

# Big History

## The Sustainability of the Human Species in a Long-Run Perspective

G. M. Marques

# Concepts

**Sustainability**

Niches

Stability

Energy

+

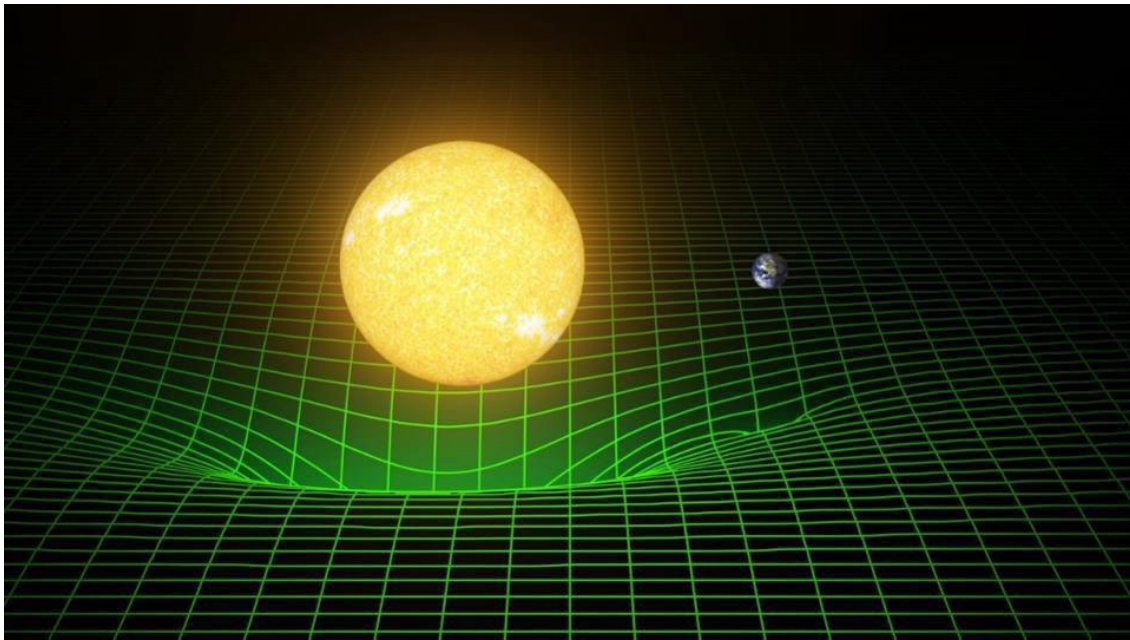
Mass

Kits of Building Blocks

Cycles

# Once upon a spacetime...

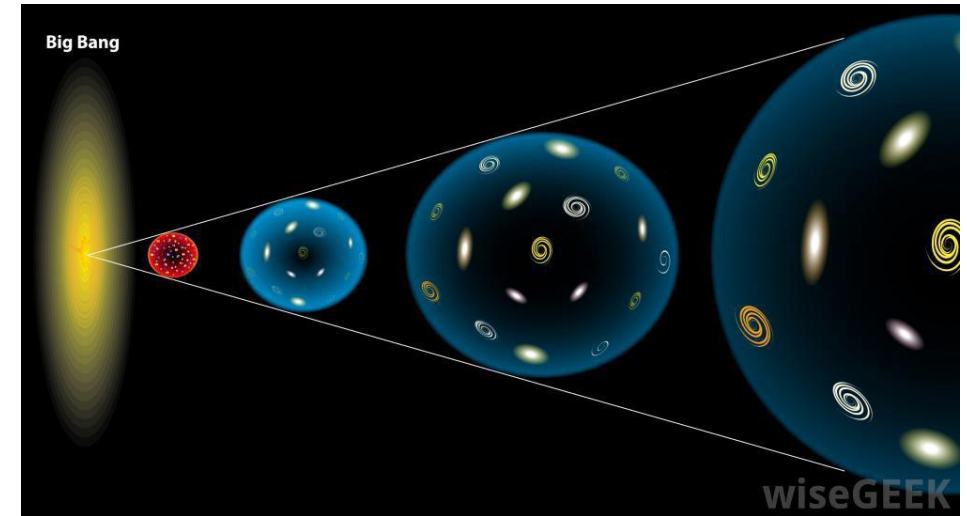
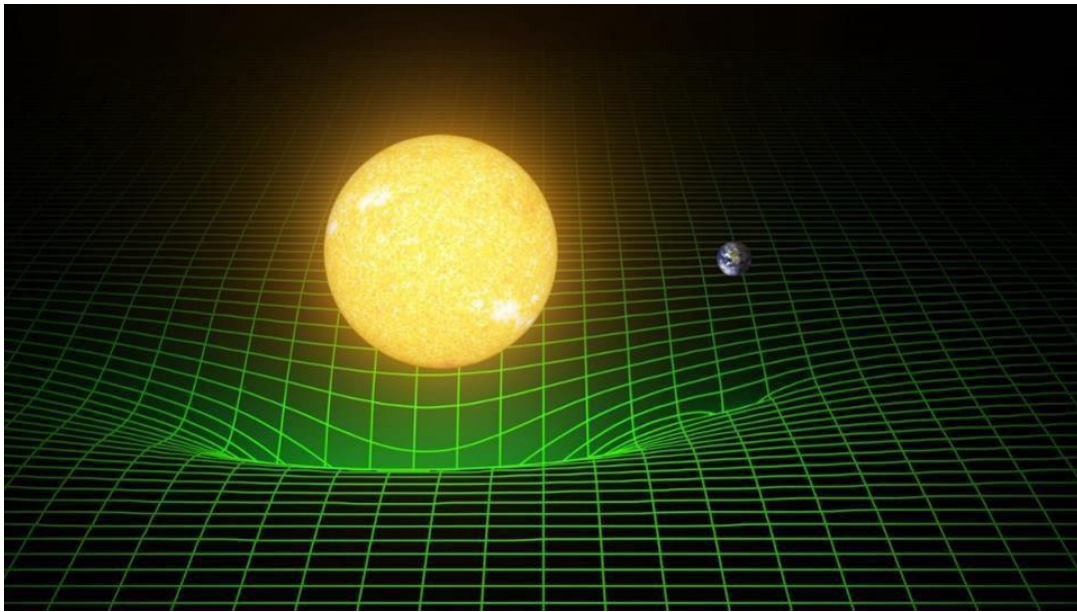
... 13.8 billion years ago



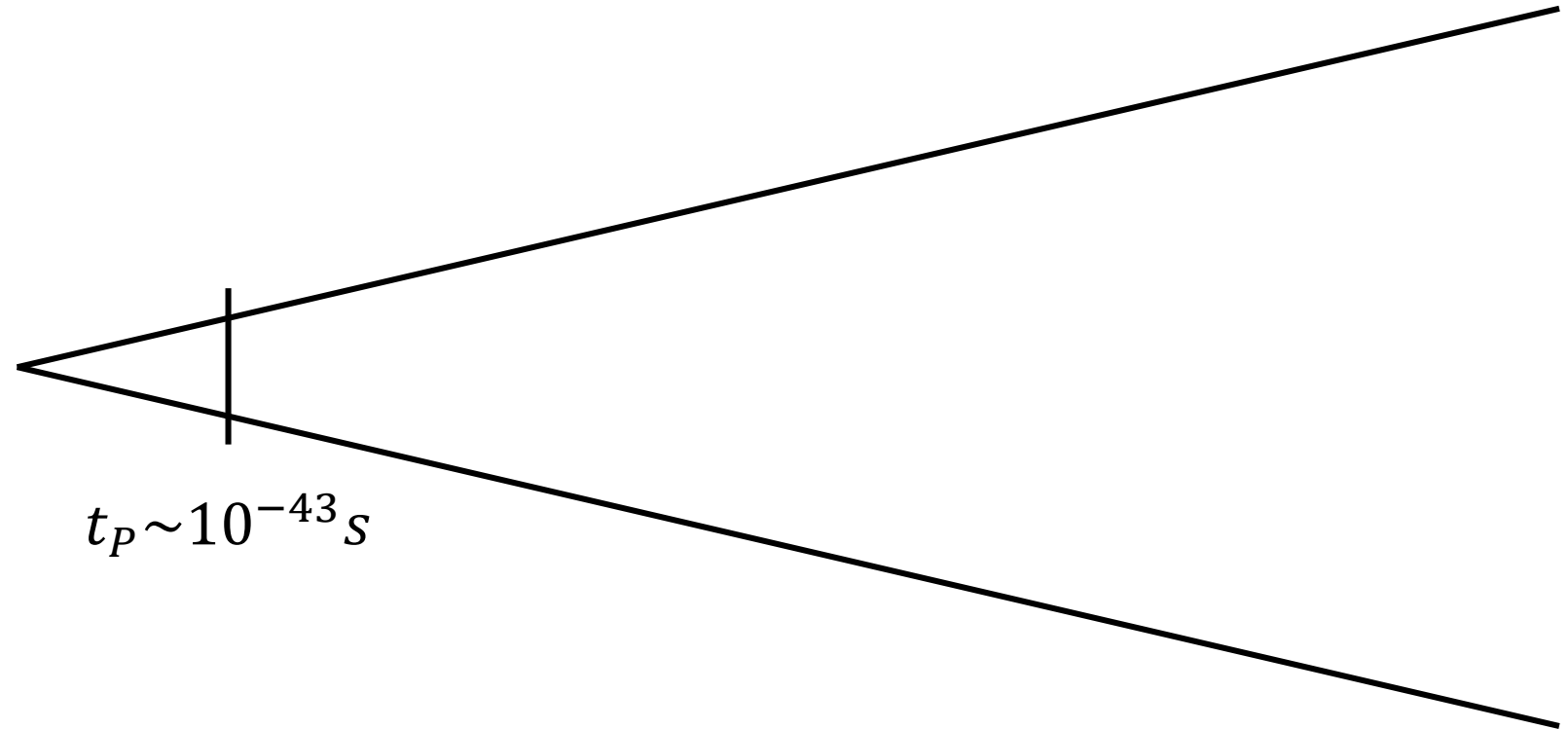
## Energy – Mass

$$E = mc^2$$

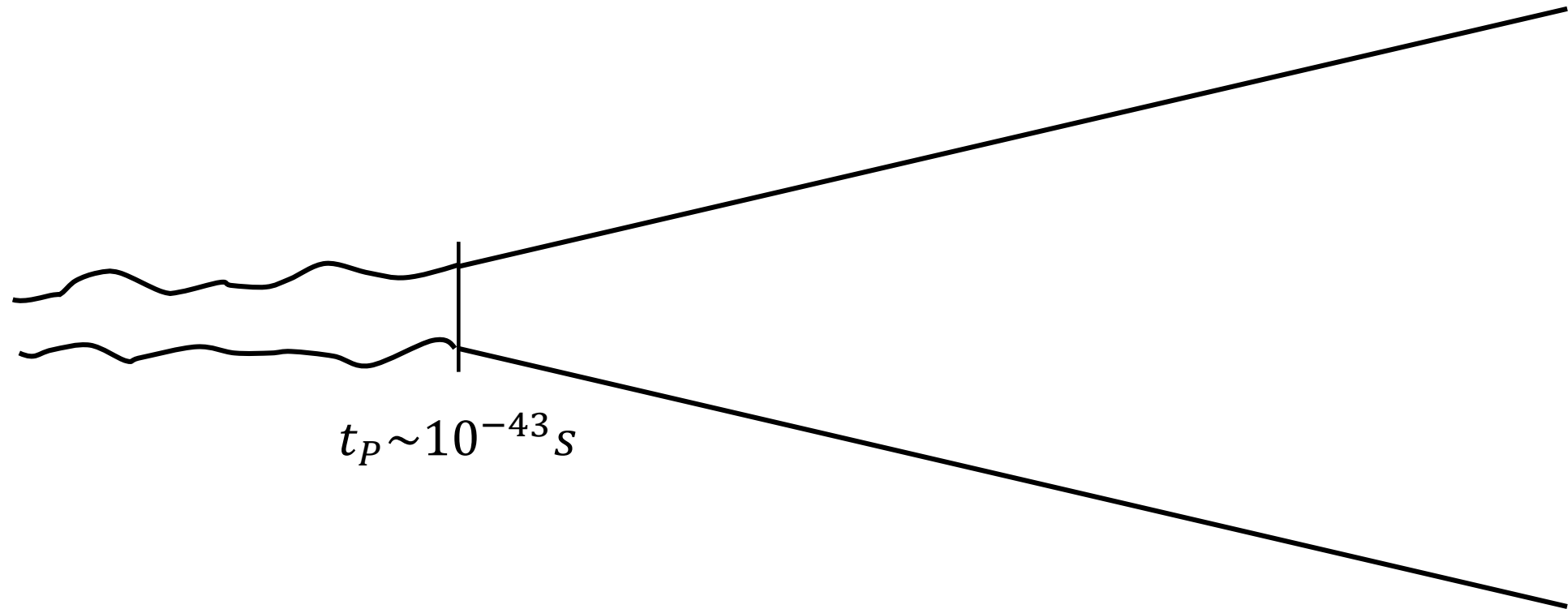
# Once upon a spacetime...



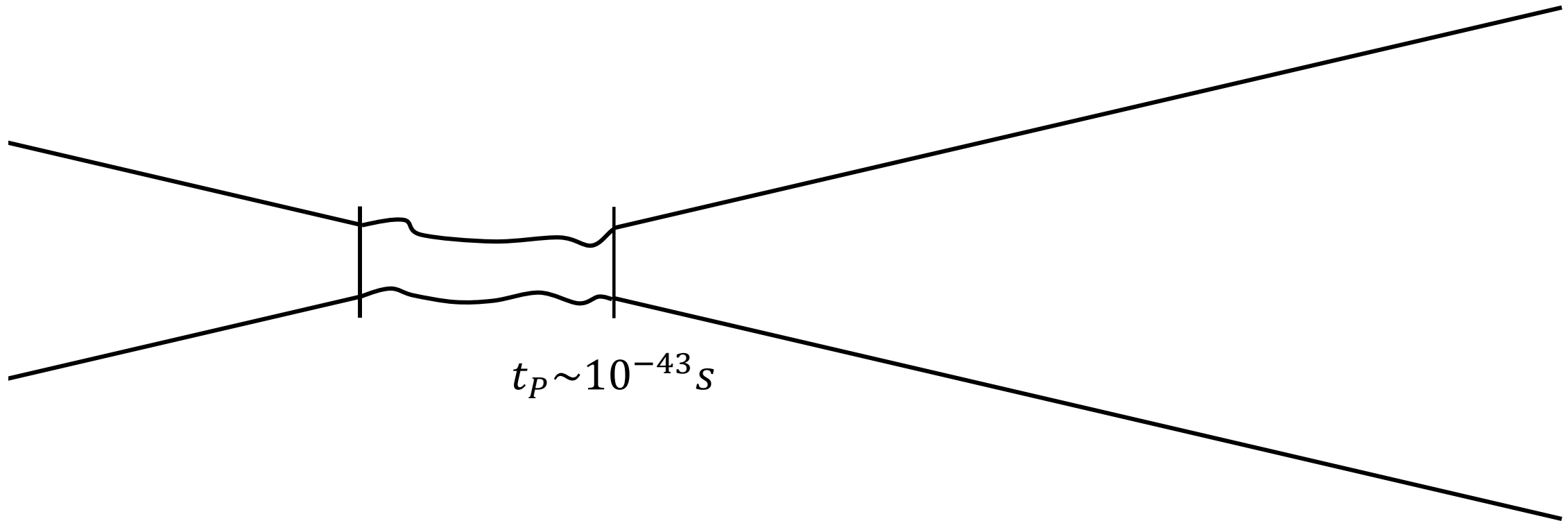
# Once upon a spacetime...



# Once upon a spacetime...



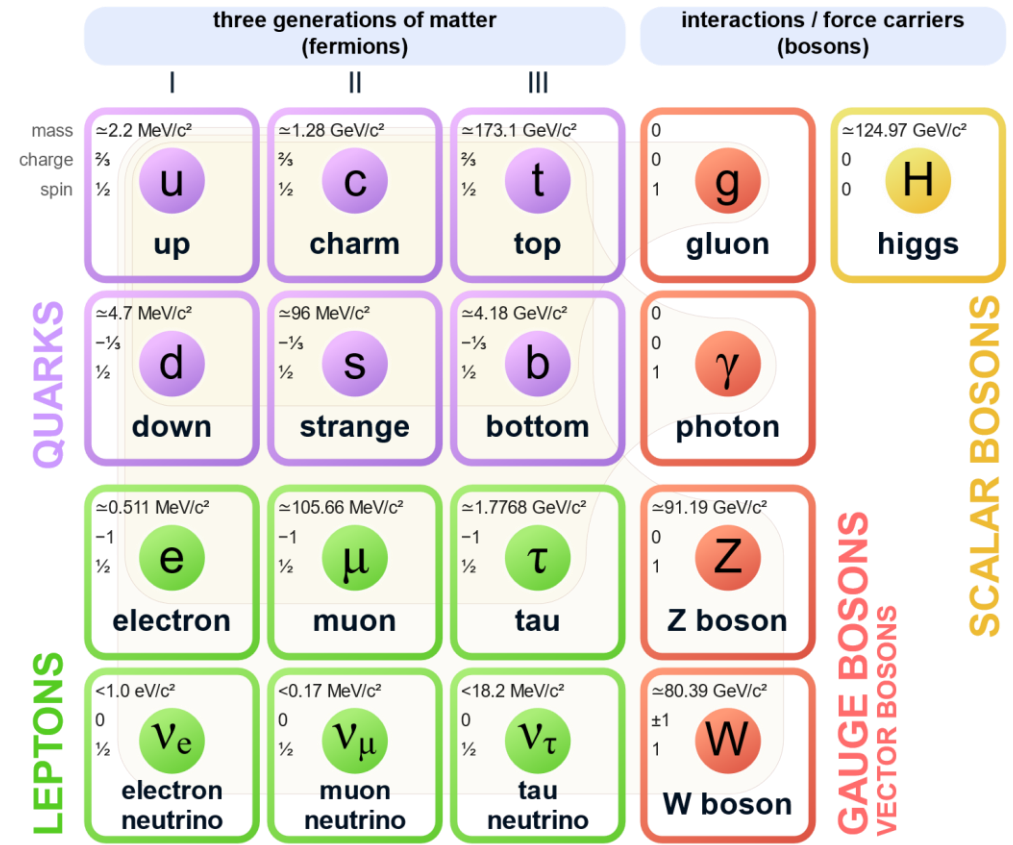
# Once upon a spacetime...



# Once upon a spacetime...

**Forces:**  
 Strong  
 Electromagnetic  
 Weak  
 Gravitational

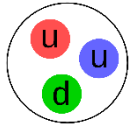
## Standard Model of Elementary Particles



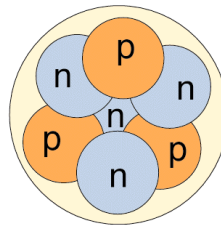
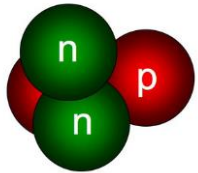
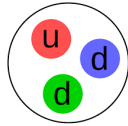


# Nucleosynthesis

Proton



Neutron



Periodic Table of the Elements

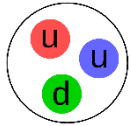
1 H Hydrogen 1.01	2 He Helium 4.00																
3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.88	23 V Vanadium 50.94	24 Cr Chromium 51.99	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.38	31 Ga Gallium 69.72	32 Ge Germanium 72.63	33 As Arsenic 74.92	34 Se Selenium 78.97	35 Br Bromine 79.90	36 Kr Krypton 84.80
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.95	43 Tc Technetium 98.91	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.6	53 I Iodine 126.90	54 Xe Xenon 131.29
55 Cs Cesium 132.91	56 Ba Barium 137.33	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.85	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.20	83 Bi Bismuth 208.98	84 Po Polonium [208.98]	85 At Astatine 209.98	86 Rn Radon 222.02
87 Fr Francium 223.02	88 Ra Radium 226.03	89-103 Actinides	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [278]	110 Ds Darmstadtium [281]	111 Rg Roentgenium [280]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [294]	118 Og Oganesson [294]
57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium 144.91	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.06	71 Lu Lutetium 174.97			
89 Ac Actinium 227.03	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium 237.05	94 Pu Plutonium 244.06	95 Am Americium 243.06	96 Cm Curium 247.07	97 Bk Berkelium 247.07	98 Cf Californium 251.08	99 Es Einsteinium [254]	100 Fm Fermium 257.10	101 Md Mendelevium 258.10	102 No Nobelium 259.10	103 Lr Lawrencium [262]			

- Alkali Metal
- Alkaline Earth
- Transition Metal
- Basic Metal
- Metalloid
- Nonmetal
- Halogen
- Noble Gas
- Lanthanide
- Actinide

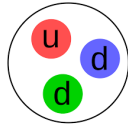
© 2017 All Elements  
www.ck12.org

# Nucleosynthesis

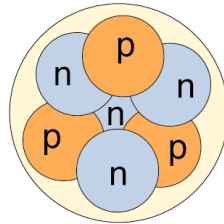
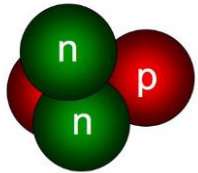
Proton



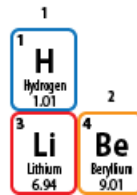
Neutron



...



75%



Periodic Table of the Elements



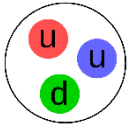
25%

- Alkali Metal
- Alkaline Earth
- Transition Metal
- Basic Metal
- Metalloid
- Nonmetal
- Halogen
- Noble Gas
- Lanthanide
- Actinide

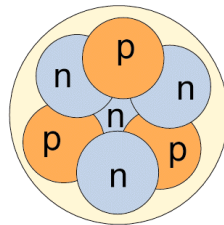
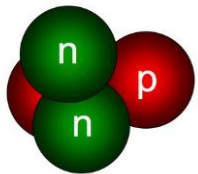
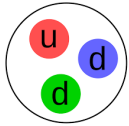
© 2017 Tech Refresh Ltd

# Photon decoupling

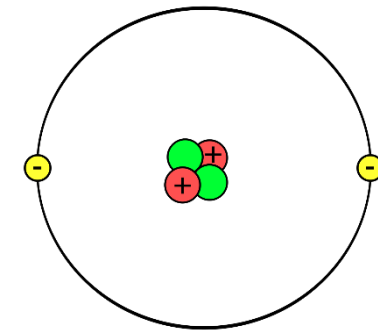
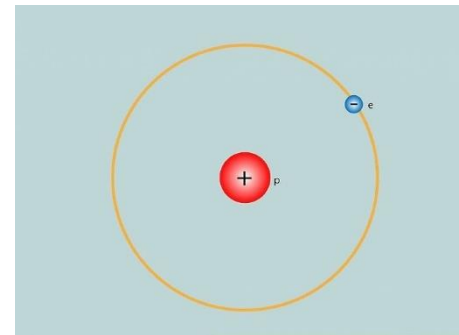
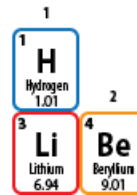
Proton



Neutron



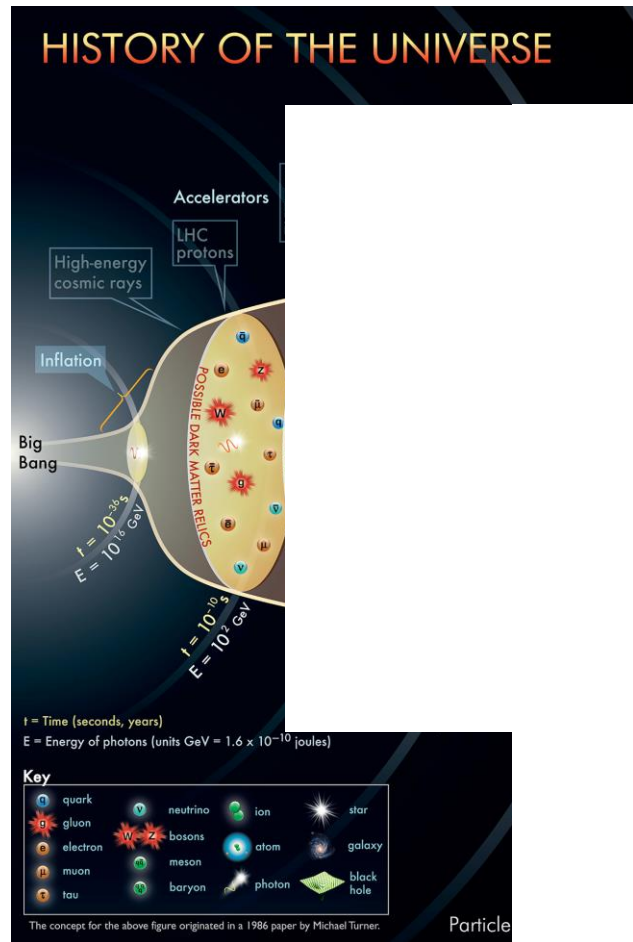
Periodic Table of the Elements



- Alkali Metal
- Alkaline Earth
- Transition Metal
- Basic Metal
- Metalloid
- Nonmetal
- Halogen
- Noble Gas
- Lanthanide
- Actinide

© 2017 Tech Refresh Ltd  
www.techrefresh.com

# Once upon a spacetime...



# The Cosmic Calendar

The 13.8 billion year history of the universe scaled down to a single year, where the Big Bang is January 1<sup>st</sup> at midnight, and right now is midnight 1 year later

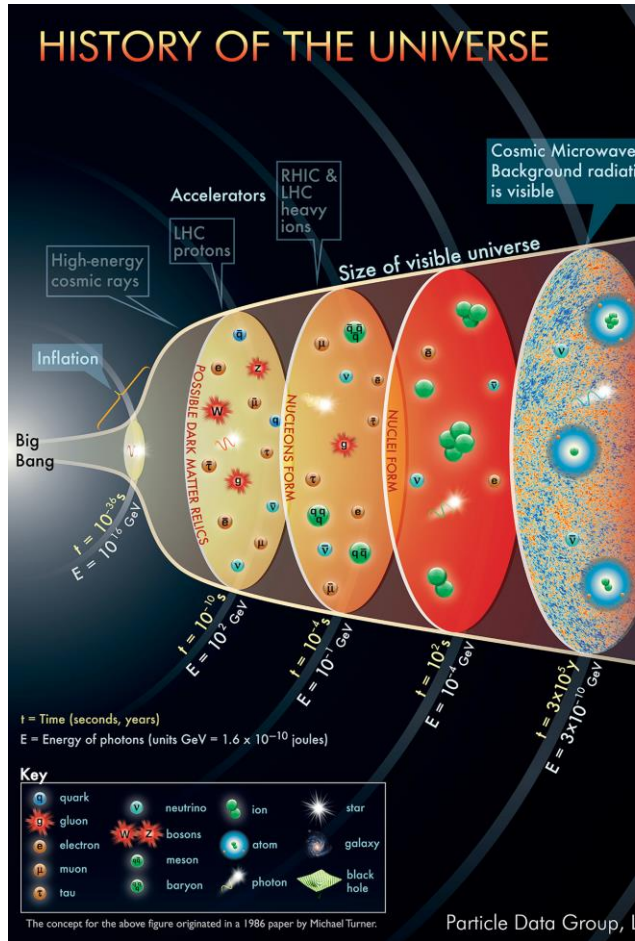
January	February	March	April	May	June	July	August	September	October	November	December
[Empty calendar grid]											



15 mins

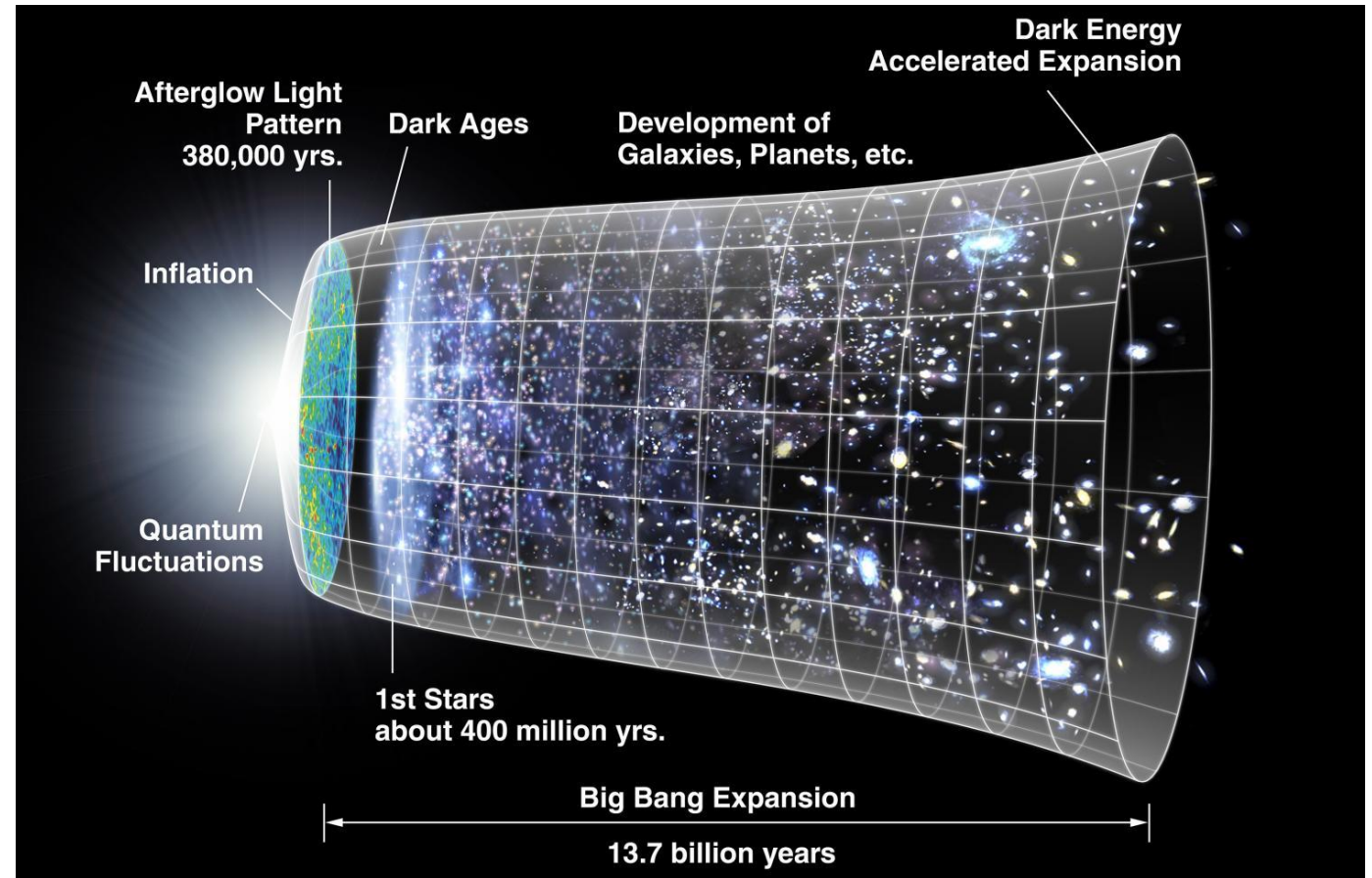
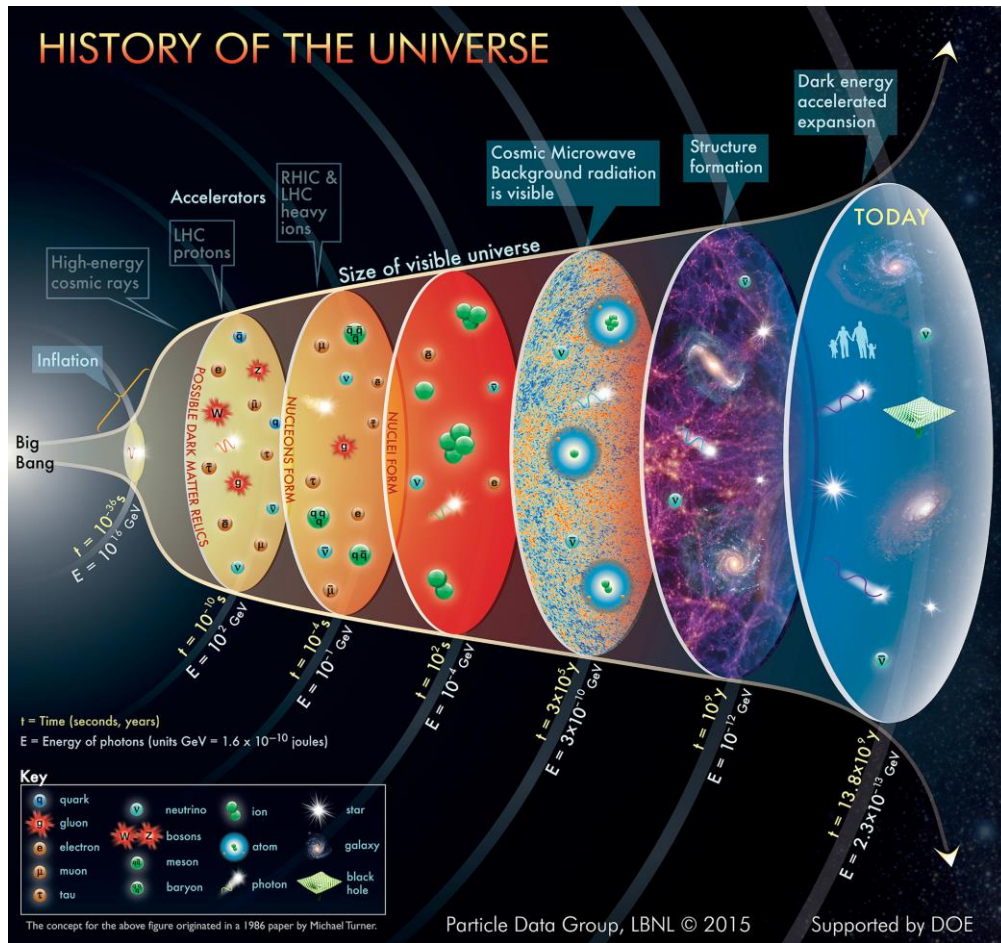
380,000 years

# Once upon a spacetime...



This would be the end of history  
were it not for Gravitation

# Once upon a spacetime...



# The Cosmic Calendar

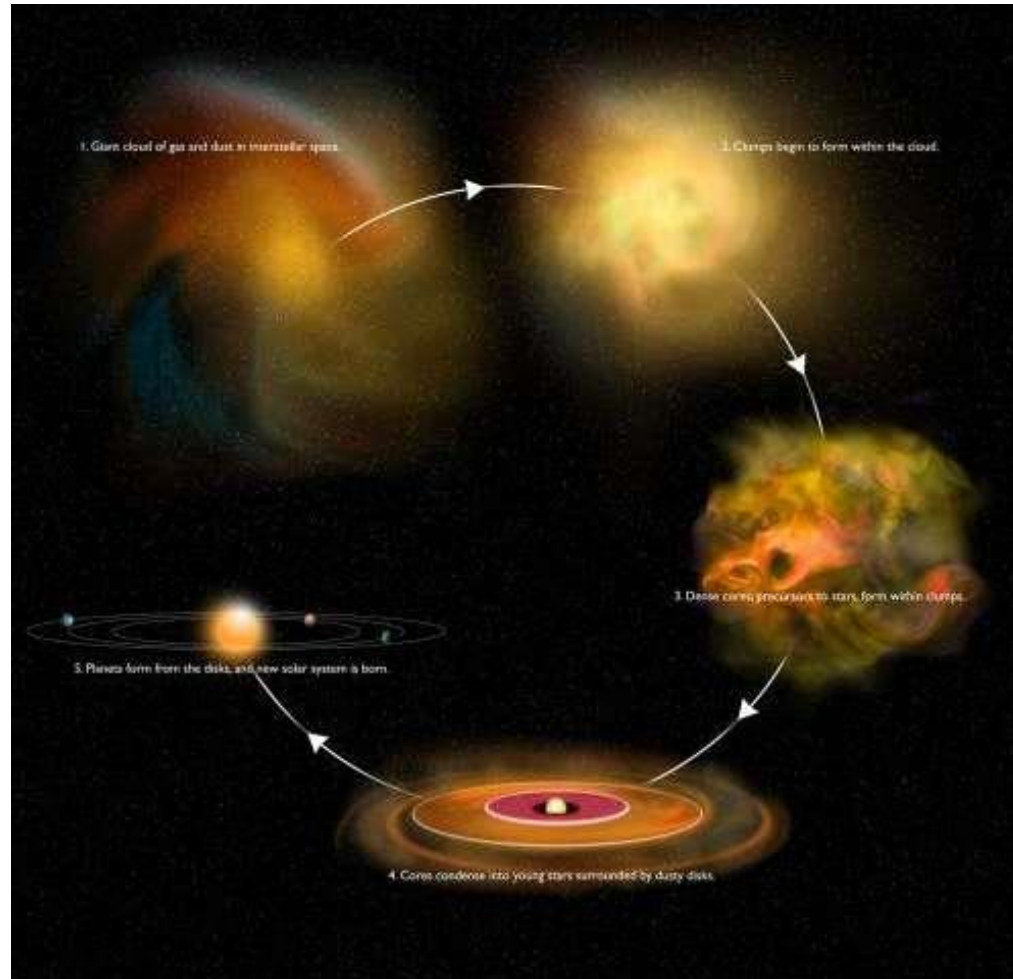
The 13.8 billion year history of the universe scaled down to a single year, where the Big Bang is January 1<sup>st</sup> at midnight, and right now is midnight 1 year later



January 11th  
470 million years



# Twinkle twinkle...



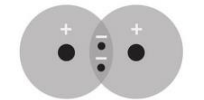
**(1st molecules)**



Hydrogen



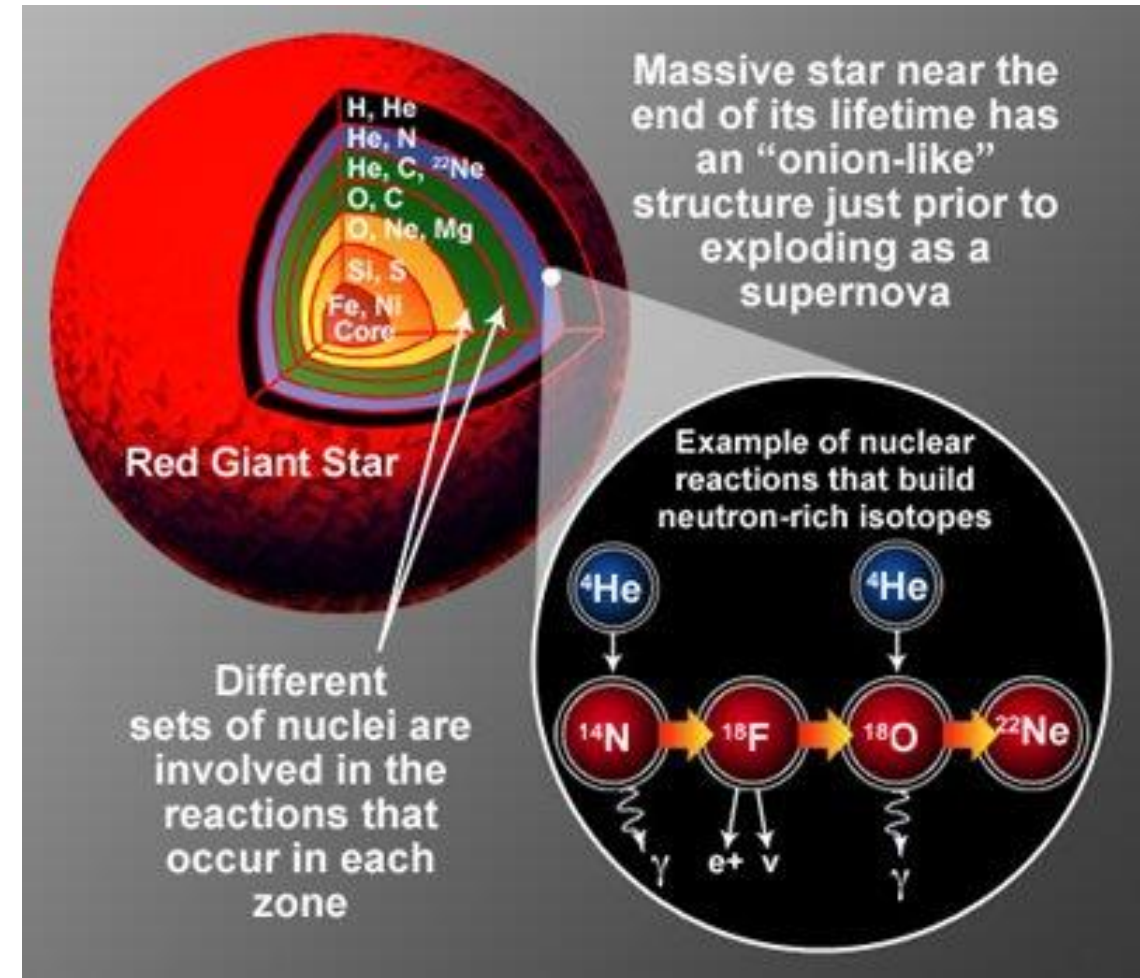
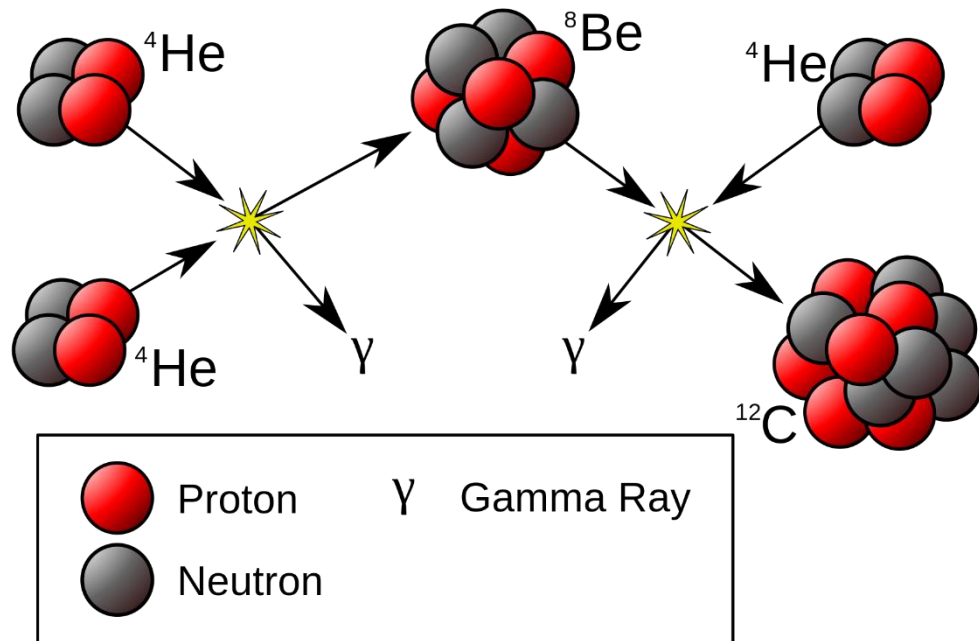
Hydrogen



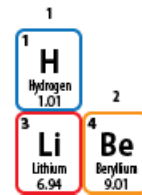
Hydrogen Molecule (H<sub>2</sub>)



