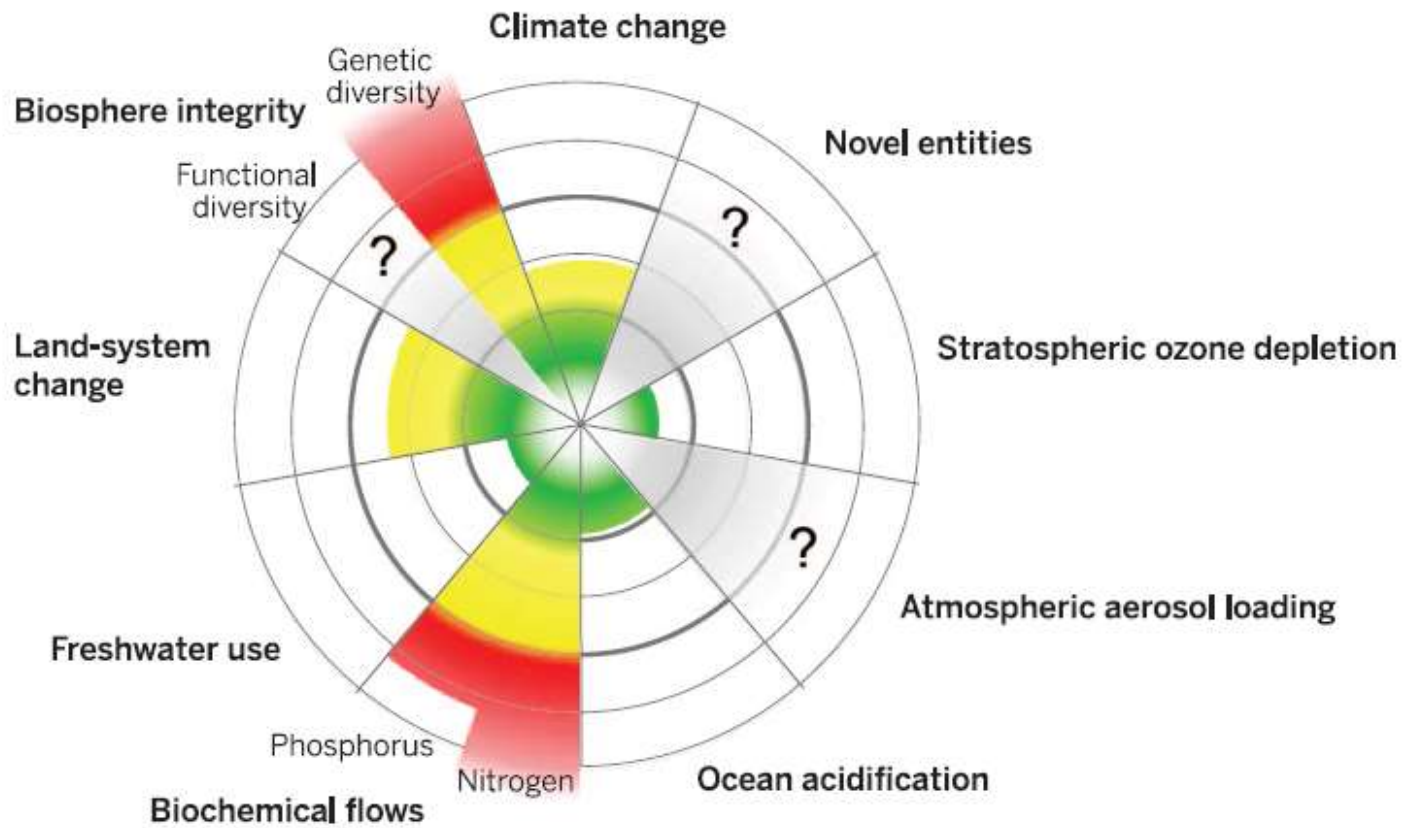


Big History

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

G. M. Marques



■ Beyond zone of uncertainty (high risk)
■ In zone of uncertainty (increasing risk)

■ Below boundary (safe)
■ Boundary not yet quantified

Concepts

Sustainability

Niches

Stability

Diversity

Technology

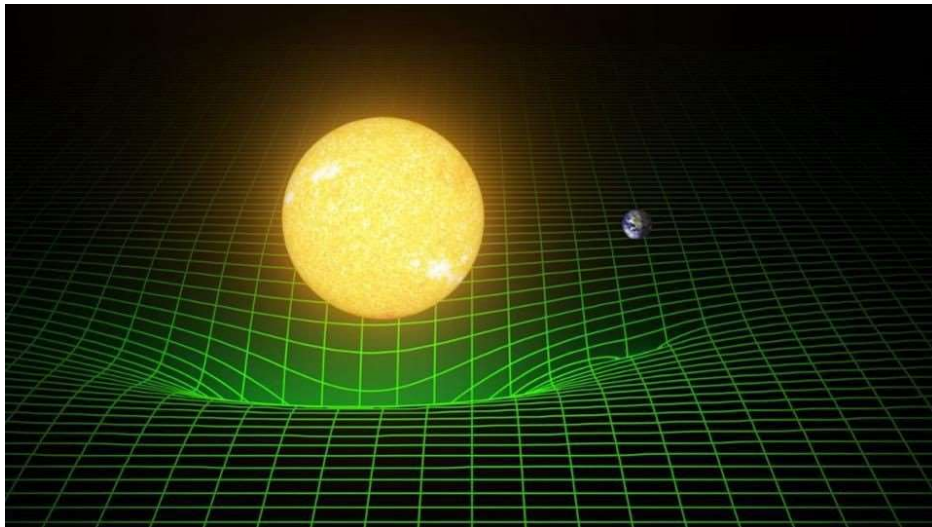
Energy
+

Kits of Building Blocks

Cycles

Mass

Once upon a spacetime...

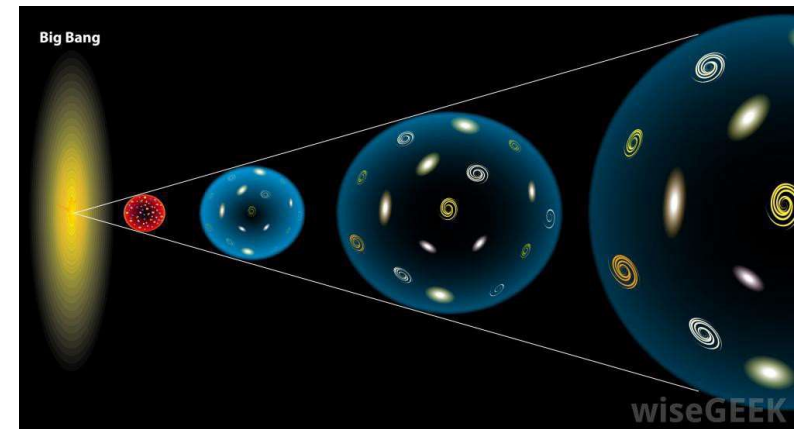
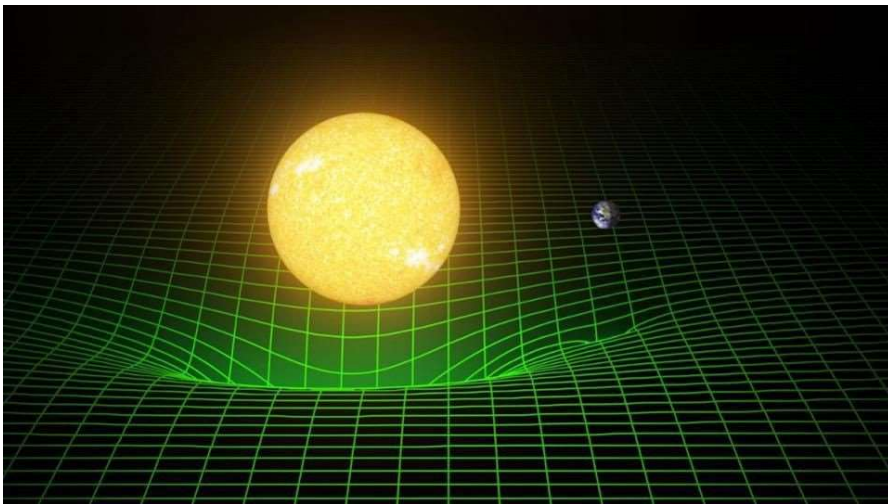


... 13.8 billion years ago

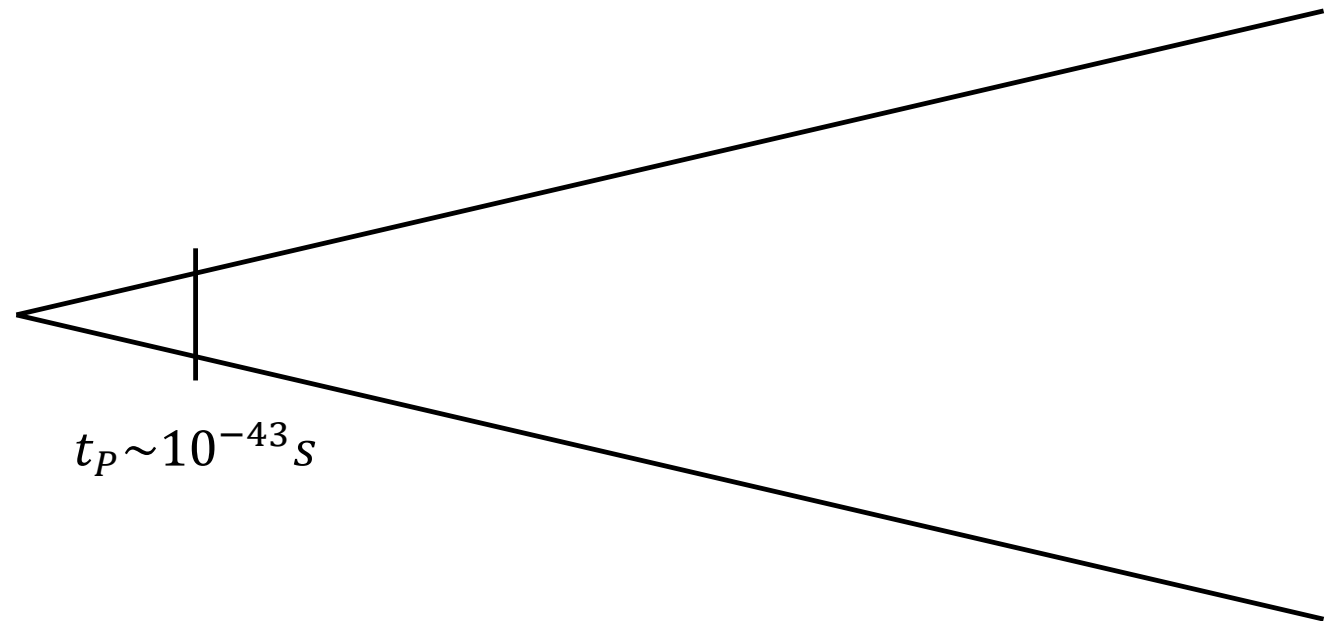
Energy – Mass

$$E = mc^2$$

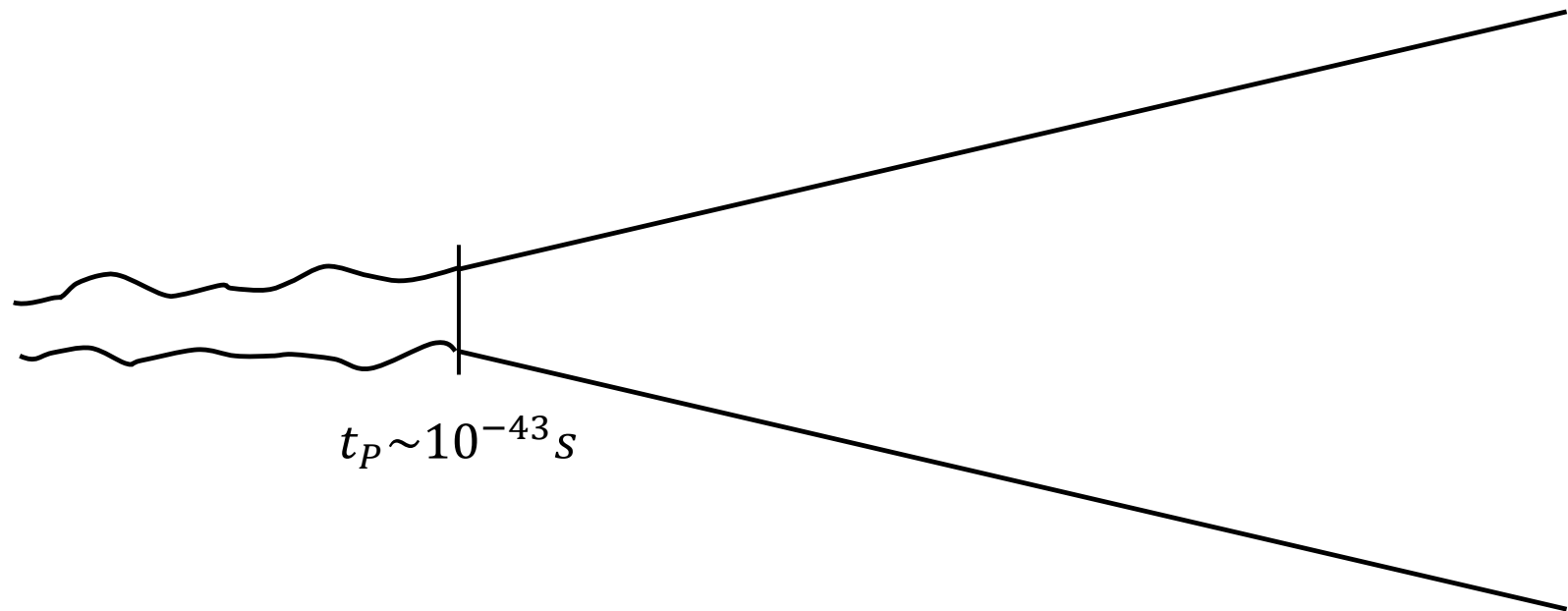
Once upon a spacetime...



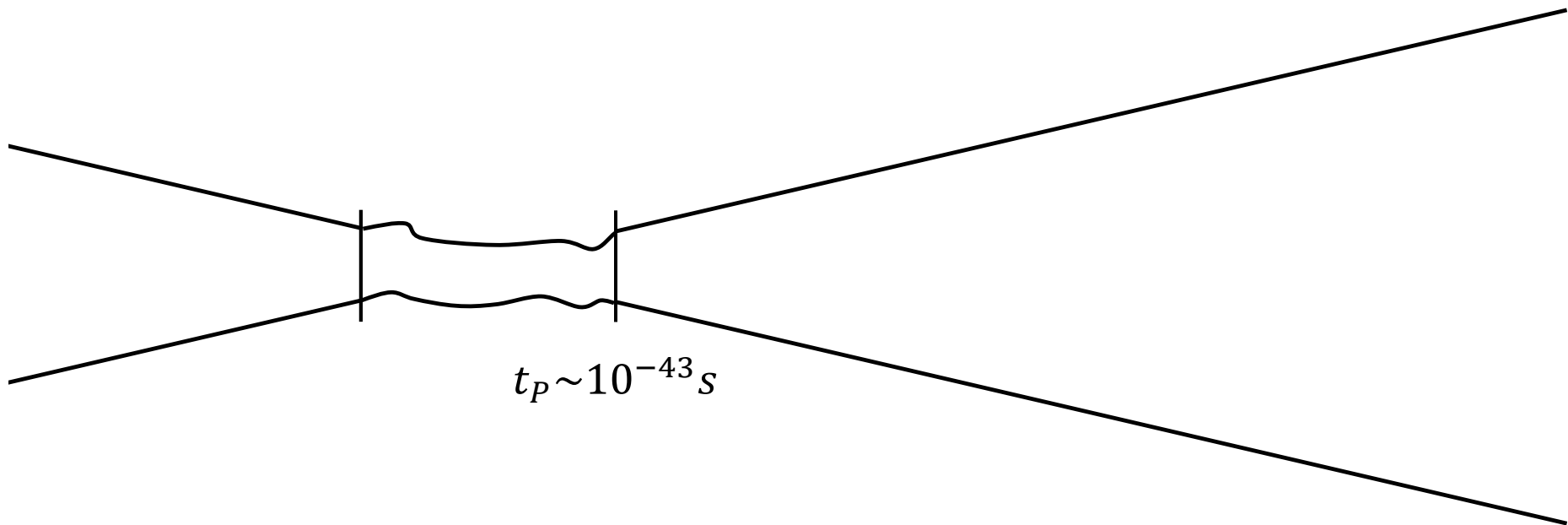
Once upon a spacetime...



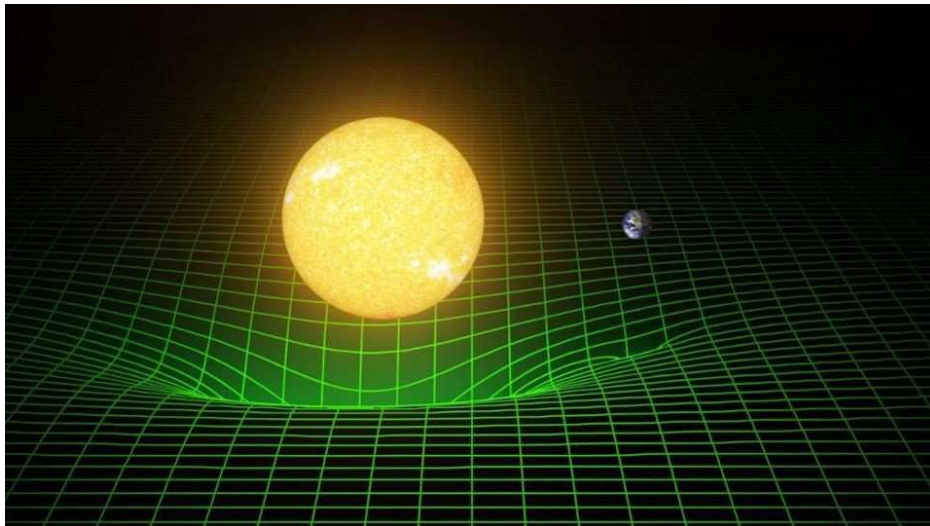
Once upon a spacetime...



Once upon a spacetime...



Once upon a spacetime...



Standard Model of Elementary Particles

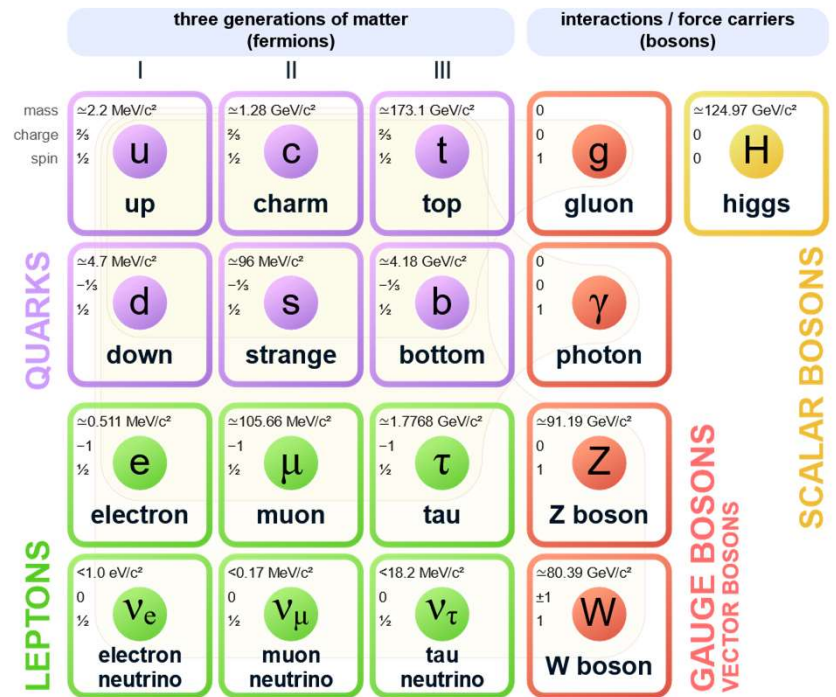
	three generations of matter (fermions)			interactions / force carriers (bosons)	
	I	II	III		
mass	$\approx 2.2 \text{ MeV}/c^2$	$\approx 1.28 \text{ GeV}/c^2$	$\approx 173.1 \text{ GeV}/c^2$	0	$\approx 124.97 \text{ GeV}/c^2$
charge	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0	0
spin	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	0
	u up	c charm	t top	g gluon	H higgs
	d down	s strange	b bottom	γ photon	
	e electron	μ muon	τ tau	Z Z boson	
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	

QUARKS (purple text)
LEPTONS (green text)
GAUGE BOSONS VECTOR BOSONS (red text)
SCALAR BOSONS (yellow text)

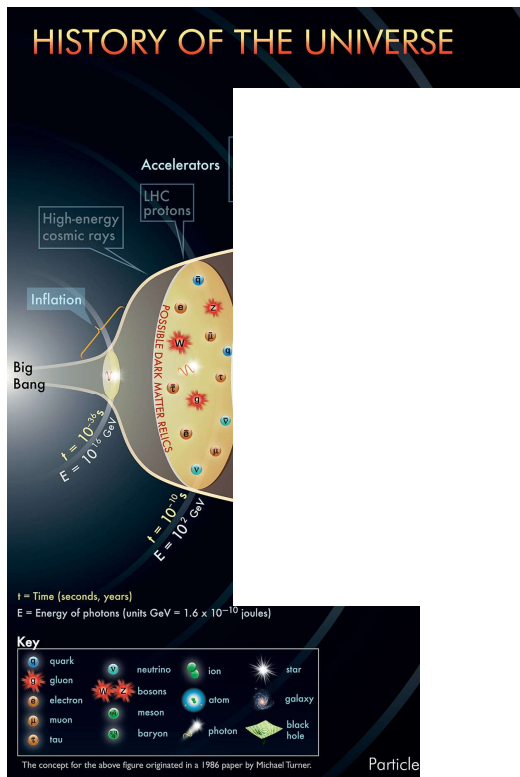
Once upon a spacetime...

Forces:
 Strong
 Electromagnetic
 Weak
 Gravitational

Standard Model of Elementary Particles

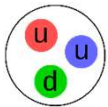


Once upon a spacetime...

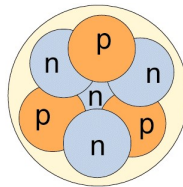
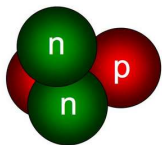
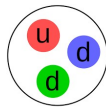


Nucleosynthesis

Proton



Neutron



Periodic Table of the Elements

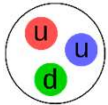
1 H Hydrogen 1.01	2 He Helium 4.00																
3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P 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 [209]	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

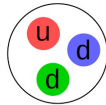
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Nucleosynthesis

Proton

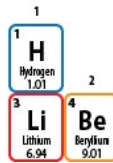


Neutron



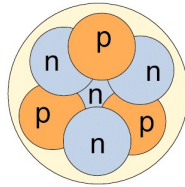
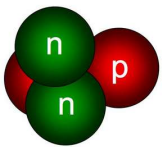
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75%



Periodic Table of the Elements

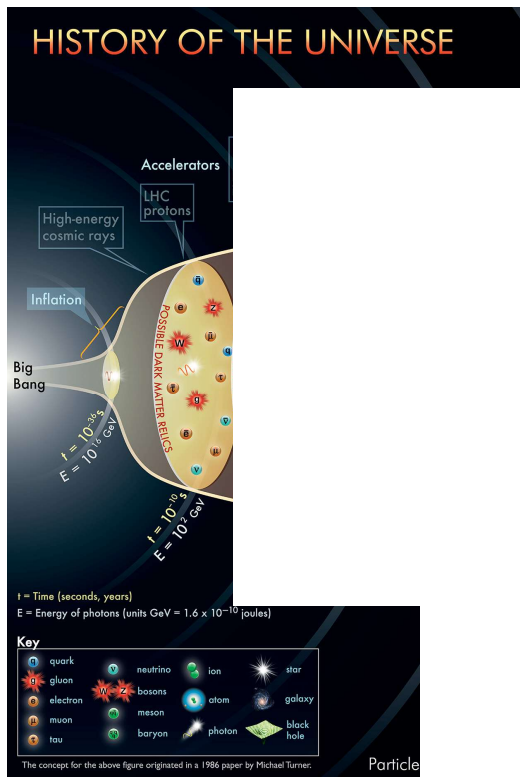
25%



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

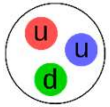
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Once upon a spacetime...

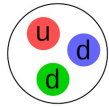


Photon decoupling

Proton



Neutron

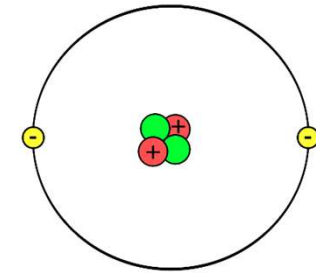
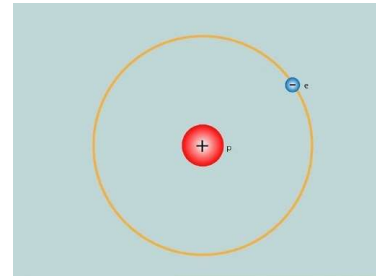
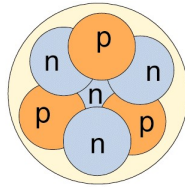
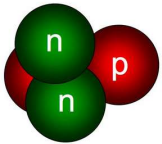


• • •

1 H Hydrogen 1.01	2 He Helium 4.00
3 Li Lithium 6.94	4 Be Beryllium 9.01

Periodic Table of the Elements

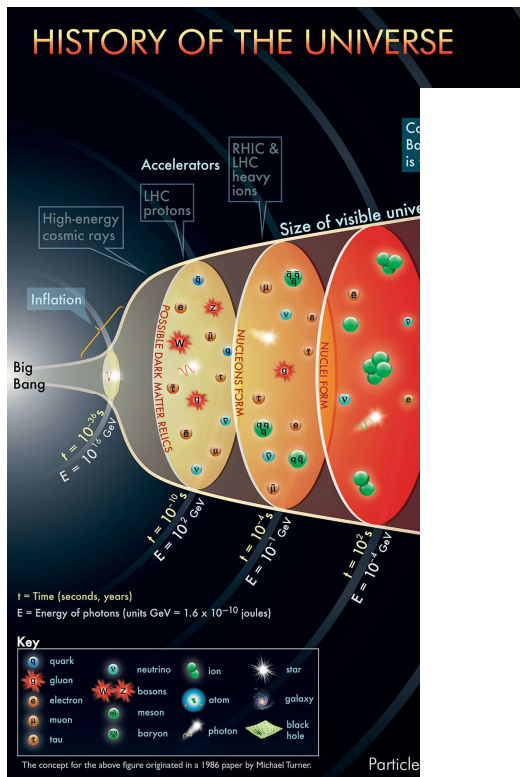
18 He Helium 4.00



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

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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 1st at midnight, and right now is midnight 1 year later

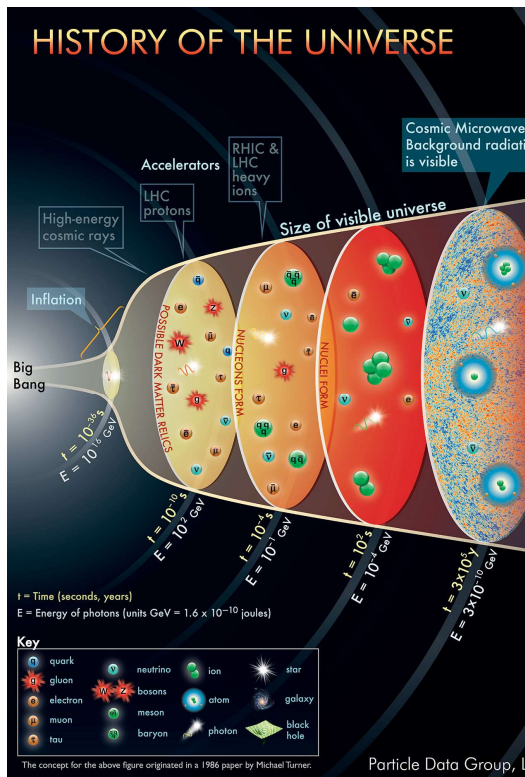
January	February	March	April	May	June	July	August	September	October	November	December
[Empty calendar grid]											



15 mins

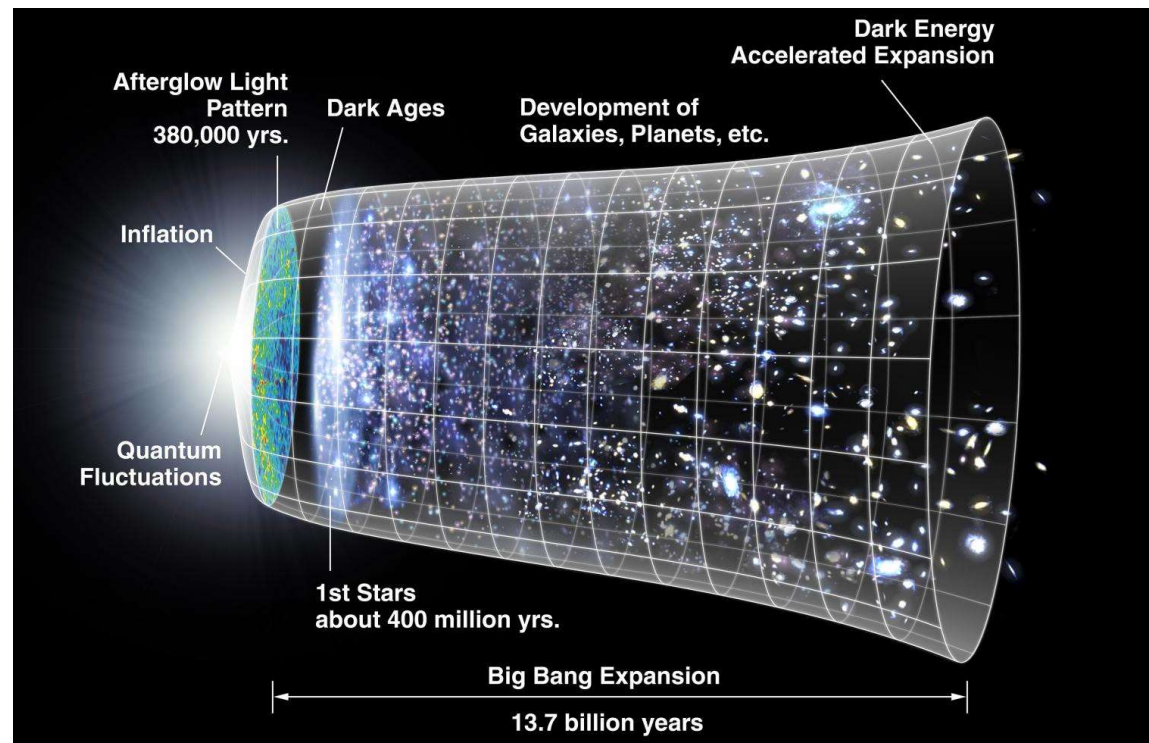
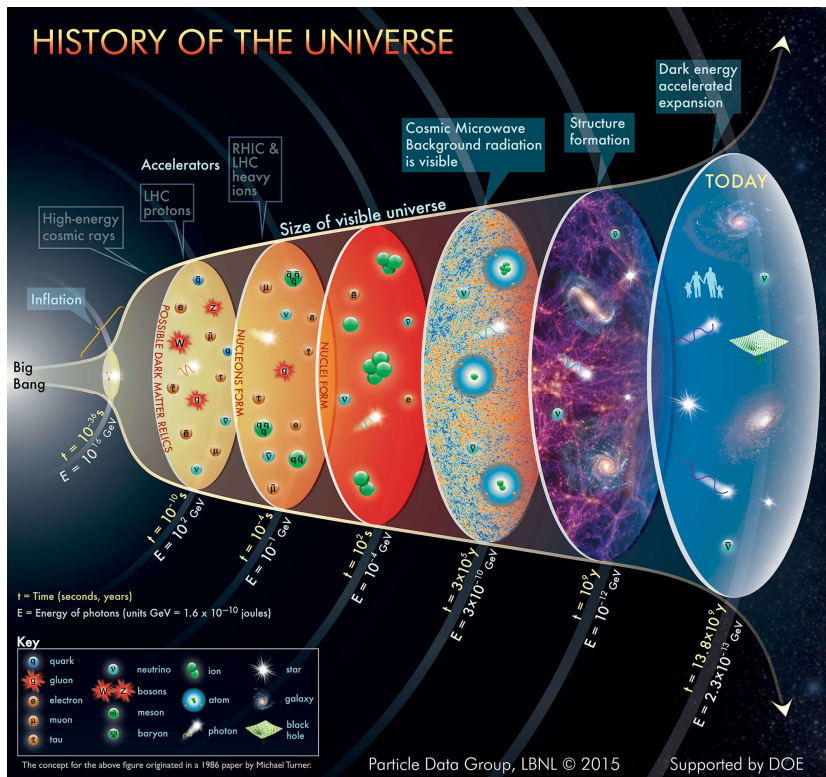
380,000 years

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 1st at midnight, and right now is midnight 1 year later



January 11th
470 million years

Summary

Big bang

Spacetime

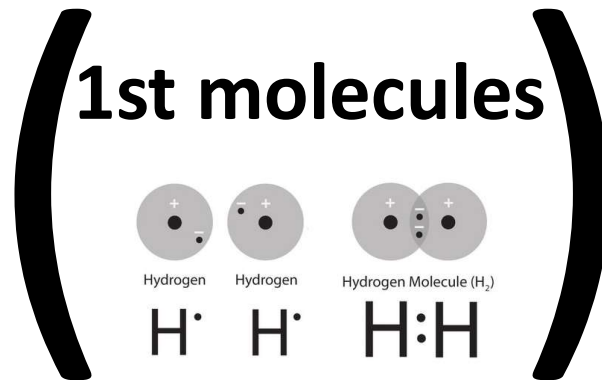
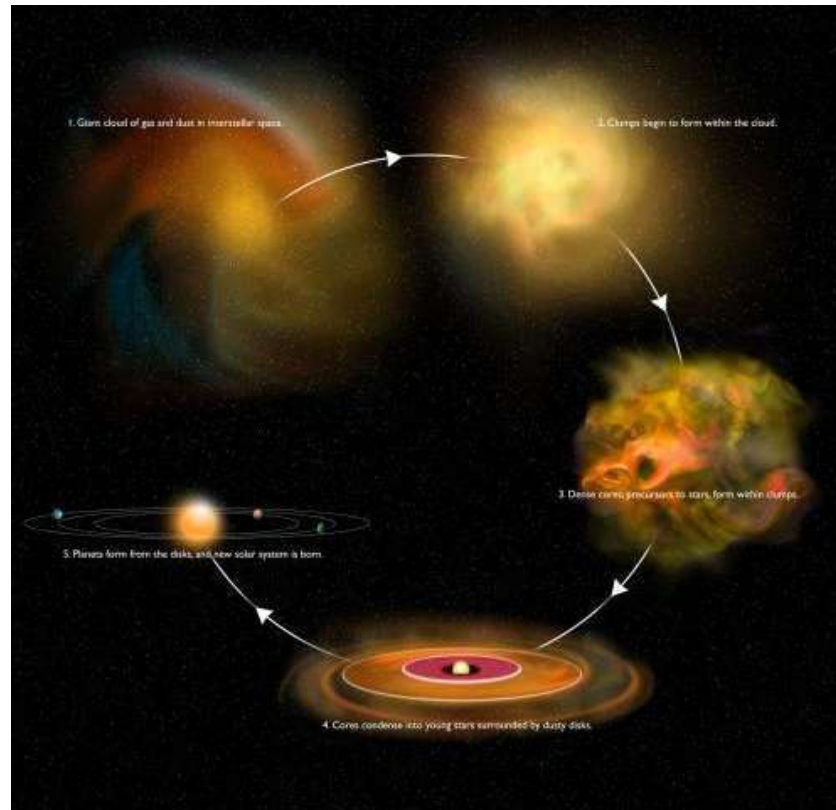
Particles

Nucleons

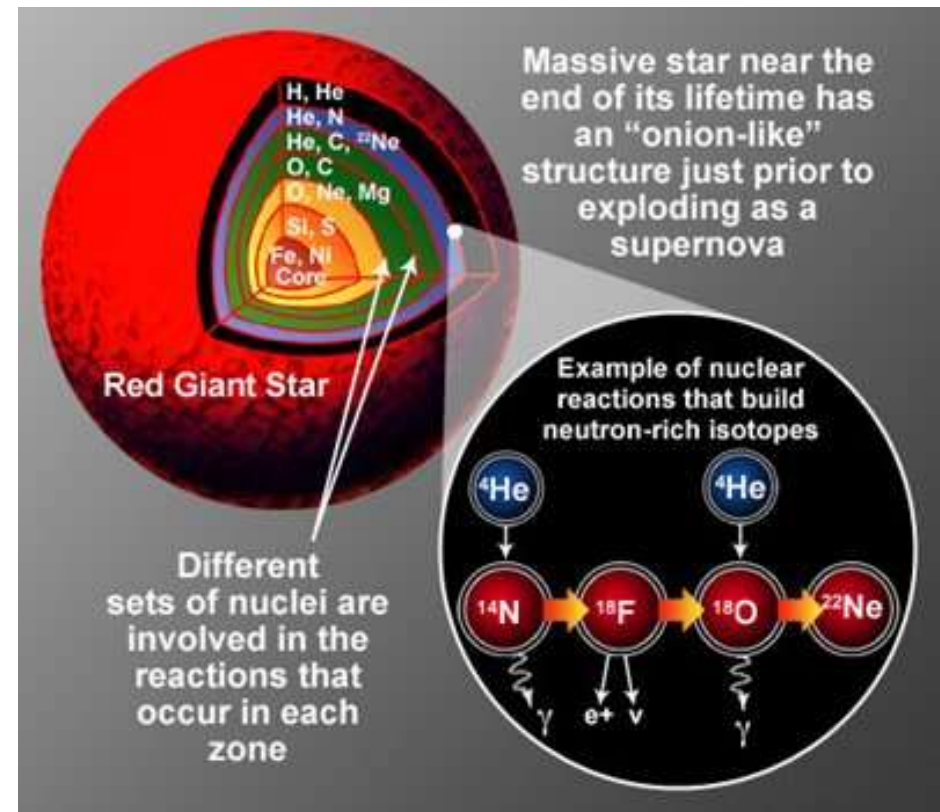
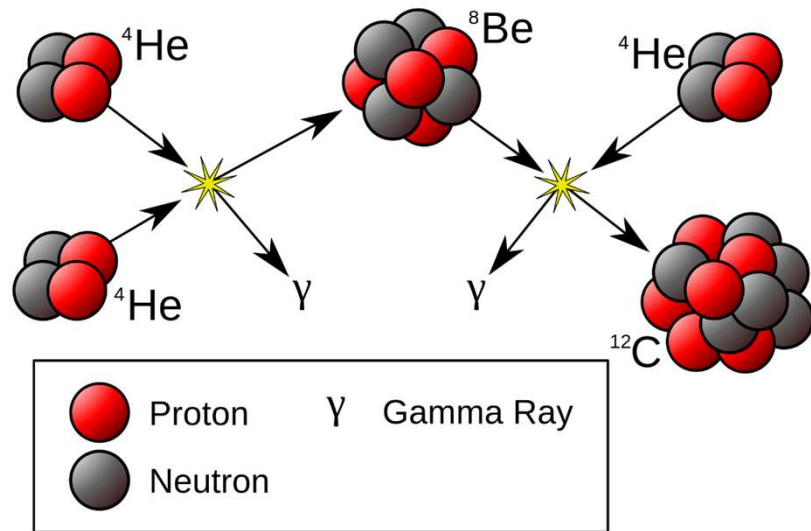
Nucleus (light)

Atoms

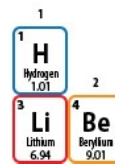
Twinkle twinkle...



Twinkle twinkle...



Nucleosynthesis



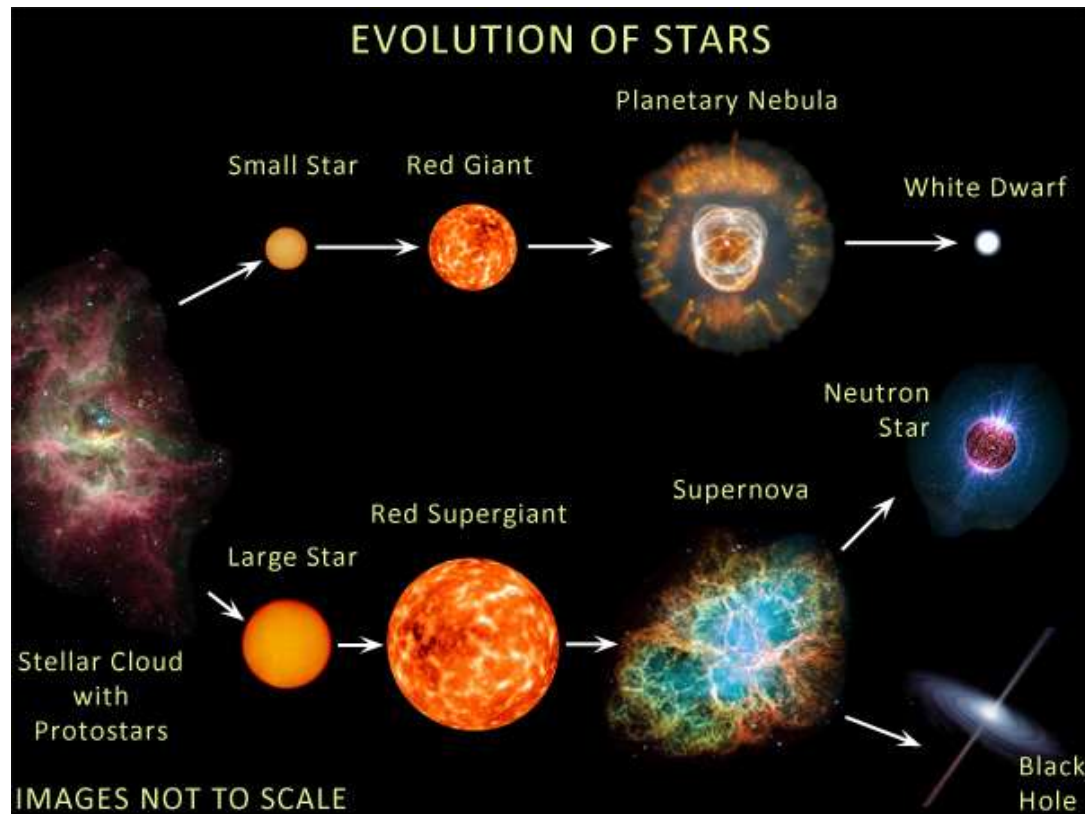
Periodic Table of the Elements



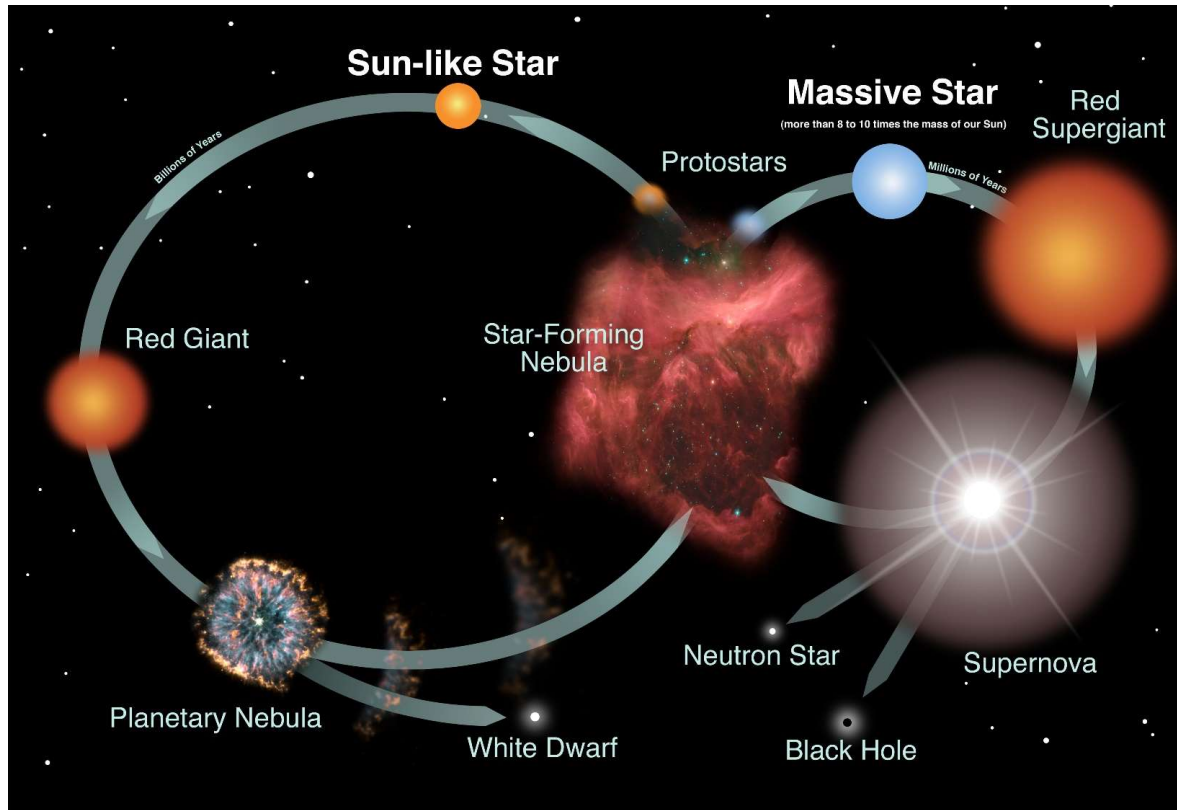
Alkali Metal Alkaline Earth Transition Metal Basic Metal Metalloid Nonmetal Halogen Noble Gas Lanthanide Actinide

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Twinkle twinkle...

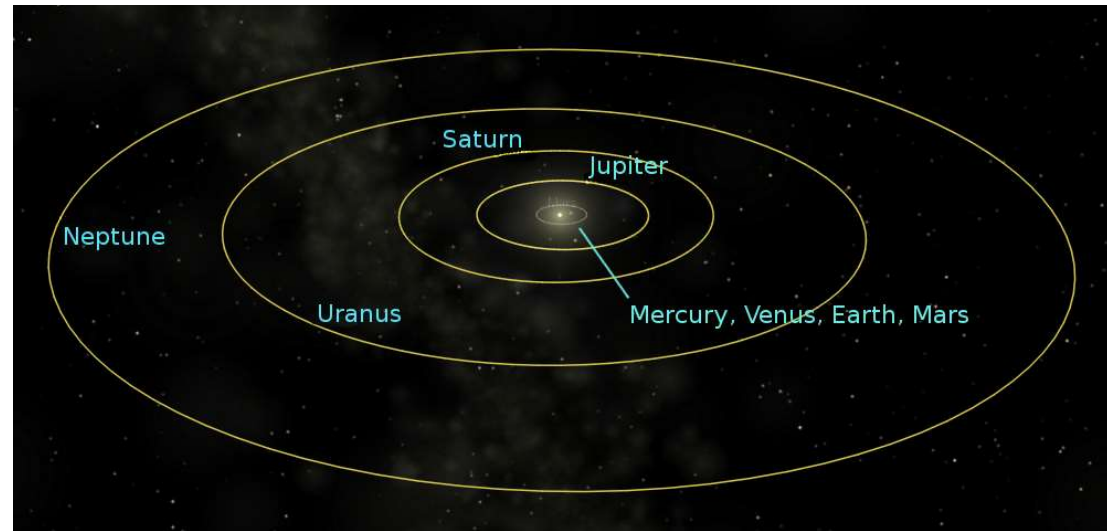
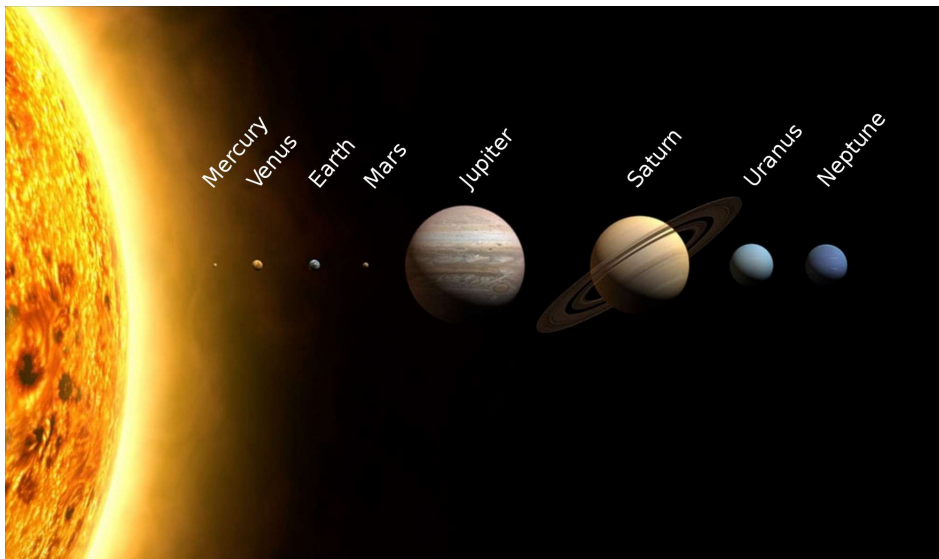


Twinkle twinkle...



