

## **Group 1**

### **4.56 Billion Years Ago - Solar Nebula Forms**

A concentration of hydrogen gas and dust swirling around our young Sun.

### **4.56 Billion Years Ago - Planetesimals Form**

Baby planets less than a few kilometers across form via impact.

### **4.56 Billion Years Ago - Planetesimals Grow Up to Form Protoplanets**

Planetesimals are large enough to attract material through gravity.

### **4.56 Billion Years Ago - Terrestrial Planets Form**

Mercury, Venus, Earth, and Mars form in the hot inner solar system.

### **4.56 Billion Years Ago - Gas Giants Form**

Jupiter, Saturn, Uranus, and Neptune form in the cooler, outer solar system.

### **4.56 Billion Years Ago Formation of Rocks in Space . . . Asteroids**

### **4.56 Billion Years Ago Formation of Dirty Snowballs in Space . . . Comets (Kuiper Belt Objects, Oort Cloud?)**

### **4.5 Billion Years Ago Formation of Earth's Moon**

Earth was hit by a Mars-sized planet. Debris blown into space around Earth eventually coalesced and formed our Moon.

## **Group 2**

### **4.4 Billion Years Ago Initial Crust on Earth**

Early Earth was HOT. Eventually the molten outer layers cooled, forming a crust. This crust was probably a bit like our ocean crust today.

### **4.4 Billion Years Ago Oldest Moon Rocks**

The Moon's magma ocean cooled, allowing a crust to form. Apollo Astronauts collected Moon rocks from some of this ancient crust.

### **4.2 Billion Years Ago Formation of Earth's Early Atmosphere and Oceans**

Volcanoes spewed gases — including water vapor — into the atmosphere. When things cooled down enough the water vapor condensed as liquid water in our oceans.

### **3.7 Billion Years Ago Mercury Chills Out**

This small planet became geologically inactive

### **3.5 to 4.5 Billion Years Ago Oceans on Mars?**

Early Mars may have had an ocean in its northern hemisphere. Features interpreted to be ancient river valleys are carved into the surface of Mars, suggesting the presence of water.

### **4.0 Billion Years Ago Oldest Rocks on Earth**

Continental crust (land!) had formed by this time. Samples from Australia have been dated to be as old as 4.4 billion years!

### **3.8 Billion Years Ago Large Impact Events Dramatically Reduced in Number**

Asteroids continue to strike Earth and the other planets, but not as frequently

## **Group 3**

### **3.8 Billion Years Ago Earliest Evidence Indicating Life (?)**

Scientists are debating the fossil evidence and chemical signatures suggested as indicators of life at this time.

### **3.5 Billion Years Ago Volcanic Activity on the Moon**

...and continues for a while. The most recent lunar volcanic flows are about 1 billion years old.

### **~3.5 Billion Years Ago First Stable Continental Crust**

In other words, things were calming down on Earth and stable land was forming.

### **3.5 Billion Years Ago Oxygen-"Rich" Atmosphere Begins to Develop**

Photosynthesis "invented" and well under way. Geologic evidence shows that photosynthetic organisms were pumping oxygen into the atmosphere.

### **3.0 Billion Years Ago First Undisputed Fossils (Single-Celled Organisms)**

The first organisms were prokaryotes (bacteria, photosynthesizing bacteria) — simple, single-celled organisms that do not have membrane-bound nucleus. The first fossils we find are stromatolites — pillar-like structures made of thin layers of sediment and photosynthetic cyanobacteria. Foreshadowing . . . Photosynthetic organisms add oxygen to our atmosphere.

### **3.0 Billion Years Ago Valles Marineris Begins Forming on Mars**

The crust of Mars stretched and broke apart, creating a long, deep chasm — as long as the distance between California and New York!

### **3.0 Billion Years Ago Earth's Moon Becomes Geologically Inactive**

Sporadic volcanism continues for another 2 billion years.

### **2.8 Billion Years Ago Floods on Mars!**

Water trapped beneath the Martian surface as ice occasionally catastrophically melted and flooded across the surface, carving giant channels.

## **Group 4**

### **2.7 Billion Years Ago First Eukaryotes**

Single-celled organisms. Eukaryotes are more complex than prokaryotes and have a nucleus and membrane-bound organelles (mitochondria) . DNA is held within nucleus. Unlike prokaryotes, eukaryotes recombine DNA when they reproduce — there are many more opportunities for genetic diversity.

