

A Brief History of Time
John C. Baez, September 23, 2004

Note: all figures are approximate!

Working Backwards from Now

60 years ago — Invention of the computer.
130 years ago — Invention of the telephone.
180 years ago — Fossil fuel revolution: coal, trains.
540 years ago — Invention of the printing press.
5,500 years ago — Invention of the wheel, writing.
8,800 years ago — The first cities.
10,300 years ago — End of the latest ice age.
18,000 years ago — Cultivation of plants, herding of animals.
35,000 years ago — Invention of the calendar, extinction of Neanderthals.
600,000 years ago — First *Homo sapiens*.
1.4 million years ago — First firemaking by humans.
1.9 million years ago — First *Homo erectus*.
5 million years ago — Humans split off from other apes (gorillas and chimpanzees).
21 million years ago — Apes split off from other monkeys.
24 million years ago — First grasses.
67 million years ago — Asteroid hit Mexico, causing ‘Cretaceous-Tertiary extinction’.
 End of dinosaurs. 50% of all species died out!
114 million years ago — First modern mammals.
150 million years ago — First birds.
205 million years ago — Pangaea split into separate continents. Triassic-Jurassic extinction.
 End of large amphibians, many reptiles.
235 million years ago — First dinosaurs, flowers.
251 million years ago — Permian-Triassic extinction. 90% of all species died out!
313 million years ago — First reptiles.
370 million years ago — Devonian extinction. 70% of marine species died out!
 First amphibians, trees.
395 million years ago — First insects on land.
440 million years ago — Ordovician-Silurian extinction. Most marine species died out.
670 million years ago — First animals.
1.3 billion years ago — First plants.
1.6 billion years ago — First blue-green algae.
1.8 billion years ago — First purple bacteria; Earth’s atmosphere gets oxygen.
3.9 billion years ago — Asteroid impacts gradually come to a halt.
4 billion years ago — First life on Earth.
4.45 billion years ago — Formation of Earth complete; storm of asteroid impacts.
4.55 billion years ago — Formation of the Sun.
13.5 billion years ago — First stars.
13.7 billion years ago — The Big Bang: beginning of the universe as we know it!

Working Backwards to the Big Bang

13.7 billion years after the Big Bang: now.
Temperature: 2.726 Kelvin

Kelvin = degrees Centigrade above absolute zero. The melting point of water is 273 Kelvin; the boiling point is 373 Kelvin.

200 million years after the Big Bang: 'reionization': first stars heat and ionize hydrogen gas.
Temperature: roughly 50 Kelvin.

380 thousand years after the Big Bang: 'recombination': hydrogen gas cools down to form molecules.
Temperature: 3000 Kelvin.

10 thousand years after the Big Bang: end of the radiation-dominated era.
Temperature: 12,000 Kelvin.

1000 seconds after the Big Bang: decay of lone neutrons.
Temperature: roughly 500 million Kelvin.

180 seconds after the Big Bang: beginning of 'nucleosynthesis': formation of helium and other elements from hydrogen
Temperature: roughly 1 billion Kelvin.

10 seconds after the Big Bang: annihilation of electron-positron pairs.
Temperature: roughly 5 billion Kelvin.

1 second after the Big Bang: decoupling of neutrinos.
Temperature: roughly 10 billion Kelvin

100 microseconds after the Big Bang: annihilation of pions.
Temperature: roughly 1 trillion Kelvin

50 microseconds after the Big Bang: 'QCD phase transition': quarks get bound into neutrons and protons.
Temperature: 1.7-2.1 trillion Kelvin

10 picoseconds after the Big Bang: 'electroweak phase transition': electromagnetic and weak force become different.
Temperature: 1-2 quadrillion Kelvin.

Note: a picosecond is a trillionth of a second. Before this the temperatures were so high that our knowledge of physics is unable to say for sure what happened, though experts have some good guesses.

Working Forwards to the Future

1.1 billion years from now: the Sun becomes 10% brighter than today. The Earth's atmosphere dries out.

3 billion years from now: the Andromeda Galaxy collides with our galaxy. Many solar systems are destroyed.

3.5 billion years from now: the Sun becomes 40% brighter than today. If the Earth is still orbiting the sun, its oceans evaporate.

5.4 billion years from now: the Sun's core runs out of hydrogen, and it enters its first red giant phase, becoming 1.6 times bigger and 2.2 times brighter than today.

6.5 billion years from now: the Sun becomes a full-fledged red giant, 170 times bigger and 2400 times brighter than today.

6.7 billion years from now: the Sun starts fusing helium and shrinks back down to 10 times bigger and 40 times brighter than today.

6.8 billion years from now: the Sun runs out of helium and, too small to start fusing carbon and oxygen, enters a second red phase. It is 180 times bigger and 3000 times brighter than today.

6.9 billion years from now: the Sun begins to pulsate every 100,000 years, ejecting more and more mass in each pulse, and finally throwing off all but the hot inner core, becoming a white dwarf.

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10^{17} years from now: all white dwarf stars cool to black dwarfs with a temperature of at most 5 Kelvin.

10^{19} years from now: all galaxies 'boil off', gradually losing their dead stars to intergalactic space.

10^{23} years from now: all galactic clusters boil off. Temperature: 10^{-13} Kelvin.

From then on: the Universe expands exponentially and cools down to a temperature of 10^{-30} Kelvin. All black holes eventually evaporate, and all other forms of matter eventually disperse into individual elementary particles.

Note: this story leaves out all the exciting twists due to future discoveries by various forms of intelligent life! We can't really tell for sure what will happen!