# Twinkle twinkle...



# Nucleosynthesis



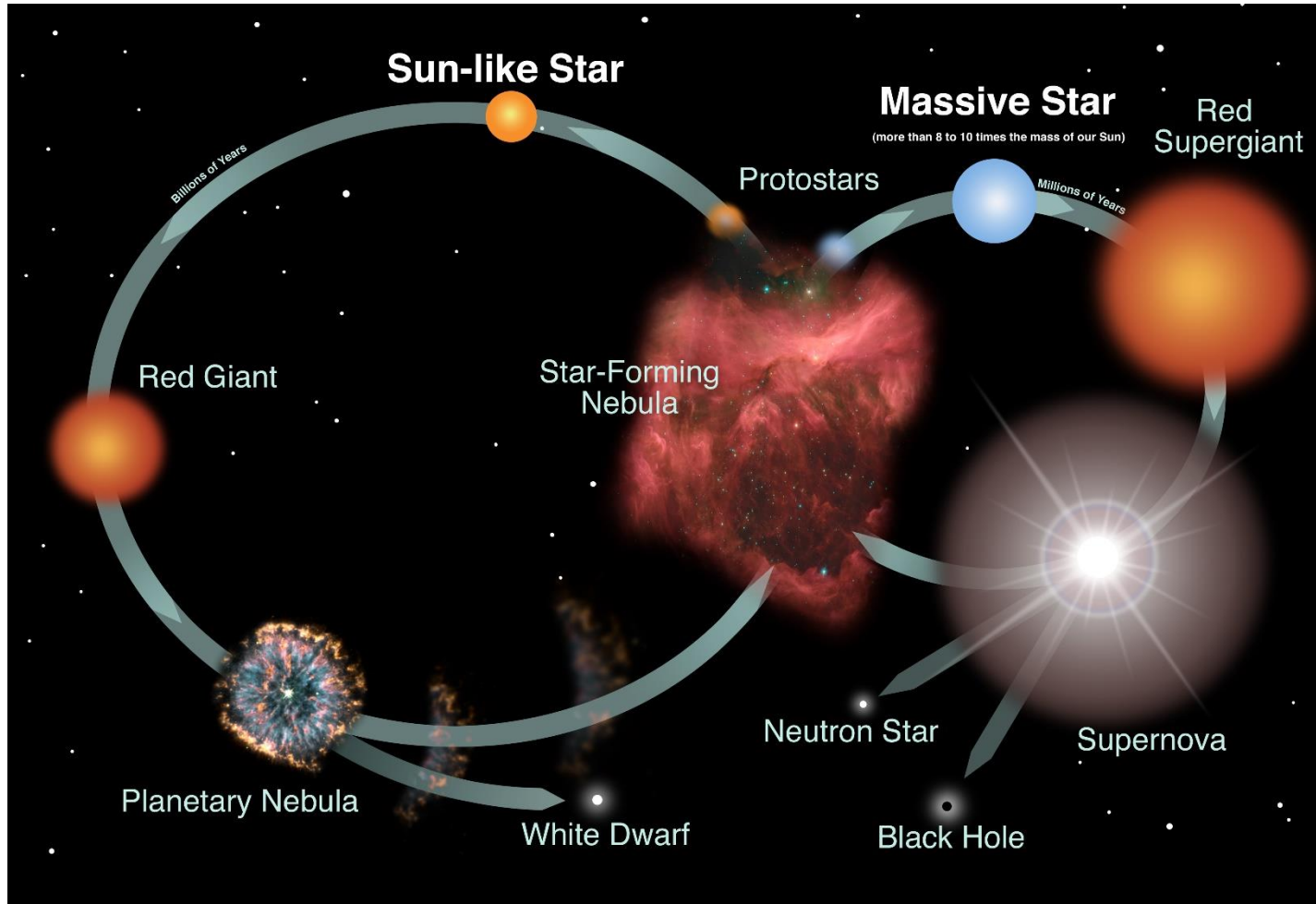
Periodic Table of the Elements



- Alkali Metal
- Alkaline Earth
- Transition Metal
- Basic Metal
- Metalloid
- Nonmetal
- Halogen
- Noble Gas
- Lanthanide
- Actinide

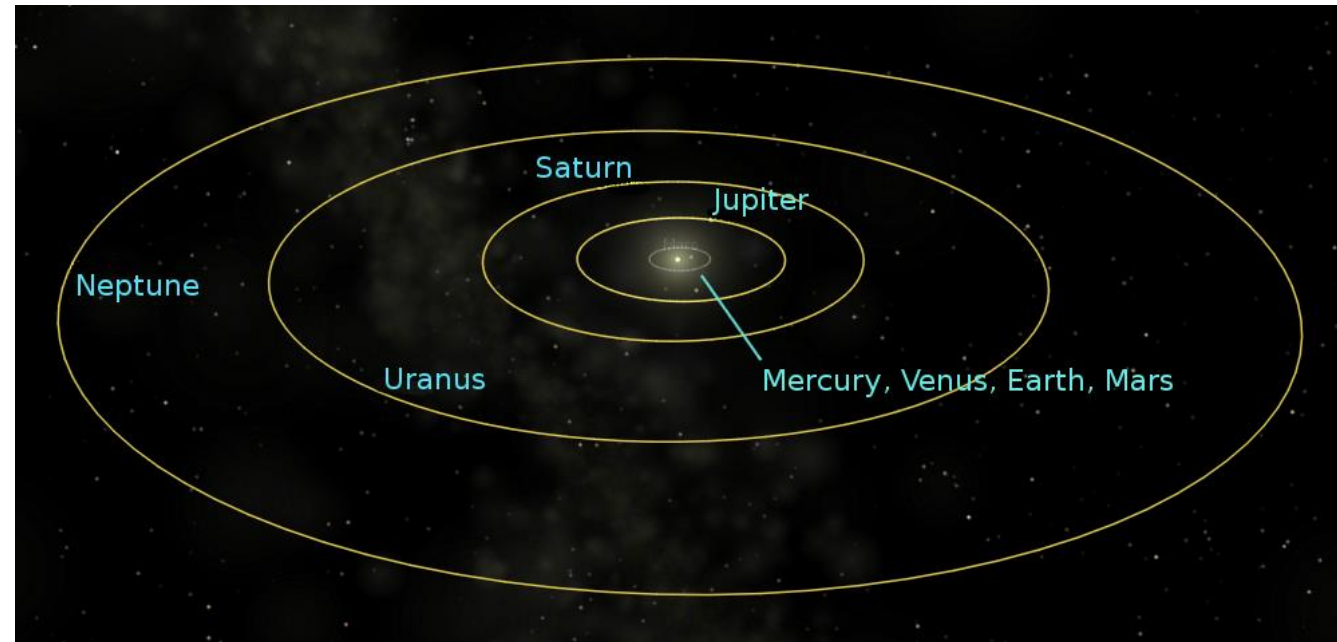
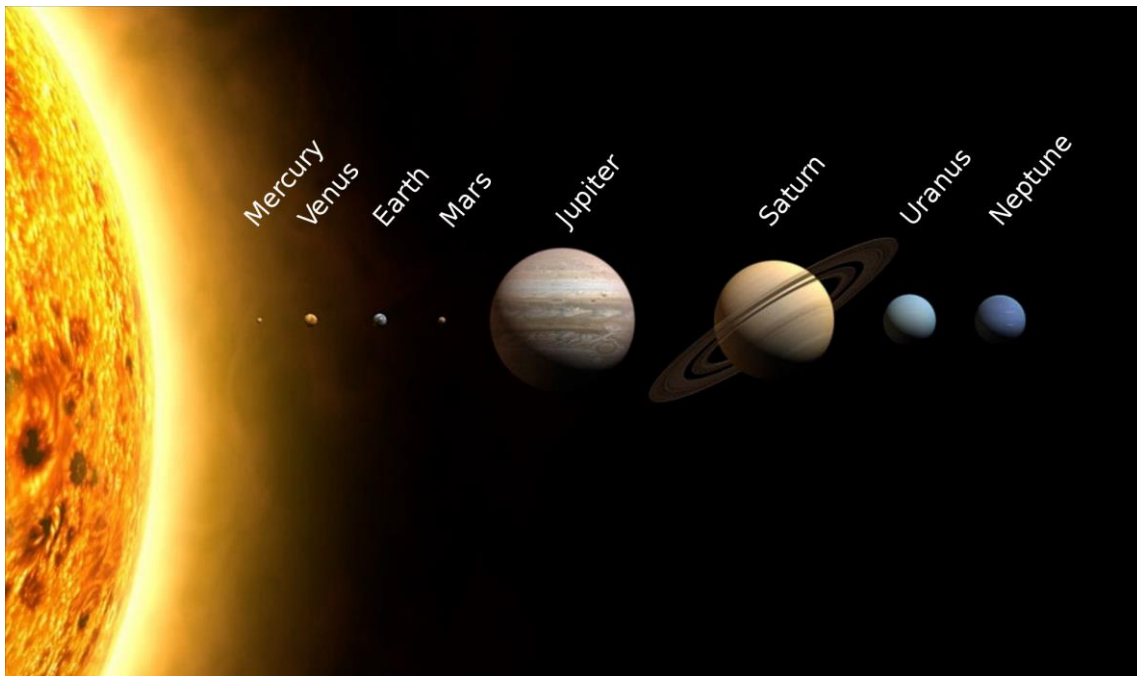
© 2017 All Rights Reserved  
www.ck12.org

# Twinkle twinkle...



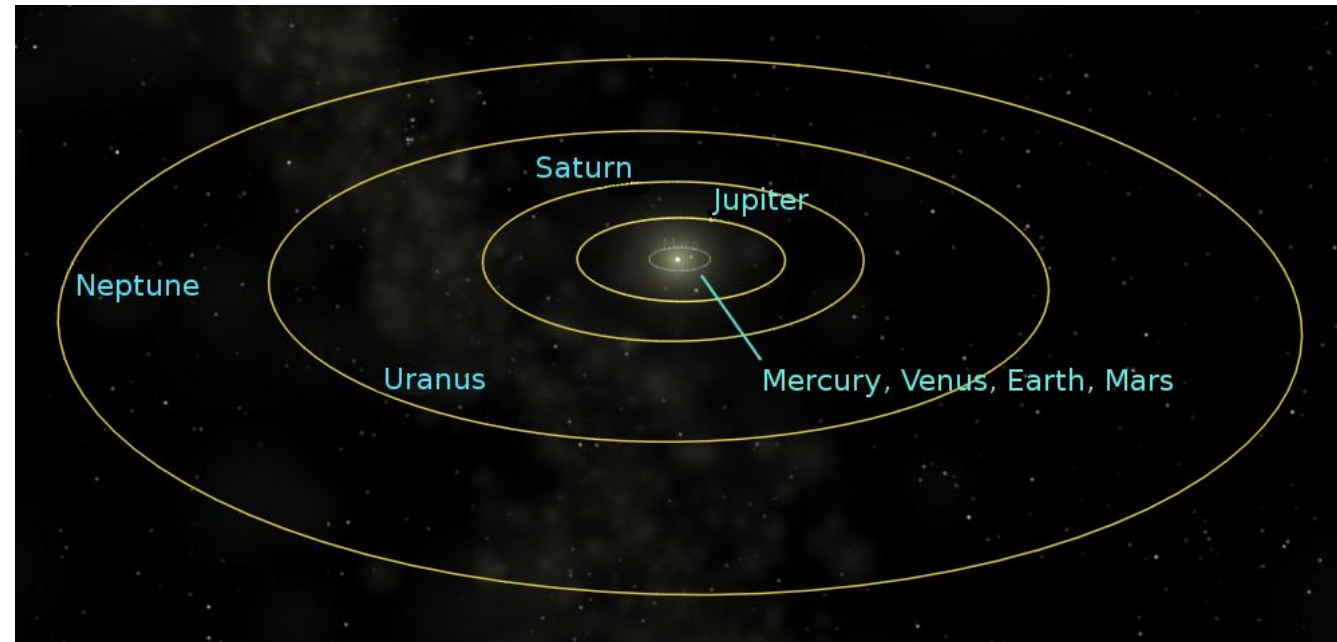
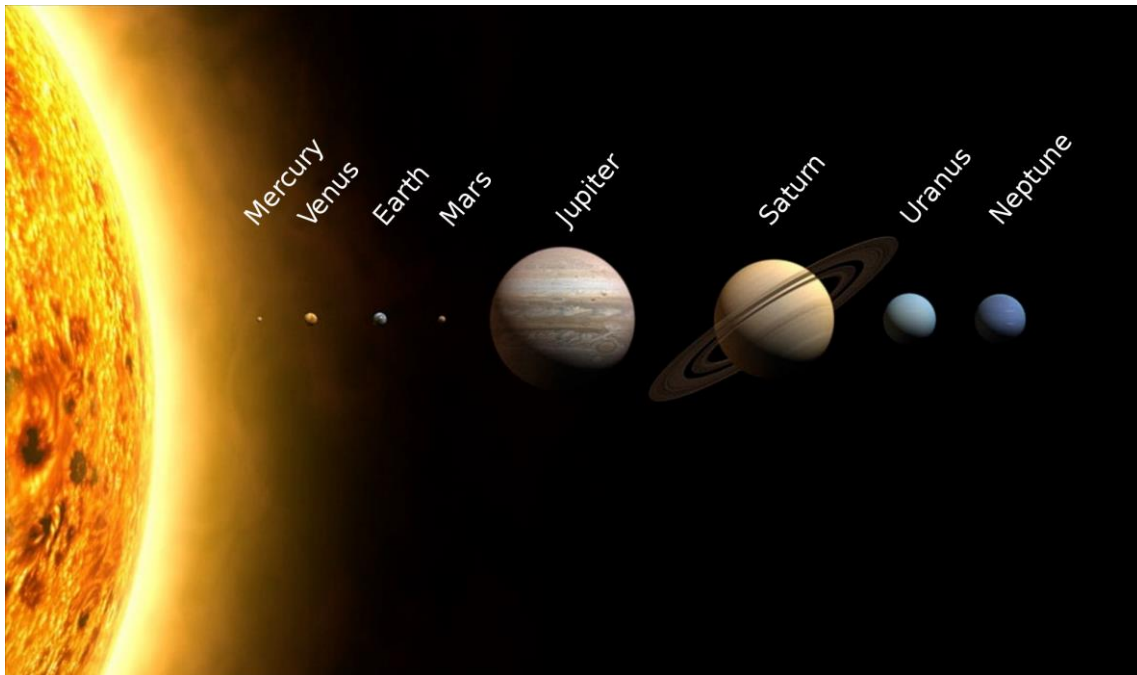
**1st cycle**

# Solar system



Our star is at least a 2nd generation star

# Solar system

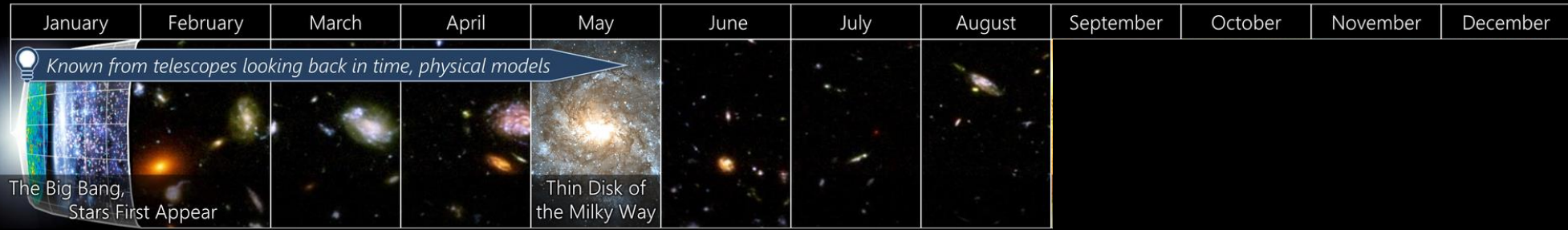


Cycle: solar year

# Solar system

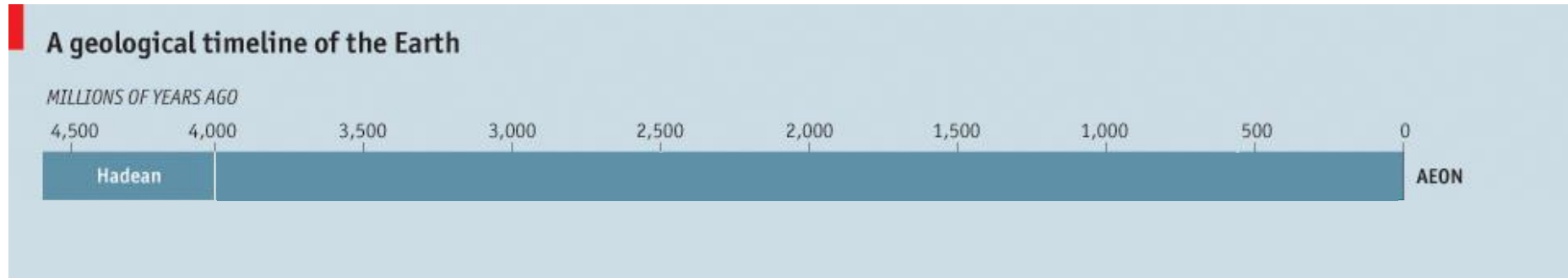
## The Cosmic Calendar

The 13.8 billion year history of the universe scaled down to a single year, where the Big Bang is January 1<sup>st</sup> at midnight, and right now is midnight 1 year later



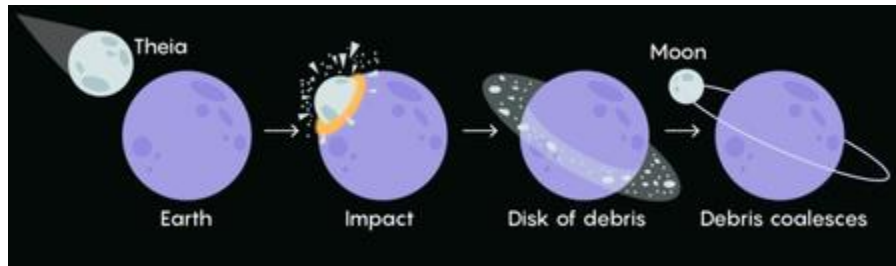
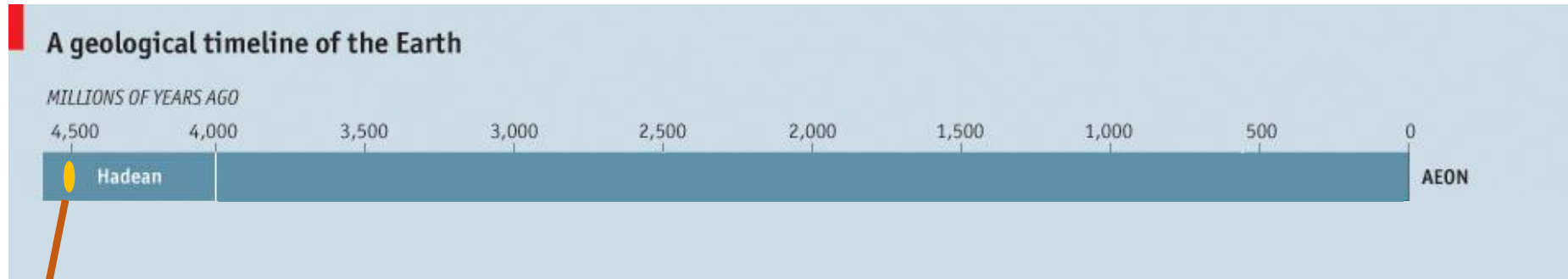
Last days of august  
4.7 billion years ago

# Hadean





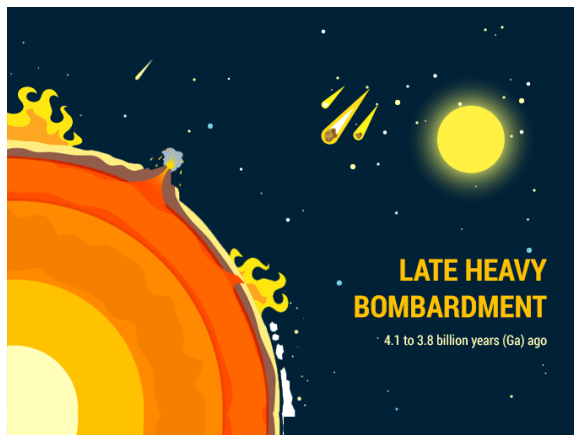
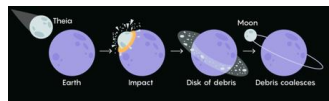
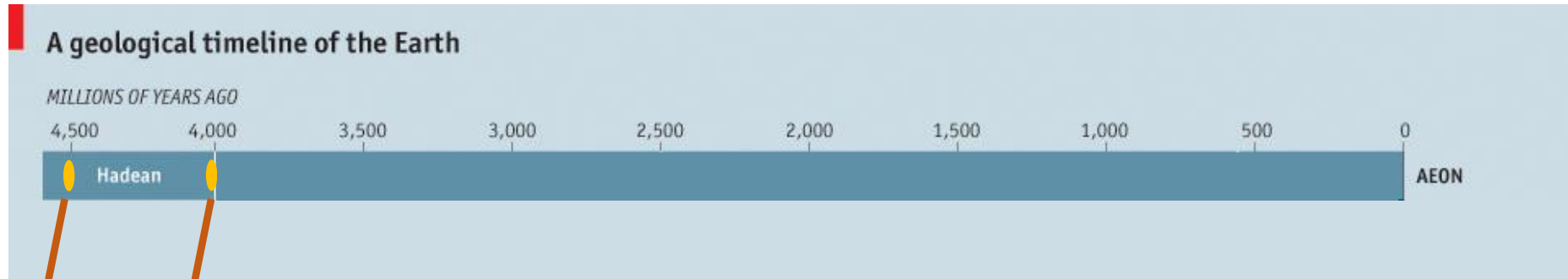
# Hadean



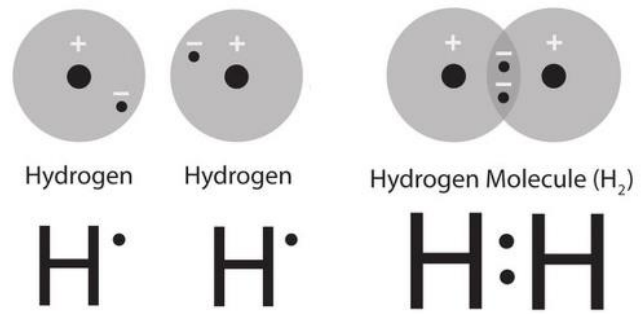
Cycle: lunar month

Cycle: 1 day = 12 hours

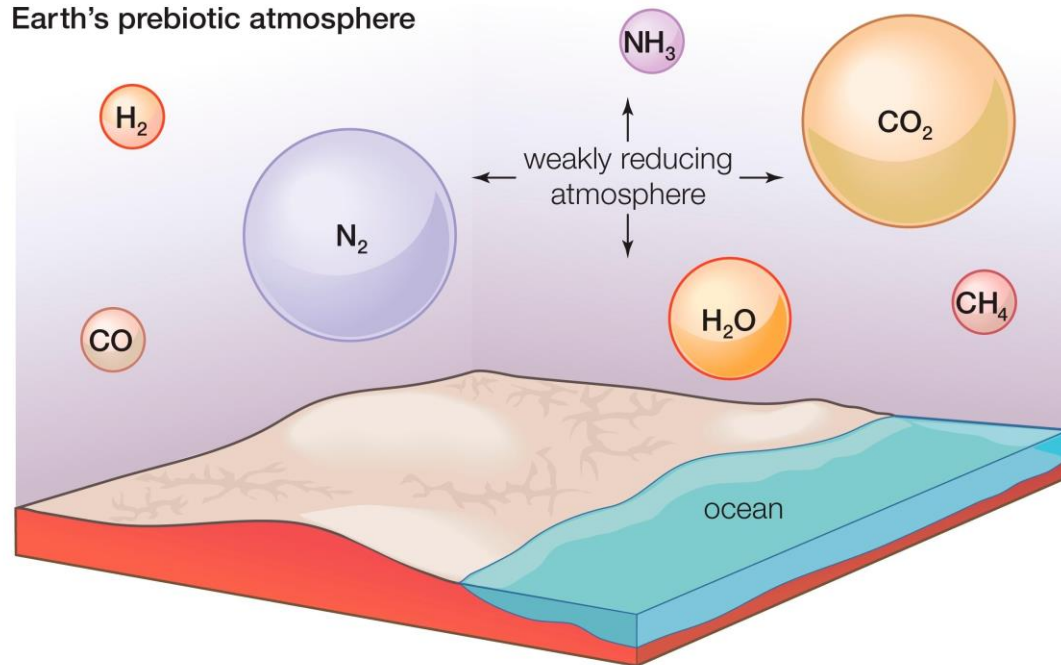
# Hadean

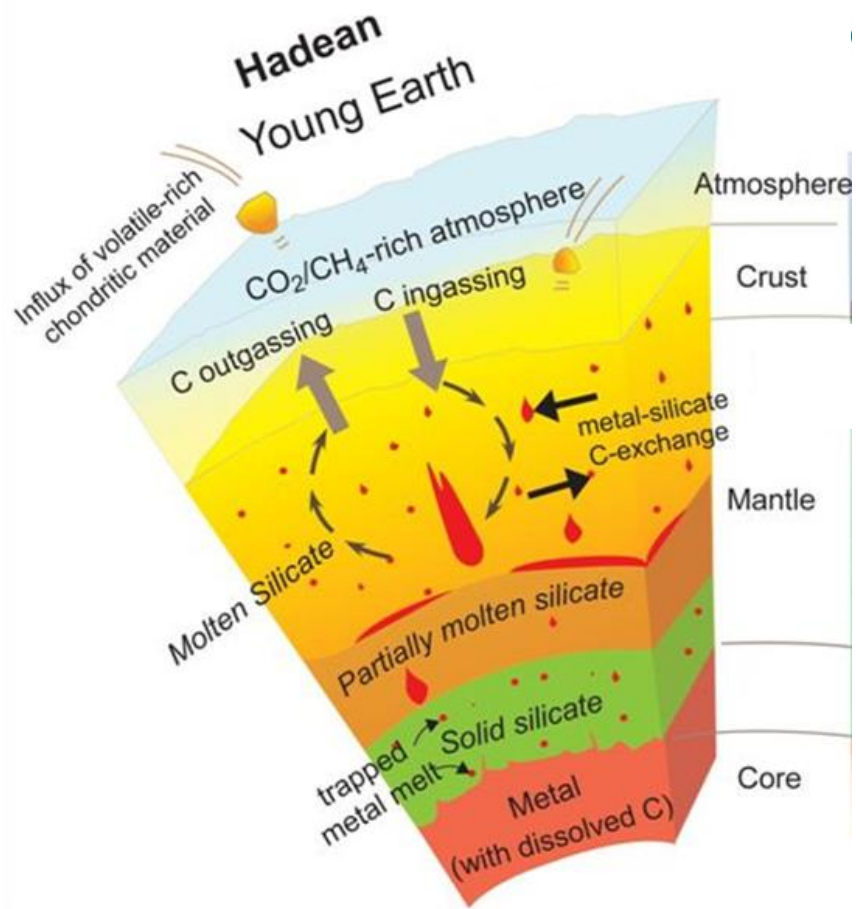


# Molecules

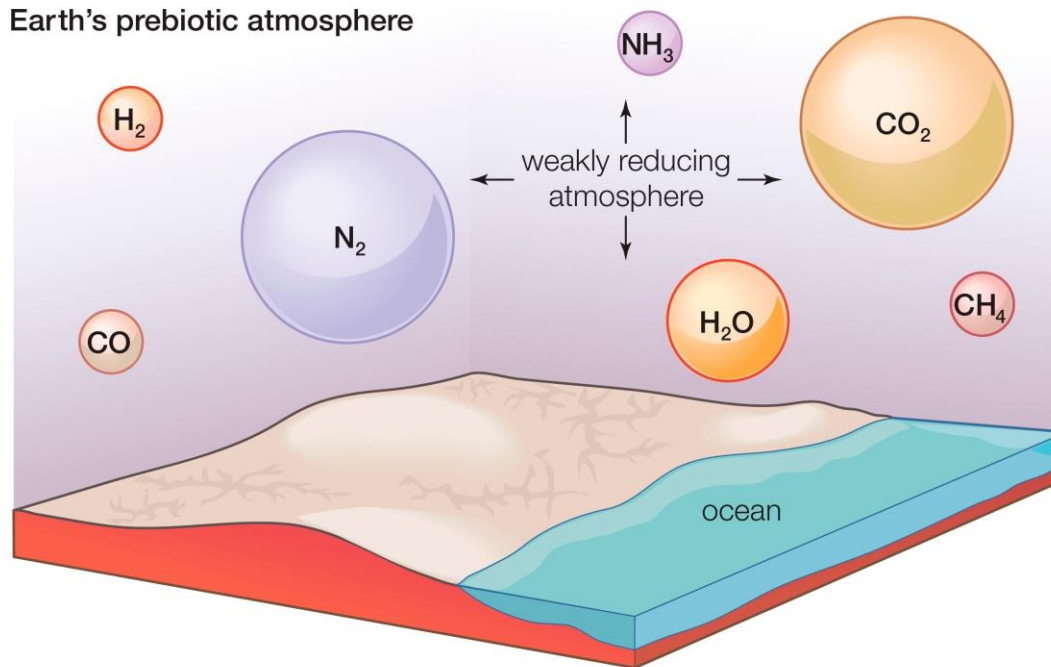


Earth's prebiotic atmosphere





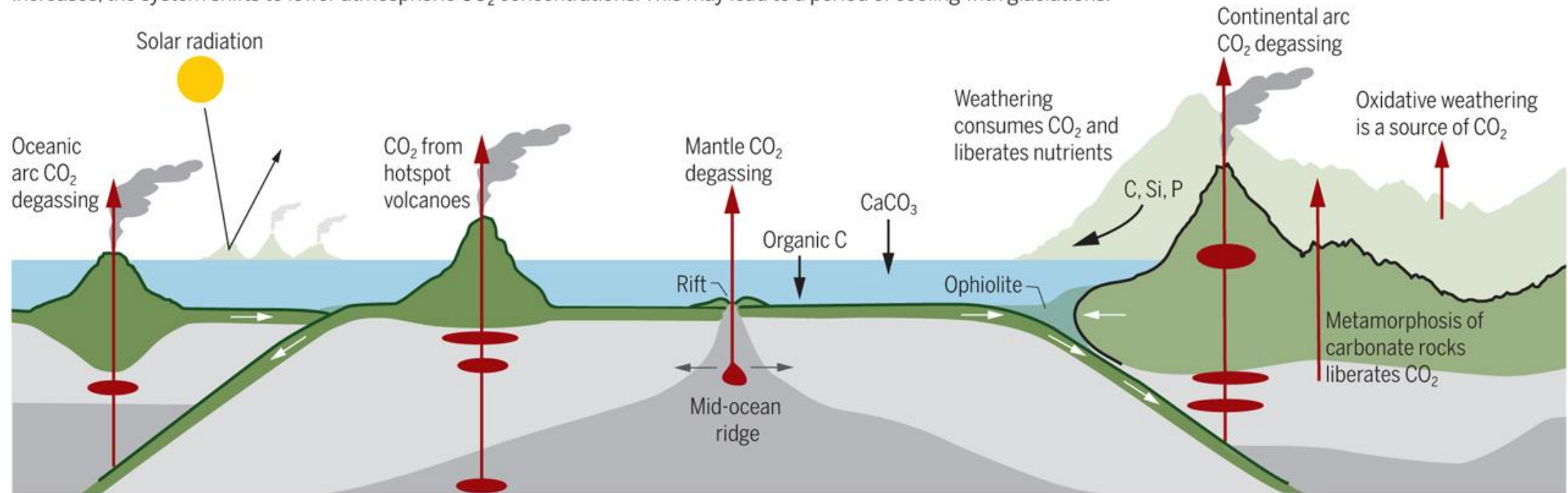
Earth's prebiotic atmosphere



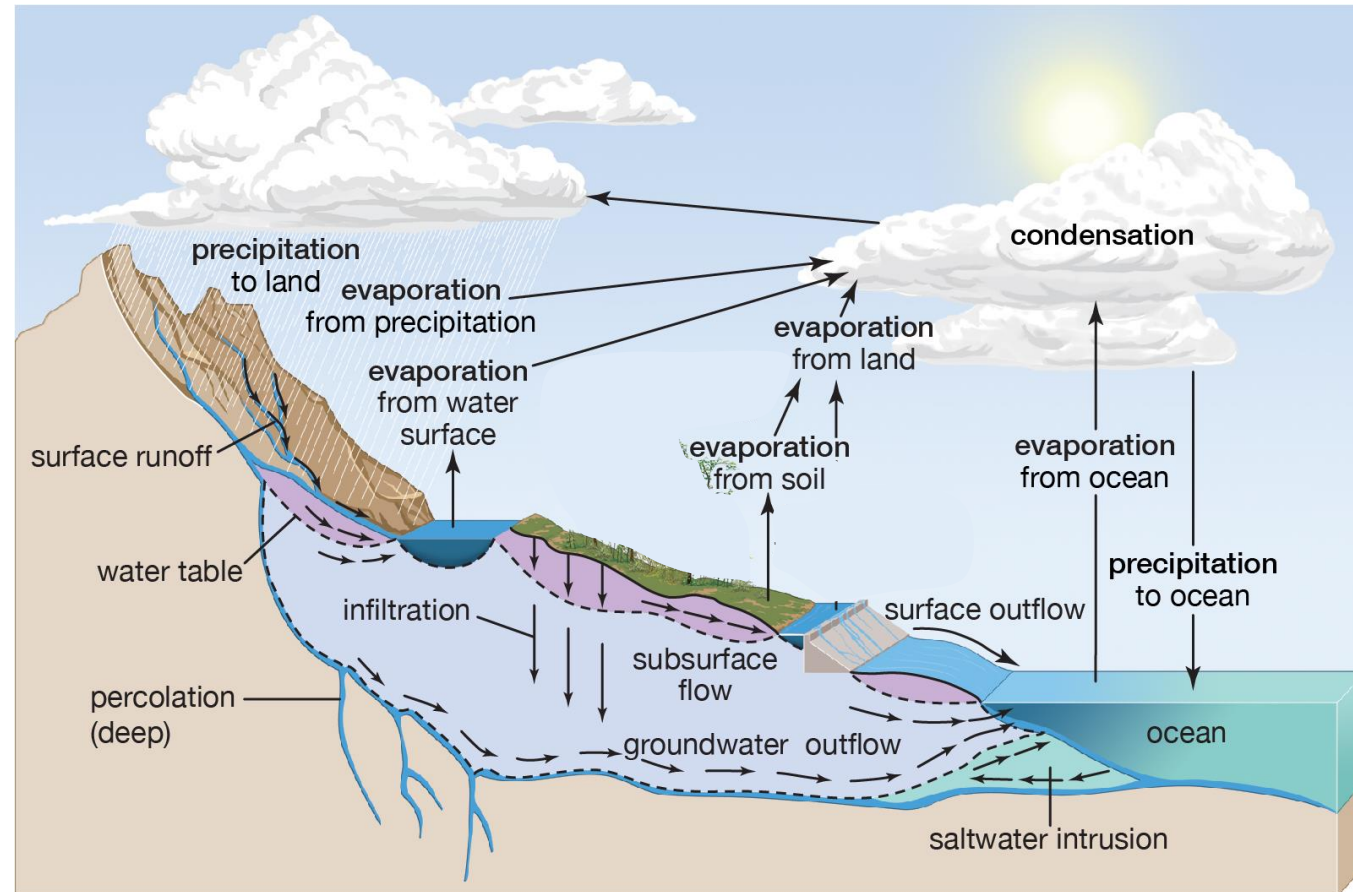
# Plate tectonics

## Geological sources and sinks of CO<sub>2</sub>

Solar radiation, as well as the differences between sinks and sources of CO<sub>2</sub>, contributes to the state of the climate. If a sink term, such as weathering of ophiolite complexes, increases, the system shifts to lower atmospheric CO<sub>2</sub> concentrations. This may lead to a period of cooling with glaciations.



# Water cycle



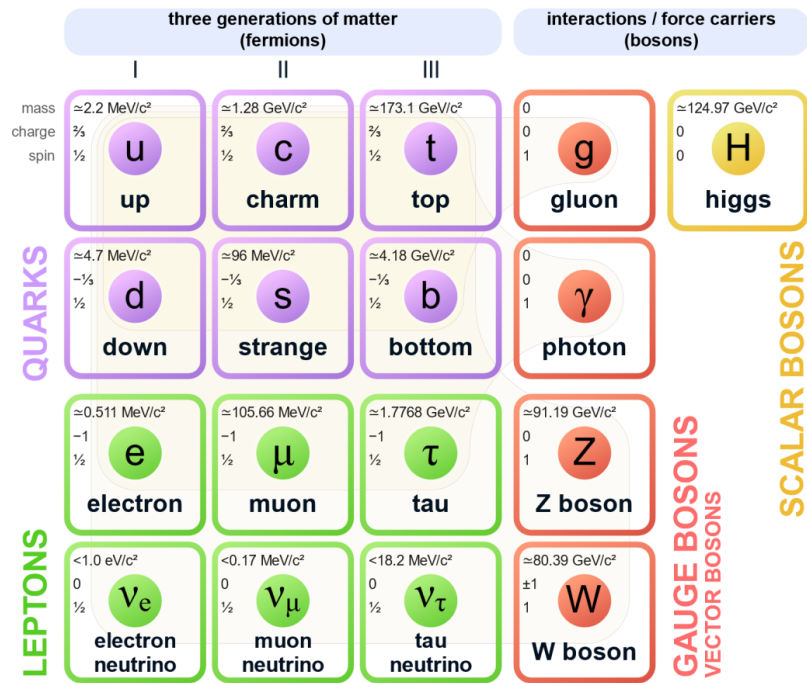
soil moisture groundwater

ocean covers 71 percent of Earth's surface  
196,950,000 sq mi (510,000,000 sq km)

© 2015 Encyclopædia Britannica, Inc.

# Kits of building blocks

## Standard Model of Elementary Particles



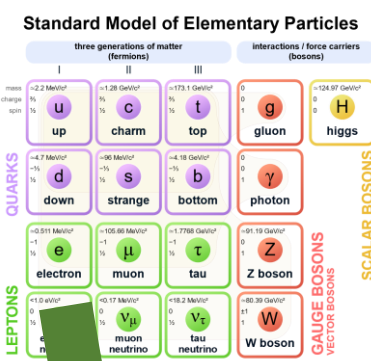
# Kits of building blocks

## Nucleus

Periodic Table of the Elements

## Atoms

Periodic Table of the Elements



Periodic Table of the Elements (Nucleus) showing elements from Hydrogen (1) to Oganesson (118). The table is color-coded by groups: Alkali Metal (red), Alkaline Earth (orange), Transition Metal (yellow), Basic Metal (green), Metalloid (light green), Nonmetal (blue), Halogen (purple), Noble Gas (pink), Lanthanide (grey), and Actinide (dark grey).

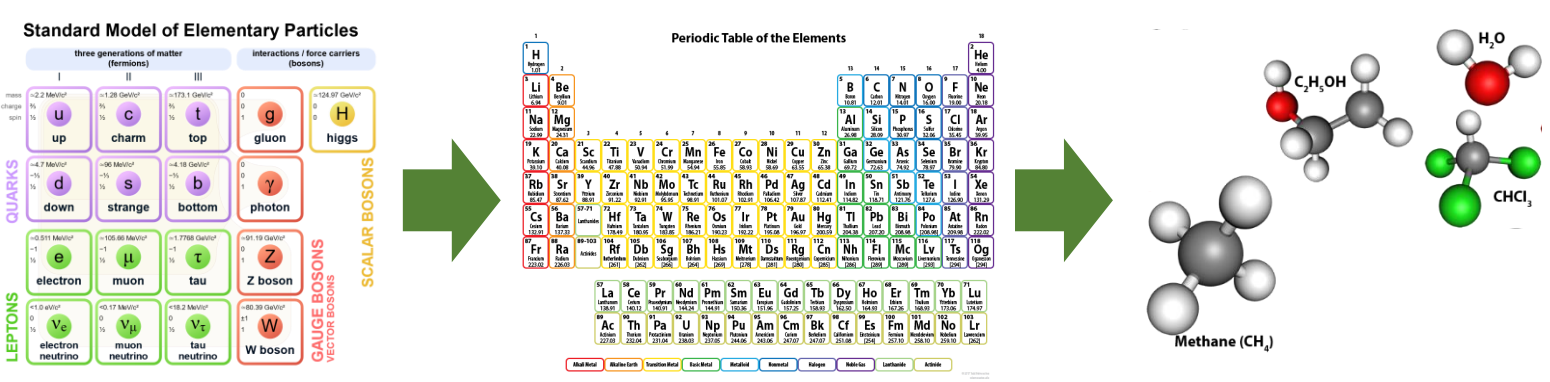
Periodic Table of the Elements (Atoms) showing elements from Hydrogen (1) to Oganesson (118). The table is color-coded by groups: Alkali Metal (red), Alkaline Earth (orange), Transition Metal (yellow), Basic Metal (green), Metalloid (light green), Nonmetal (blue), Halogen (purple), Noble Gas (pink), Lanthanide (grey), and Actinide (dark grey).

