

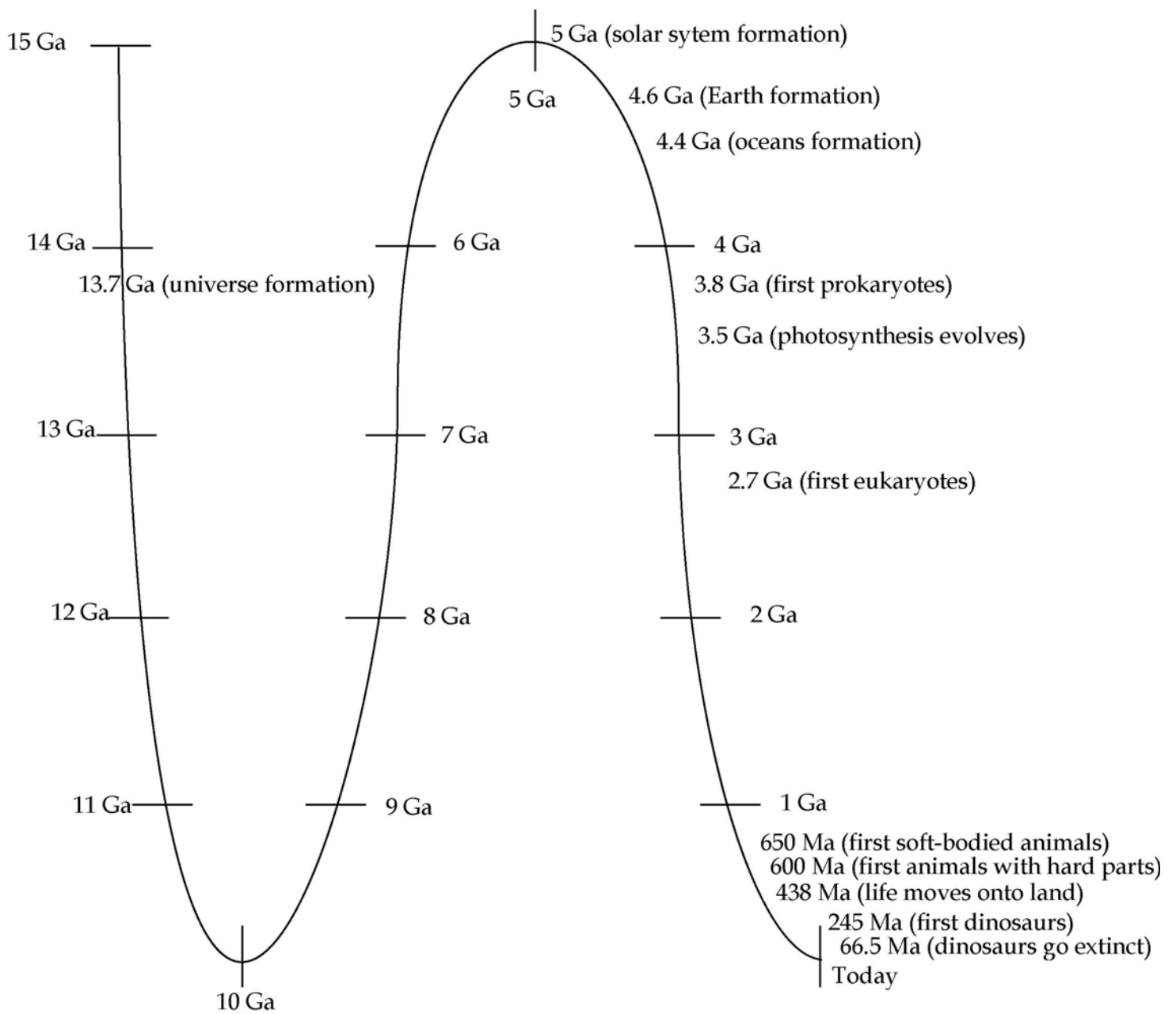
Brief History of Earth

10-25 Ka	Wisconsin ice age (most recent one; land bridges form and humans migrate from Asia into North America)
100-300 Ka	Homo Sapiens first appear.
400 Ka	San Francisco Bay forms.
1.6 Ma	Period of frequent ice ages begins and continues to today.
2-4 Ma	Ancient Hominids first appear.
50-25 Ma	San Andreas Fault forms as North American margin stops subducting.
63 Ma	Primates evolve.
65 Ma	Dinosaurs and other organisms go extinct making the way for the Age of Mammals.
145 Ma	First mammals, including platypus, shrews, and opossums.
152 Ma	First birds evolve from small, fast-running dinosaurs.
225 Ma	Pangaea , the most recent supercontinent completes its formation, and then begins its breakup (to create the Atlantic Ocean).
230 Ma	First dinosaurs, reptiles that distinguished themselves from others by standing upright on two legs.
240 Ma	First vertebrates to fly – the Pterosaurs, dinosaur cousins.
245 Ma	The largest mass extinction in Earth's history. Over 75% of all marine groups eliminated, making way for the Age of Dinosaurs
350-290 Ma	Giant Swamp Forests thrived in lowlands at the edges of rivers and seas (like today's Louisiana bayous). Tropical climates encouraged dense growth of ferns, tree ferns, and club-mosses. The buried material from these forests eventually became much of the world's current coal resources.
400 Ma	First lungs.
430 Ma	First jawed fish.
438 Ma	First plants move onto land, followed within 10 million years by animals (aquatic scorpions and other arthropods).
475 Ma	Pacific Plate subducts under North America's western margin. The western margin grows through accretion of oceanic rocks and islands (terranes).
520 Ma	First vertebrates (cartilaginous fish with tails and fins).
570 Ma	First organisms with hard parts. Beginning of the Age of Trilobites. Also existing early on were brachiopods and ammonites.
