine place ...
... and worth fighting for!"
Ernest Hemingway


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