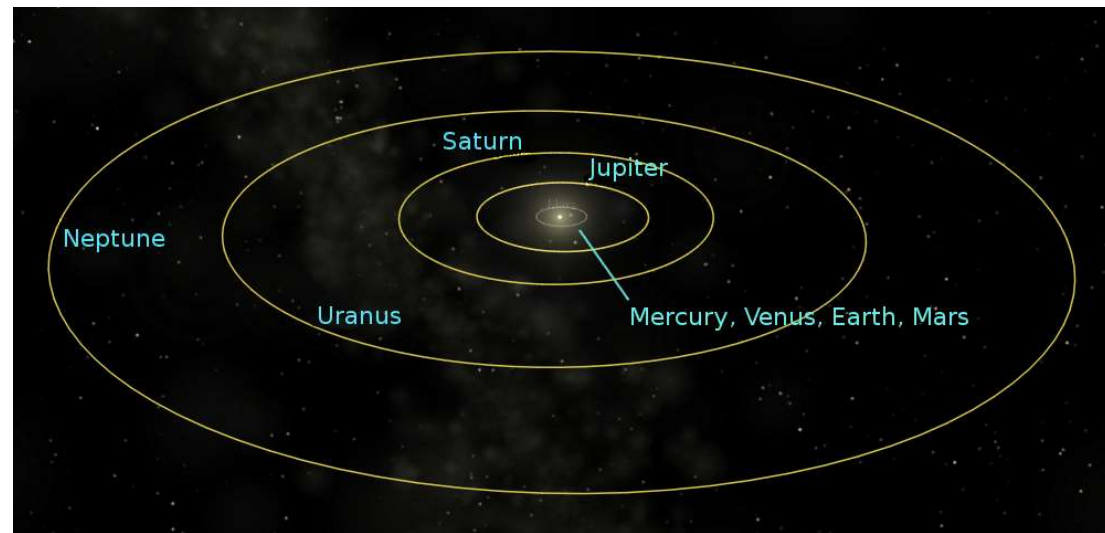
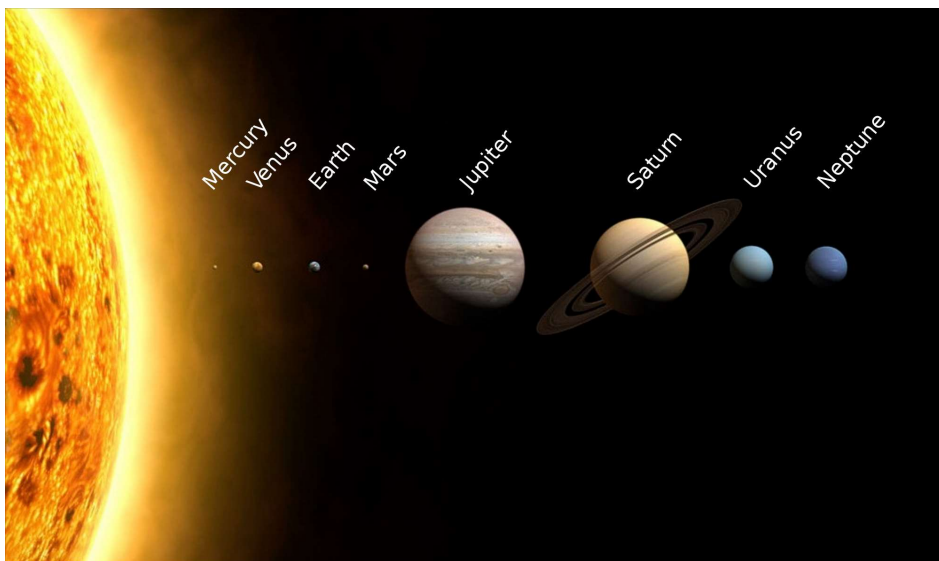
1st cycle

Solar system



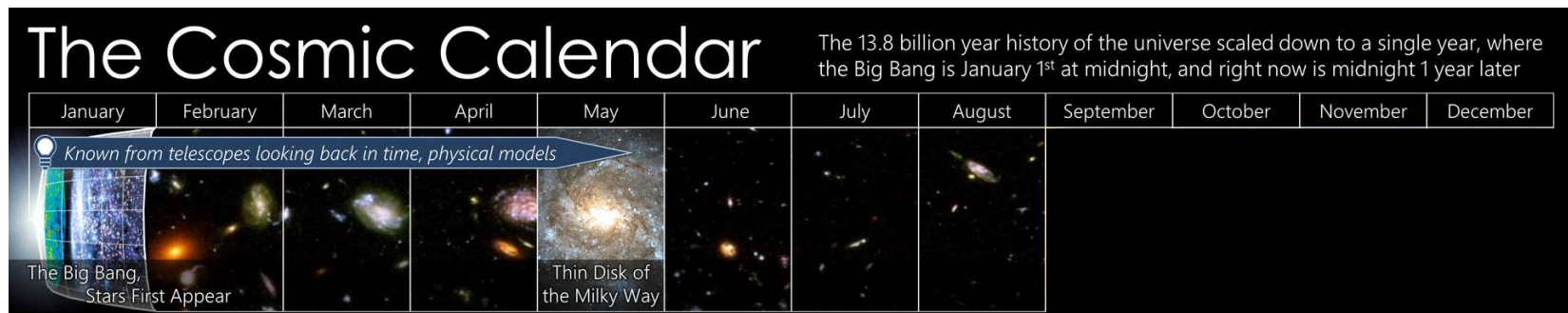
Our star is at least a 2nd generation star

Solar system



Cycle: solar year

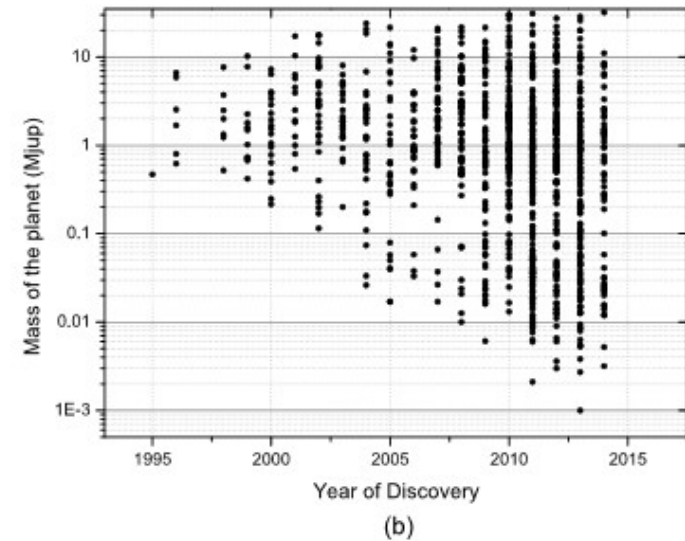
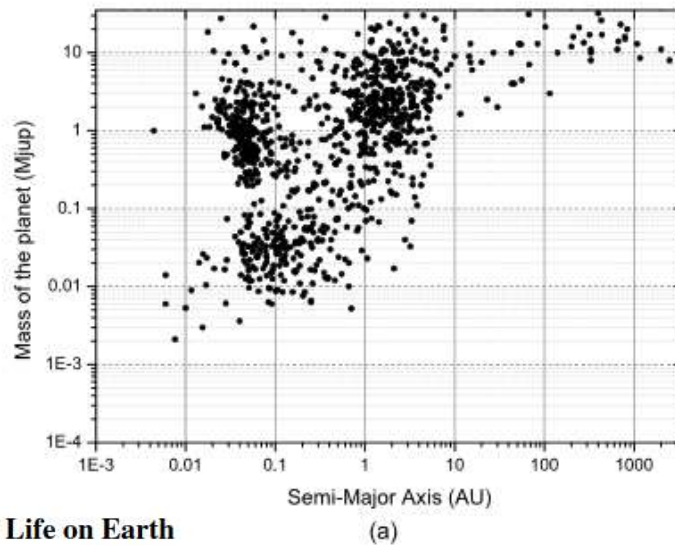
Solar system



↑
Last days of august
4.7 billion years ago

Planets

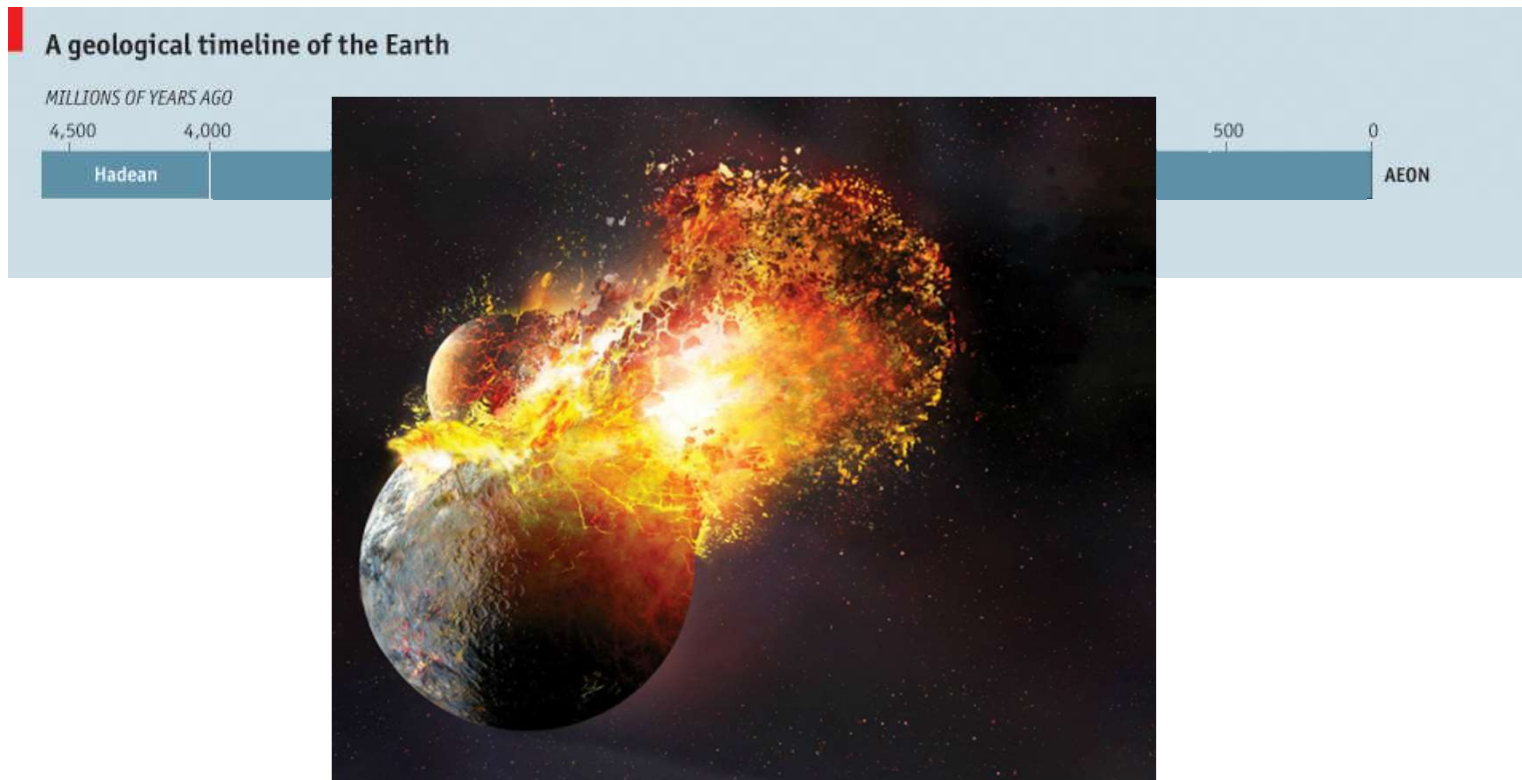
Fig. 2 Exoplanets discovered around other stars (as of July 2014). Planetary mass as a function of (a) the distance to the host star (semi-major axis in astronomical units) and (b) year of discovery. Most of them, especially those discovered until the end of the first decade of the 21st century, were giant planets, orbiting close to their host star (source exoplanet.eu). For reference, the mass of the Earth is $3.15 \times 10^{-3} M_{\text{jup}}$



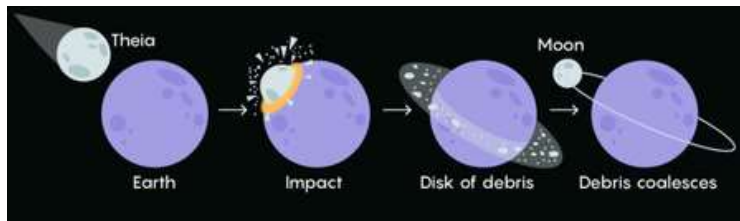
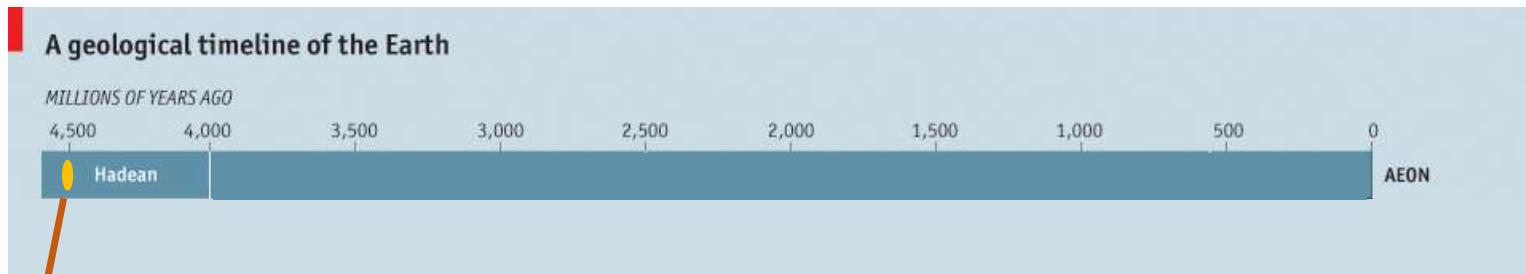
Astrobiology and the Possibility of Life on Earth and Elsewhere...

Hervé Cottin¹ · Julia Michelle Kotler^{2,3} · Kristin Bartik⁴ · H. James Cleaves II^{5,6,7,8} · Charles S. Cockell⁹ · Jean-Pierre P. de Vera¹⁰ · Pascale Ehrenfreund¹¹ · Stefan Leuko¹² · Inge Loes Ten Kate¹³ · Zita Martins¹⁴ · Robert Pascal¹⁵ · Richard Quinn¹⁶ · Petra Rettberg¹² · Frances Westall¹⁷

Hadean



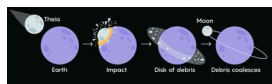
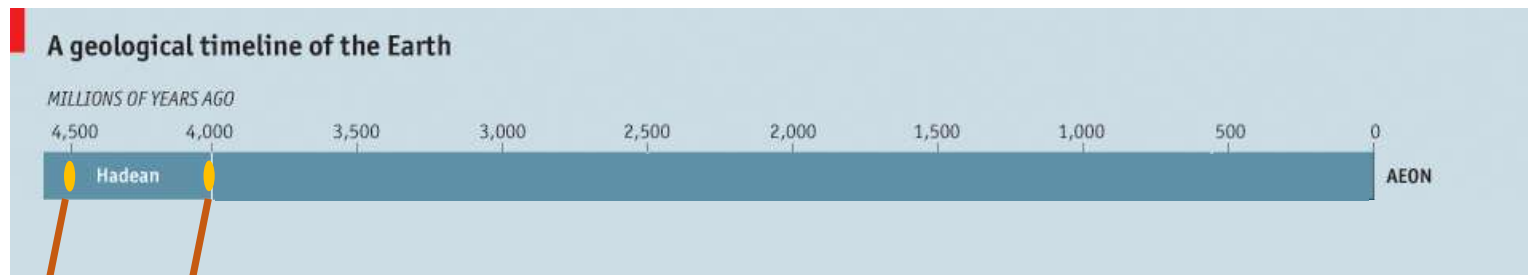
Hadean



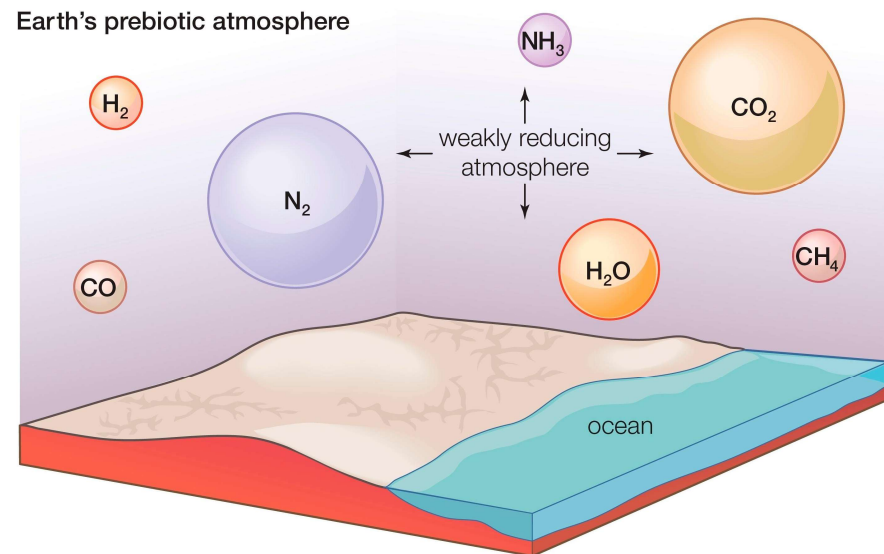
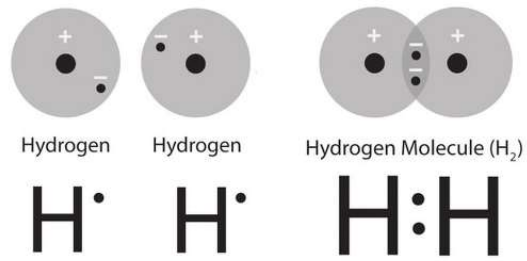
Cycle: lunar month

Cycle: 1 day = 12/21 hours

Hadean



Molecules



Elemental composition of the Earth



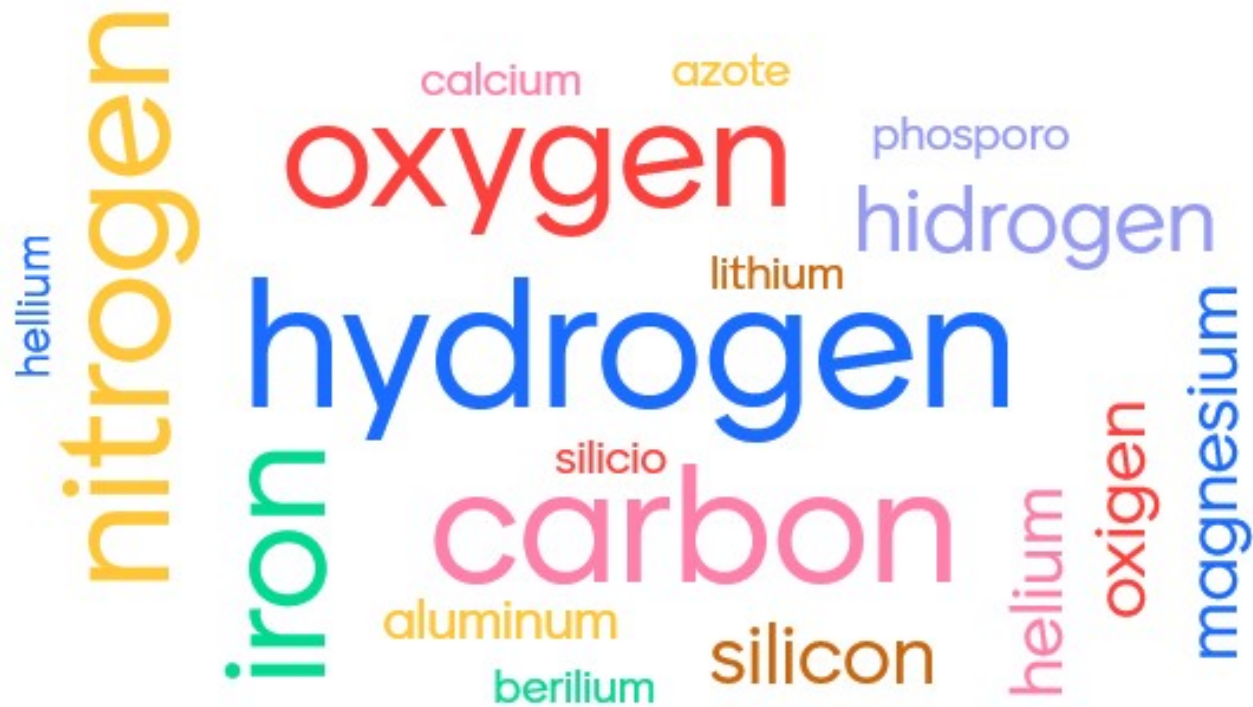
Periodic Table of the Elements

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 84.90
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 [209]	85 At Astatine [209]	86 Rn Radon [222]
87 Fr Francium [223]	88 Ra Radium [226]	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]			

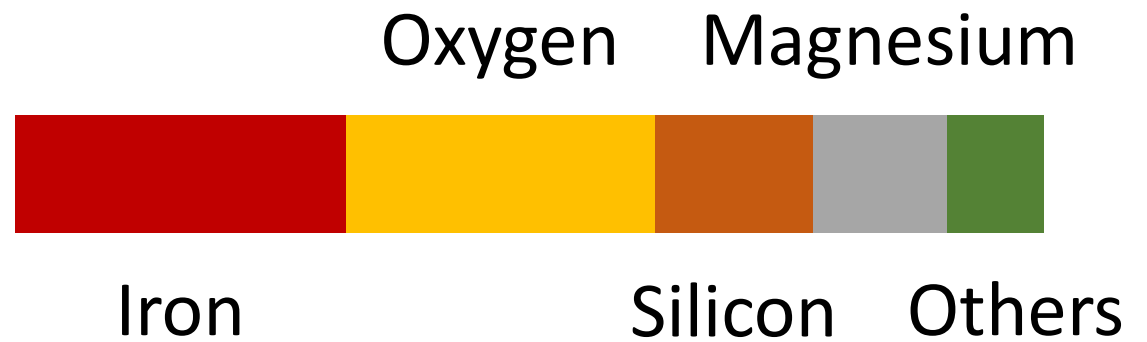
Alkali Metal
Alkaline Earth
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Semetal
Halogen
Noble Gas
Lanthanide
Actinide

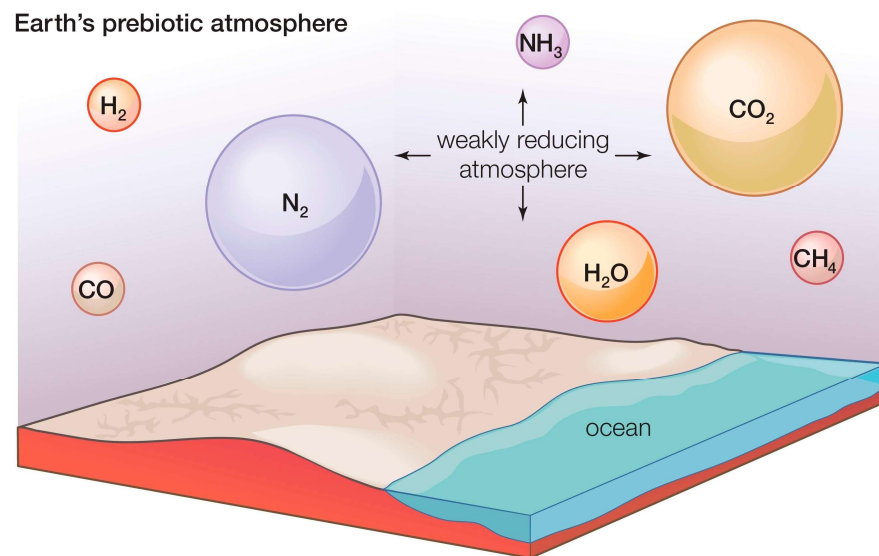
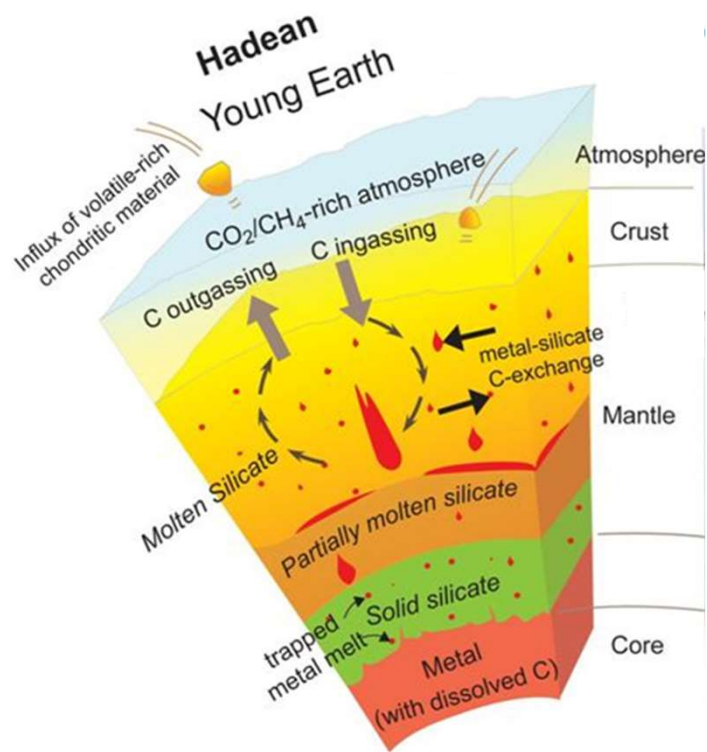
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Internet poll results



Elemental composition of the Earth





The Lithosphere

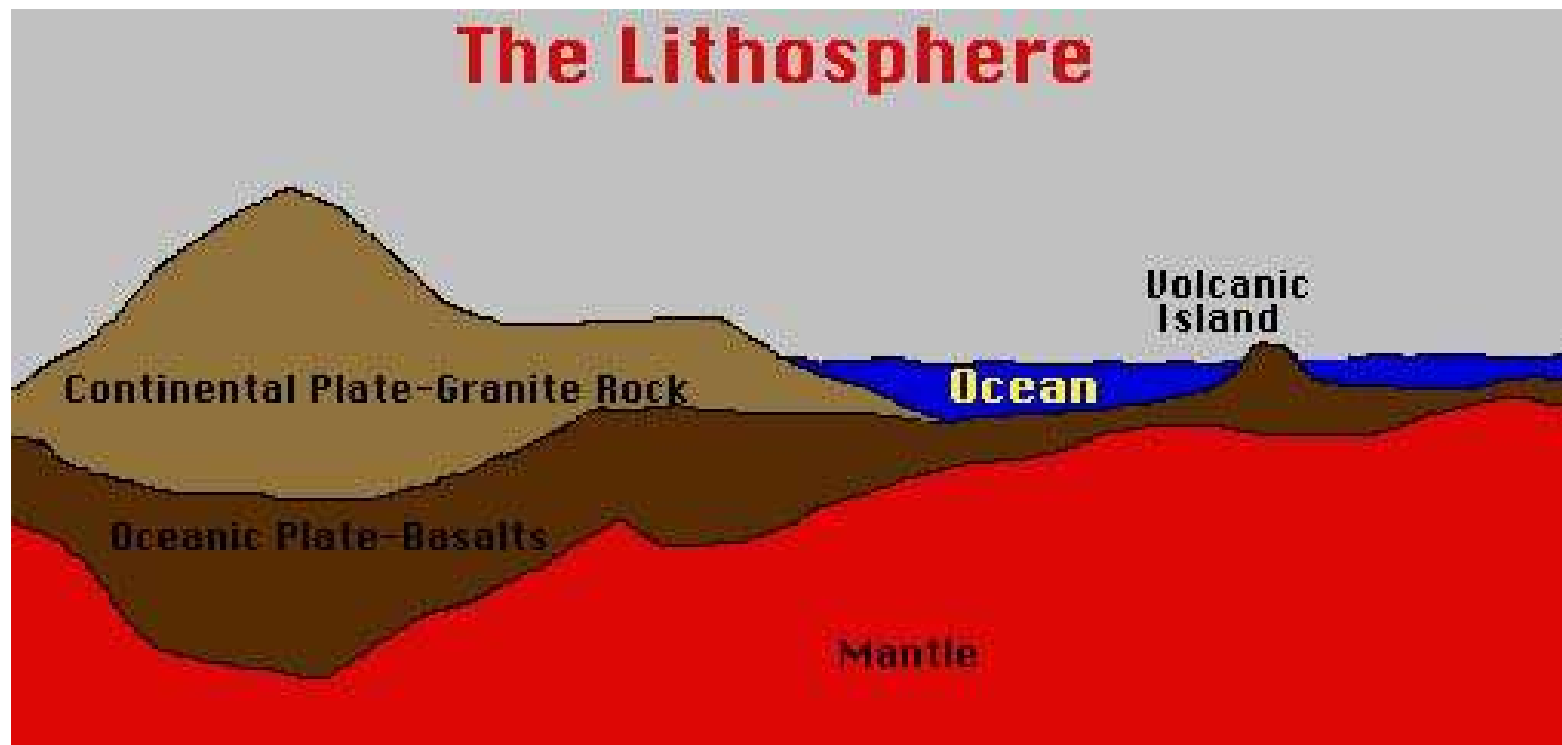
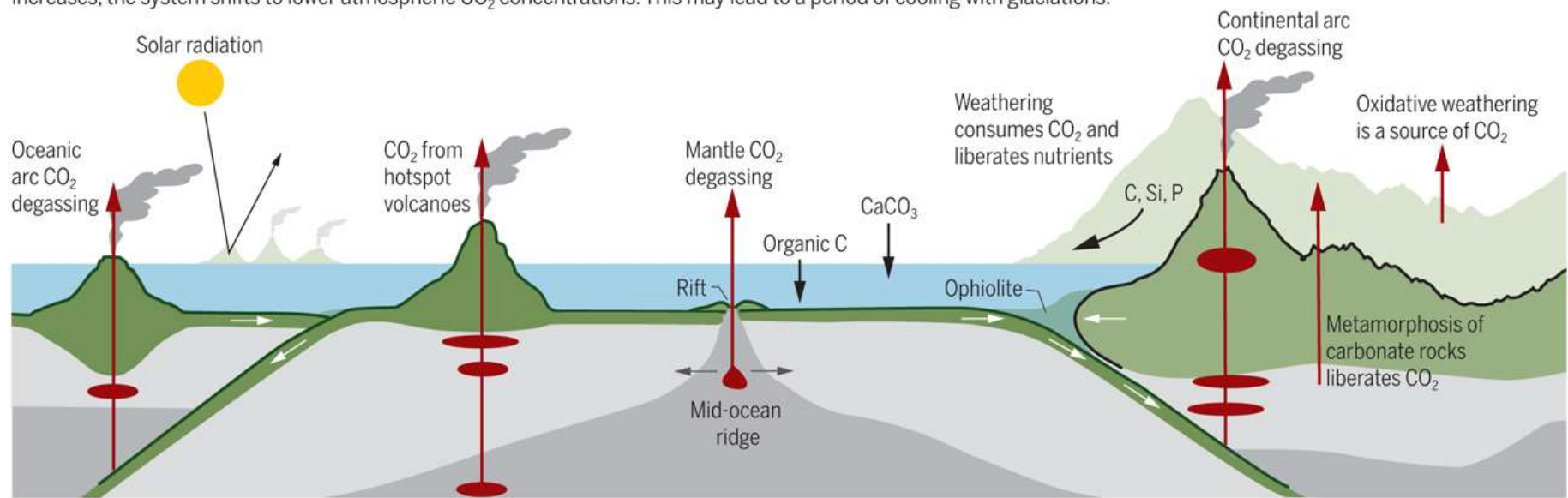


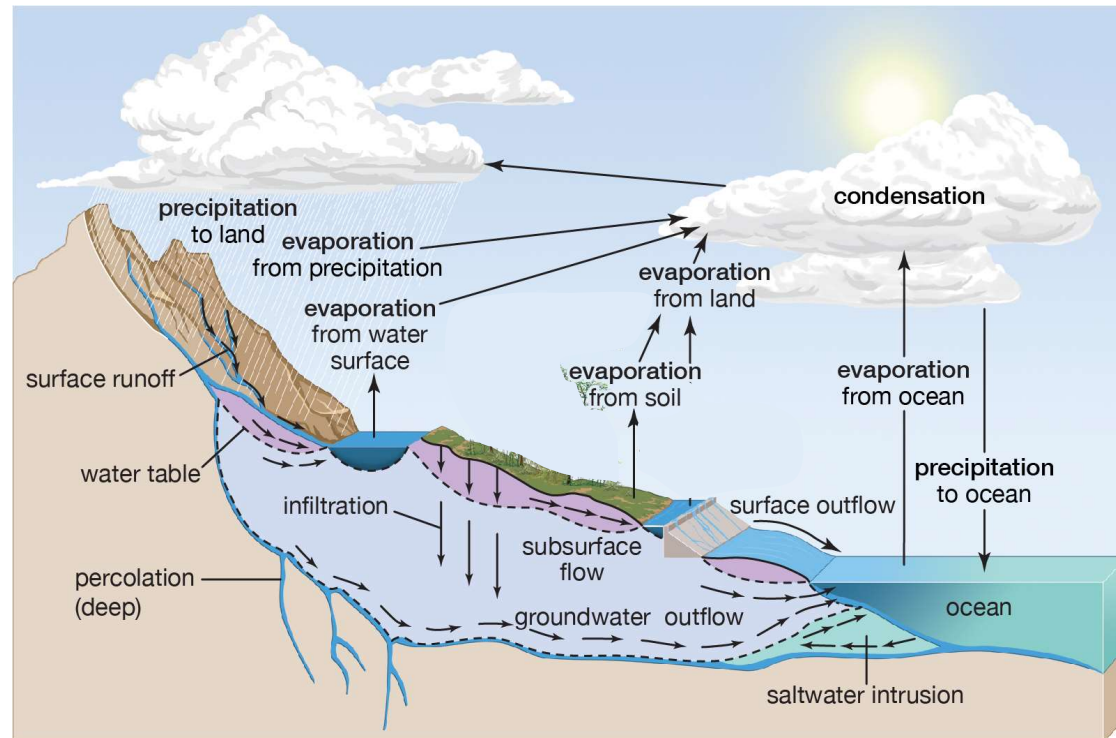
Plate tectonics

Geological sources and sinks of CO₂

Solar radiation, as well as the differences between sinks and sources of CO₂, contributes to the state of the climate. If a sink term, such as weathering of ophiolite complexes, increases, the system shifts to lower atmospheric CO₂ 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)

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Kits of building blocks

Standard Model of Elementary Particles

three generations of matter (fermions)			interactions / force carriers (bosons)		
	I	II	III		
mass	$\approx 2.2 \text{ MeV}/c^2$	$\approx 1.28 \text{ GeV}/c^2$	$\approx 173.1 \text{ GeV}/c^2$	0	$\approx 124.97 \text{ GeV}/c^2$
charge	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0	0
spin	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	0
	u up	c charm	t top	g gluon	H higgs
	d down	s strange	b bottom	γ photon	
	e electron	μ muon	τ tau	Z Z boson	
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	

QUARKS (left side of fermion table)

LEPTONS (left side of fermion table)

GAUGE BOSONS VECTOR BOSONS (left side of boson table)

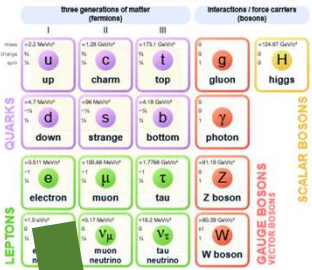
SCALAR BOSONS (right side of boson table)

Kits of building blocks

Nucleus

Atoms

Standard Model of Elementary Particles



Periodic Table of the Elements

The periodic table is color-coded by groups:

- Alkali Metal:** Group 1 (Li, Na, K, Rb, Cs, Fr)
- Alkaline Earth:** Group 2 (Be, Mg, Ca, Sr, Ba, Ra)
- Transition Metal:** Groups 3-10
- Basic Metal:** Groups 11-12
- Metalloid:** Groups 13-14
- Nonmetal:** Groups 15-16
- Halogens:** Group 17
- Noble Gas:** Group 18
- Lanthanide:** Groups 3-10 (bottom row)
- Actinide:** Groups 3-10 (bottom row)

Periodic Table of the Elements

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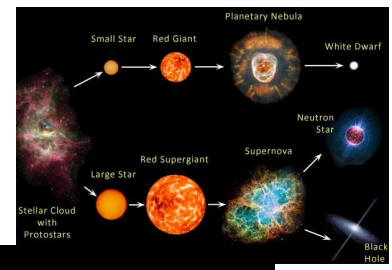
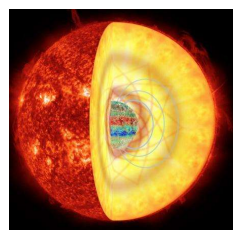
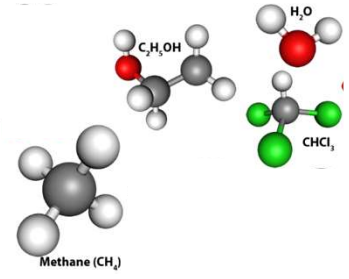
Kits of building blocks

Standard Model of Elementary Particles

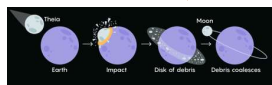
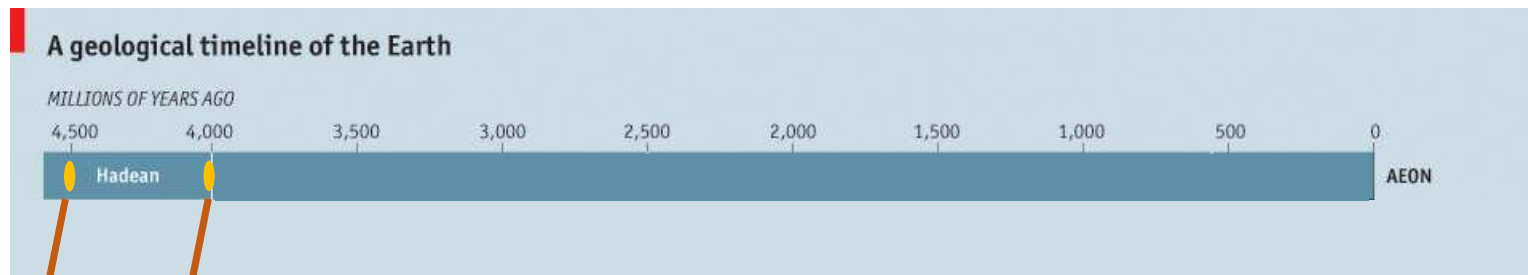
three generations of matter (fermions)			interactions / force carriers (bosons)	
I	II	III	I	II
$m = 2.2 \text{ MeV}/c^2$ u up	$m = 1.28 \text{ GeV}/c^2$ c charm	$m = 173.1 \text{ GeV}/c^2$ t top	g gluon	$m = 124.37 \text{ GeV}/c^2$ H higgs
$m = 4.7 \text{ MeV}/c^2$ d down	$m = 98 \text{ MeV}/c^2$ s strange	$m = 4.18 \text{ GeV}/c^2$ b bottom	\(\gamma\) photon	
$m = 0.511 \text{ MeV}/c^2$ e electron	$m = 105.66 \text{ MeV}/c^2$ \(\mu\) muon	$m = 1.7768 \text{ GeV}/c^2$ \(\tau\) tau	Z Z boson	
$m = 0.1 \text{ eV}/c^2$ \(\nu_e\) electron neutrino	$m = 0.17 \text{ MeV}/c^2$ \(\nu_\mu\) muon neutrino	$m = 1.82 \text{ MeV}/c^2$ \(\nu_\tau\) tau neutrino	W W boson	

QUARKS (left side of fermion table)
LEPTONS (left side of fermion table)
GAUGE BOSONS VECTOR BOSONS (left side of boson table)
SCALAR BOSONS (right side of boson table)

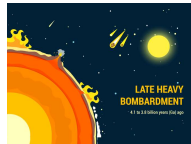
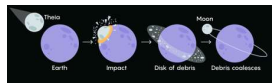
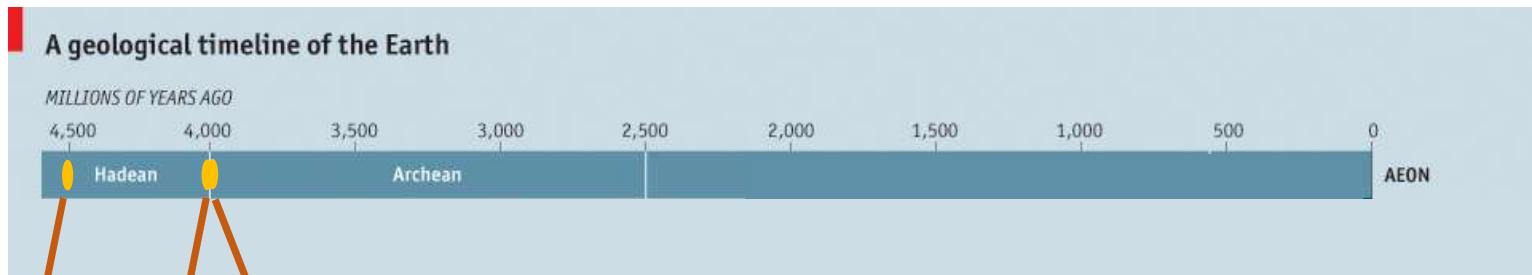
Periodic Table of the Elements



Hadean



Archean



Life

Natural selection

- Replication (with errors)
- Finite resources

Energy

+

Mass (building blocks)

Life

Evolution of life

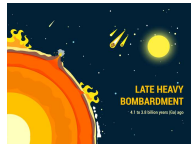
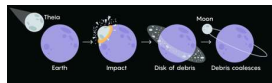
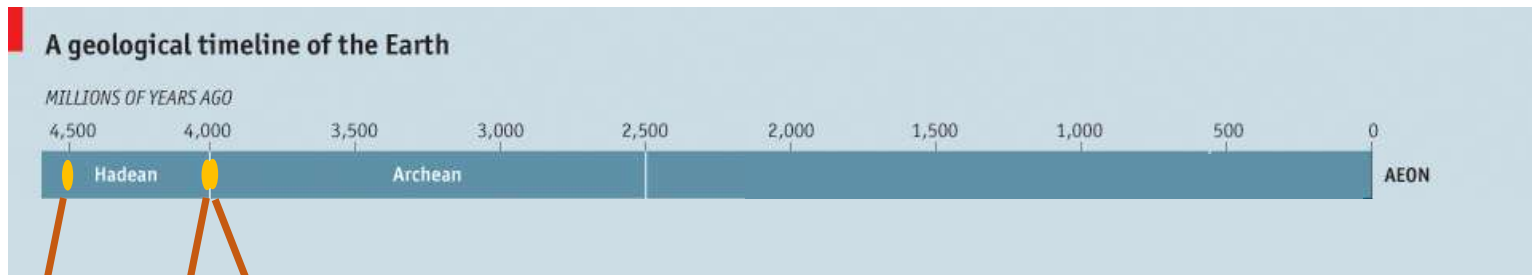
- Replication (with errors)
- Finite resources
- Metabolism

Energy

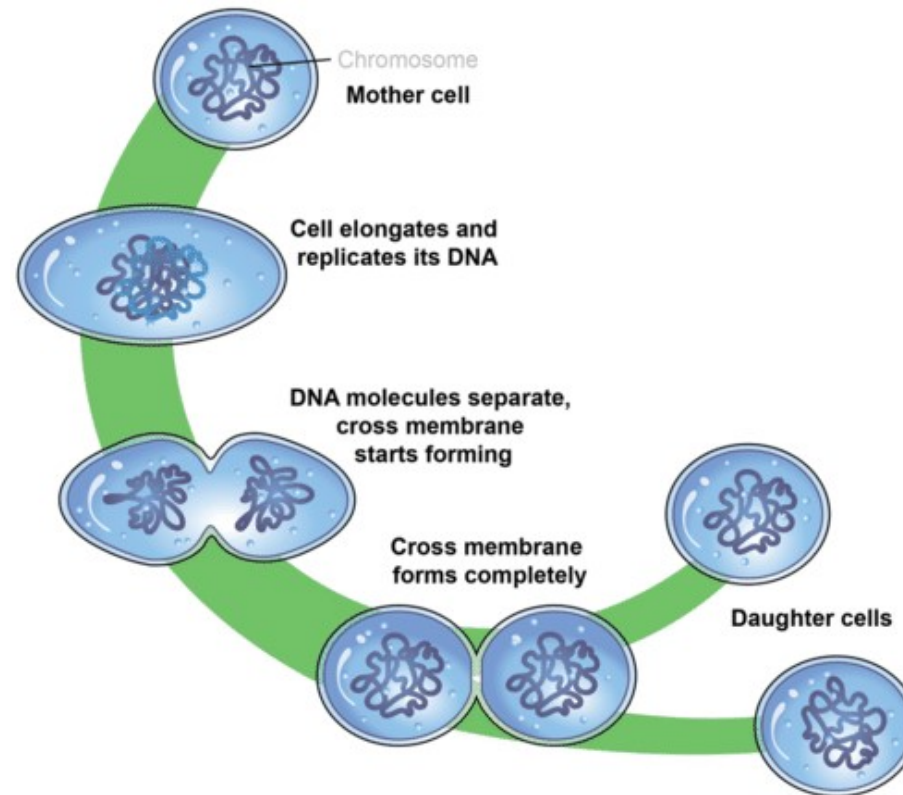
+

Mass (building blocks)

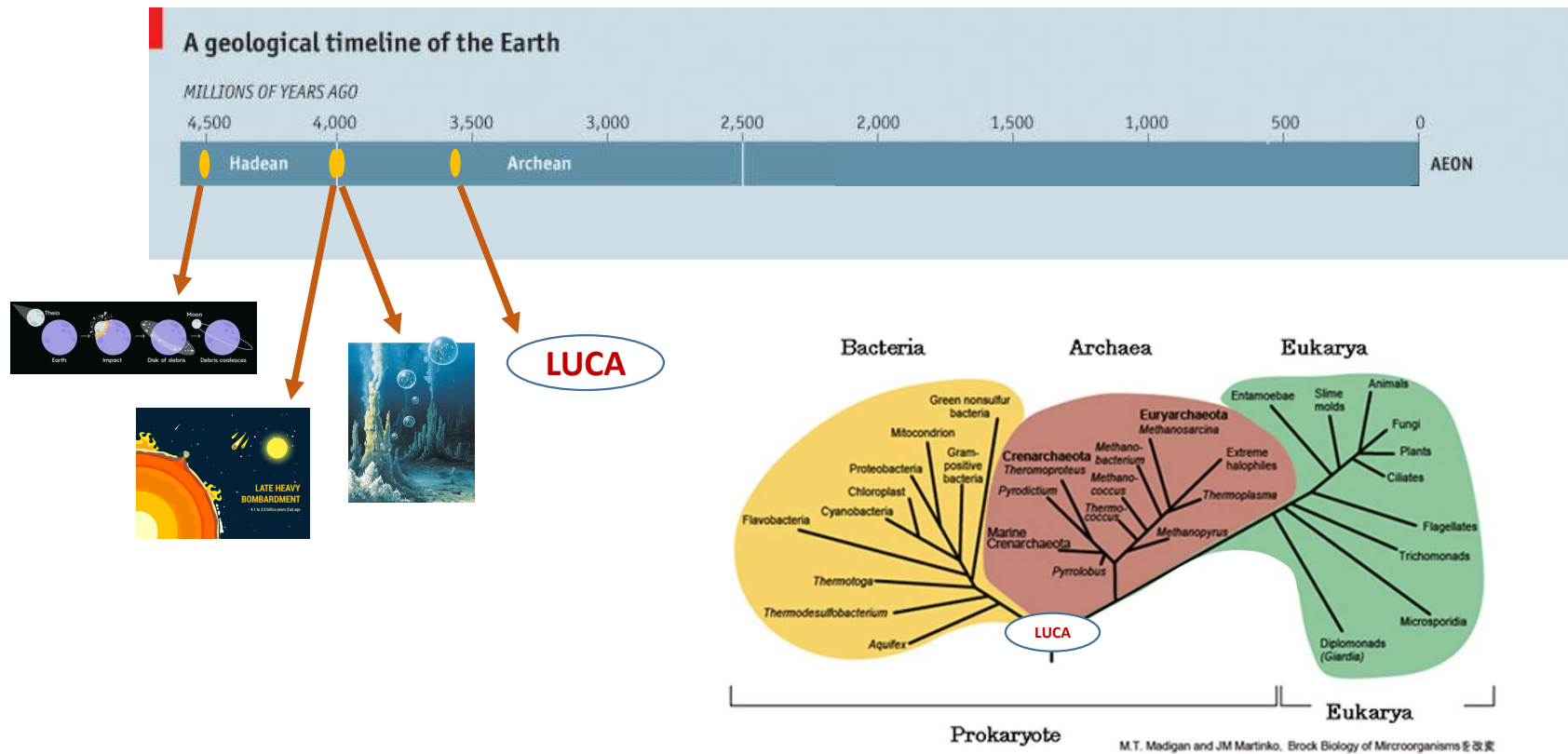
Archean



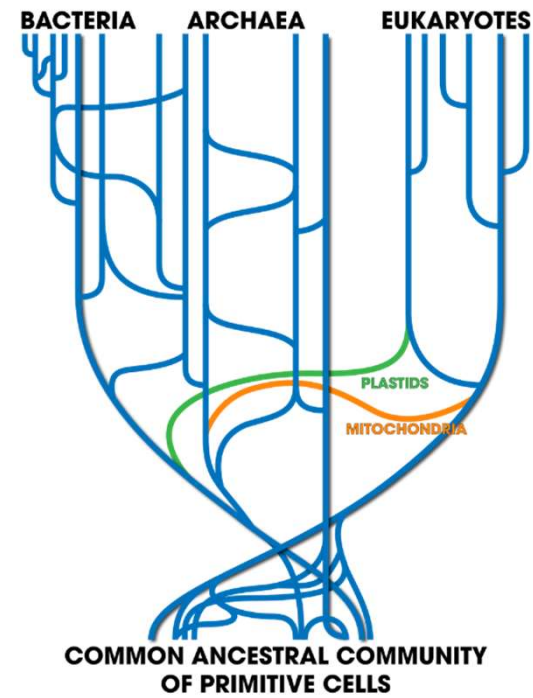
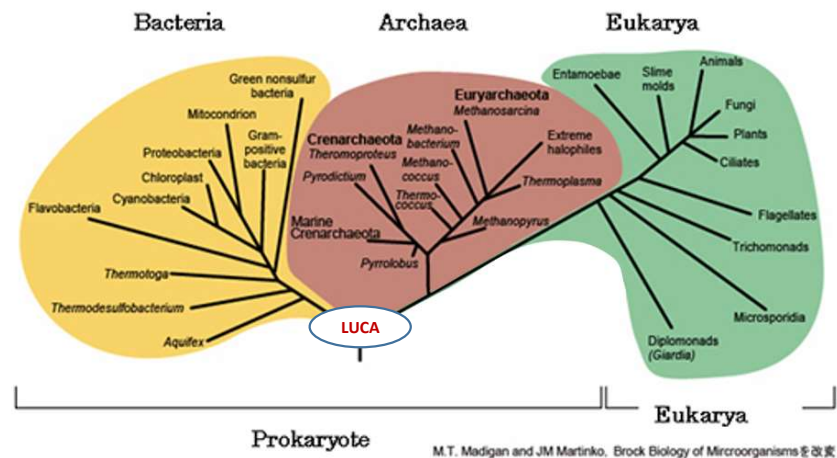
Life cycle



