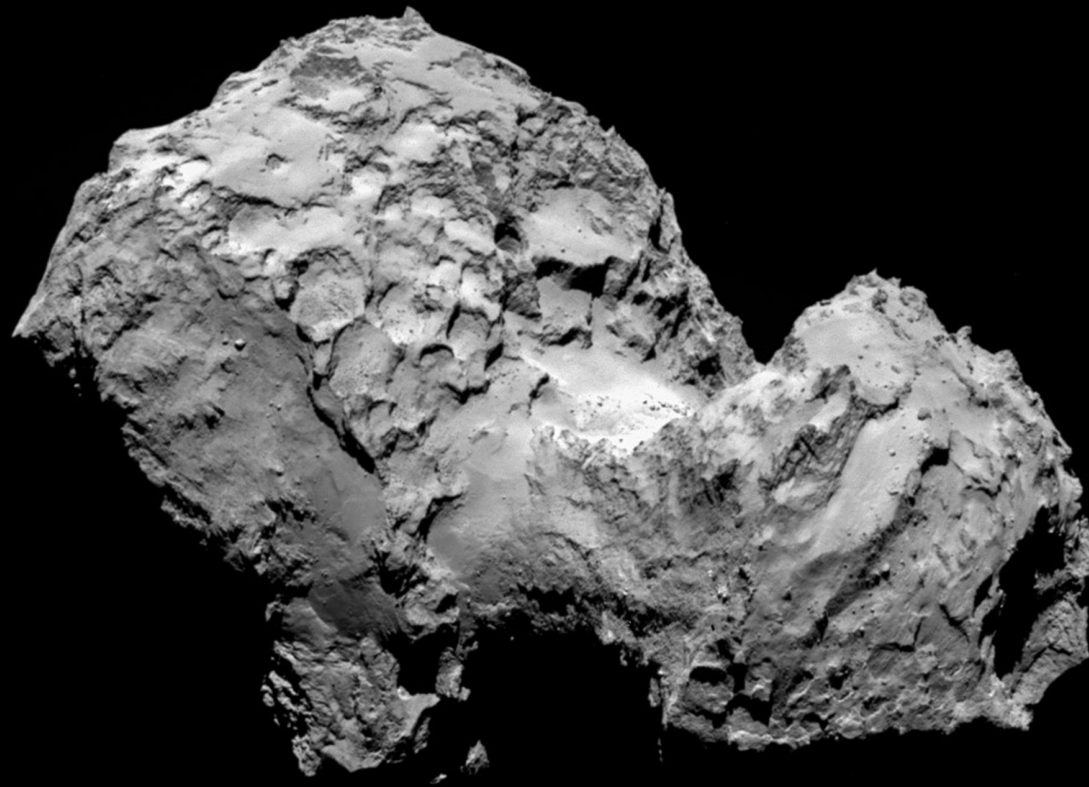


On Time:
A Hands-On
Workshop Exploring
the History of
Earth and Life

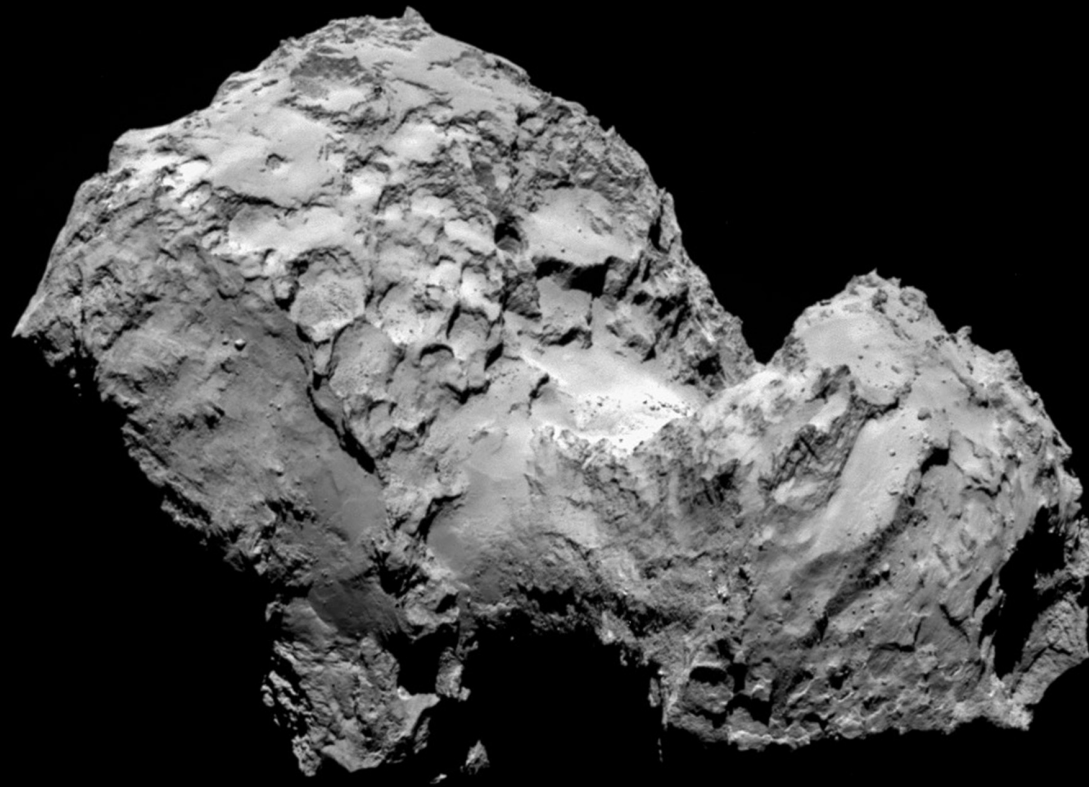


James Morris
Brandeis University
AP Annual Conference
July 20, 2023



317 million miles away from Earth

4600 million years old



317 million miles away from Earth

4600 million years old

MONDAY, JULY 25, 1994

Science Musings

CHET RAYMO

Teaching a sense of wonder

What should sixth graders
know about science?

250 million years ago

1 billion years ago

150,000 years ago

Paleozoic

Phanerozoic

Permian

Pleistocene

Pliocene



INTERNATIONAL STRATIGRAPHIC CHART

International Commission on Stratigraphy



Eonothem Eon	Erathem Era	System Period	Series Epoch	Stage Age	Age Ma	GSSP	
Phanerozoic	Cenozoic	Quaternary	Holocene		0.0117	↗	
			Pleistocene	Upper		0.126	
				"Ionian"		0.781	
			Pliocene	Calabrian		1.806	↗
				Gelasian		2.588	↗
			Neogene	Miocene	Piacenzian		3.600
		Zanclean				5.332	↗
		Pliocene		Messinian		7.246	↗
				Tortonian		11.608	↗
				Serravallian		13.82	↗
				Langhian		15.97	↗
				Burdigalian		20.43	↗
				Aquitanian		23.03	↗
		Paleogene	Oligocene	Chattian		28.4 ± 0.1	↗
	Rupelian				33.9 ± 0.1	↗	
	Eocene		Priabonian		37.2 ± 0.1	↗	
			Bartonian		40.4 ± 0.2	↗	
			Lutetian		48.6 ± 0.2	↗	
			Ypresian		55.8 ± 0.2	↗	
	Paleocene		Thanetian		58.7 ± 0.2	↗	
			Selandian		~ 61.1	↗	
			Danian		65.5 ± 0.3	↗	
			Cretaceous	Maastrichtian		70.6 ± 0.6	↗
				Campanian		83.5 ± 0.7	↗
				Santonian		85.8 ± 0.7	↗
				Coniacian		~ 88.6	↗
				Turonian		93.6 ± 0.8	↗
	Cenomanian			99.6 ± 0.9	↗		
Mesozoic	Upper	Albian		112.0 ± 1.0	↗		
		Aptian		125.0 ± 1.0	↗		
		Barremian		130.0 ± 1.5	↗		
		Hauterivian		~ 133.9	↗		
		Valanginian		140.2 ± 3.0	↗		
	Lower	Berriasian		145.5 ± 4.0	↗		