- Alkali Metal
- Alkaline Earth
- Transition Metal
- Basic Metal
- Metalloid
- Nonmetal
- Halogen
- Noble Gas
- Lanthanide
- Actinide

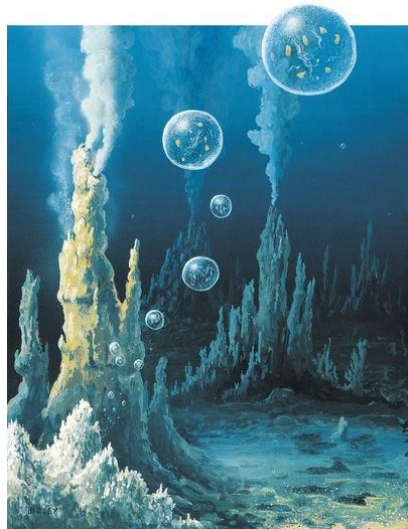
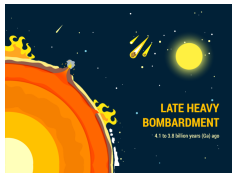
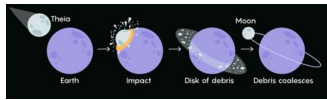
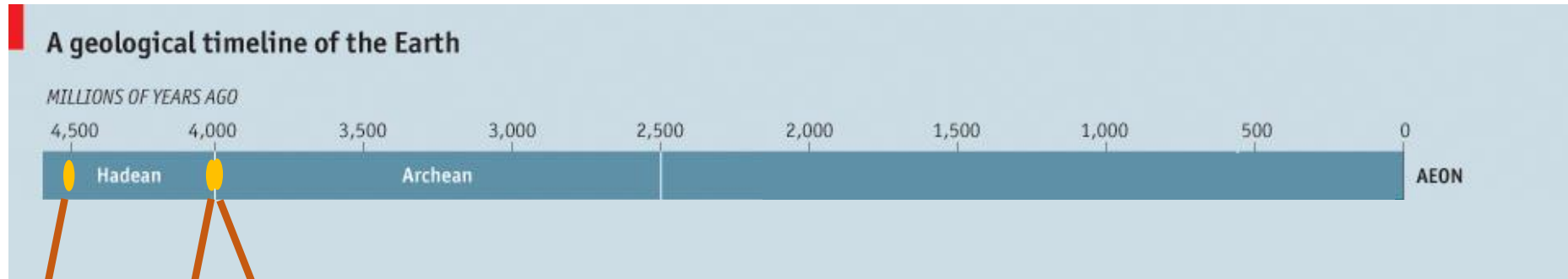
- Alkali Metal
- Alkaline Earth
- Transition Metal
- Basic Metal
- Metalloid
- Nonmetal
- Halogen
- Noble Gas
- Lanthanide
- Actinide



# Kits of building blocks



# Archean



## Natural selection

- Replication (with errors)
- Finite resources

Energy

+

Mass (building blocks)

## Evolution of life

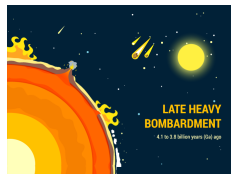
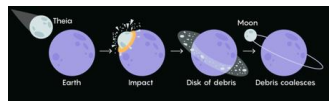
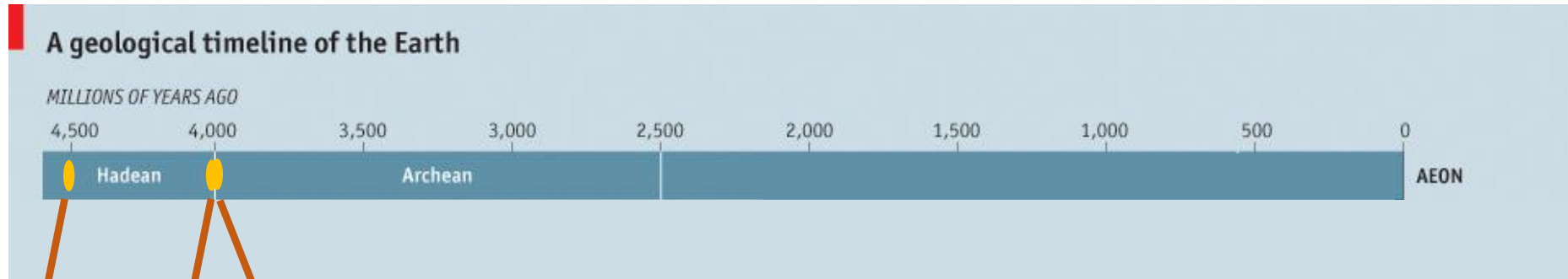
- Replication (with errors)
- Finite resources
- Metabolism

Energy

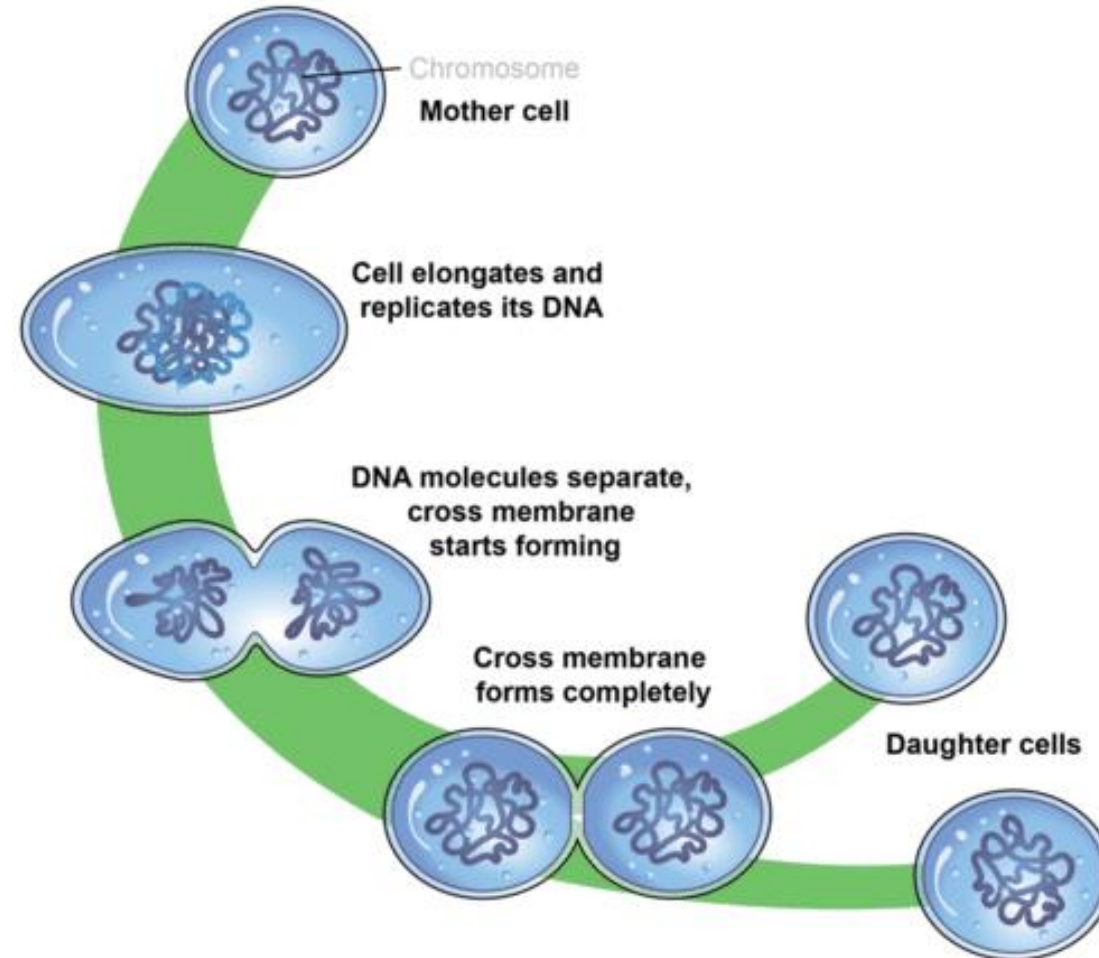
+

Mass (building blocks)

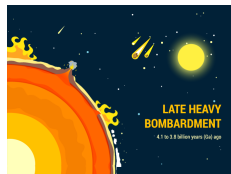
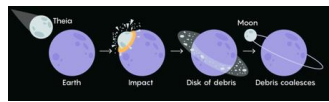
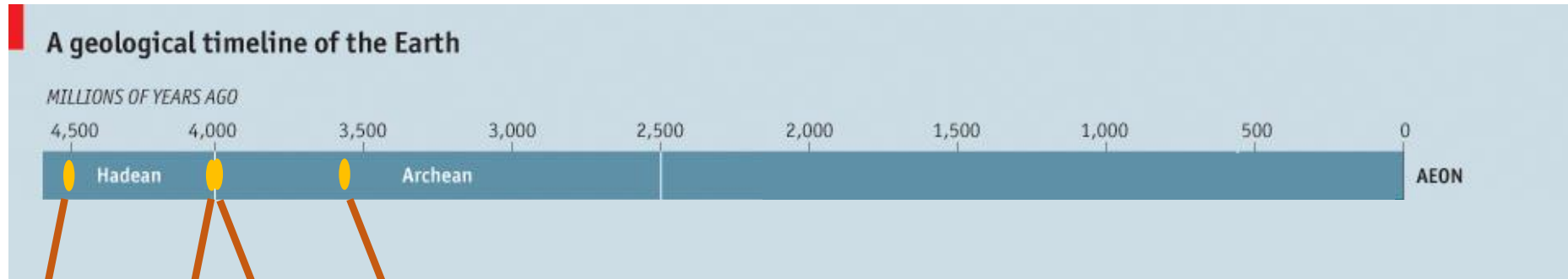
# Archean



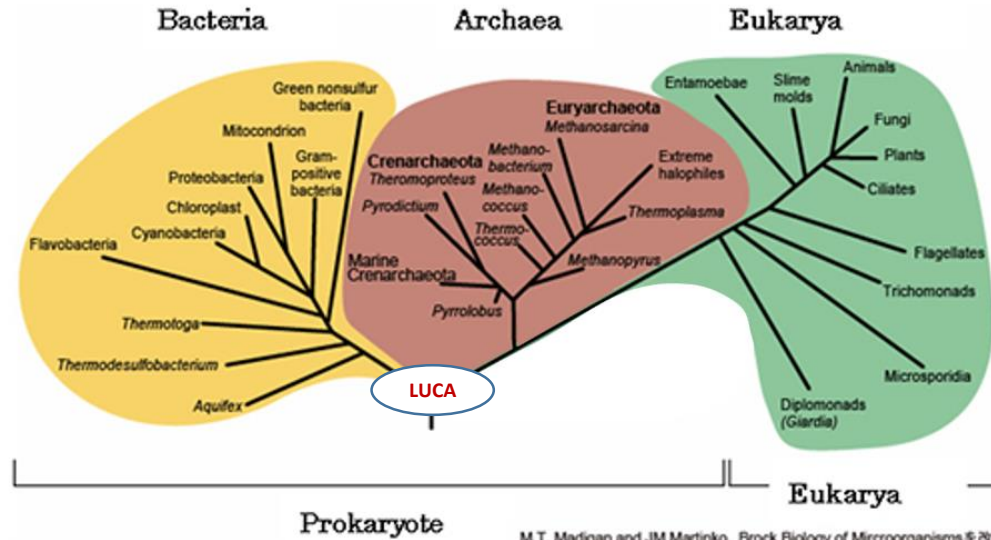
# Life cycle



# Archean



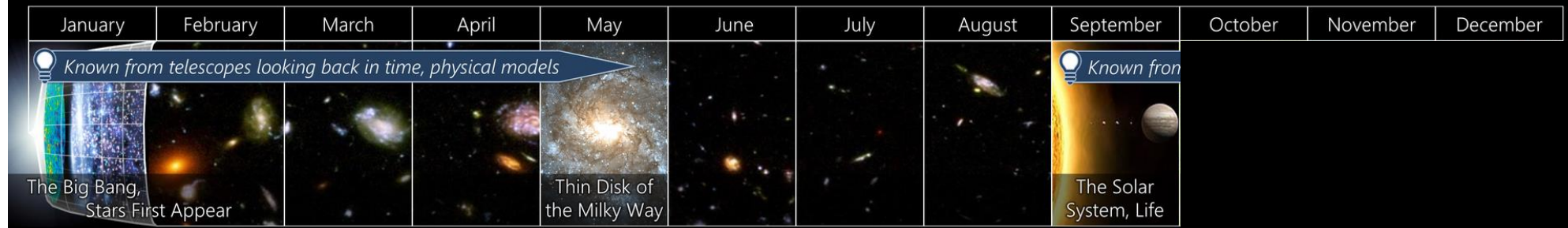
LUCA



# LUCA

## The Cosmic Calendar

The 13.8 billion year history of the universe scaled down to a single year, where the Big Bang is January 1<sup>st</sup> at midnight, and right now is midnight 1 year later

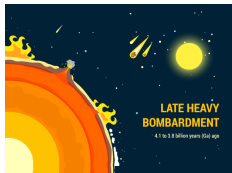
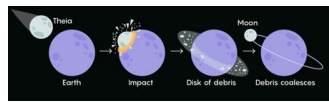
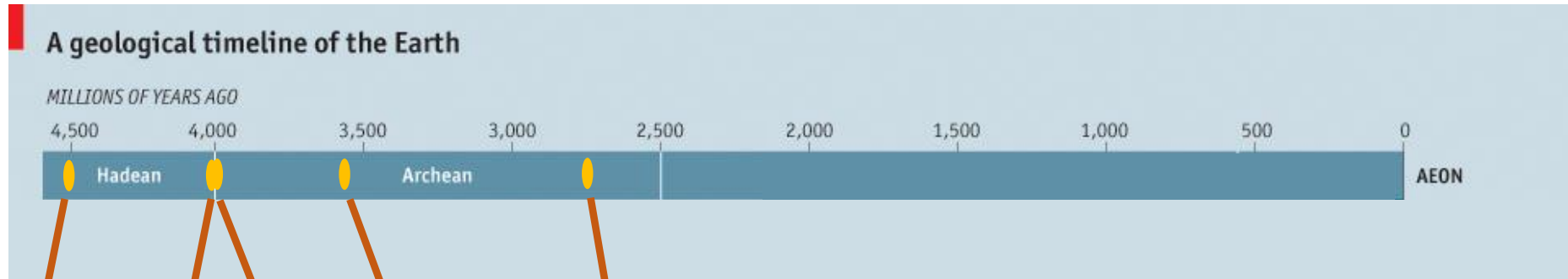


Last week of September  
3.7 billion years ago

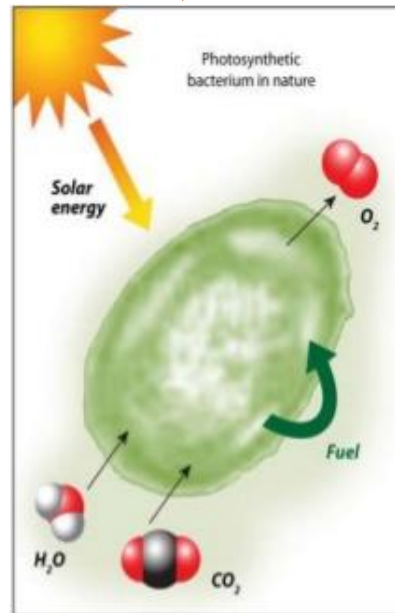




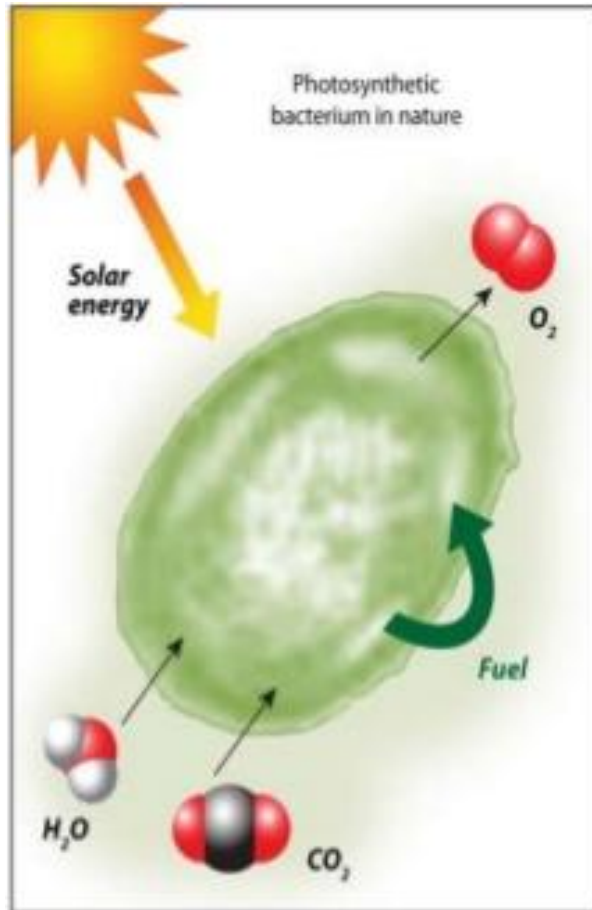
# Archean



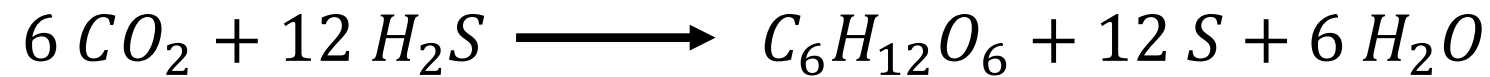
LUCA



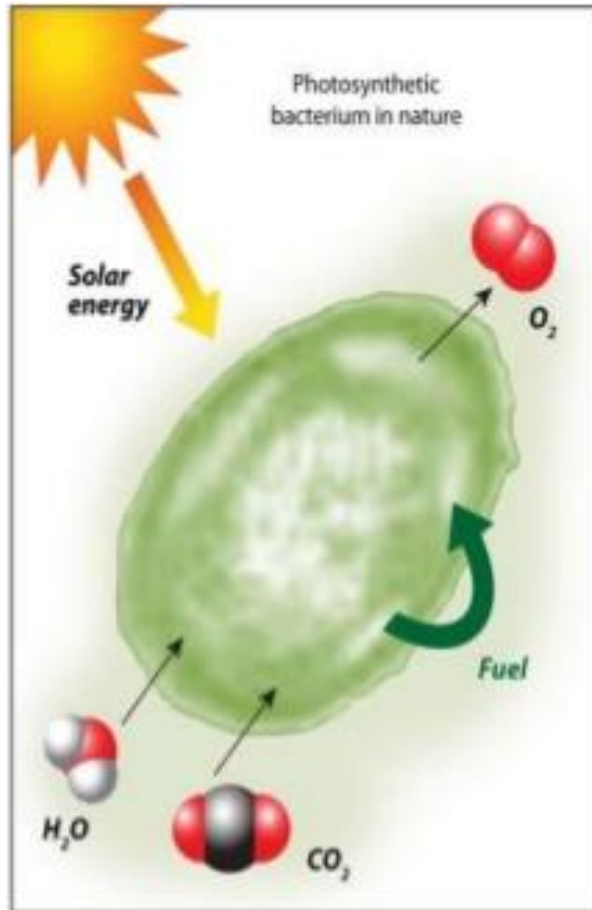
# Photosynthesis



Solar energy



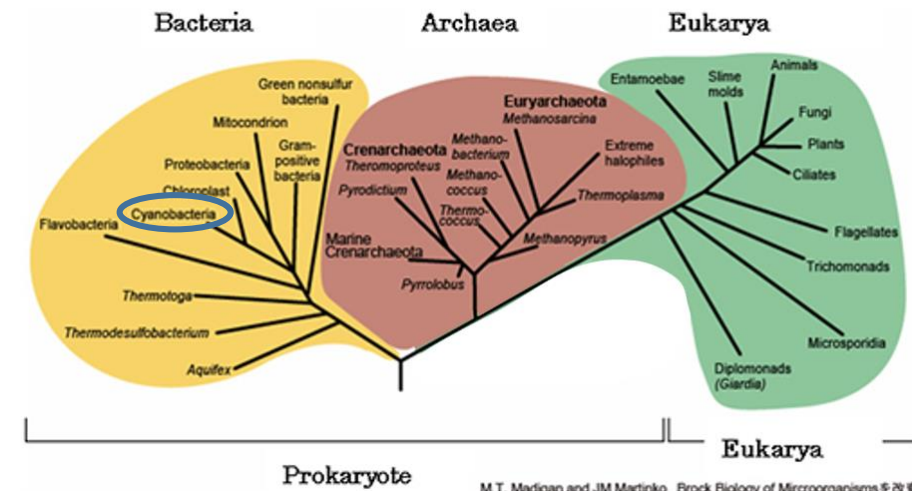
# Photosynthesis



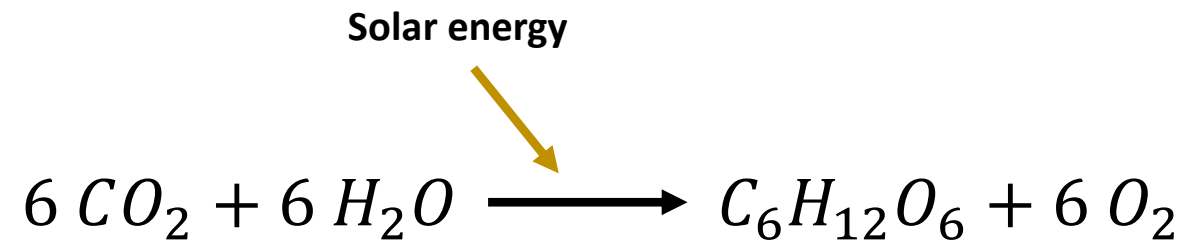
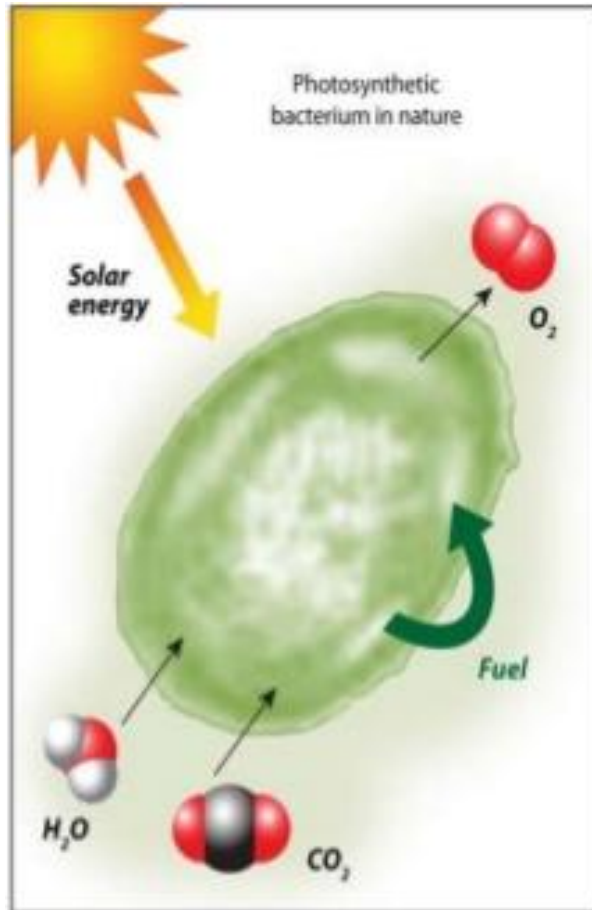
Solar energy



- Not plants!

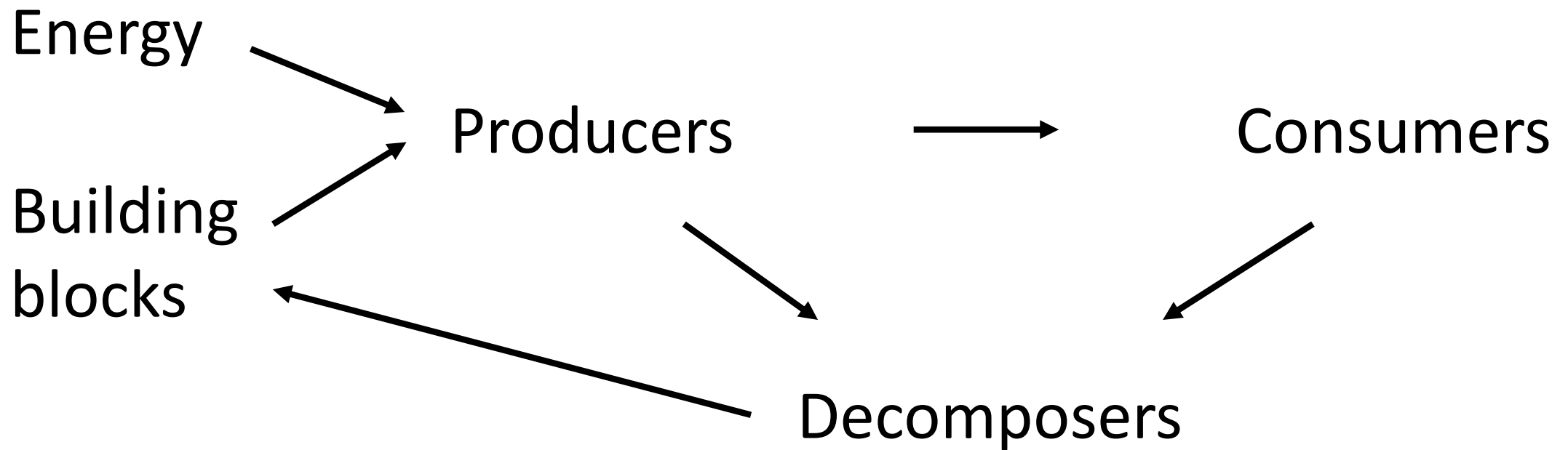


# Photosynthesis

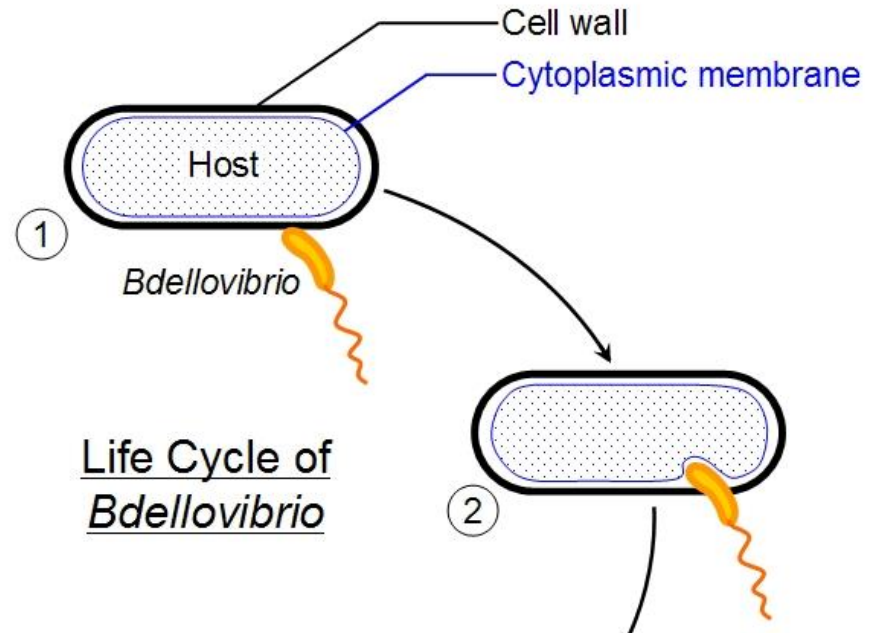


- Not plants!
- Energy sources

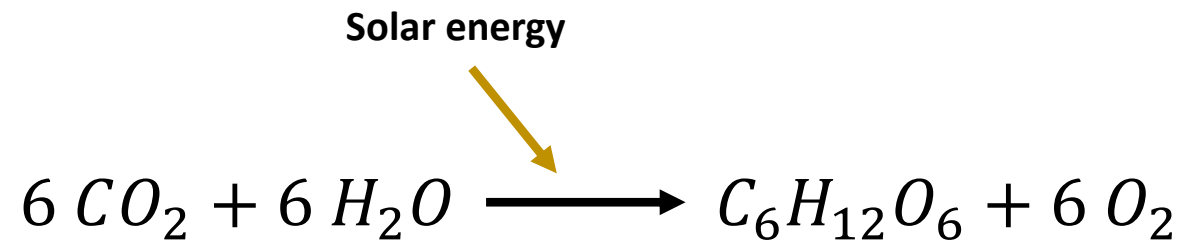
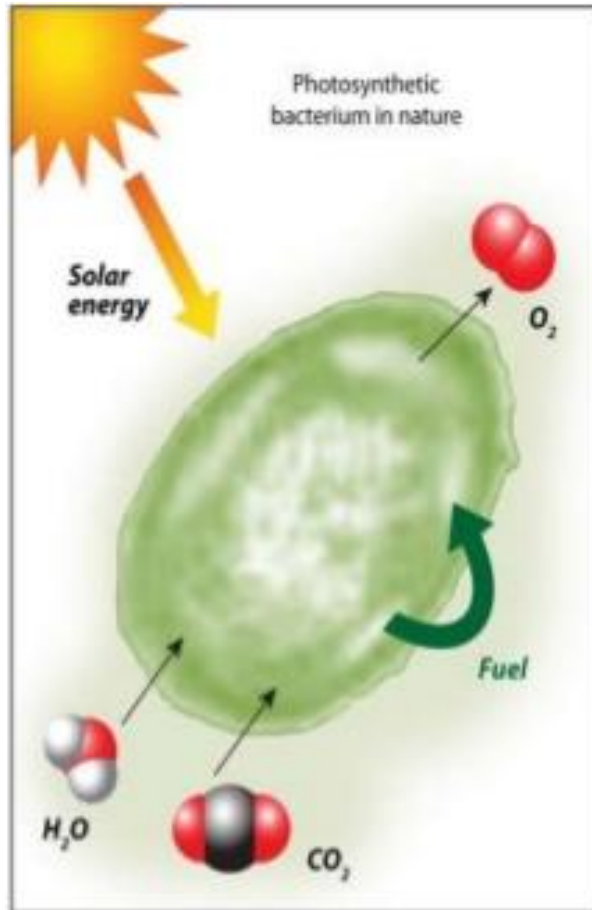
# Trophic cycle



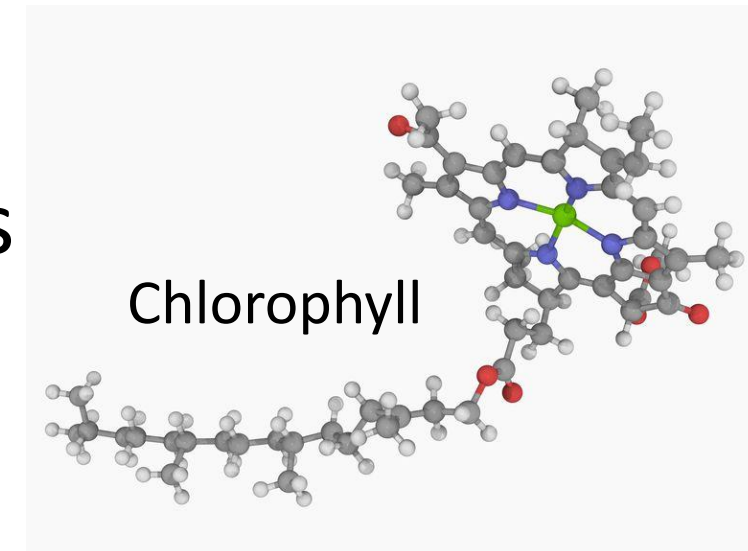
# Prokaryote predation (example)



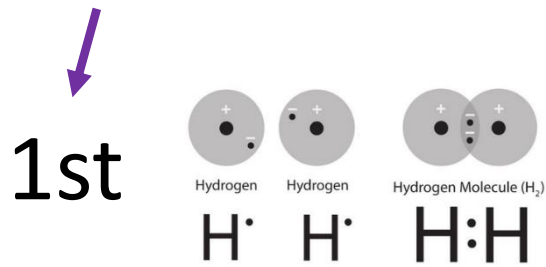
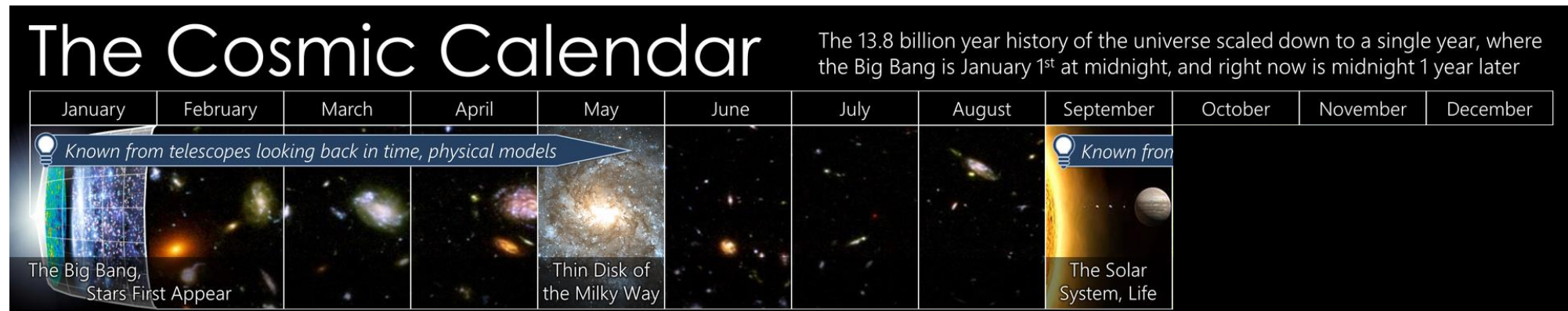
# Photosynthesis



- Not plants!
- Energy sources
- Molecules



# Molecular revolutions



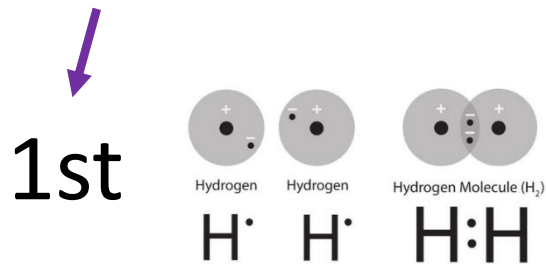
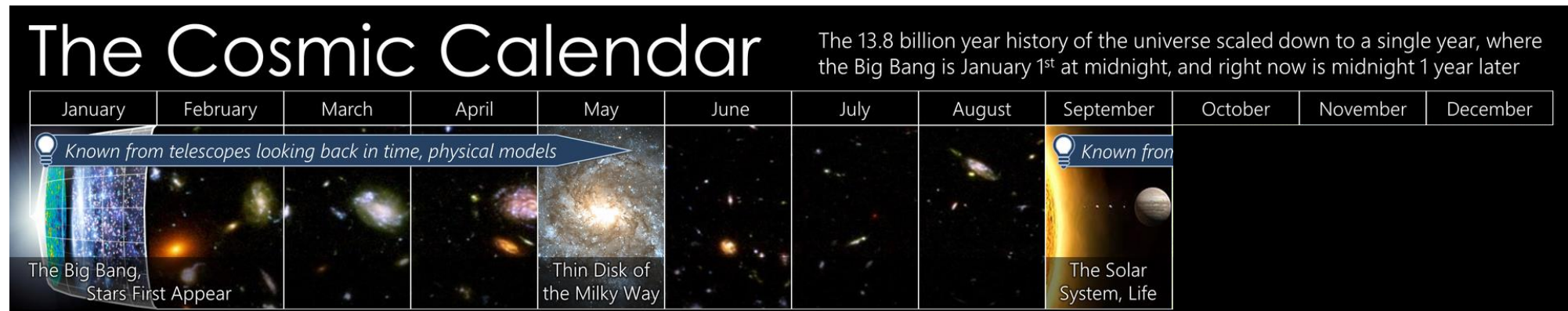
Proof of concept!

2<sup>nd</sup>    3<sup>rd</sup>    4<sup>th</sup>

Abiotic    Biotic    Synthesized



# Molecular revolutions

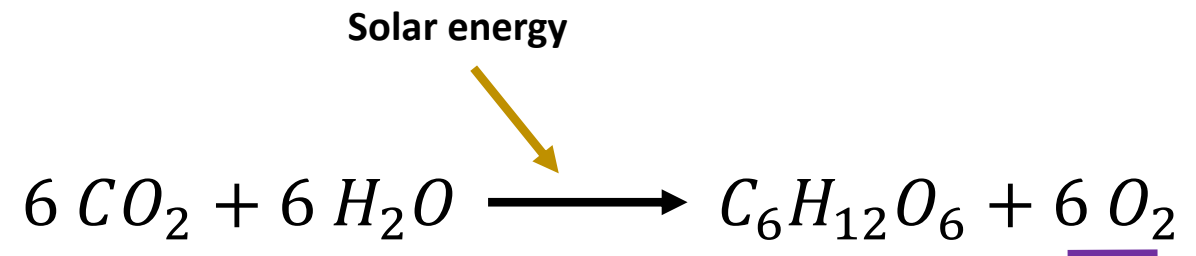
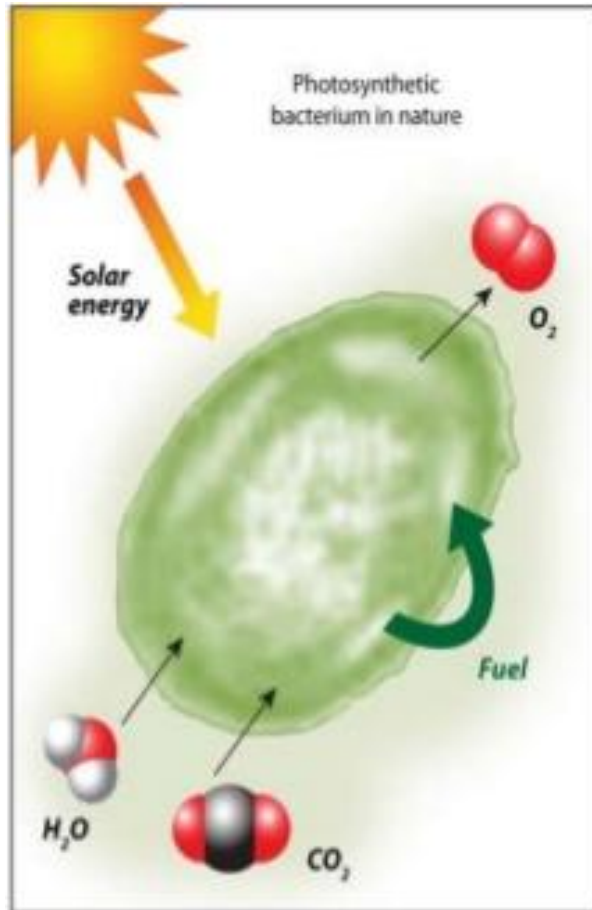


Proof of concept!

2<sup>nd</sup>    3<sup>rd</sup>    4<sup>th</sup>

Abiotic    Biotic    Synthesized

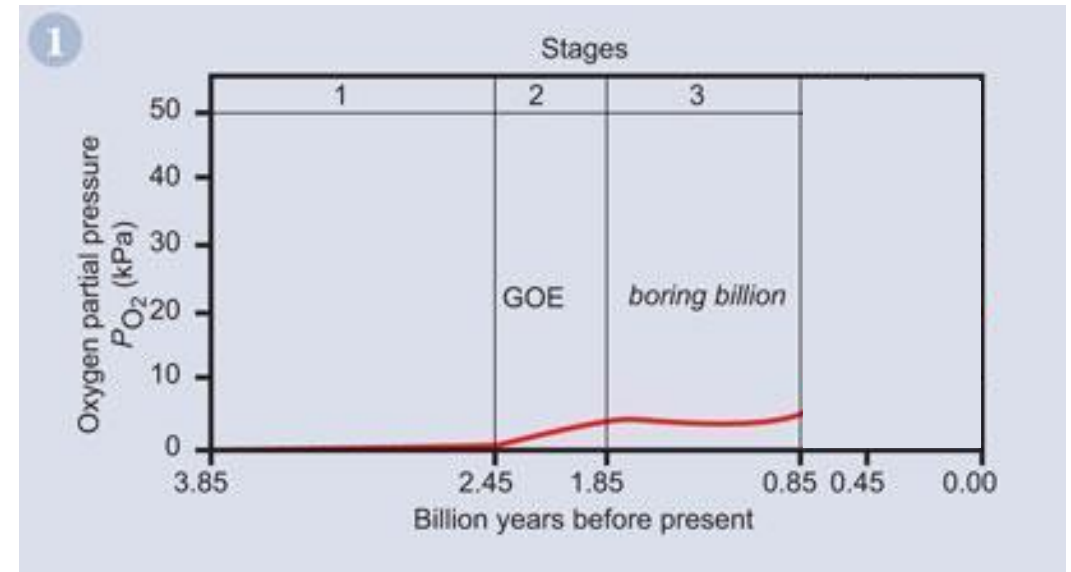
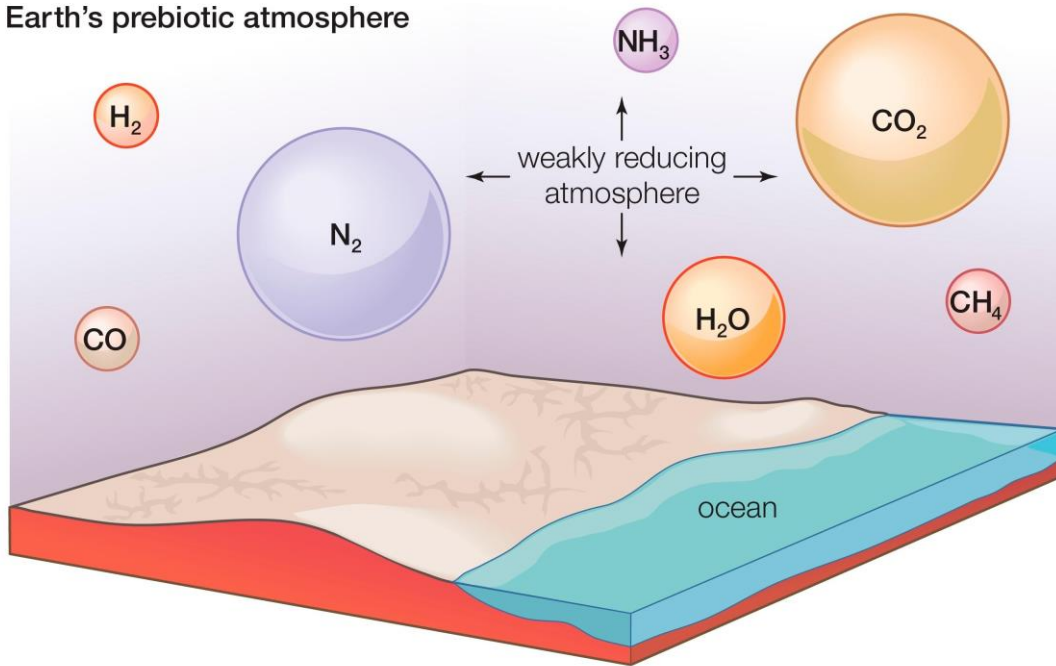
# Photosynthesis