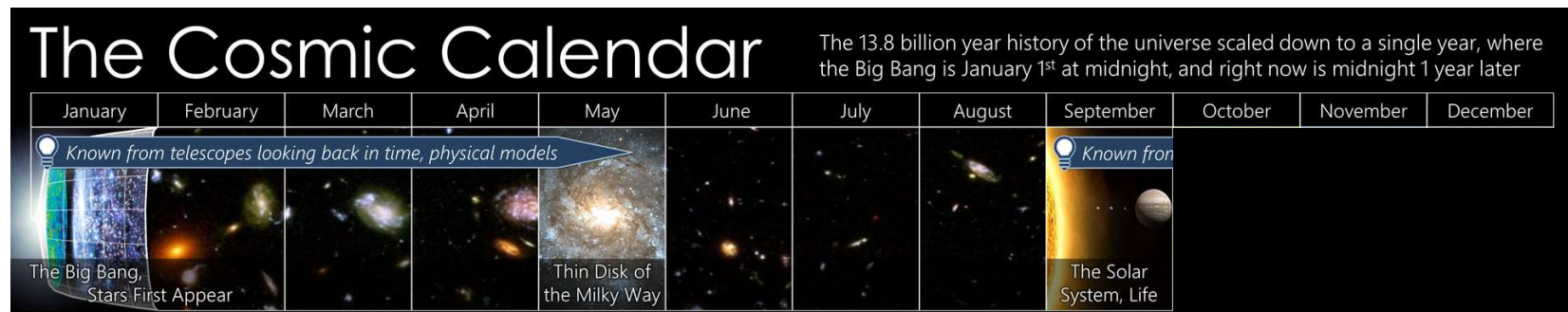
Archean



LUCA

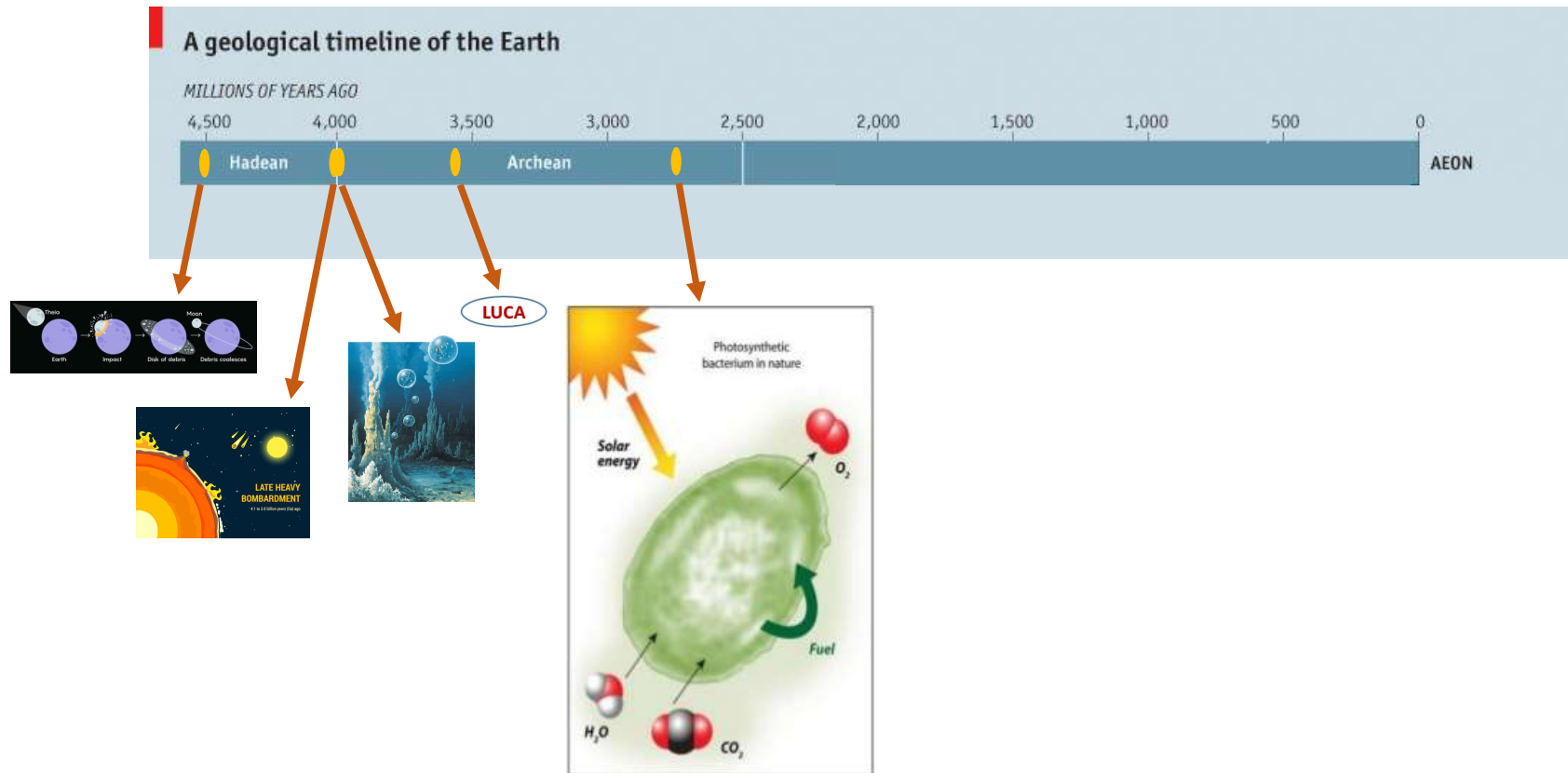


LUCA

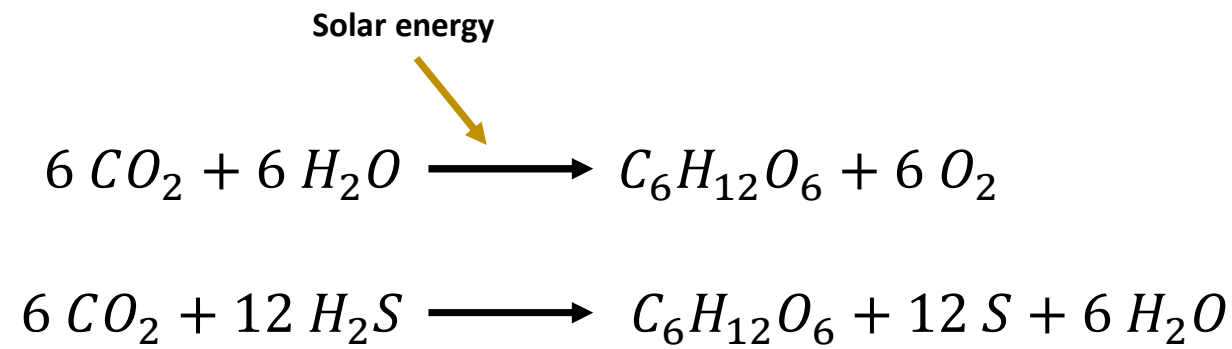
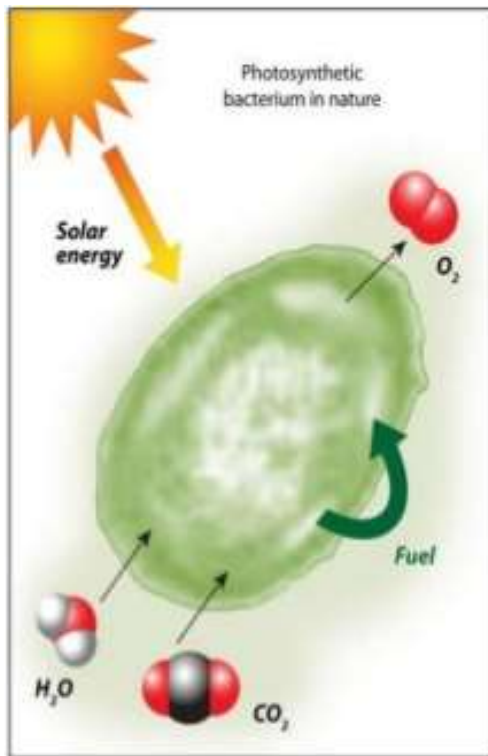


Last week of September
3.7 billion years ago

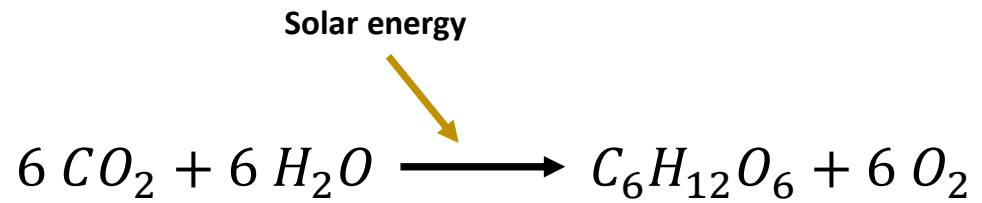
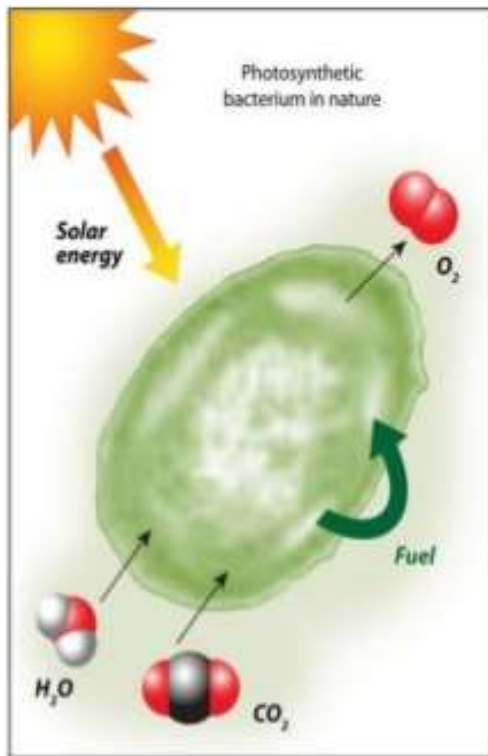
Archean



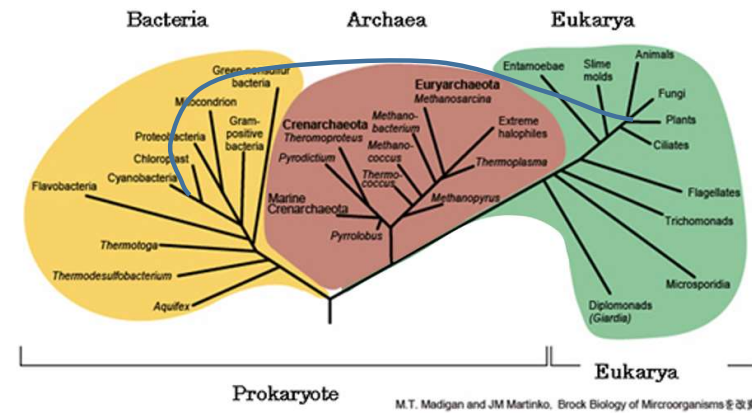
Photosynthesis



Photosynthesis

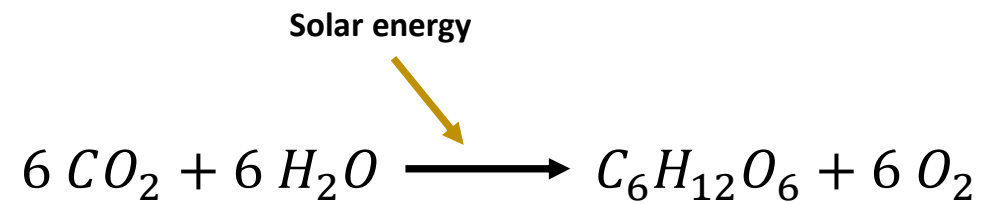
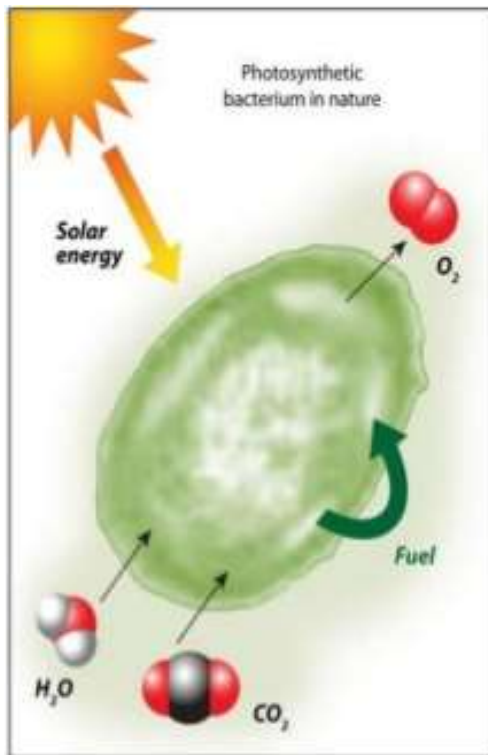


- Not plants!



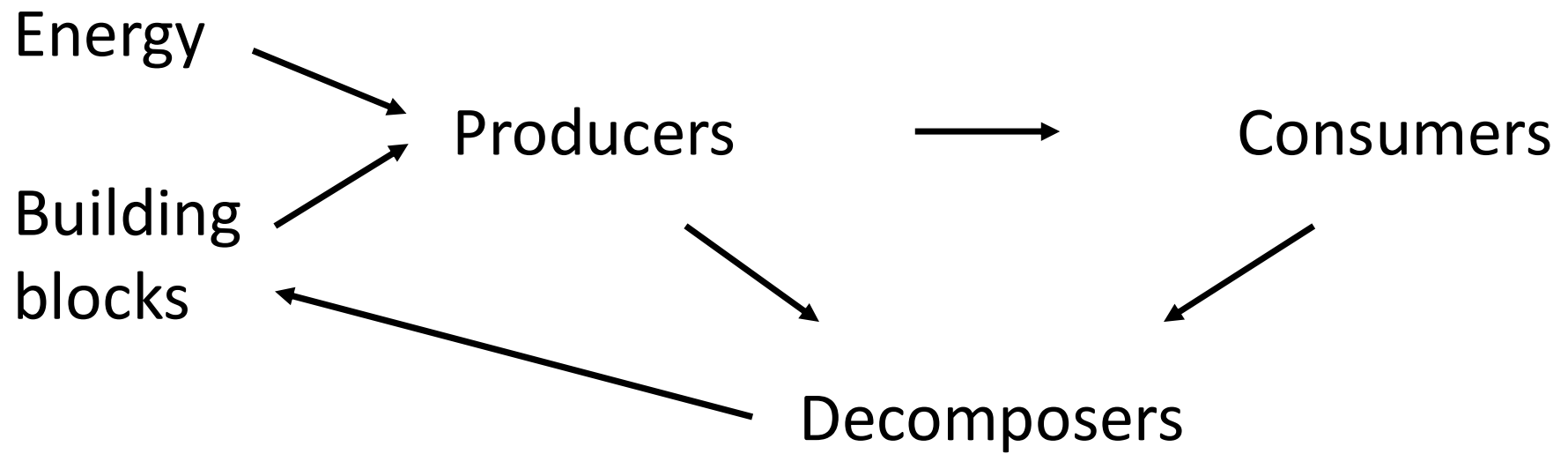
M.T. Madigan and JM Martinko, Brock Biology of Microorganisms 11e

Photosynthesis

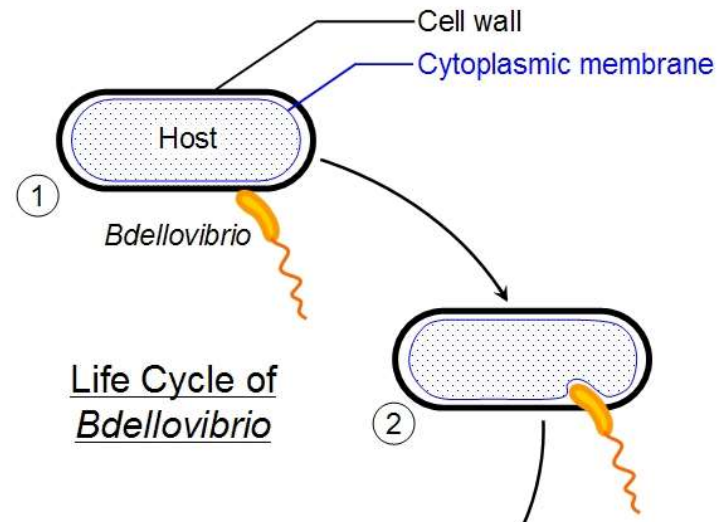


- Not plants!
- Energy sources

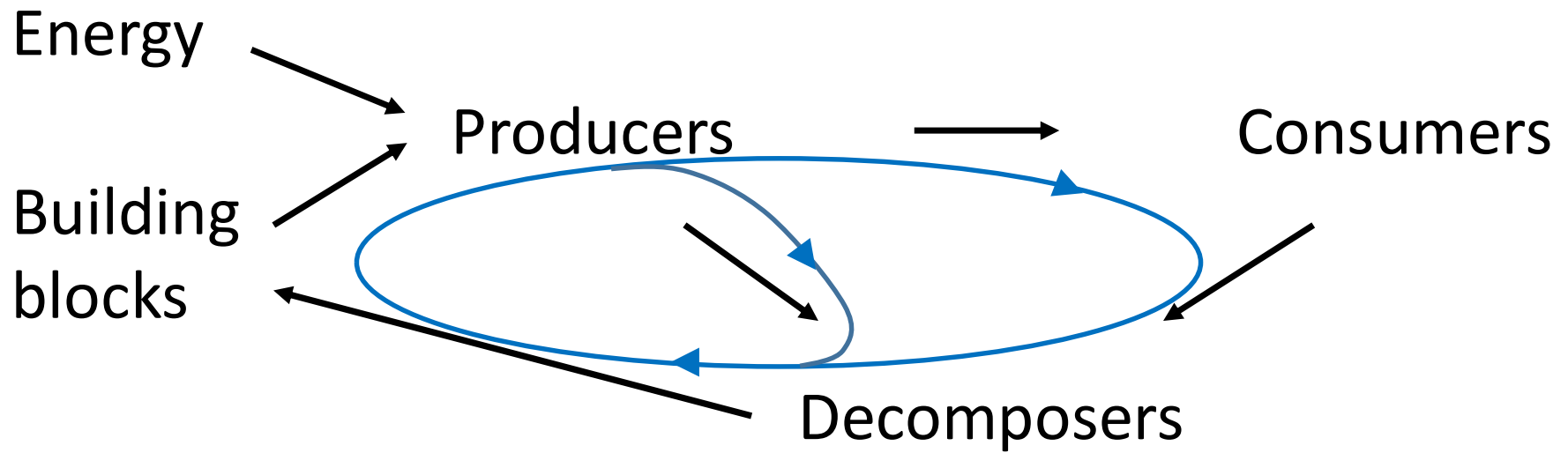
Trophic cycle



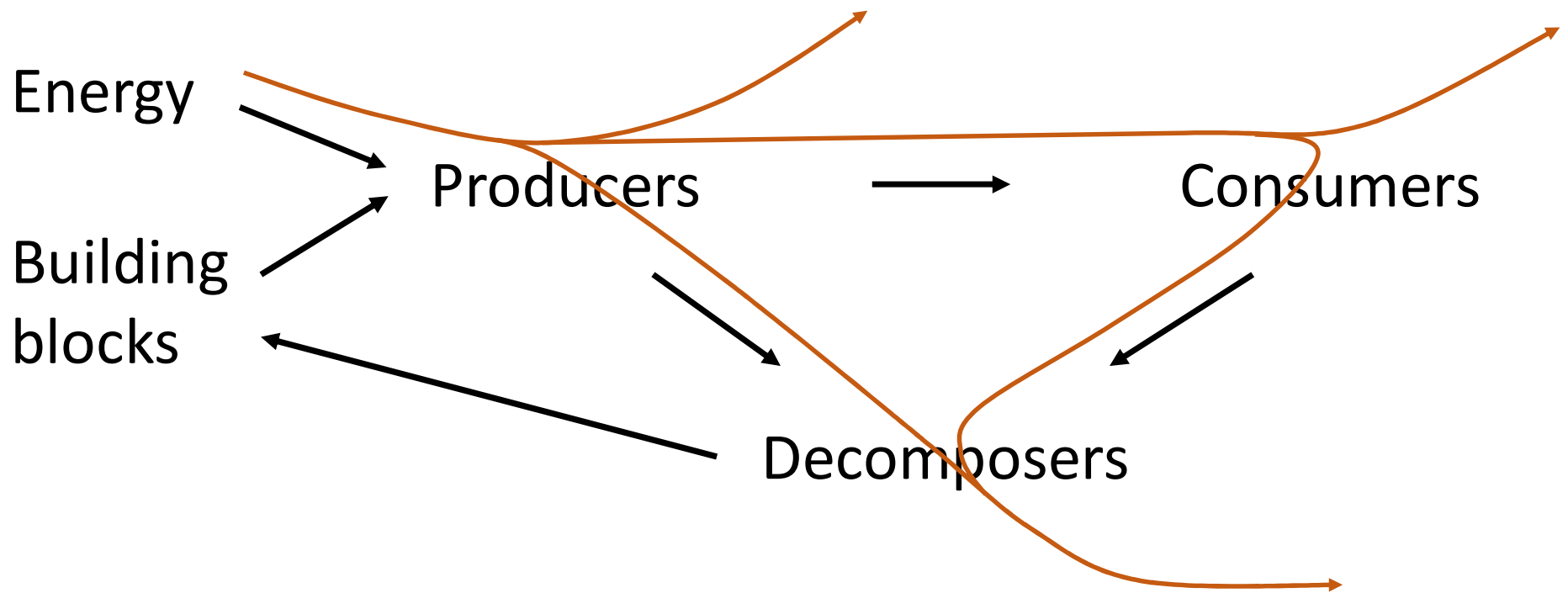
Prokaryote predation (example)



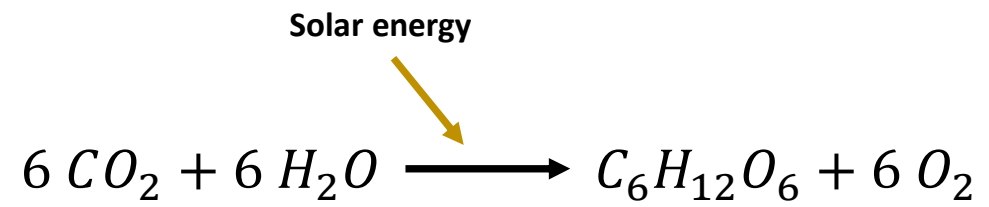
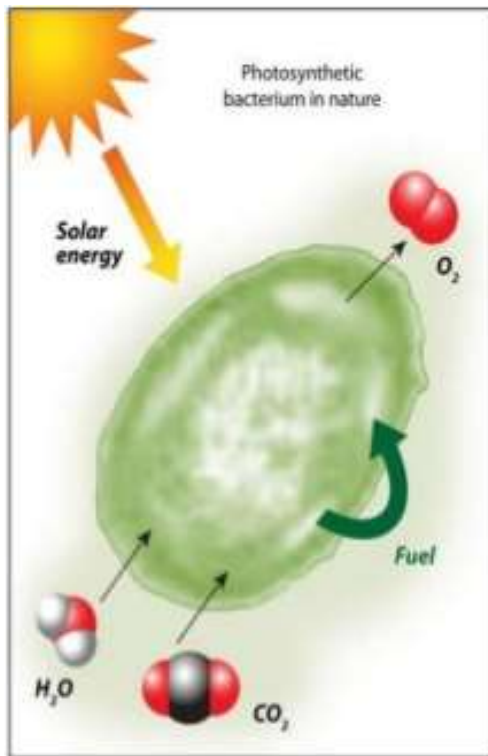
Trophic cycle



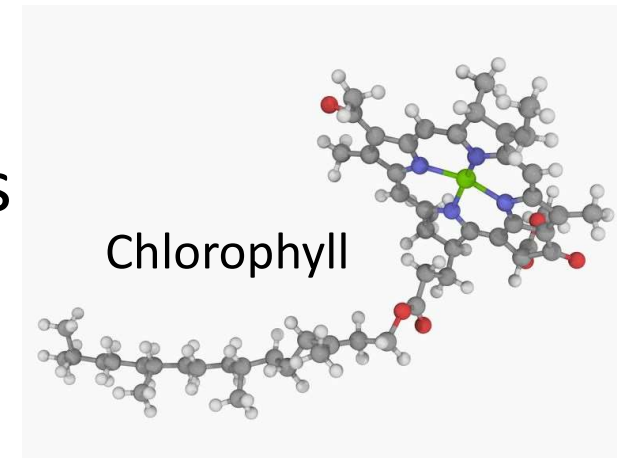
Trophic cycle



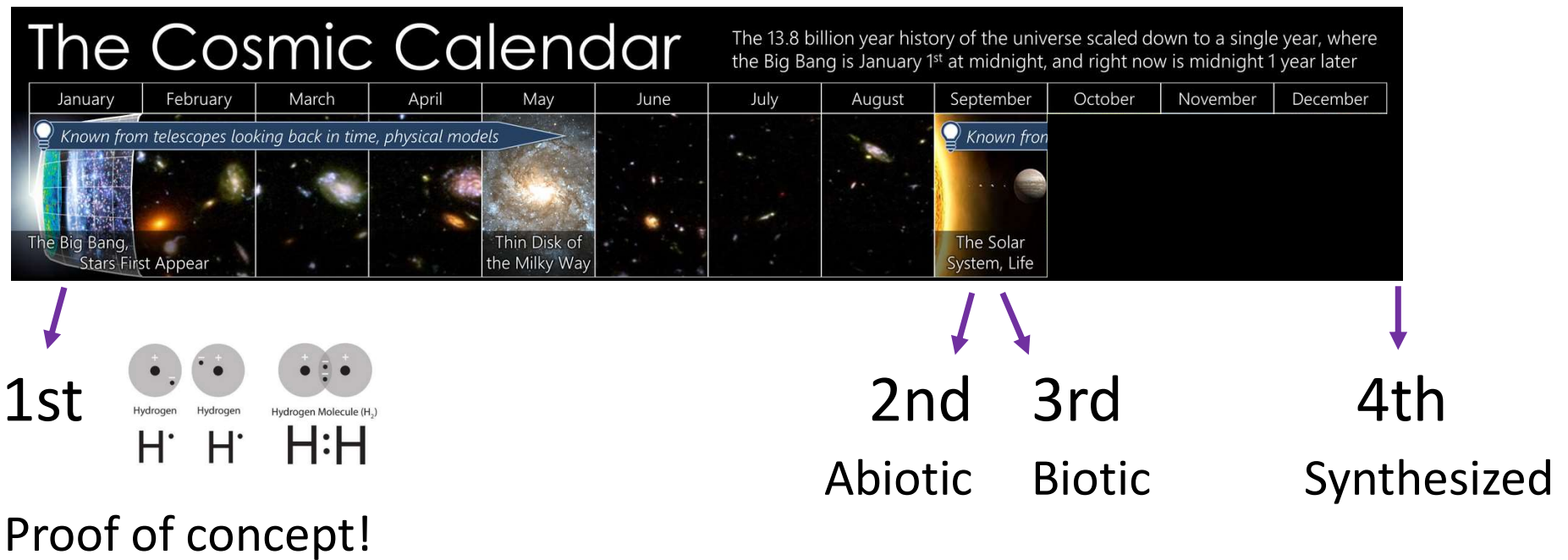
Photosynthesis



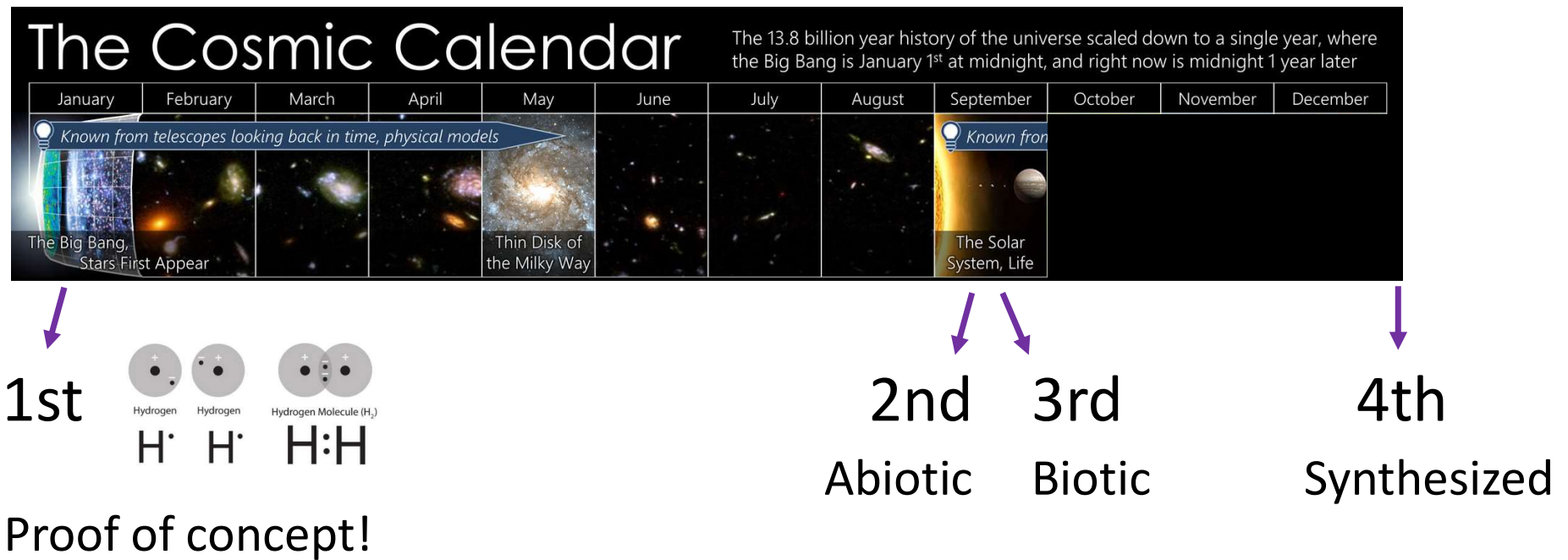
- Not plants!
- Energy sources
- Molecules



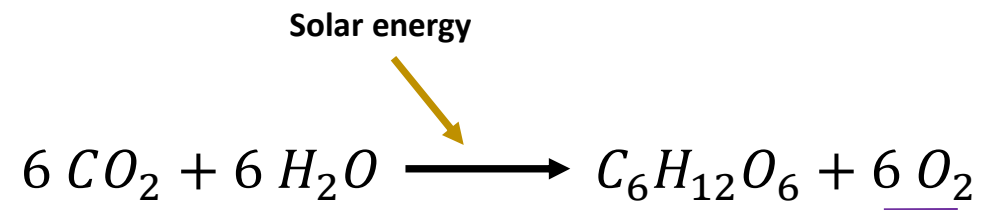
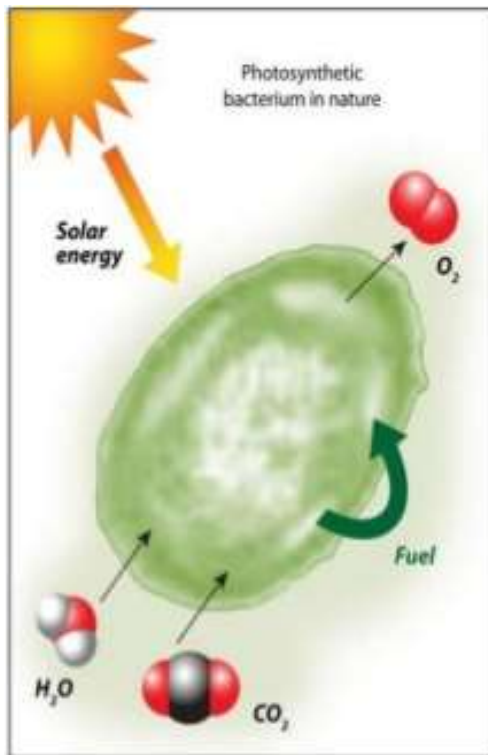
Molecular revolutions



Molecular revolutions



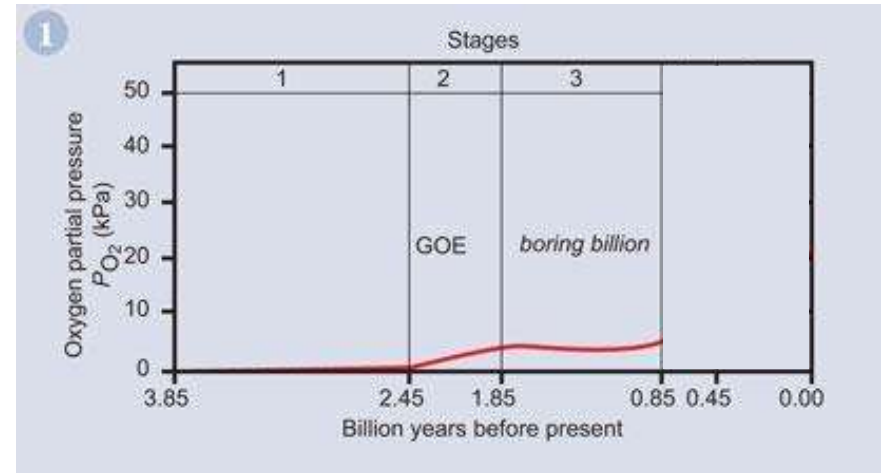
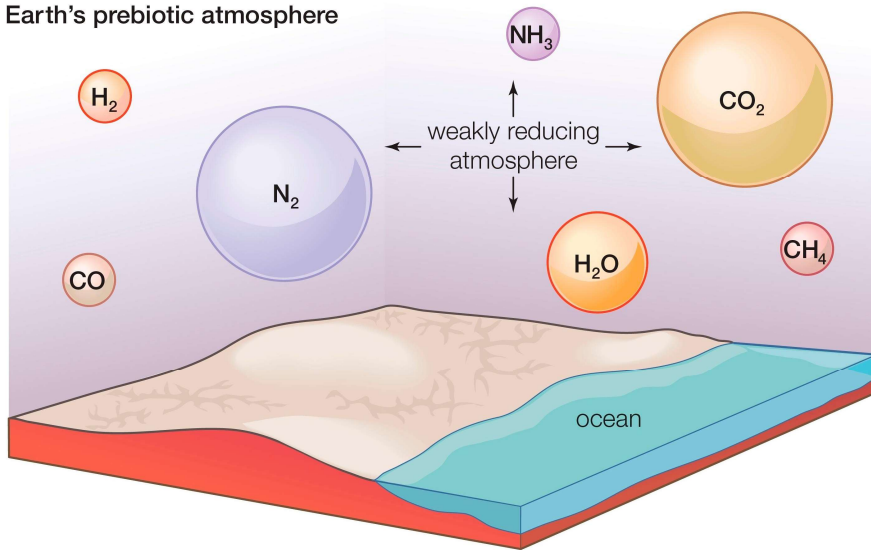
Photosynthesis



- Not plants!
- Energy sources
- Molecules

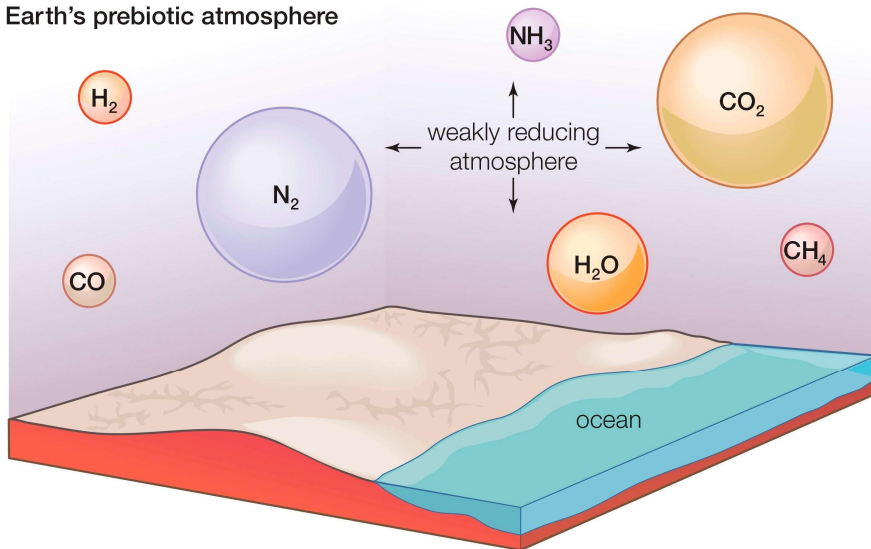
The Great Oxidation Event

Earth's prebiotic atmosphere

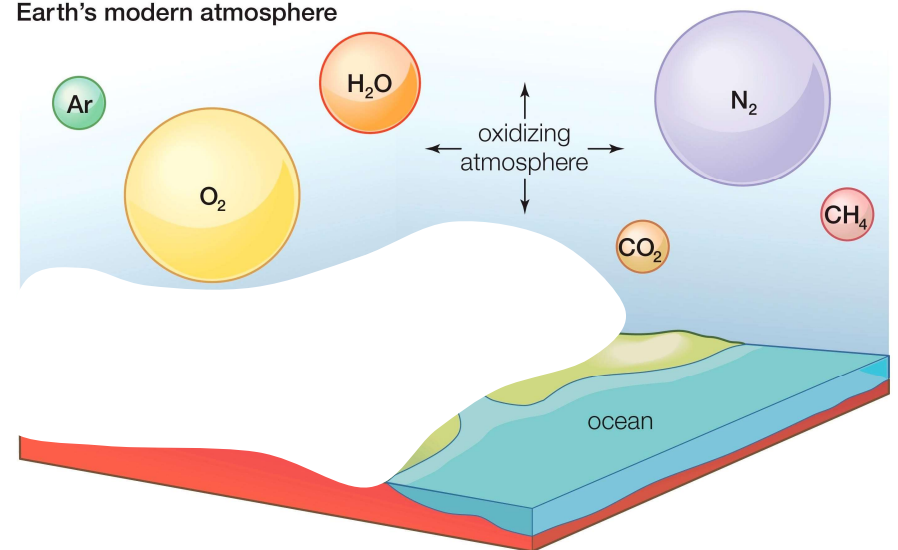


The Great Oxidation Event

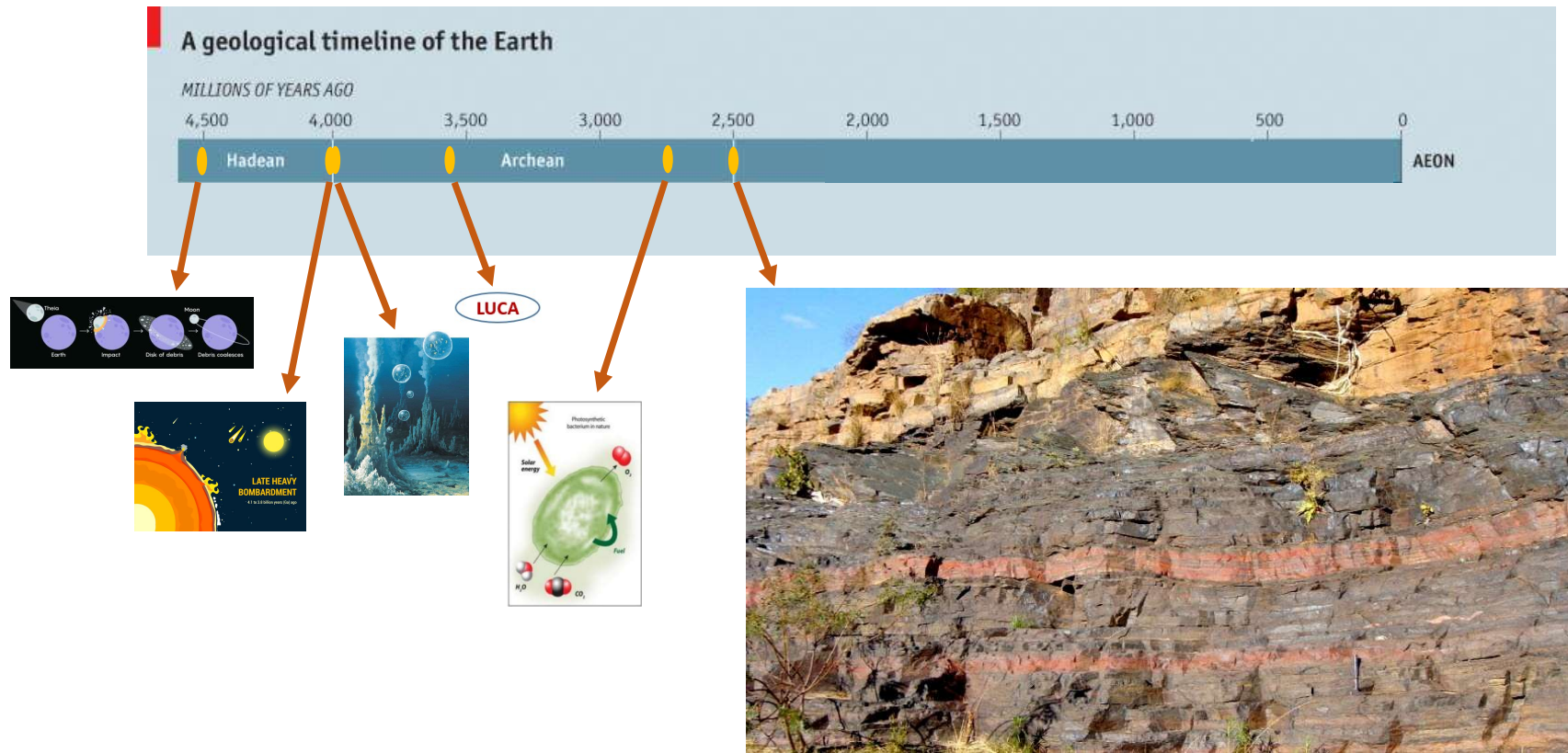
Earth's prebiotic atmosphere



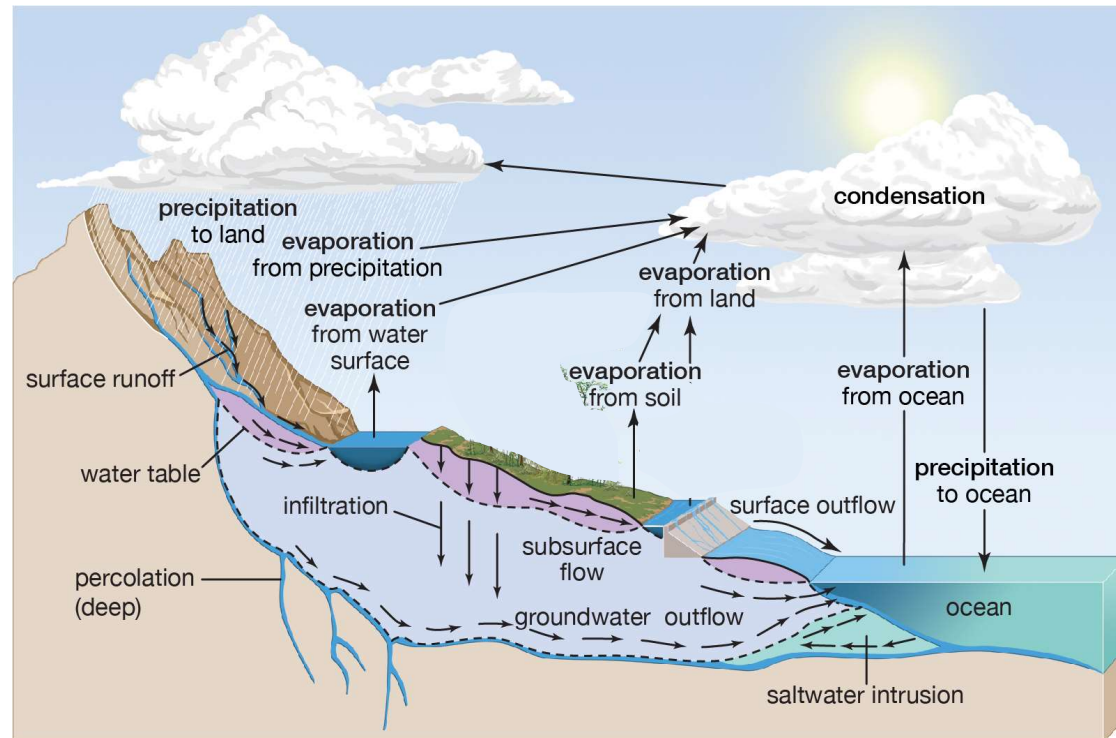
Earth's modern atmosphere



Archean



Water cycle

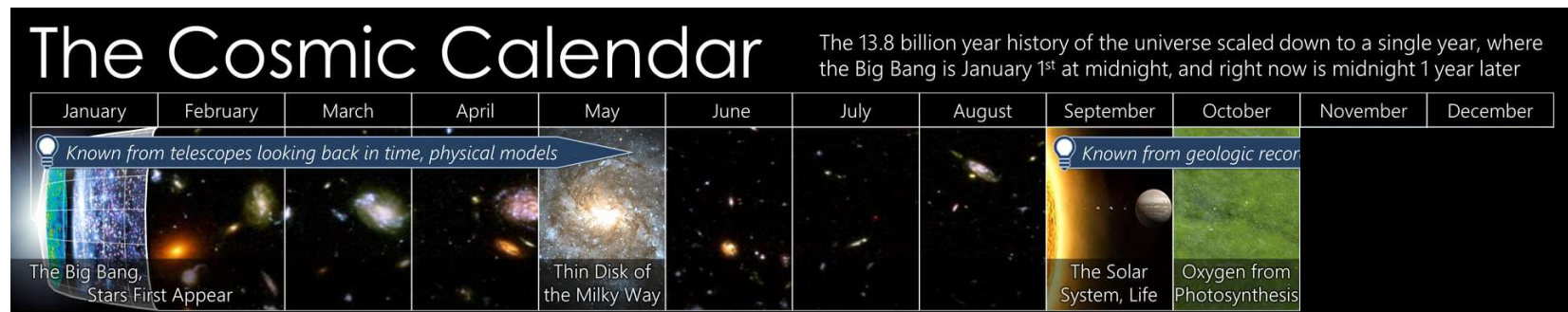


soil moisture groundwater

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

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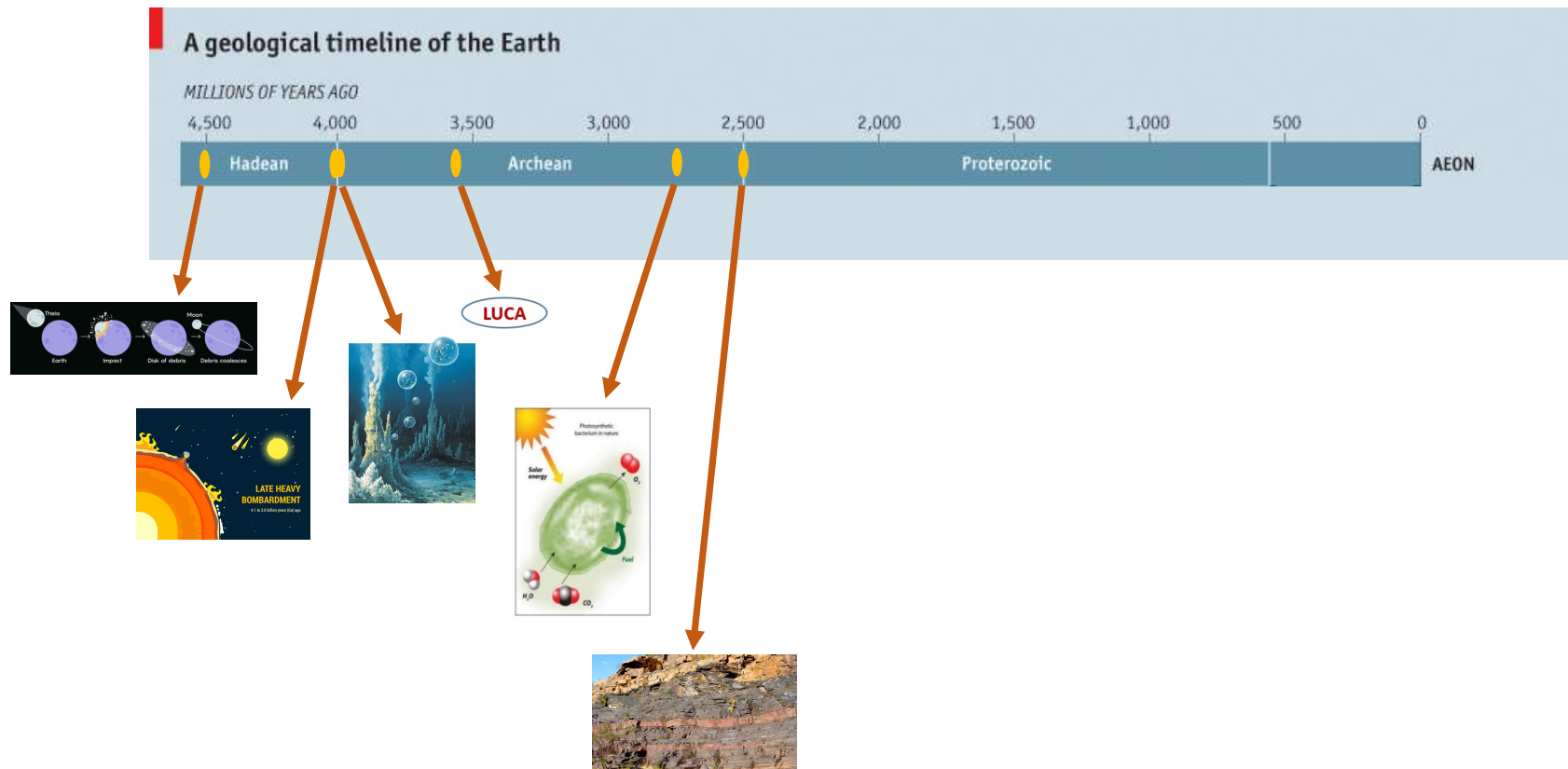
The Great Oxidation Event