670 Ma	First multicelled animals evolve: Ediacaran fauna, soft-bodied marine animals that get their food primarily from small algae.
700 Ma	Rodinia breaks up into Gondwanaland (Australia, India, Africa, S. American, Antarctica) and Laurasia (N. America, Greenland, Europe, and Asia).
1 Ga	Sexual reproduction begins leading to an increase in the rate of evolution. Red Beds stop forming in large amounts and free oxygen begins to accumulate in the atmosphere. The atmosphere begins to evolve to one closer to today's: 80% Nitrogen, 20% Oxygen. Eventually enough oxygen accumulates in the atmosphere that UV radiation interacted with it in the upper atmosphere, split the molecules, and produced ozone , a gas that then acted as a UV shield, protecting life on Earth's surface.
1.2 Ga	Rodinia , the oldest known supercontinent, forms through collision of Earth's plates. Plate Tectonics has likely been active for billions of years.
2 Ga	Red Beds form on land. These beds are land-based rust piles that take the place of the oceanic BIFs as free oxygen now leaves the oceans and enters the atmosphere. The Red Beds absorb most of the available oxygen.
2.7 Ga	Eukaryotes evolve: organisms with a nucleus.
3.8-2 Ga	Banded Iron Formations (BIFs) form in a long-lived oceanic rust storm. Earth's oceans would have had a lot of dissolved iron, due to the accumulation of hundreds of millions of years of rock weathering and underwater volcanic eruptions. Newly formed oxygen, released from photosynthesis, readily and quickly combined with the iron to form layers of rust.
3.5 Ga	First prokaryotes to perform photosynthesis : energy derived from sunlight is used to make their food. These organisms, cyanobacteria that create mounds called Stromatolites , lived in mucous layers to avoid UV-radiation damage by the sun. Ocean and atmospheric chemistry begins to change as O ₂ is added and CO ₂ removed. (Photosynthesis: 6H ₂ O + 6CO ₂ + sunlight = C ₆ H ₁₂ O ₆ (sugar) +6O ₂ .)