- Not plants!
- Energy sources
- Molecules

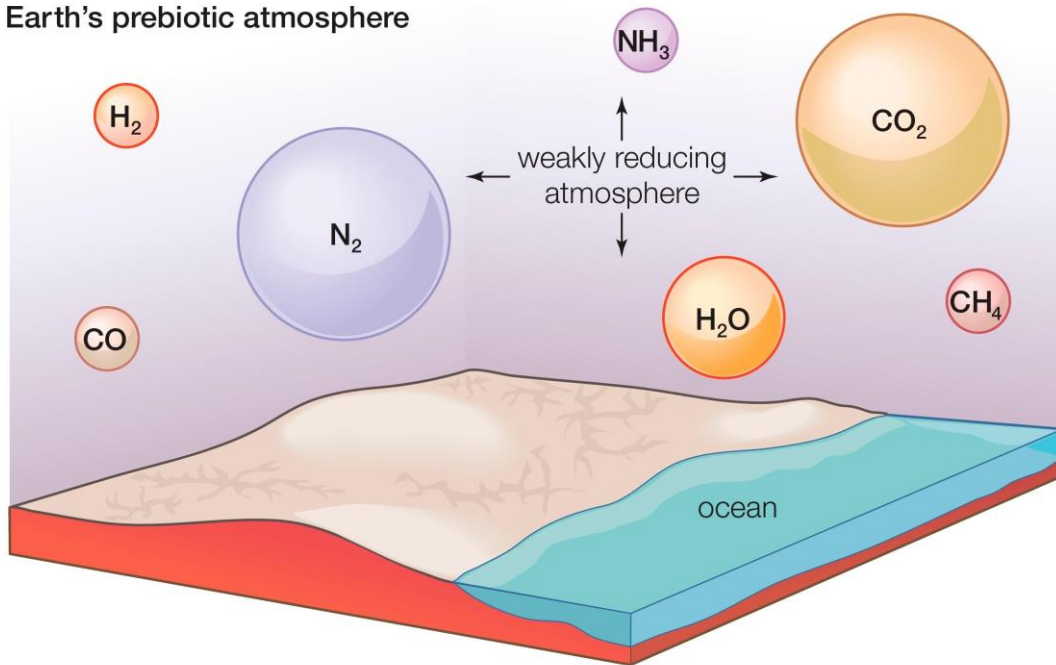
# The Great Oxidation Event

Earth's prebiotic atmosphere

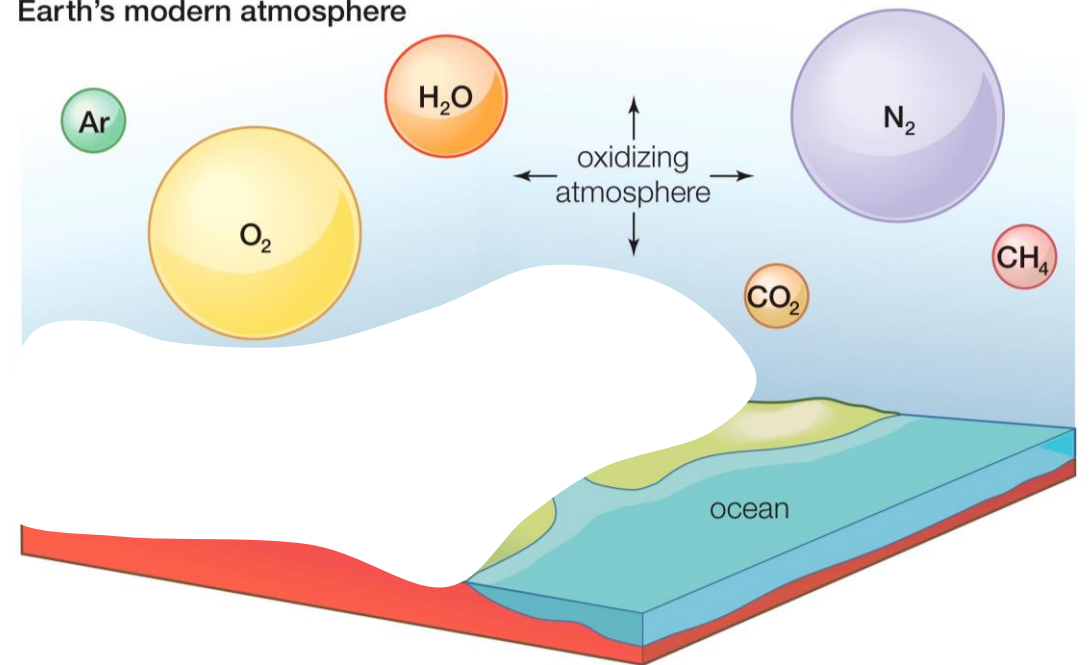


# The Great Oxidation Event

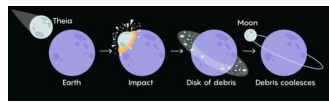
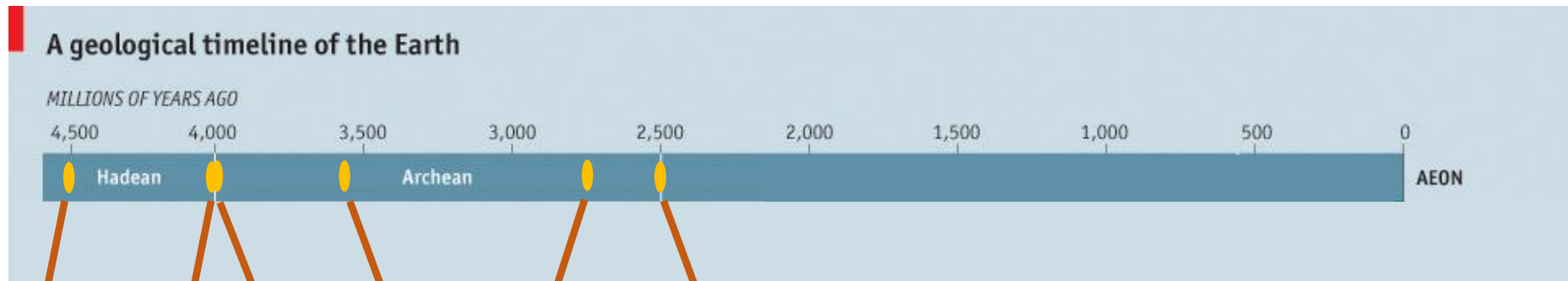
Earth's prebiotic atmosphere



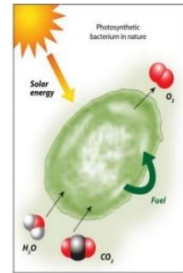
Earth's modern atmosphere



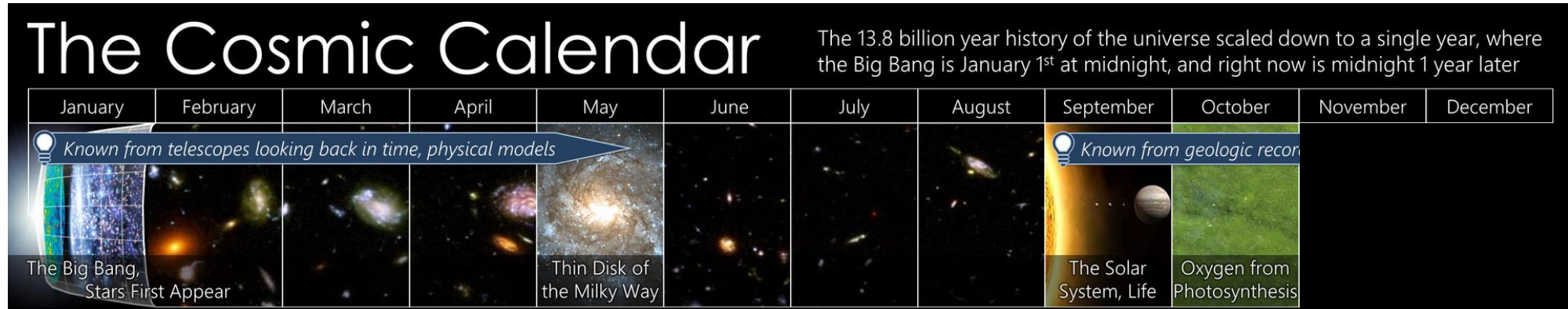
# Archean



LUCA

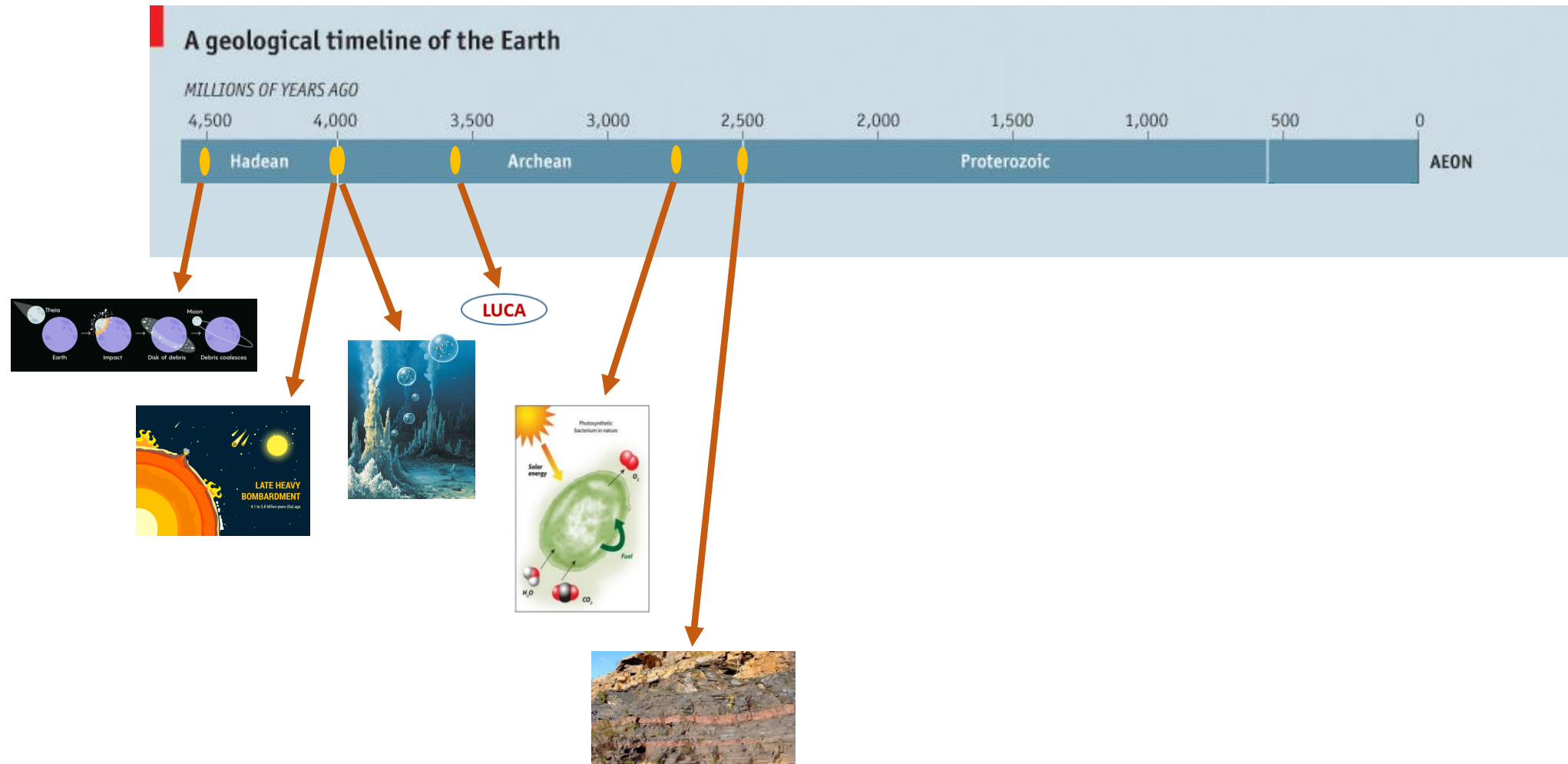


# The Great Oxidation Event



Last week of October  
2.5 billion years ago

# Proterozoic



# Kits of building blocks

**Standard Model of Elementary Particles**

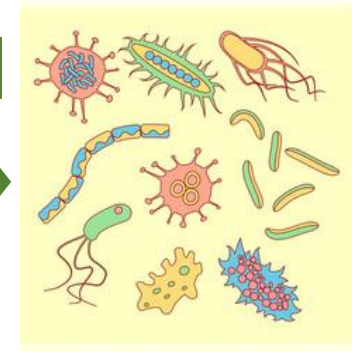
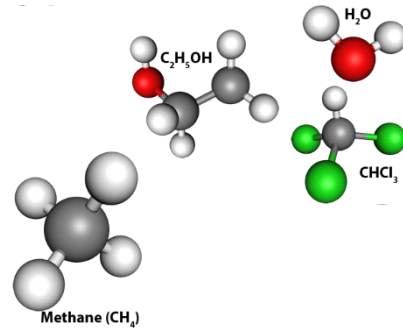
three generations of matter (fermions)			interactions / force carriers (bosons)	
I	II	III	0	1
$\frac{2}{3}$ +2.2 MeV/c <sup>2</sup> u up	$\frac{2}{3}$ +1.28 GeV/c <sup>2</sup> c charm	$\frac{2}{3}$ +173.1 GeV/c <sup>2</sup> t top	0 g gluon	0 H higgs
$-\frac{1}{3}$ -4.7 MeV/c <sup>2</sup> d down	$-\frac{1}{3}$ +96 MeV/c <sup>2</sup> s strange	$-\frac{1}{3}$ +4.18 GeV/c <sup>2</sup> b bottom	0 γ photon	
$-1$ +0.511 MeV/c <sup>2</sup> e electron	$-1$ +105.66 MeV/c <sup>2</sup> μ muon	$-1$ +1.778 GeV/c <sup>2</sup> τ tau	0 Z Z boson	
0 +1.0 eV/c <sup>2</sup> ν <sub>e</sub> electron neutrino	0 +0.17 MeV/c <sup>2</sup> ν <sub>μ</sub> muon neutrino	0 +18.2 MeV/c <sup>2</sup> ν <sub>τ</sub> tau neutrino	1 W W boson	

**QUARKS** (left column)  
**LEPTONS** (left column)  
**SCALAR BOSONS** (right column)  
**GAUGE BOSONS VECTOR BOSONS** (right column)



**Periodic Table of the Elements**

Map: Alkali Metals, Alkaline Earths, Transition Metals, Lanthanides, Actinides, Noble Gases

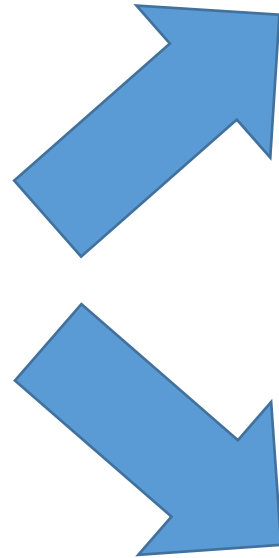
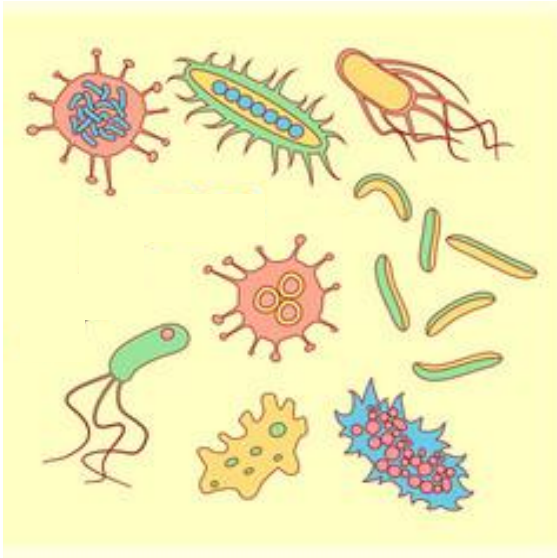






# Prokaryote organisms

Prokaryote



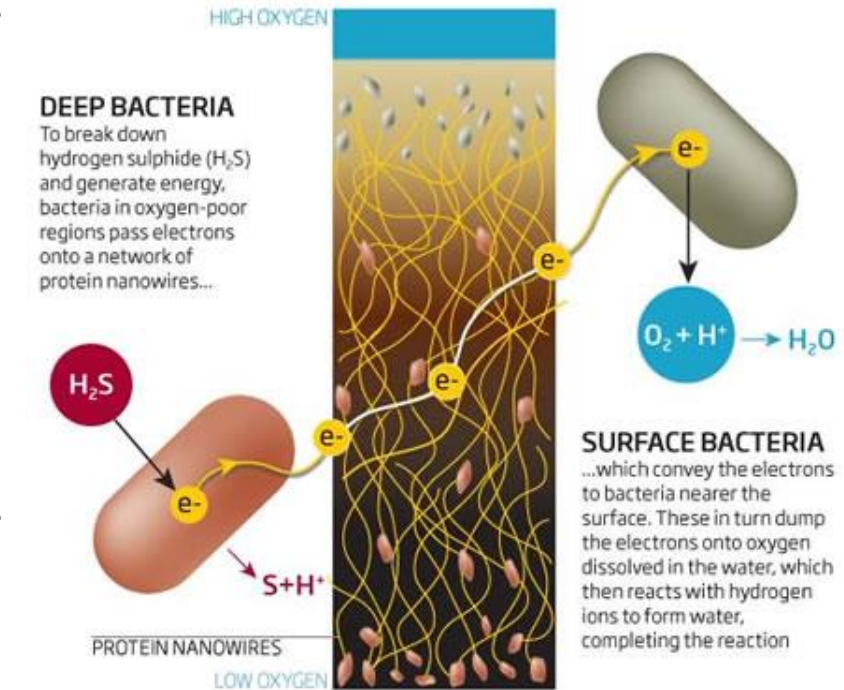
From organisms of the same species

From organisms of different species

## Electric partnership

©NewScientist

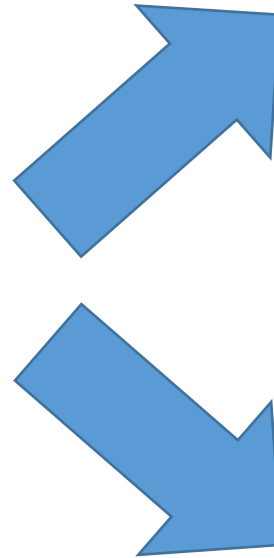
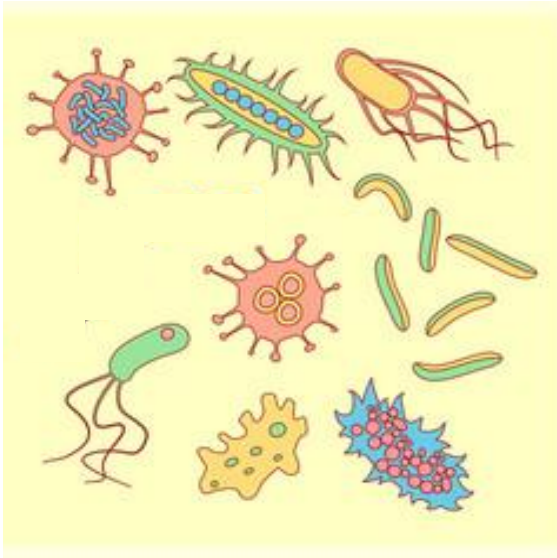
A nanowire network may allow bacteria in oxygen-poor ocean sediments to access the oxygen they need to break down their food



Symbiosis

# Prokaryote organisms

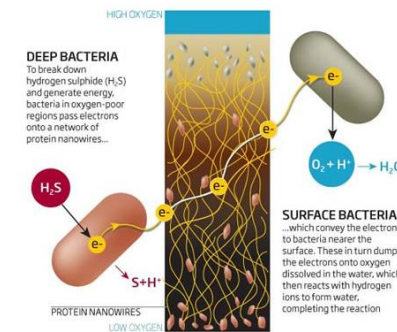
Prokaryote



From organisms of the same species

From organisms of different species

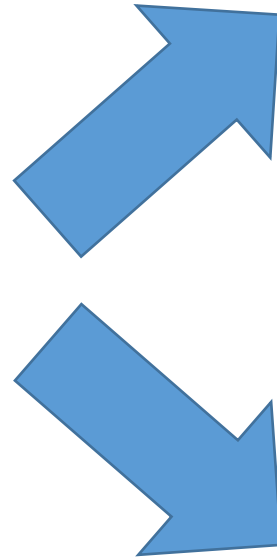
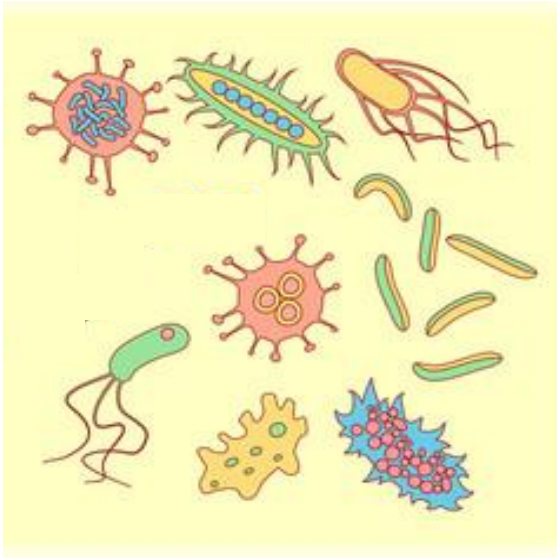
## Colonies



## Symbiosis

# Prokaryote organisms

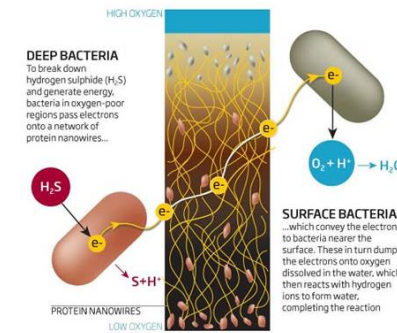
Prokaryote



From organisms of the same species

From organisms of different species

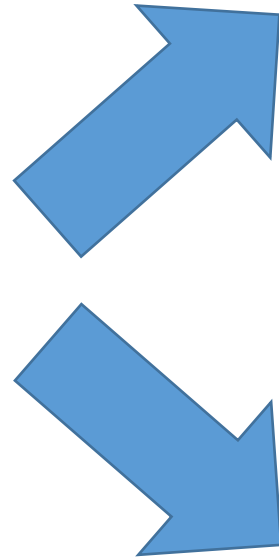
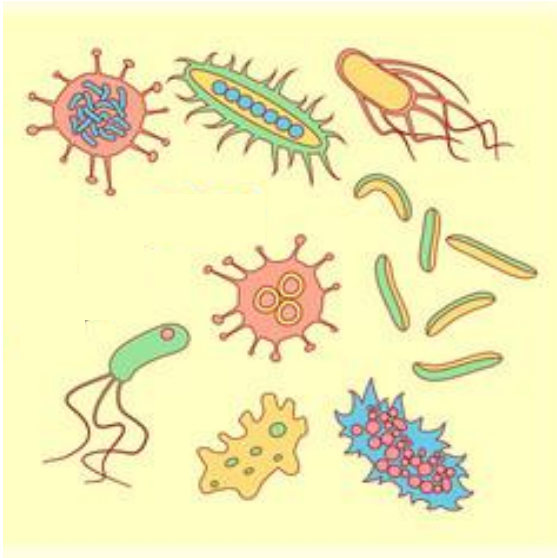
## Colonies



Ectosymbiosis

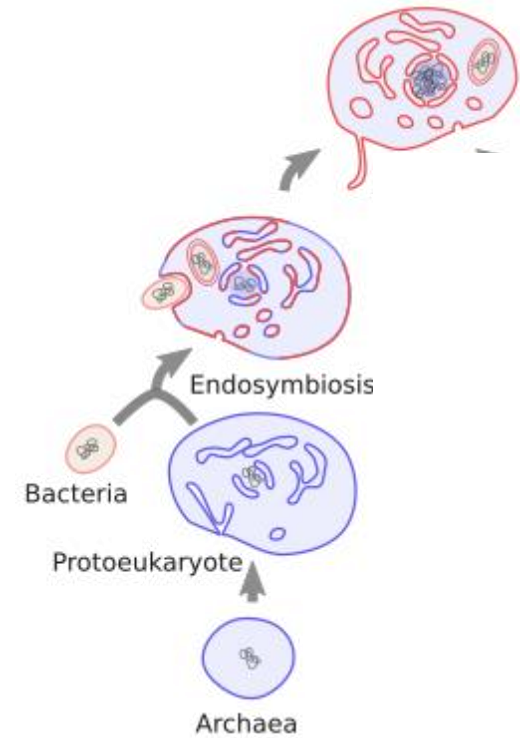
# Prokaryote organisms

Prokaryote



From organisms of the same species

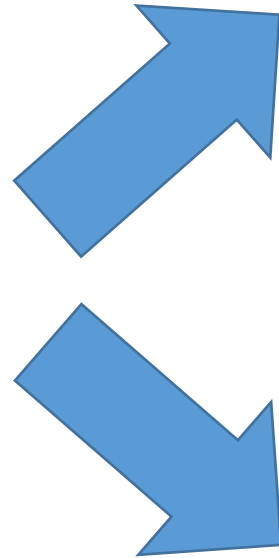
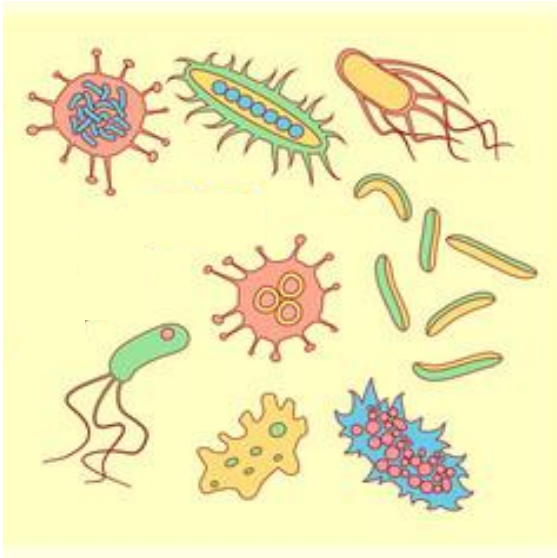
From organisms of different species



Endosymbiosis

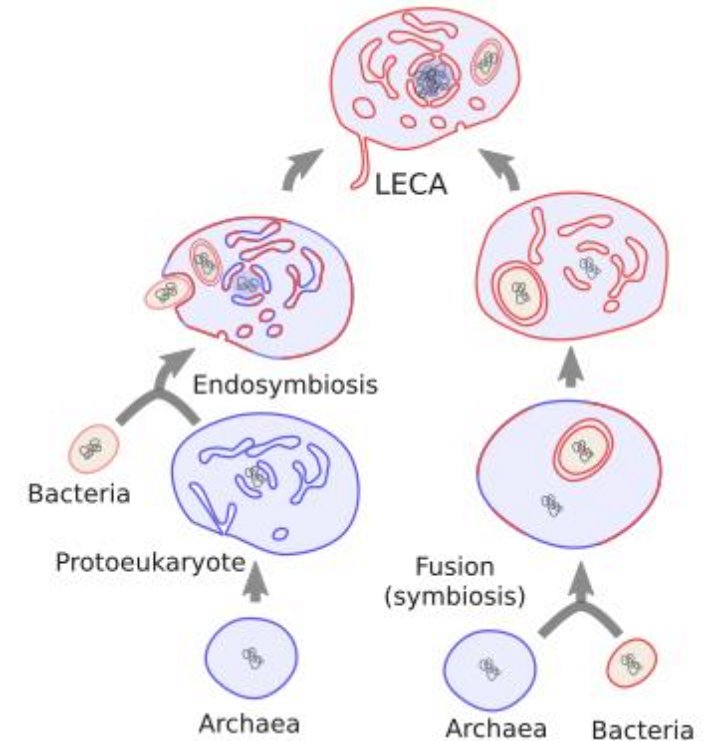
# Prokaryote organisms

Prokaryote



From organisms of the same species

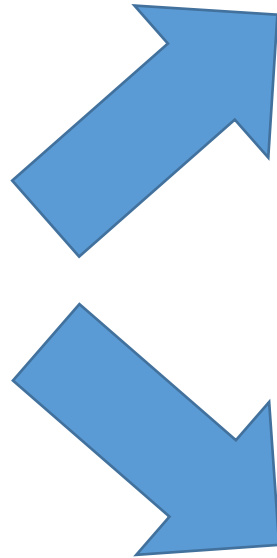
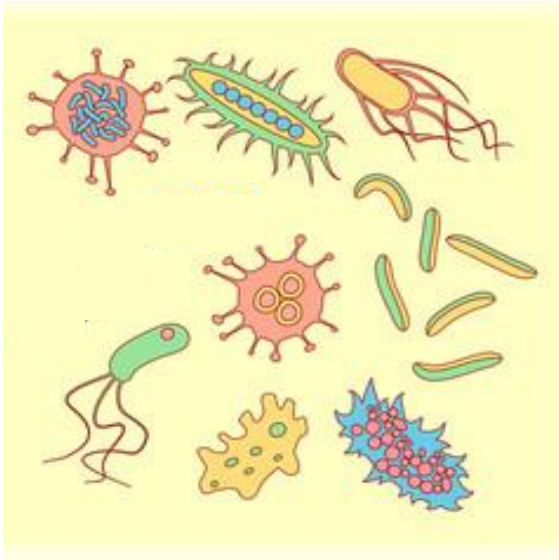
From organisms of different species



Endosymbiosis

# Prokaryote organisms

Prokaryote



From organisms of the same species

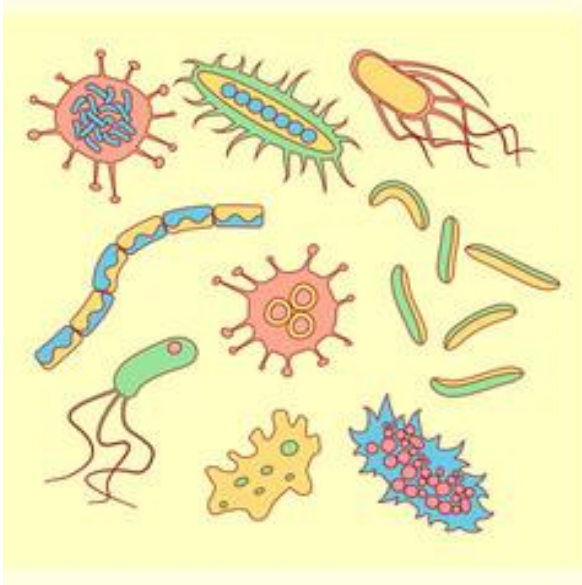
From organisms of different species



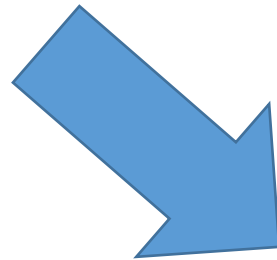
Eukaryote

# Unicellular organisms

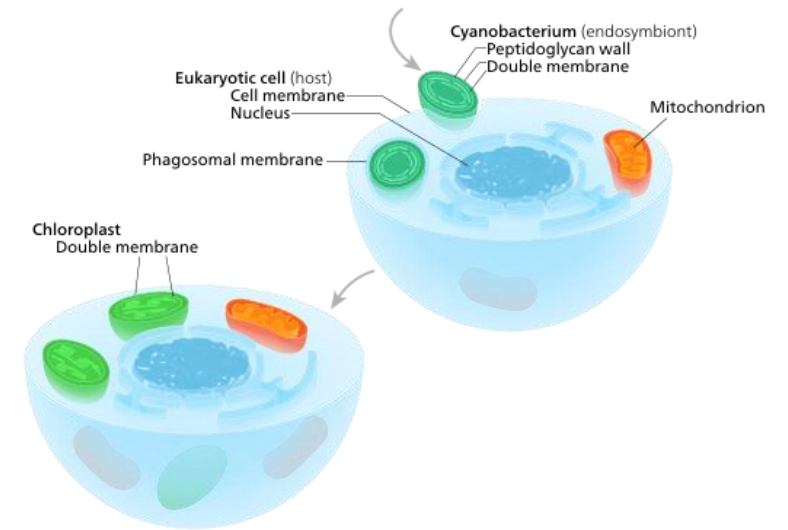
Prokaryote



Eukaryote



From organisms of  
different species

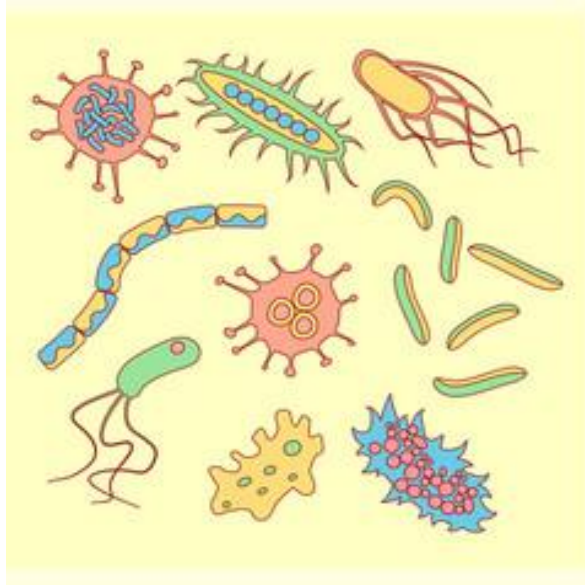


Endosymbiosis



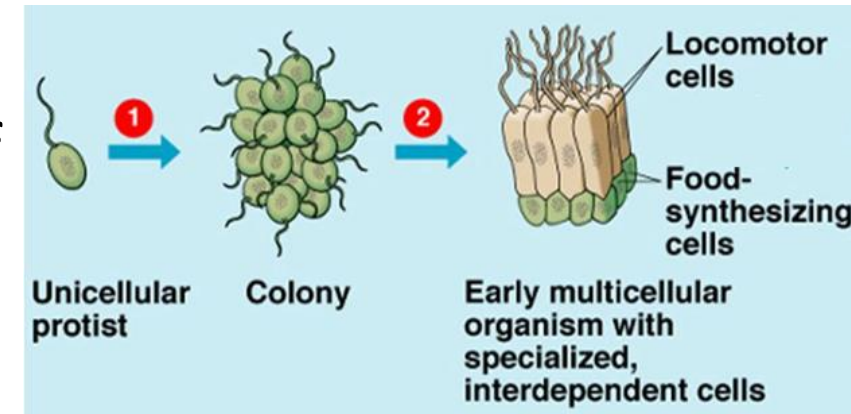
# Unicellular organisms

Prokaryote

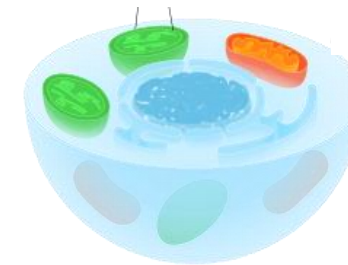


Eukaryote

From organisms of the same species



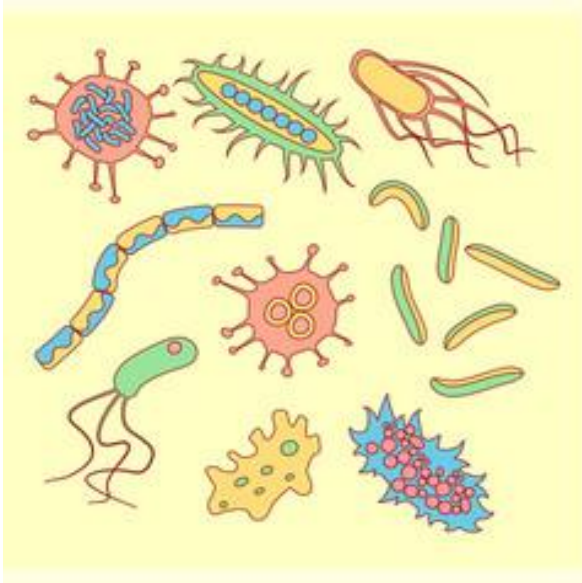
From organisms of different species



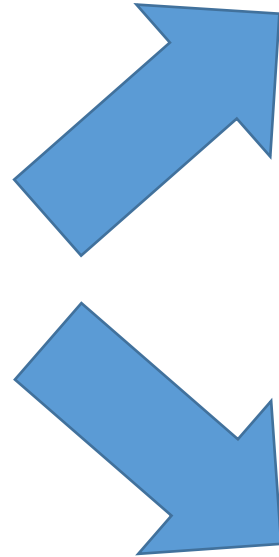
Endosymbiosis

# Unicellular organisms

Prokaryote



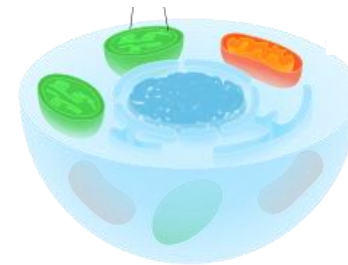
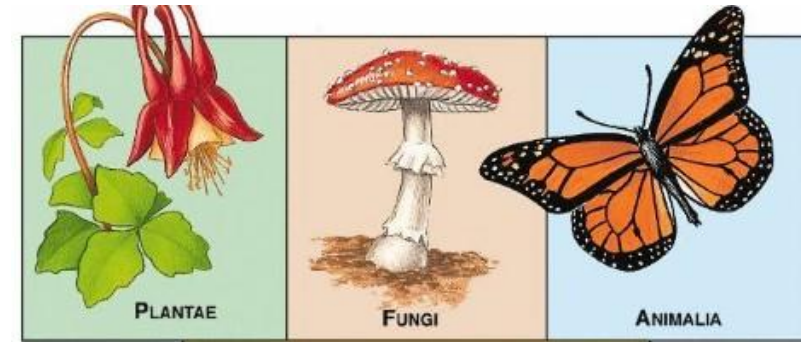
Eukaryote



From organisms of the same species

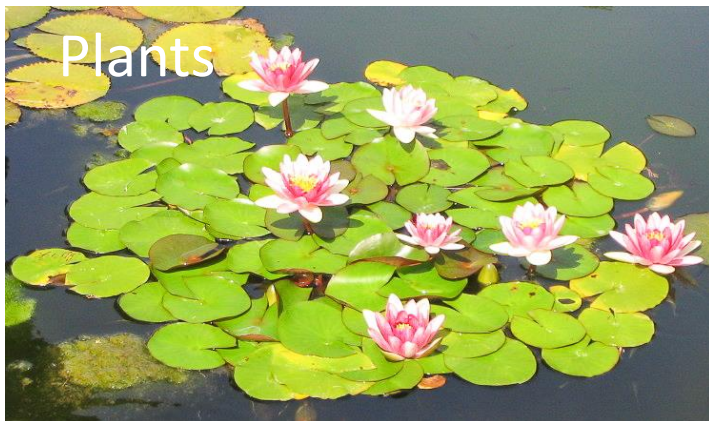
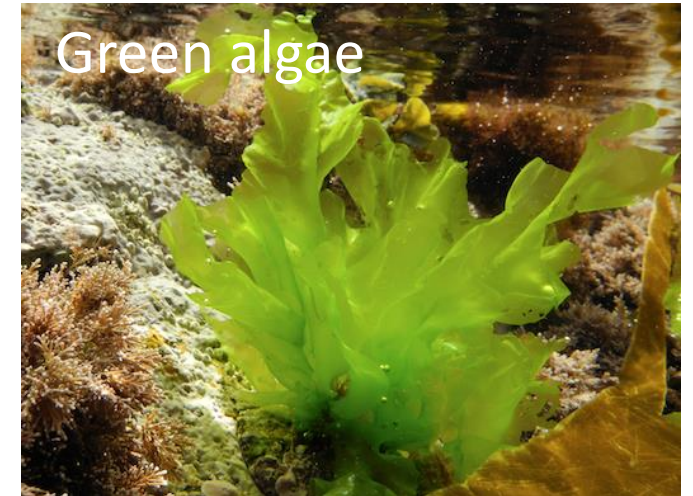
From organisms of different species