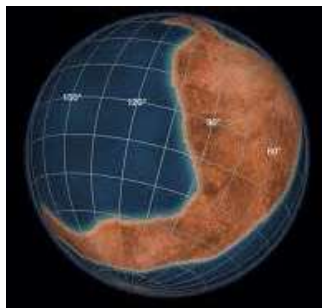
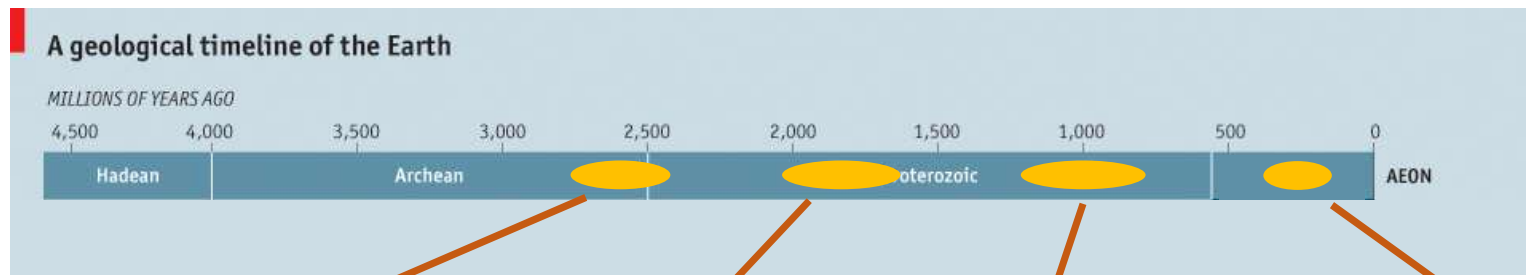
Last week of October
2.5 billion years ago



Proterozoic



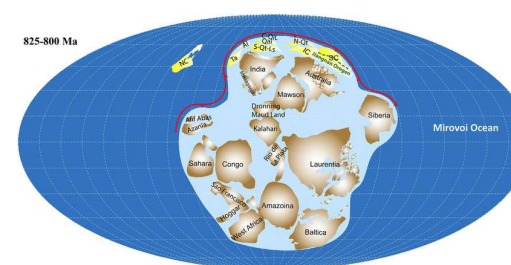
Supercontinents



Kenorland



Columbia/Nuna



Rodinia



Pangea

Kits of building blocks

Standard Model of Elementary Particles

three generations of matter (fermions)			Interactions / force carriers (bosons)	
I	II	III	0	1
u up	c charm	t top	g gluon	H higgs
d down	s strange	b bottom	γ photon	
e electron	μ muon	τ tau	Z Z boson	
ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	

LEPTONS

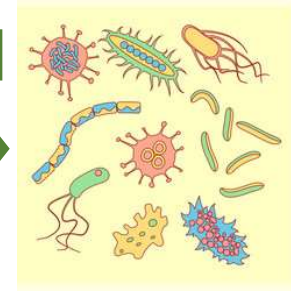
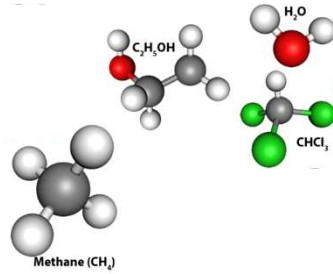
QUARKS

SCALAR BOSONS

GAUGE BOSONS
VECTOR BOSONS



Periodic Table of the Elements



Elemental composition of Life



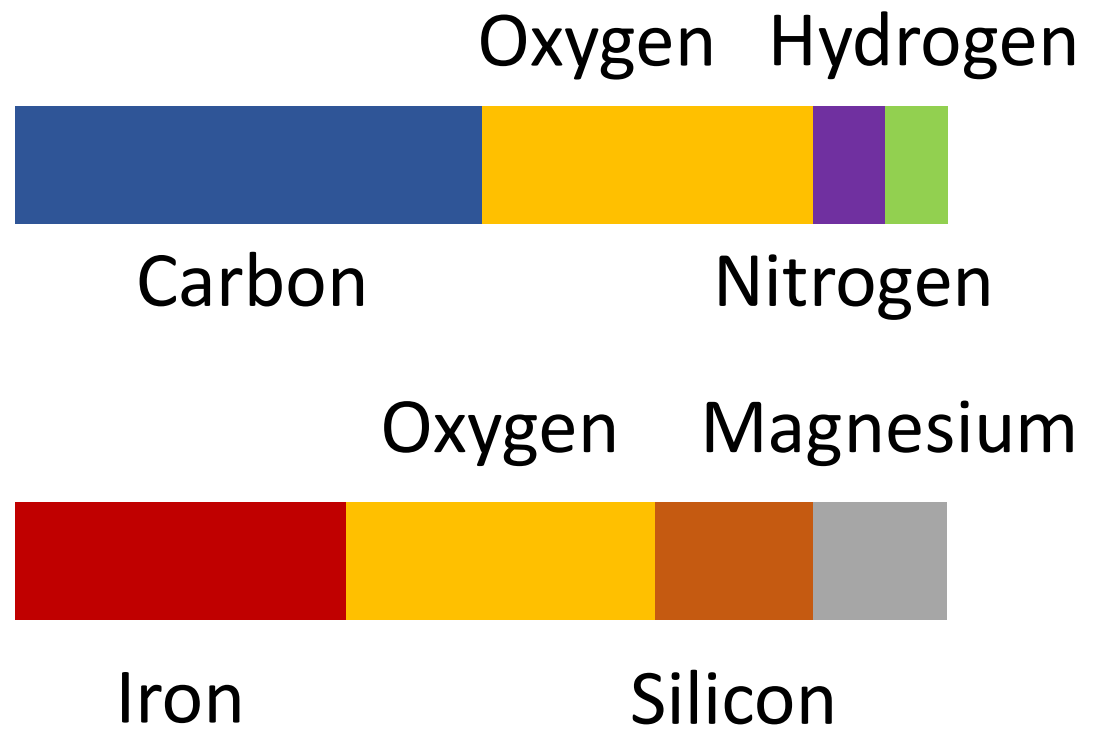
Periodic Table of the Elements

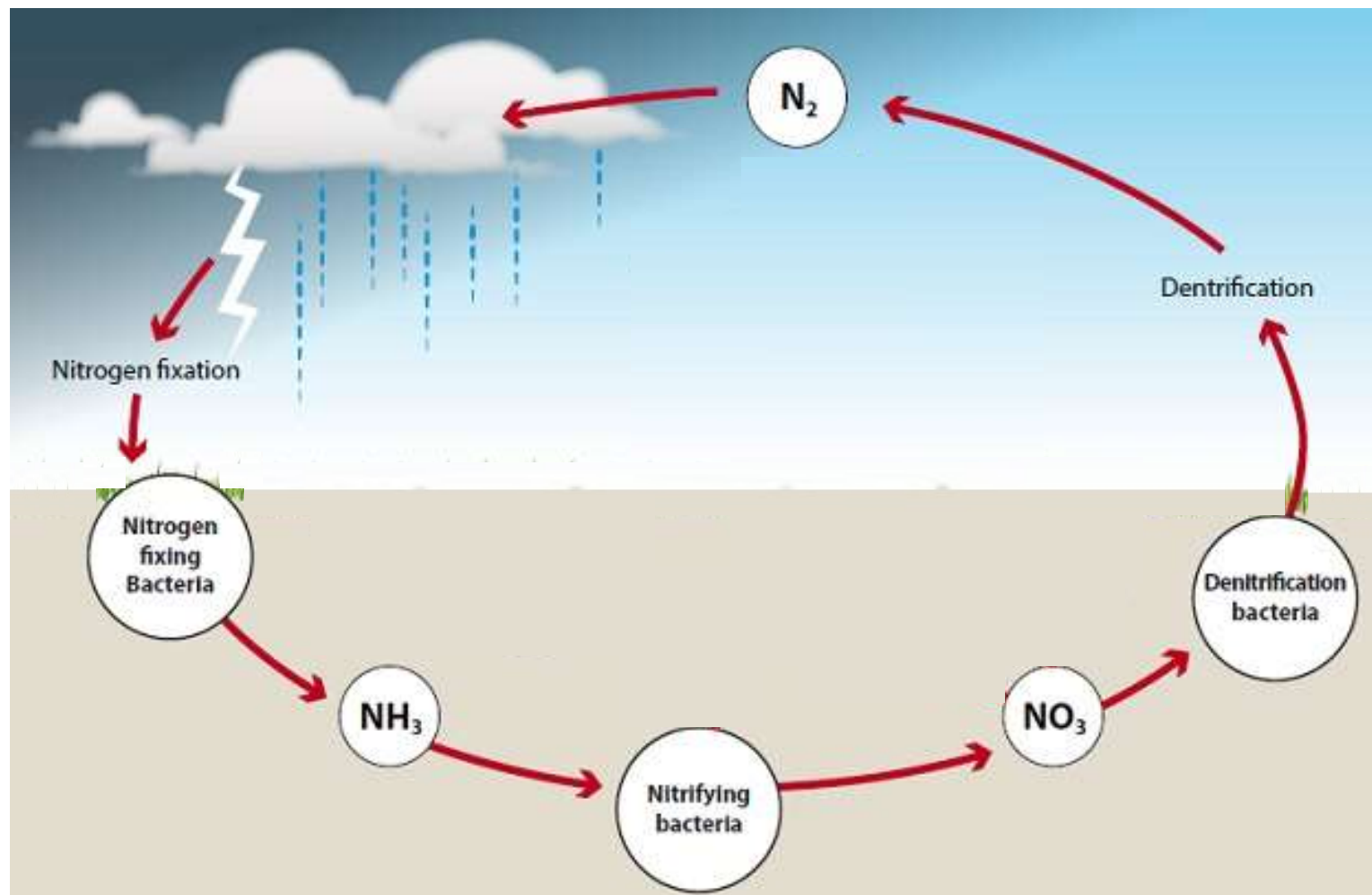
1 H Hydrogen 1.01																	2 He Helium 4.00
3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P 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 84.90
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 [209]	85 At Astatine [209]	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
Semimetal
Halogen
Noble Gas
Lanthanide
Actinide

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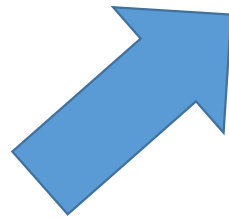
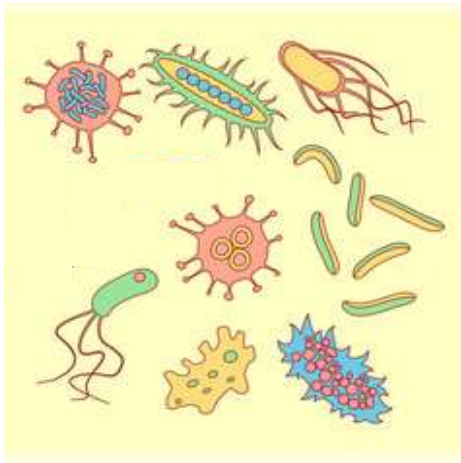
Elemental composition of Life





Prokaryote organisms

Prokaryote



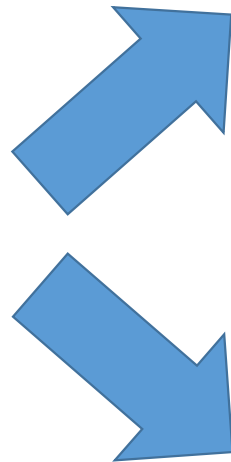
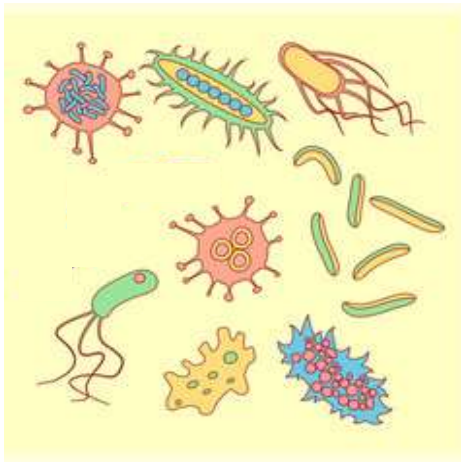
From organisms of
the same species

Colonies



Prokaryote organisms

Prokaryote



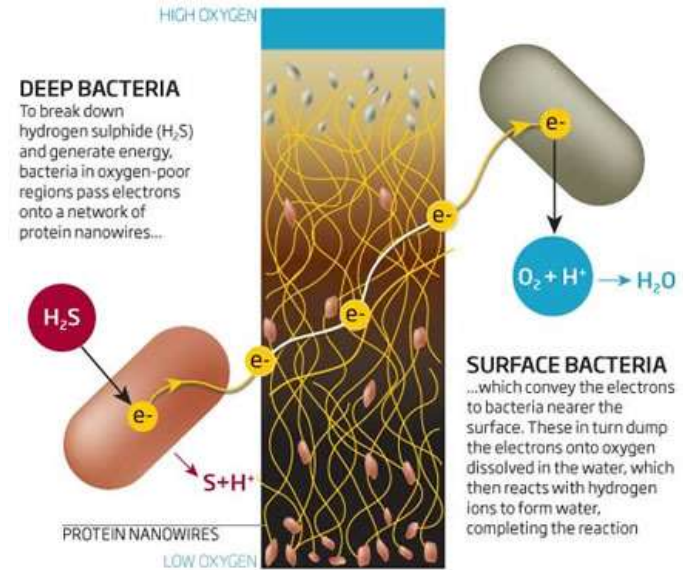
From organisms of the same species

From organisms of different species

Electric partnership

©NewScientist

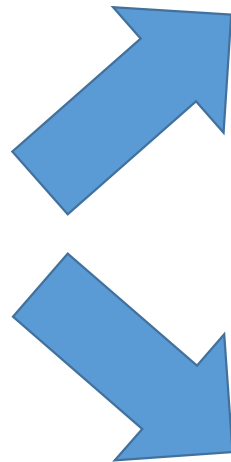
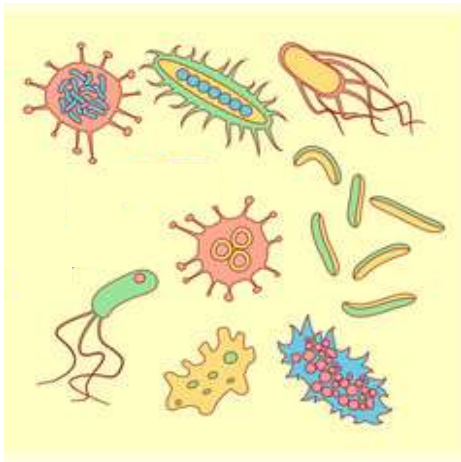
A nanowire network may allow bacteria in oxygen-poor ocean sediments to access the oxygen they need to break down their food



Symbiosis

Prokaryote organisms

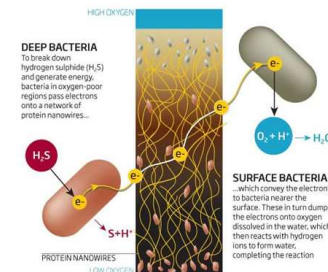
Prokaryote



From organisms of the same species

From organisms of different species

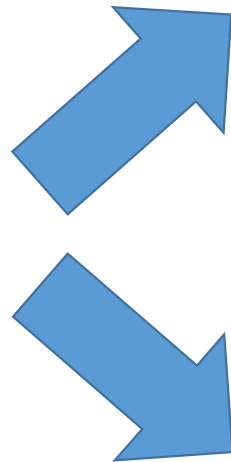
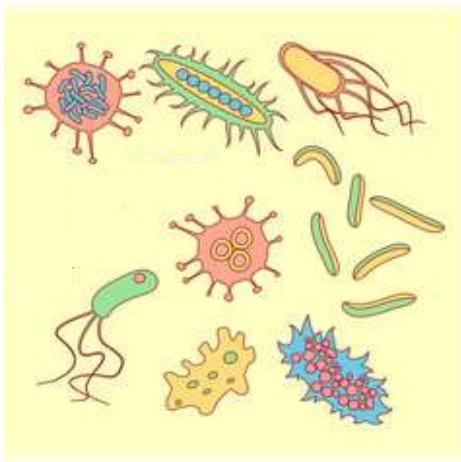
Colonies



Symbiosis

Prokaryote organisms

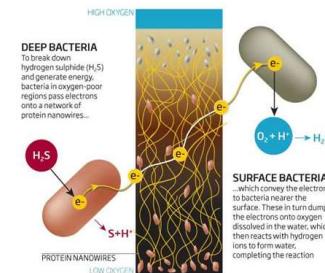
Prokaryote



From organisms of the same species

From organisms of different species

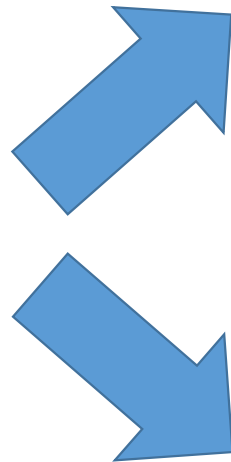
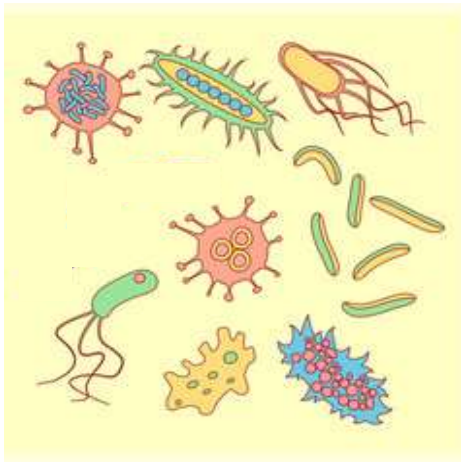
Colonies



Ectosymbiosis

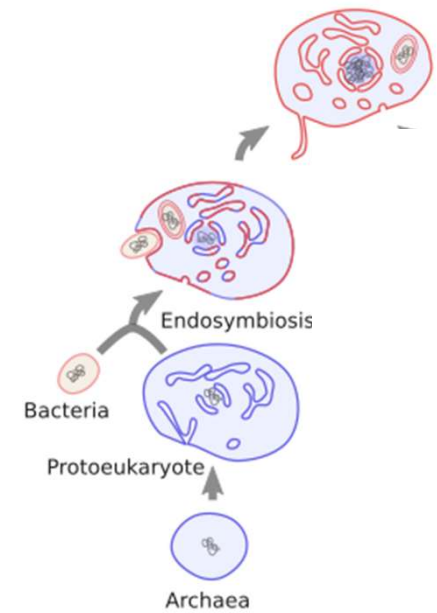
Prokaryote organisms

Prokaryote



From organisms of the same species

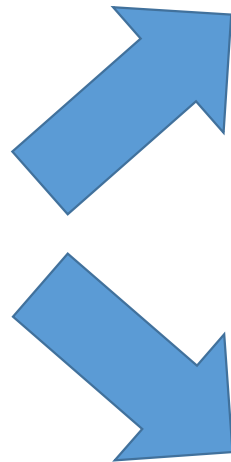
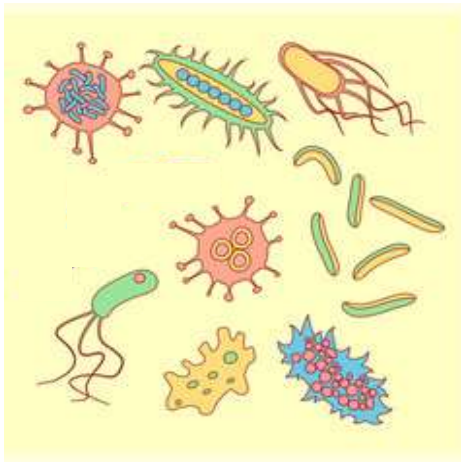
From organisms of different species



Endosymbiosis

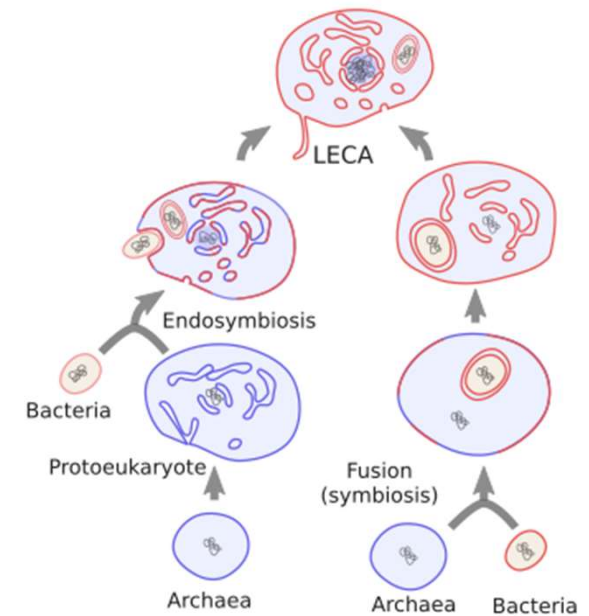
Prokaryote organisms

Prokaryote



From organisms of the same species

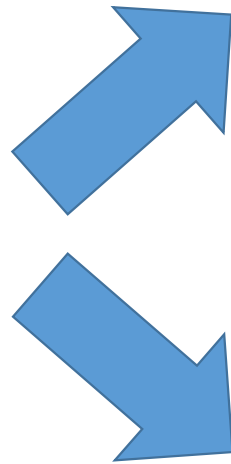
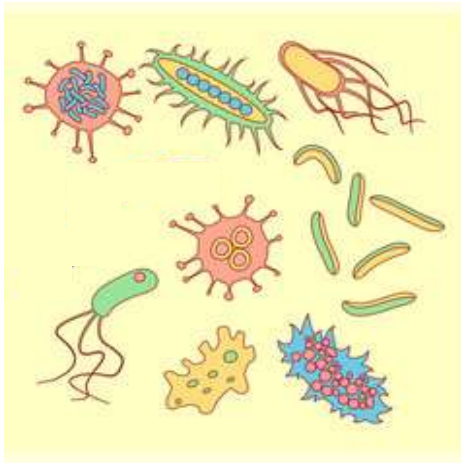
From organisms of different species



Endosymbiosis

Prokaryote organisms

Prokaryote



From organisms of the same species

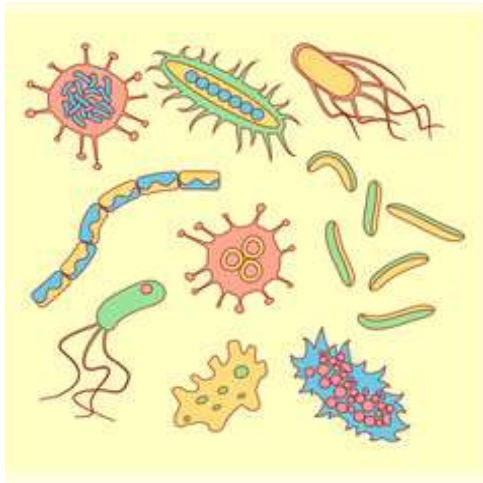
From organisms of different species



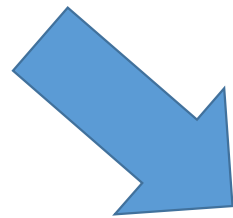
Eukaryote

Unicellular organisms

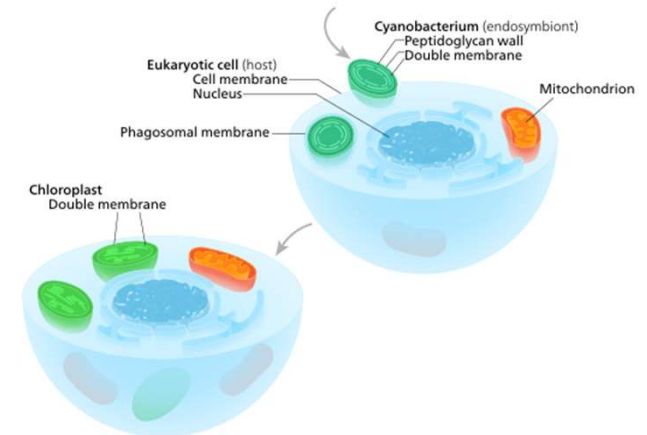
Prokaryote



Eukaryote



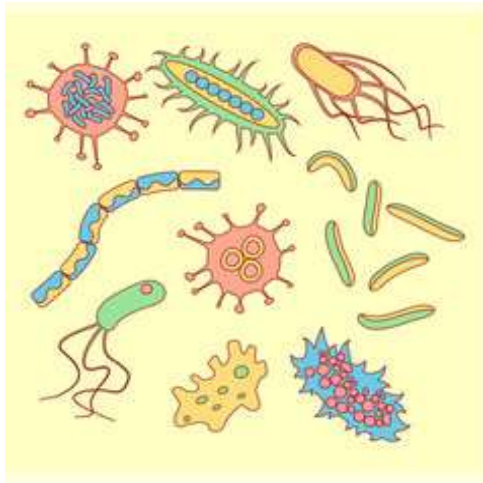
From organisms of different species



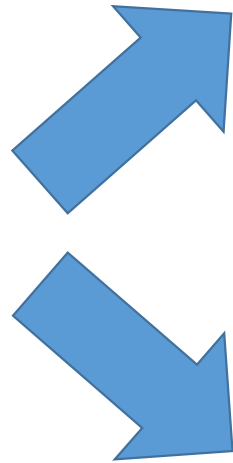
Endosymbiosis

Unicellular organisms

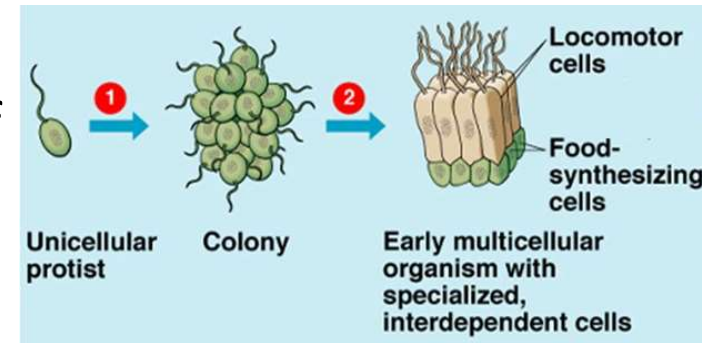
Prokaryote



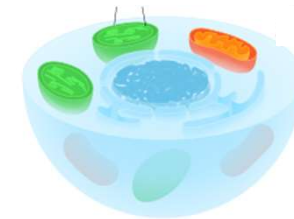
Eukaryote



From organisms of the same species



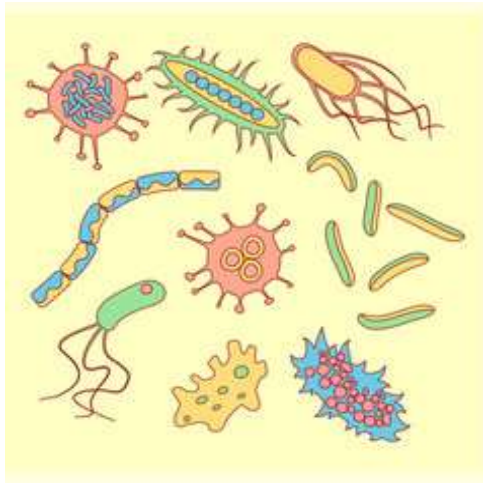
From organisms of different species



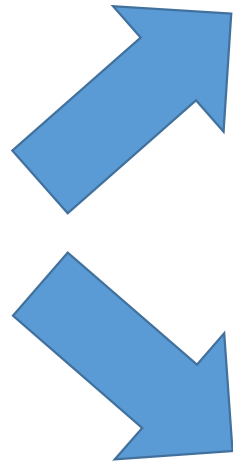
Endosymbiosis

Unicellular organisms

Prokaryote



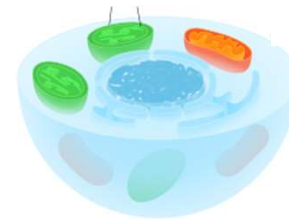
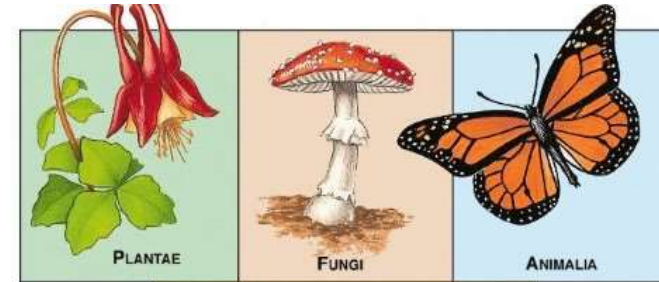
Eukaryote



From organisms of the same species

From organisms of different species

Multicellulars



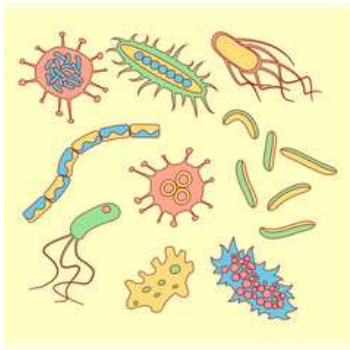
Endosymbiosis

Multicellulars

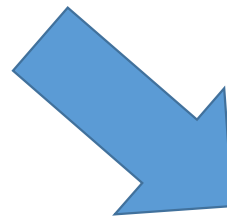
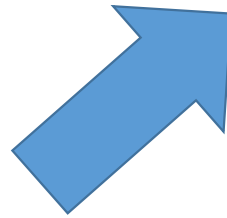


Organisms

Prokaryote

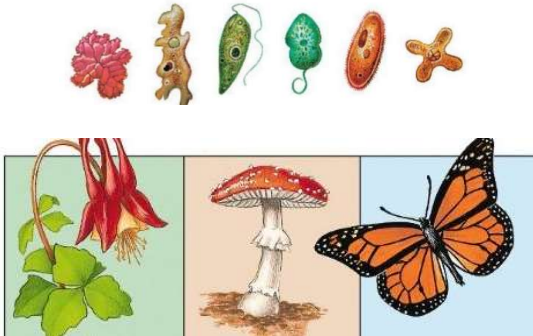


From organisms of the same species

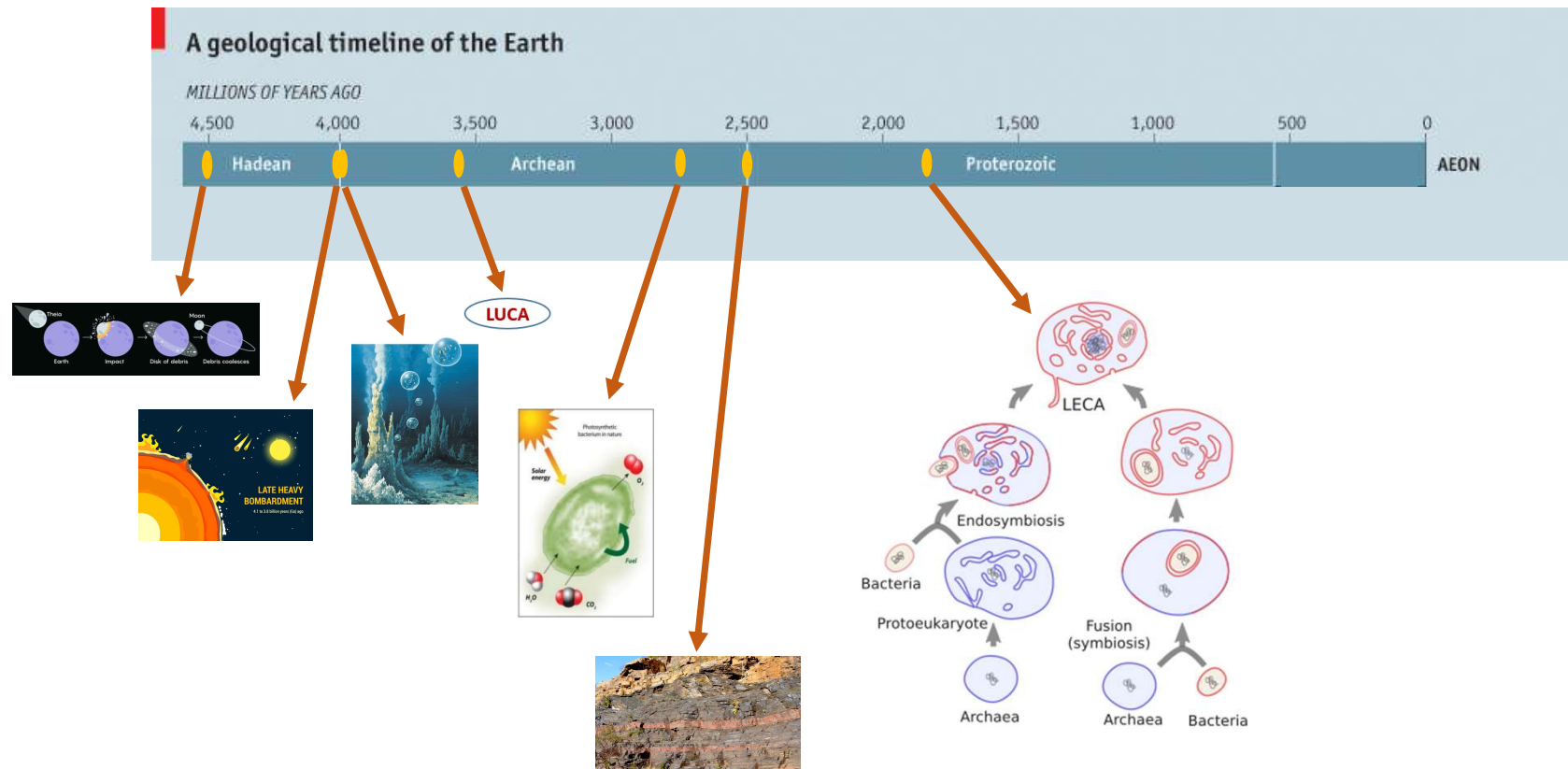


From organisms of different species

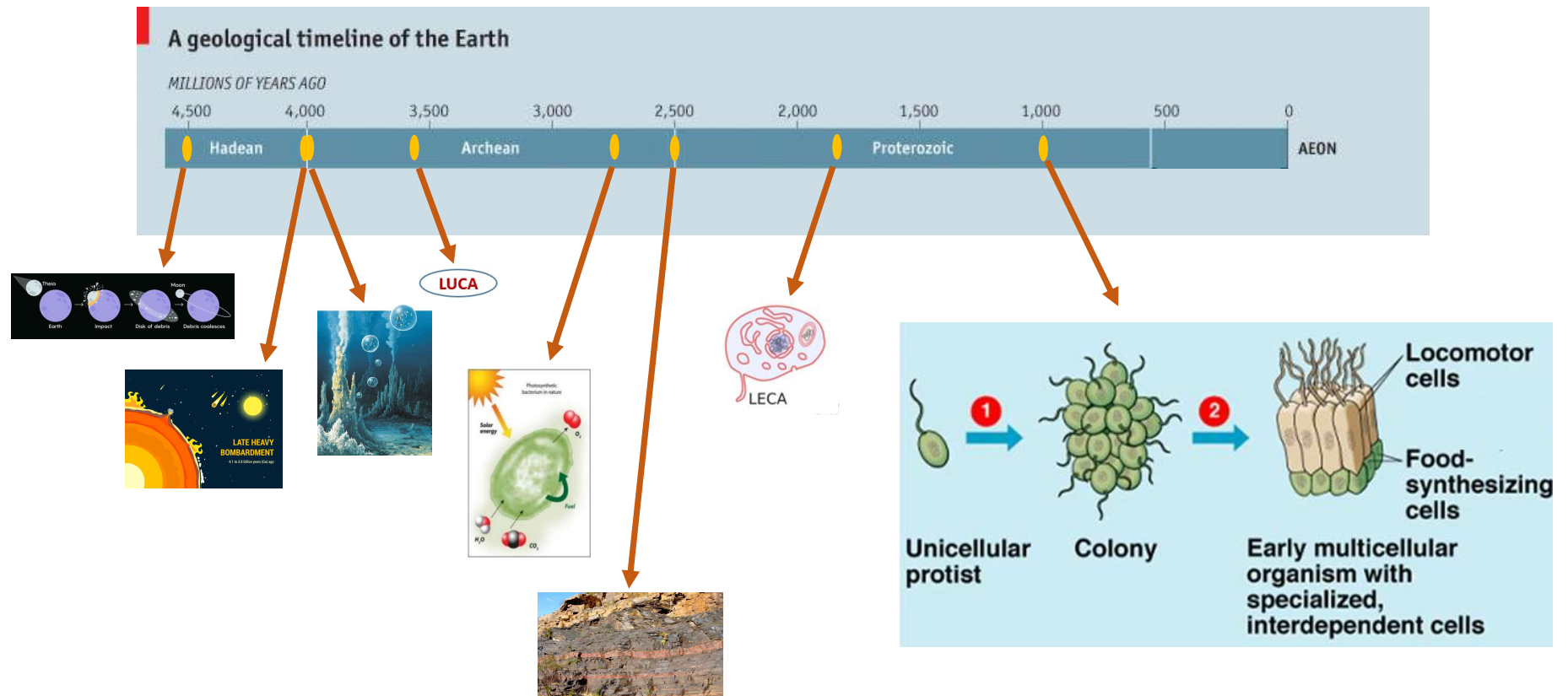
Eukaryote



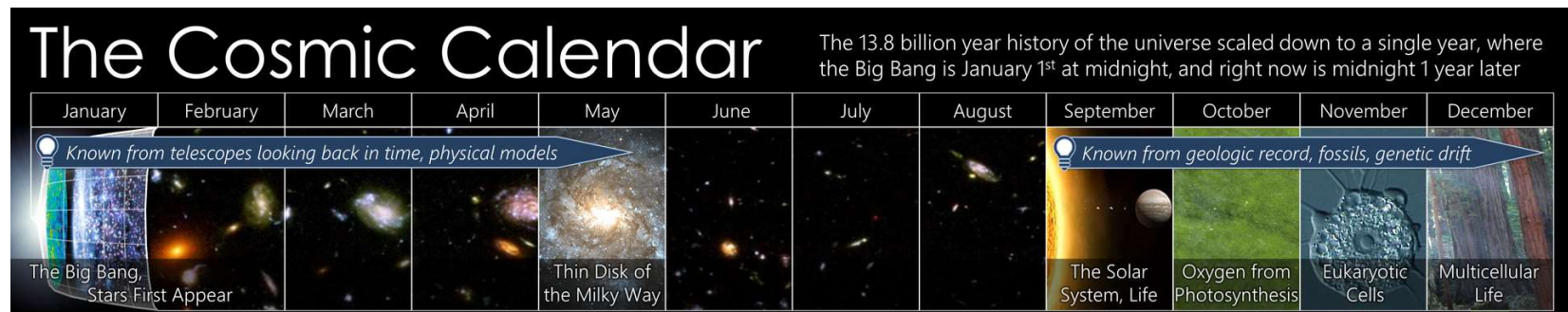
Proterozoic



Proterozoic

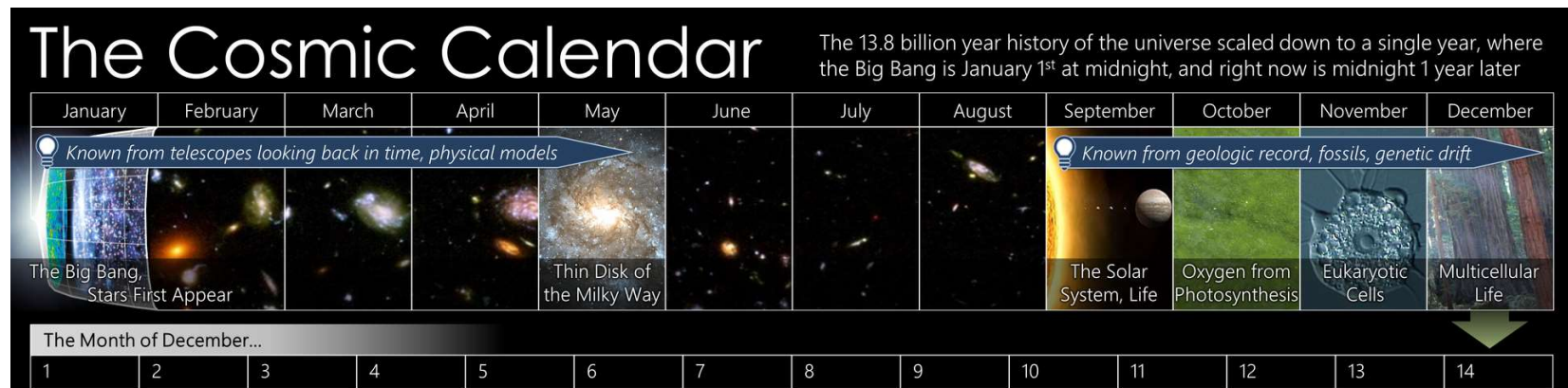


Multicellularity



First week of December
1 billion years ago

Multicellularity



December 5th
1 billion years ago

Kits of building blocks

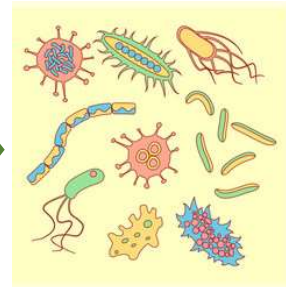
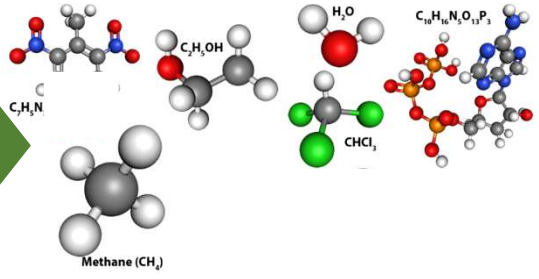
Standard Model of Elementary Particles

three generations of matter (fermions)			Interactions / force carriers (bosons)	
I	II	III	0	1
u up	c charm	t top	g gluon	H higgs
d down	s strange	b bottom	γ photon	
e electron	μ muon	τ tau	Z Z boson	
ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	

QUARKS
LEPTONS
SCALAR BOSONS
GAUGE BOSONS
VECTOR BOSONS



Periodic Table of the Elements



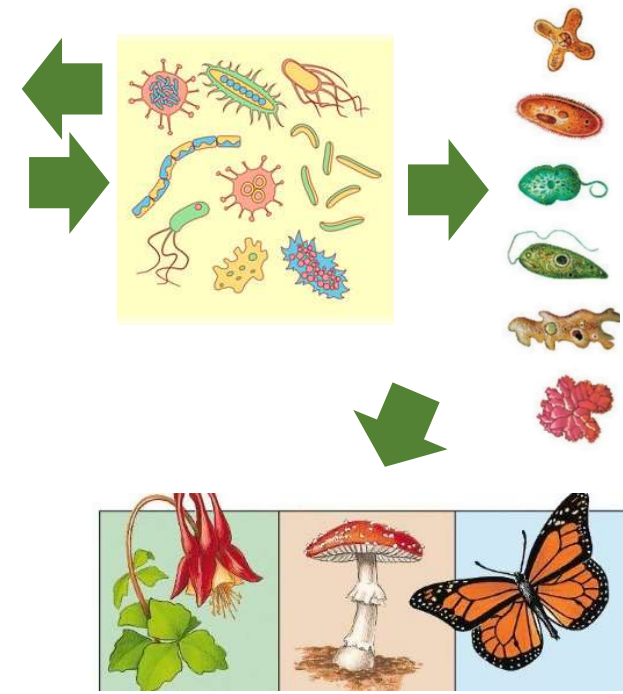
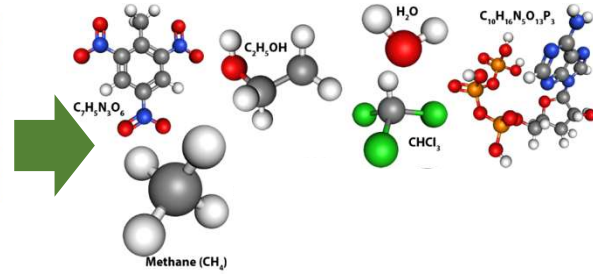
Kits of building blocks

Standard Model of Elementary Particles

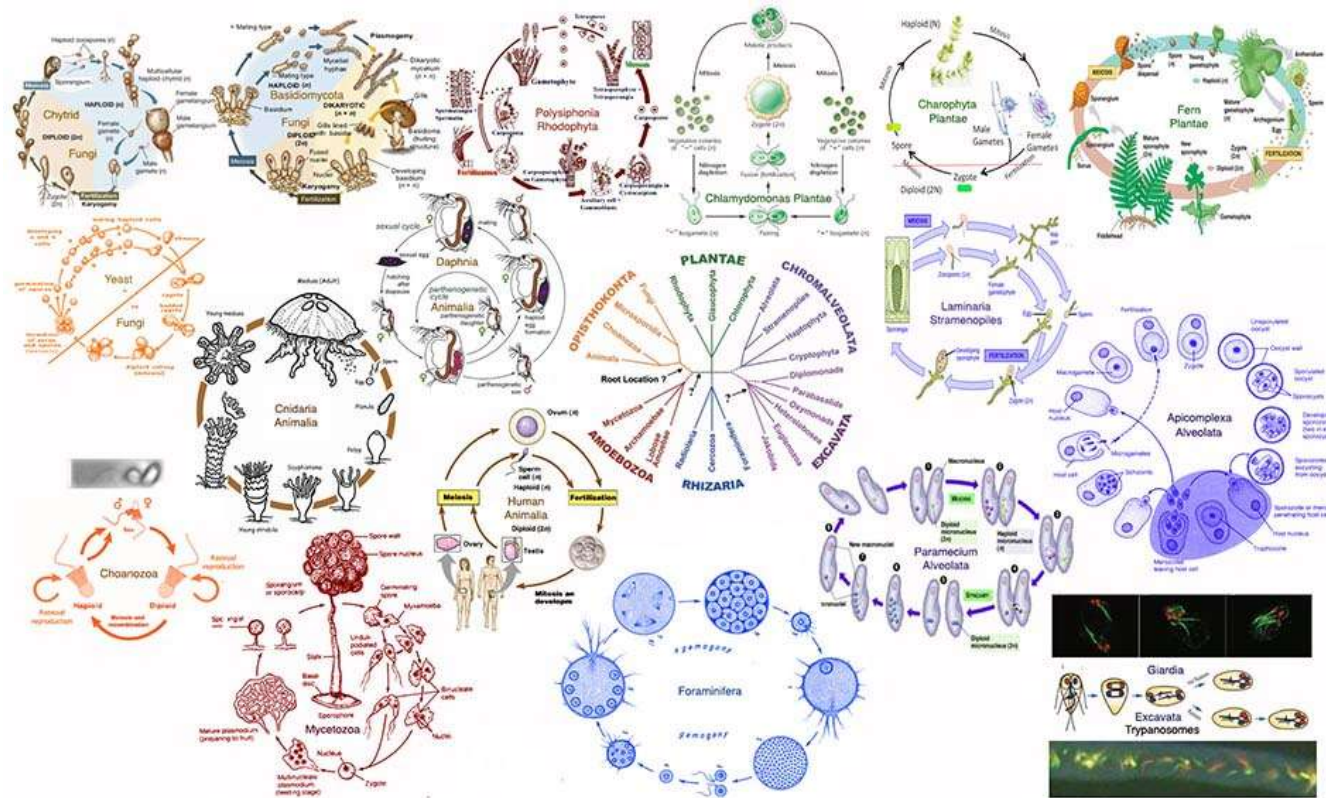
three generations of matter (fermions)			Interactions / force carriers (bosons)	
I	II	III	0	1
u up +2.2 MeV/c ²	c charm +1.28 GeV/c ²	t top +173.1 GeV/c ²	g gluon	H higgs +124.97 GeV/c ²
d down +4.7 MeV/c ²	s strange +98 MeV/c ²	b bottom +4.18 GeV/c ²	γ photon	
e electron +0.511 MeV/c ²	μ muon +105.66 MeV/c ²	τ tau +1.7768 GeV/c ²	Z Z boson +91.187 GeV/c ²	
ν _e electron neutrino +0.1 eV/c ²	ν _μ muon neutrino +1.88 MeV/c ²	ν _τ tau neutrino +1.82 MeV/c ²	W W boson +80.385 GeV/c ²	

QUARKS: u, c, t, d, s, b
 LEPTONS: e, μ, τ, ν_e, ν_μ, ν_τ
 GAUGE BOSONS: g, γ, Z, W
 SCALAR BOSONS: H