Eonothem Eon	Erathem Era	System Period	Series Epoch	Stage Age	Age Ma	GSSP
Phanerozoic	Mesozoic	Jurassic	Upper	Tithonian	145.5 ± 4.0	
				Kimmeridgian	150.8 ± 4.0	
				Oxfordian	~ 155.6	
			Middle	Callovian	161.2 ± 4.0	
				Bathonian	164.7 ± 4.0	↗
				Bajocian	167.7 ± 3.5	↗
			Lower	Aalenian	171.6 ± 3.0	↗
				Toarcian	175.6 ± 2.0	↗
				Pliensbachian	183.0 ± 1.5	↗
				Sinemurian	189.6 ± 1.5	↗
		Triassic	Upper	Hettangian	196.5 ± 1.0	↗
				Rhaetian	199.6 ± 0.6	↗
				Norian	203.6 ± 1.5	↗
			Middle	Carnian	216.5 ± 2.0	↗
	Ladinian			~ 228.7	↗	
	Lower		Anisian	237.0 ± 2.0	↗	
			Olenekian	~ 245.9	↗	
			Induan	~ 249.5	↗	
			Changhsingian	251.0 ± 0.4	↗	
			Wuchiapingian	253.8 ± 0.7	↗	
	Paleozoic	Permian	Lopingian	260.4 ± 0.7	↗	
			Guadalupian	265.8 ± 0.7	↗	
			Wordian	268.0 ± 0.7	↗	
			Roadian	270.6 ± 0.7	↗	
			Kungurian	275.6 ± 0.7	↗	
			Artinskian	284.4 ± 0.7	↗	
		Carboniferous	Pennsylvanian	Sakmarian	294.6 ± 0.8	↗
				Asselian	299.0 ± 0.8	↗
			Mississippian	Gzhelian	303.4 ± 0.9	↗
				Kasimovian	307.2 ± 1.0	↗
	Paleozoic	Carboniferous	Moscovian	311.7 ± 1.1	↗	
			Bashkirian	318.1 ± 1.3	↗	
			Serpukhovian	328.3 ± 1.6	↗	
			Visean	345.3 ± 2.1	↗	
Permian		Tournaisian	359.2 ± 2.5	↗		

Eonothem Eon	Erathem Era	System Period	Series Epoch	Stage Age	Age Ma	GSSP
Phanerozoic	Paleozoic	Devonian	Upper	Famennian	359.2 ± 2.5	↗
				Frasnian	374.5 ± 2.6	↗
			Middle	Givetian	385.3 ± 2.6	↗
				Eifelian	391.8 ± 2.7	↗
			Lower	Emsian	397.5 ± 2.7	↗
				Pragian	407.0 ± 2.8	↗
		Lochkovian		411.2 ± 2.8	↗	
		Pridoli		416.0 ± 2.8	↗	
		Silurian	Ludlow	Ludfordian	418.7 ± 2.7	↗
				Gorstian	421.3 ± 2.6	↗
			Wenlock	Homerian	422.9 ± 2.5	↗
				Sheinwoodian	426.2 ± 2.4	↗
			Llandovery	Telychian	428.2 ± 2.3	↗
				Aeronian	436.0 ± 1.9	↗
	Ordovician		Upper	Rhuddanian	439.0 ± 1.8	↗
				Hirnantian	443.7 ± 1.5	↗
			Middle	Katian	445.6 ± 1.5	↗
				Sandbian	445.8 ± 1.6	↗
		Lower	Darriwilian	455.8 ± 1.6	↗	
			Dapingian	460.9 ± 1.6	↗	
			Floian	468.1 ± 1.6	↗	
			Tremadocian	478.6 ± 1.7	↗	
	Cambrian	Furongian	Stage 10	488.3 ± 1.7	↗	
			Stage 9	~ 492 *		
			Paibian	~ 496 *	↗	
			Guzhangian	~ 499	↗	
		Series 3	Drumian	~ 503	↗	
			Stage 5	~ 506.5	↗	
Series 2		Stage 4	~ 510 *			
		Stage 3	~ 515 *			
Terreneuvian		Stage 2	~ 521 *			
		Fortunian	~ 528 *			
				Fortunian	542.0 ± 1.0	↗

This chart was drafted by Gabi Ogg. Intra Cambrian unit ages with * are informal, and awaiting ratified definitions.

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Eonothem Eon	Erathem Era	System Period	Age Ma	GSSP GSSA	
Precambrian	Proterozoic	Neo-proterozoic	Ediacaran	542	↗
			Cryogenian	~635	↗
			Tonian	850	↗
		Meso-proterozoic	Stenian	1000	↗
			Ectasian	1200	↗
			Calymmian	1400	↗
	Paleo-proterozoic	Statherian	Orosirian	1600	↗
			Rhyacian	1800	↗
			Siderian	2050	↗
		Neoproterozoic		2300	↗
				2500	↗
	Archean	Neoproterozoic		2800	↗
				3200	↗
		Mesoarchean		3600	↗
			4000	↗	
Hadean (informal)			~4600		

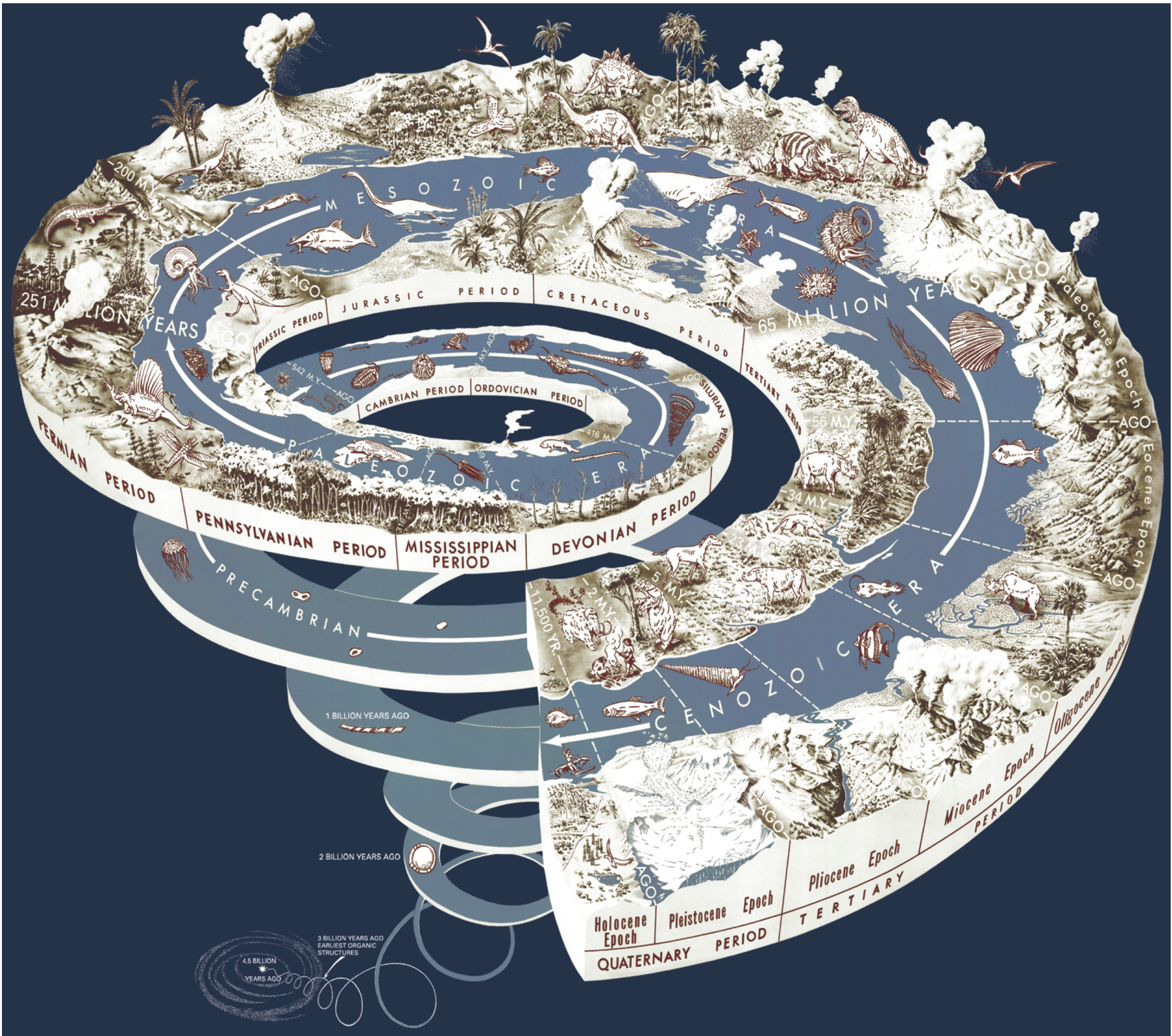
Subdivisions of the global geologic record are formally defined by their lower boundary. Each unit of the Phanerozoic (~542 Ma to Present) and the base of Ediacaran are defined by a basal Global Boundary Stratotype Section and Point (GSSP), whereas Precambrian units are formally subdivided by absolute age (Global Standard Stratigraphic Age, GSSA). Details of each GSSP are posted on the ICS website (www.stratigraphy.org).

