

Deep Time: Earth's history and future

By Colin Johnston, Armagh Planetarium

	Earth	Sun	Elsewhere in Solar System
4.54 billion years ago	Forms in Sun's proto-planetary disc		Other planets form. There are at least five rocky inner planets. The four giant planets' orbits are relatively tightly clustered between the present day orbits of Jupiter and Saturn.
4.527 billion years ago	Collision with other planet; Formation of the Moon from debris		
4.5-4 billion years ago	Mainly carbon dioxide atmosphere, surface water, molten core and magnetic field		Mars also has a mainly carbon dioxide atmosphere, surface water, molten core and magnetic field
4.2 billion years ago	Earliest oceans of water existed		
4-3.8 billion years ago			Gravitational interactions between giant planets cause them to migrate to present positions, sweep debris to present day Asteroid and Kuiper Belts. Late Heavy bombardment: 'storm' of asteroid impacts on inner planets
3.8 billion years ago	Earliest life in oceans?		
3.5 billion years ago			
3 billion years ago	First photosynthetic life?		
2.4 billion years ago	Atmosphere becoming rich in oxygen		
2 billion years ago		Sun's luminosity is about 89% current value	
1 billion years ago	Earth's biological	Sun's luminosity is	

	productivity peaks	about 95% present value	
470 million years ago	First plant and animal life on land?		
Now	Thick, mainly nitrogen and oxygen atmosphere, extensive liquid water, molten core generating magnetic field		
400 million years from now			Saturn's ring have dwindled to nothing
700 million years from now?	Mean temperature is 40°C. Declining atmospheric levels of carbon dioxide causes extinction of most plants and animals on land. As a result atmospheric oxygen levels decrease.		
1 billion years from now?	Mean temperature is 70°C, oceans shrinking, bacteria the only lifeforms, beginning of 'moist greenhouse'	Sun is 10% brighter than it is now	
1.2 billion years from now?	Earth's oceans boiling, conditions on Earth eventually resemble those of present day Venus. Mean temperature is 370°C, Final extinction of life?		
2 billion years from now?	Earth and Moon tidally locked		
3.5 billion years from now?			Triton breaks up, Neptune gains spectacular new rings
4 billion years from now?			Milky Way and Andromeda galaxies collide
5 billion years from now?			Milky Way and Andromeda have merged into a giant elliptical galaxy – 'Milkomeda'?
6.4 billion years from now?	Hot and airless	Sun a subgiant, diameter 1.5 its current value,	

		luminosity twice its current value	
7 billion years from now?	Sun's reduction in mass means Earth's orbital radius has increased to 1.4 times its current value, surface temperature is about 1400°C	Sun moves into red giant phase, diameter about 160 million km	Mercury absorbed by expanding Sun, Venus probably meets the same fate, icy moons of Jupiter vaporised, icy Kuiper Belt Objects melt
7.6 billion years from now?		Core temperature about 55 million°C, helium flash, followed by the Sun shrinking	
7.7 billion years from now?	Earth cools	Sun is 10 times its current diameter, luminosity 20-50% current value. Helium burning in core.	
20 million years later?	Earth destroyed?	Sun burning carbon and oxygen in core, expands to red giant again. Diameter 240 million km, luminosity 3000 times current value. Sun goes through series of helium flashes (3 or 4), swelling and losing mass each time	
7.8 billion years from now?		Sun a white dwarf surrounded by planetary nebula which disperse over thousands of years.	Gas giant planets still survive
500 billion years from now			Milkomeda and other galaxies in the Local Group have merged into one huge galaxy
1 quadrillion (10^{15}) years from now?		Sun cooled to a black dwarf	

Further reading

Plait, Philip, Death from the skies! Viking Penguin, New York, 2008

Ward, Peter and Brownlee, Donald, The life and death of planet Earth, Paitkus, London, 2007

Adams, Fred and Laughlin, Greg, the five ages of the universe, The Free Press, New York, 1999

<http://www.psr.d.hawaii.edu/Aug06/cataclysmDynamics.html>