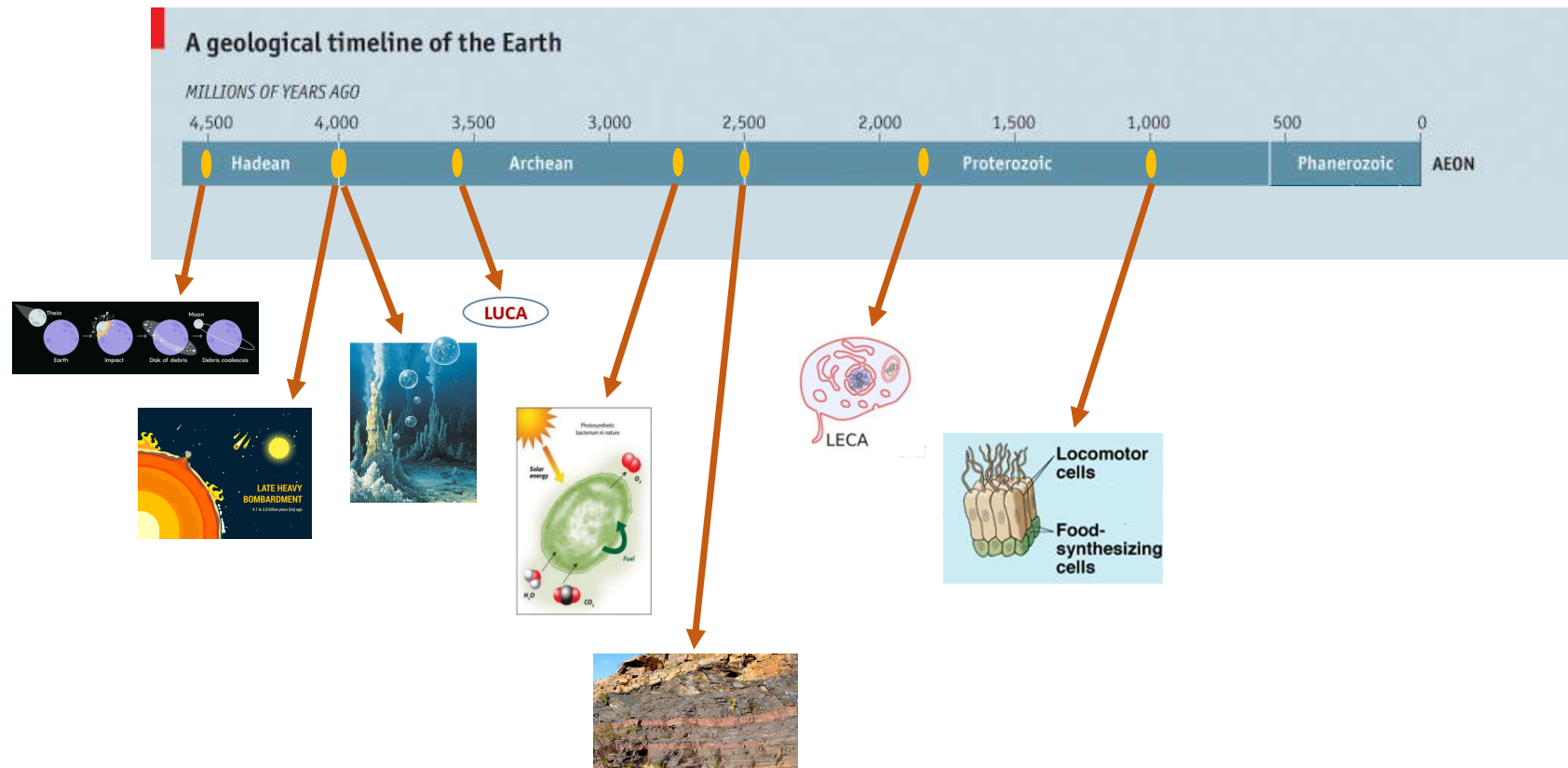
Periodic Table of the Elements



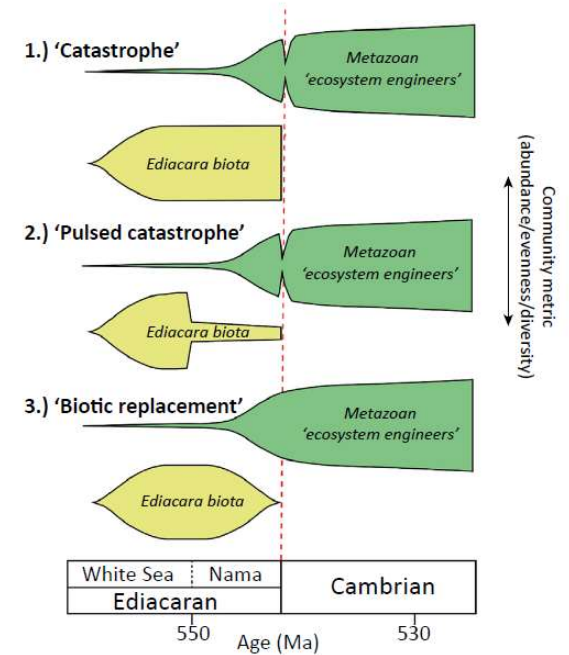
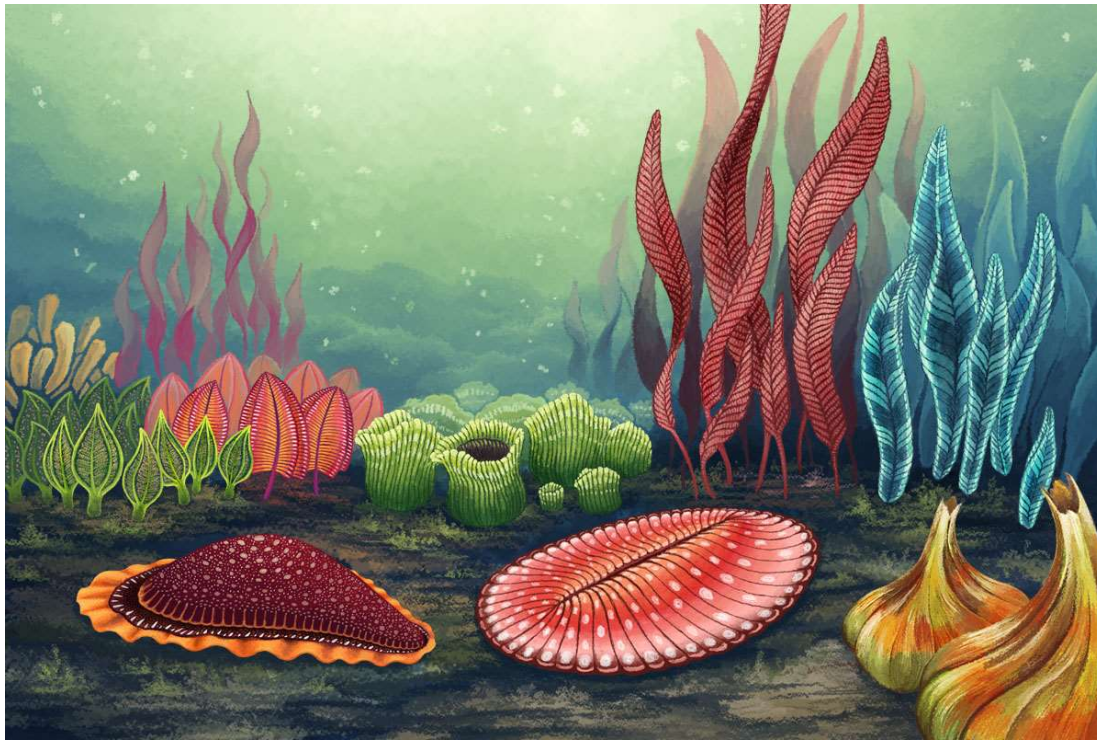
Life cycles



Phanerozoic



Ediacarian explosion



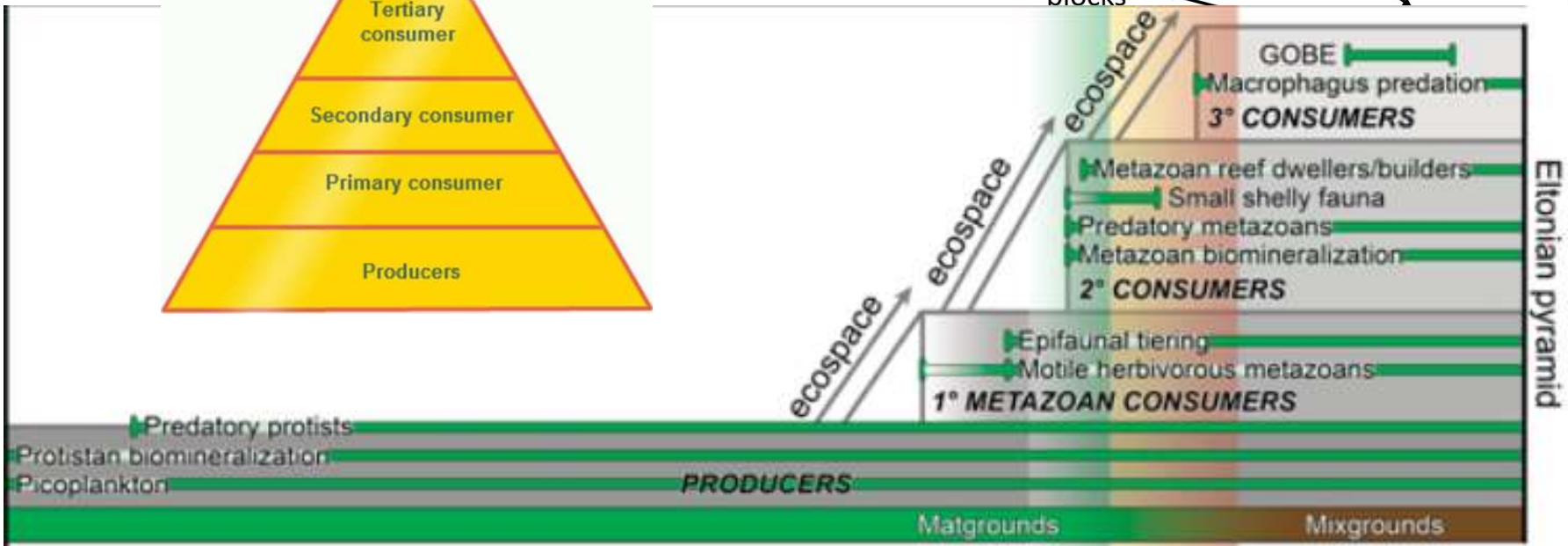
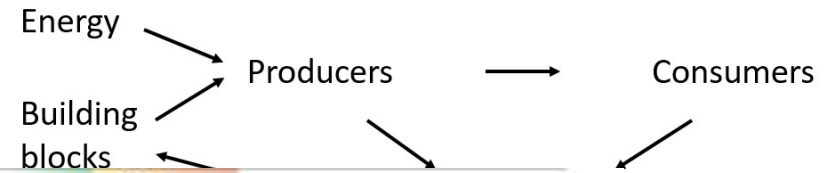
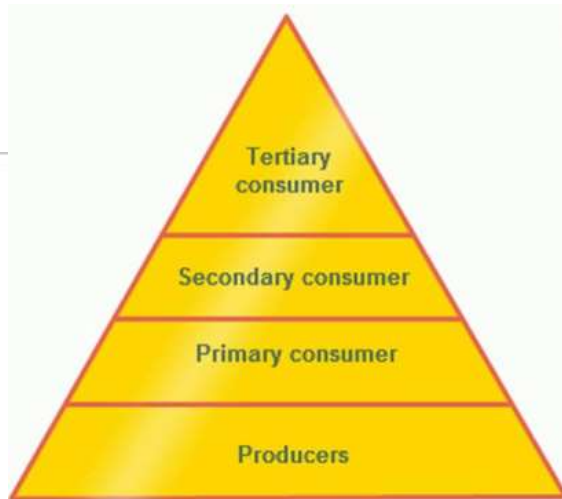
Opinion

Ediacaran Extinction and Cambrian Explosion

Simon A.F. Darroch,^{1*} Emily F. Smith,² Marc Lallamne,³ and Douglas H. Erwin⁴

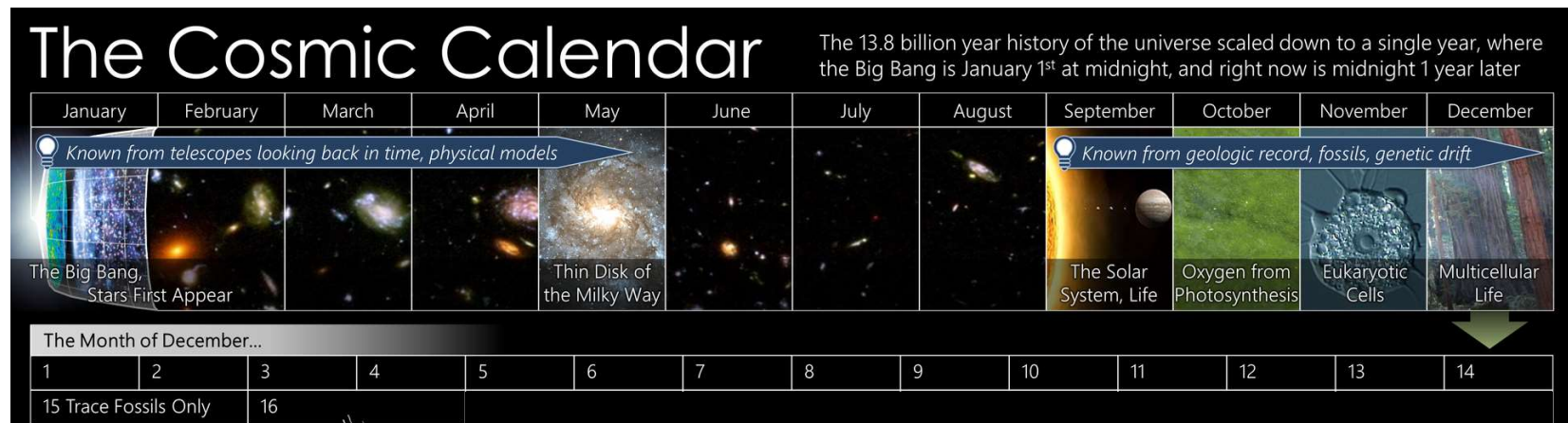
Trends in Ecology & Evolution, September 2018, Vol. 33, No. 9 Trends in Ecology & Evolution, September 2018, Vol. 33, No. 9 Trends in Ecology & Evolution, September 2018, Vol. 33, No. 9

Ediacarian explosion



www.geosociety.org/gsatoday/archive/26/11/pdf/i1052-5173-26-11-4.pdf

Cambrian Explosion

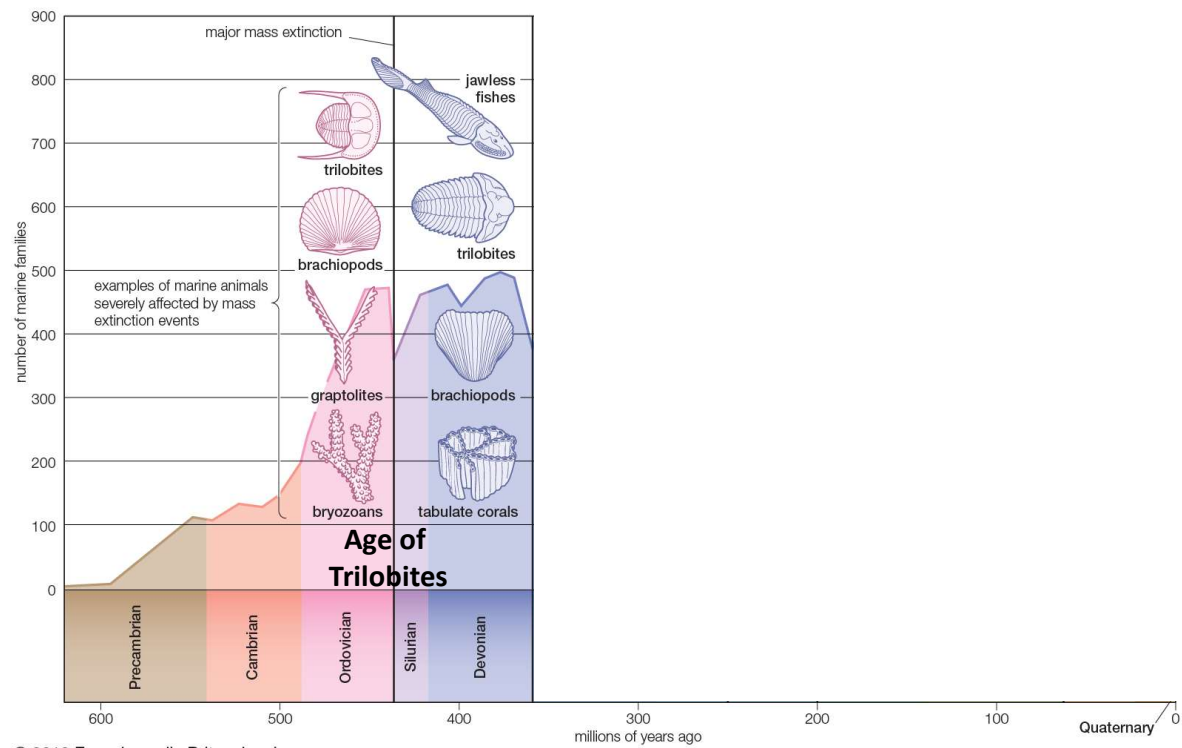


December 16th
550 million years ago

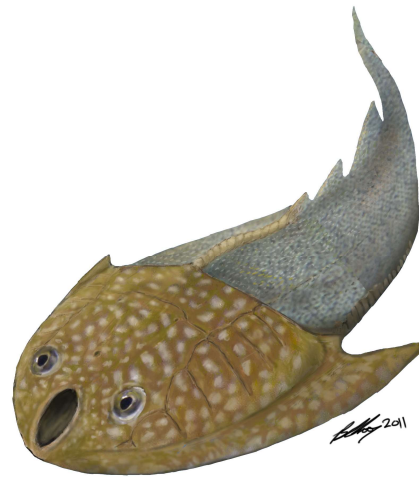


Cambrian explosion

Diversity of marine animal families over geologic time



Bio technologies



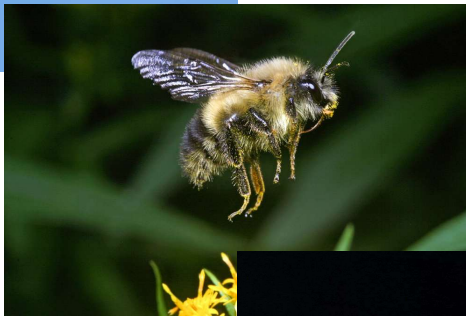
www.smithsonianmag.com/videos/category/science/the-hagfish-is-the-slimy-sea-creature-of-you/

Bio technologies

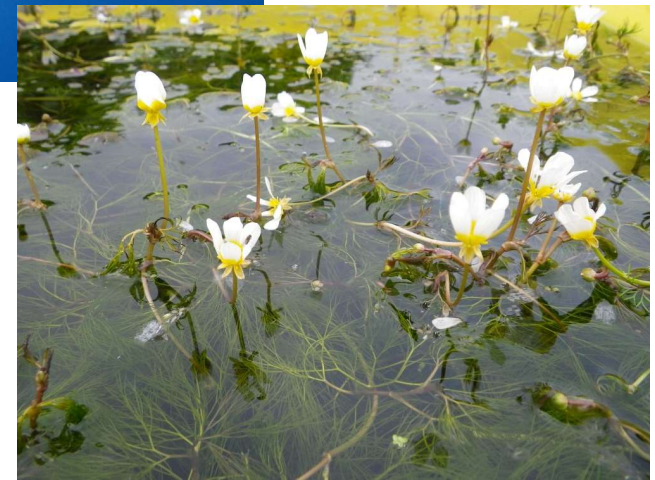


www.smithsonianmag.com/videos/category/science/the-hagfish-is-the-slimy-sea-creature-of-you/

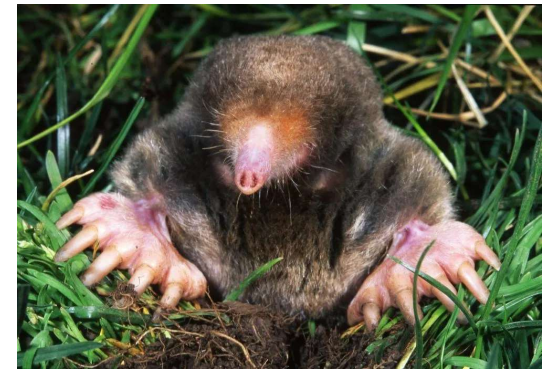
Bio technologies



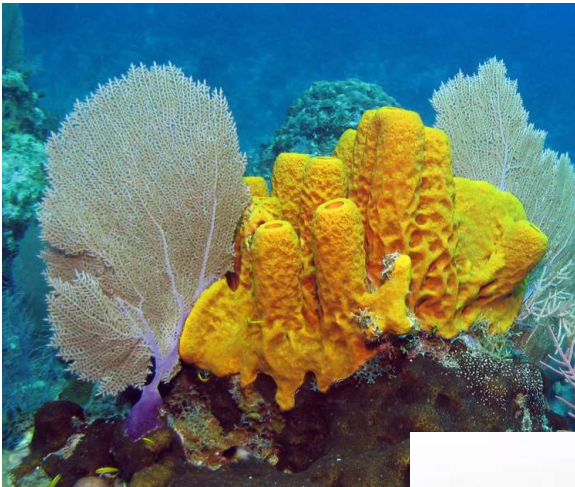
Bio technologies



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

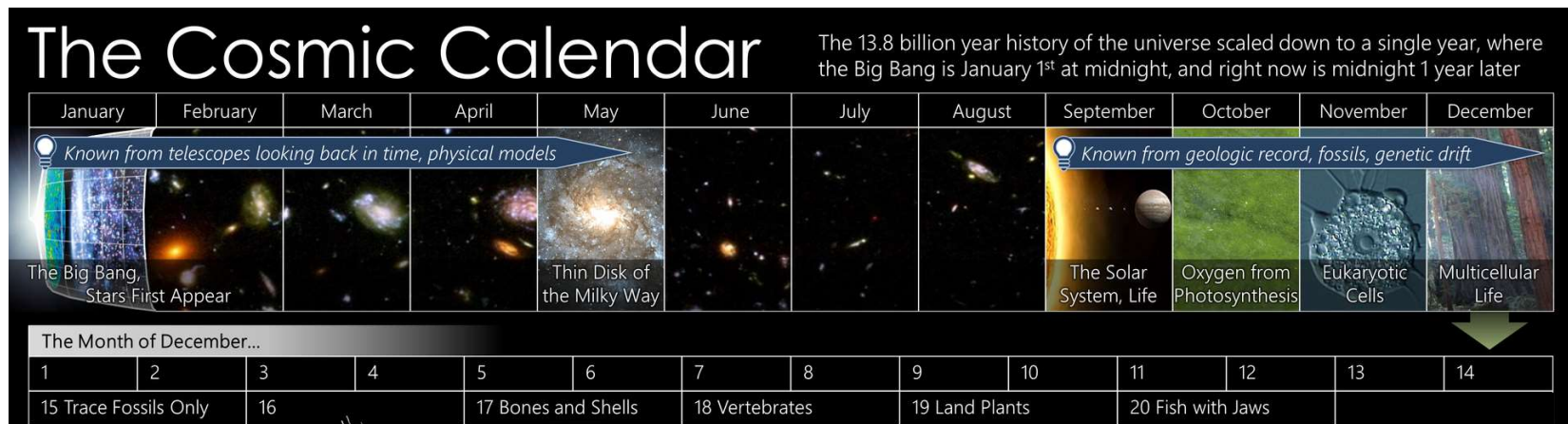


Rafflesia



Chloroplasts

Jaws

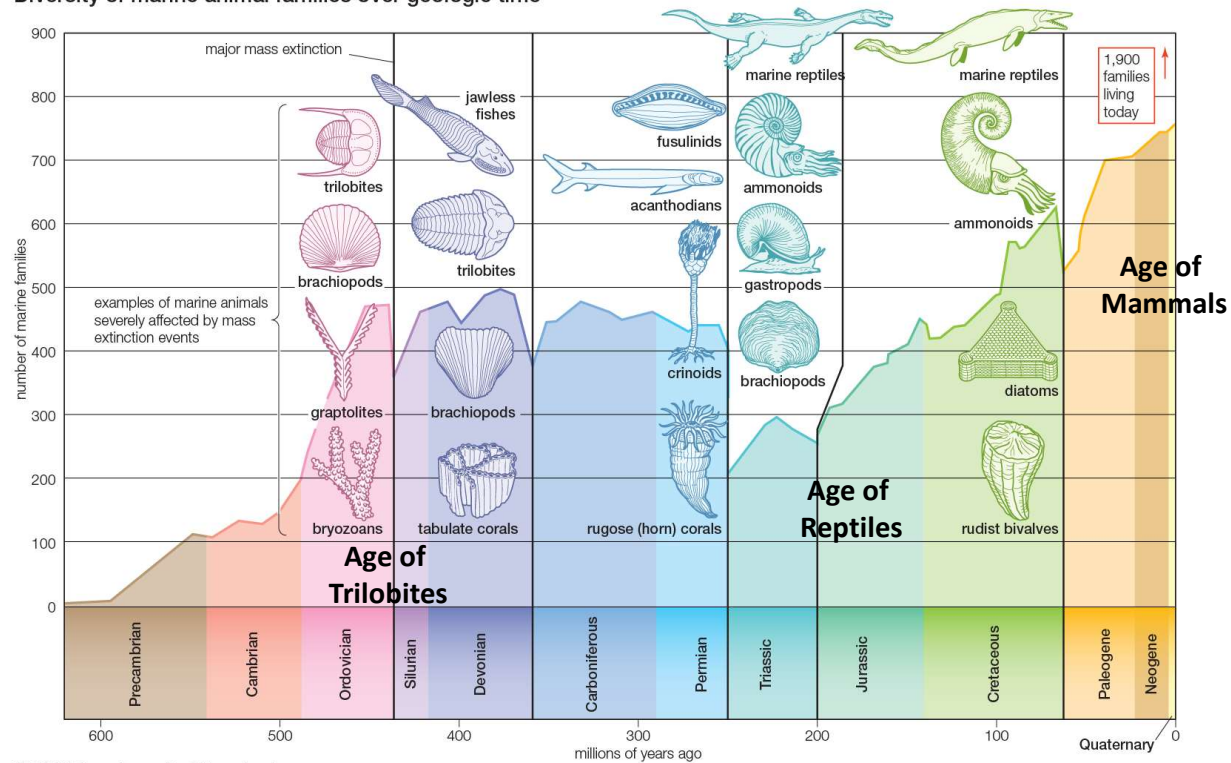


December 20th
450 million years ago



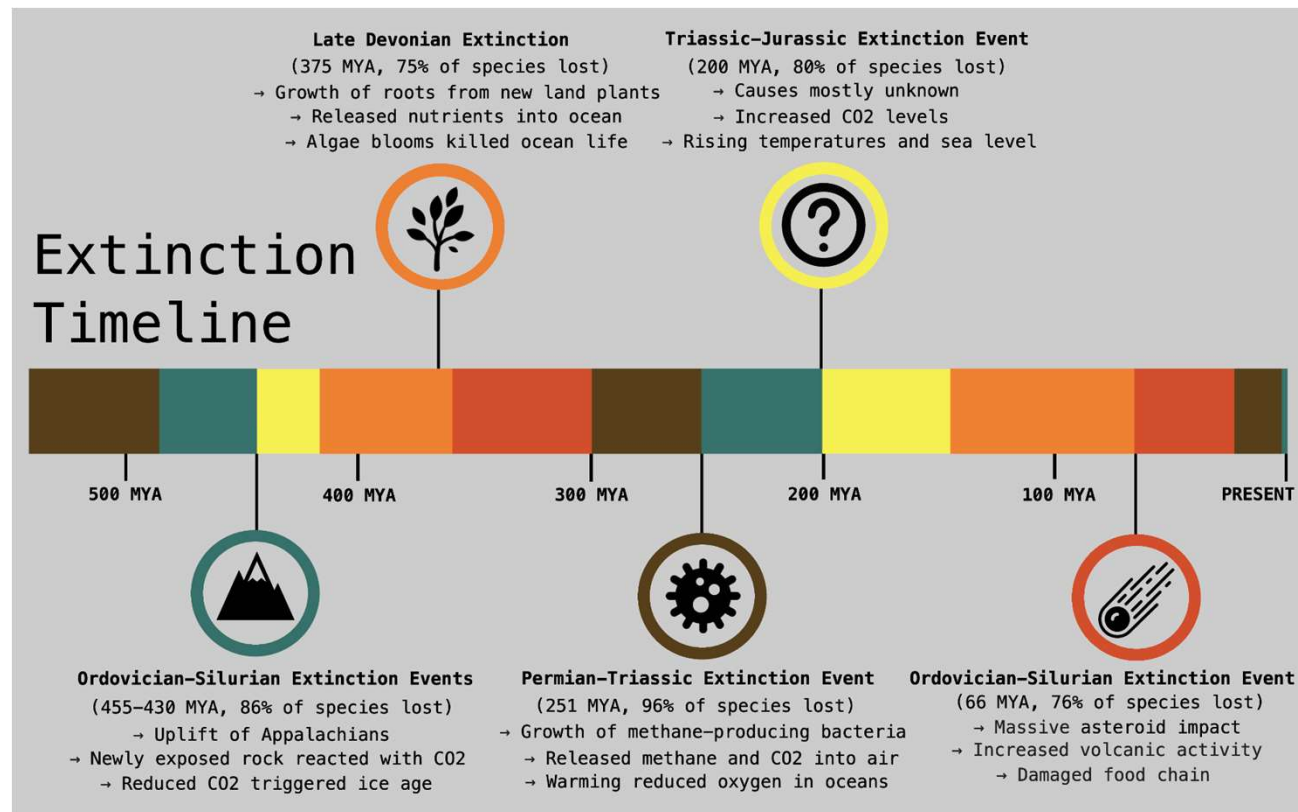
Mass extinctions

Diversity of marine animal families over geologic time



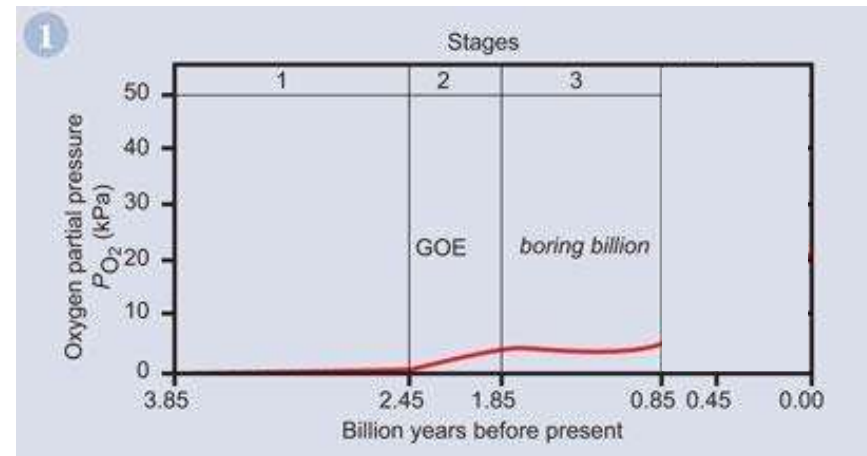
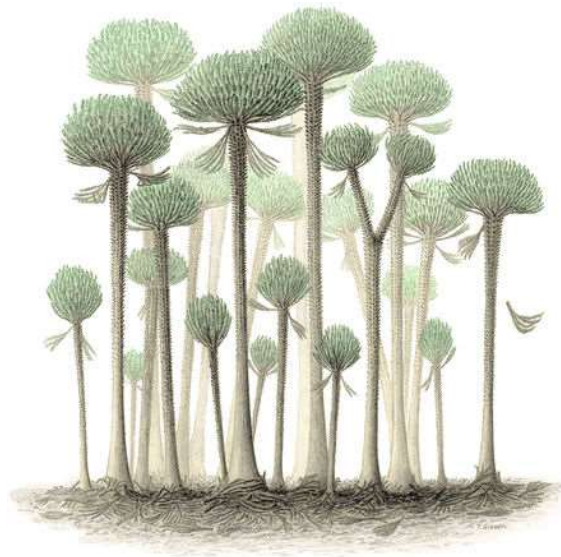
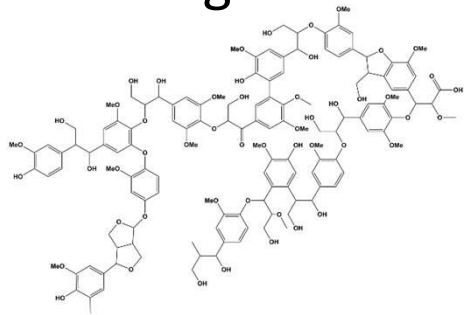
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Mass extinctions



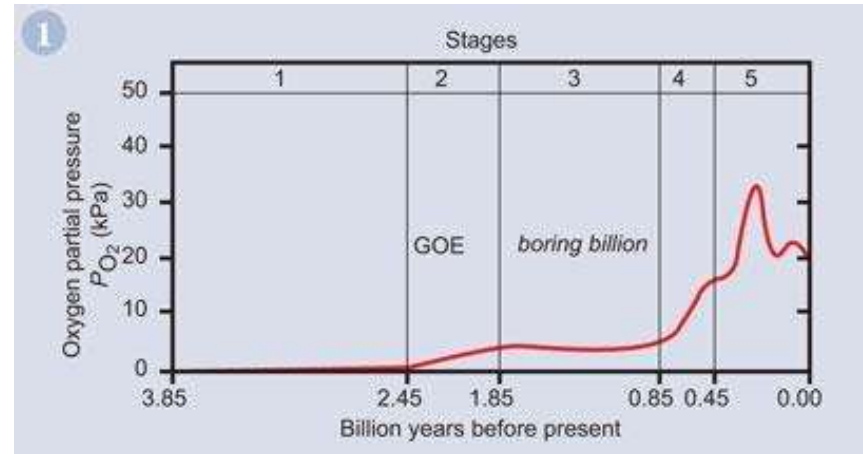
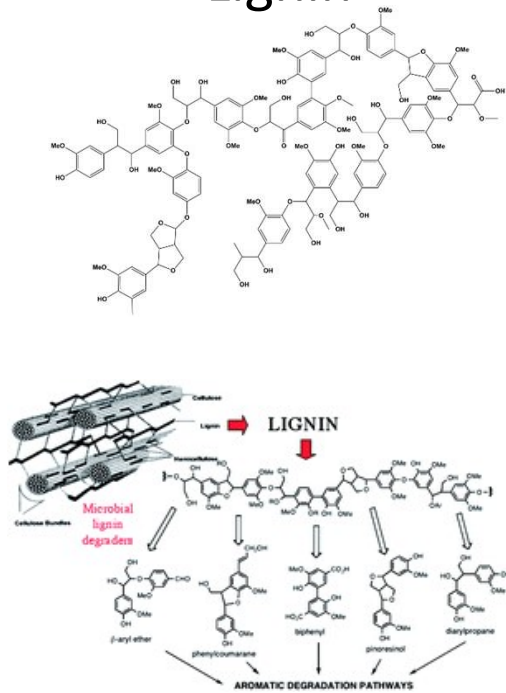
Oxygen

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



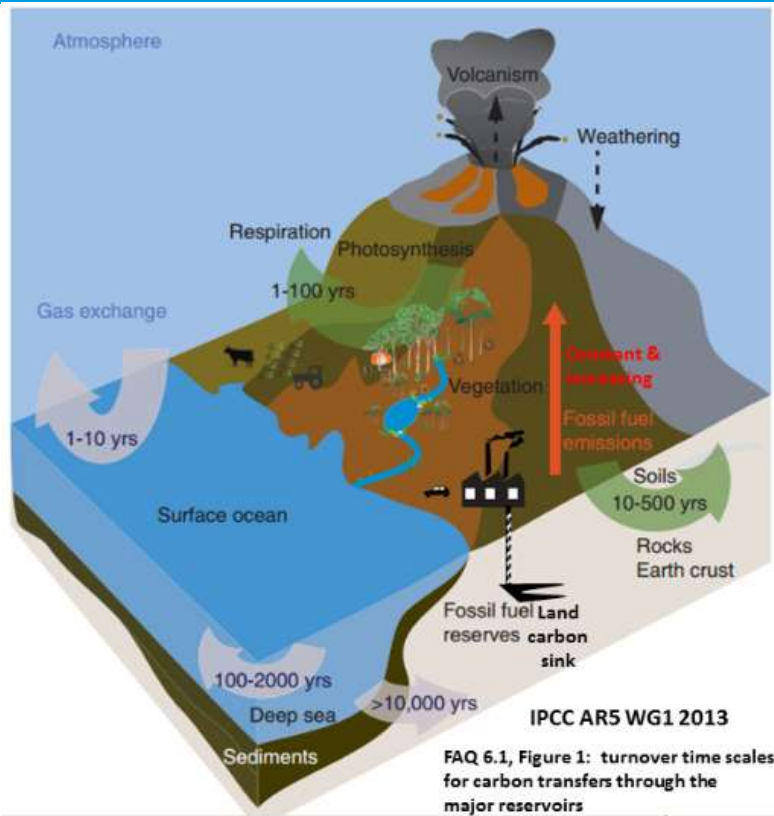
1 METER
3.2 FEET
EARLY DINOSAUR
EORAPTOR



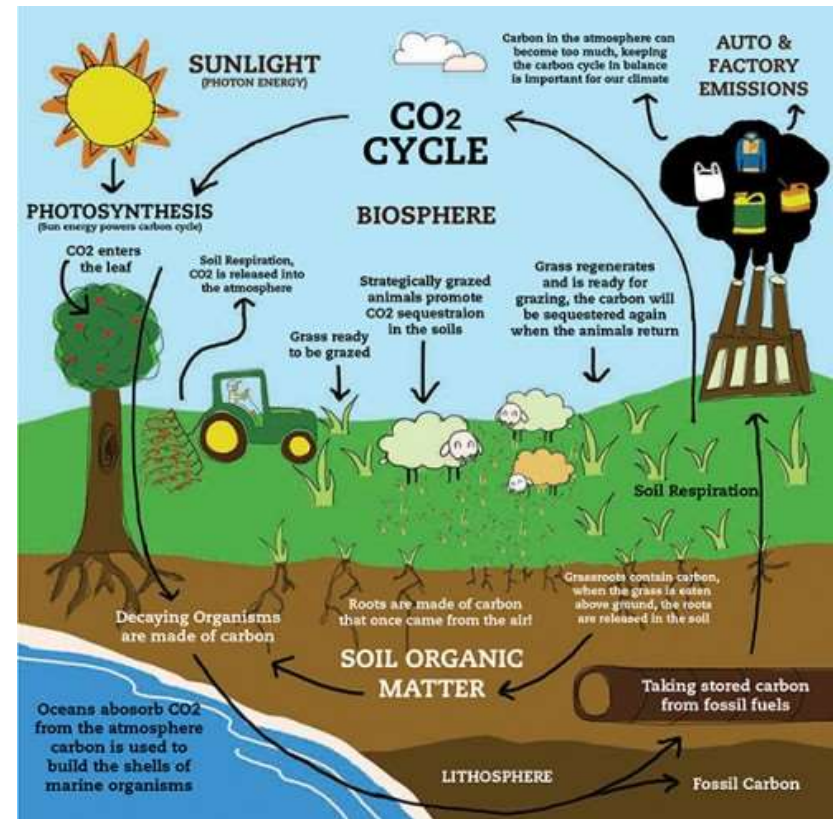
HUMAN
1.8 METERS
6 FEET

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

Carbon cycle




FAQ 6.1, Figure 1: turnover time scales for carbon transfers through the major reservoirs



www.tes.com/lessons/zF17nAR3qZM-cA/the-carbon-cycle

The Cosmic Calendar

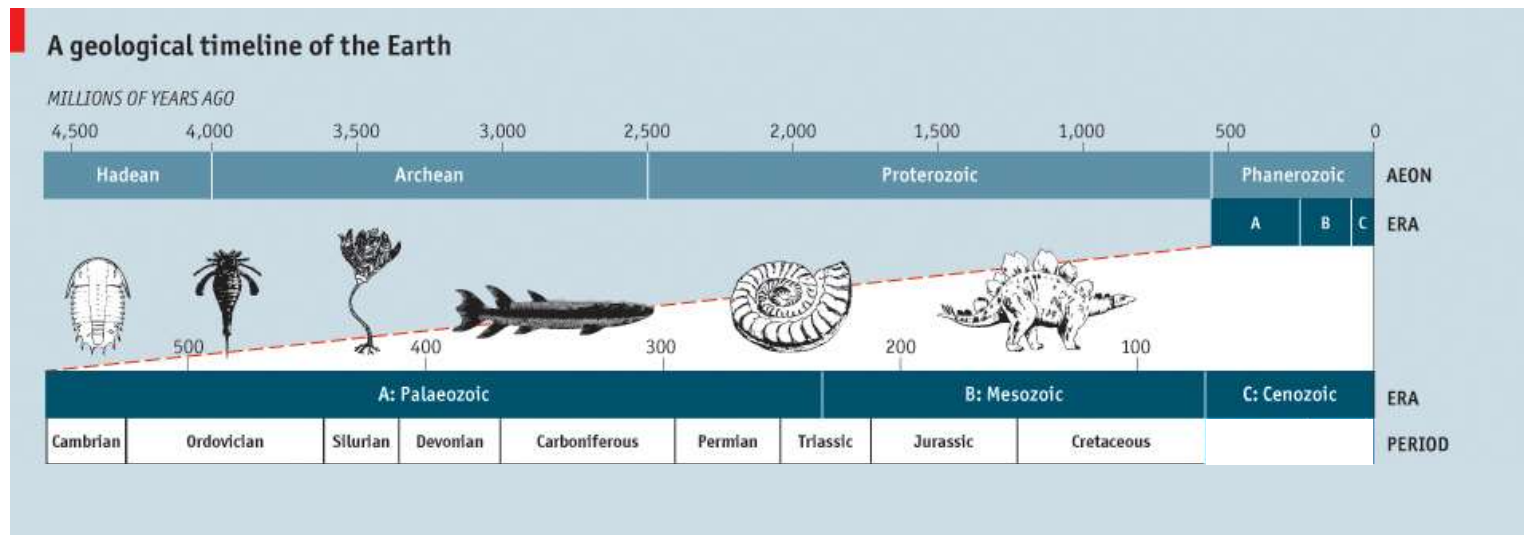
The 13.8 billion year history of the universe scaled down to a single year, where the Big Bang is January 1st at midnight, and right now is midnight 1 year later

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

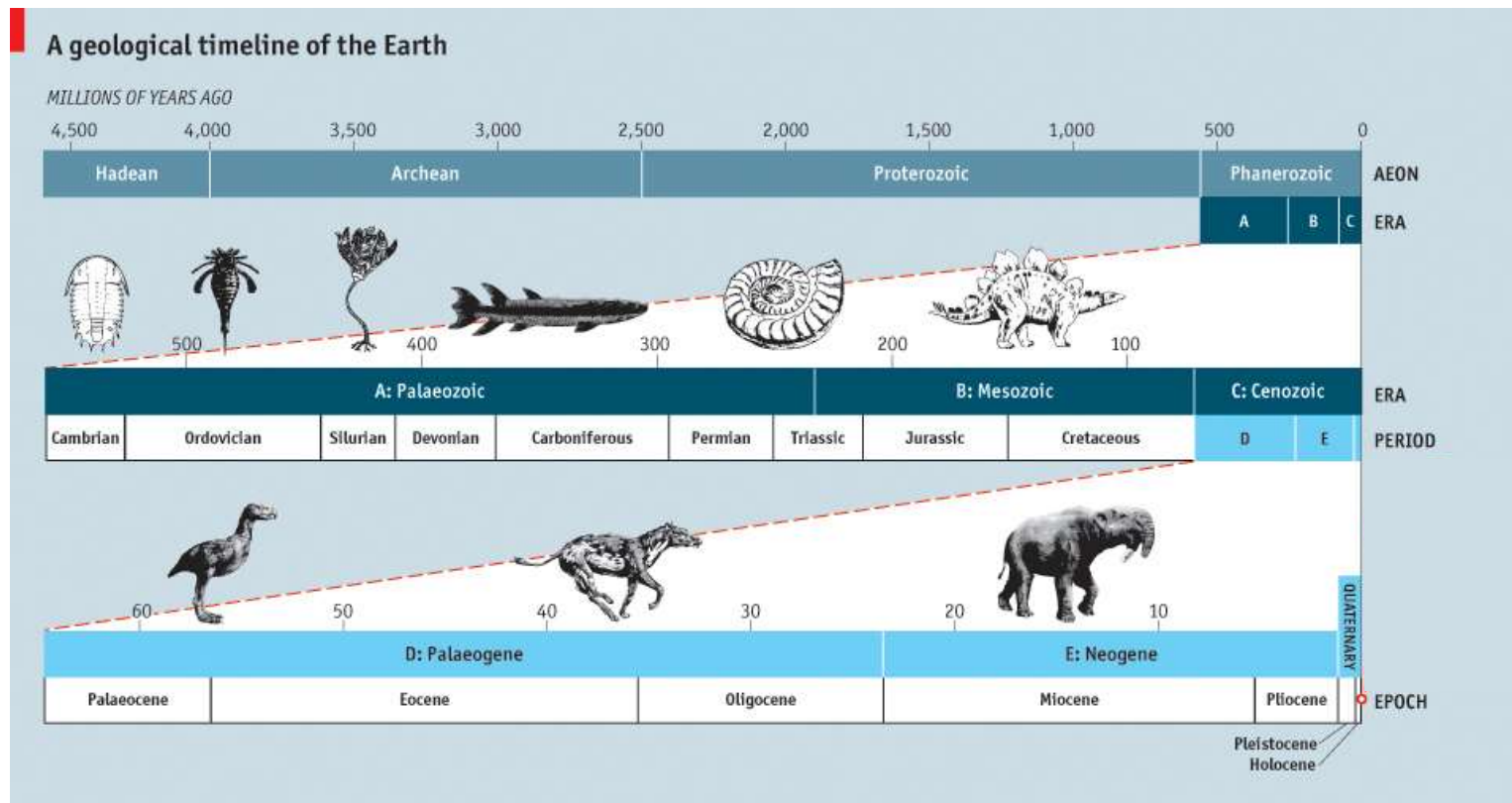
The Month of December...

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 Pangaëa 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...											