Numerical ages of the unit boundaries in the Phanerozoic are subject to revision. Some stages within the Cambrian will be formally named upon international agreement on their GSSP limits. Most sub-Series boundaries (e.g., Middle and Upper Aptian) are not formally defined.

Colors are according to the Commission for the Geological Map of the World (www.cgmw.org).

The listed numerical ages are from 'A Geologic Time Scale 2004', by F.M. Gradstein, J.G. Ogg, A.G. Smith, et al. (2004; Cambridge University Press) and 'The Concise Geologic Time Scale' by J.G. Ogg, G. Ogg and F.M. Gradstein (2008).

Eon	Era	Period	Epoch	m.y.		
Phanerozoic	Cenozoic	Quaternary	Holocene	1.5 23 65 250		
			Pleistocene			
		Neogene	Pliocene			
			Miocene			
		Paleogene	Oligocene			
			Eocene			
			Paleocene			
		Mesozoic	Cretaceous			
			Jurassic			
	Triassic					
	Paleozoic	Permian				
		Carboniferous	Pennsylvanian			
			Mississippian			
		Devonian				
		Silurian				
		Ordovician				
		Cambrian				
		Precambrian	Proterozoic		540	
	Archean		2500			
Hadean			3800 4600			



How old is the Earth?

When did life originate?

When did the dinosaurs roam the Earth?

How long have modern humans been around?

♥ Darren Naish liked



Rhys D. Webb @rhysdwebb · Nov 2

A T. Rex was closer in time to seeing an i-pad than it was to seeing a stegosaurus. [#MyOneScienceTweet](#)