## Multicellulars

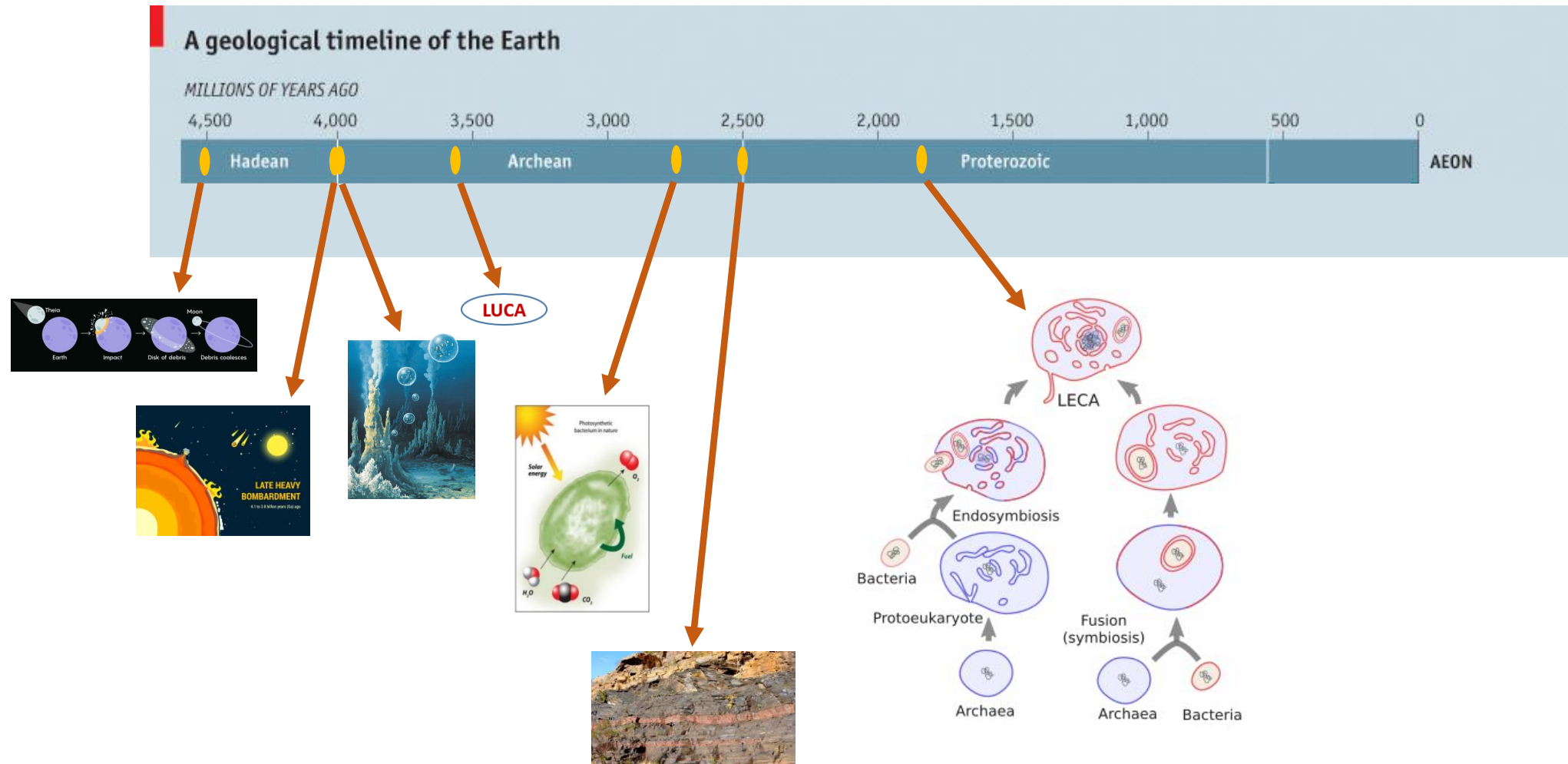


Endosymbiosis

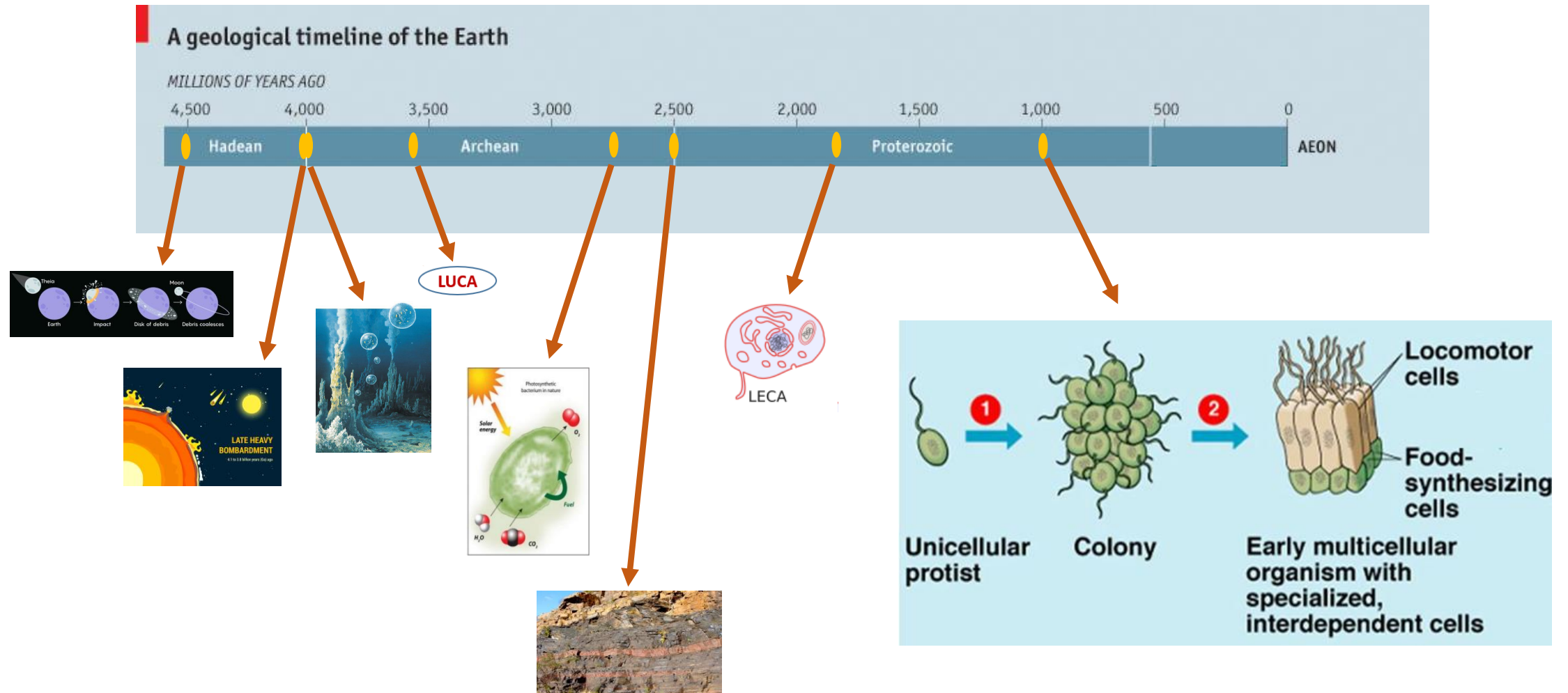
# Multicellulars



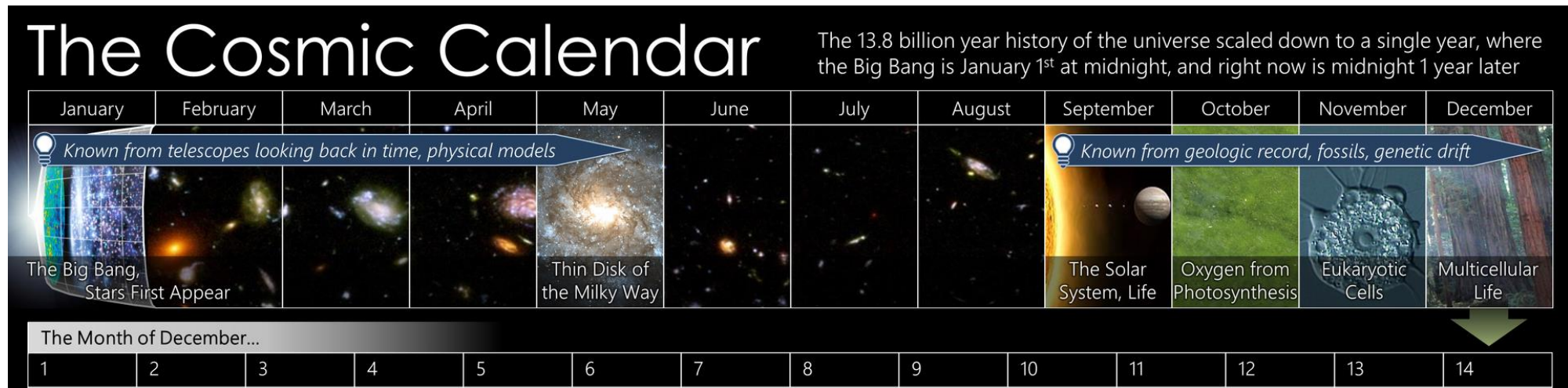
# Proterozoic



# Proterozoic



# Multicellularity



December 5th  
1 billion years ago

# Kits of building blocks

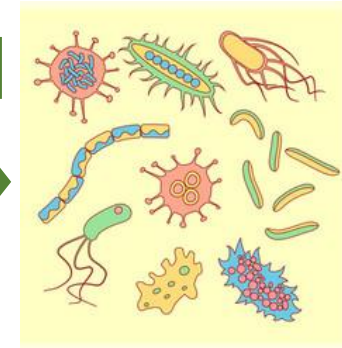
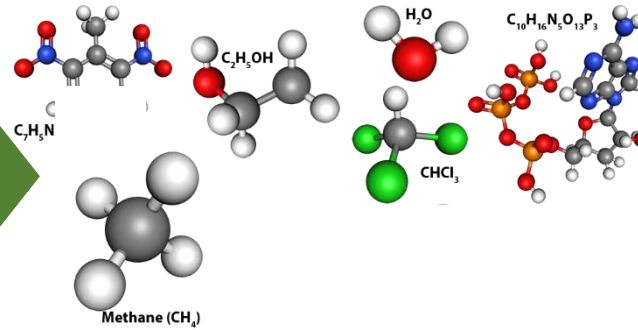
**Standard Model of Elementary Particles**

three generations of matter (fermions)			interactions / force carriers (bosons)	
I	II	III	0	124.07 GeV/c <sup>2</sup>
$\frac{2}{3}$ +2/3 MeV/c <sup>2</sup> 1/6 u up	$\frac{2}{3}$ +1.28 GeV/c <sup>2</sup> 1/6 c charm	$\frac{2}{3}$ +173.1 GeV/c <sup>2</sup> 1/6 t top	0 g gluon	0 H higgs
$-\frac{1}{3}$ -4.7 MeV/c <sup>2</sup> 1/6 d down	$-\frac{1}{3}$ +96 MeV/c <sup>2</sup> 1/6 s strange	$-\frac{1}{3}$ +4.18 GeV/c <sup>2</sup> 1/6 b bottom	0 $\gamma$ photon	
$-\frac{1}{2}$ +0.511 MeV/c <sup>2</sup> 1/6 e electron	$-\frac{1}{2}$ +105.66 MeV/c <sup>2</sup> 1/6 $\mu$ muon	$-\frac{1}{2}$ +1.7768 GeV/c <sup>2</sup> 1/6 $\tau$ tau	0 Z Z boson	
0 +1.0 eV/c <sup>2</sup> 1/6 $\nu_e$ electron neutrino	0 +0.17 MeV/c <sup>2</sup> 1/6 $\nu_\mu$ muon neutrino	0 +18.2 MeV/c <sup>2</sup> 1/6 $\nu_\tau$ tau neutrino	0 W W boson	

**QUARKS**  
**LEPTONS**  
**SCALAR BOSONS**  
**GAUGE BOSONS VECTOR BOSONS**



**Periodic Table of the Elements**



# Kits of building blocks

**Standard Model of Elementary Particles**

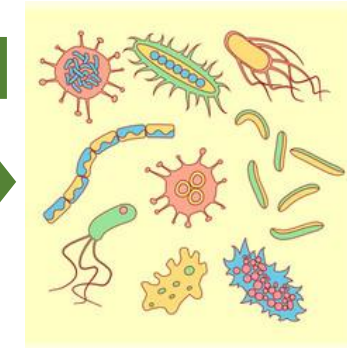
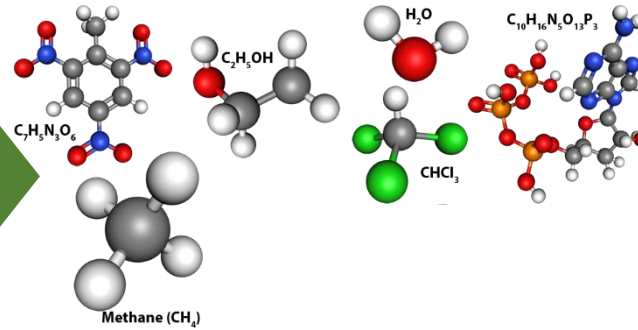
three generations of matter (fermions)			interactions / force carriers (bosons)	
I	II	III	0	1
$\frac{2}{3}$ +2.2 MeV/c <sup>2</sup> u up	$\frac{2}{3}$ +1.28 GeV/c <sup>2</sup> c charm	$\frac{2}{3}$ +173.1 GeV/c <sup>2</sup> t top	0 g gluon	0 H higgs
$-\frac{1}{3}$ -4.7 MeV/c <sup>2</sup> d down	$-\frac{1}{3}$ +96 MeV/c <sup>2</sup> s strange	$-\frac{1}{3}$ +4.18 GeV/c <sup>2</sup> b bottom	0 $\gamma$ photon	
$-1$ +0.511 MeV/c <sup>2</sup> e electron	$-1$ +105.66 MeV/c <sup>2</sup> $\mu$ muon	$-1$ +1.7768 GeV/c <sup>2</sup> $\tau$ tau	0 Z Z boson	
$0$ +1.0 eV/c <sup>2</sup> $\nu_e$ electron neutrino	$0$ +0.17 MeV/c <sup>2</sup> $\nu_\mu$ muon neutrino	$0$ +18.2 MeV/c <sup>2</sup> $\nu_\tau$ tau neutrino	1 W W boson	

**QUARKS** (left column), **LEPTONS** (right column), **SCALAR BOSONS** (top right), **GAUGE BOSONS VECTOR BOSONS** (bottom right)



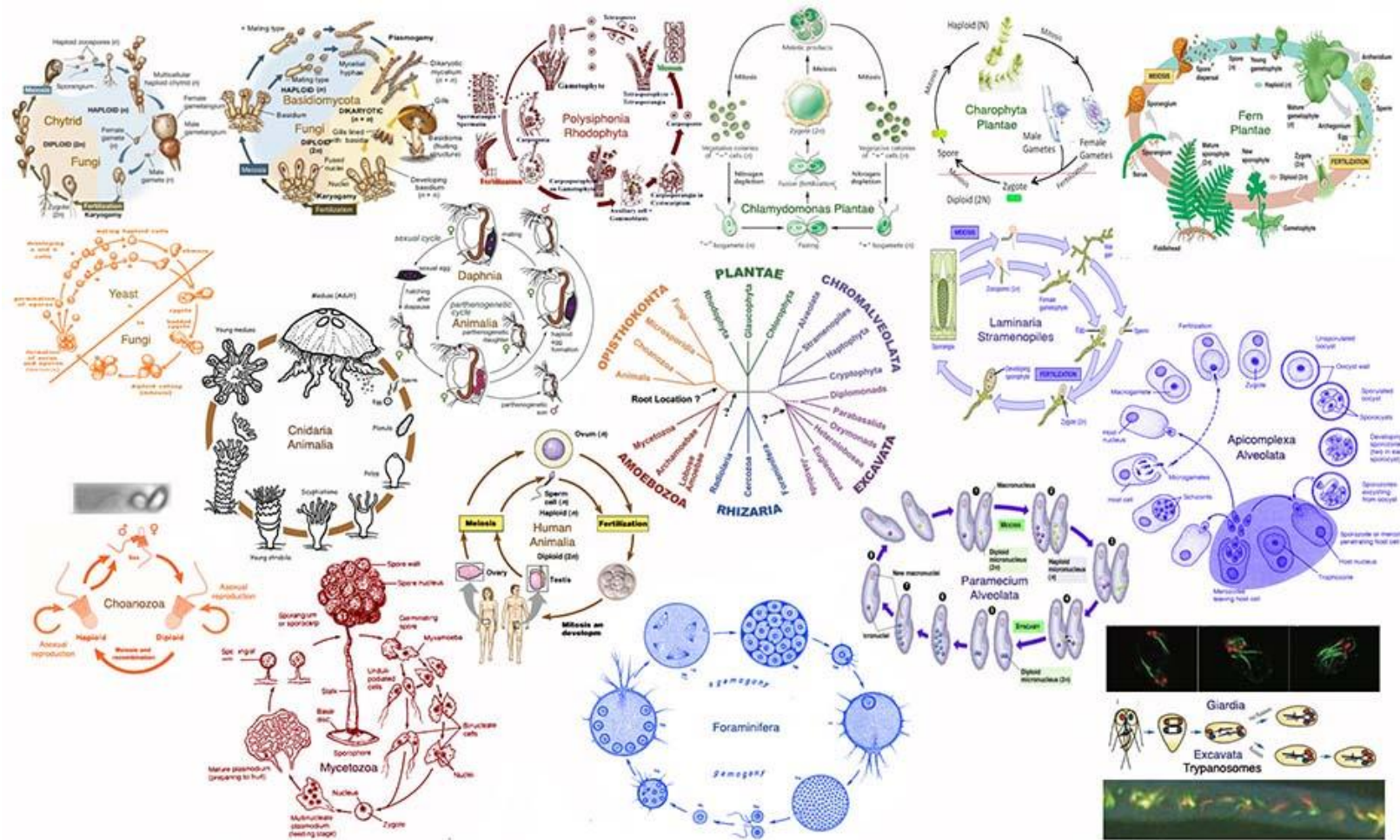
**Periodic Table of the Elements**

[Main Group](#)
[Transition Metal](#)
[Transition Metal](#)
[Lanthanide](#)
[Actinide](#)

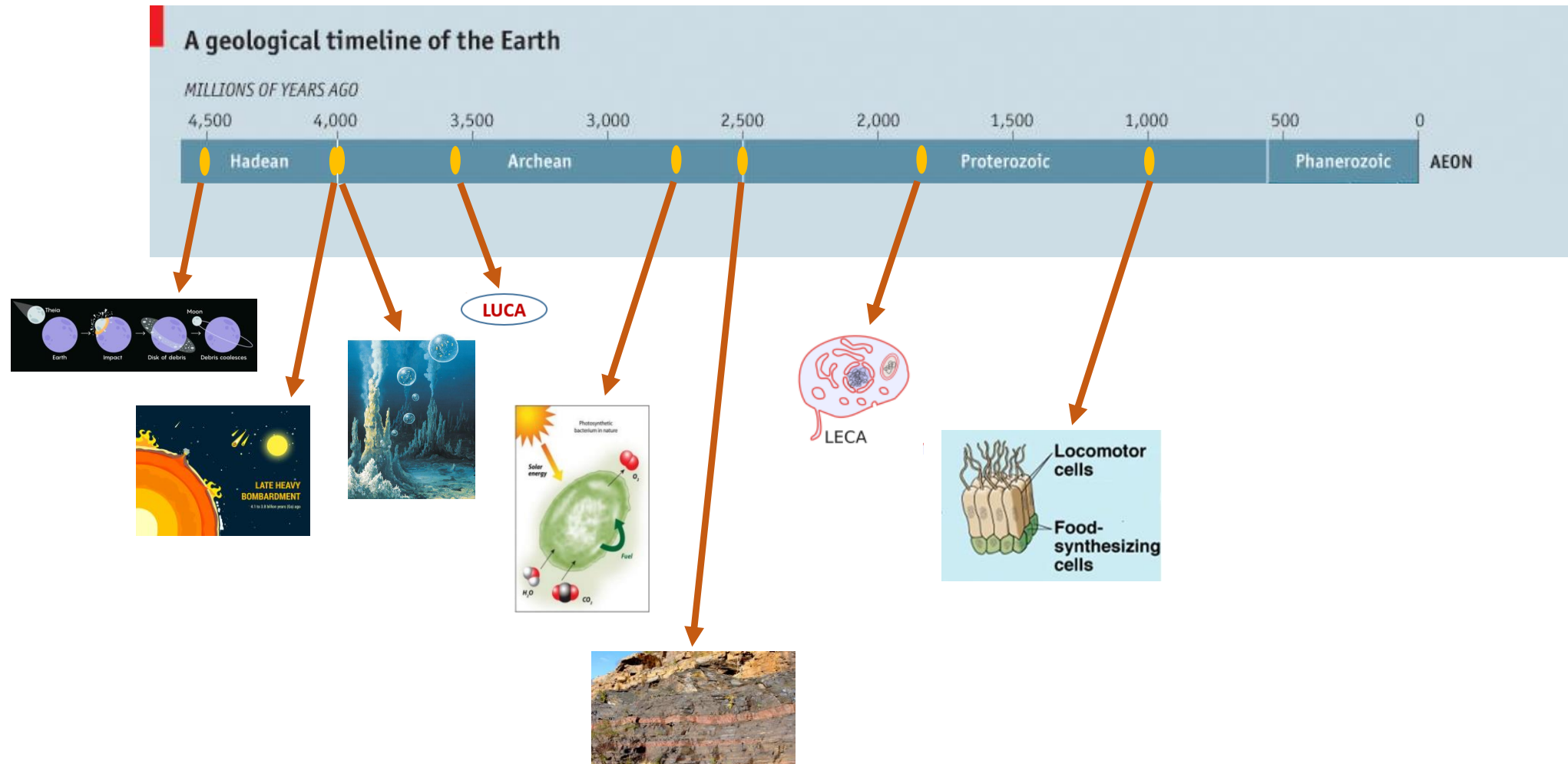




# Life cycles

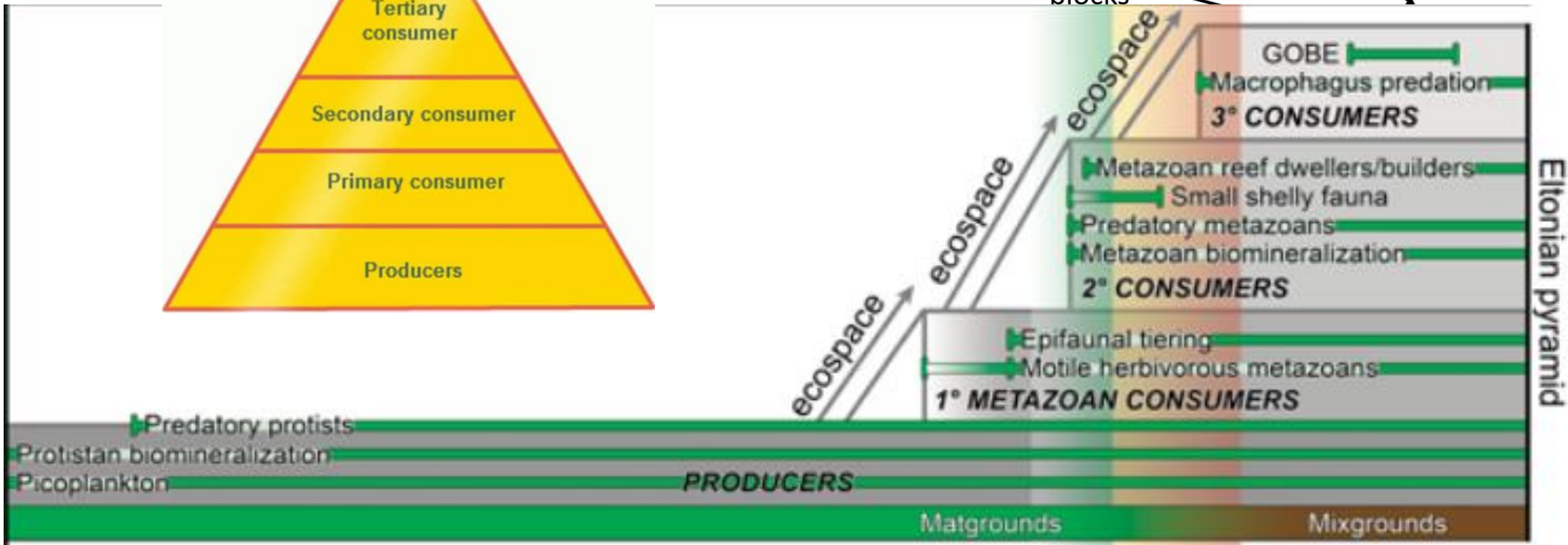
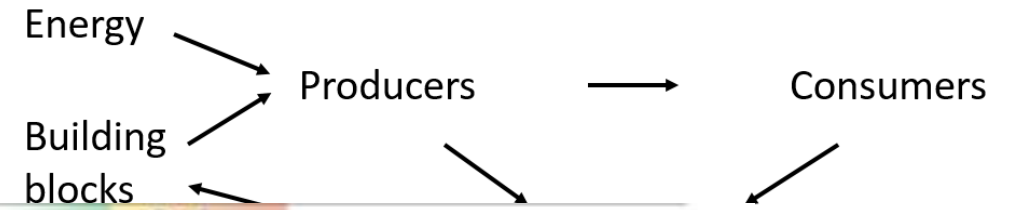
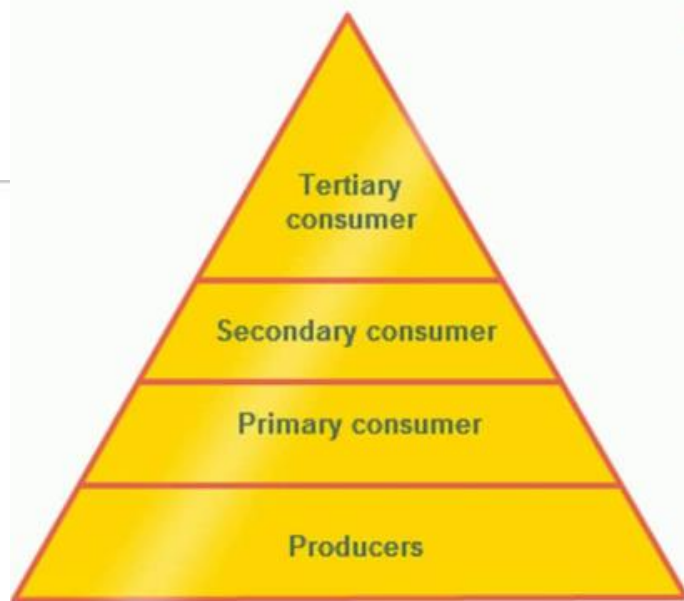


# Phanerozoic



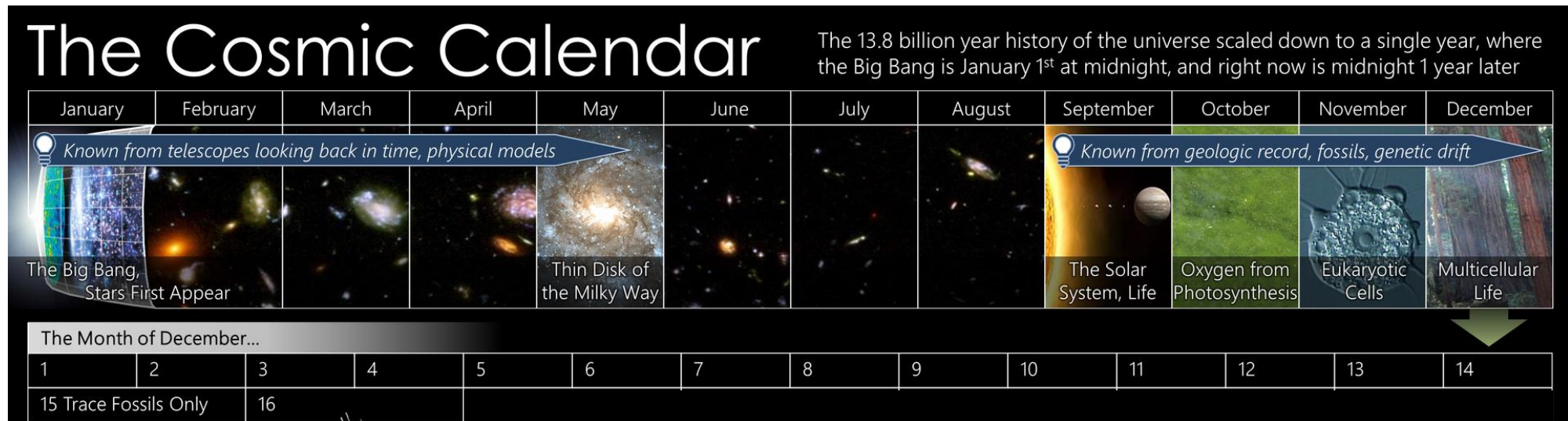


# Ediacarian explosion



[www.geosociety.org/gsatoday/archive/26/11/pdf/i1052-5173-26-11-4.pdf](http://www.geosociety.org/gsatoday/archive/26/11/pdf/i1052-5173-26-11-4.pdf)

# Cambrian Explosion

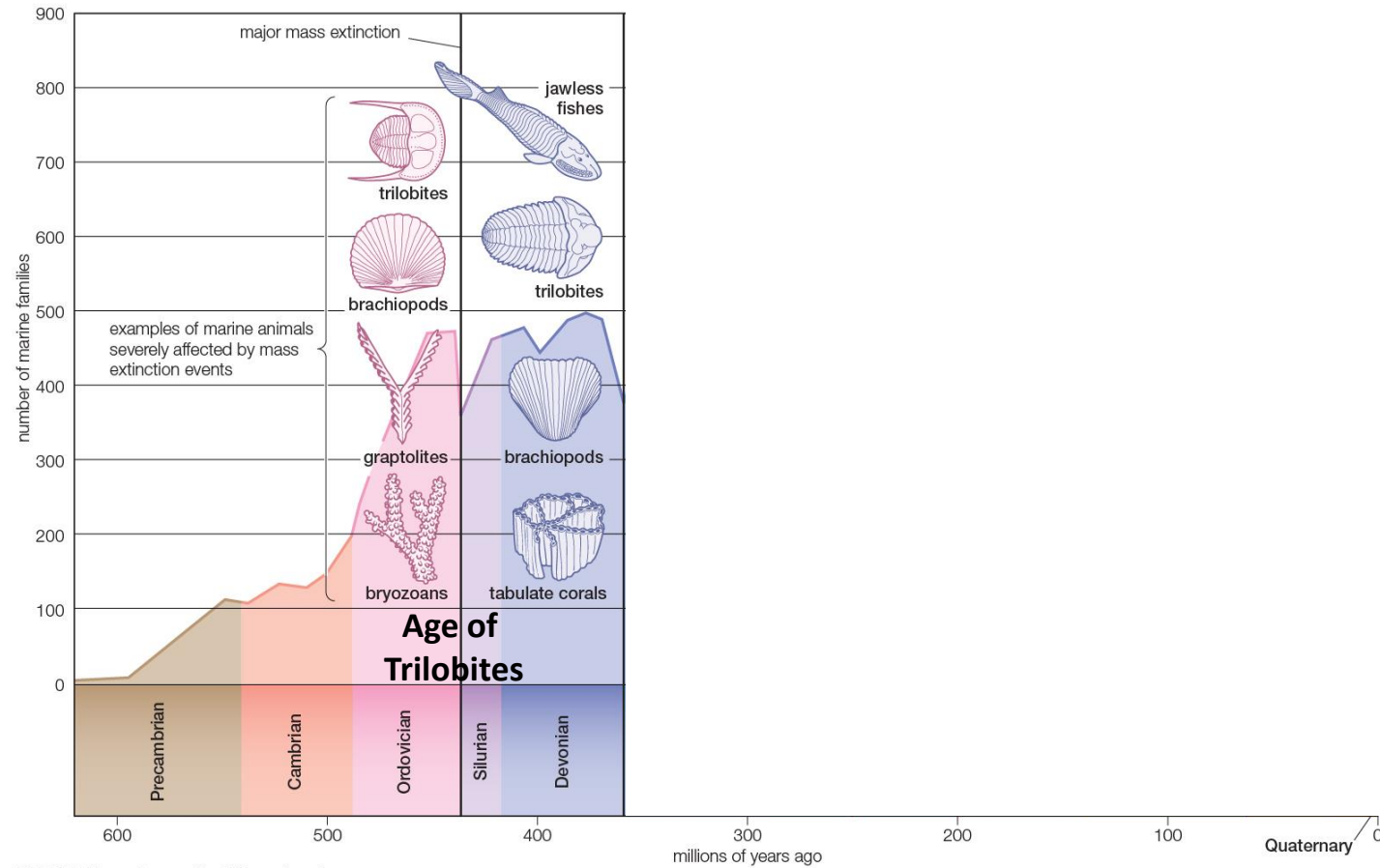


December 16th  
550 million years ago



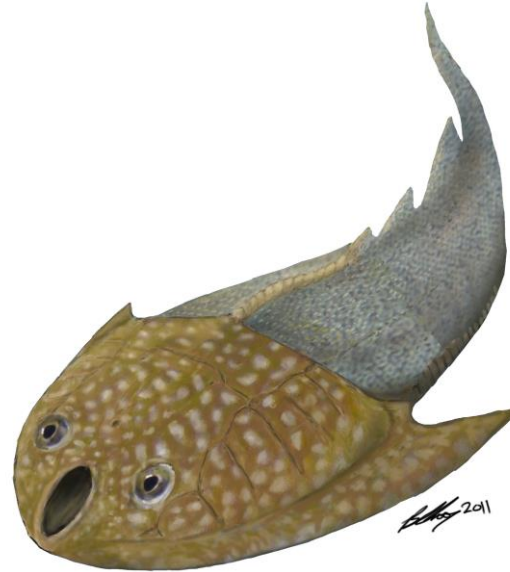
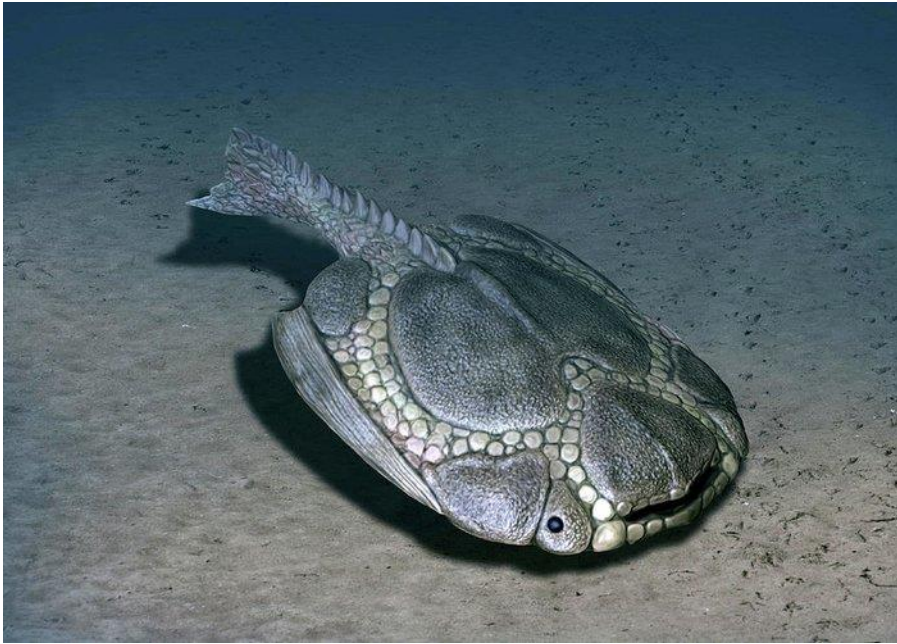
# Cambrian explosion

Diversity of marine animal families over geologic time



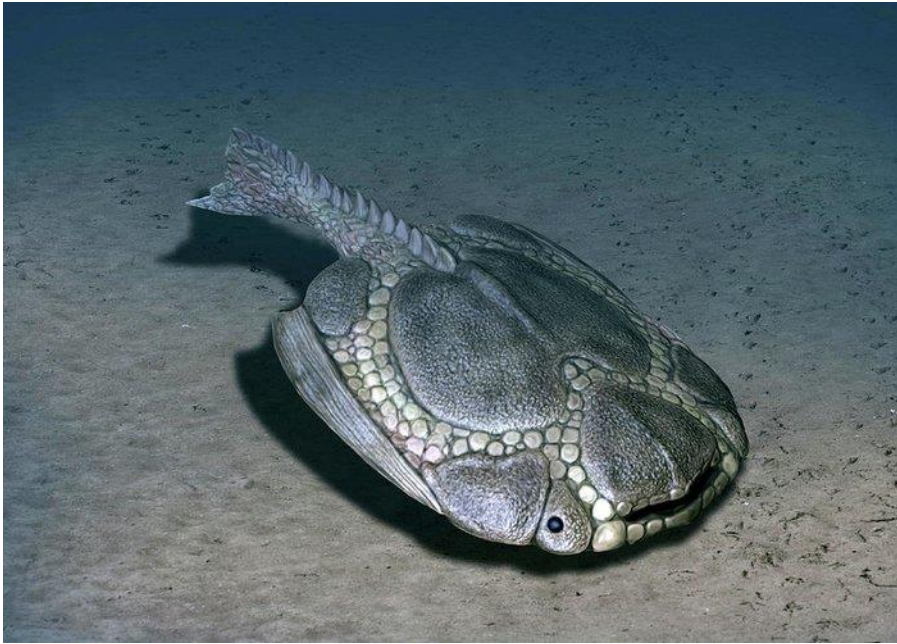
© 2012 Encyclopædia Britannica, Inc.

# Bio technologies



[www.smithsonianmag.com/videos/category/science/the-hagfish-is-the-slimy-sea-creature-of-you/](http://www.smithsonianmag.com/videos/category/science/the-hagfish-is-the-slimy-sea-creature-of-you/)

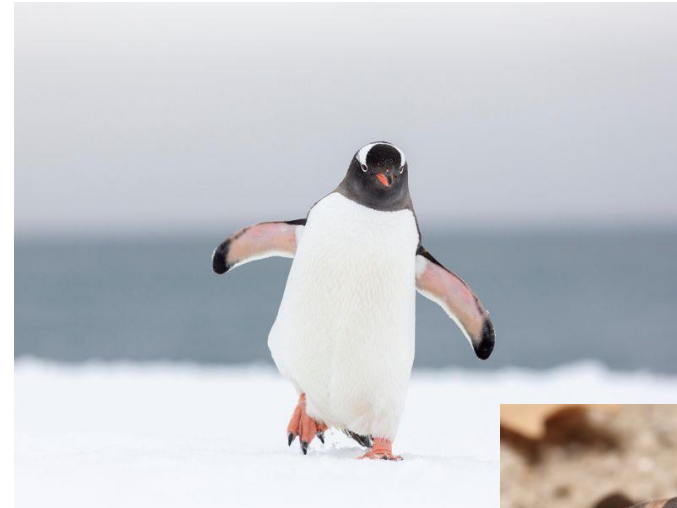
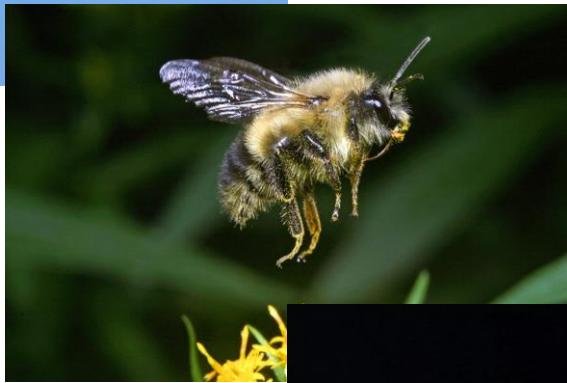
# Bio technologies



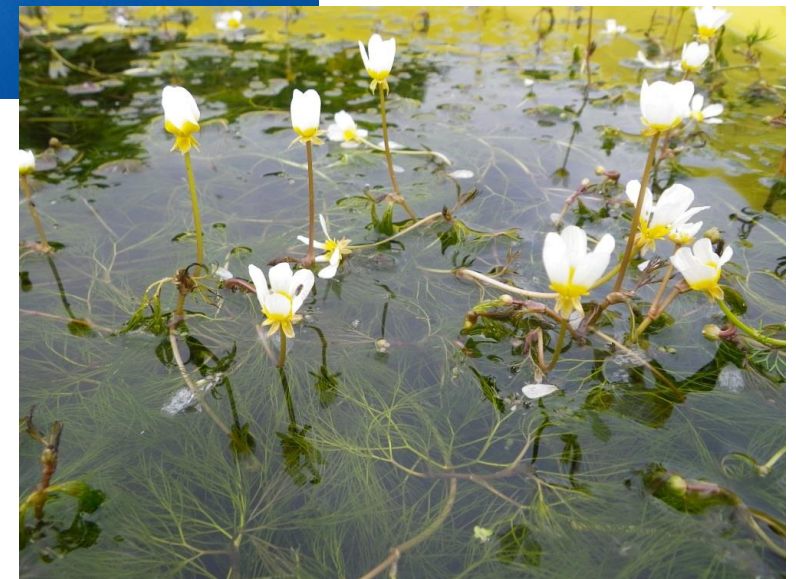
[www.smithsonianmag.com/videos/category/science/the-hagfish-is-the-slimy-sea-creature-of-you/](http://www.smithsonianmag.com/videos/category/science/the-hagfish-is-the-slimy-sea-creature-of-you/)



# Bio technologies



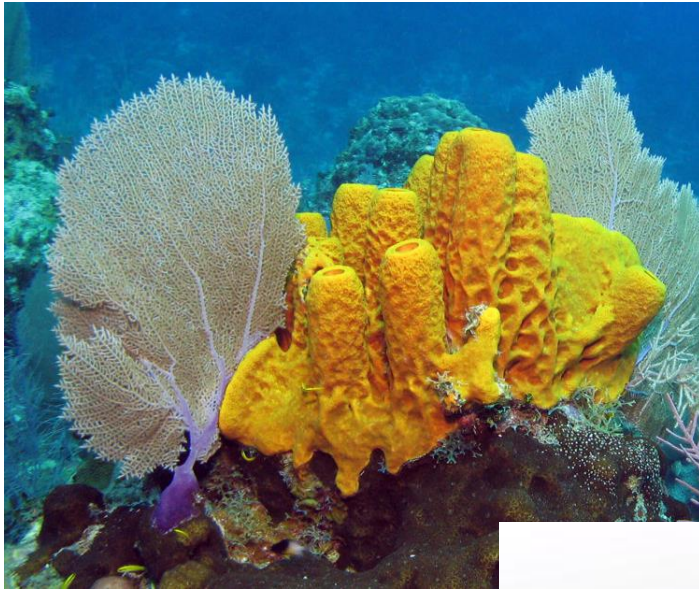
# Bio technologies



# Bio technologies



# Bio technologies



# Bio technologies

www.sciencemag.org/news/2016/05/first-eukaryotes-found-without-normal-cellular-power-supply  
www.ncbi.nlm.nih.gov/pubmed/27185558

## Monocercomonoides



## Mitochondria

## Orobanche



## Rafflesia

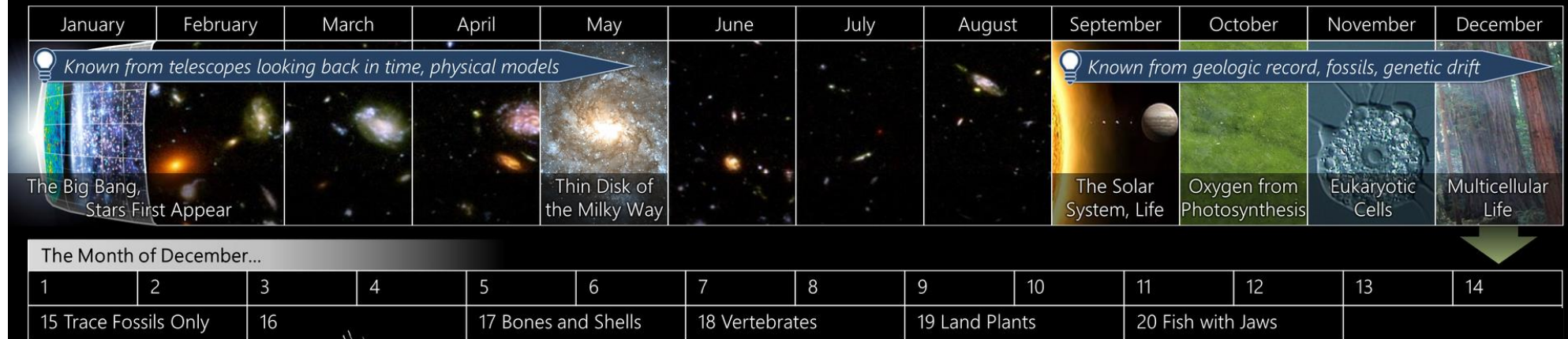


## Chloroplasts

# Jaws

## The Cosmic Calendar

The 13.8 billion year history of the universe scaled down to a single year, where the Big Bang is January 1<sup>st</sup> at midnight, and right now is midnight 1 year later

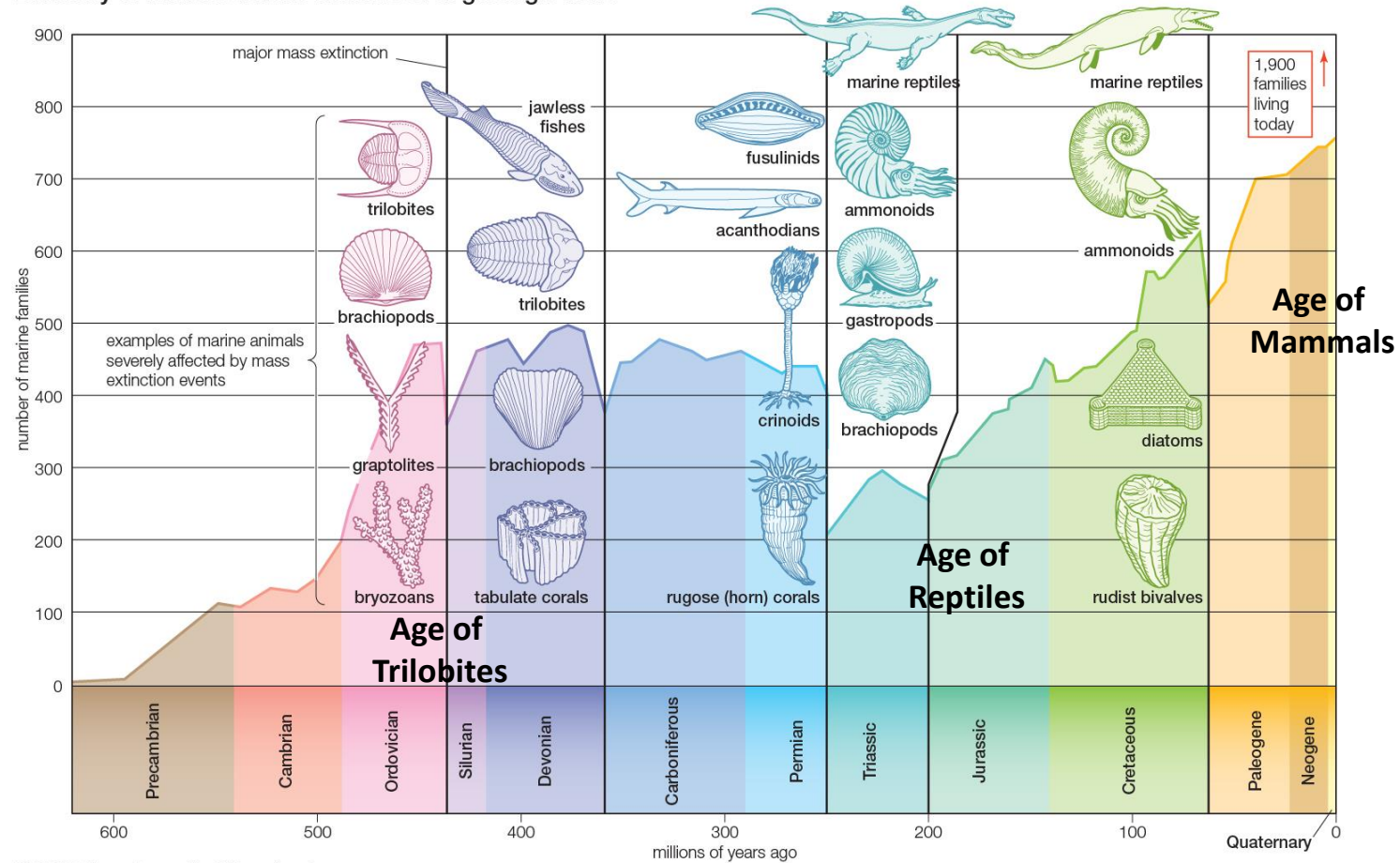


December 20th  
450 million years ago



# Mass extinctions

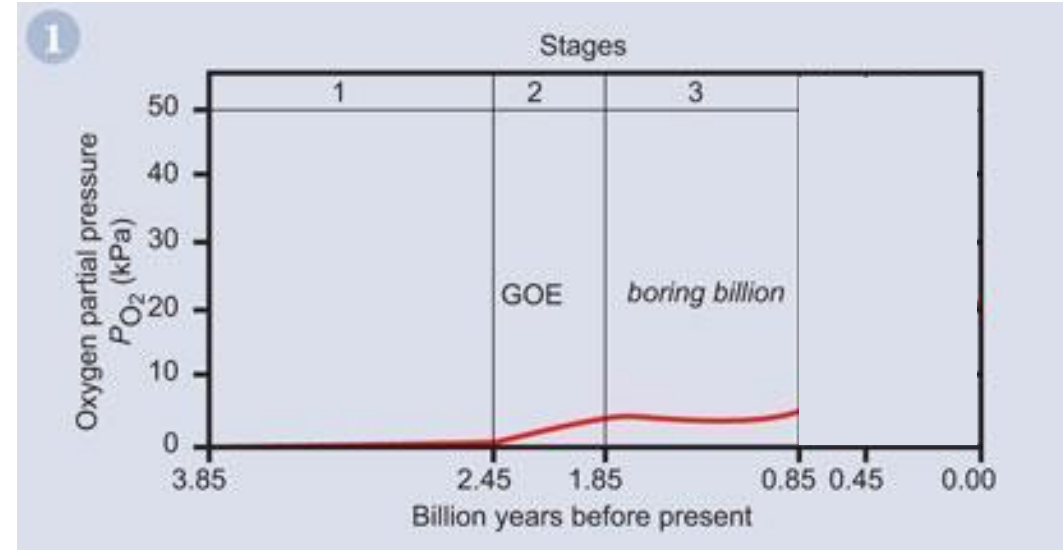
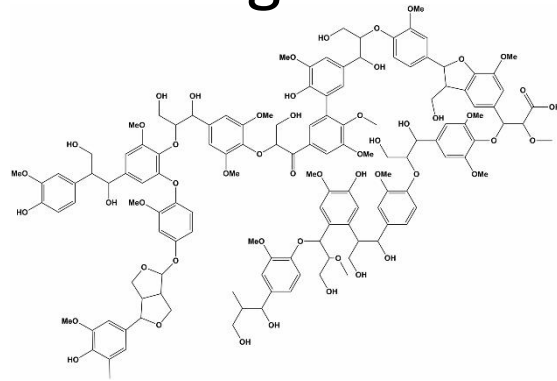
Diversity of marine animal families over geologic time



© 2012 Encyclopædia Britannica, Inc.