Phanerozoic

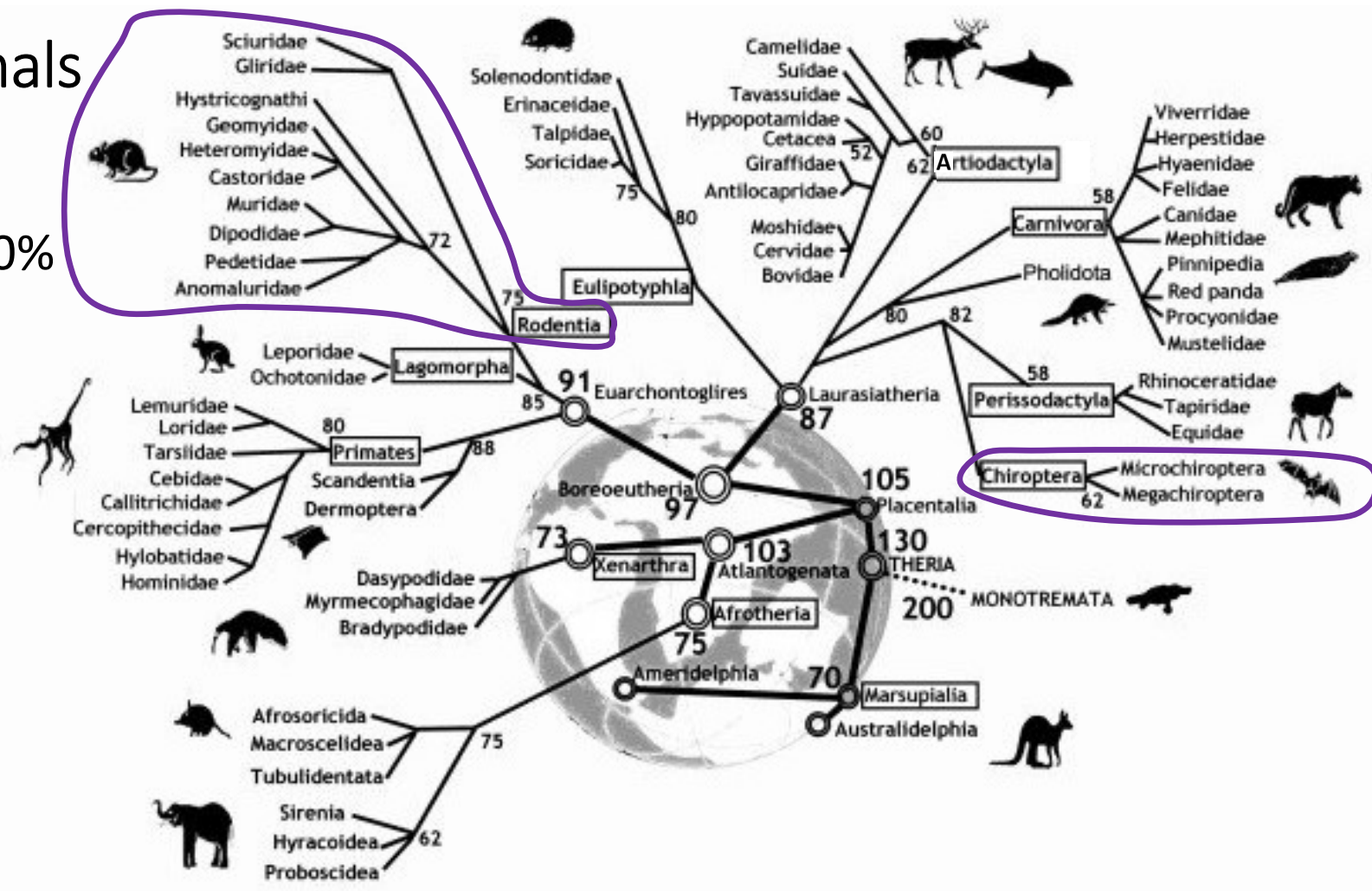


Cenozoic



Mammals

40%

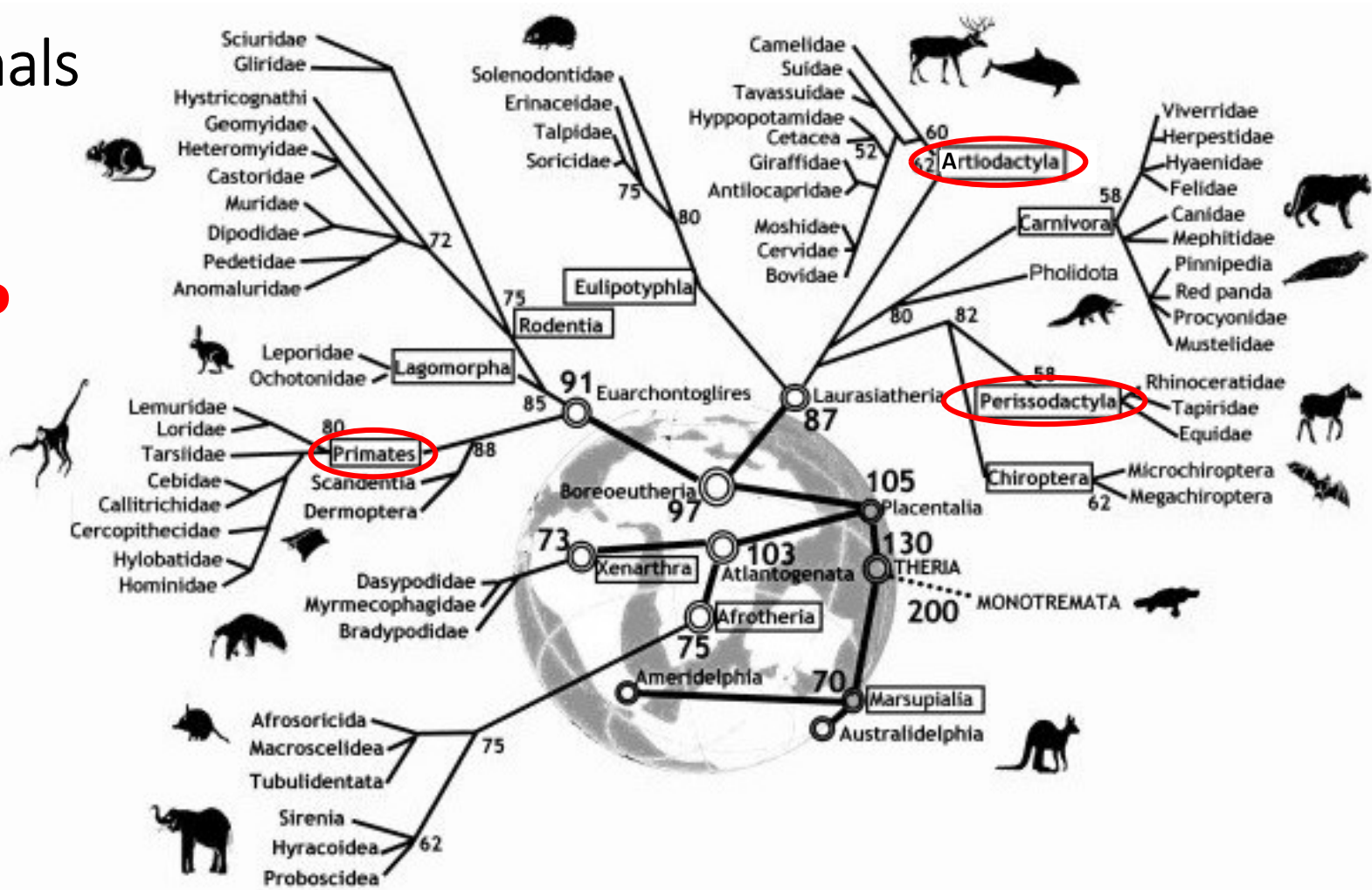


20%

www.researchgate.net/publication/51713113_The_genome_diversity_and_karyotype_evolution_of_mammals

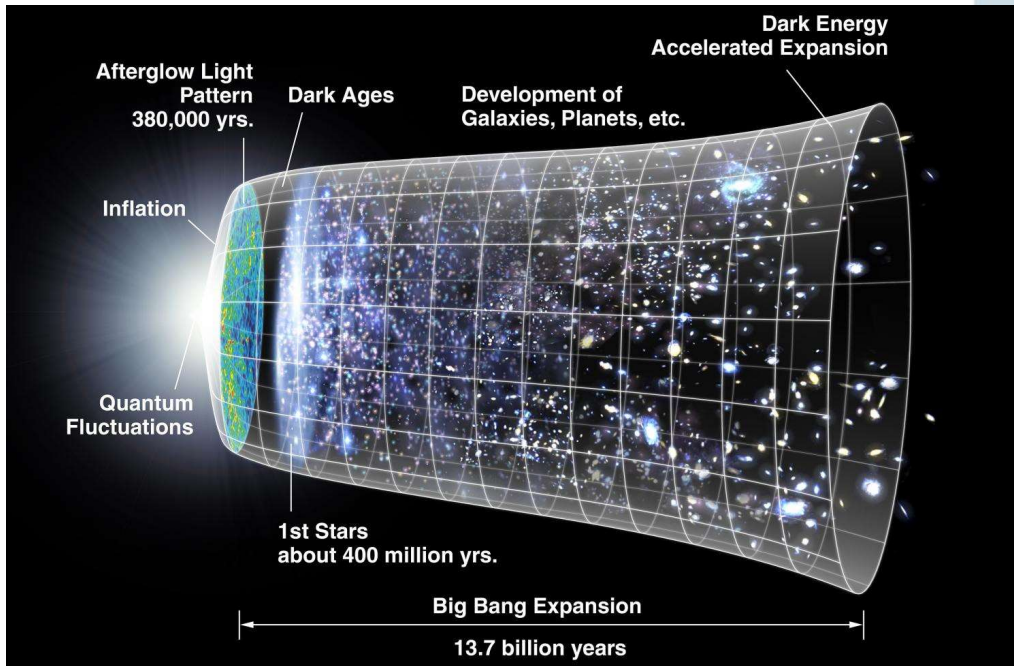
Mammals

APP

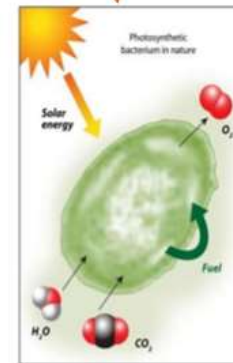
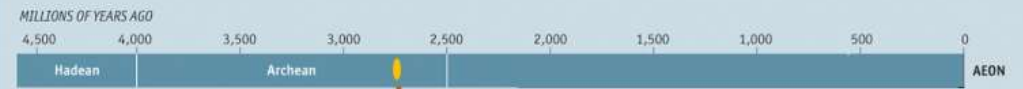


www.researchgate.net/publication/51713113_The_genome_diversity_and_karyotype_evolution_of_mammals

Cumulative dynamics → Phase transition

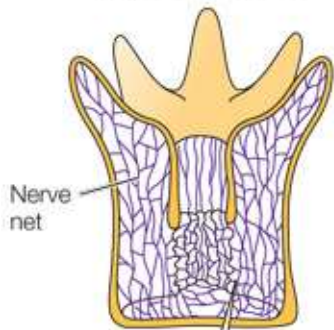


A geological timeline of the Earth



Nervous system

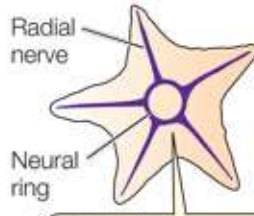
(1) Sea anenome



Nerve net

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

(2) Sea star

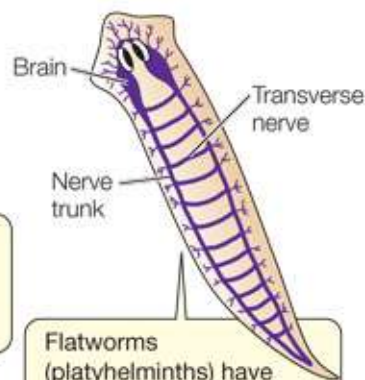


Radial nerve

Neural ring

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

(3) Flatworm



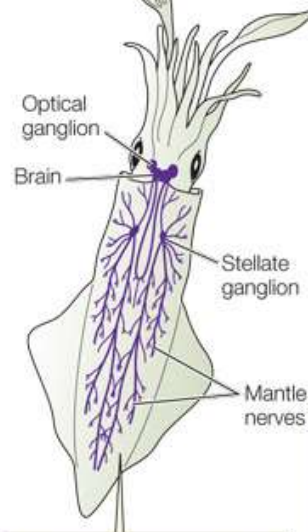
Brain

Nerve trunk

Transverse nerve

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



Optical ganglion

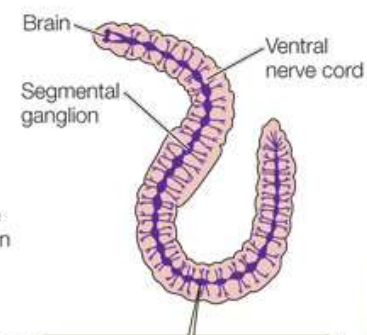
Brain

Stellate ganglion

Mantle nerves

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

(5) Earthworm



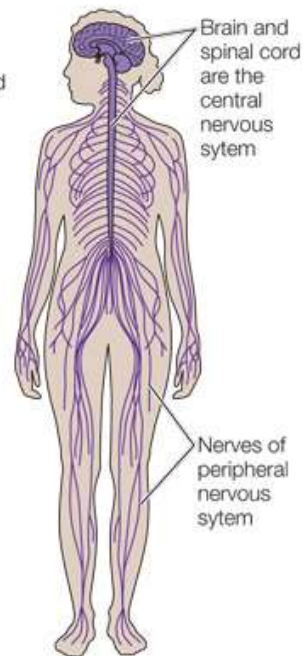
Brain

Segmental ganglion

Ventral nerve cord

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.

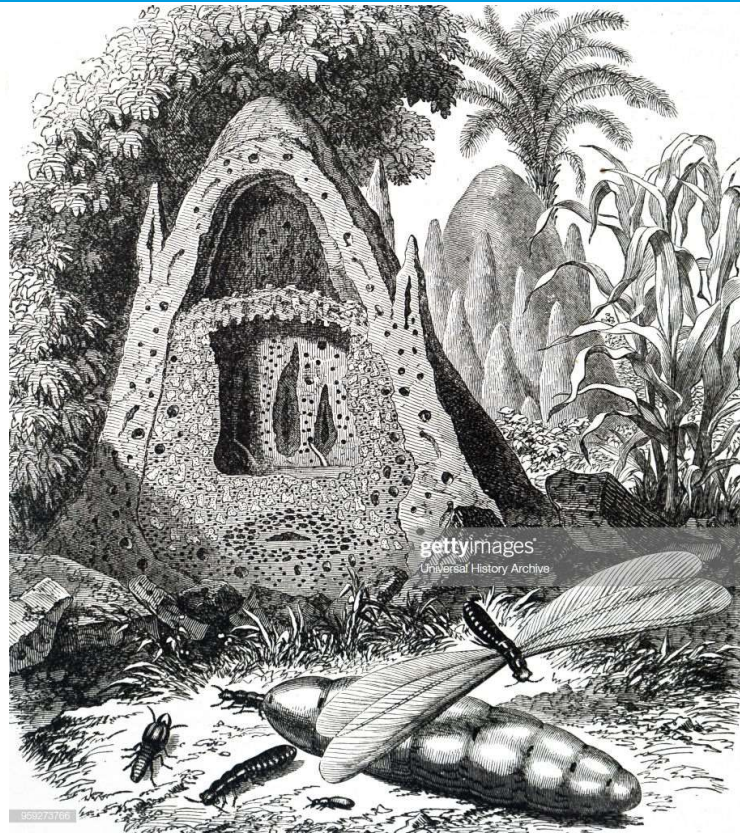
(6) Human



Brain and spinal cord are the central nervous system

Nerves of peripheral nervous system

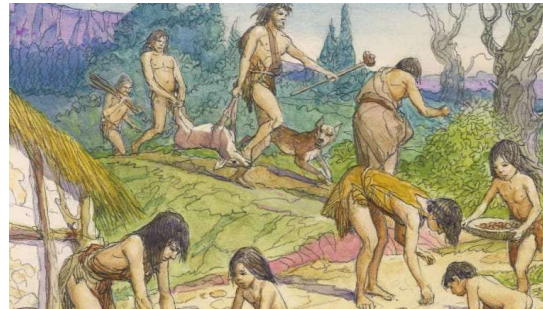
Animals



Stellate ganglion
Mantle nerves

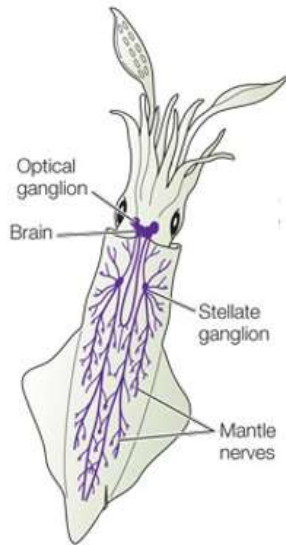
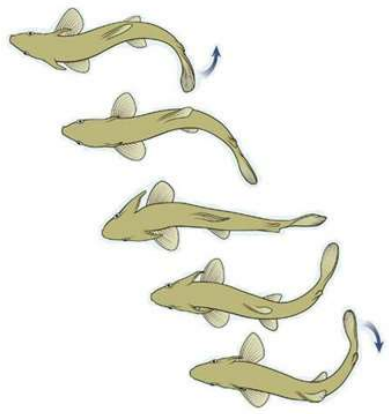


citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.136.2311



Eusociality





citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.136.2311



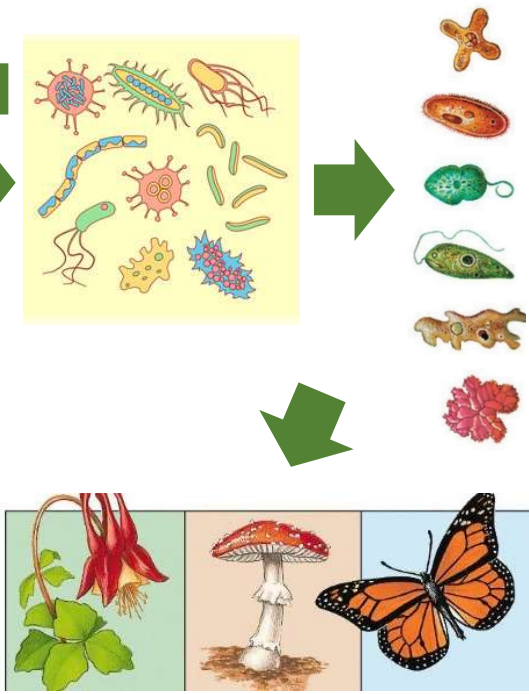
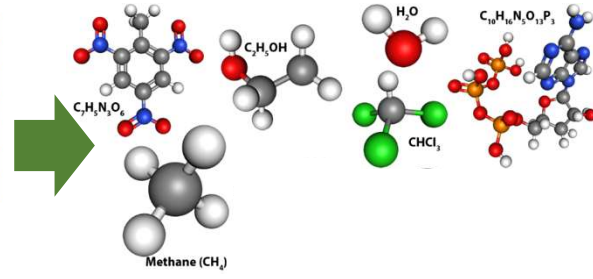
Kits of building blocks

Standard Model of Elementary Particles

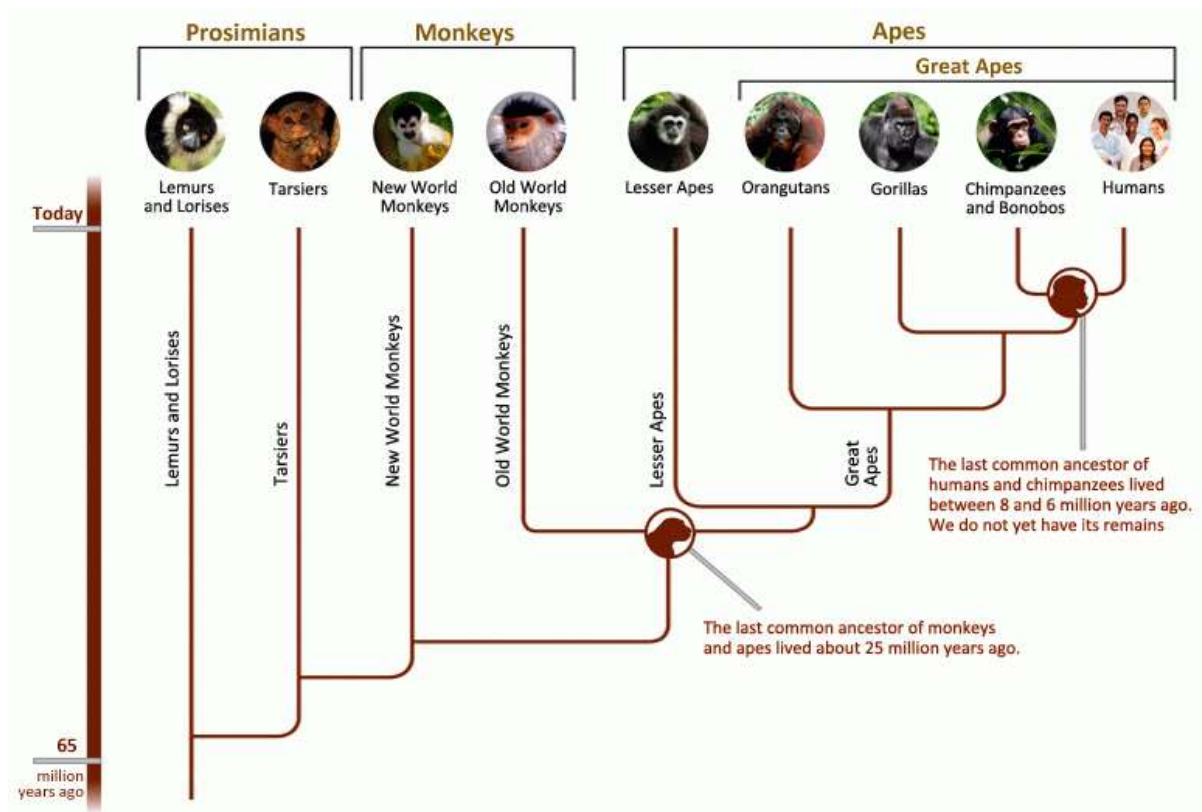
three generations of matter (fermions)			Interactions / force carriers (bosons)	
I	II	III	G	H
u up +2.2 MeV/c ²	c charm +1.28 GeV/c ²	t top +173.1 GeV/c ²	g gluon	H higgs +124.97 GeV/c ²
d down +4.7 MeV/c ²	s strange +98 MeV/c ²	b bottom +4.18 GeV/c ²	γ photon	
e electron +0.511 MeV/c ²	μ muon +105.66 MeV/c ²	τ tau +1.7768 GeV/c ²	Z Z boson +91.187 GeV/c ²	
ν _e electron neutrino +0.1 MeV/c ²	ν _μ muon neutrino +0.17 MeV/c ²	ν _τ tau neutrino +1.82 MeV/c ²	W W boson +80.385 GeV/c ²	

QUARKS: u, c, t, d, s, b
 LEPTONS: e, μ, τ, ν_e, ν_μ, ν_τ
 GAUGE BOSONS: g, γ, Z, W
 SCALAR BOSONS: H

Periodic Table of the Elements



Primates







Homo

The Cosmic Calendar

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

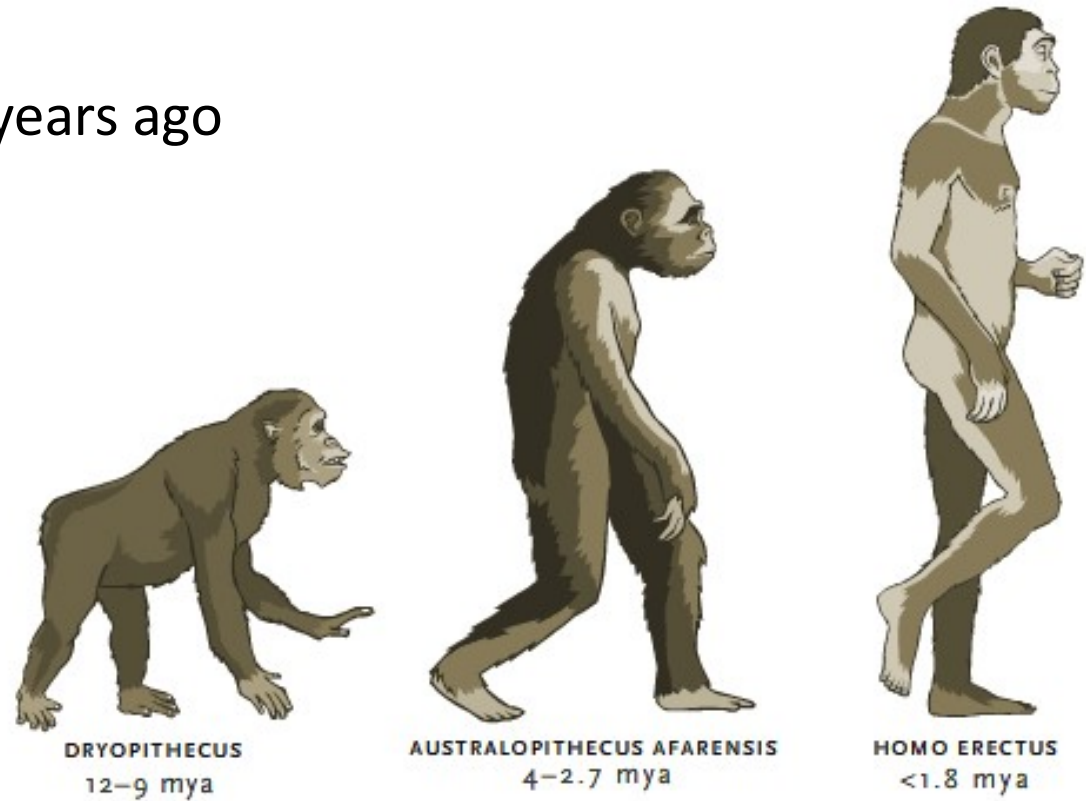
January	February	March	April	May	June	July	August	September	October	November	December
 Known from telescopes looking back in time, physical models					 Known from geologic record, fossils, genetic drift						
The Big Bang, Stars First Appear				Thin Disk of the Milky Way				The Solar System, Life	Oxygen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

The Month of December...

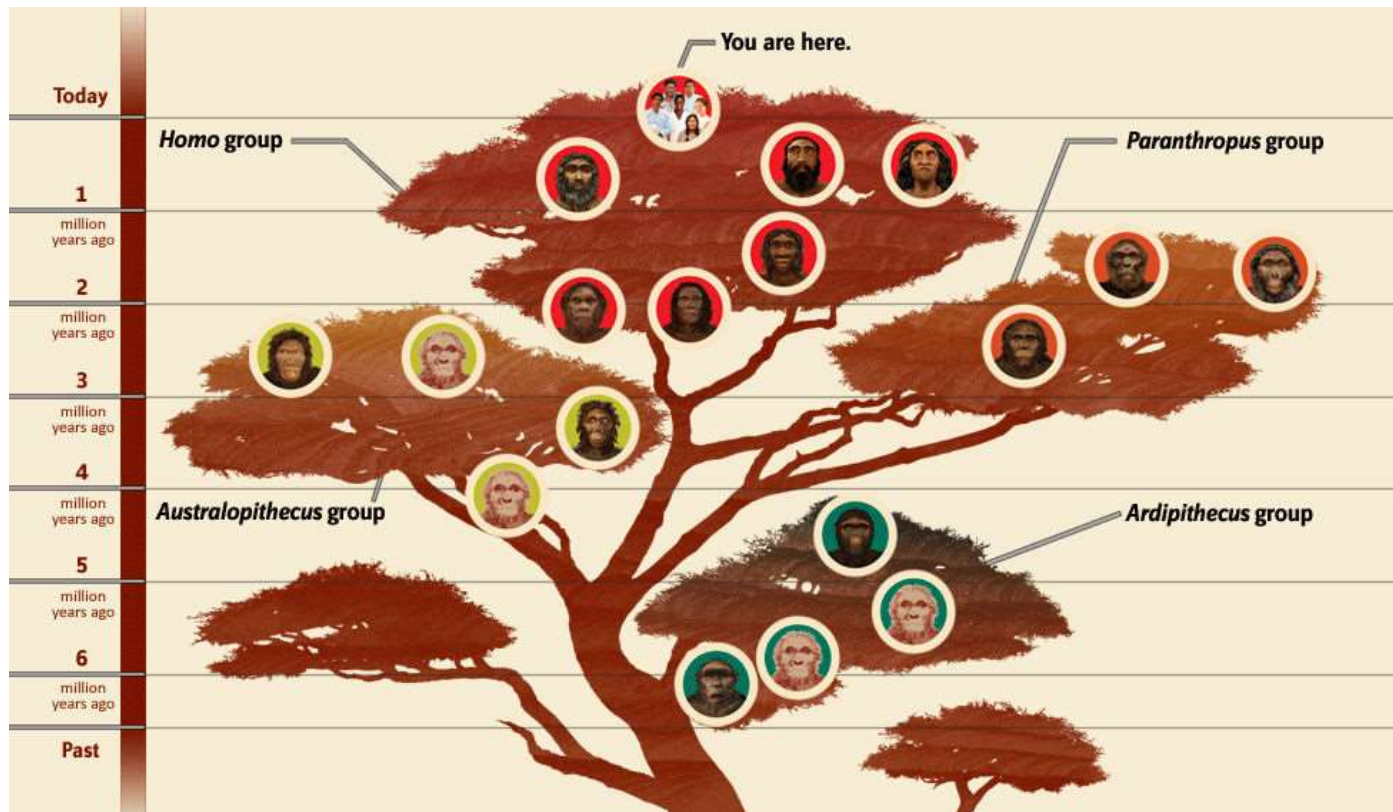
1	2	3	4	5	6	7	8	9	10	11	12	13	14
15 Trace Fossils Only	16		17 Bones and Shells		18 Vertebrates		19 Land Plants		20 Fish with Jaws		21 Insects		
22 Amphibians	23 Reptiles		24 Pangaëa Forms		25 Dinosaurs		26 Mammals		27 Birds		28 Flowers		
29 Tyrannosaurids	30 Dinosaurs Extinct, Mammals Take Over on Land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

Important Human Transitions

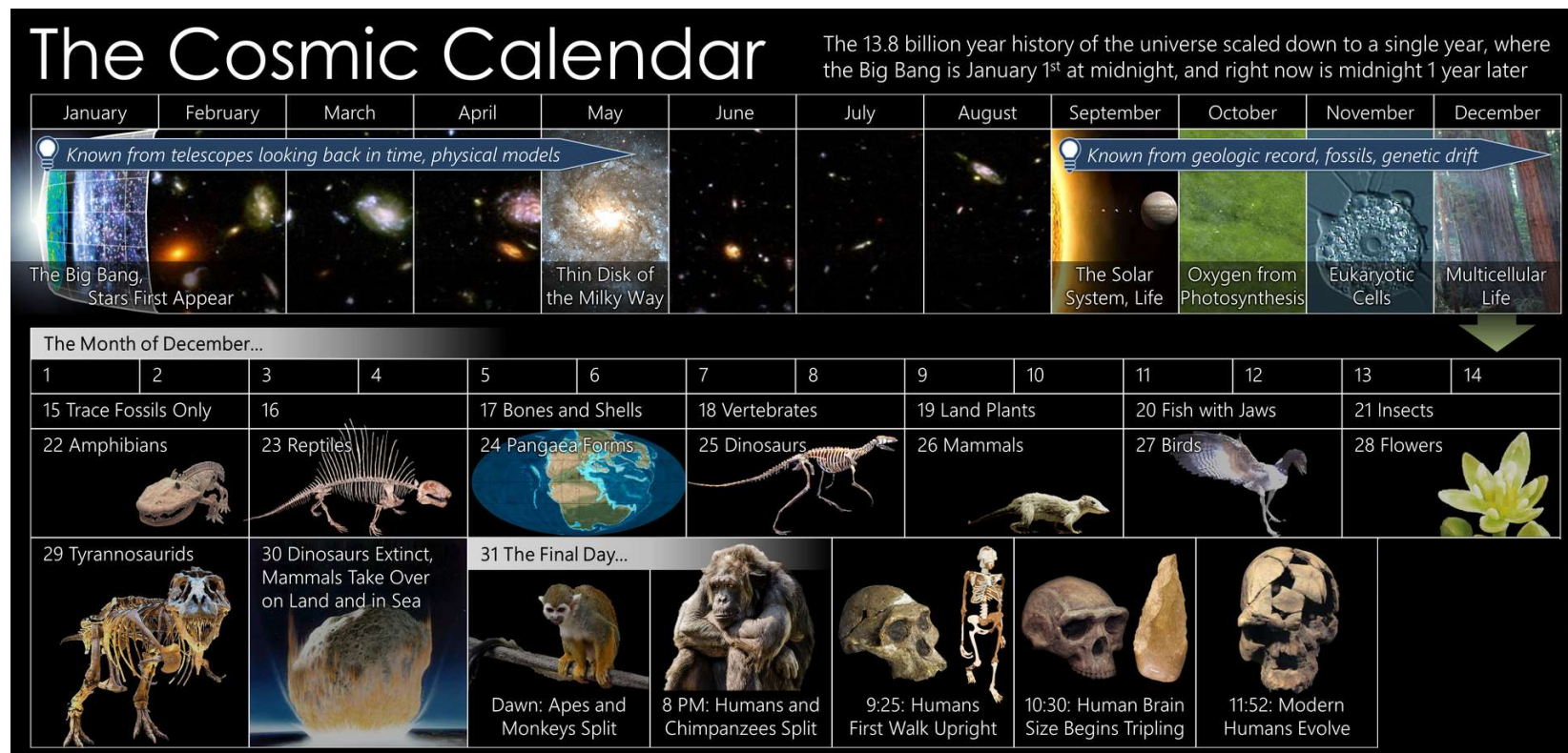
Bipedalism 7 million years ago

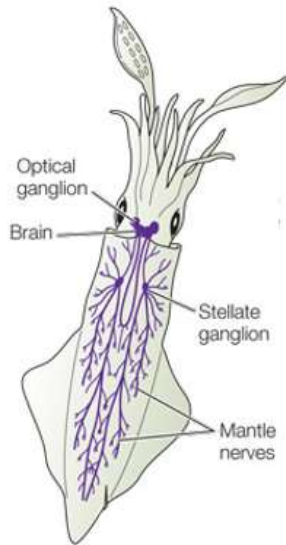
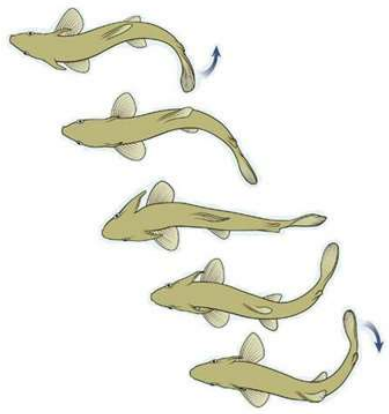


Homo

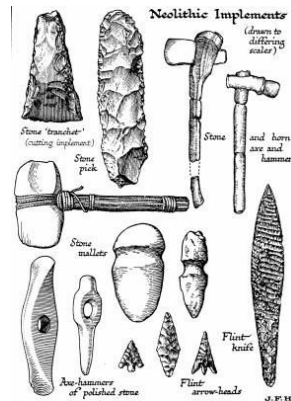


Homo sapiens





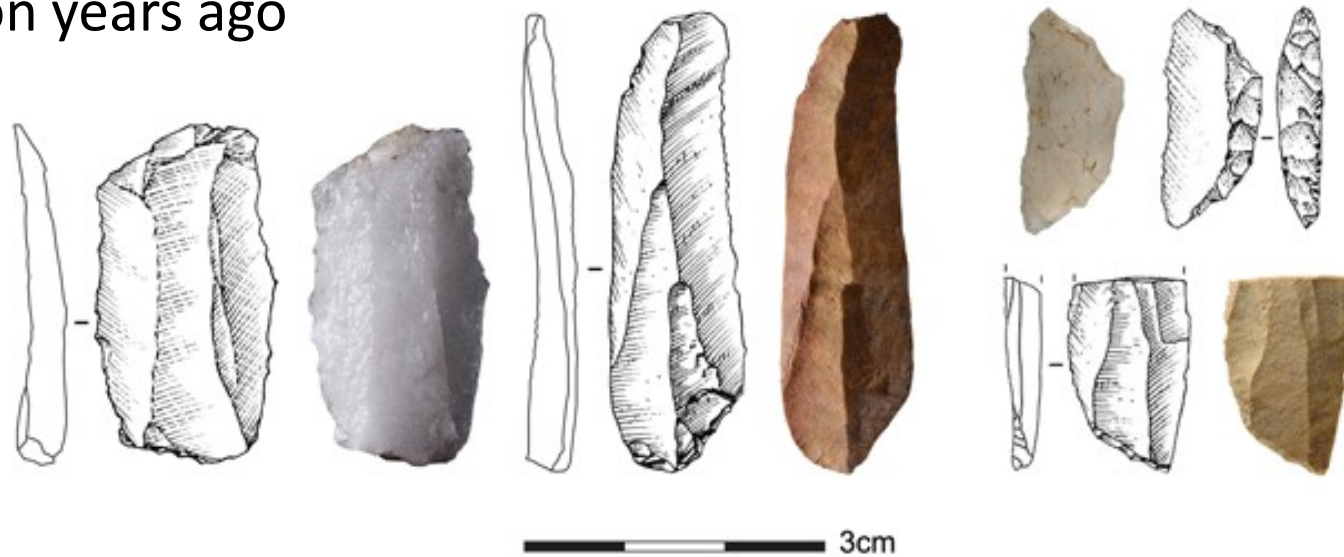
citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.136.2311



Important Human Transitions

Bipedalism 7 million years ago

Stone tools 3.3 million years ago



Tools



Tools



Life

Natural selection

- Replication (with errors)
- Finite resources

Energy + Mental space
+
Mass (building blocks)

Cultural evolution

Natural selection

- Replication (with errors)
- Finite resources

Energy + Mental space
+
Mass (building blocks)

Helmets

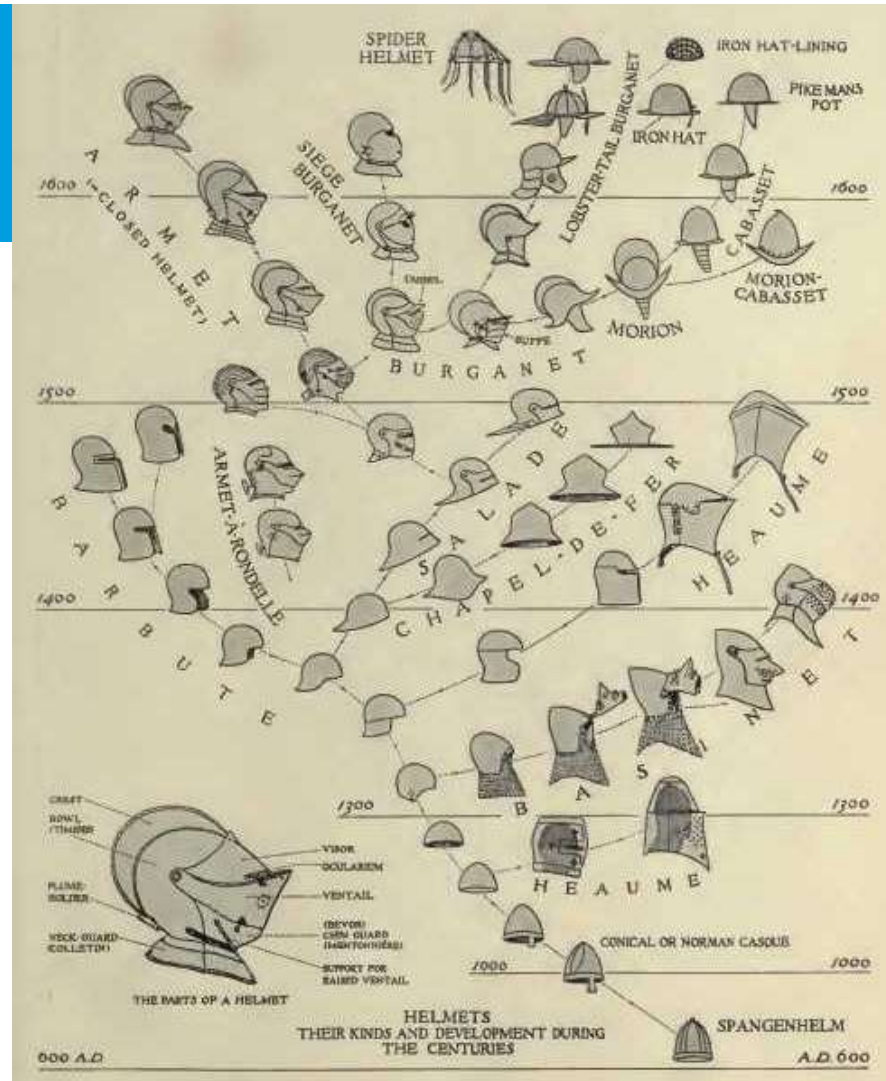
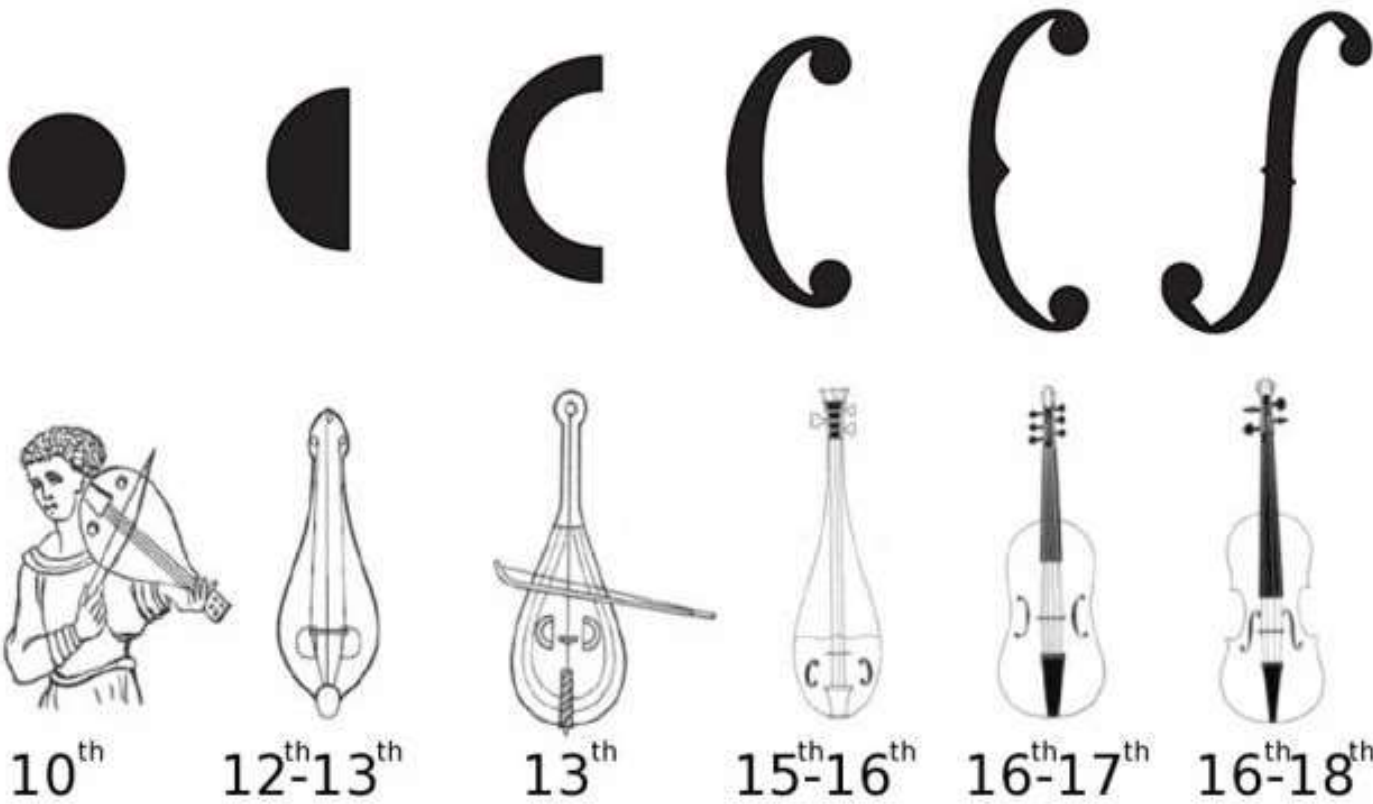


Diagram of helmet evolution, Bashford Dean, 1915

Violins



Collective learning



Collective learning



Culture

Cultural forgetting

Collective learning

Information

Disinformation



The Cosmic Calendar

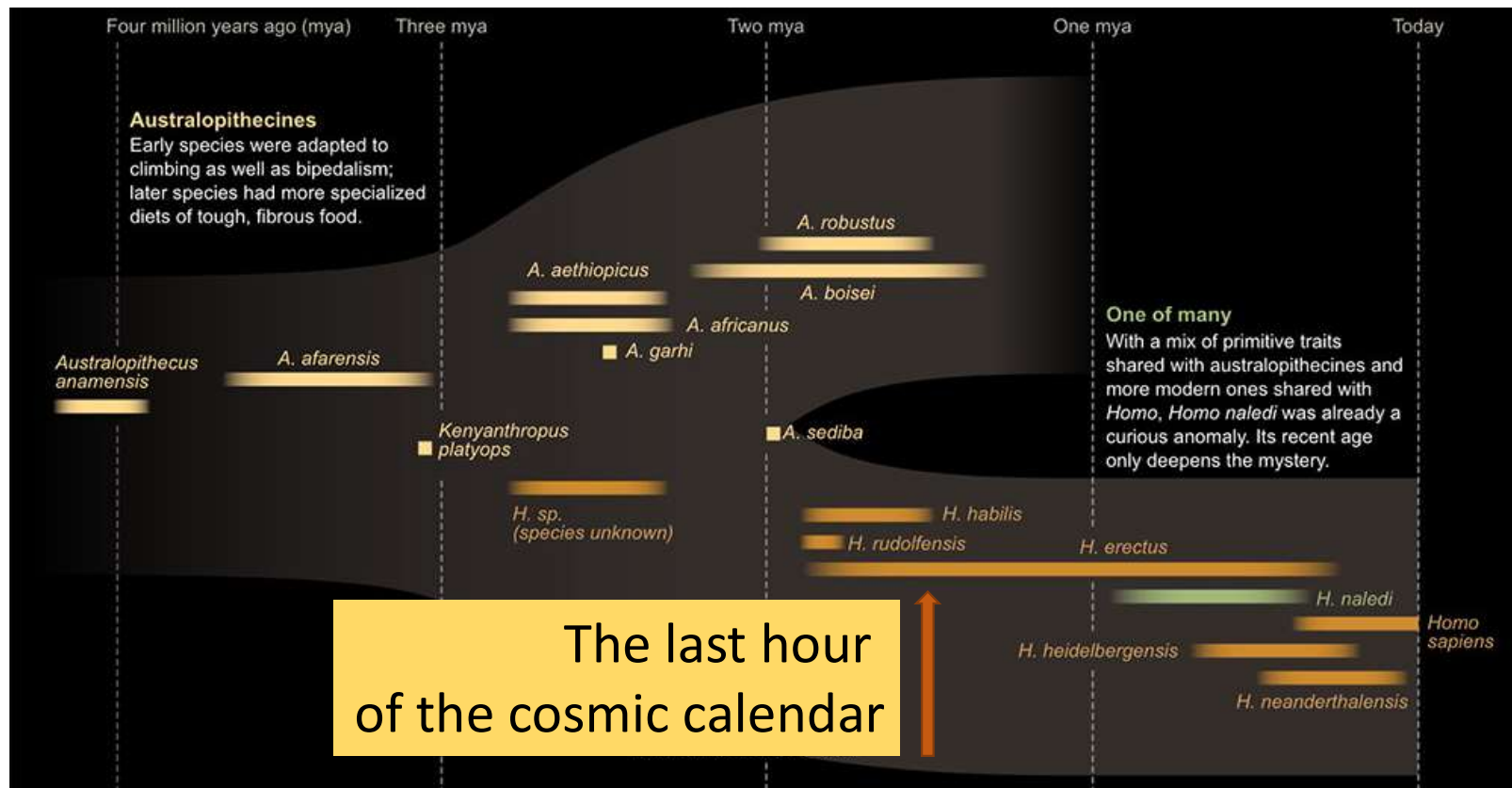
The 13.8 billion year history of the universe scaled down to a single year, where the Big Bang is January 1st at midnight, and right now is midnight 1 year later

January	February	March	April	May	June	July	August	September	October	November	December
 Known from telescopes looking back in time, physical models								 Known from geologic record, fossils, genetic drift			
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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 Pangaëa 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...		Dawn: Apes and Monkeys Split		8 PM: Humans and Chimpanzees Split		9:25: Humans First Walk Upright		10:30: Human Brain Size Begins Tripling	

Homo

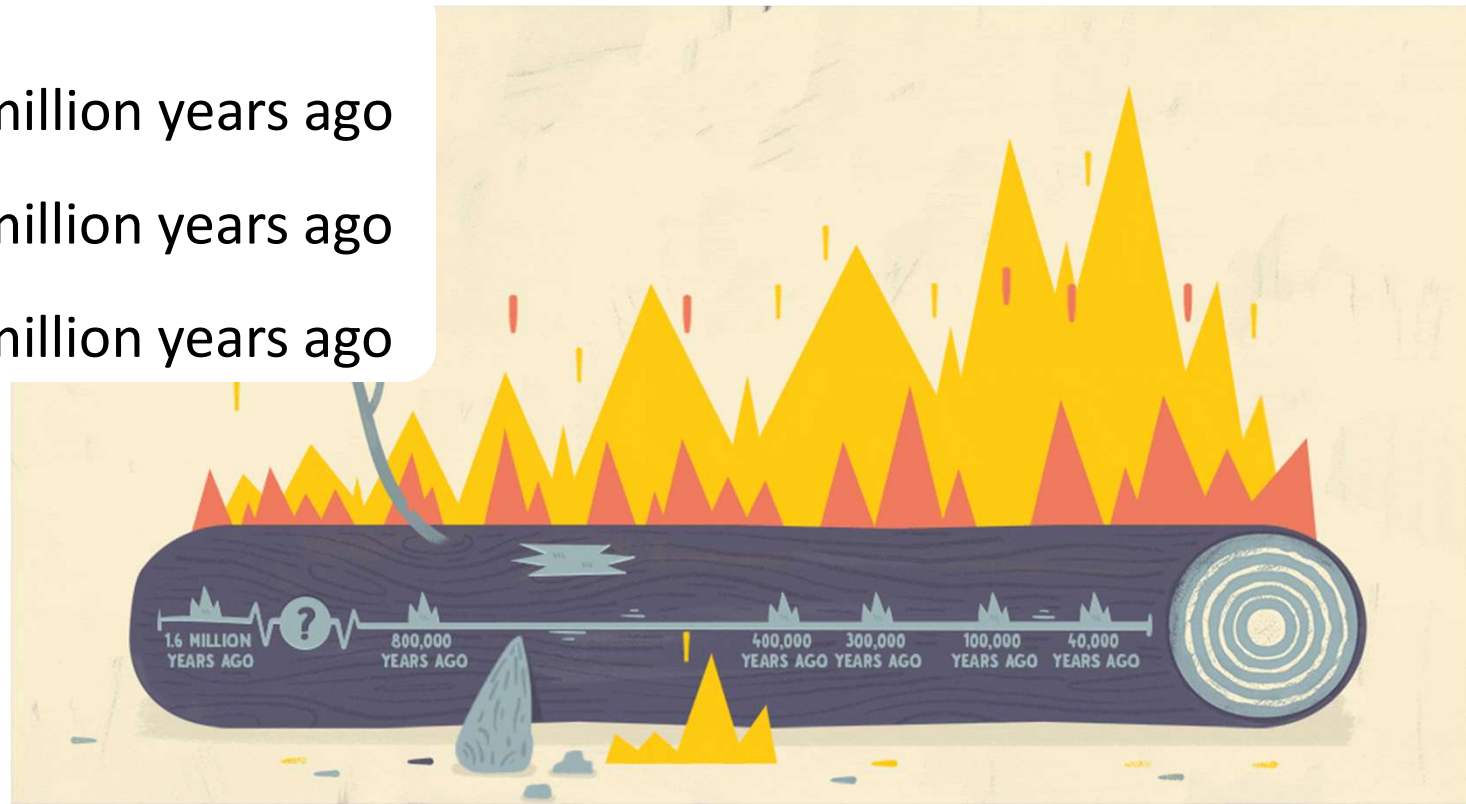


Important Human Transitions

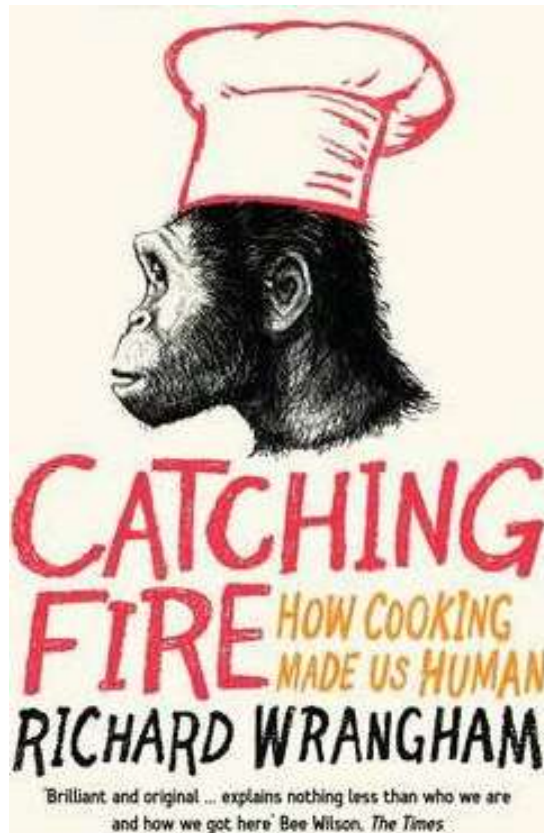
Bipedalism 7 million years ago

Stone tools 3.3 million years ago

Use of Fire 1.3 million years ago



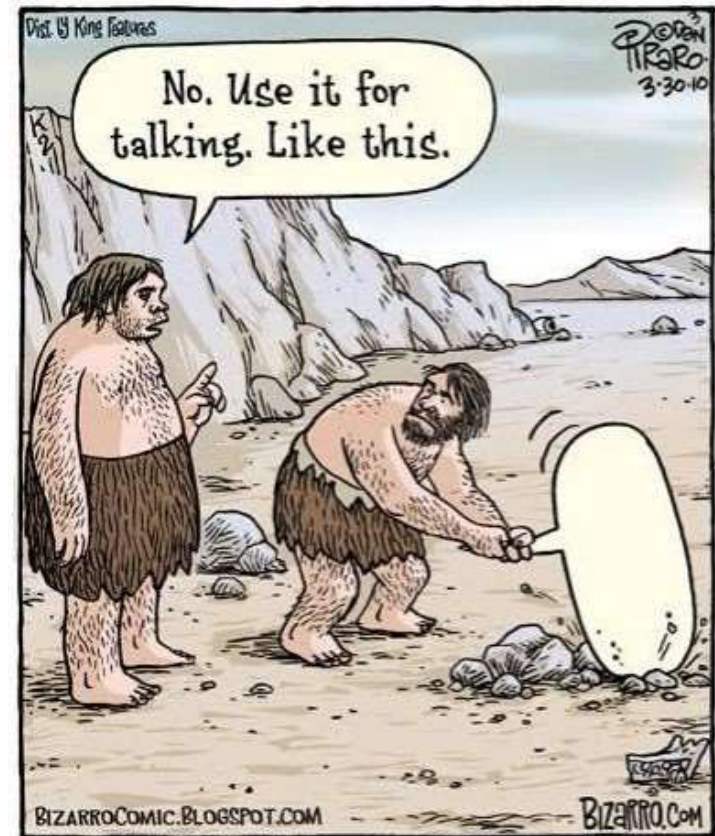
Cooking



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

Important Human Transitions

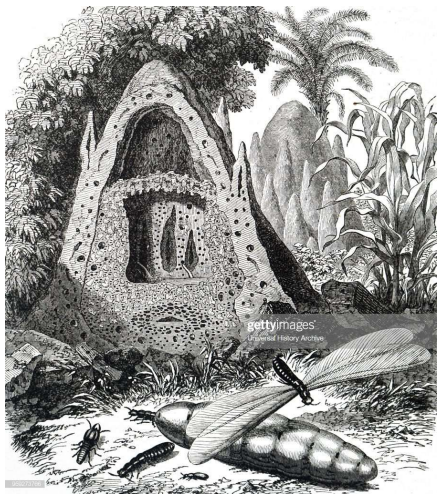
Bipedalism	7 million years ago
Stone tools	3.3 million years ago
Use of Fire	1.3 million years ago
Language	



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

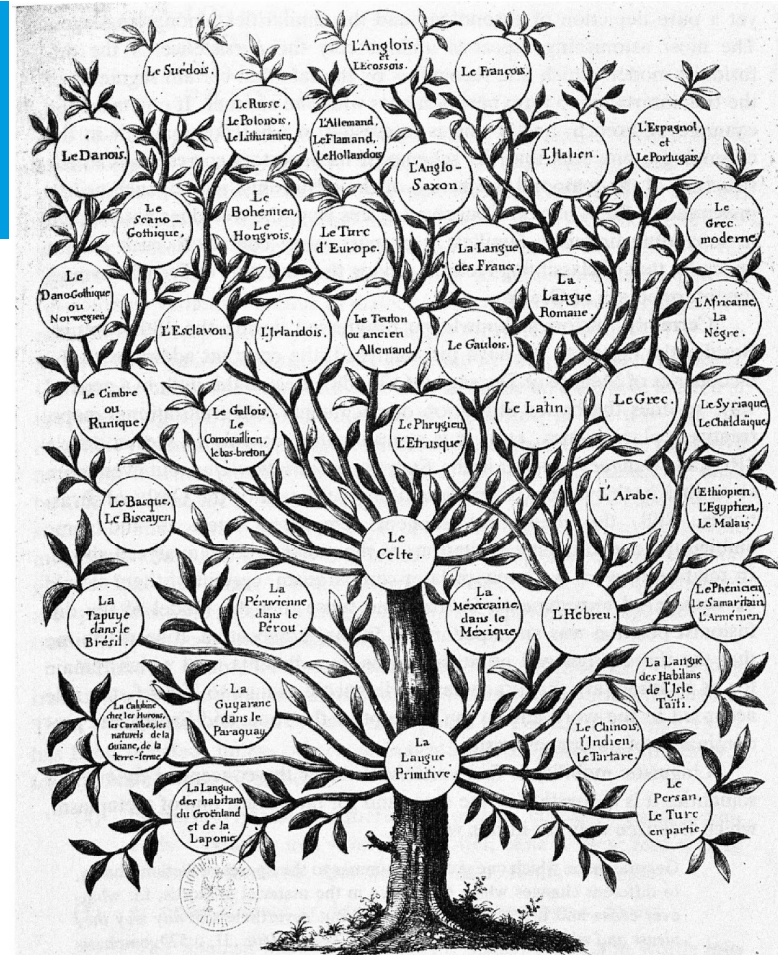
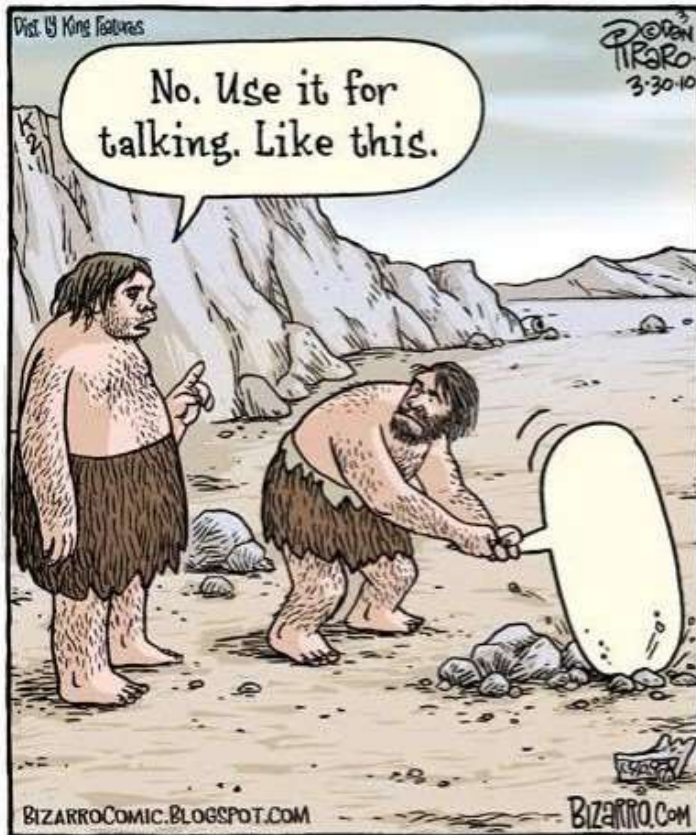
New ability	Wider consequences
The ability to transmit larger quantities of information about the surrounding world	Planning and carrying out complex actions, such as avoiding lions and hunting bison
The ability to transmit larger quantities of information about social relationships	Larger and more cohesive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

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

Language



ARBRE GÉNÉALOGIQUE
des Langues mortes et vivantes.