💬 13

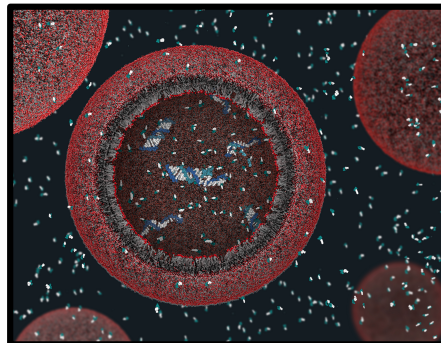
↻ 385

♥ 735

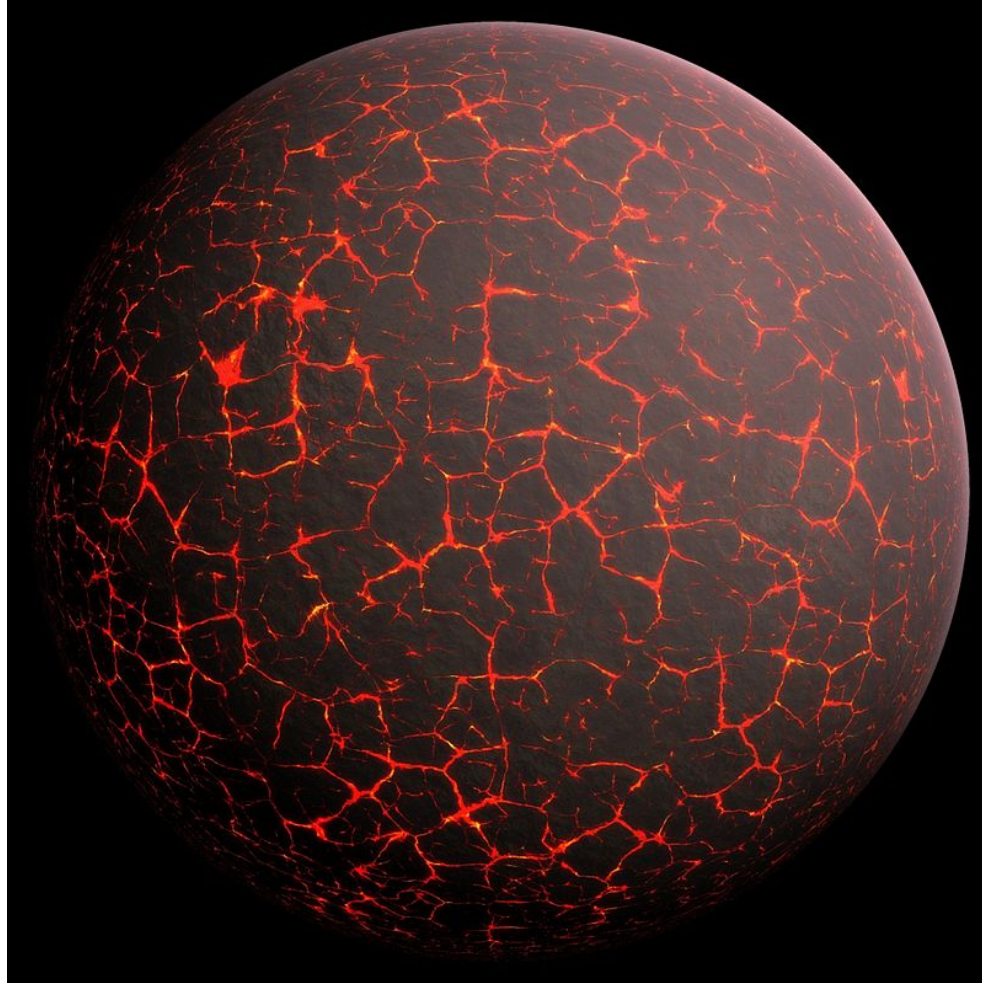


It's About Time

An In-Class Activity on
the History of Life and Earth

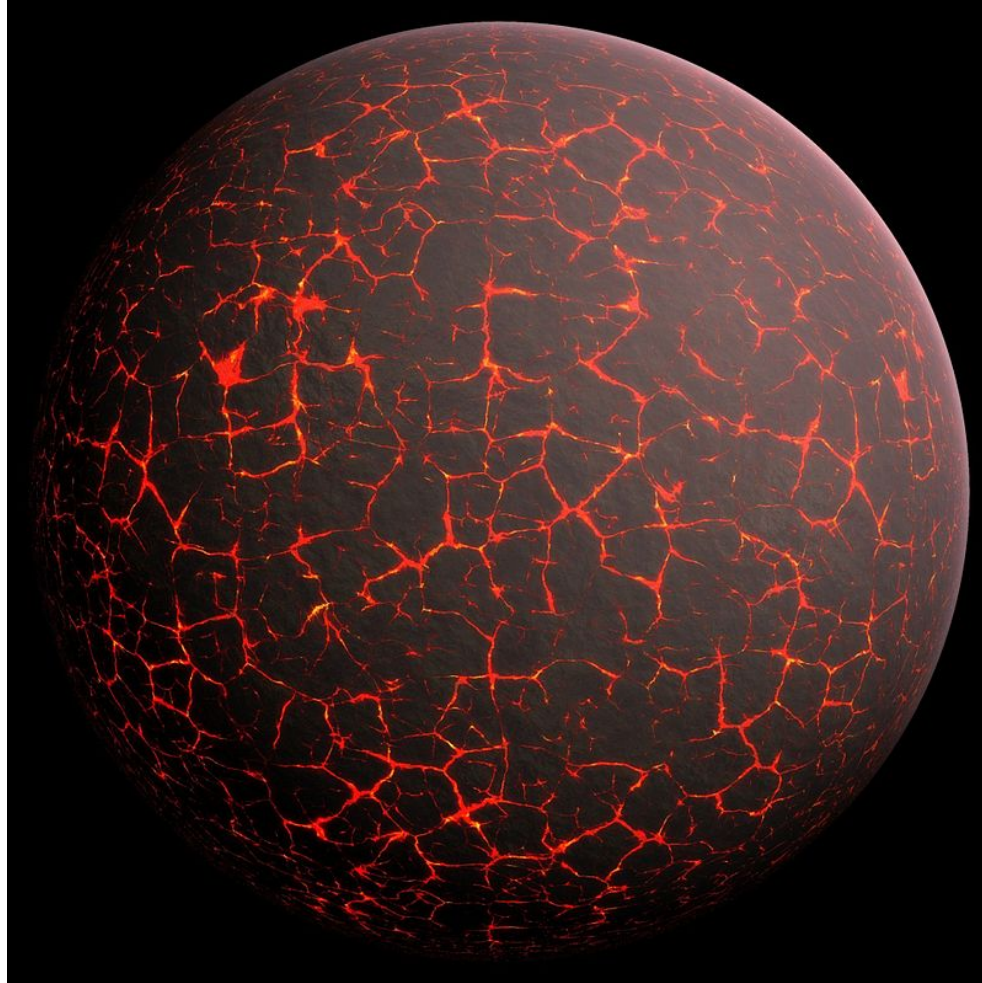


Formation of Earth



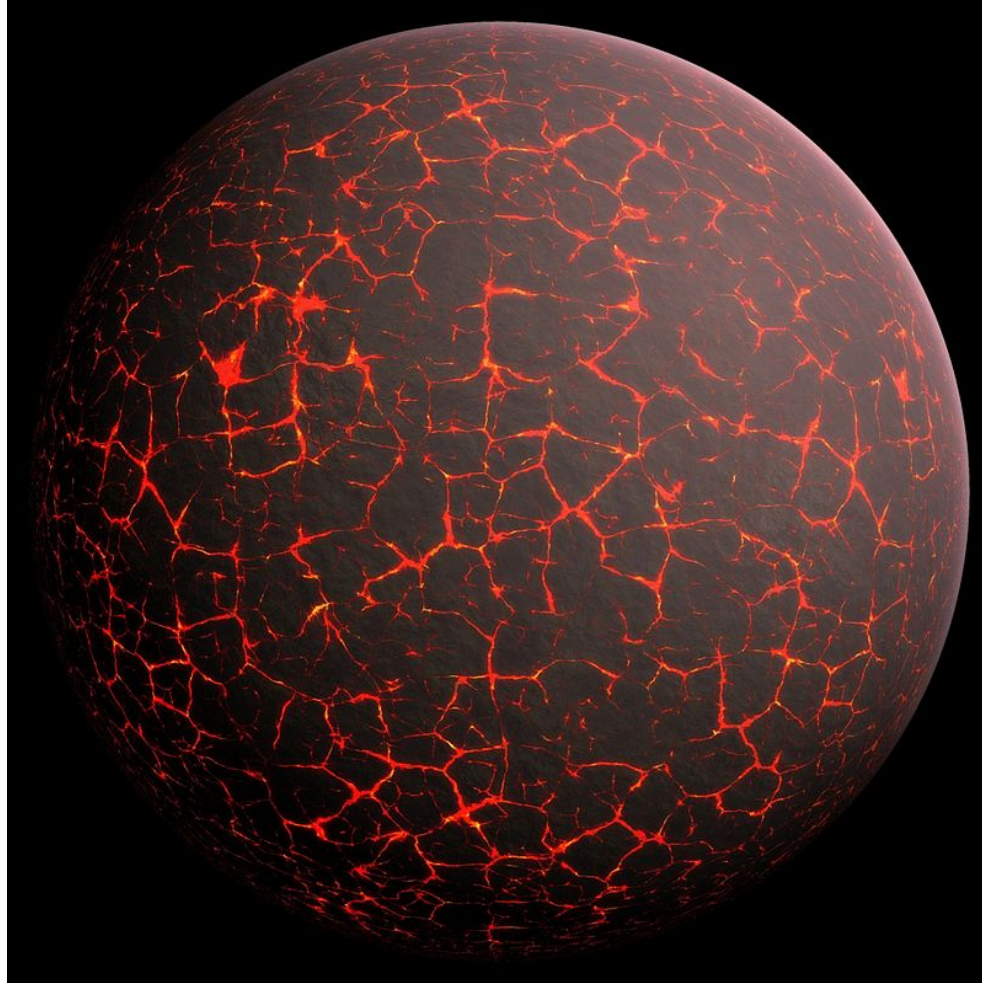
4600 million years ago (mya)

Formation of Earth



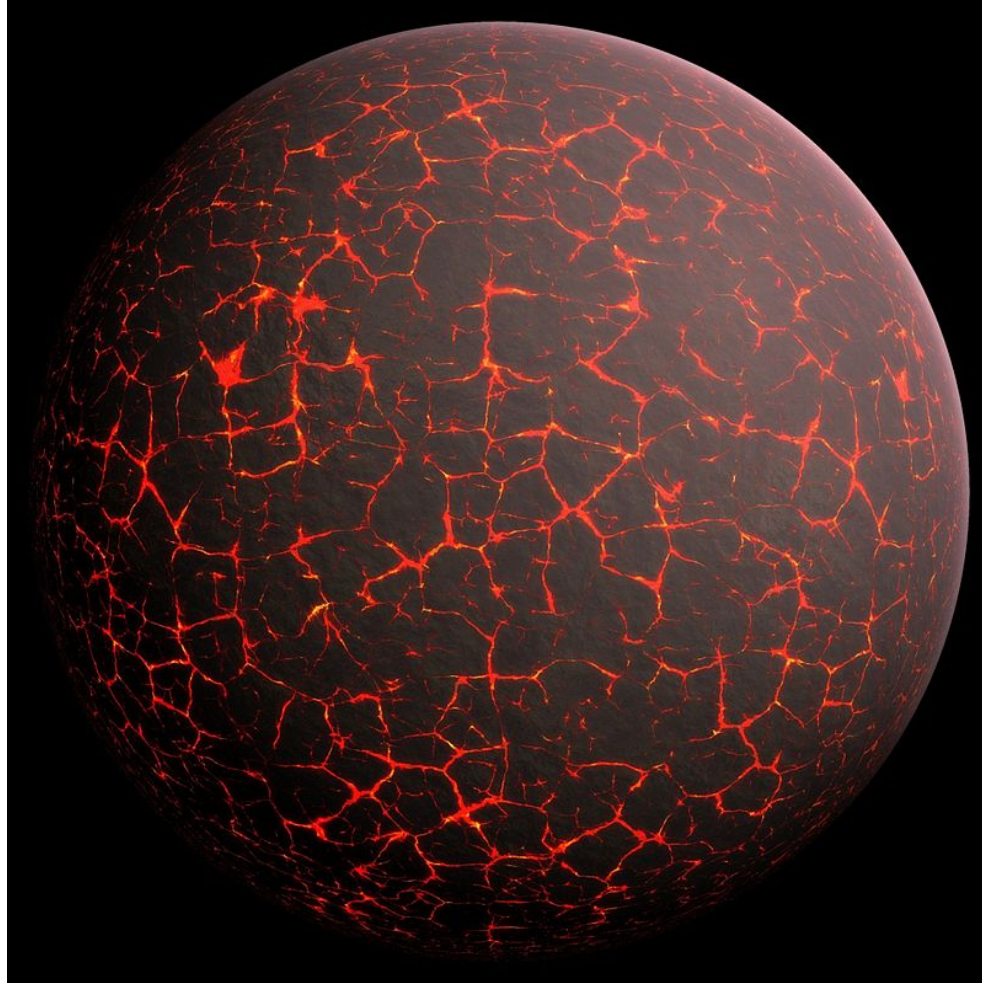
4.6 billion years ago (bya)

Formation of Earth



4.567 billion years ago (bya)

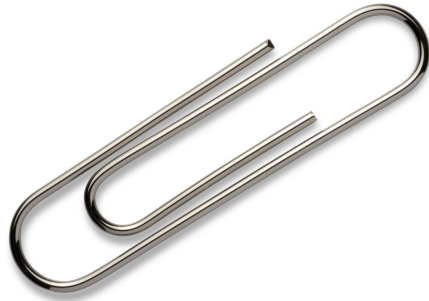
Formation of Earth



4.6 billion years ago (bya)

What is 4.6 billion?

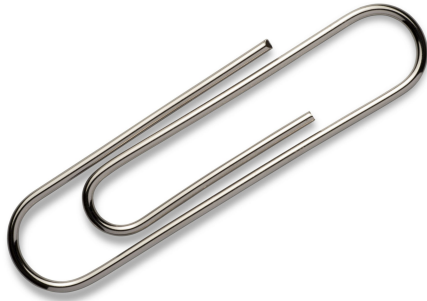
Imagine a chain of 4.6 billion paperclips -
Approximately how many times will it circle Earth?



Take a guess
and write it down

What is 4.6 billion?

Imagine a chain of 4.6 billion paperclips -
Approximately how many times will it circle Earth?