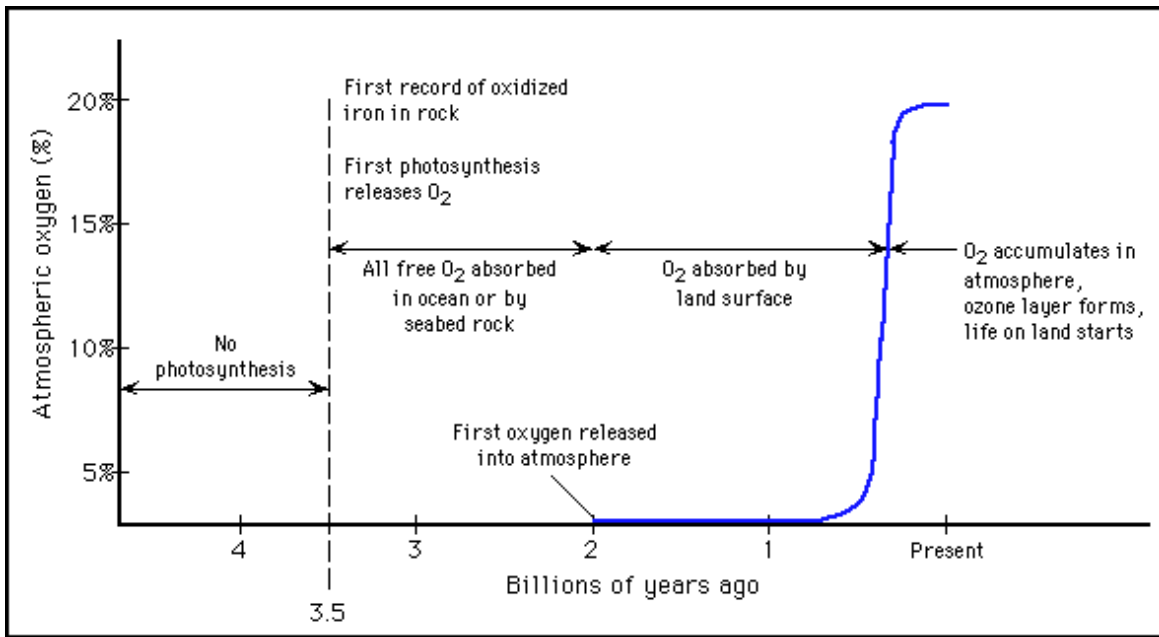
3.8 Ga	The earliest known life forms develop, in the oceans where they are hidden from the sun's ultraviolet rays (no ozone layer yet, because no oxygen in the atmosphere). These early bacteria were known as prokaryotes : single celled organisms with no nucleus, otherwise known as bacteria. These early life forms were likely chemosynthetic , making food from energy derived from gases emitted at hydrothermal vents on the bottom of the seafloor.
4.4 Ga	Earth's surface cools enough for a solid crust to form. Earth's atmosphere (accumulated gases from volcanic outgassing and comets) contains (in decreasing order) carbon dioxide, nitrogen, water vapor, methane, ammonia, carbon monoxide, sulfur dioxide, hydrogen sulfide, and hydrogen cyanide. Because of the solid cooler surface conditions, much of the atmospheric water now rains down and fills in basins to form the first oceans.
4.5 Ga	A Mars-sized object crashes into Earth creating debris that ends up in orbit around the Earth, eventually coalescing through accretion to form the Moon .
4.6 Ga	As the solar disk cools down, orbiting material collides and clumps to form larger objects (accretion). Continued accretion led to larger bodies with higher gravity that swept up more material within their orbits and ultimately became planets . Not all the material got swept up in this process. A large belt of leftover rocky debris – asteroids – exists between Mars and Jupiter. A belt of leftover icy debris – comets – orbits in the outer solar system. At this point, the interior of the Earth is mostly molten from the heat of accretion. Density stratification occurs: dense material, like iron, sinks to form the core while less dense material rises to form the crust ; the remainder becomes the mantle layer. All planets are hot from the accretion process. Volcanic activity and continual meteorite collisions dominate the surface. Gases from volcanoes and comets form an early, hot, toxic, atmosphere.
5 Ga	Debris from past supernovas is perturbed, likely by nearby star activity, and starts to clump together to form a new star – a single hot, spinning mass of gas – our proto Sun. The gas giants (Jupiter, Saturn, Neptune, Uranus) began forming soon after the Sun started coalescing, through similar processes. Large clumps of H and He separately coalesced and contracted, increasing in density and attracting material to become gas giant protoplanets. They are not stars because they never grew big enough and hot enough for fusion to occur in their cores. Eventually the material in the proto Sun completely condenses, fusion starts, and our Sun forms. As the Sun spins, the surrounding matter flattens into a rotating disk and begins to condense into solids, liquids, and gases – all very hot! It was too hot near the Sun for ices and many gases (like water, ammonia, and methane) to be stable, so condensates near the Sun consisted of iron oxides, aluminum oxides, and silicates – high-density minerals stable at high temperatures. In the cooler outer solar system, all materials were stable and condensed alongside each other. Hence, the inner rocky planets formed from the accretion of rocky material, whereas the moons, comets, and gas giants of the outer solar system formed (or completed their formation) from the accretion of all materials.