Arbre d'après les Principes de l'Arbre du Monde Trinité sur la Génération des Langues.

DÉDIÉ A MONSIEUR L'ABBÉ SICARD.

à l'Institut des Sourds-Muets, Membre de l'Institut National, Par Félix Gallot, & G. Grélier Sculpt.

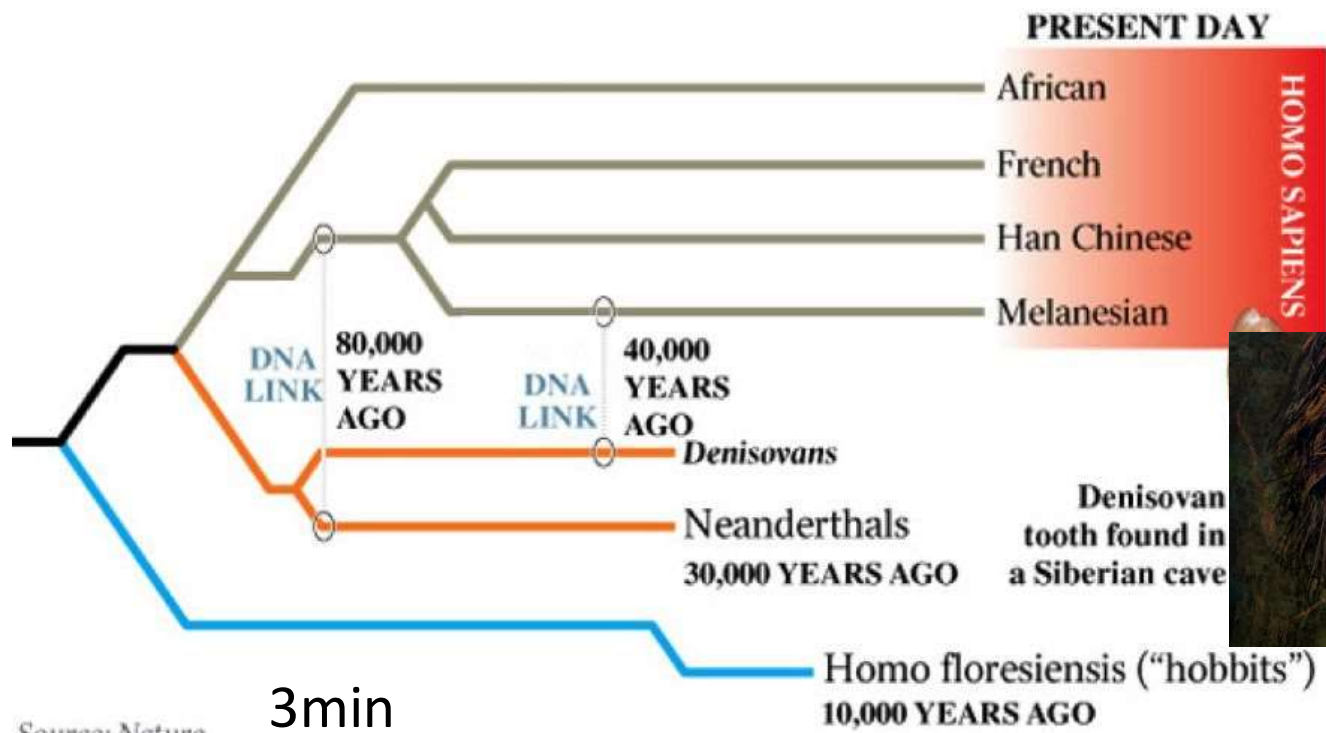
Important Human Transitions

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

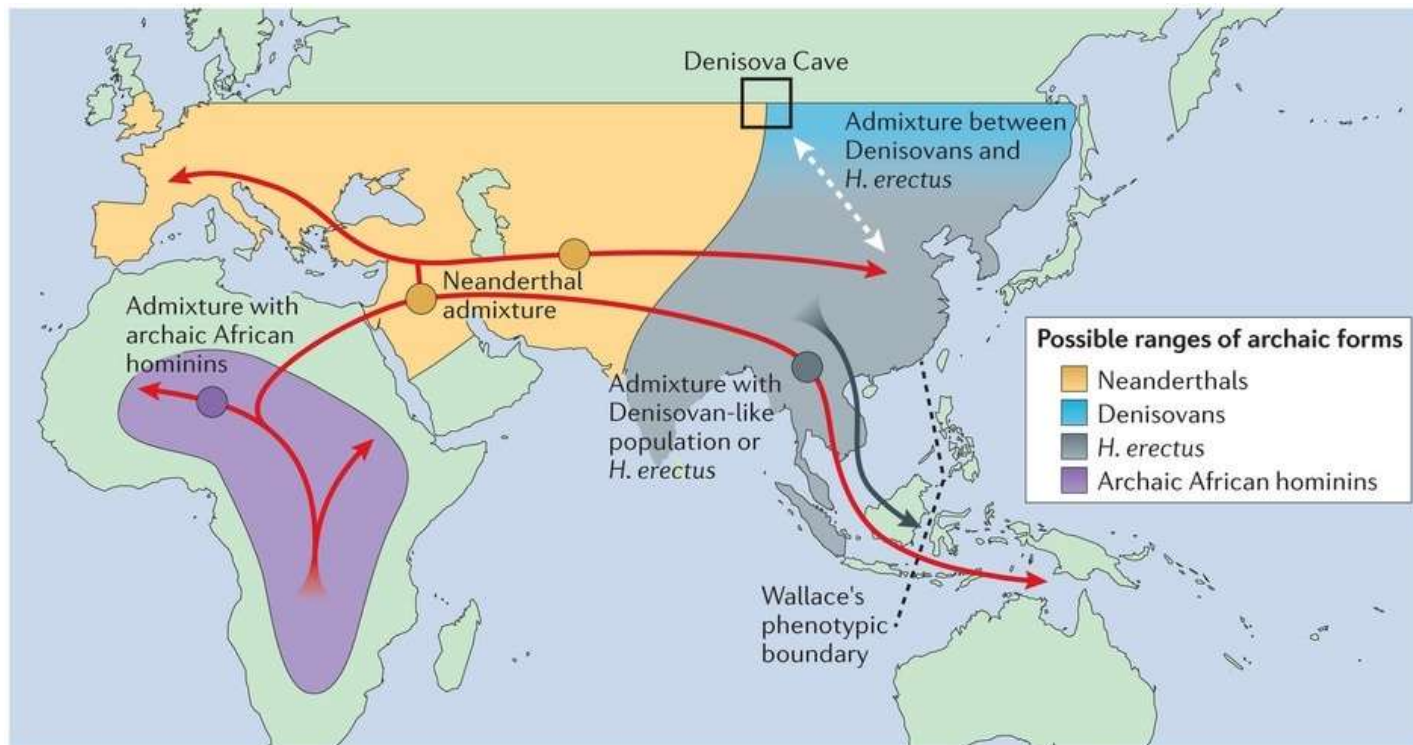
4min



Homo

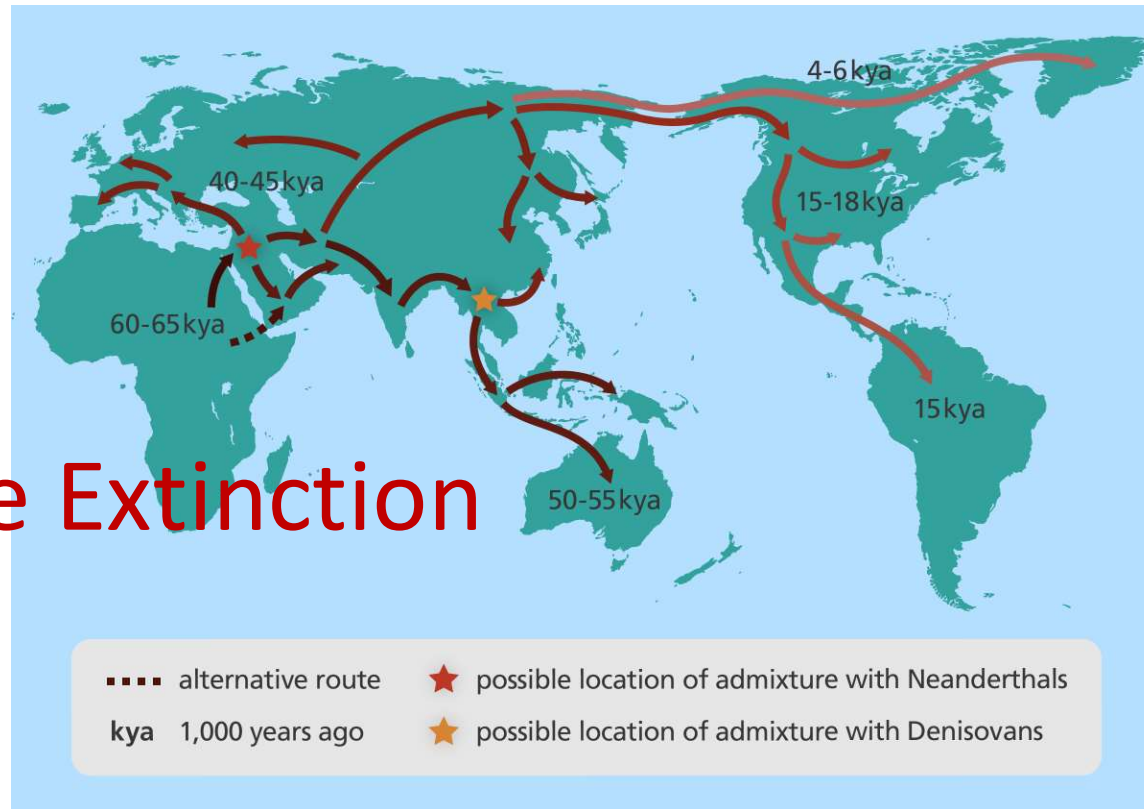


Homo



Nature Reviews | Genetics

Early human migrations



First Wave Extinction

Early human migrations



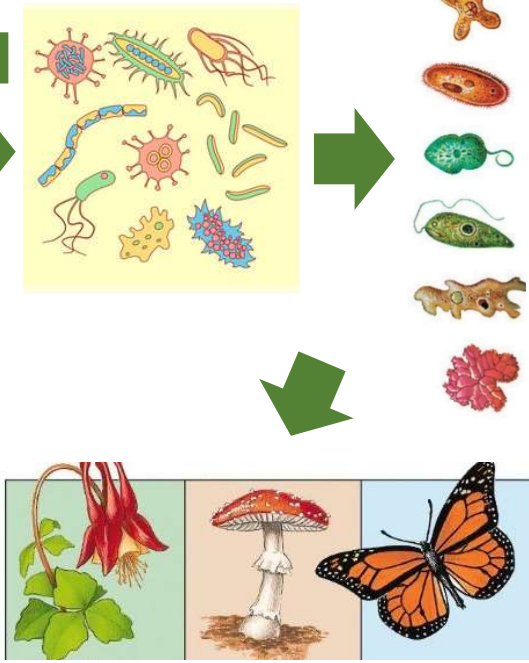
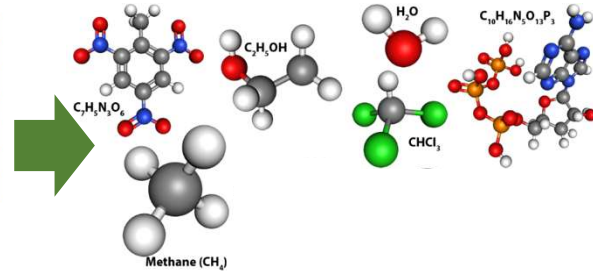
Kits of building blocks

Standard Model of Elementary Particles

three generations of matter (fermions)			Interactions / force carriers (bosons)	
I	II	III	0	1
u up	c charm	t top	g gluon	H higgs
d down	s strange	b bottom	γ photon	
e electron	μ muon	τ tau	Z Z boson	
ν _e electron neutrino	ν _μ muon neutrino	ν _τ tau neutrino	W W boson	

QUARKS (up, down, charm, strange, top, bottom)
LEPTONS (electron, muon, tau, electron neutrino, muon neutrino, tau neutrino)
GAUGE BOSONS / VECTOR BOSONS (photon, Z boson, W boson)
SCALAR BOSONS (higgs)

Periodic Table of the Elements

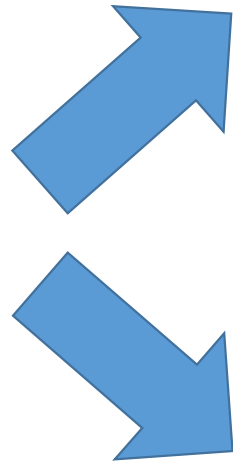
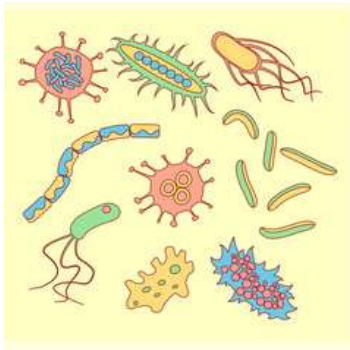


?



Organisms

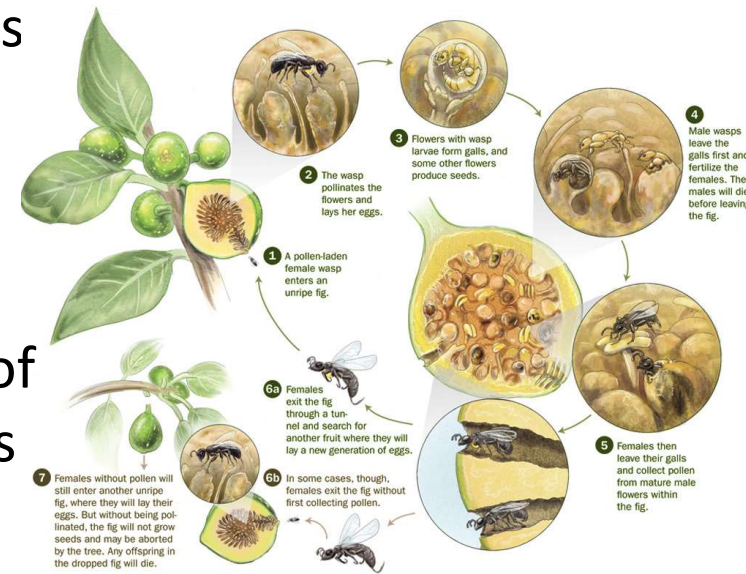
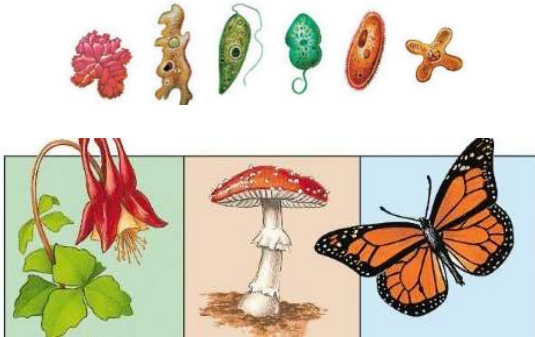
Prokaryote



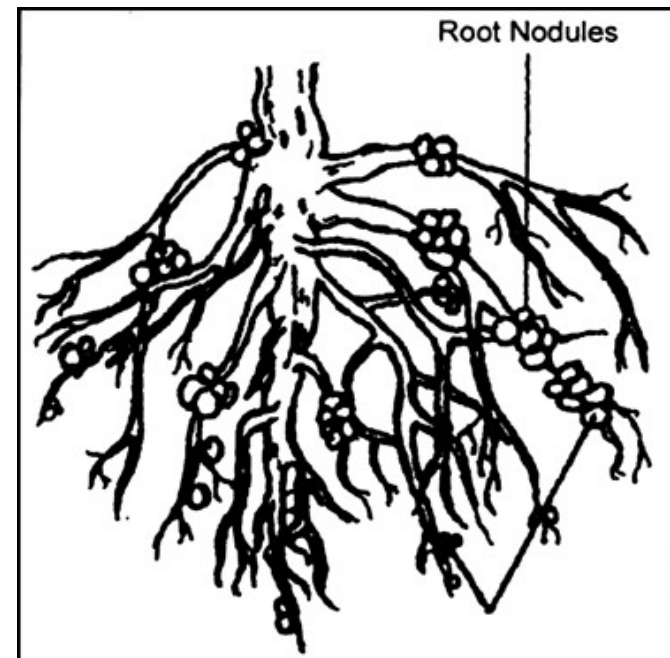
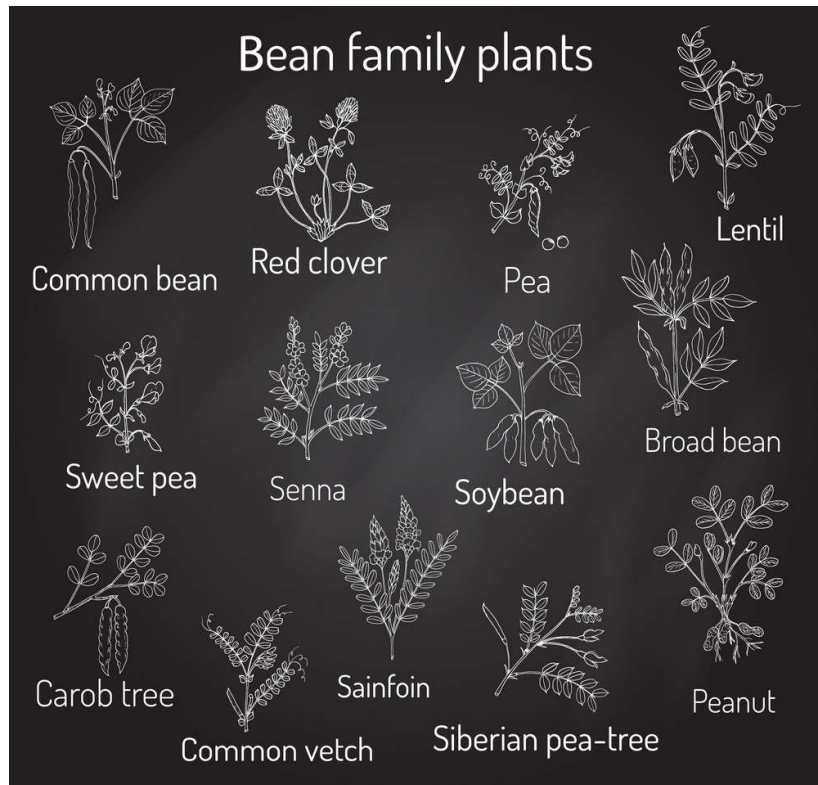
From organisms of the same species

From organisms of different species

Eukaryote

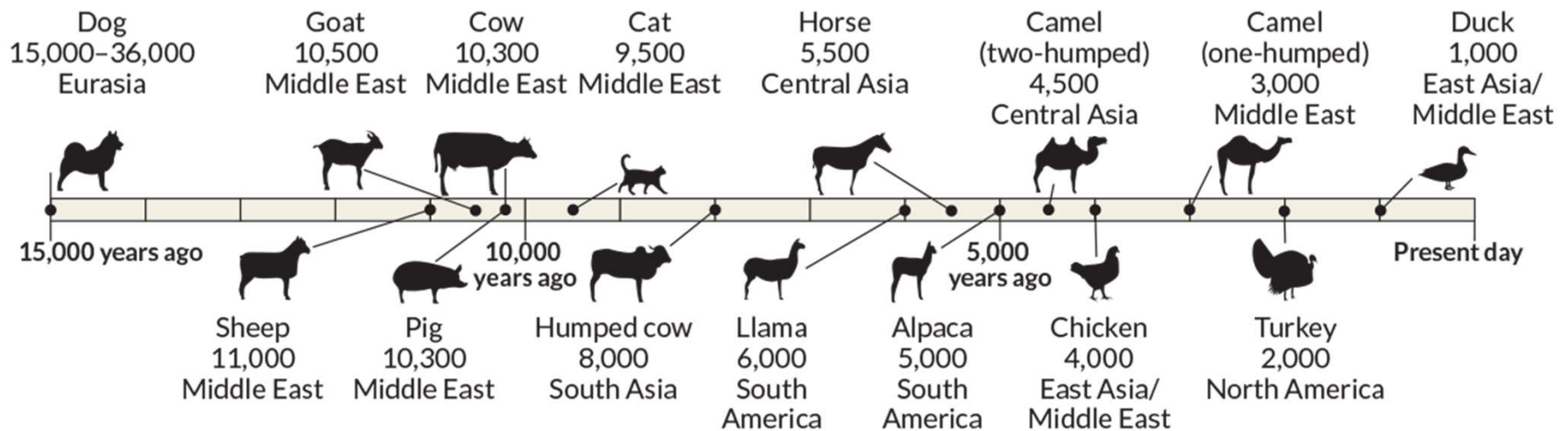


Fabaceae (FKA Leguminosae)

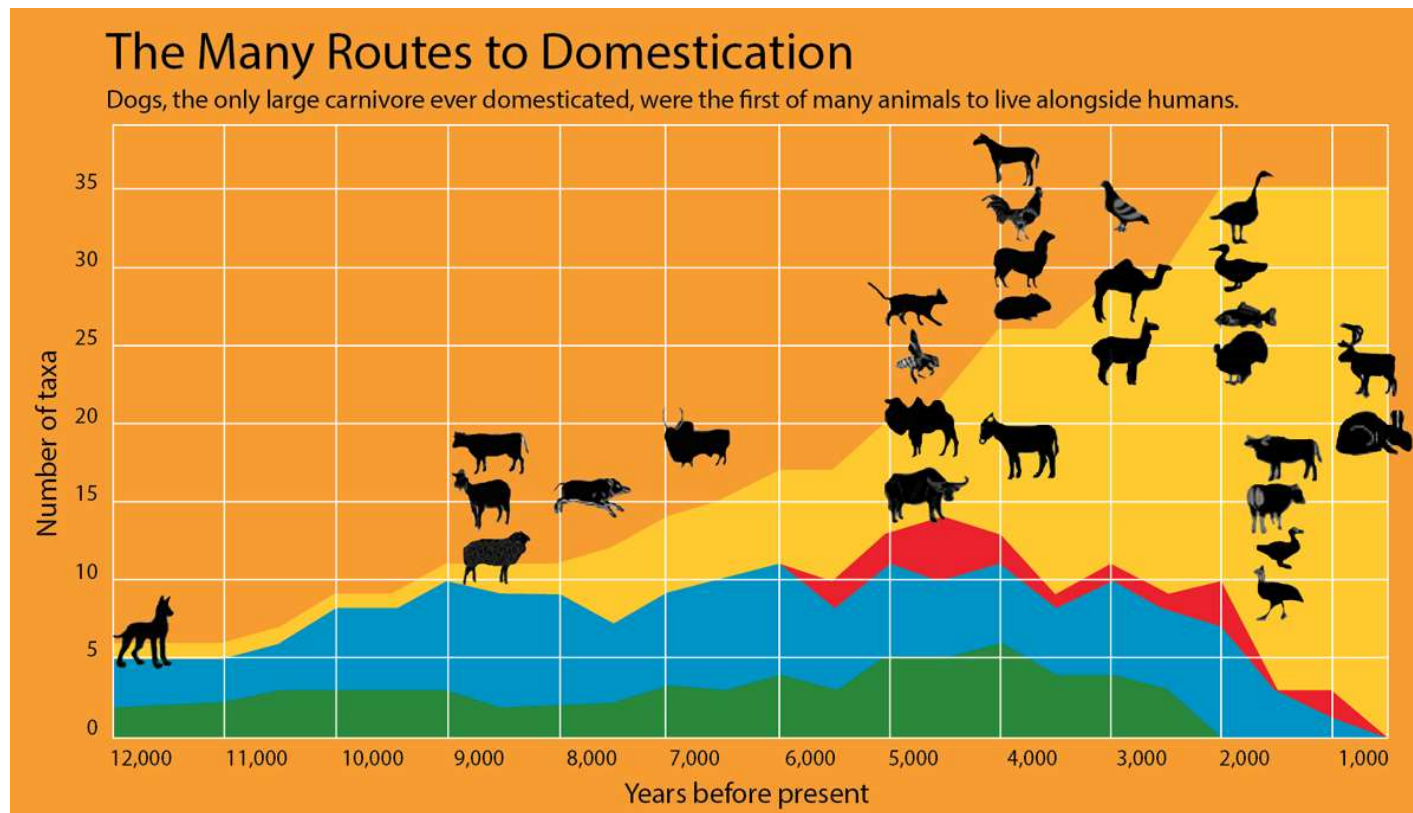


Domestication

Approximate time frame of domestication based on archaeology



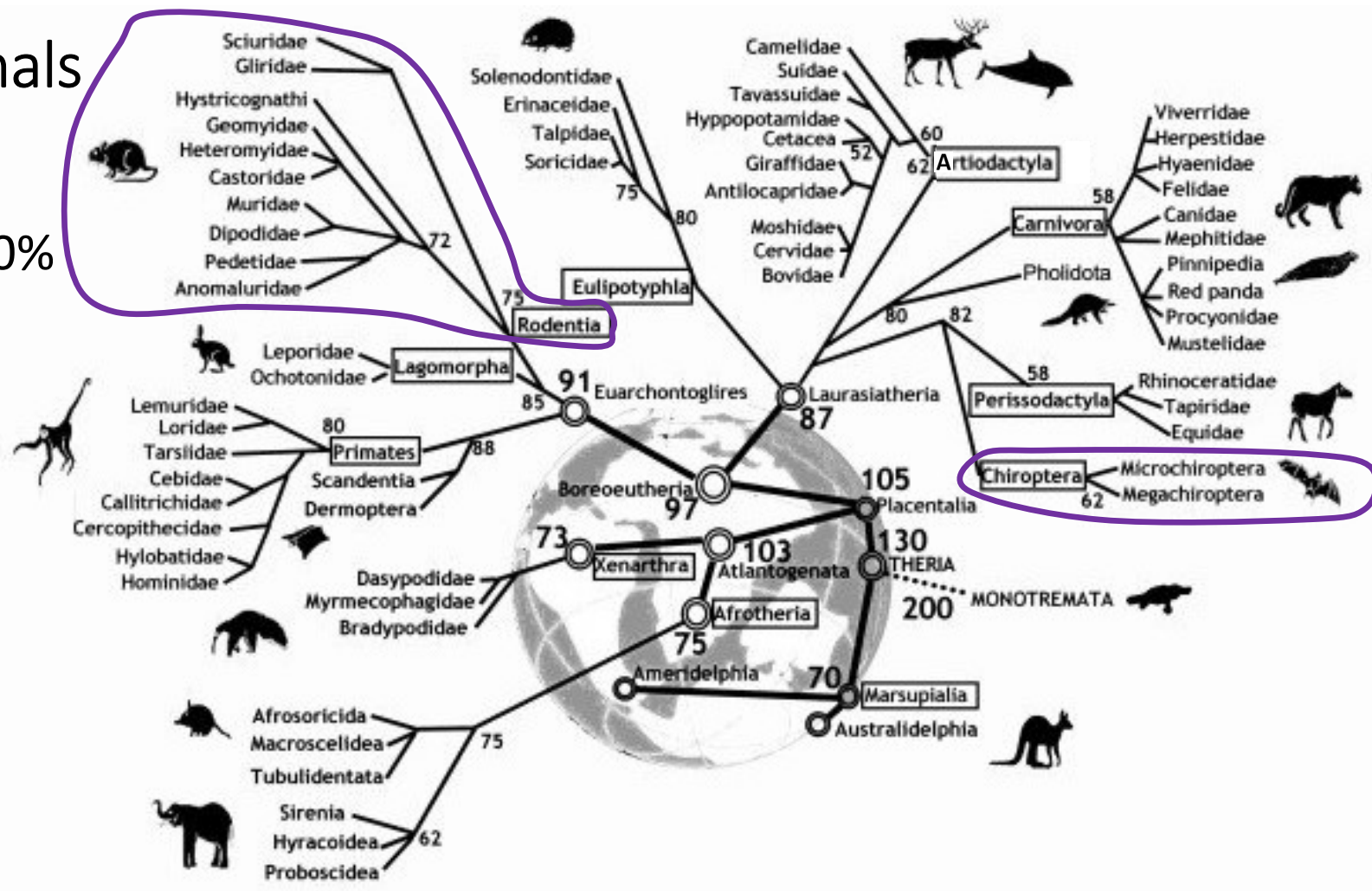
Domestication



discovermagazine.com/2016/dec/the-origins-of-dogs

Mammals

40%

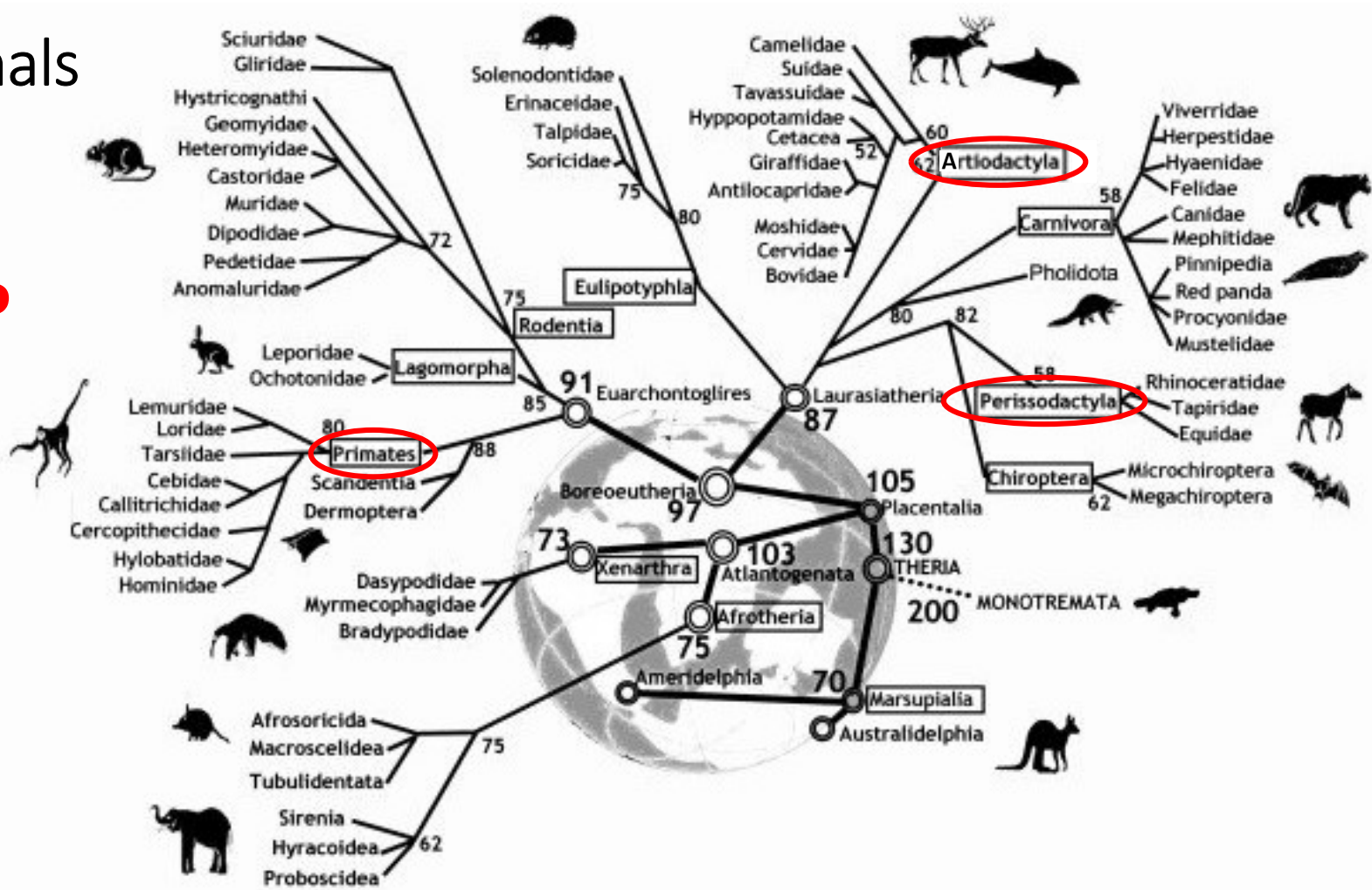


20%

www.researchgate.net/publication/51713113_The_genome_diversity_and_karyotype_evolution_of_mammals

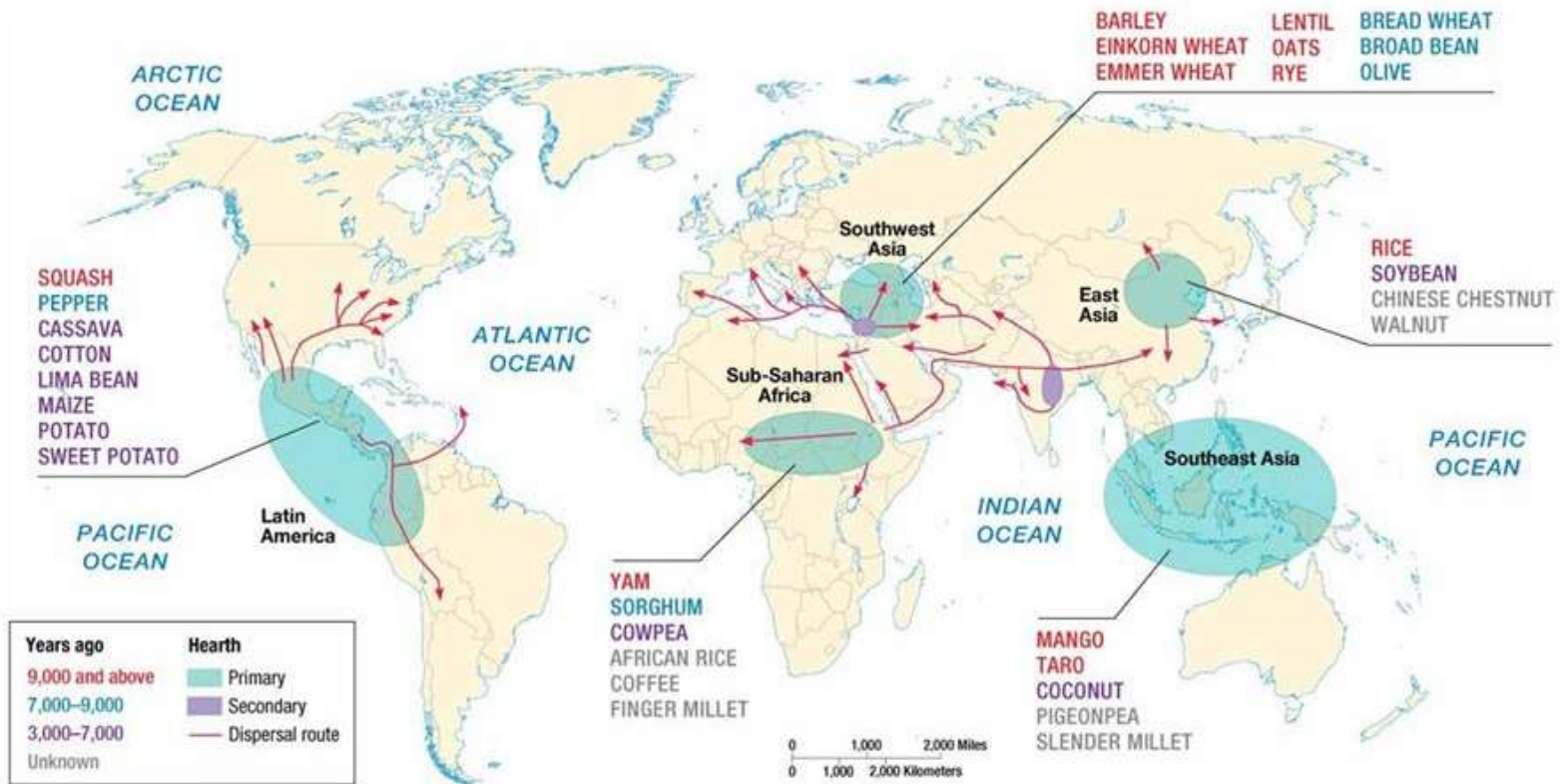
Mammals

APP

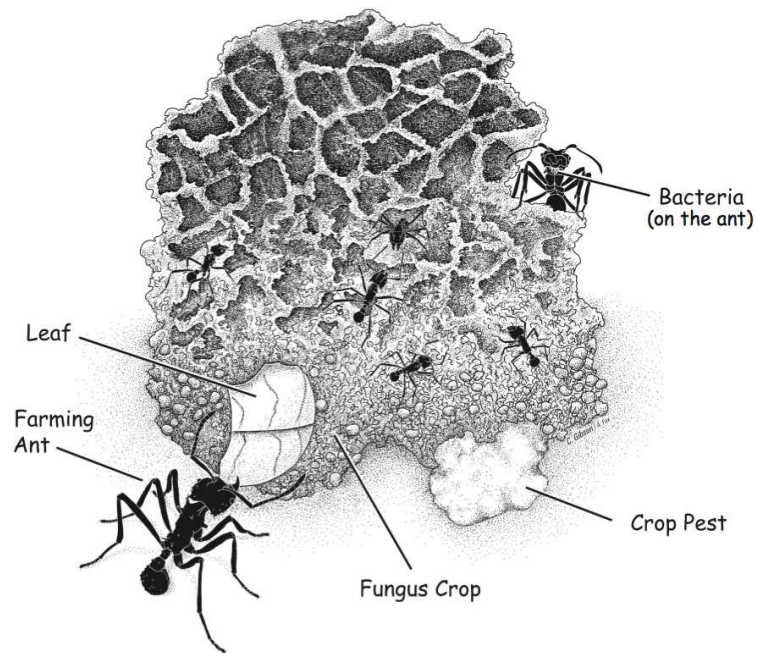


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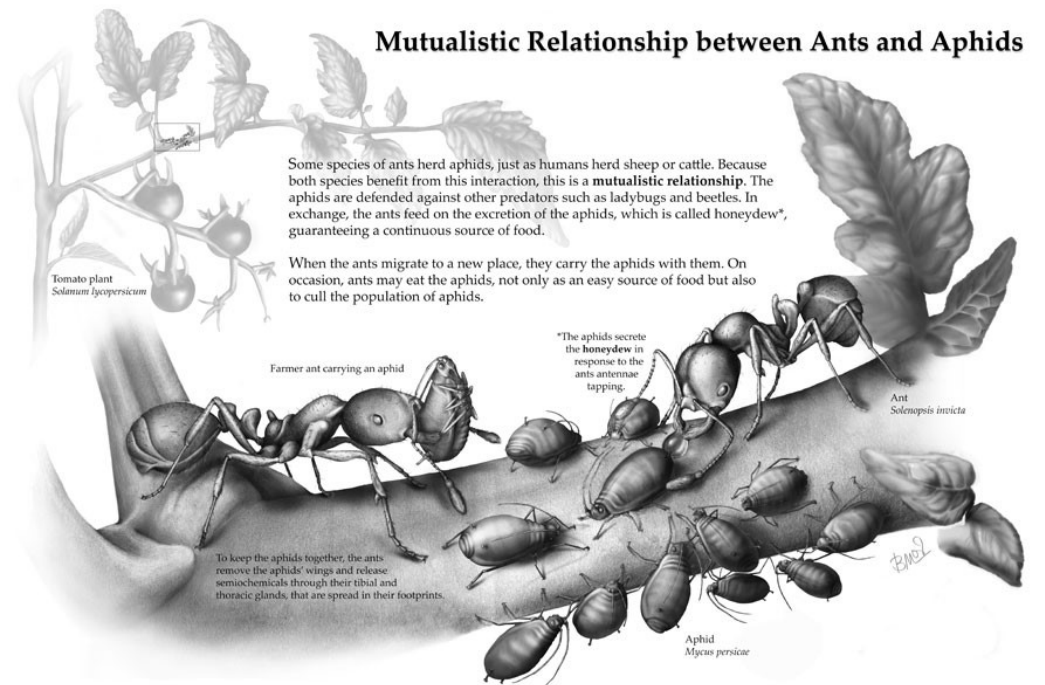
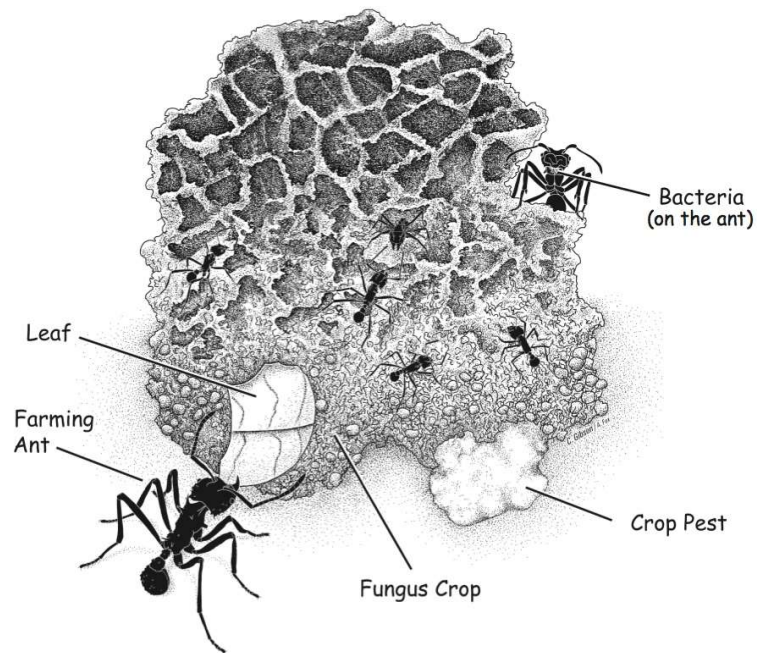
Agriculture