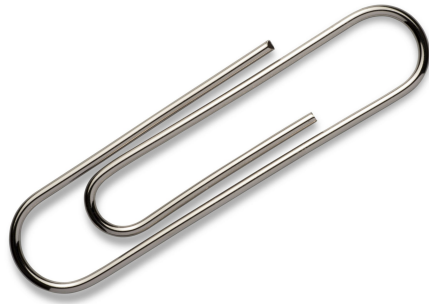
1 paperclip = 1 inch

63,360 inches / mile

Circumference of Earth ~ 24,000 miles

What is 4.6 billion?

Imagine a chain of 4.6 billion paperclips -
Approximately how many times will it circle Earth?



1 paperclip = 1 inch

63,360 inches / mile

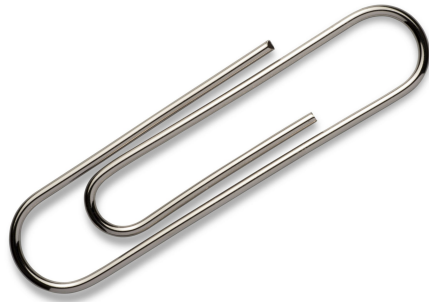
Circumference of Earth ~ 24,000 miles

$$4.6 \text{ billion paperclips} \times \frac{1 \text{ inch}}{1 \text{ paperclip}} \times \frac{1 \text{ mile}}{63,360 \text{ inches}} = 72,601 \text{ miles}$$

$$72,601 \text{ miles} \times \frac{1 \text{ circumference}}{24,000 \text{ miles}} = 3$$

What is 4.6 billion?

Imagine a chain of 4.6 billion paperclips -
Approximately how many times will it circle Earth?



1 paperclip = 1 inch

63,360 inches / mile

Circumference of Earth ~ 24,000 miles

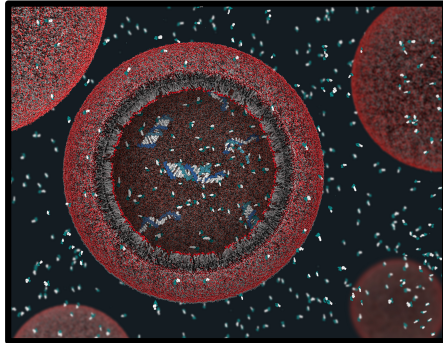
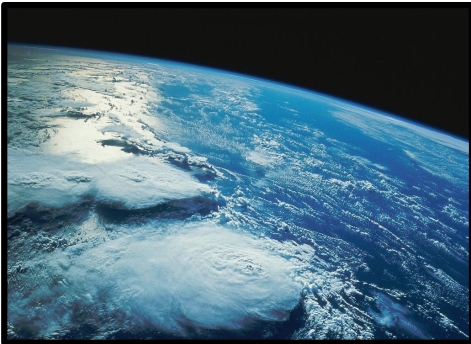
About 3 times!

How does this number compare to your estimate?

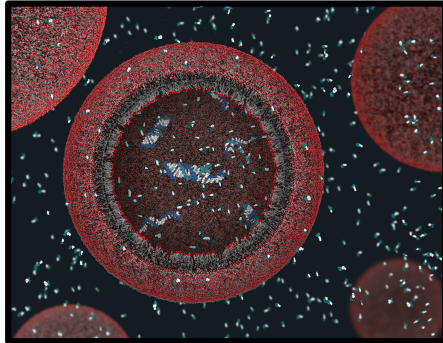
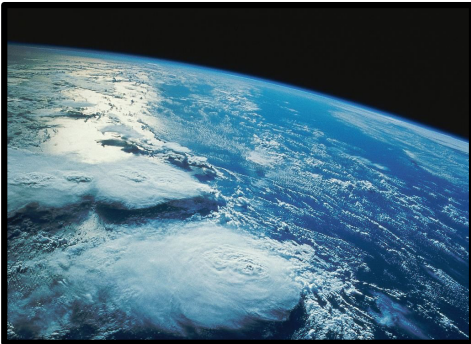
Build a Timeline



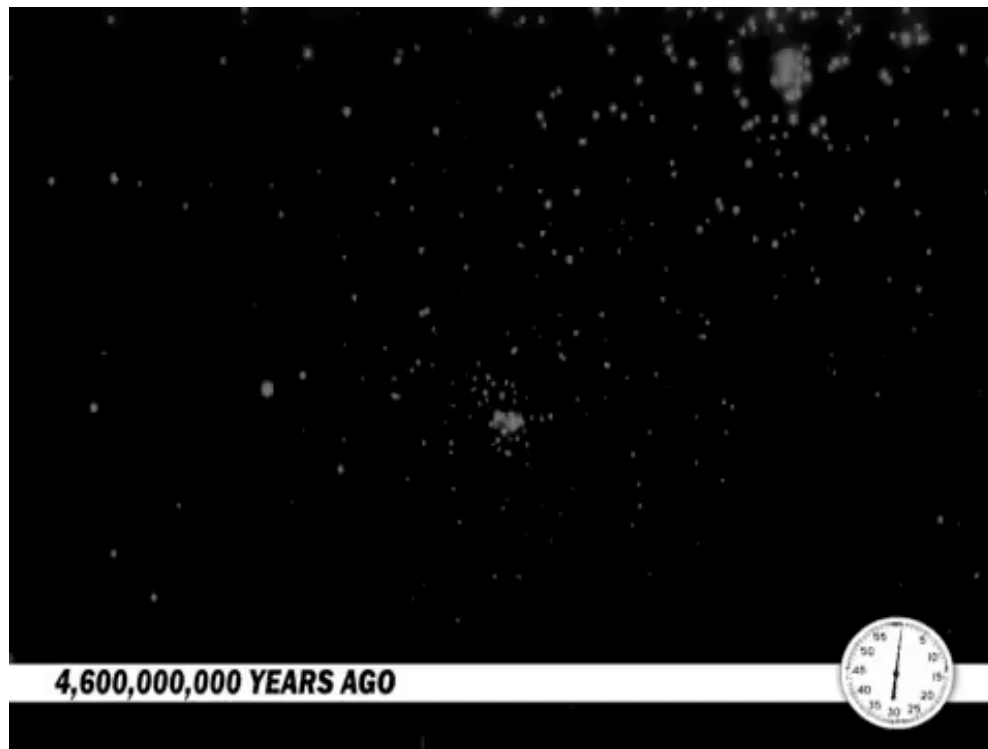
Build a Timeline



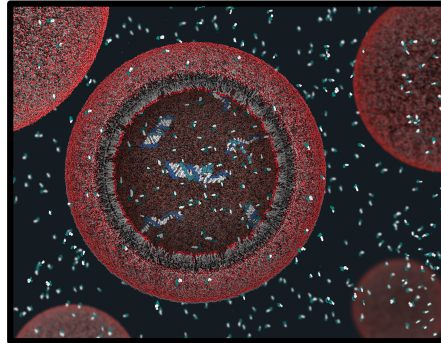
Build a Timeline To Scale



The Evolution of Life in 60 Seconds



Build a Timeline To Scale



Earth's Timeline to Scale

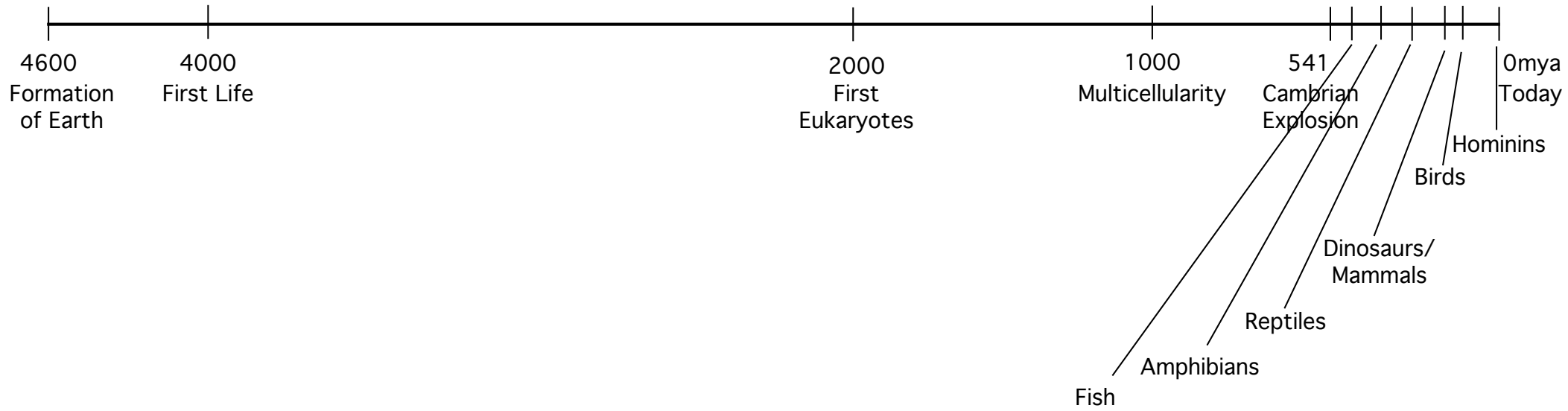
Key Event	Date (in billions of years ago, or bya)	Date (in millions of years ago, or mya)	Fraction of Earth's history	Distance from right edge of 30 cm page
Formation of Earth	4.6	4600	$4600/4600 = 1$	$1 \times 30 = 30$
Origin of life	4			
Atmospheric oxygen	2.5			
First eukaryotic cell	2			
First multicellular organism	1			
Cambrian explosion	0.542			
First fish	0.500			
First amphibians	0.400			
First reptiles	0.300			
First dinosaurs and mammals	0.200			
First birds	0.150			
Earliest hominins	0.006			
Modern humans	0.0002			