12.7-5 Ga	Throughout most of the life of a star, deep in their cores, H nuclei are fused to produce He and energy. Stars “shine” because they are radiating the energy produced from this nuclear fusion. High-mass stars burn the hydrogen fuel in their core rapidly and are short lived—the largest lasting only 10 million years. Low-mass stars burn their fuel slowly—the smallest lasting hundreds of billions of years. (Note: our Sun is medium sized and will last 10 billion years.) Once the H is nearly used up, He atoms begin to fuse, and the core temperature of the star rises dramatically. As temperatures rise higher, elements of successively higher mass—like carbon, nitrogen, and oxygen—are produced through fusion. Stars that are ten times more massive than the Sun can create elements as heavy as iron. Eventually the energy produced can't be shed fast enough; a high-mass star explodes in a supernova event, ejecting much, if not all of its matter, and producing a supernova remnant . Elements up to uranium can form in the supernova's blast waves. New stars eventually form from supernova remnants. Through repeated generations of star birth and death by supernova, these remnants can be enriched enough in heavy elements to form planets. <i>(Based on the abundance of heavy elements in our solar system, our Sun is likely a third- or fourth-generation star.)</i>
12.7 Ga	The universe is no longer smooth and uniform. High-density regions of H and He gas generate gravitational fields – the more mass, the more gravity. The more gravity, the more mass from surrounding areas is pulled in. Eventually localized regions condense under their own weight. Gravitational energy is converted into heat – temperature rises. Once the size of this dense spinning sphere of gas is great enough, and its core temperature rises above 10^6 K, nuclear fusion begins – primarily the fusion of H to produce He and energy. As this newly created energy radiates outward, a shining star is born. When billions of stars orbit a shared center of gravity, we call them a galaxy . There are hundreds of billions of galaxies in the observable Universe.
13.7 Ga	Big Bang : the universe is born in an instant in time and expands outwards from one infinitesimally small point. Original material = very high energy (hot) subatomic particles. Universe inflates and cools until protons, neutrons, and electrons form, and matter is governed by the laws of physics as we know them. 380 m.y. later, the universe is 75% Hydrogen (H) and 25% Helium (He) gas.

*Age is when division begins: Ka = thousands of years old; Ma = millions of years old; Ga = billions of years old.

For more information, see <http://www.ccsf.edu/TimeLife>.



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This timeline shows the creation of oxygen in Earth's atmosphere. Copyright © Columbia University, NY

You can find this timeline laid out in a walk along the four floors of the CCSF, Ocean Campus Science Building. It is supported by panels, posters, fossils, murals, and models. You can also find the entire exhibit transcribed and photographed online at www.ccsf.edu/Earth.



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