# Oxygen

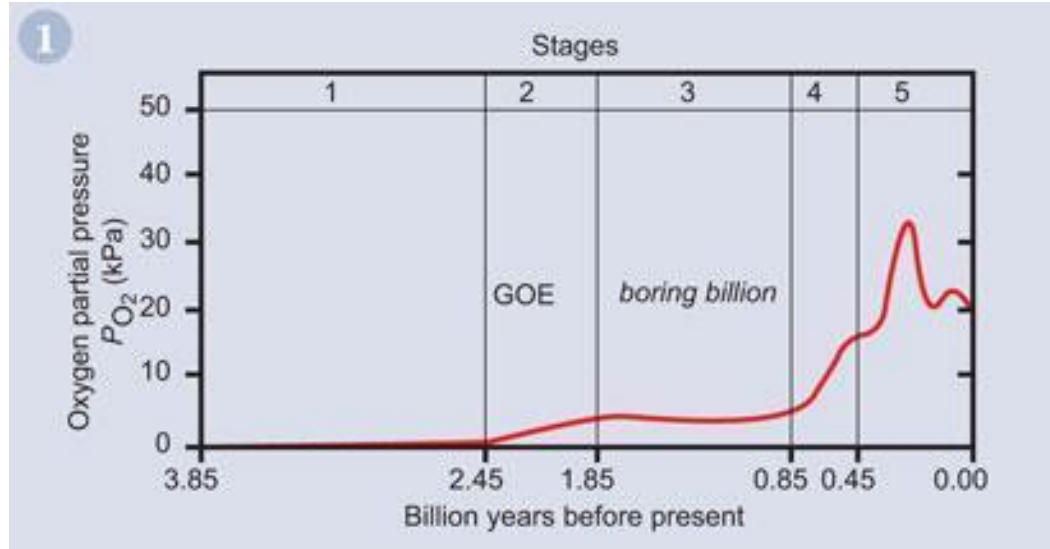
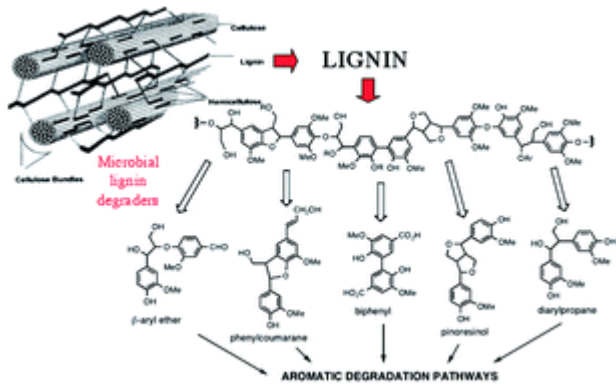
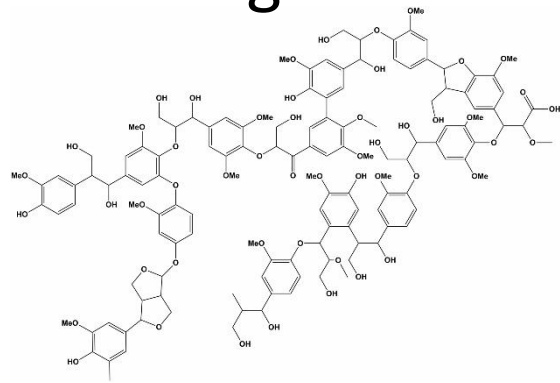
## Lignin





# Oxygen

## Lignin



MODERN DAY HAWK  
61 CENTIMETERS (cm)  
24 INCHES



19 CENTIMETERS  
7.5 INCHES

LARGEST MODERN DAY  
DRAGONFLY

PALEOZOIC ERA DRAGONFLY  
65 CENTIMETERS (cm)  
25 INCHES



1 METER  
3.2 FEET  
EARLY DINOSAUR  
EORAPTOR

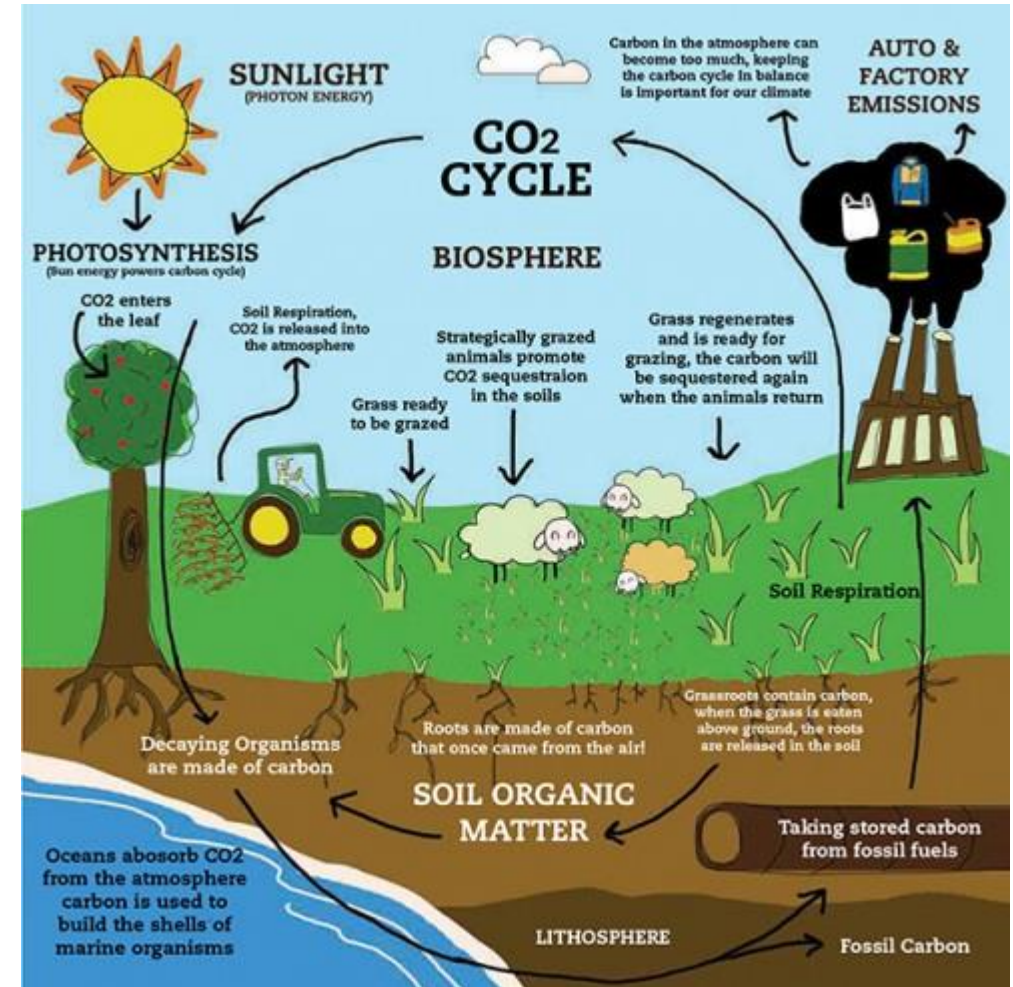
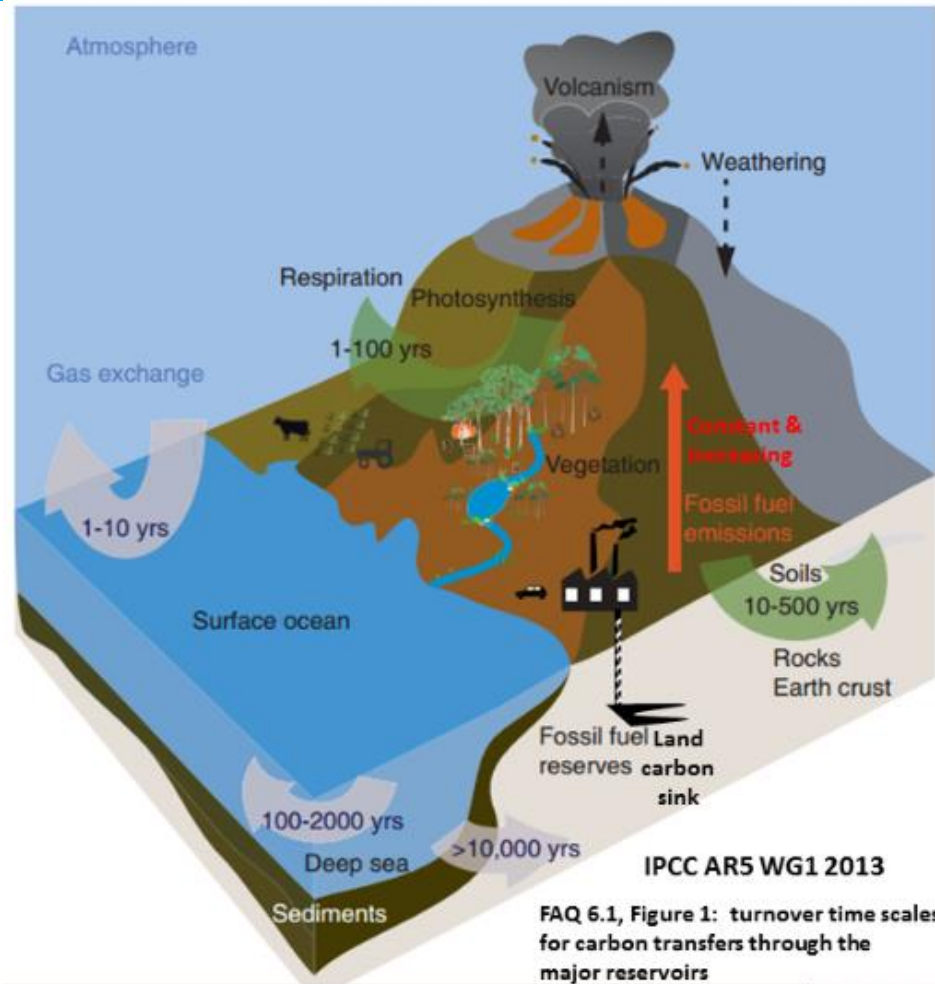


HUMAN  
1.8 METERS  
6 FEET

<https://pubs.rsc.org/en/content/articlelanding/2011/np/c1np00042j>

www.youtube.com/watch?v=wQLKMUWANG

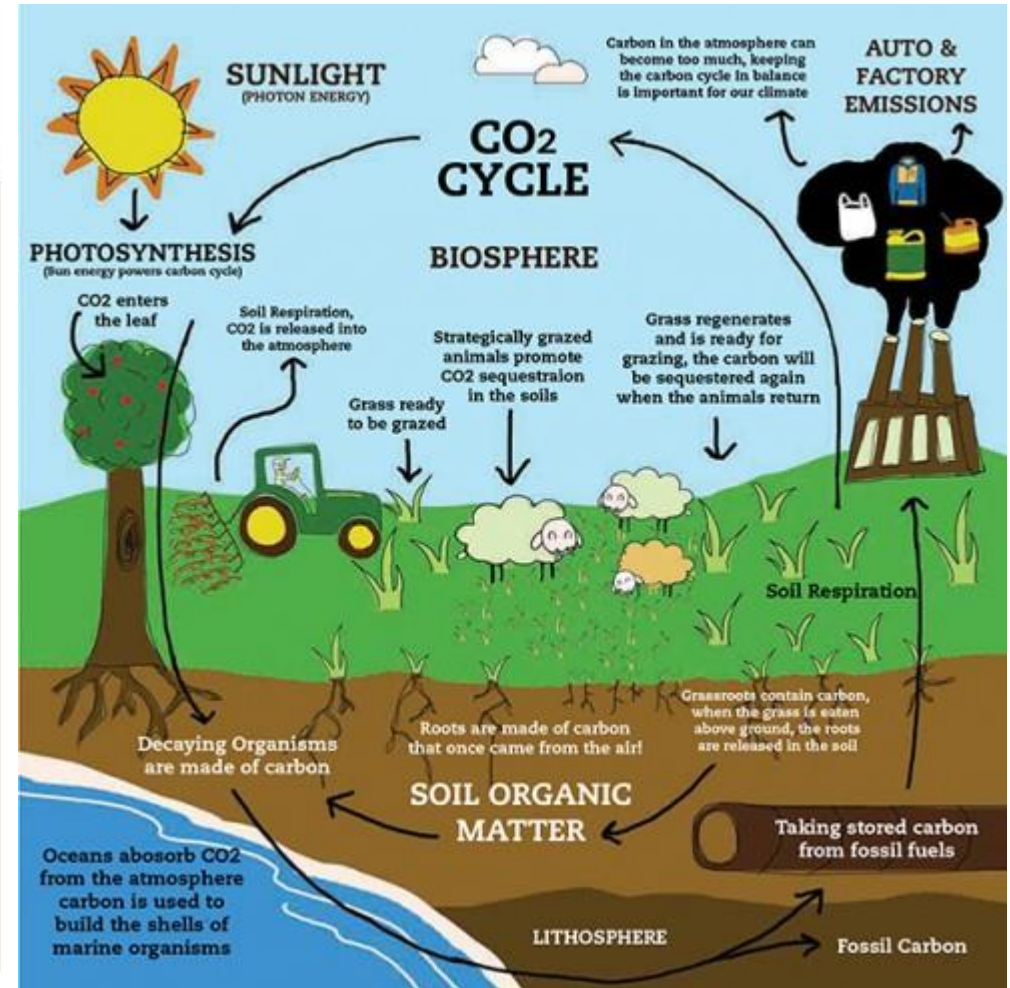
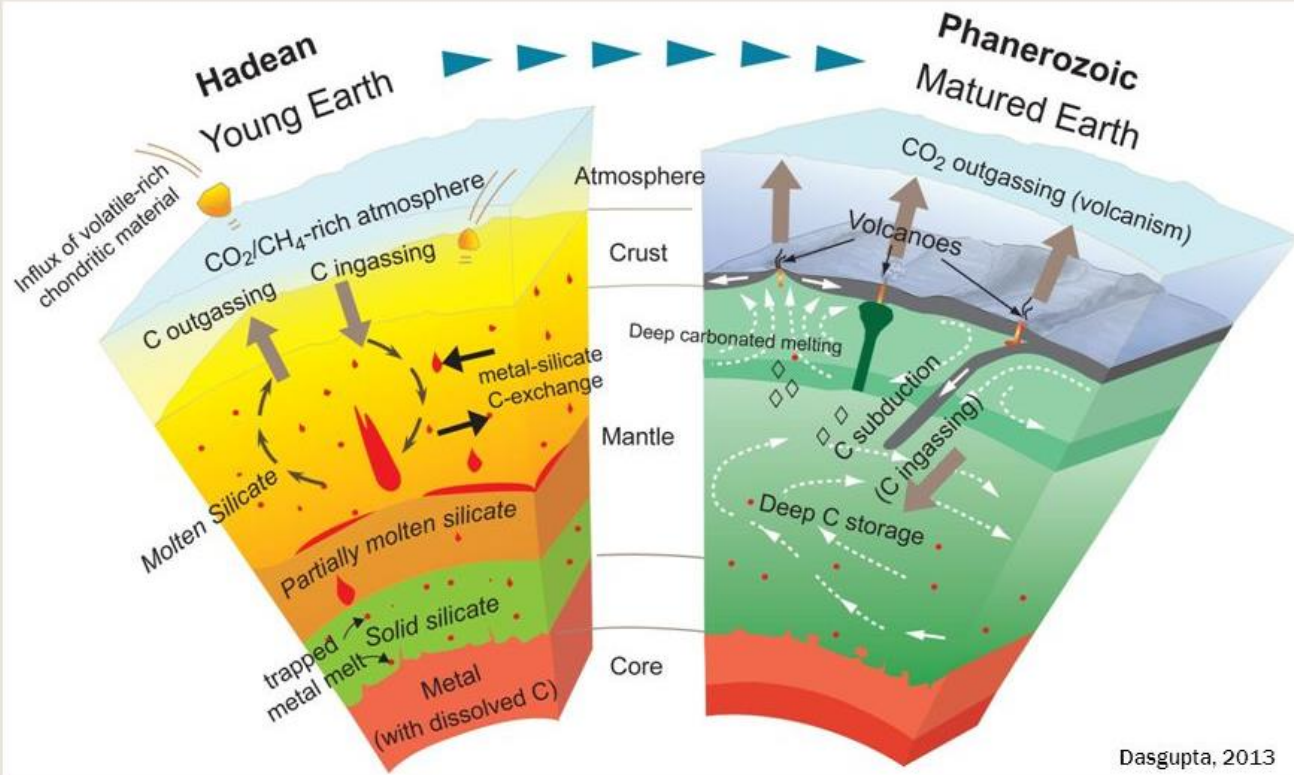
# Carbon cycle



www.tes.com/lessons/zFi7nAR3qzM-cA/the-carbon-cycle

# Carbon cycle



## MANTLE CARBON CYCLE



www.tes.com/lessons/zFi7nAR3qzM-cA/the-carbon-cycle

# The Cosmic Calendar

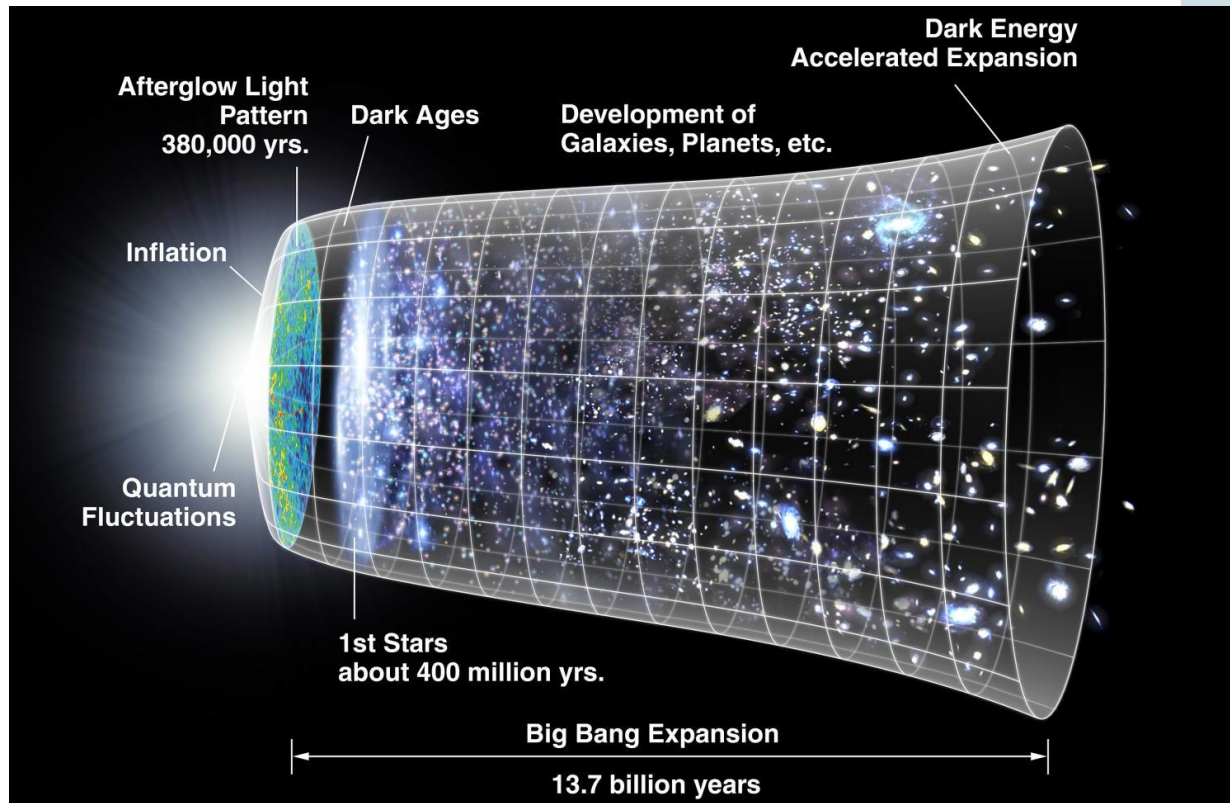
The 13.8 billion year history of the universe scaled down to a single year, where the Big Bang is January 1<sup>st</sup> at midnight, and right now is midnight 1 year later

January	February	March	April	May	June	July	August	September	October	November	December
 <i>Known from telescopes looking back in time, physical models</i>					 <i>Known from geologic record, fossils, genetic drift</i>						
The Big Bang, Stars First Appear				Thin Disk of the Milky Way				The Solar System, Life	Oxygen from Photosynthesis	Eukaryotic Cells	Multicellular Life

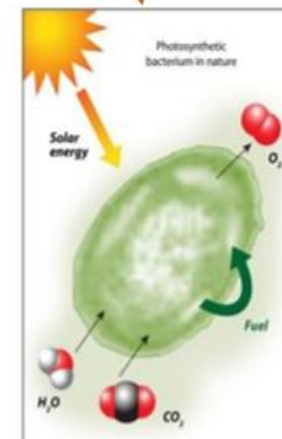
## The Month of December...

1	2	3	4	5	6	7	8	9	10	11	12	13	14
15 Trace Fossils Only		16		17 Bones and Shells		18 Vertebrates		19 Land Plants		20 Fish with Jaws		21 Insects	
22 Amphibians		23 Reptiles		24 Pangaea Forms		25 Dinosaurs		26 Mammals		27 Birds		28 Flowers	
29 Tyrannosaurids		30 Dinosaurs Extinct, Mammals Take Over on Land and in Sea		31 The Final Day...									

# Cumulative dynamics → Phase transition

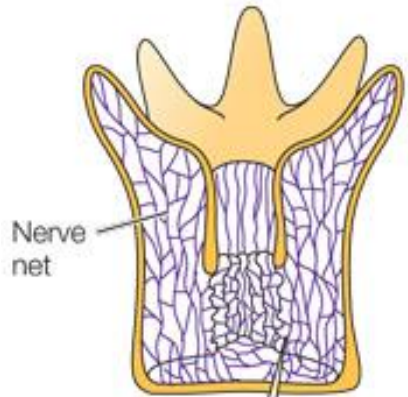


A geological timeline of the Earth



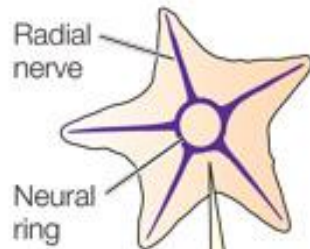
# Nervous system

(1) Sea anenome



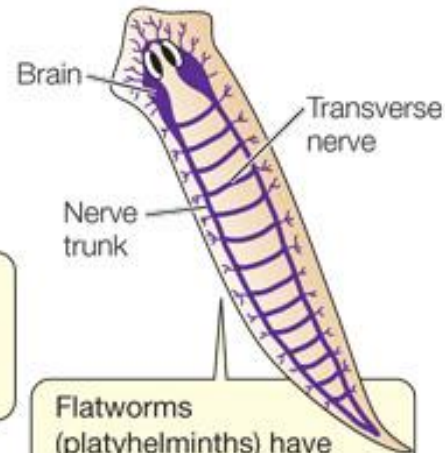
Cnidarians have radial symmetry and diffuse nervous systems based on nerve nets.

(2) Sea star



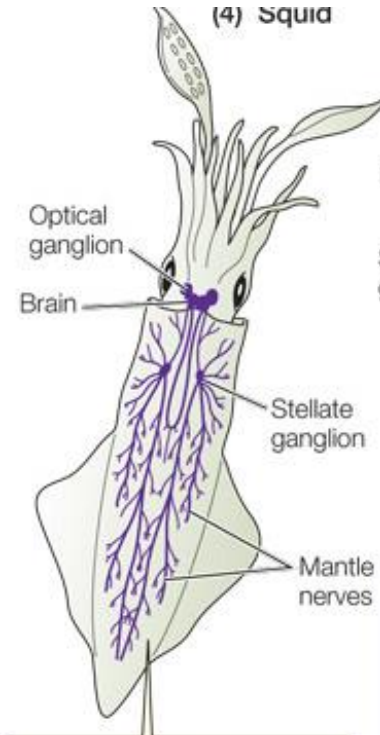
Echinoderm nervous systems are simple, perhaps because of their radial symmetry.

(3) Flatworm



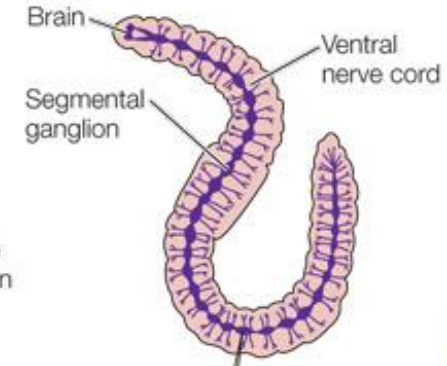
Flatworms (platyhelminths) have bilateral symmetry and show both centralization, with a ladderlike central nervous system, and cephalization, with a brain at the anterior end.

(4) Squid



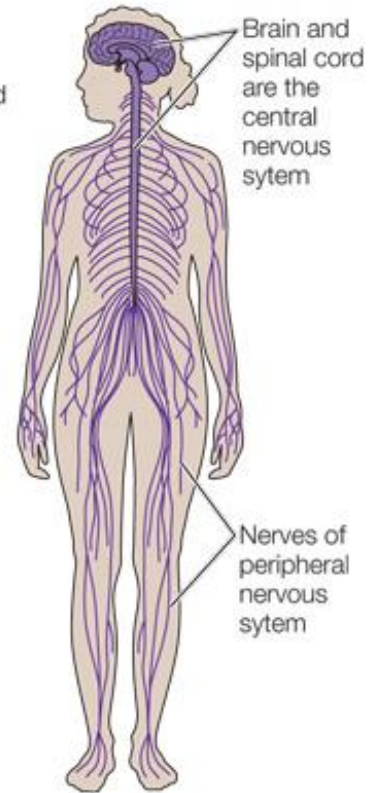
Molluscan nervous systems vary among groups, but squids and octopuses (like vertebrates) have well-centralized nervous systems dominated by a large brain.

(5) Earthworm

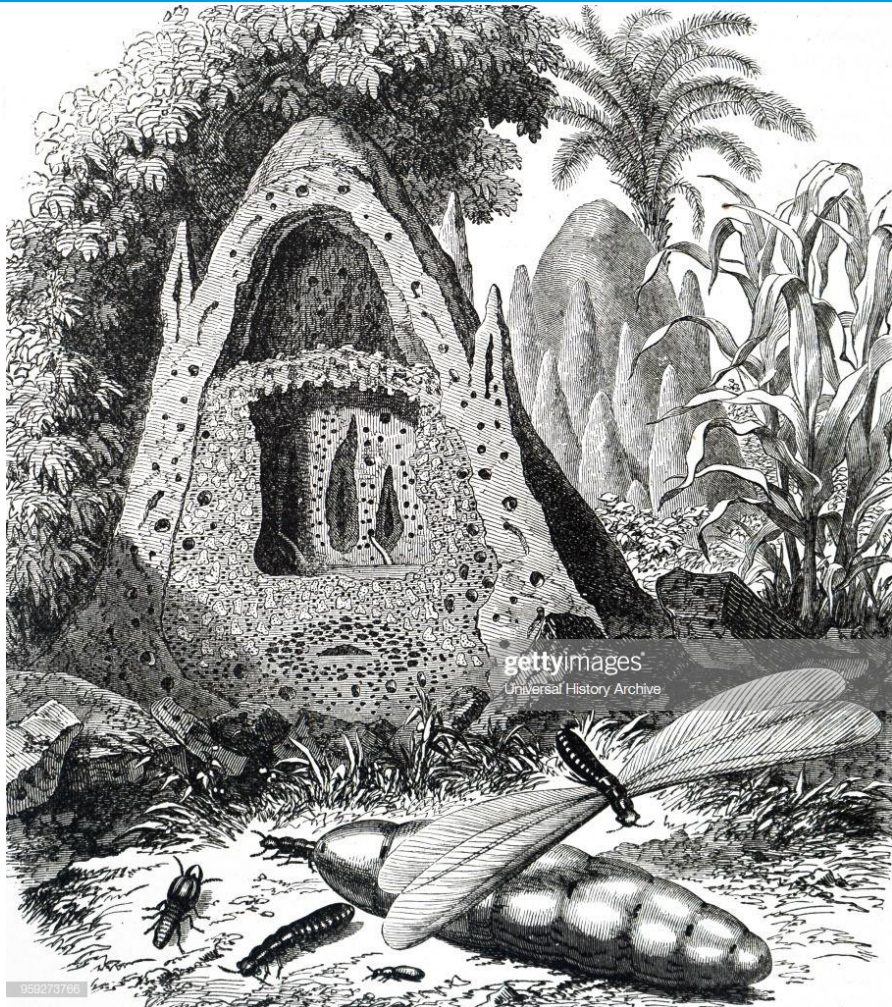


Annelid nervous systems consist of a small brain and a ventral nerve cord, with each segmental ganglion largely responsible for sensory and motor functions within the segment.

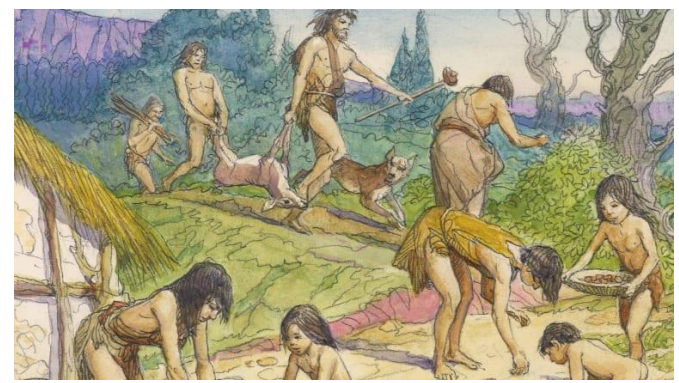
(6) Human



# Animals



[citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.136.2311](http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.136.2311)



# Eusociality





# Kits of building blocks

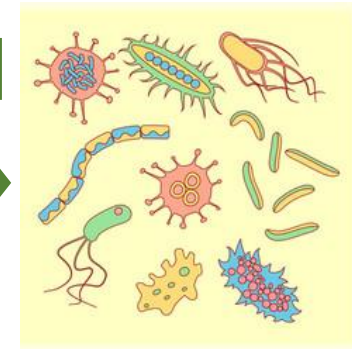
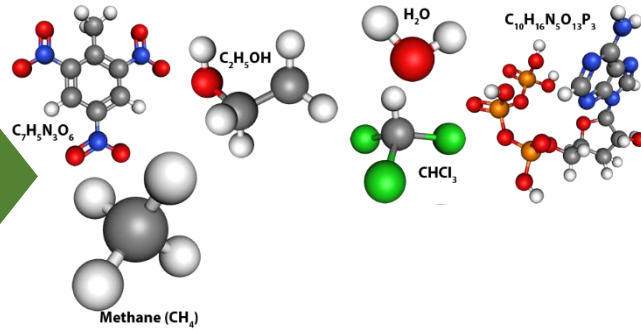
**Standard Model of Elementary Particles**

three generations of matter (fermions)			interactions / force carriers (bosons)	
I	II	III		
$\frac{2}{3}$ +2/3 MeV/c <sup>2</sup> 1/6 u up	$\frac{2}{3}$ +1.28 GeV/c <sup>2</sup> 1/6 c charm	$\frac{2}{3}$ +173.1 GeV/c <sup>2</sup> 1/6 t top	0 g gluon	0 H higgs
$-\frac{1}{3}$ -4.7 MeV/c <sup>2</sup> 1/6 d down	$-\frac{1}{3}$ +96 MeV/c <sup>2</sup> 1/6 s strange	$-\frac{1}{3}$ +4.18 GeV/c <sup>2</sup> 1/6 b bottom	0 γ photon	
$-1$ +0.511 MeV/c <sup>2</sup> 1/6 e electron	$-1$ +105.66 MeV/c <sup>2</sup> 1/6 μ muon	$-1$ +1.7768 GeV/c <sup>2</sup> 1/6 τ tau	0 Z Z boson	
$0$ +1.0 eV/c <sup>2</sup> 1/6 ν <sub>e</sub> electron neutrino	$0$ +0.17 MeV/c <sup>2</sup> 1/6 ν <sub>μ</sub> muon neutrino	$0$ +18.2 MeV/c <sup>2</sup> 1/6 ν <sub>τ</sub> tau neutrino	0 W W boson	

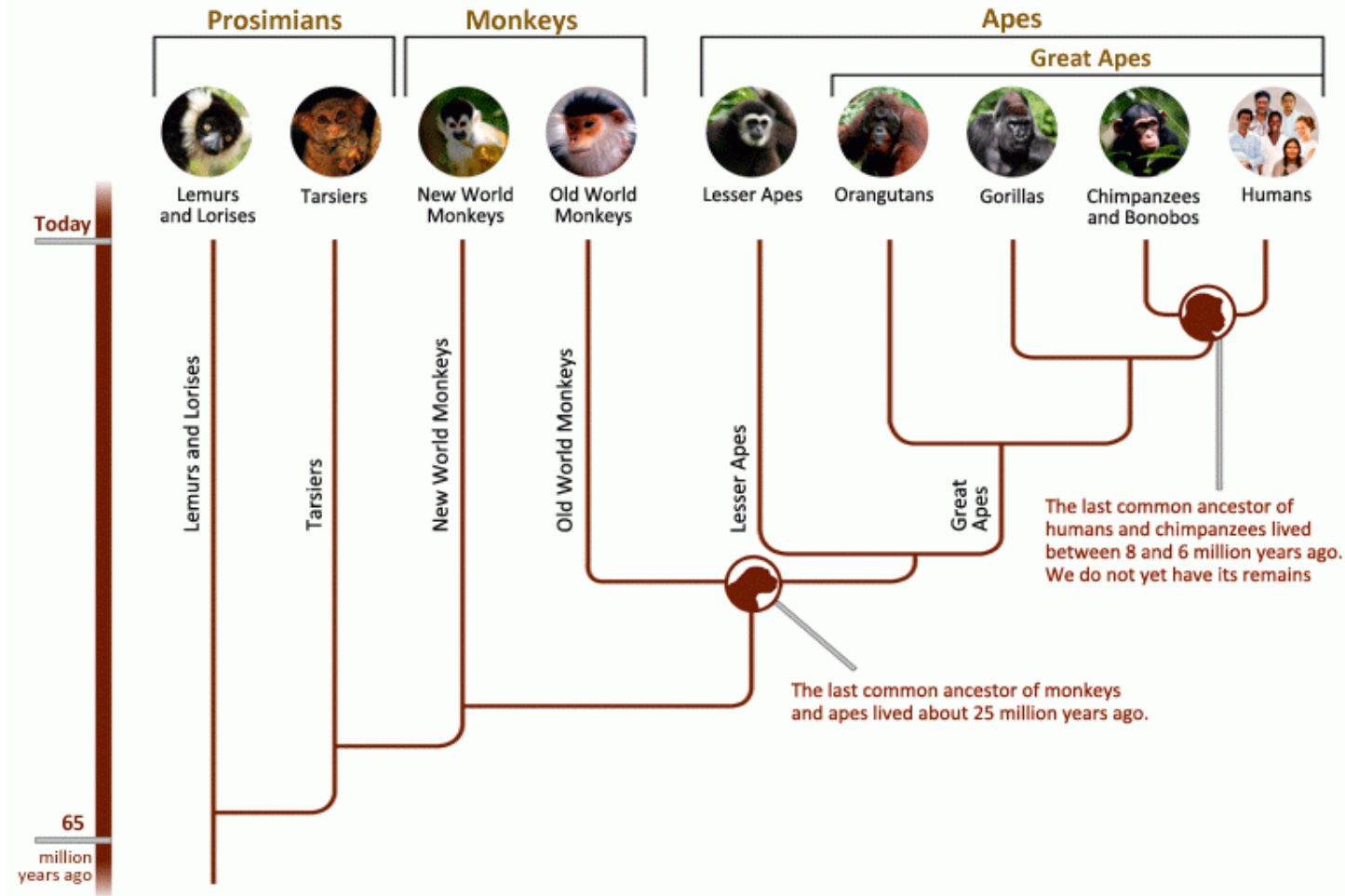
**SCALAR BOSONS**  
GAUGE BOSONS  
VECTOR BOSONS



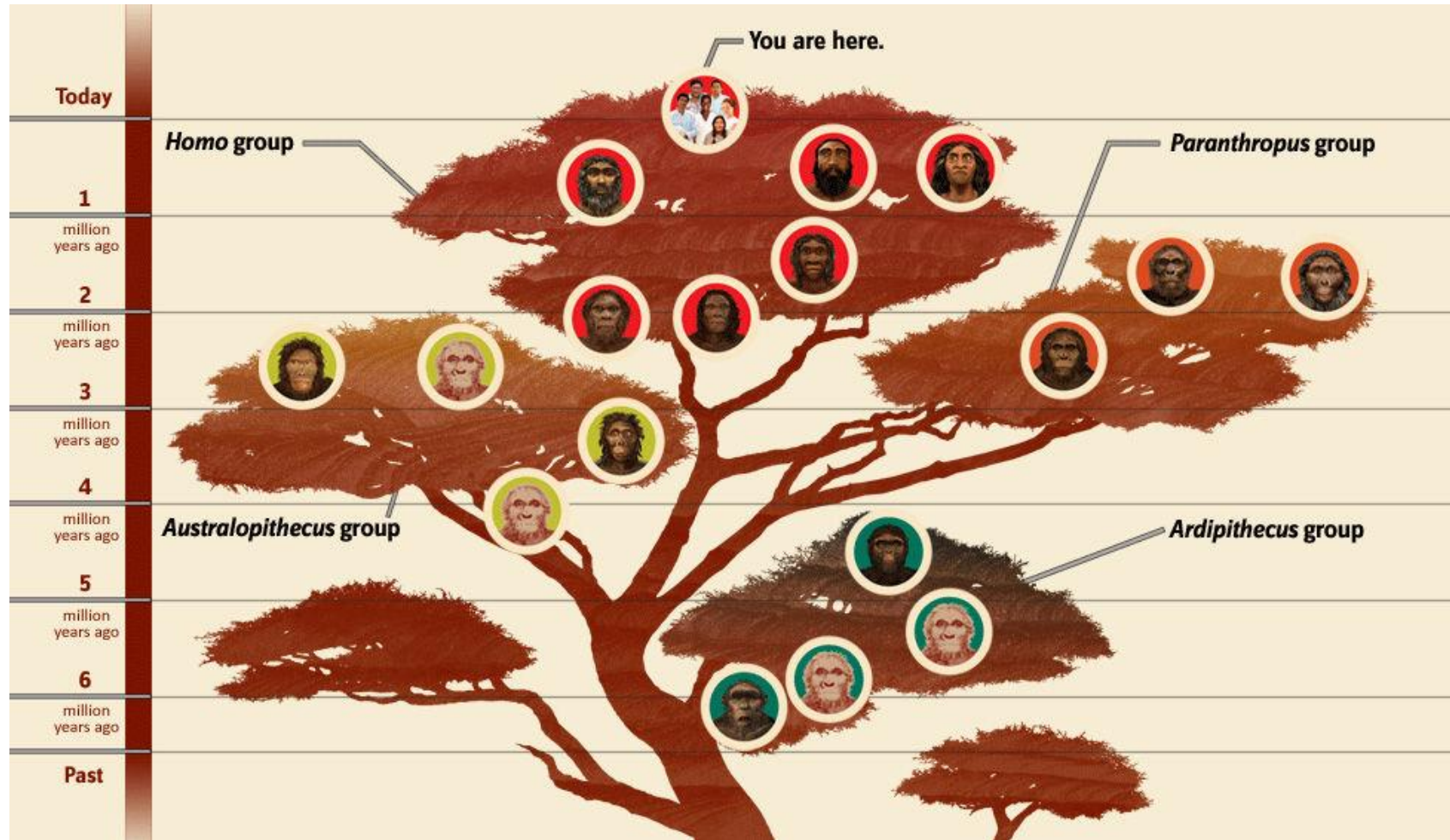
**Periodic Table of the Elements**



# Primates



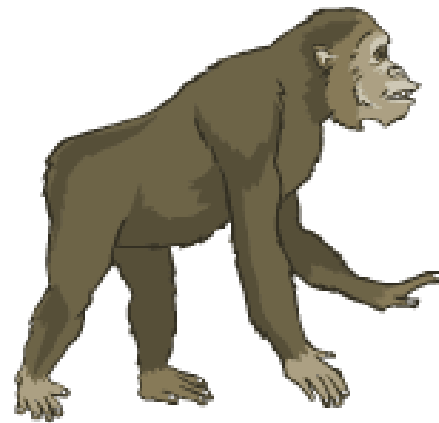
# Homo



# Important Human Transitions

Bipedalism

7 million years ago



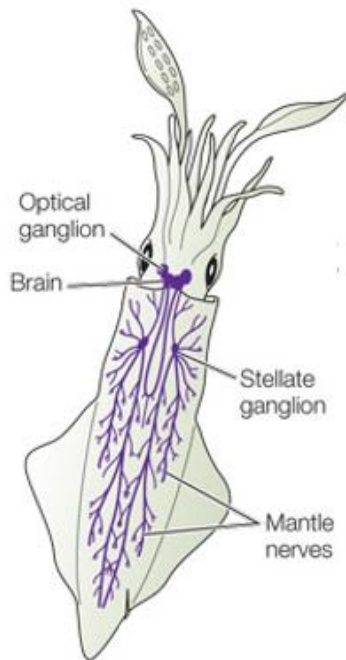
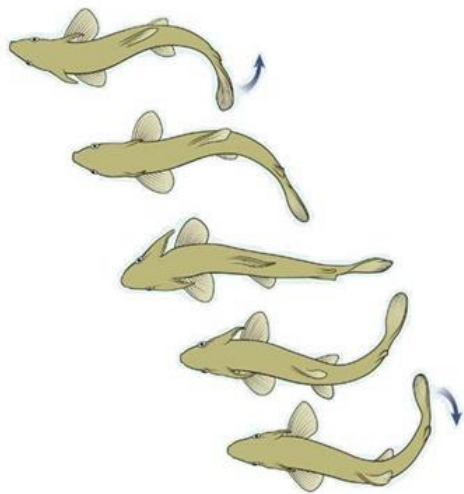
**DRYOPITHECUS**  
12–9 mya