Multiply
by 1000

Divide
by 4600

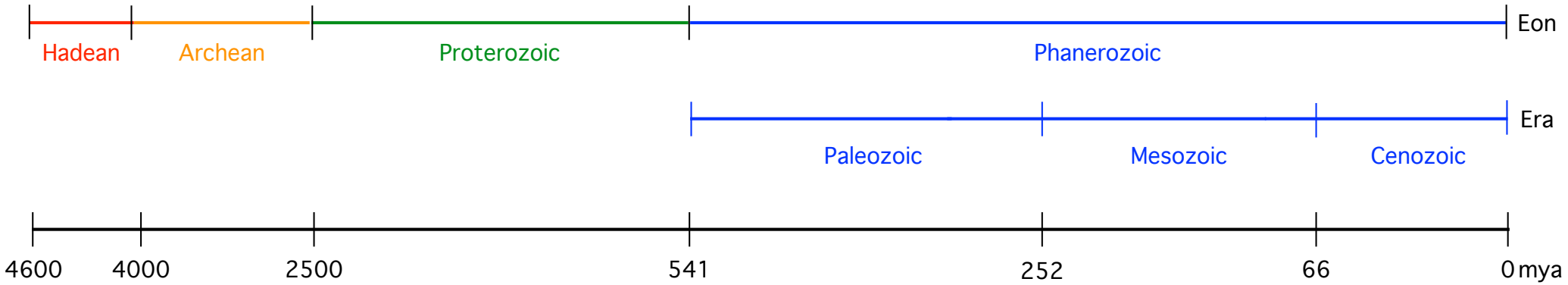
Multiply
by 30

Earth's Timeline to Scale

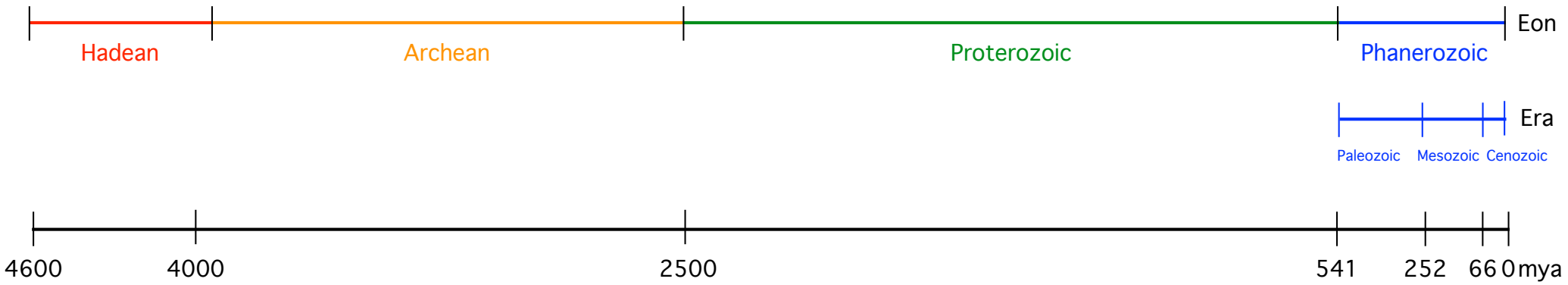


Geologic Time Scale

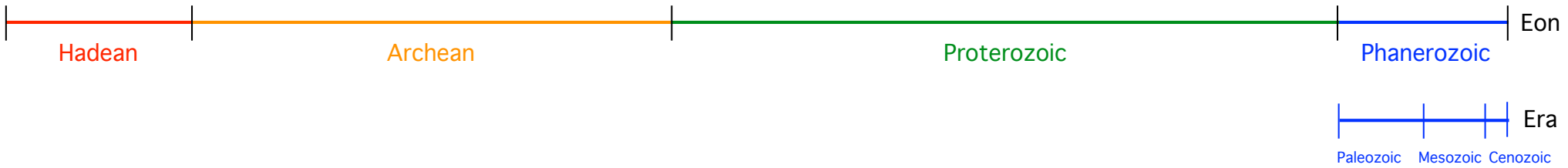
Not To Scale



Geologic Time Scale To Scale



Geologic Time Scale Key Events



Rise of
Atmospheric
Oxygen

First
Eukaryotes

Today

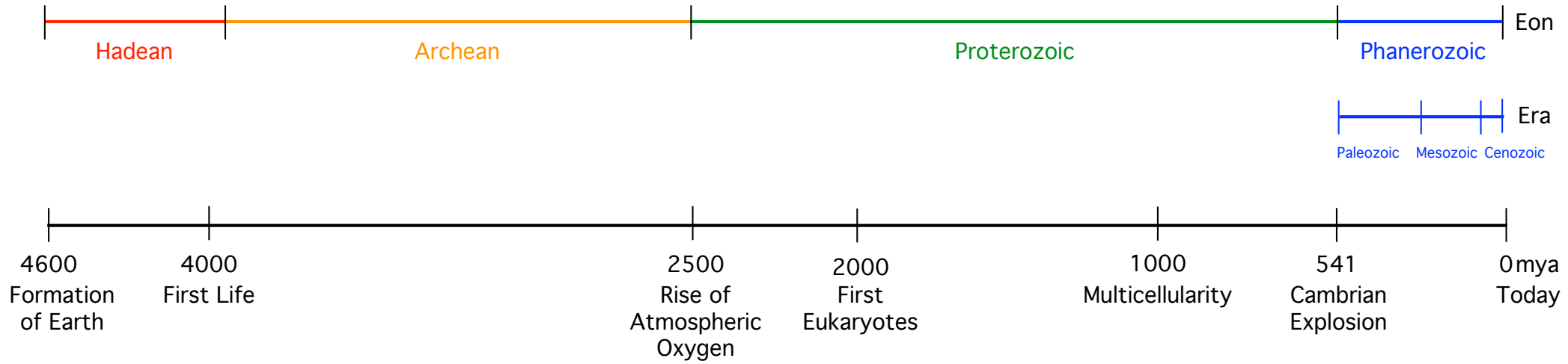
Formation
of Earth

First Life

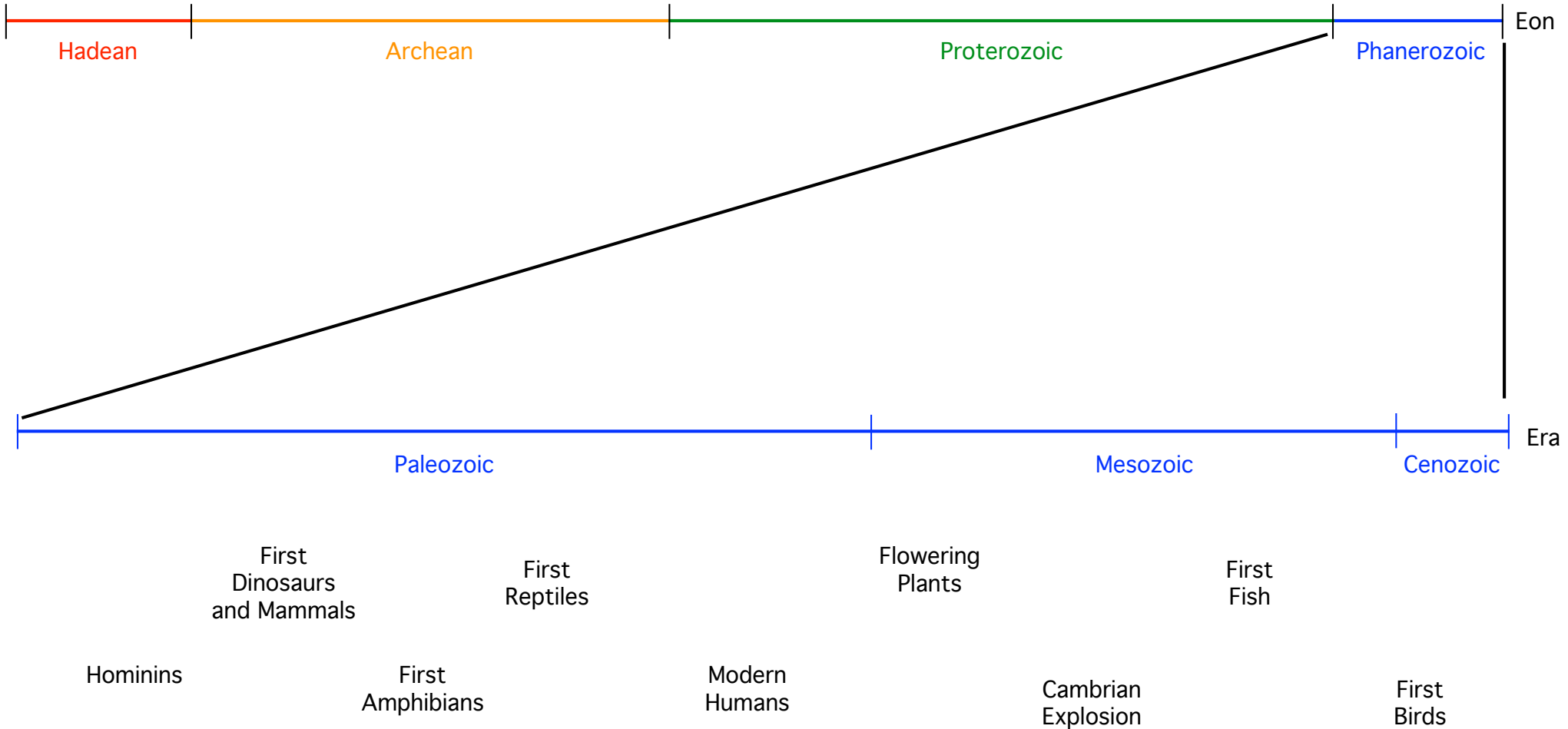
Cambrian
Explosion

Multicellularity

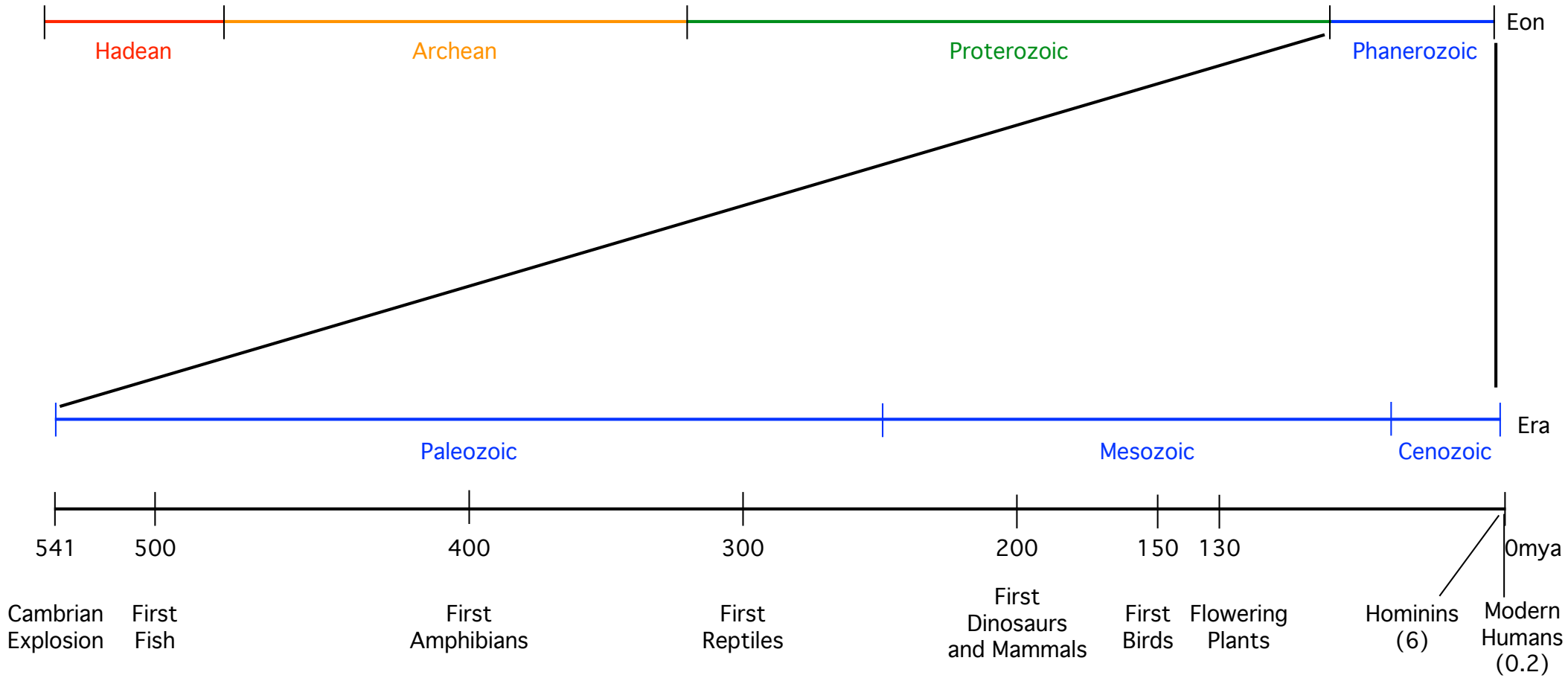
Geologic Time Scale Key Events



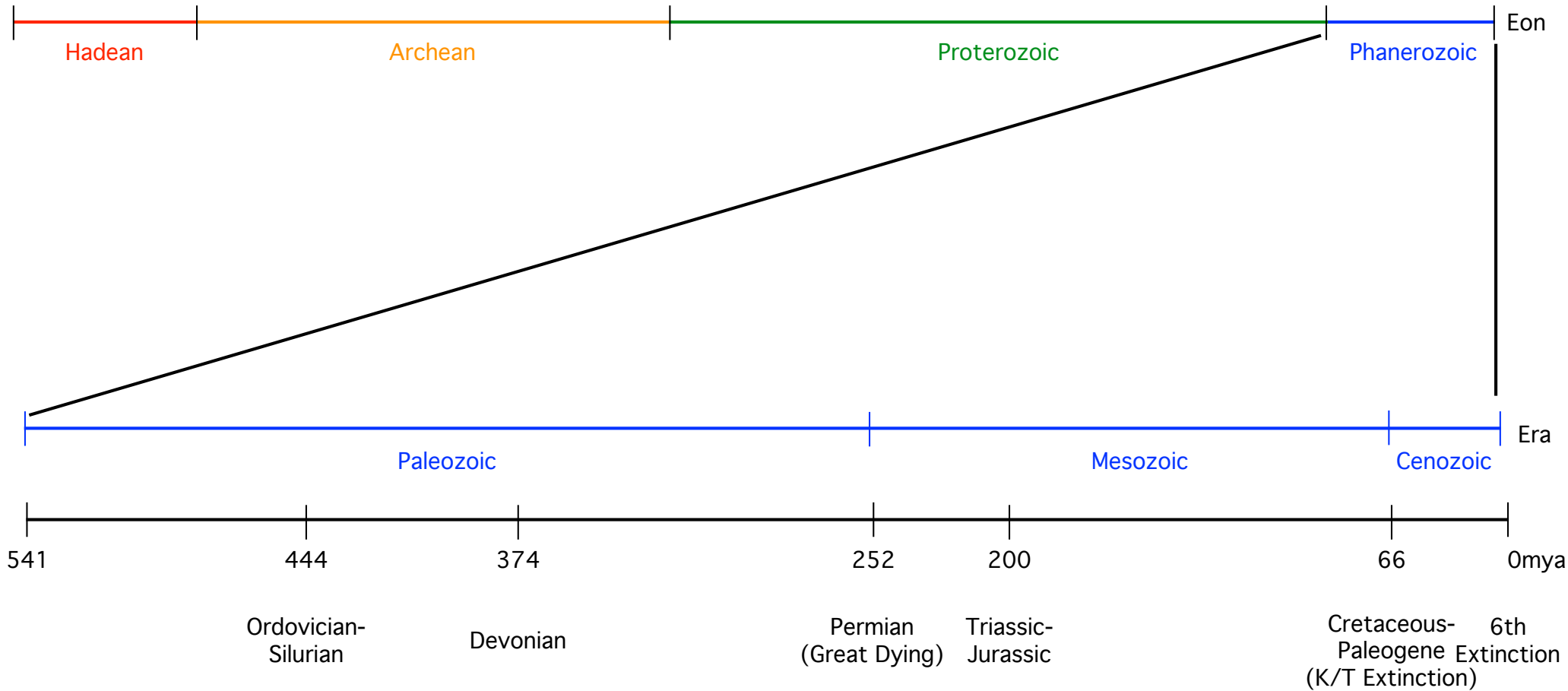
Geologic Time Scale Key Events



Geologic Time Scale Key Events

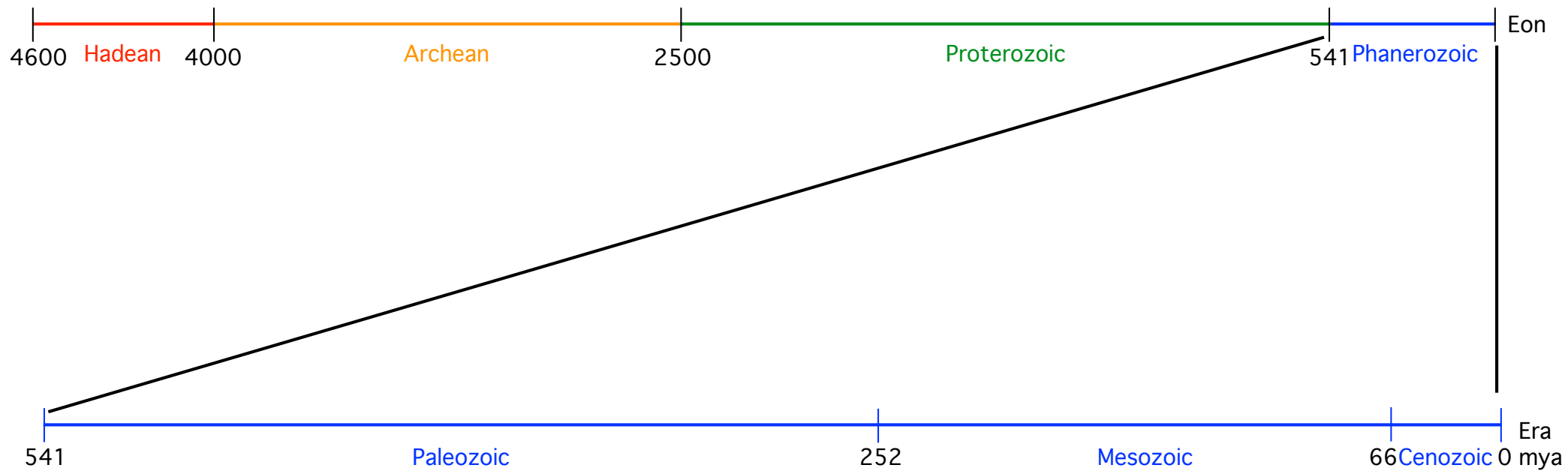


Geologic Time Scale Mass Extinctions

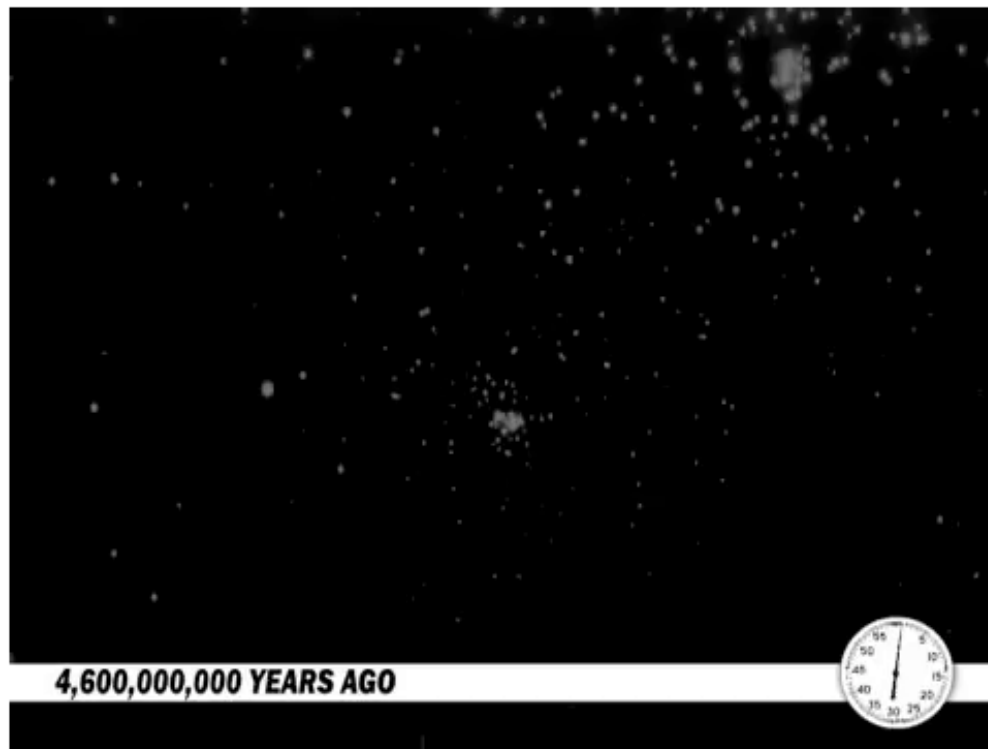


Geologic Time Scale

Find Events and Place them on the Timeline



Geologic Time Scale Map Timeline on Something Familiar



60 Seconds

Geologic Time Scale Map Timeline on Something Familiar

January

M	T	W	T	F	S	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

February

M	T	W	T	F	S	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	

March

M	T	W	T	F	S	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

April

M	T	W	T	F	S	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

May