Domestication



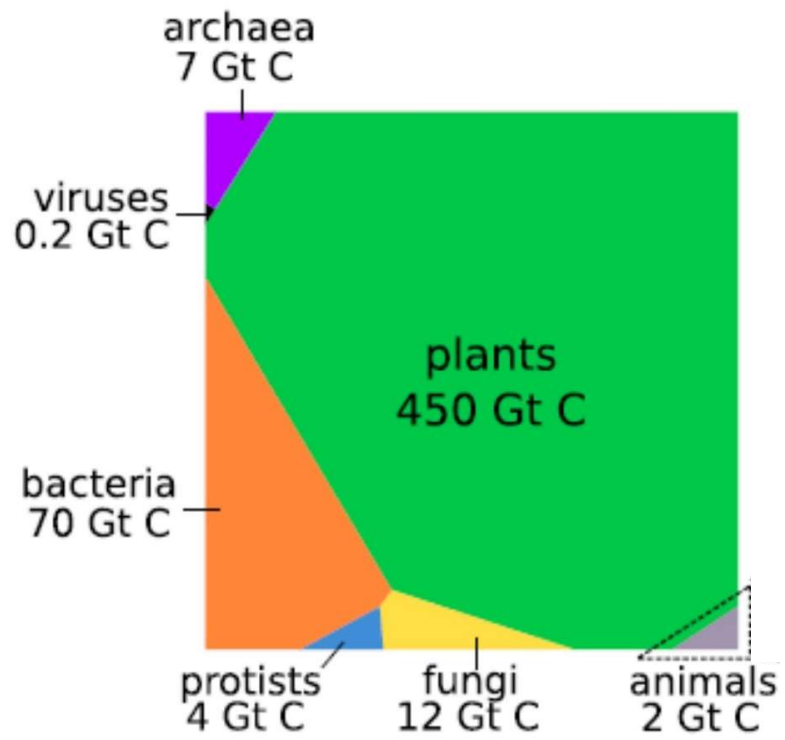
Domestication

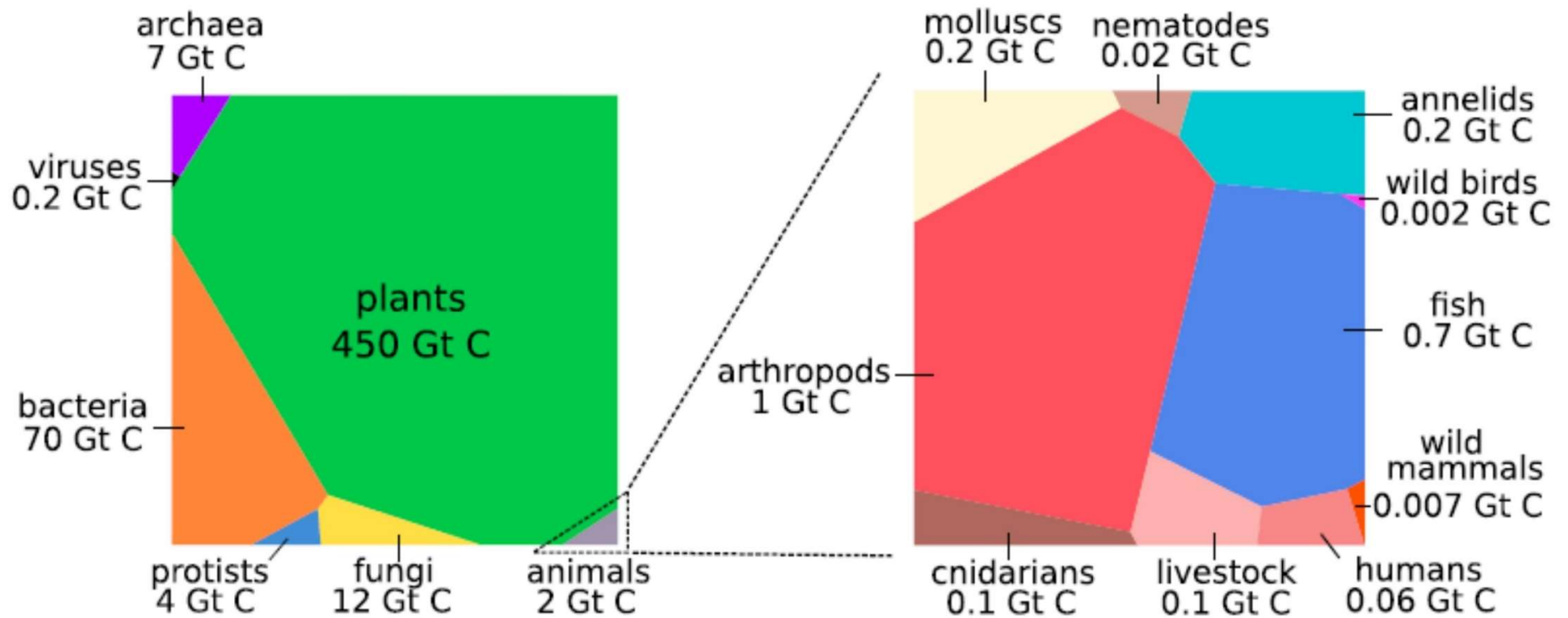


Agriculture



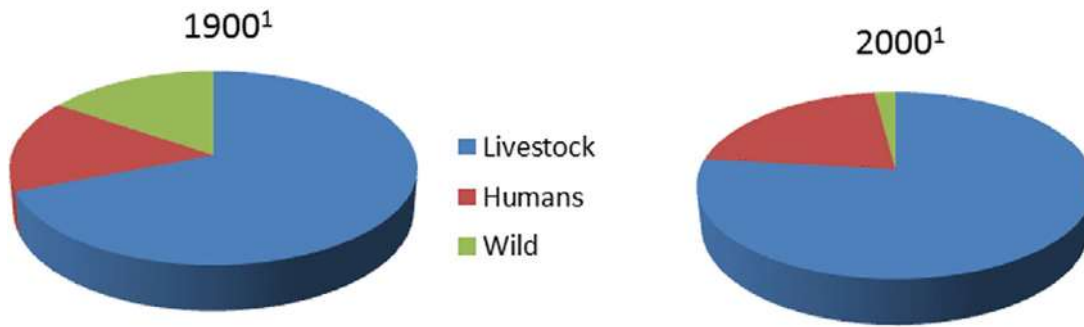
Second Wave Extinction



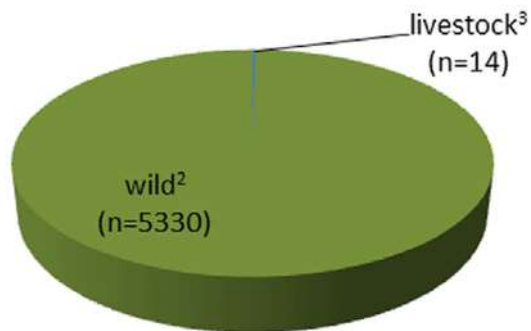


Agriculture

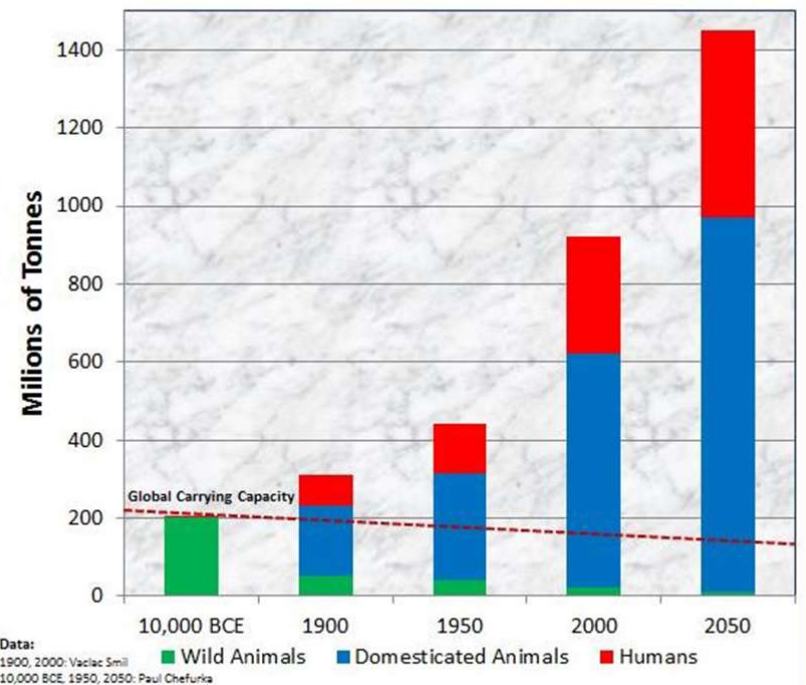
Global terrestrial mammal biomass



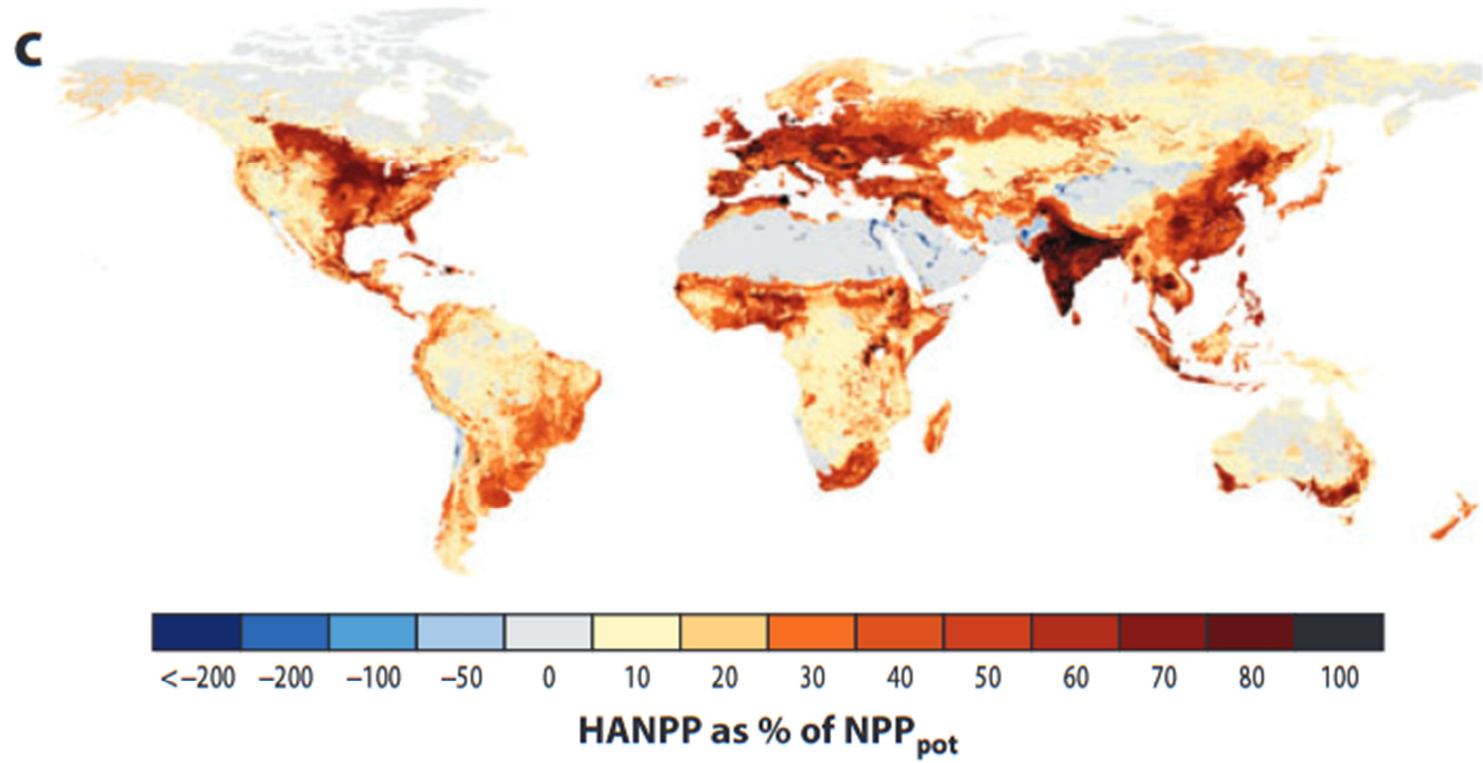
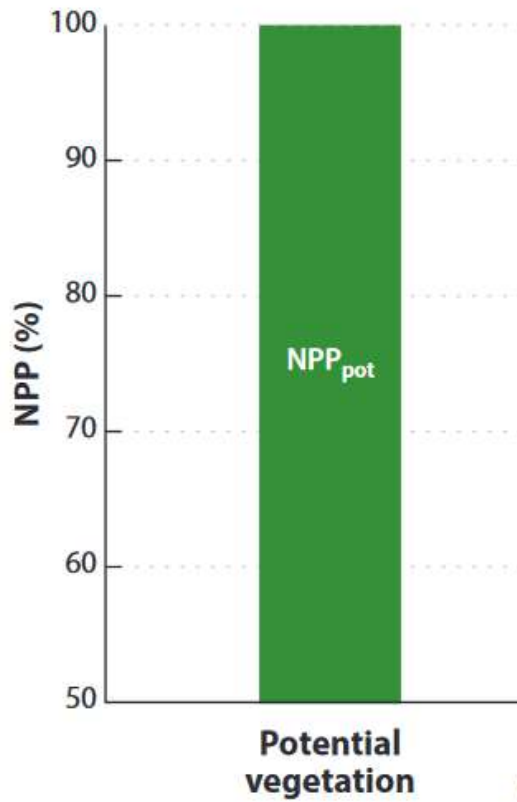
Global terrestrial mammal species diversity



Terrestrial Vertebrate Biomass

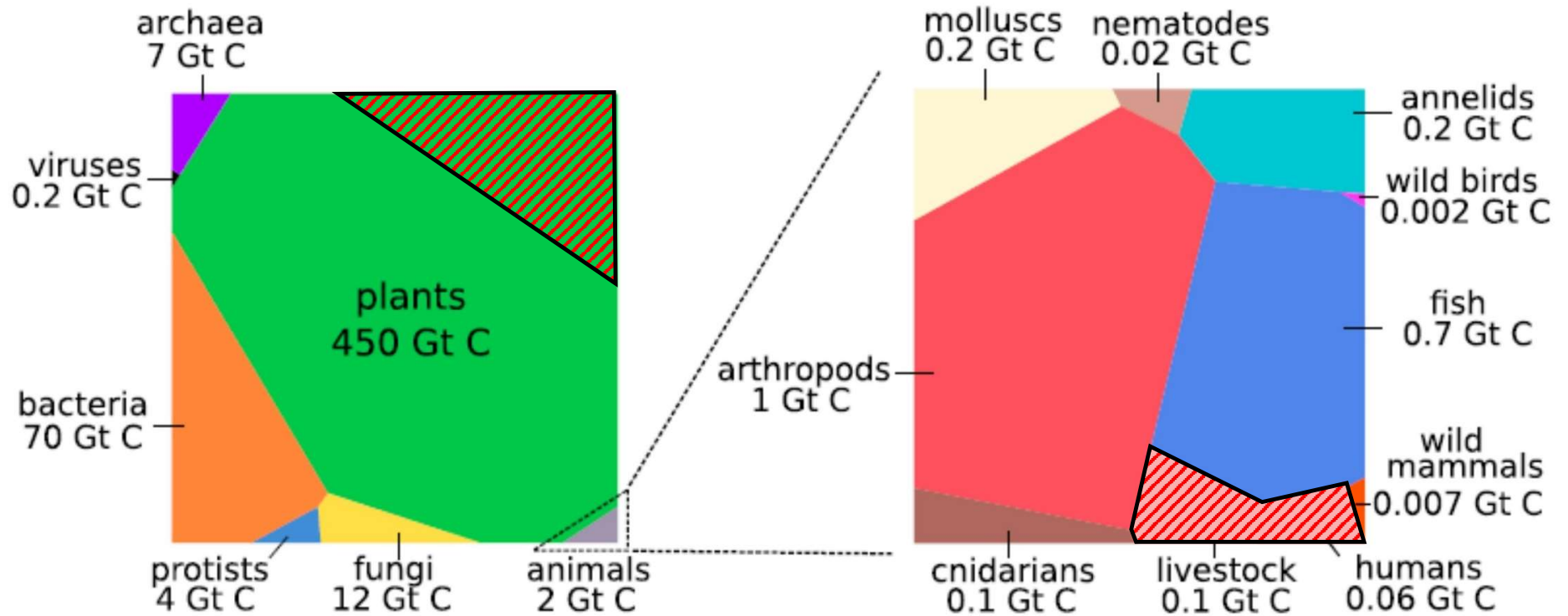


Agriculture



www.annualreviews.org/doi/pdf/10.1146/annurev-environ-121912-094620

Agriculture



www.pnas.org/content/115/25/6506

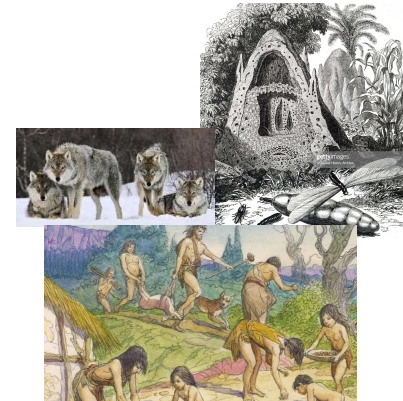
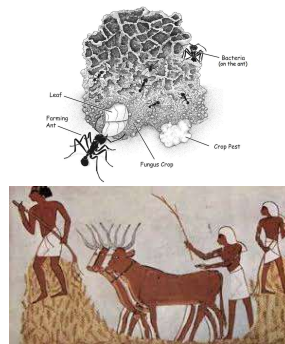
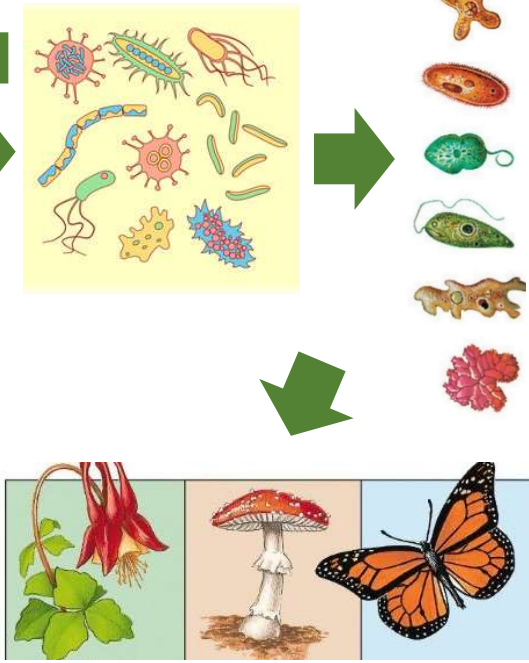
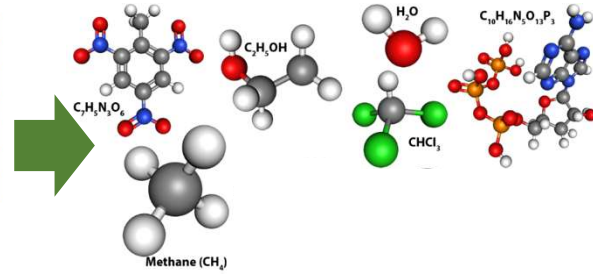
Kits of building blocks

Standard Model of Elementary Particles

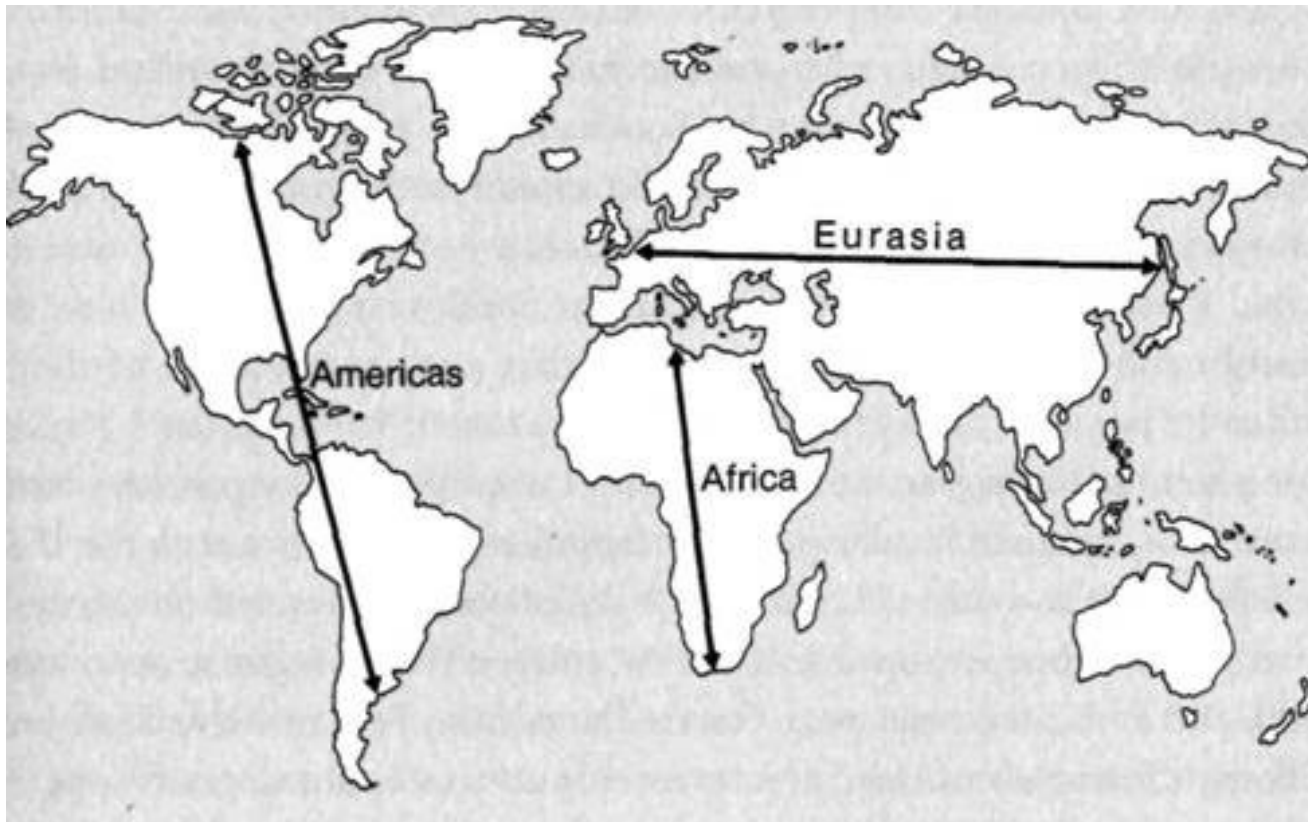
three generations of matter (fermions)			Interactions / force carriers (bosons)	
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d down	s strange	b bottom	γ photon	
e electron	μ muon	τ tau	Z Z boson	
ν _e electron neutrino	ν _μ muon neutrino	ν _τ tau neutrino	W W boson	

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

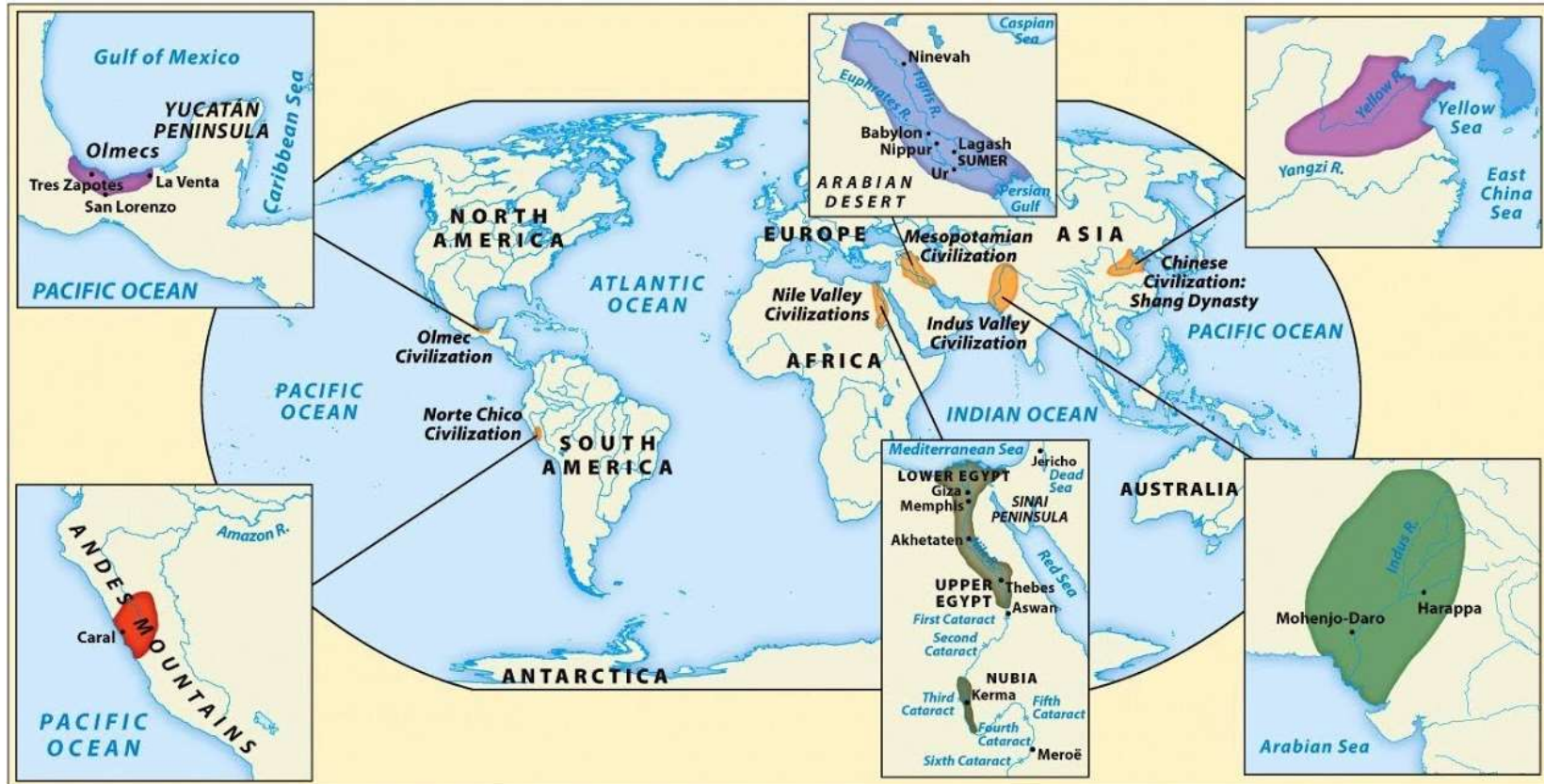
Periodic Table of the Elements



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)

www.ancient.eu/civilization/

Eusociality



Civilizations

Primary characteristics

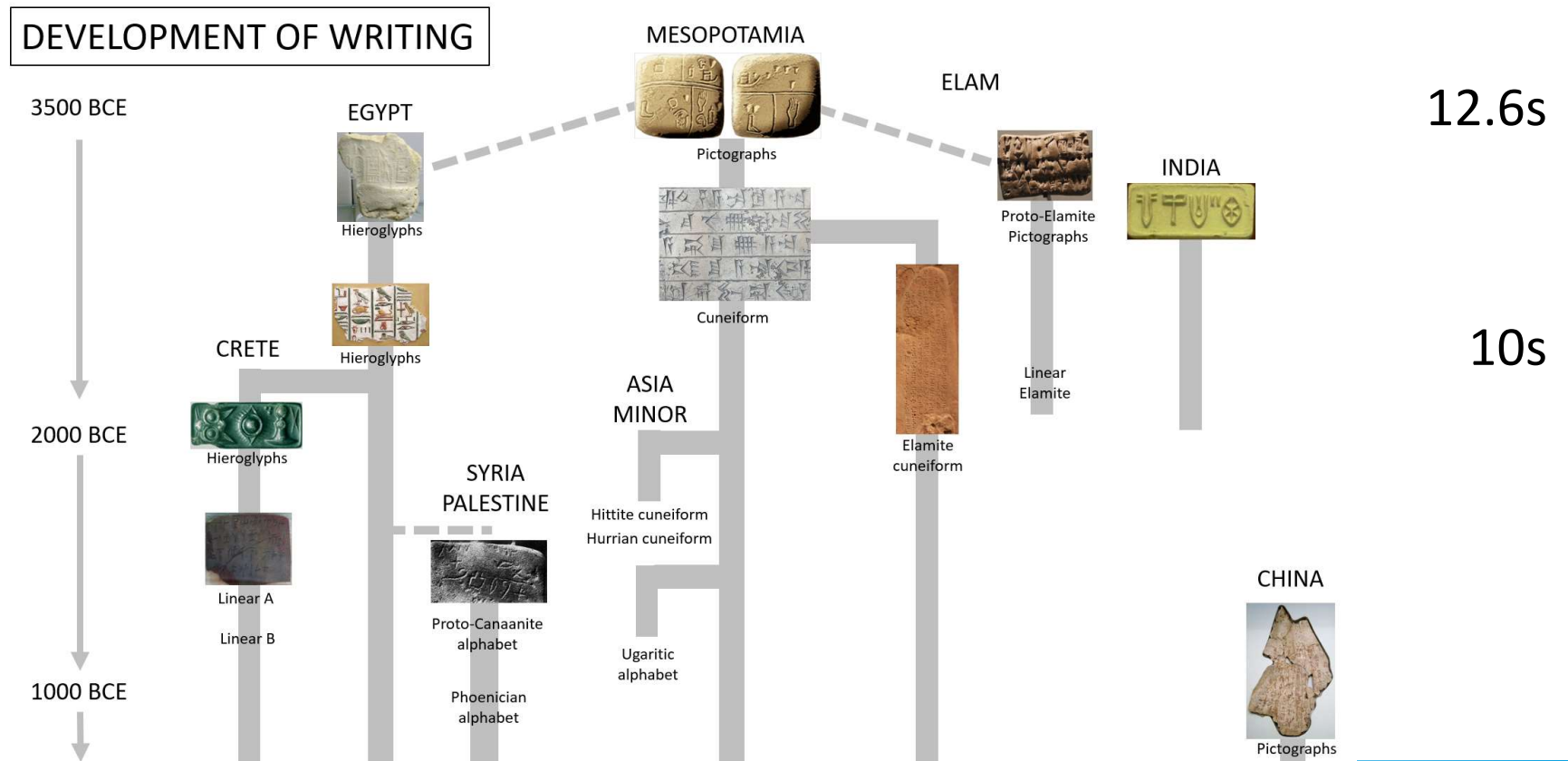
1. Urban settlements
2. Full-time specialists not involved in agricultural activities
3. Concentration of surplus production
4. Class structure
5. State-level organization (government)

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/

Writing



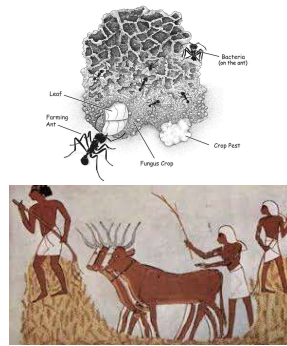
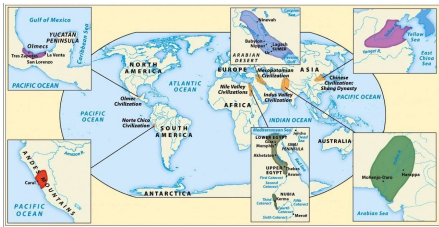
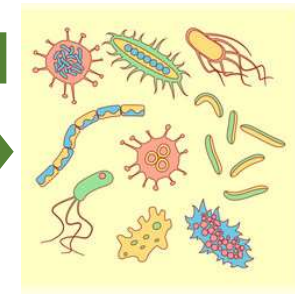
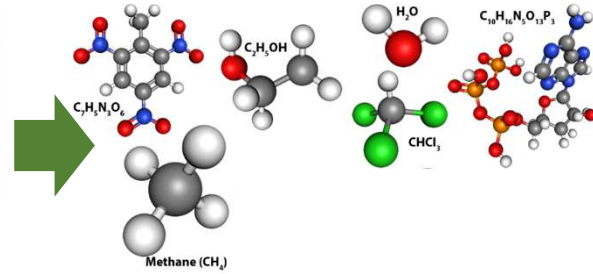
Kits of building blocks

Standard Model of Elementary Particles

three generations of matter (fermions)			Interactions / force carriers (bosons)	
I	II	III	0	1
u up	c charm	t top	g gluon	H higgs
d down	s strange	b bottom	γ photon	
e electron	μ muon	τ tau	Z Z boson	
ν _e electron neutrino	ν _μ muon neutrino	ν _τ tau neutrino	W W boson	

QUARKS: u, c, t, d, s, b, e, μ, τ, ν_e, ν_μ, ν_τ
 LEPTONS: e, μ, τ, ν_e, ν_μ, ν_τ
 GAUGE BOSONS: g, γ, Z, W
 VECTOR BOSONS: g, γ, Z, W
 SCALAR BOSONS: H

Periodic Table of the Elements



Summary

Big bang	Stars	Planets	Life	Humans	Civilization
Spacetime	Stars	Molecules	Replicator	Primates	Religion
Particles	Nucleus (heavy)	Environments	Cell	Homo	Agriculture
Nucleons	White dwarfs	(atmosphere,	Prokaryote	Collective learning	Agrovillages
Nucleus (light)	Neutron stars	liquid medium,	Photosynthesis	Language	Civilizations
Atoms	Blackholes	solid medium)	Eukaryote	Tribes	Writing
	Stellar systems	Moon	Multicellulars	Out of Africa	Money
	Galaxies	Plate tectonics	Land invasion	Tools	Law
	Clusters		Animals		Globalization
			Mammals		
			Eusociality		

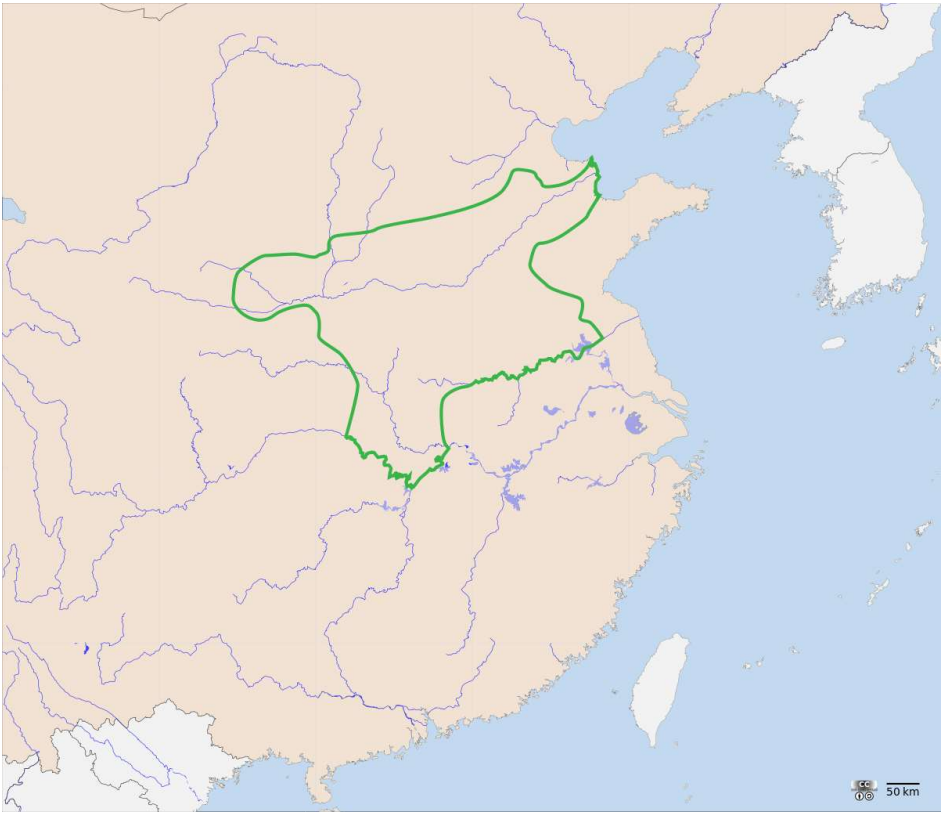
Great Pyramid of Giza

10s



Shang dynasty

9s



Olmec civilization

8s



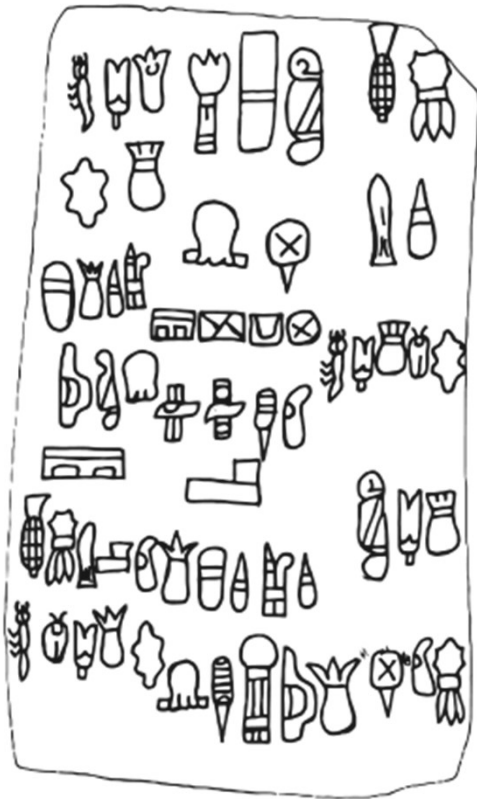
Identical ancestors point (isopoint)

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

Third independent writing system

7s

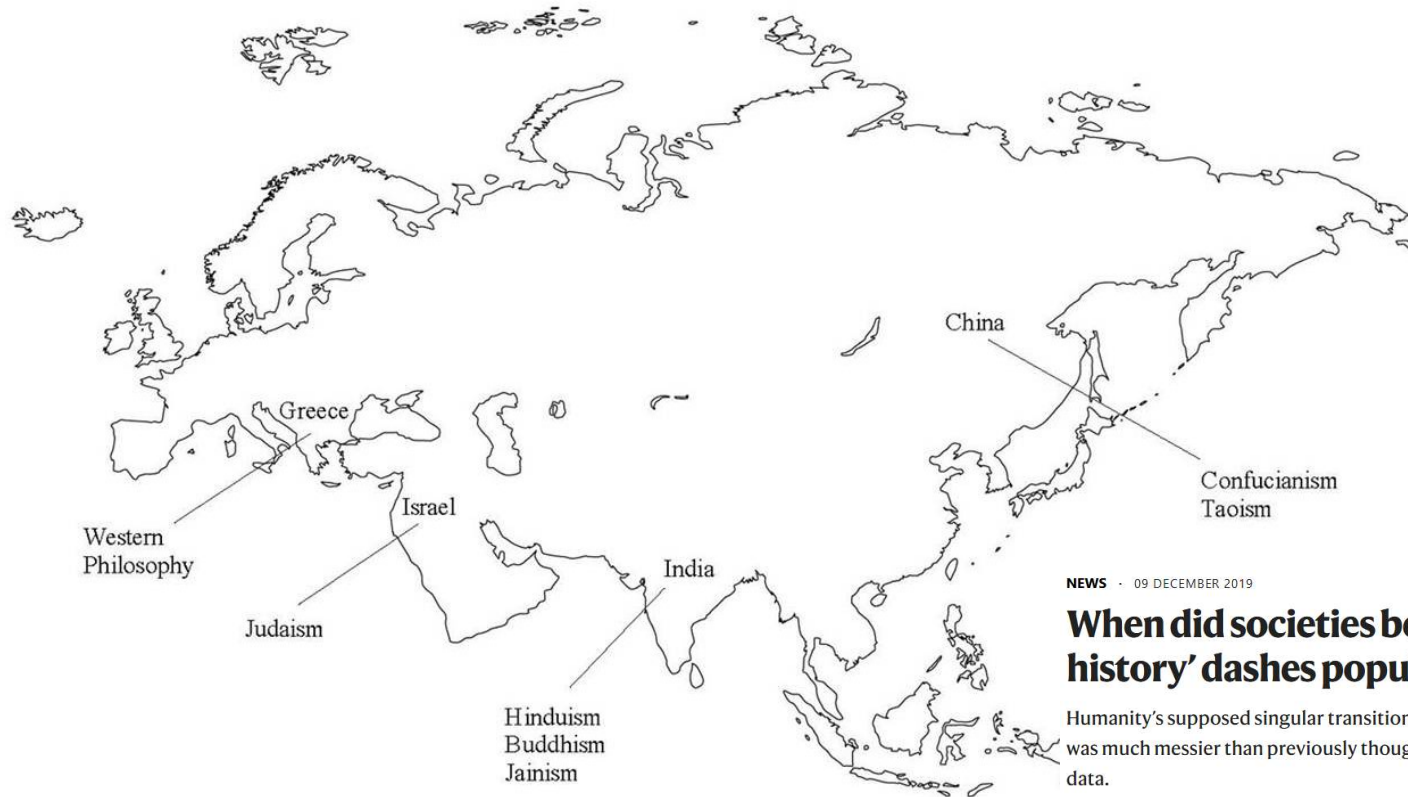
Cascajal block 900BCE



Maya script 300-200BCE

The Axial Age (800 – 200 BCE)

6s



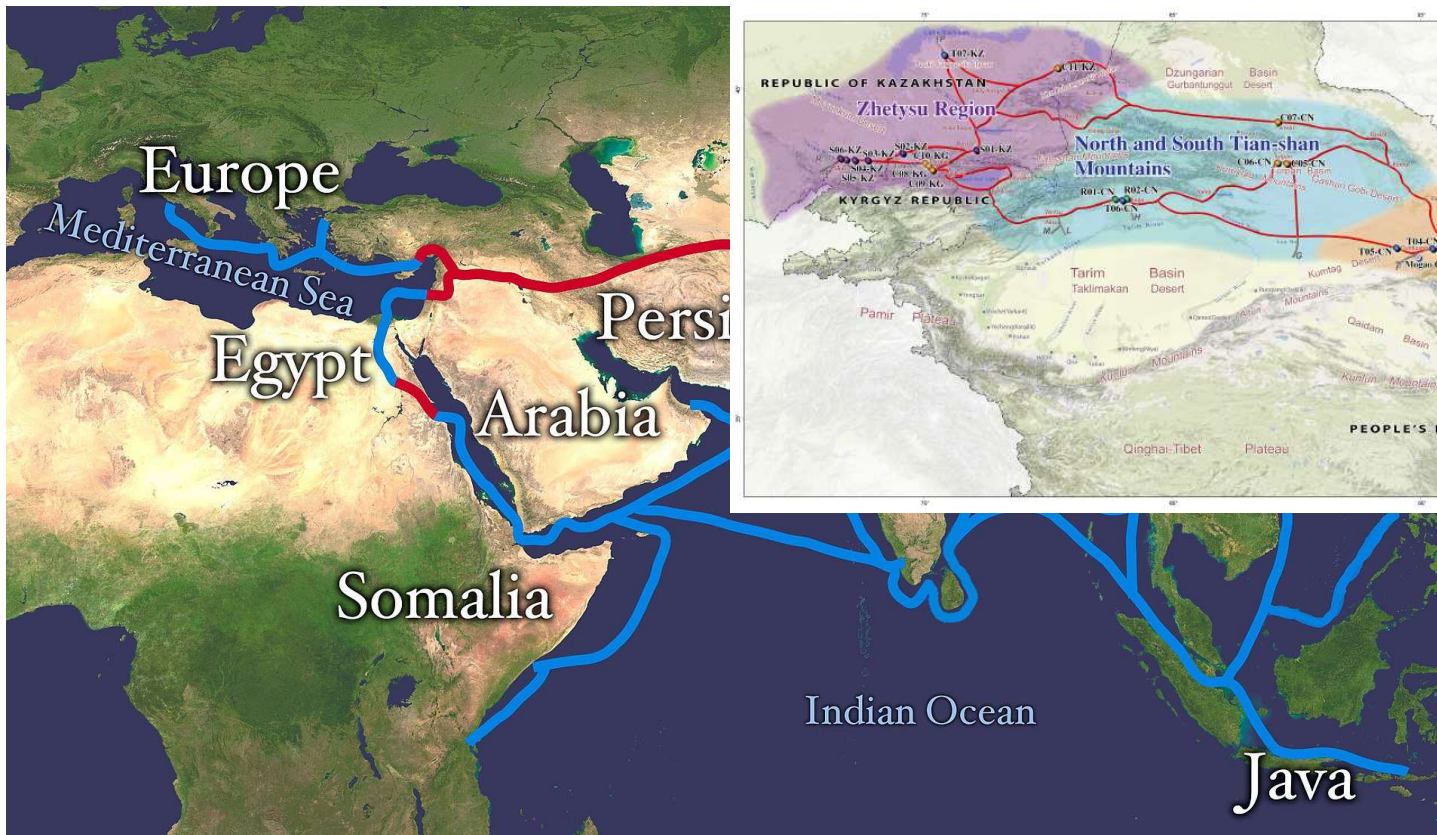
NEWS · 09 DECEMBER 2019

When did societies become modern? 'Big history' dashes popular idea of Axial Age

Humanity's supposed singular transition to modernity in the first millennium BC was much messier than previously thought, finds sweeping study of historical data.

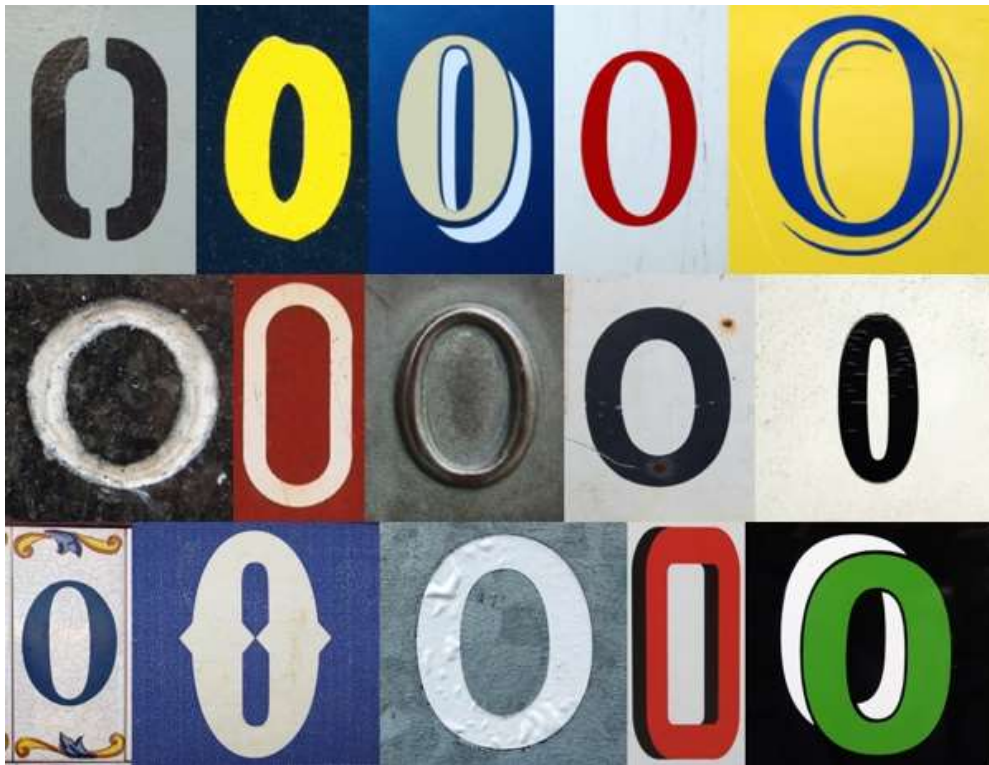
Silk road

5s



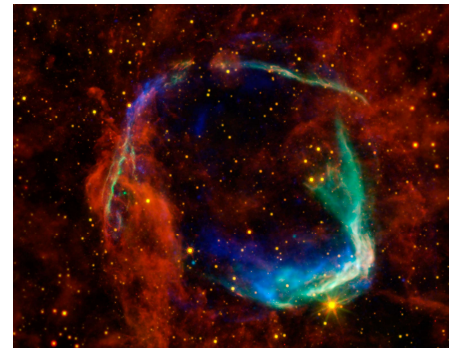
Zero

4s



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

3s



交子 Jiaozi

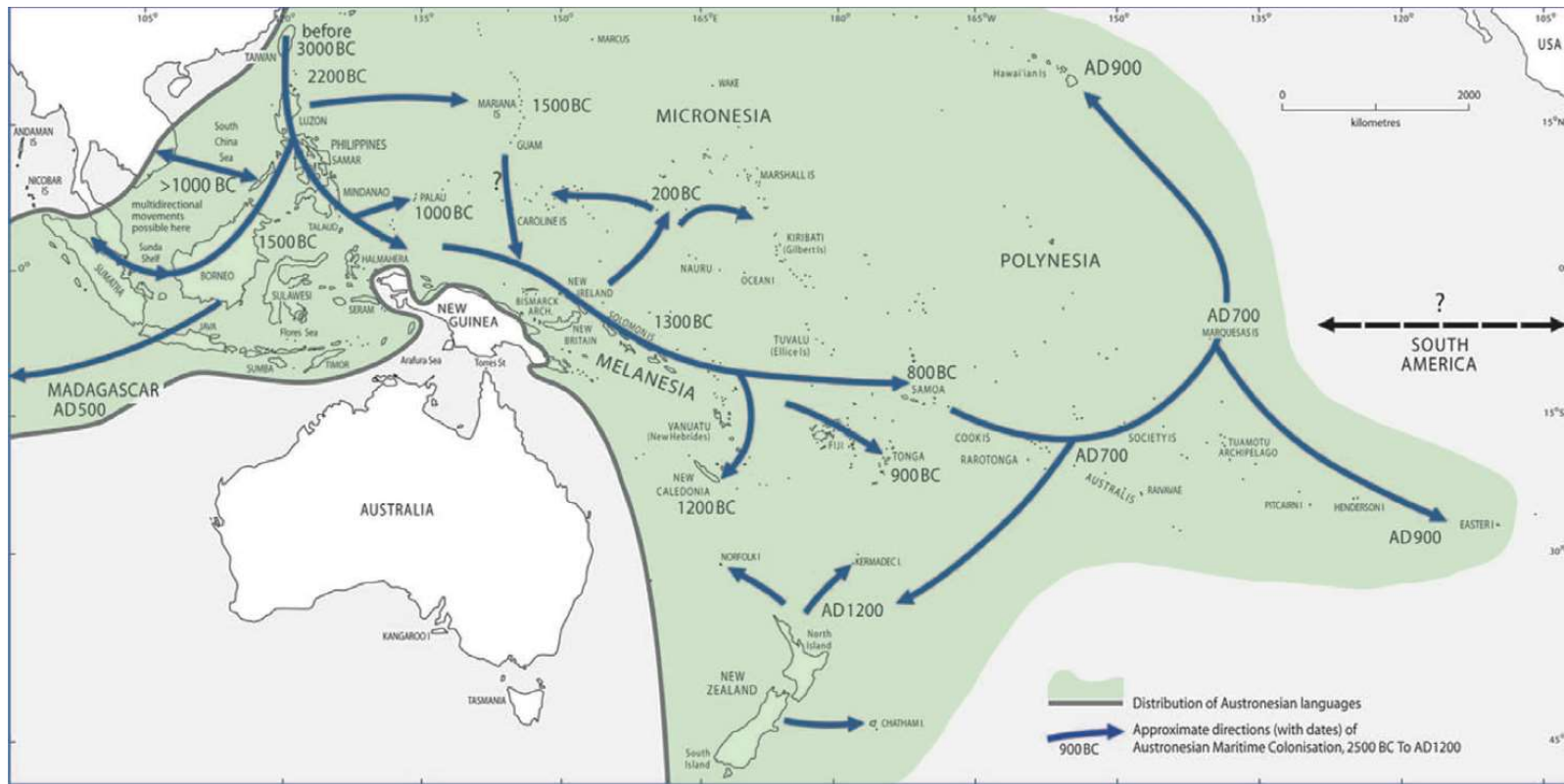
Promissory notes



Banknotes

New Zealand settlement

2s



First globalization

1s





Os