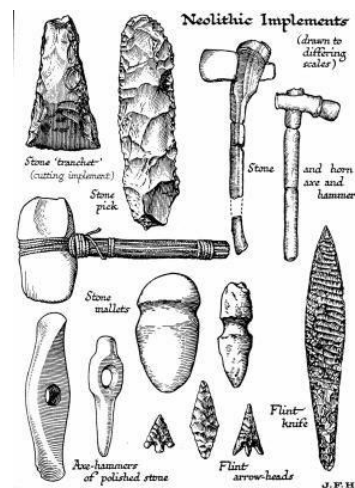
**AUSTRALOPITHECUS AFARENSIS**  
4–2.7 mya



**HOMO ERECTUS**  
<1.8 mya



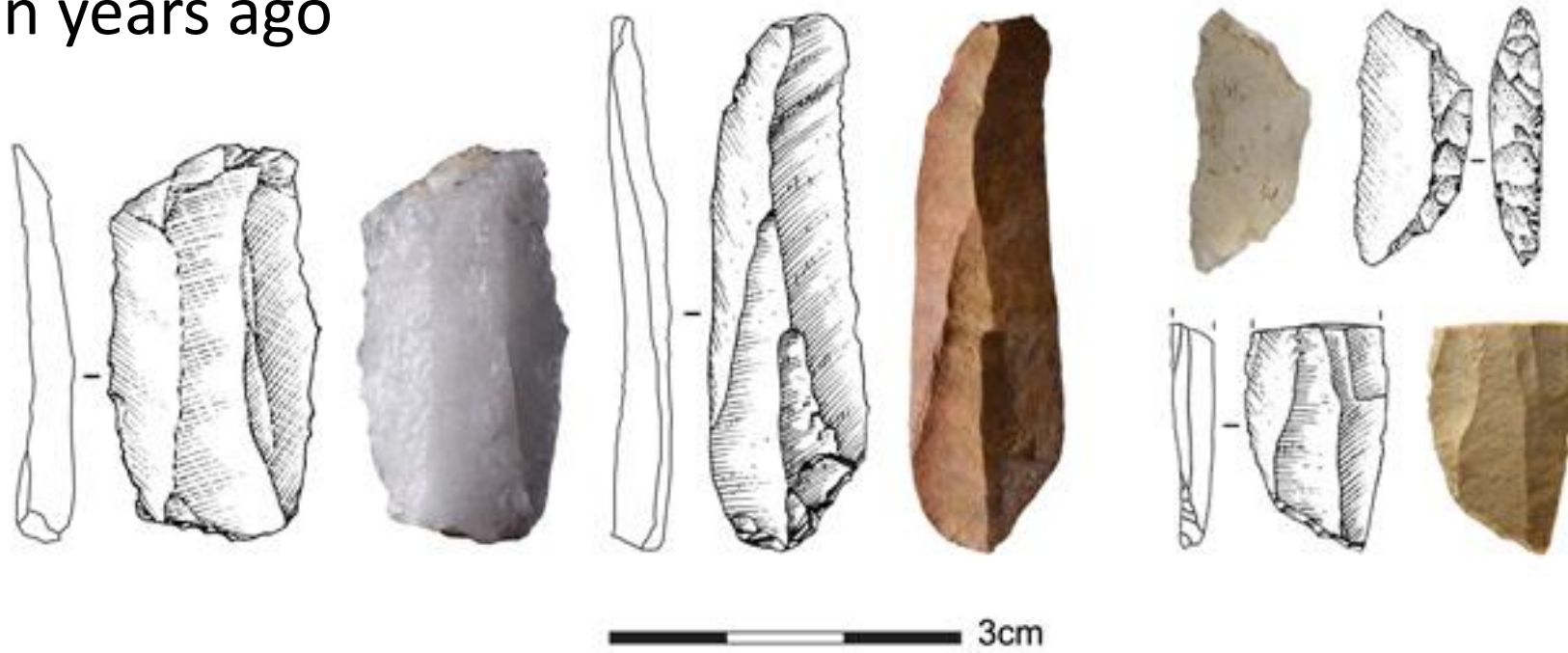
[citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.136.2311](https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.136.2311)



# Important Human Transitions

Bipedalism 7 million years ago

Stone tools 3.3 million years ago



# Tools



# Tools





# Collective learning



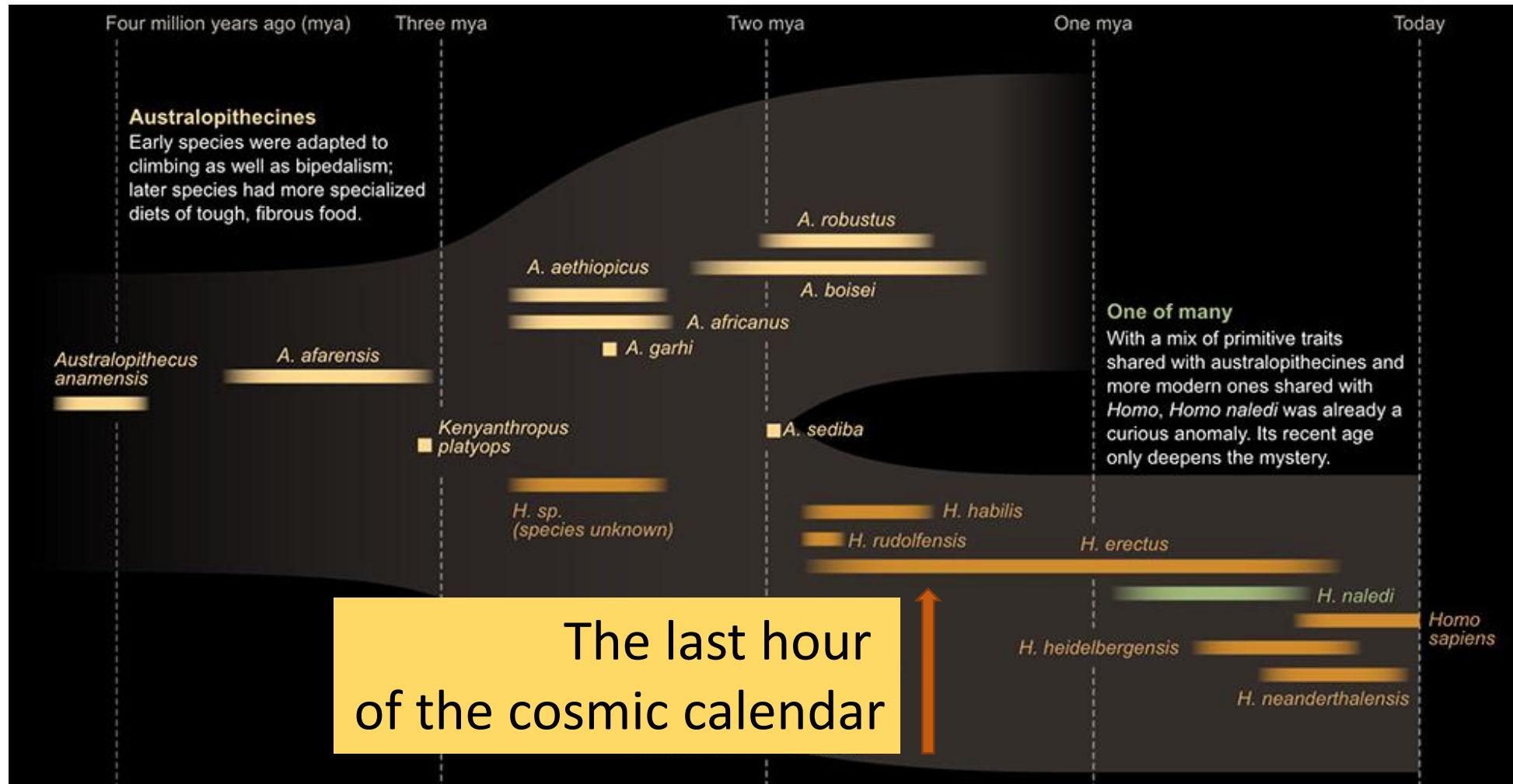
Collective learning



Culture

Cultural forgetting

# Homo

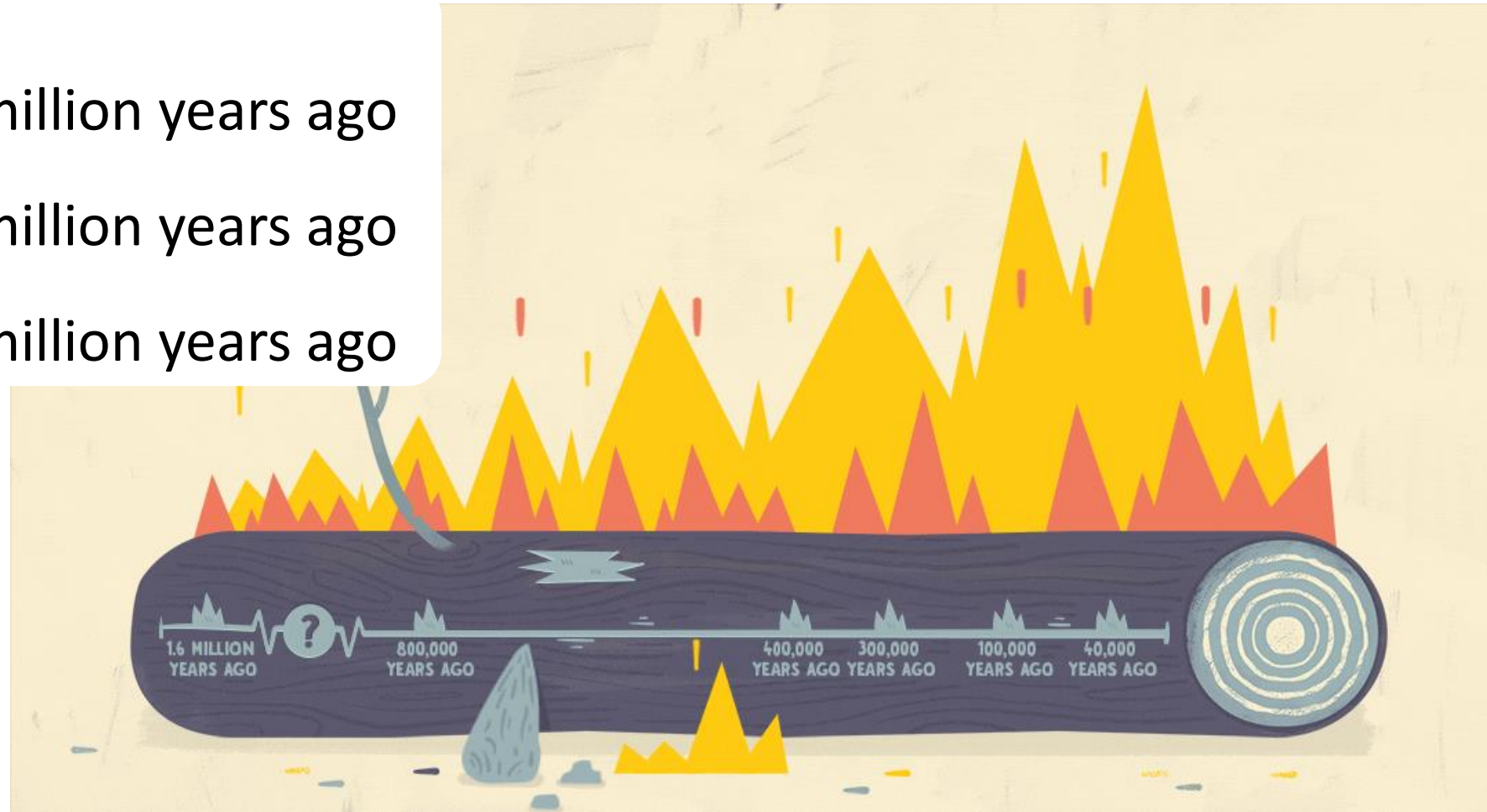


# Important Human Transitions

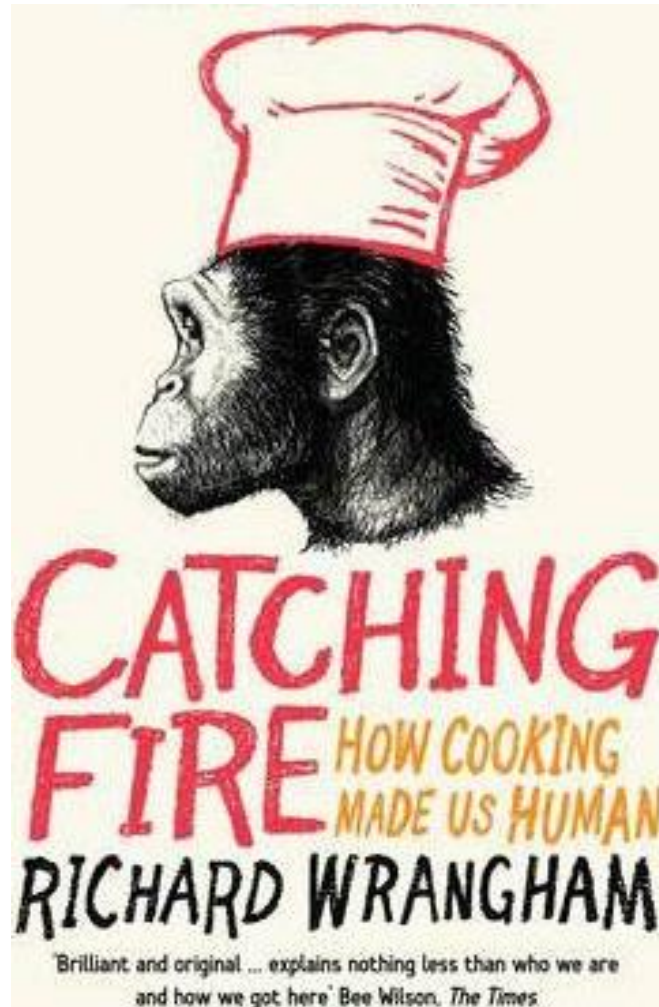
Bipedalism 7 million years ago

Stone tools 3.3 million years ago

Use of Fire 1.3 million years ago



# Cooking



[scientificamerican.com/article/food-for-thought-was-cooking-a-pivotal-step-in-human-evolution/](https://scientificamerican.com/article/food-for-thought-was-cooking-a-pivotal-step-in-human-evolution/)

# Important Human Transitions

Bipedalism 7 million years ago

Stone tools 3.3 million years ago

Use of Fire 1.3 million years ago

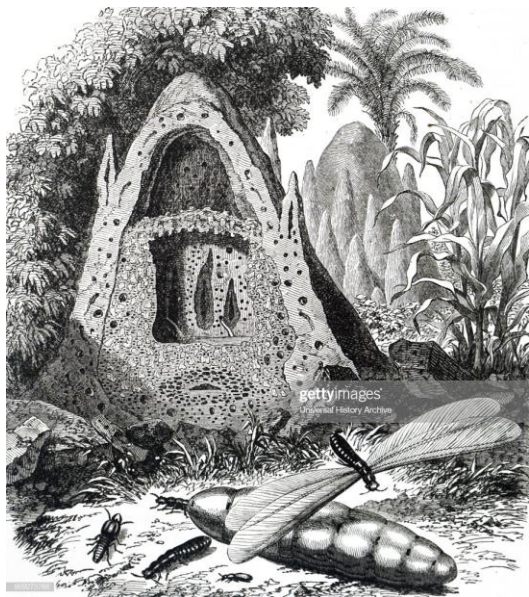
Language



# Cognitive revolution

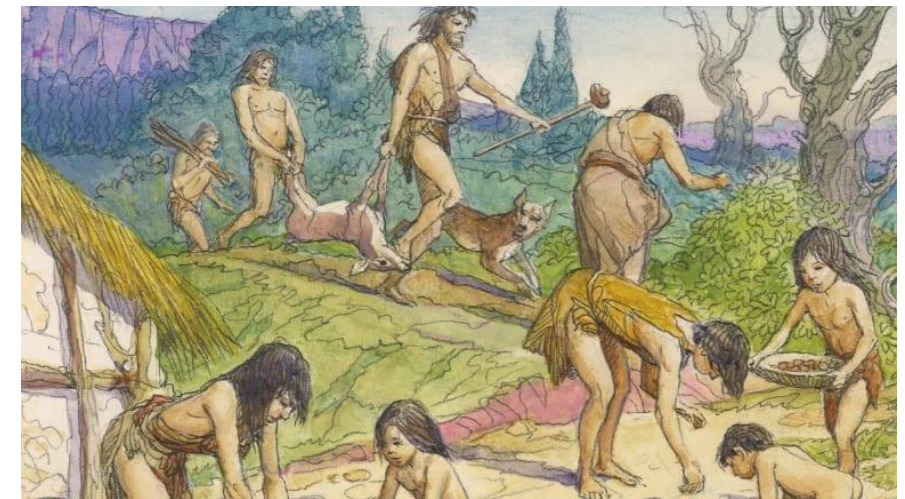
## New ability

The ability to transmit larger quantities of information about the surrounding world



## Wider consequences

Planning and carrying out complex actions, such as avoiding lions and hunting bison



# Cognitive revolution

<b>New ability</b>	<b>Wider consequences</b>
The ability to transmit larger quantities of information about the surrounding world	Planning and carrying out complex actions, such as avoiding lions and hunting bison
The ability to transmit larger quantities of information about social relationships	Larger and more cohesive groups, numbering up to 150 individuals

# Cognitive revolution

New ability	Wider consequences
The ability to transmit larger quantities of information about the surrounding world	Planning and carrying out complex actions, such as avoiding lions and hunting bison
The ability to transmit larger quantities of information about social relationships	Larger and more cohesive groups, numbering up to 150 individuals
The ability to transmit information about things that do not <i>physically</i> exist, such as tribal spirits, nations, limited liability companies and human rights	a. Cooperation between very large numbers of strangers b. Rapid innovation of social behaviour

Adapted from Sapiens of Yuval Hariri



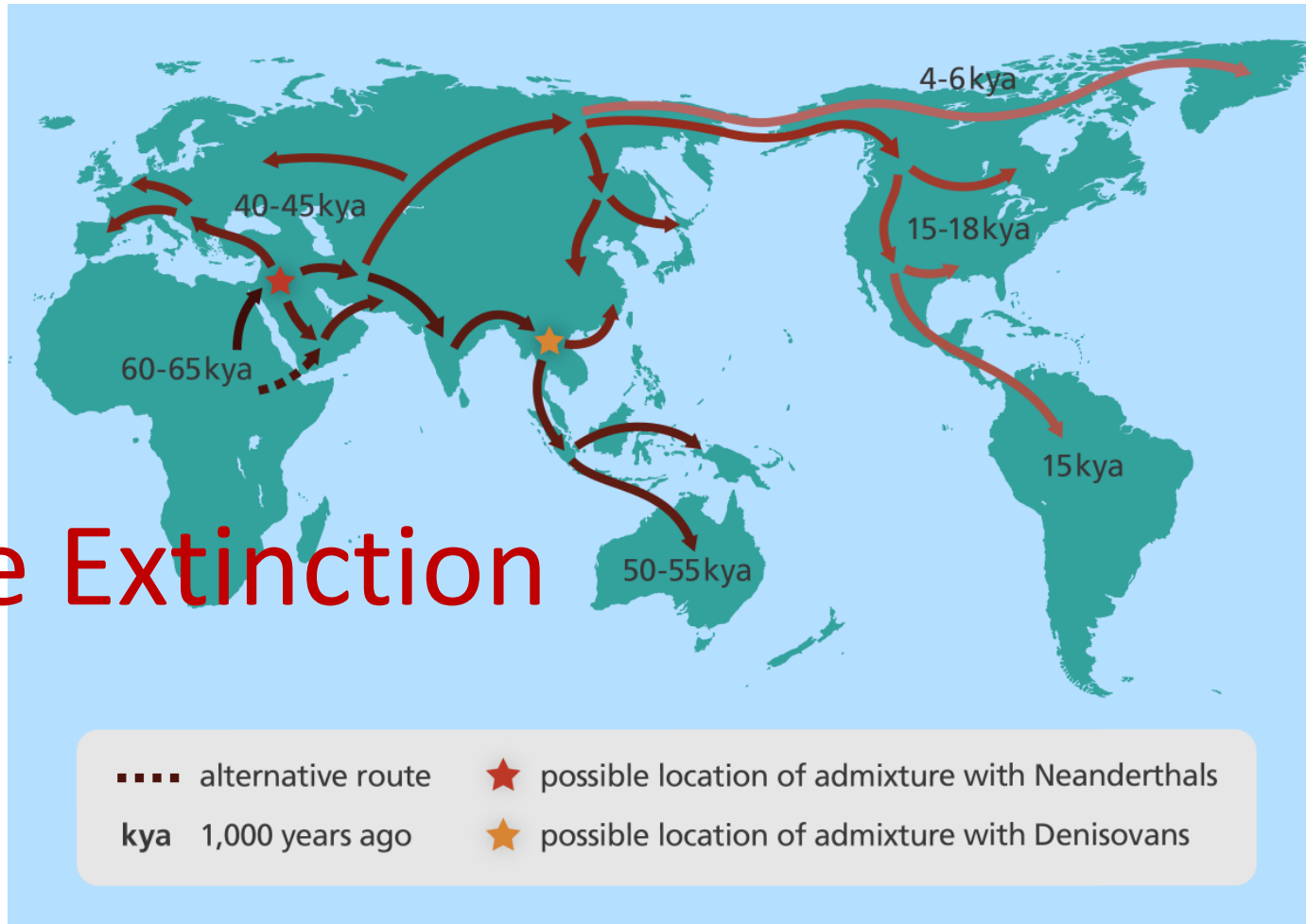
# Important Human Transitions

Bipedalism	7 million years ago
Stone tools	3.3 million years ago
Use of Fire	1.3 million years ago
Language	
Burials	110,000 years ago

4min



# Early human migrations



## First Wave Extinction

# Kits of building blocks

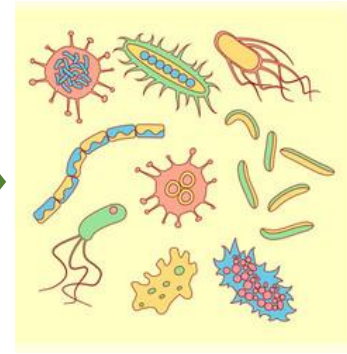
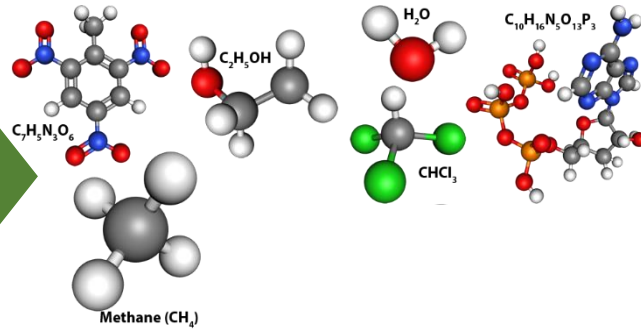
**Standard Model of Elementary Particles**

three generations of matter (fermions)			interactions / force carriers (bosons)	
I	II	III		
$\frac{2}{3}$ +2/3 MeV/c <sup>2</sup> 1/6 u up	$\frac{2}{3}$ +1.28 GeV/c <sup>2</sup> 1/6 c charm	$\frac{2}{3}$ +173.1 GeV/c <sup>2</sup> 1/6 t top	0 g gluon	0 H higgs
$-\frac{1}{3}$ -4.7 MeV/c <sup>2</sup> 1/6 d down	$-\frac{1}{3}$ +96 MeV/c <sup>2</sup> 1/6 s strange	$-\frac{1}{3}$ +4.18 GeV/c <sup>2</sup> 1/6 b bottom	0 γ photon	
$-1$ +0.511 MeV/c <sup>2</sup> 1/6 e electron	$-1$ +105.66 MeV/c <sup>2</sup> 1/6 μ muon	$-1$ +1.7768 GeV/c <sup>2</sup> 1/6 τ tau	0 Z Z boson	
$0$ +1.0 eV/c <sup>2</sup> 1/6 ν <sub>e</sub> electron neutrino	$0$ +0.17 MeV/c <sup>2</sup> 1/6 ν <sub>μ</sub> muon neutrino	$0$ +18.2 MeV/c <sup>2</sup> 1/6 ν <sub>τ</sub> tau neutrino	0 W W boson	

**SCALAR BOSONS**  
GAUGE BOSONS  
VECTOR BOSONS



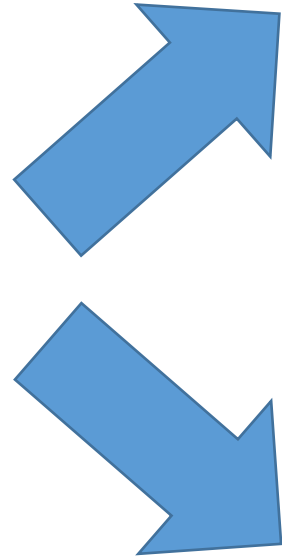
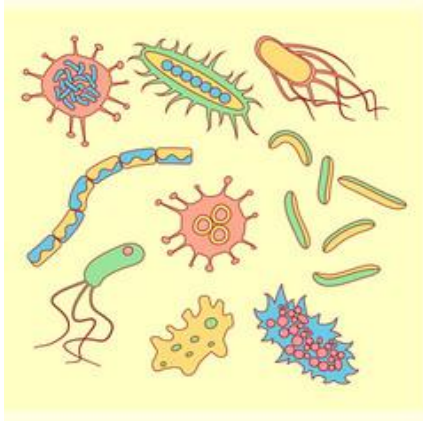
**Periodic Table of the Elements**



?

# Organisms

Prokaryote

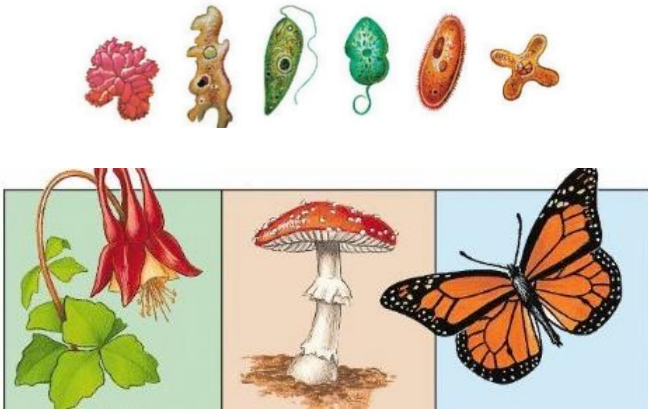


From organisms of the same species



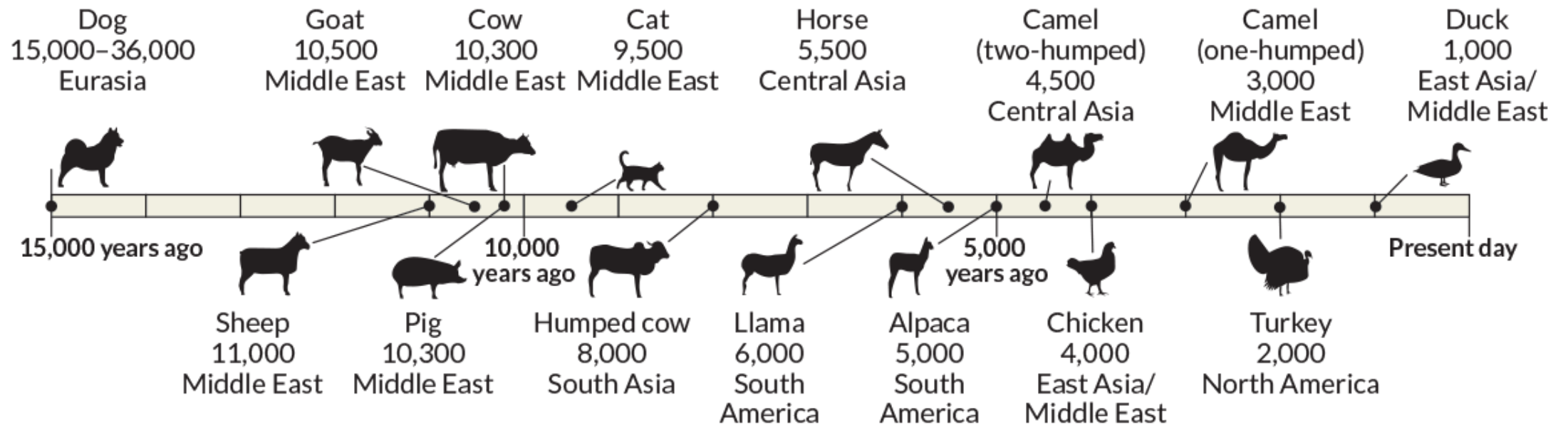
From organisms of different species

Eukaryote

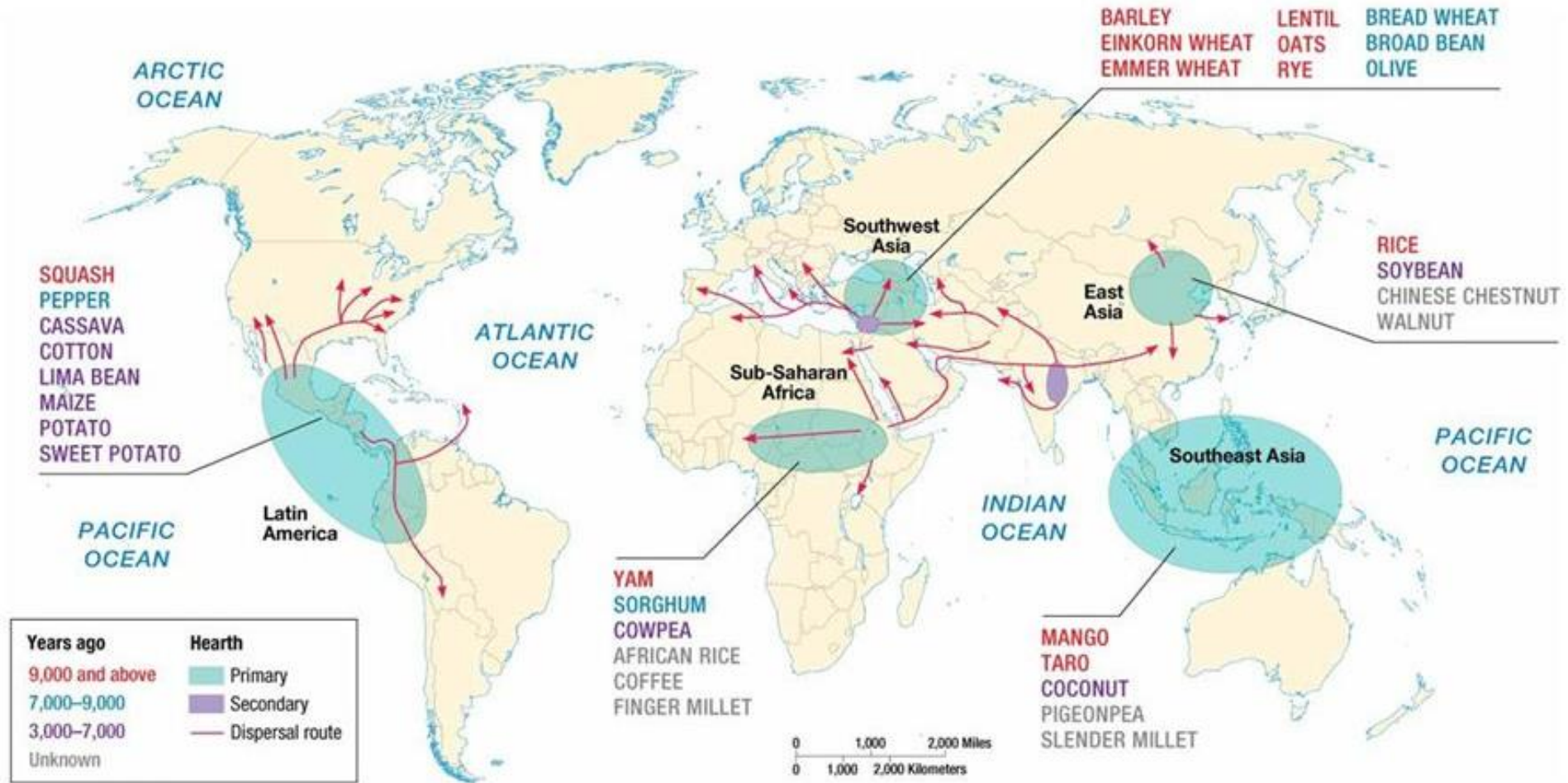


# Domestication

Approximate time frame of domestication based on archaeology



# Agriculture



# Domestication

Wheat didn't like rocks and pebbles  
Wheat didn't like sharing space,  
water and nutrients  
Wheat got sick  
Wheat was attacked by rabbits and  
locust swarms  
Wheat was thirsty  
Wheat was hungry



# Domestication

## Domestication is not unidirectional

### RESEARCH ARTICLE

## Large-Scale Psychological Differences Within China Explained by Rice Versus Wheat Agriculture

T. Talhelm<sup>1,\*</sup>, X. Zhang<sup>2,3</sup>, S. Oishi<sup>1</sup>, C. Shimin<sup>4</sup>, D. Duan<sup>2</sup>, X. Lan<sup>5</sup>, S. Kitayama<sup>5</sup>

+ See all authors and affiliations

Science 09 May 2014:  
Vol. 344, Issue 6184, pp. 603-608  
DOI: 10.1126/science.1246850

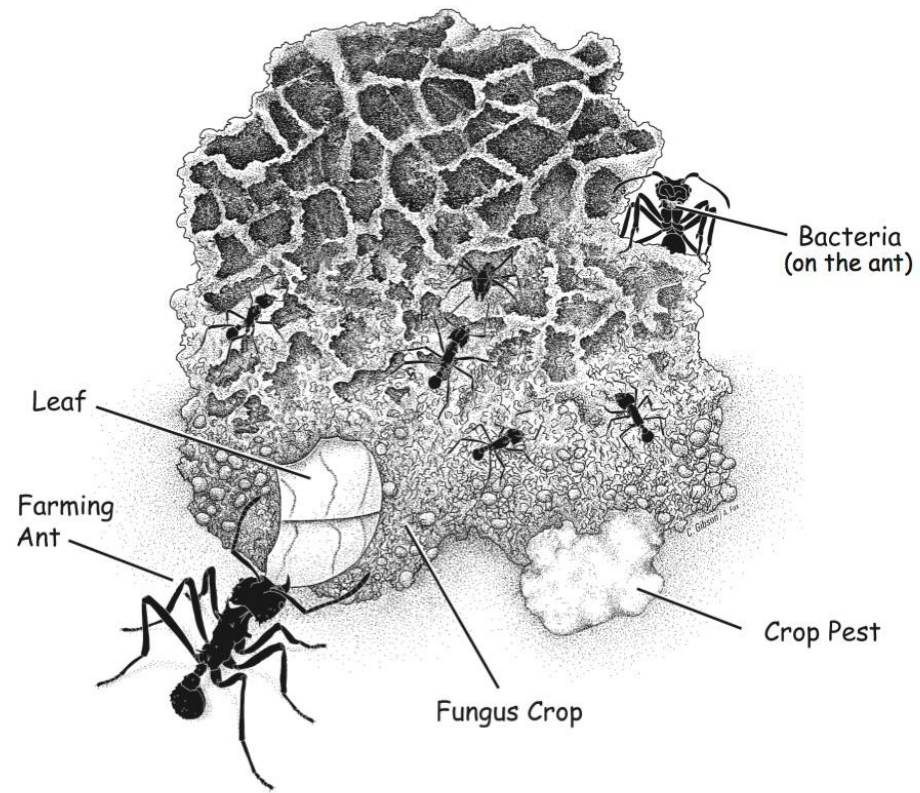
### North-south divide

The 'rice theory' suggests that the history of subsistence farming, wheat and rice, explains psychological differences between Chinese living in the north and south

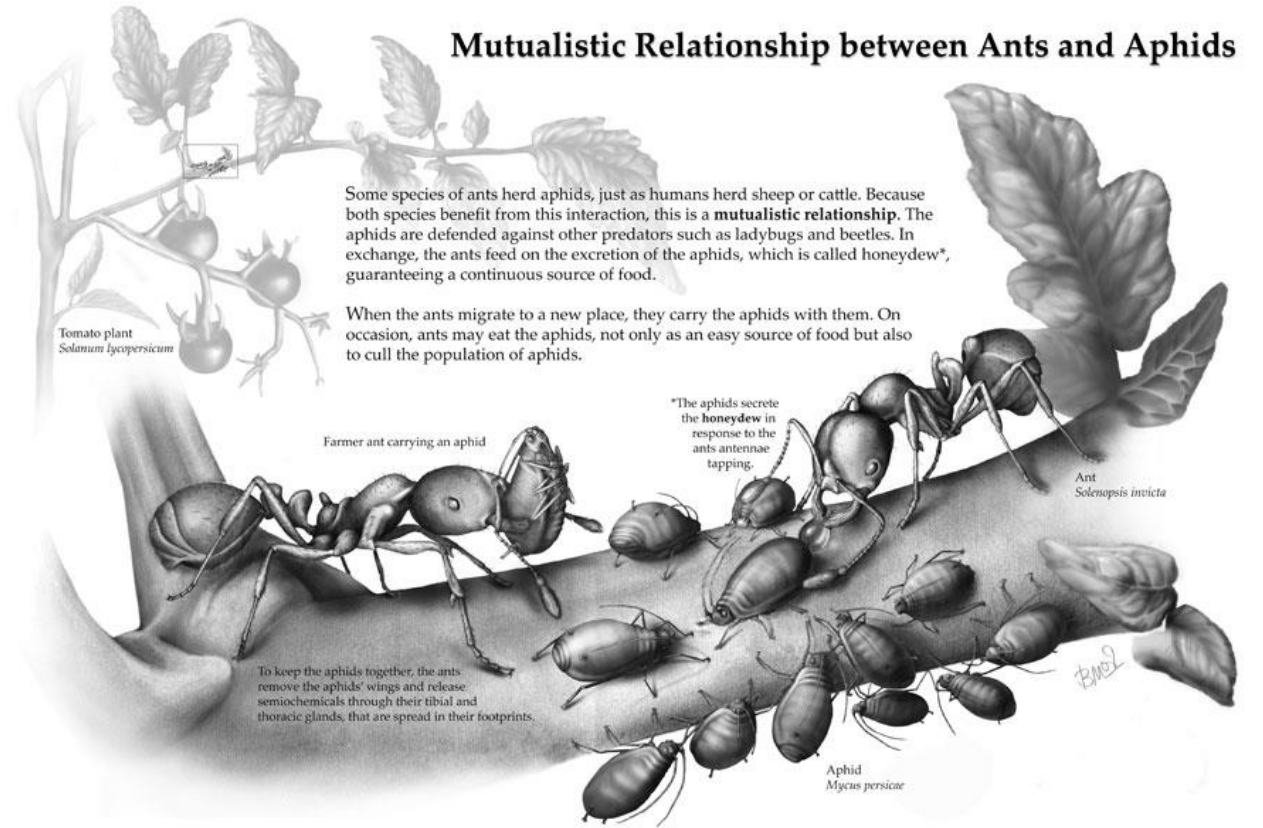
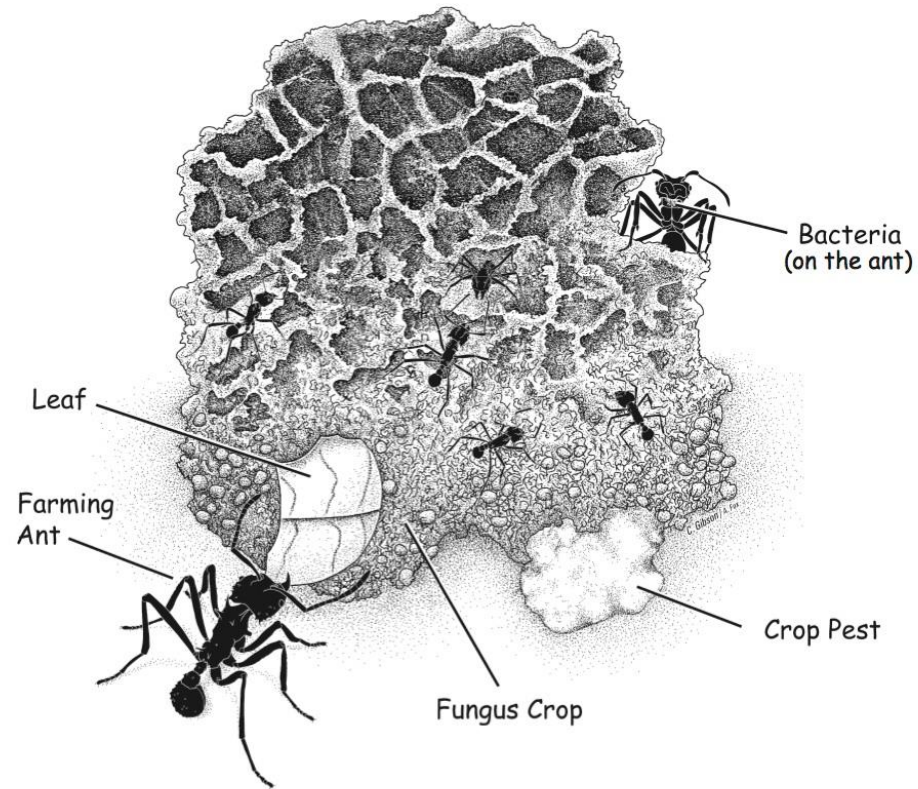