M	T	W	T	F	S	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

June

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

July

M	T	W	T	F	S	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

August

M	T	W	T	F	S	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

September

M	T	W	T	F	S	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

October

M	T	W	T	F	S	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

November

M	T	W	T	F	S	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

December

M	T	W	T	F	S	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

One Year

Geologic Time Scale Map Timeline on Something Familiar



Football Field

Geologic Time Scale

Map Timeline on Something Familiar



Can you come up with one of your own?

Geologic Time Scale Map Timeline on Something Familiar

TWO-MINUTE ENTREATY

by ANTHONY DOERR

Tattoo Earth's 4.5-billion-year timeline onto your arm, shoulder to fingertip, and your upper arm will get nothing but geologic mayhem: meteorites, magma, acid rain. Life won't begin until your bicep, and from there to your wrist it's all single-celled, oceangoing stuff. Reproductive sex won't show up until your wristwatch, and creatures that are finally big enough to see—tubes and fronds and weird Precambrian plant-animals—will crisscross the back of your hand.

Trilobites paddle across your palm; ancient forests grow from your knuckles; dinosaurs wind around the joints at the ends of your fingers. Mammals burrow into your cuticles.

Orangutans, arrowheads, Cleopatra, the names of the stars—they all have to fit on the sliver of fingernail at the end of your longest finger.

And you? Your grandma's toffee bars, your CD collection, your treehouse, your best-ever Halloween costume, every regret you'll ever have, every dream you'll ever dream, every mouth you'll ever kiss (or wish you had)—they'll all ride the microscopic edge of your fingernail, a tattoo so thin you'd need an electron microscope to glimpse it.

File your nail and you'll wipe out your entire family tree, and Shakespeare and ancient Greece with it.

We are each no more than a spark, a mote illuminated for a split-second as it passes through a beam of light.

Pascal said, "When I consider the short duration of my life, swallowed up in the eternity before and after... I am frightened."

People say, "Who wants to feel so small? Let me eat my burrito."

I say, Be big. Big-hearted, big-witted, big-eyed. See, try, love, read, make, paint, and taste everything you can while you can.

You still have some hours left. Go.

We are like butterflies who flutter for a day and think it is forever.

~ CARL SAGAN