### **~2.5 Billion Years Ago First Ice Age**

### **2.2 Billion Years Ago Significant Available O<sub>2</sub> in Atmosphere**

Oxygen had been building up via photosynthesizing organisms, but chemical processes used most of it.

### **2.2 Billion Years Ago Formation of Ozone Shield**

As oxygen became more abundant in the atmosphere, some of it formed an ozone shield, protecting Earth's surface from harmful ultraviolet rays.

### **900 Million Years Ago Tallest Volcano in our Solar System Begins to Form**

Olympus Mons, 22 kilometers (14 miles) high, began forming. Some lava flows are so fresh that they might be younger than 1 million years. If Olympus Mons were on Earth, it would almost fill the entire state of Arizona.

### **790 – 630 Million Years Ago Snowball Earth**

Earth covered by ice from poles to equator

## **Group 5**

### **~600 Million Years Ago Early Multicelled Critters**

Ediacaran Fauna — funky-looking fossils found in Australia, China, Russia, Canada, and the United States. None had shells, so all we have are traces of these organisms with soft bodies. They look a bit like sea pens and jelly fish.

### **540 Million Years Ago First Shells**

Shells — and other hard parts — offer protection and support to organisms. They also preserve far better than soft tissue, giving us a rich fossil record. Starting about 540 million years ago, lots of different shelled organisms are found as fossils.

### **525 Million Years Ago Earliest Chordates**

Organisms with a notochord — a first step to a vertebra. A notochord is a stiff rod of dense tissue.

### **510 Million Years Ago First Fish**

The early fish did not have jaws or a vertebrae (they did have a notochord!). Many had plates covering all or part of their bodies. Some probably burrowed into the soft seafloor and dredged up their food.

### **438 Million Years Ago Ordovician Extinction**

### **430 Million Years Ago First Land Plants**

There MAY be fossil spores from plants as early as ~500 million years ago. Think of “mosses” when you think of the first land plants — these early conquerors were low to the ground and needed access to water to reproduce. Only bacteria, slime, etc., were on land before this.

### **430 Million Years Ago First Insects**

Not far behind the plants! Some fossil evidence for insects includes "bite" marks in plant fossils.

#### **420 Million Years Ago First Vascular Plants**

Vascular plants have a plumbing systems for transporting water and nutrients. Early vascular plants required water to reproduce (think ferns and horsetails).

#### **410 Million Years Ago Forests!**

Once they made it onto land and developed an efficient piping system and strong tissue to support high growth, plants quickly grew taller, creating forests with multiple levels of growth.

#### **400 Million Years Ago Whopping Big Lava Flows Cover the Surface of Venus**

Unlike other terrestrial planets, much of the surface of Venus is not heavily cratered. It appears to have been covered and smoothed by lava flows between 300 and 500 million years ago.

## **Group 6**

### **370 Million Years Ago First Amphibians**

There may be tracks at 390 million years ago, indicating earlier amphibians. The first amphibians probably lived in shallow, heavily vegetated waters. They evolved their “legs” to maneuver around all the vegetation. So legs came first, then the amphibians headed onto land. Amphibians are cold-blooded terrestrial animals that need to return to the water to reproduce (indeed, many must stay in moist environments so that they don't dry out). These first amphibians are the ancestors to our frogs and salamanders.

### **360 Million Years Ago Devonian Extinction**

70% of marine species extinct. Little effect on land based life.

### **365 Million Years Ago First Gymnosperms (Seed-bearing Plants)**

Gymnosperms don't need water for fertilization. They also invented the “pre-packaged” seed — self-contained with nutrients. This allowed the seed to stay dormant until conditions were right for sprouting. Seeds could be dispersed by organisms. The first gymnosperms were the ancestors of our pine trees, giant redwoods, and ginkos!

### **~310 Million Years Ago First Reptiles**

Reptiles “invented” the self-contained egg, which includes all the things a developing embryo needs (nutrients, protection from drying out, shedding of waste). Unlike amphibians, which have to go back to water to lay their eggs, reptiles could live away from bodies of water. Reptiles are cold-blooded, terrestrial animals with skin that prevents them from drying out.