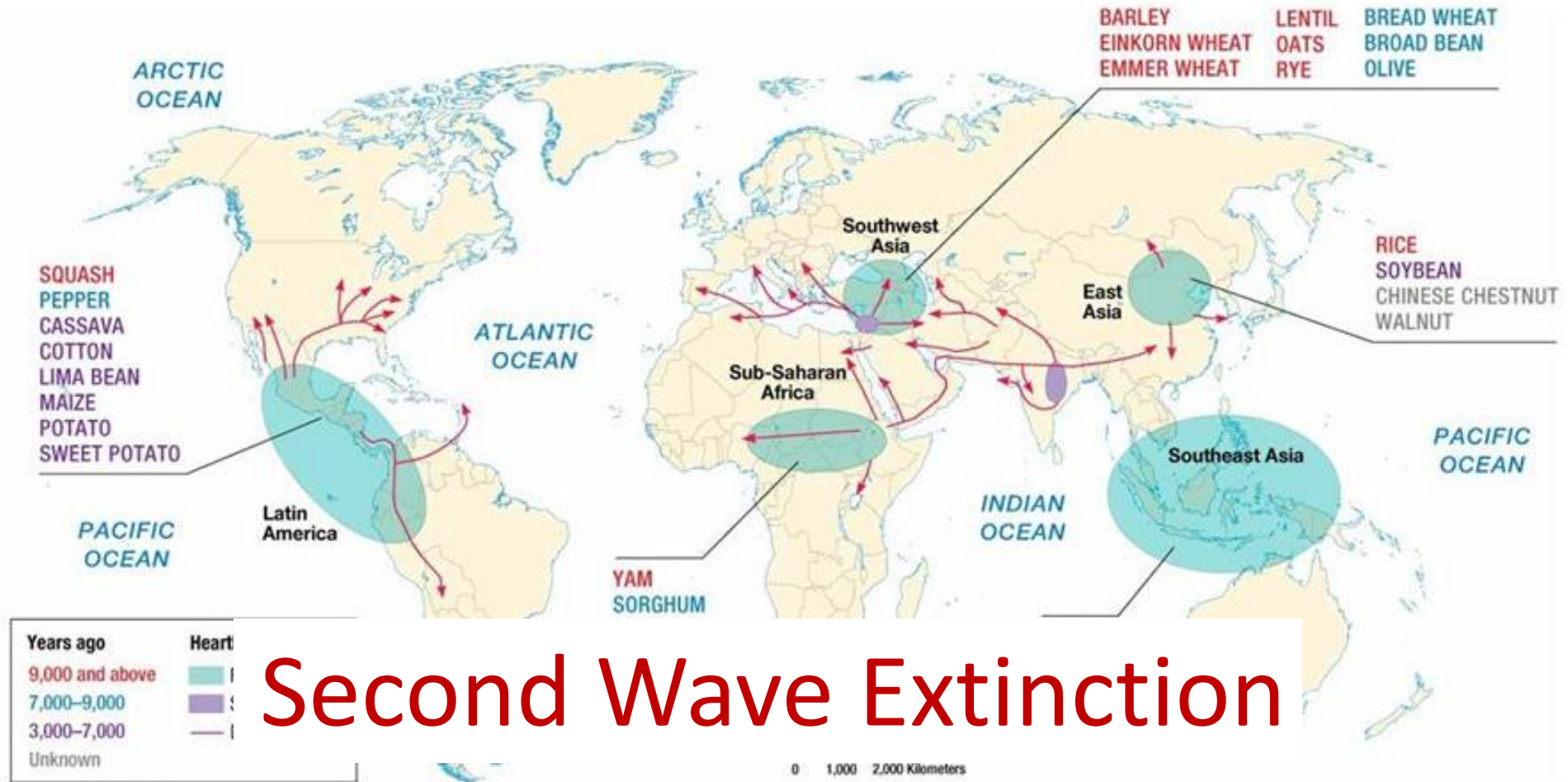
# Domestication



# Domestication



# Agriculture



## Second Wave Extinction

# Kits of building blocks

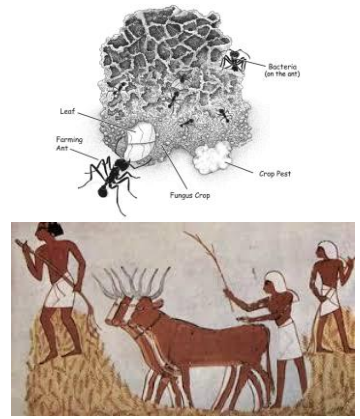
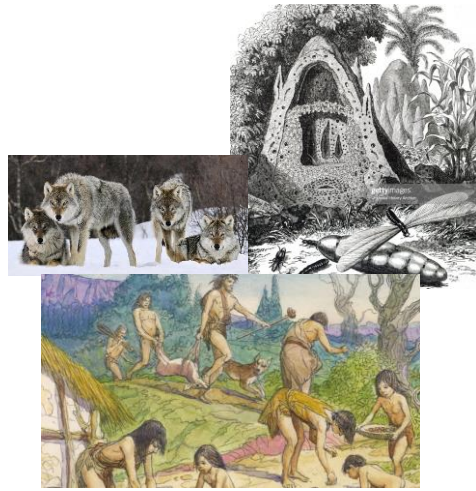
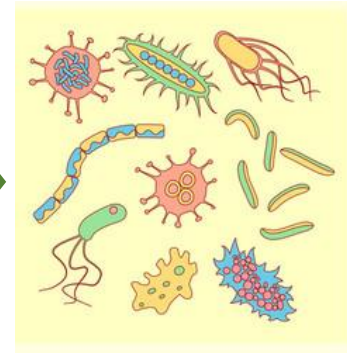
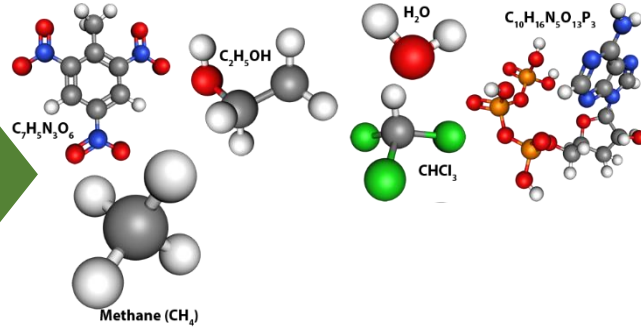
**Standard Model of Elementary Particles**

three generations of matter (fermions)			interactions / force carriers (bosons)	
I	II	III		
$\frac{2}{3}$ +2/3 MeV/c <sup>2</sup> +2/3 u up	$\frac{2}{3}$ +1.28 GeV/c <sup>2</sup> +2/3 c charm	$\frac{2}{3}$ +173.1 GeV/c <sup>2</sup> +2/3 t top	0 +0 g gluon	0 +124.07 GeV/c <sup>2</sup> 0 H higgs
$\frac{1}{3}$ -4.7 MeV/c <sup>2</sup> -1/3 d down	$\frac{1}{3}$ +96 MeV/c <sup>2</sup> -1/3 s strange	$\frac{1}{3}$ +4.18 GeV/c <sup>2</sup> -1/3 b bottom	0 +0 γ photon	
$\frac{2}{3}$ +0.511 MeV/c <sup>2</sup> -1/3 e electron	$\frac{2}{3}$ +105.66 MeV/c <sup>2</sup> -1/3 μ muon	$\frac{2}{3}$ +1.7768 GeV/c <sup>2</sup> -1/3 τ tau	0 +0 Z Z boson	
$\frac{1}{2}$ +1.0 eV/c <sup>2</sup> 0 ν <sub>e</sub> electron neutrino	$\frac{1}{2}$ +0.17 MeV/c <sup>2</sup> 0 ν <sub>μ</sub> muon neutrino	$\frac{1}{2}$ +18.2 MeV/c <sup>2</sup> 0 ν <sub>τ</sub> tau neutrino	0 +0 W W boson	

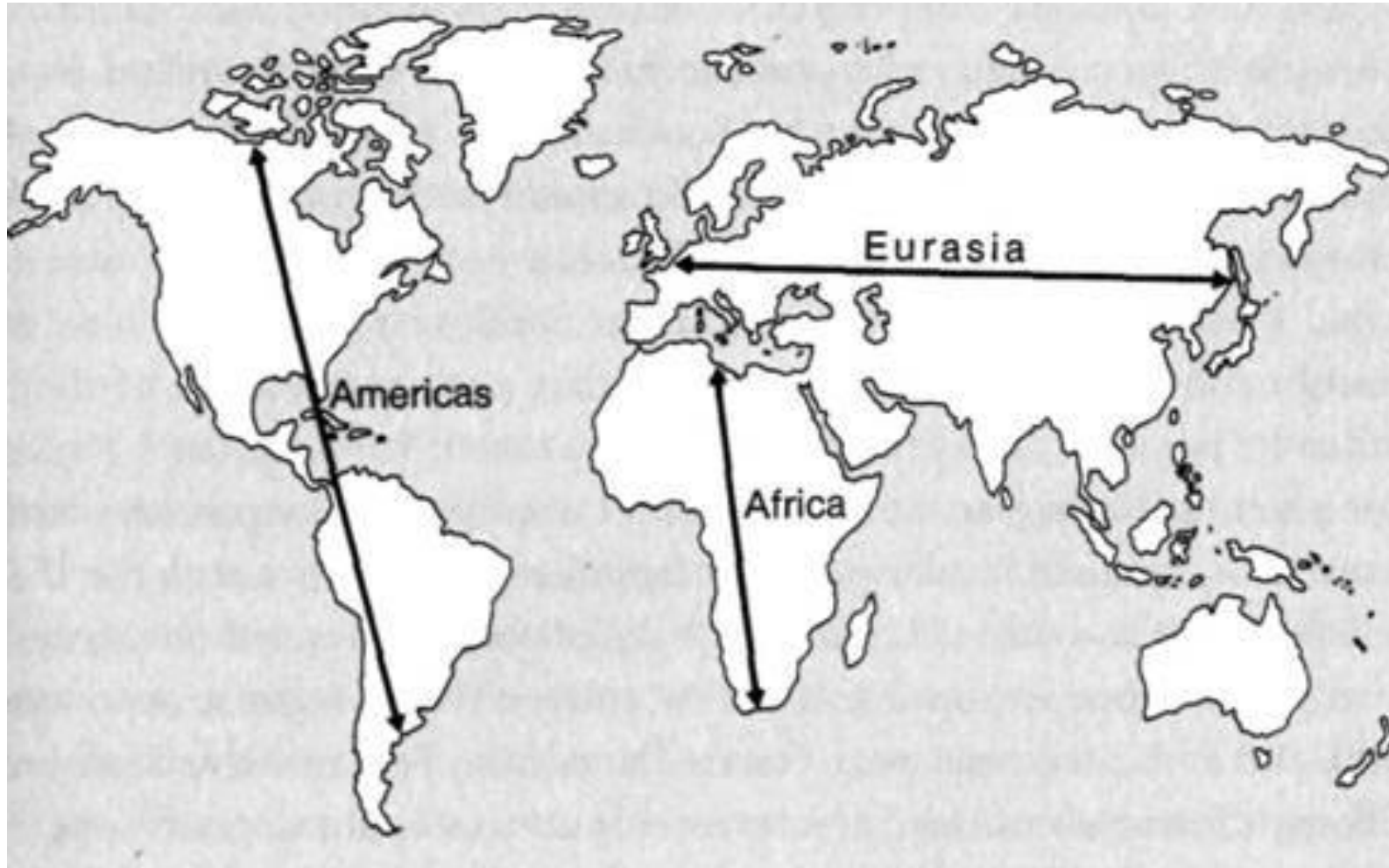
**QUARKS** (left column), **LEPTONS** (right column), **SCALAR BOSONS** (top right), **GAUGE BOSONS VECTOR BOSONS** (bottom right)



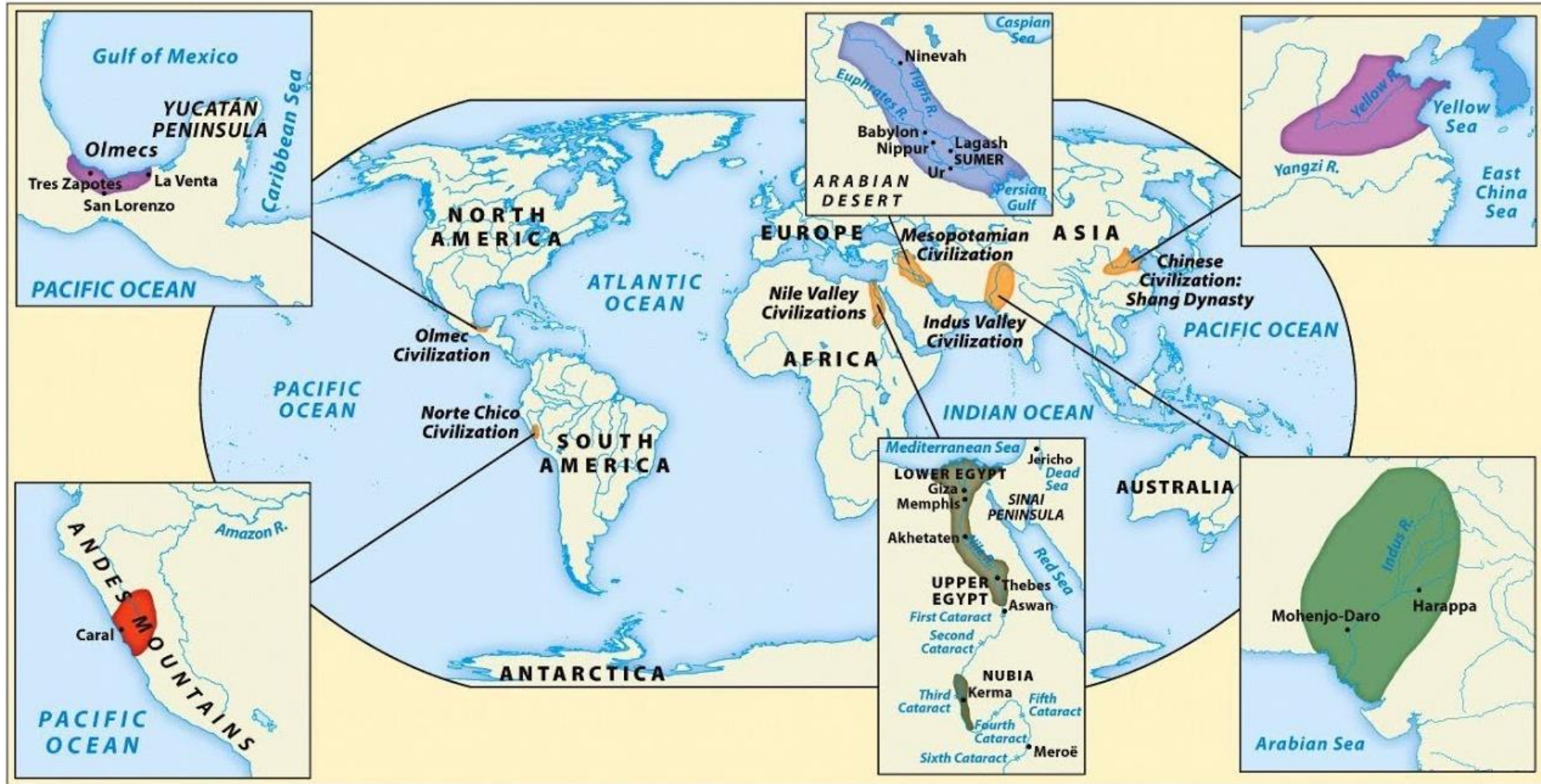
**Periodic Table of the Elements**



# Guns, Germs and Steel



# Civilizations



# Civilizations

## Primary characteristics

1. Urban settlements
2. Full-time specialists not involved in agricultural activities
3. Concentration of surplus production
4. Class structure
5. State-level organization (government)

# Eusociality





# Civilizations

## Primary characteristics

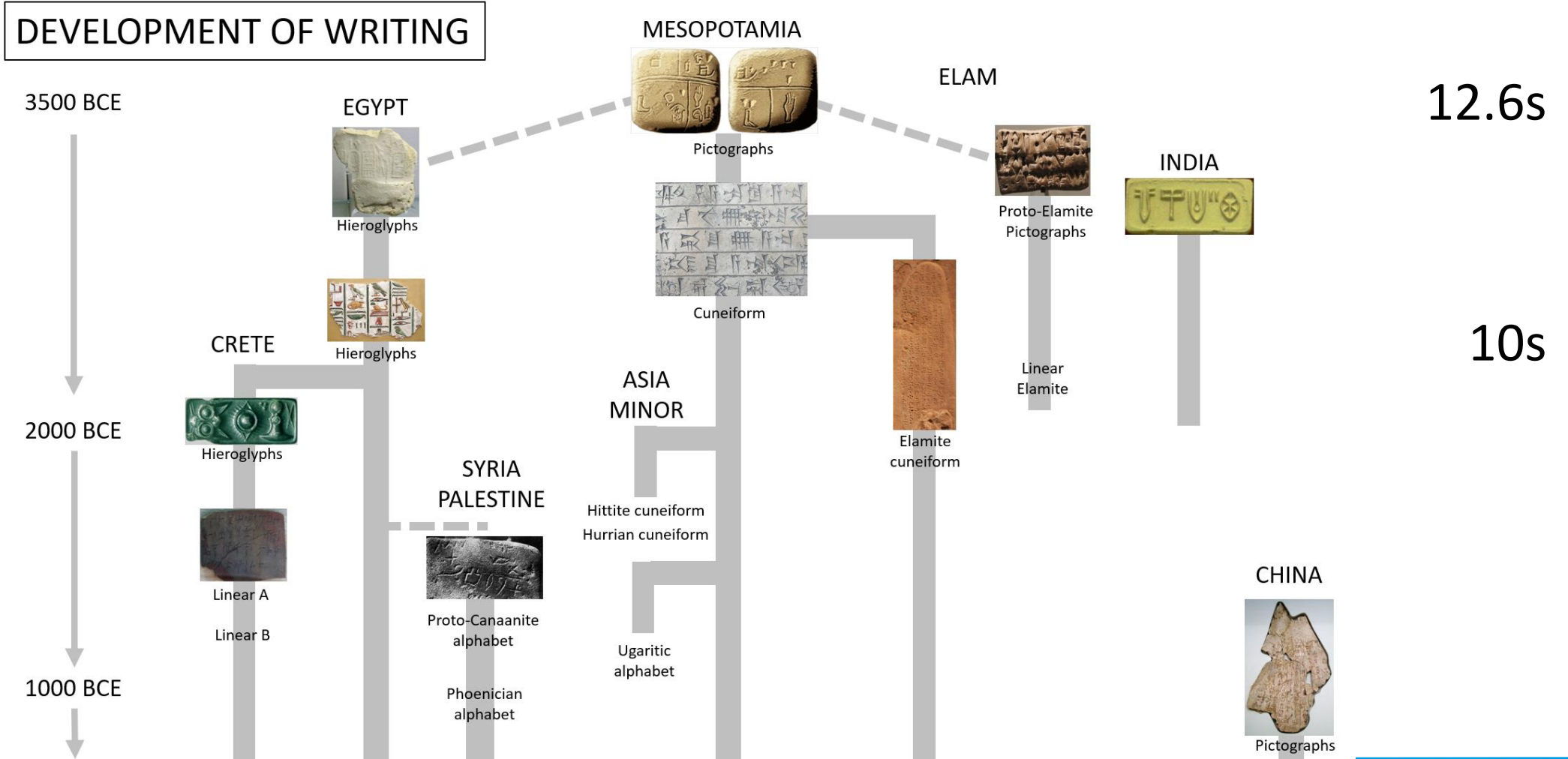
1. Urban settlements
2. Full-time specialists not involved in agricultural activities
3. Concentration of surplus production
4. Class structure
5. State-level organization (government)

## Secondary characteristics

6. Monumental public building
7. Extensive trading networks
8. Standardized monumental artwork
9. Writing
10. Development of exact sciences

[www.ancient.eu/civilization/](http://www.ancient.eu/civilization/)

# Writing



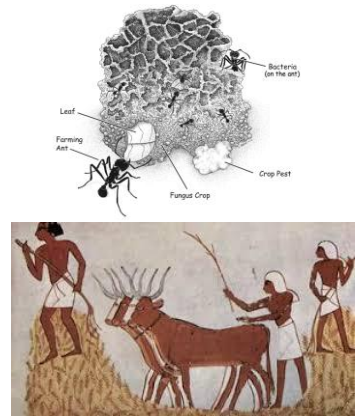
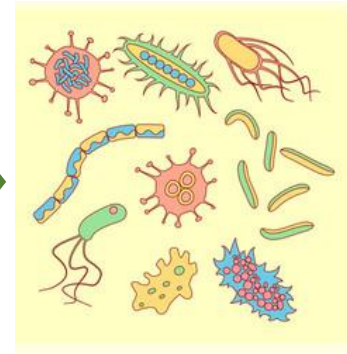
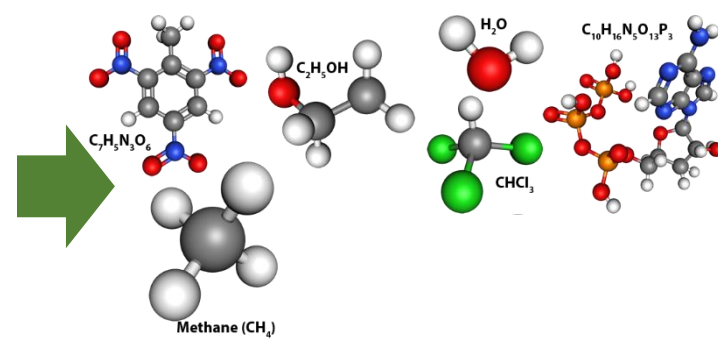
# Kits of building blocks

## Standard Model of Elementary Particles

three generations of matter (fermions)			interactions / force carriers (bosons)	
I	II	III	g	H
$\pm 2/3$ MeV/c <sup>2</sup>	$\pm 1.28$ GeV/c <sup>2</sup>	$\pm 173.1$ GeV/c <sup>2</sup>	0	$\pm 124.07$ GeV/c <sup>2</sup>
u	c	t	g	H
up	charm	top	gluon	higgs
$-1/3$	$-1/3$	$-1/3$	0	0
d	s	b	$\gamma$	0
down	strange	bottom	photon	
$\pm 0.511$ MeV/c <sup>2</sup>	$\pm 105.66$ MeV/c <sup>2</sup>	$\pm 1.7768$ GeV/c <sup>2</sup>	0	0
e	$\mu$	$\tau$	Z	0
electron	muon	tau	Z boson	
0	0	0	W	0
$\nu_e$	$\nu_\mu$	$\nu_\tau$	W	0
electron neutrino	muon neutrino	tau neutrino	W boson	

**SCALAR BOSONS**  
 GAUGE BOSONS  
 VECTOR BOSONS

### Periodic Table of the Elements



# Great Pyramid of Giza

10s



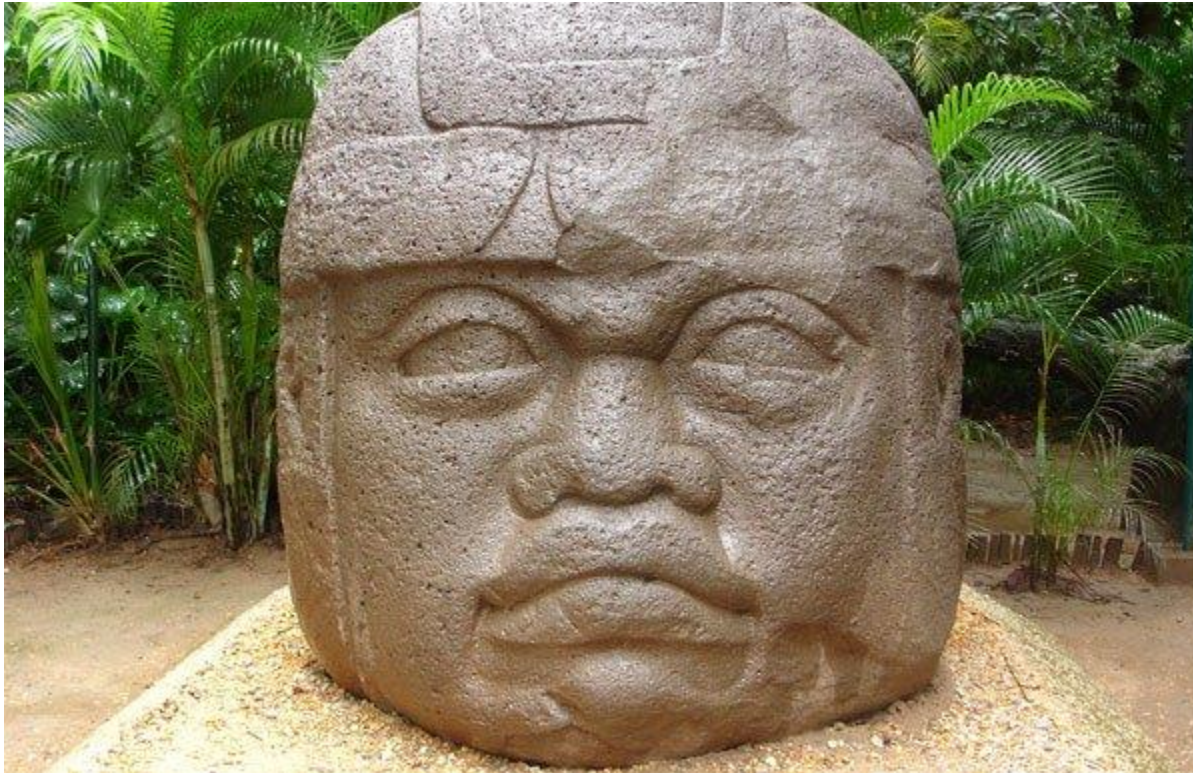
# Shang dynasty

9s



# Olmec civilization

8s



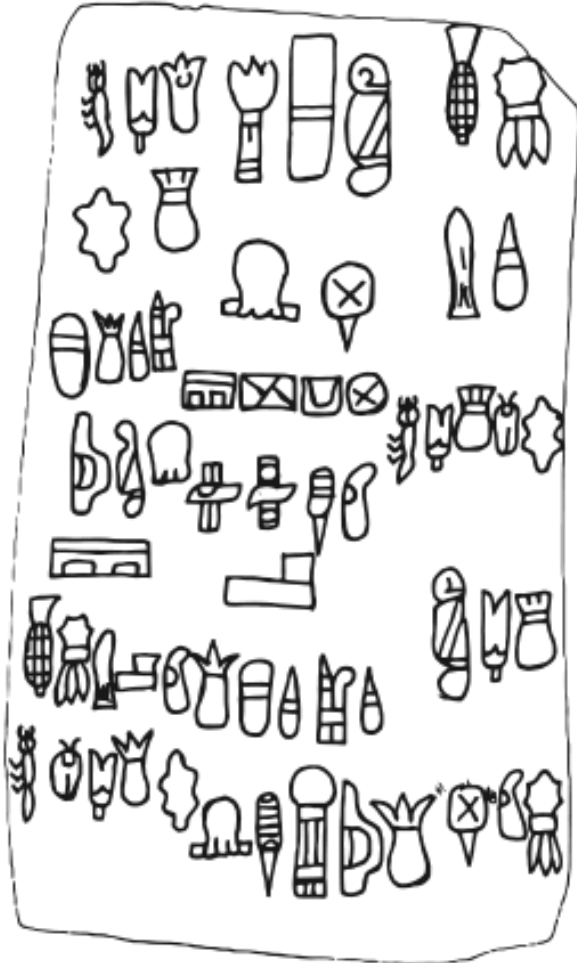
Identical ancestors point (isopoint)

[journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1001555](https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1001555)  
<http://tedlab.mit.edu/~dr/Papers/Rohde-MRCA-two.pdf>

# Third independent writing system

7s

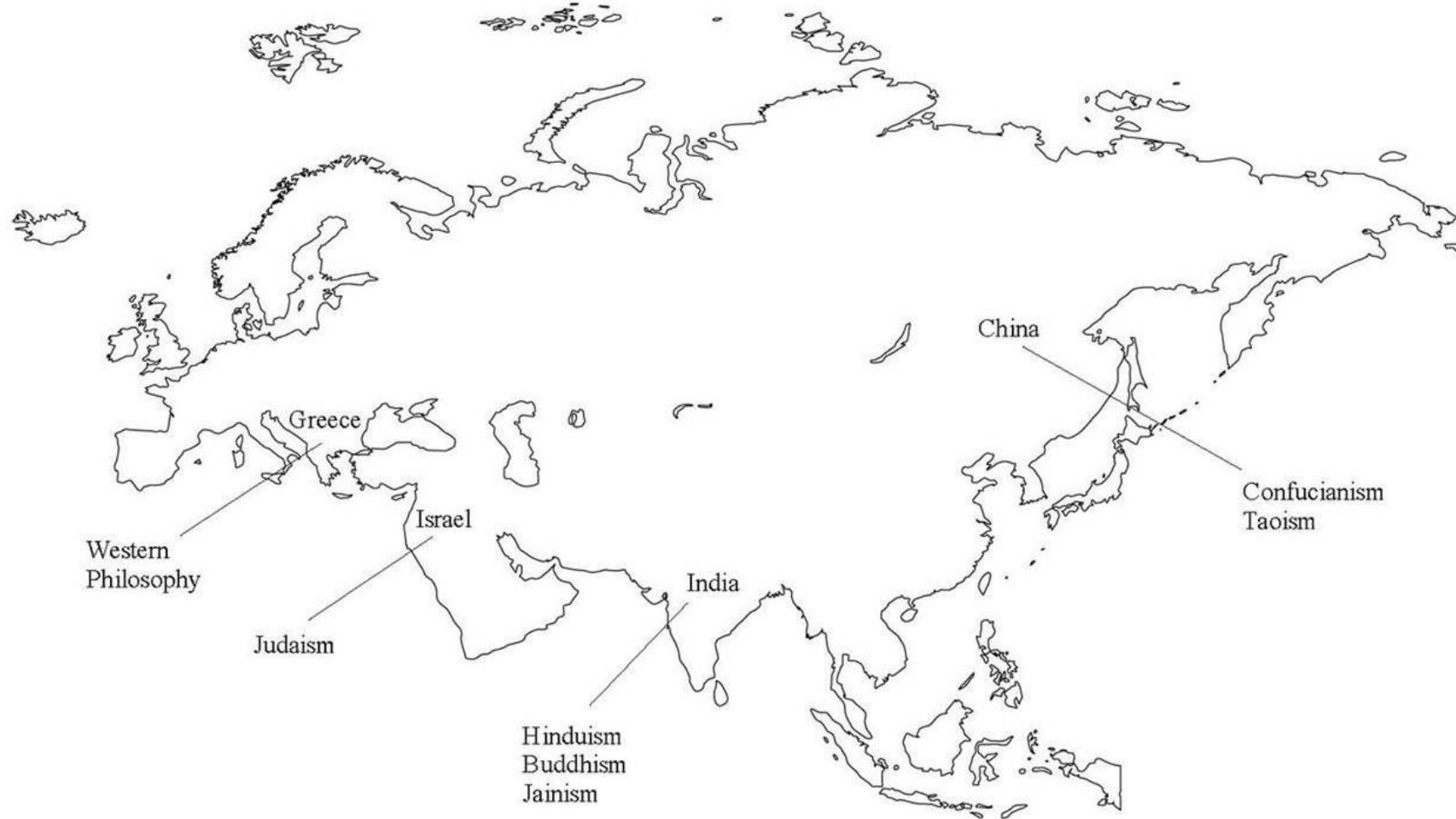
Cascajal block 900BCE



Maya script 300-200BCE

# The Axial Age (800 – 200 BCE)

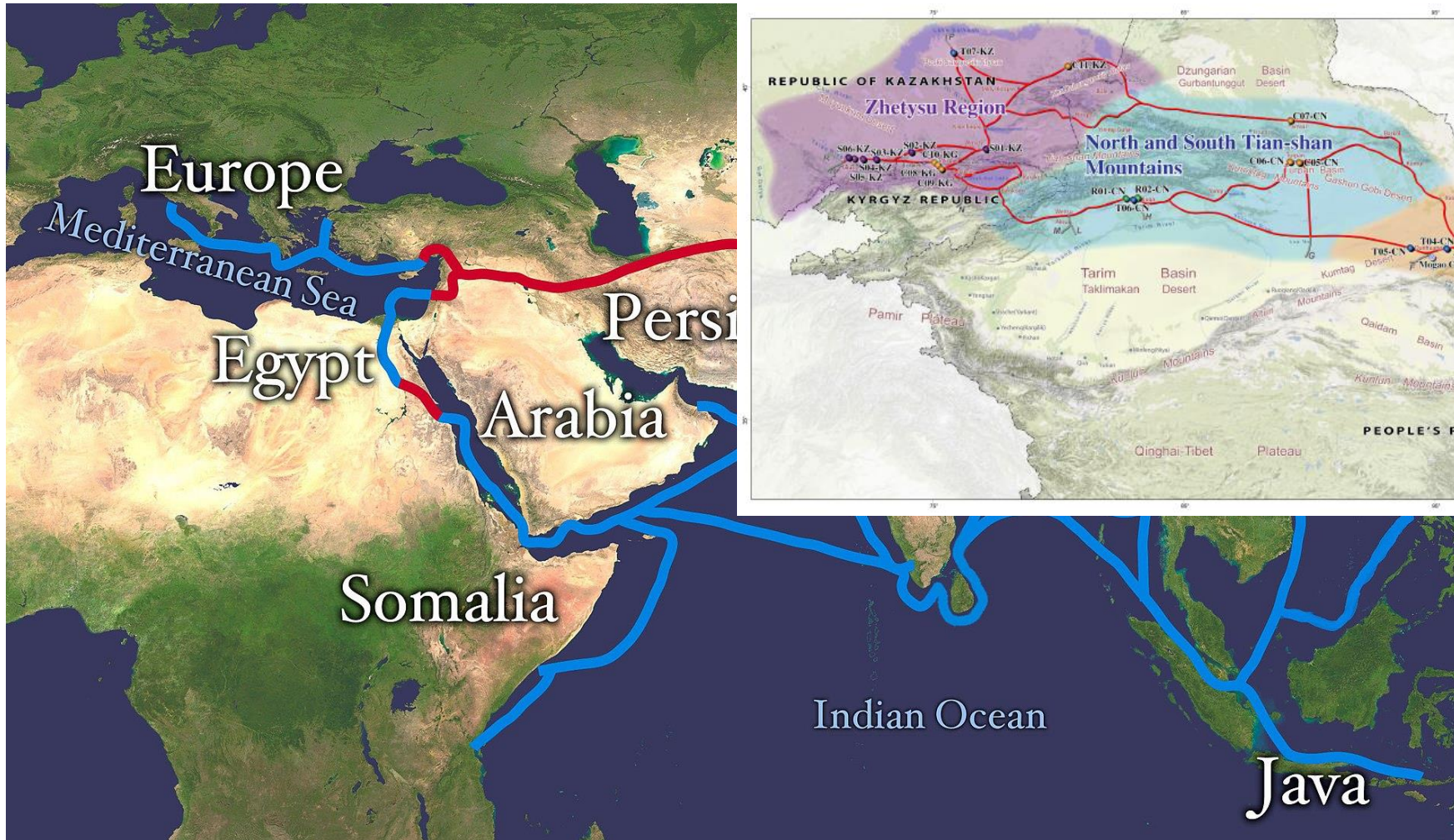
6s

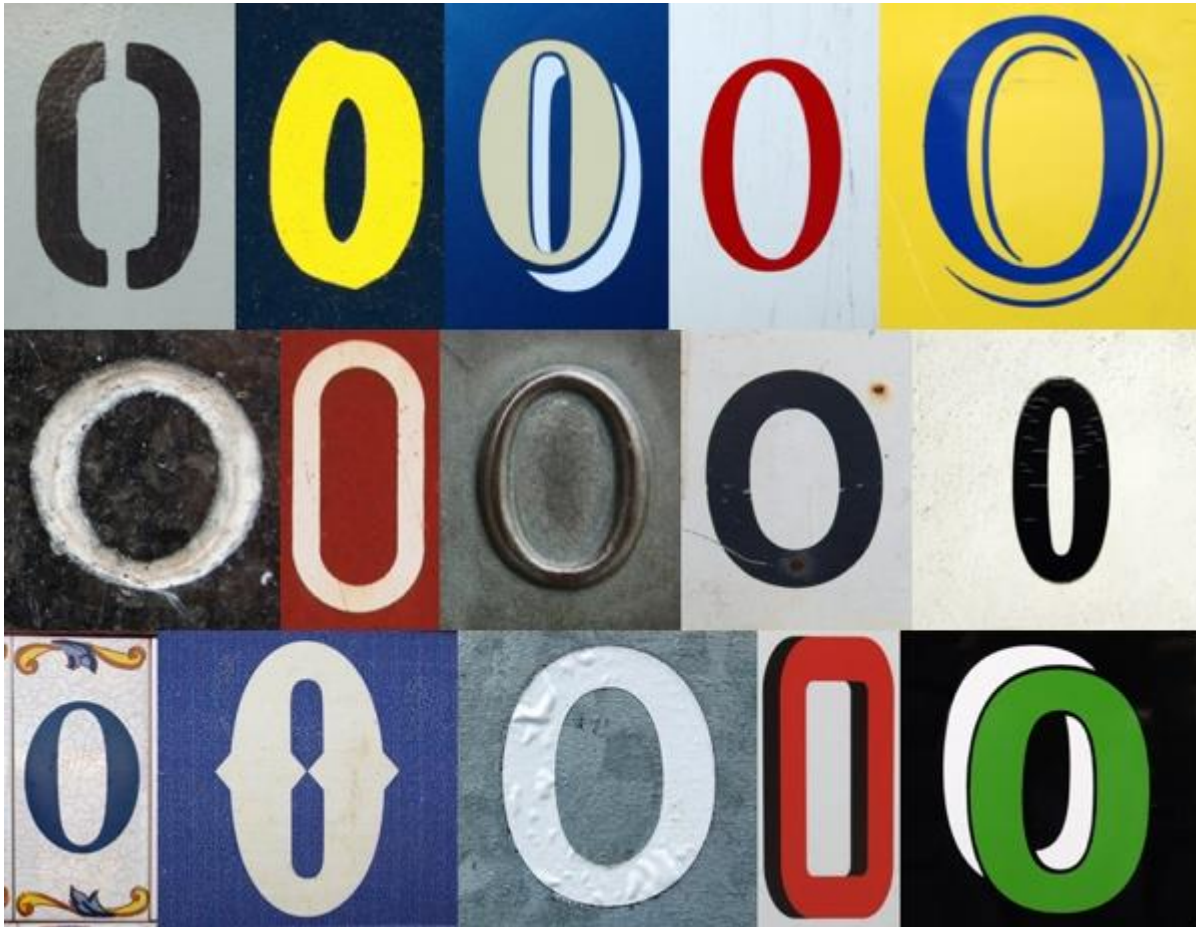




# Silk road

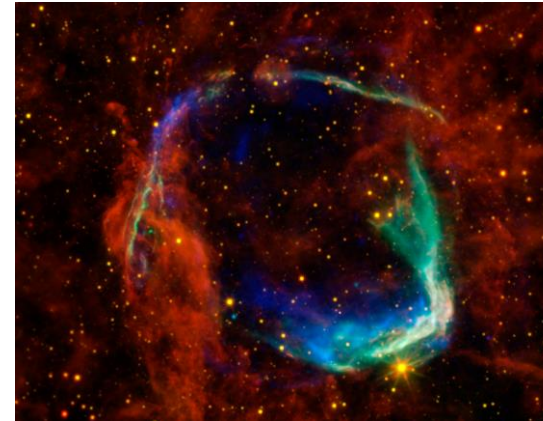
# 5s





Zero  
Positional system → Algorithm

## Supernova SN 185



“In the 2nd year of the epoch Zhongping [中平], the 10th month, on the day Kwei Hae [癸亥] [December 7, Year 185], a 'guest star' appeared in the middle of Nan Mun [asterism containing Alpha Centauri], The size was half a bamboo mat. It displayed various colors, and gradually lessened. In the 6th month of the succeeding year it disappeared.”

# Precursors of banknotes



交子 Jiaozi

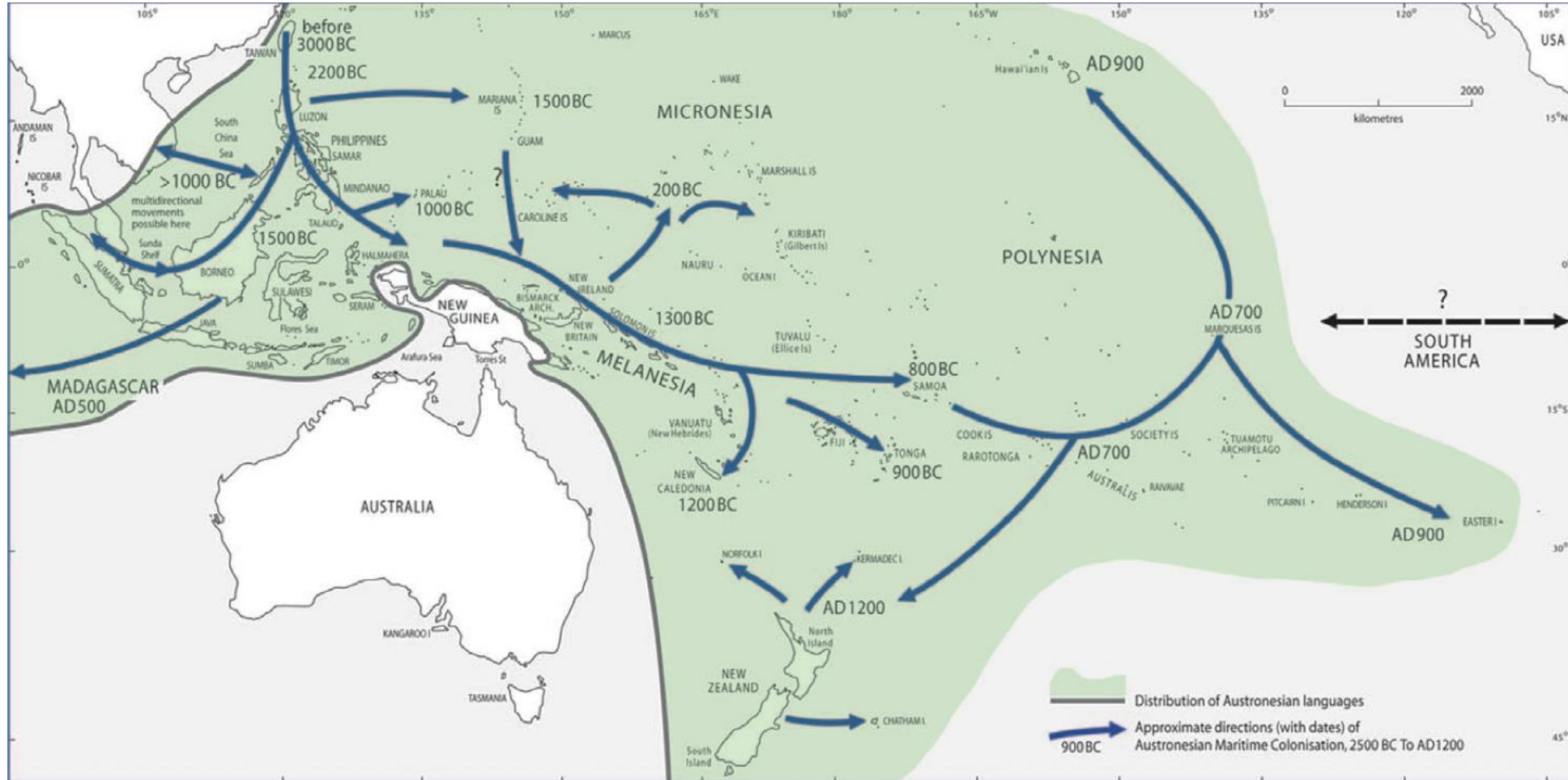
Promissory notes



Banknotes

# New Zealand settlement

2s



# First globalization

1s



Os

2019

Os