### **250 Million Years Ago Permian Extinction**

90% of all Marine Species Become Extinct. Marine organisms, amphibians, and plants are hit hard by the largest mass extinction event known in Earth history. The cause is debated and may be related to multiple events, including volcanism, global climate change, and ocean overturn. This event may have cleared the playing field of competitors and aided the rise of the dinosaurs. Extinction seems to cause rapid speciation events . . .

## **Group 7**

### **250 Million Years Ago Supercontinent Pangaea Assembled**

All the continents came together (again!) to form one big land mass

### **250 Million Years Ago First Dinosaurs**

Could be as late as 220 million years ago. These reptiles started out as small carnivorous critters walking around on two legs (bipedal).

### **210 Million Years Ago Triassic Extinction**

### **210 Million Years Ago First Mammals**

+/- 30 million years; mammal features are challenging to identify in the fossil record. The first mammals were small, nocturnal critters. Early mammal fossils have some evidence of pits for whiskers and fur, suggesting another element of “mammal-ism” — that of being warm-blooded.

### **220 Million Years Ago First Birds**

Protoavis may actually be an early dinosaur, and not the first bird. It shares many characteristics with the early dinosaurs, but may also have had feathers.

### **155 Million Years Ago First (Undisputed) Birds ( Archaeopteryx )**

Most scientists believe that Archaeopteryx , a relative of the dinosaurs, is the ancestor of today's birds (so think of T-Rex the next time you see a sparrow . . .). Archaeopteryx has some reptile characteristics (teeth, long bony tail, grasping claws on its wing) and some bird characteristics (feathers; bird-like hip; thin, hollow bones). It probably was a weak flyer.

**~100 Million Years Ago First Angiosperms (Flowering Plants)**

Lots of debate on the timing of this event! Gymnosperms are commonly pollinated by wind; angiosperms have flowers that attract insects and birds, increasing the opportunities for pollination. Pollinated seeds are encased in nutrients — giving us the fruit we enjoy!

**100 Million Years Ago Tycho Crater Forms on the Moon**

This is a clear, “fresh” (non-eroded) crater.

**65 Million Years Ago KT Extinction**

Asteroid Smashes Into Earth; Extinction of Dinosaurs

## **Group 8**

### **55 Million Years Ago First Primates**

### **55 Million Years Ago First Grasses**

Grasslands became very widespread as our climate cooled in the last 45 million years.

### **~50 Million Years Ago India Collides With Asia**

### **~45 Million Years Ago Initial Uplift of the Himalayas**

### **~45 Million Years Ago Most Recent Period of Global Cooling Begins**

### **~30 Million Years Ago Antarctic Ice Sheet Develops**

Antarctica had separated from all other land masses. As global climate cooled, an ice sheet grew across the continent. The ice sheet is this old, but the actual ice is not ; the ice that makes up the ice sheet is constantly taken away by melting and as icebergs and renewed by falling snow.

### **~5 to 1.5 Million Years Ago Giant "Armadillos" Roam Gulf Coast of North America**

Really. These critters were about 1.5 meters (5 feet) across. We have one inside...

### **5–10 Million Years Ago Uplift of the Colorado Plateau Initiated**

The Grand Canyon is young geologically! As the Plateau rose, rivers cut down deeper and deeper, forming the canyon.

## **Group 9**

### **4 Million Years Ago First Early Hominid**

Ardipithicus ramidus

### **2.5 Million Years Ago Hominids Making and Using Tools**

### **~2 Million Years Ago Northern Hemisphere Ice Sheets First Form**

The most recent period of glaciation is initiated.

### **500,000 Years Ago First Human Use of Fire**

### **200,000–30,000 Years Ago Neanderthals on the Scene**

### **150,000–200,000 Years Ago Homo Sapiens First Appear**

### **10,000 Years Ago Modern Human Civilization Begins**

Agriculture, animal husbandry, villages

### **3000 Years Ago Humans Creating Calendars and Navigating Based on Stars, Moon, and Sun**

### **40 Years Ago That's One Small Step for Man . . . One Giant Leap for Mankind**

On July 20, 1969, Neil Armstrong was the first human to set foot on the lunar soil of our Moon.

## Scale

3 ft = 100,000,000 years

30 ft = 1,000,000,000 years