Origin of Stars, Earth, Moon, Oceans and Life

Cornell University | Oceanography

CORNELL VOTES! EVERY PERSON EVERY VOICE

Outline

The Origin Of…

1. Universe
2. Galaxies/Stars
3. Our Solar System
4. Earth and Moon
5. Atmosphere
6. Ocean
7. Life

Some Miscellaneous Stuff…

1. Names of Modern Oceans
2. Average Depth of the Modern Ocean
3. Latitude and Longitude
4. Contour Plots

Section I

1. Origin of Universe (Big Bang)
2. Origin of Stars/Galaxies

Evolution of the Universe

Age to the Universe (*years*)

~300 thousand

~500 Million

~1 Billion

~9 Billion

~14 Billion

S.G. Djorgovski et al. & Digital Media Center, Caltech

Universe Filled with Glowing Ionized Gas

The Dark Ages Start (hydrogen and some helium)

Stars and Galaxies Form
Reionization Begins - Light Returns to the Universe

The Dark Ages End…

Reionization Complete Universe Becomes Transparent to Visible Light

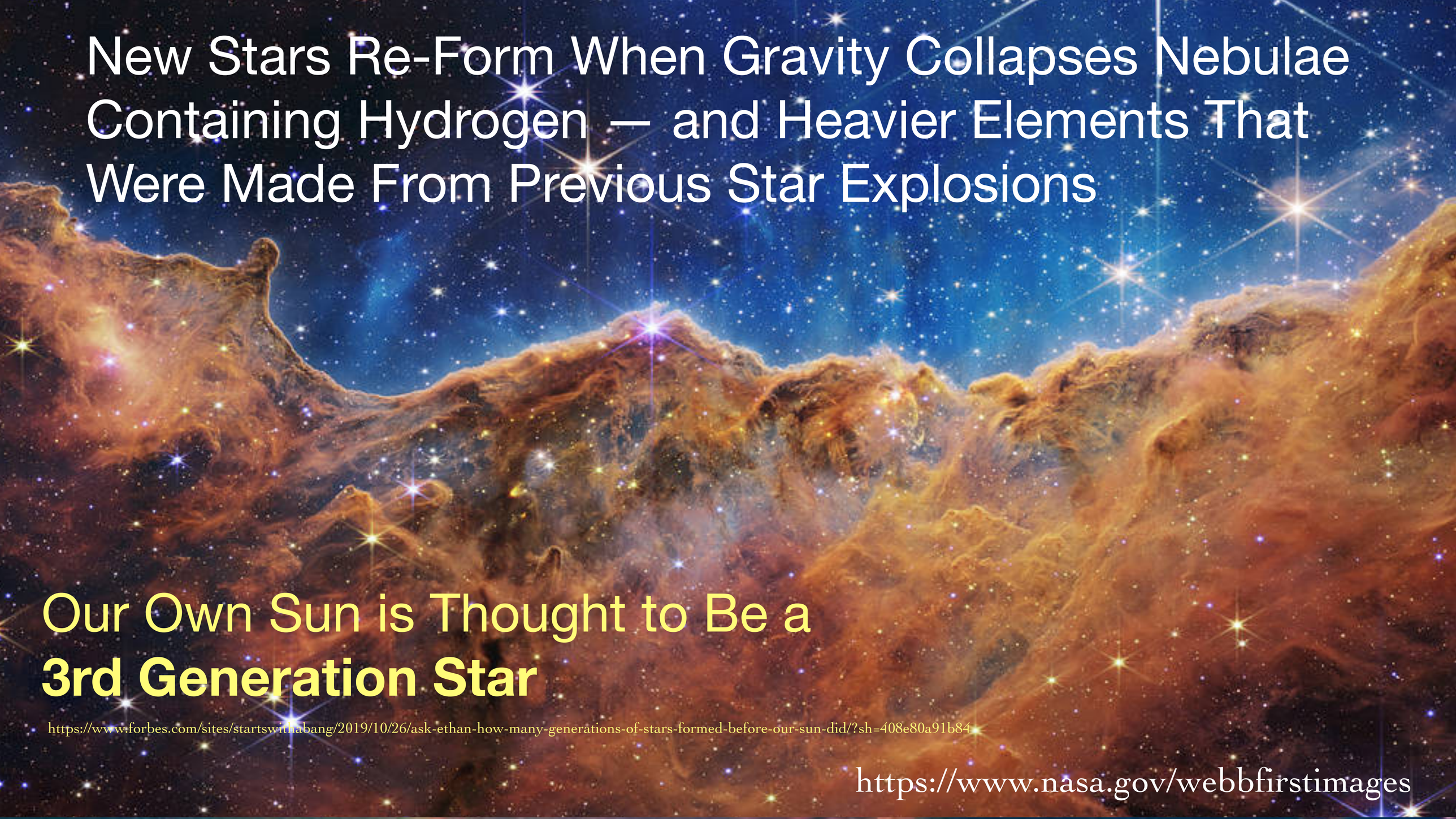
Our Solar System Forms (about 4.5 billion year ago)

Large Stars Explode When They Get Old To Form Nebula Containing Dust With a Wide Range of Light and Heavy Elements.

1. When the Big Bang happened (and then cooled a bit) there was **only hydrogen** *(and a little bit of helium)* in the universe

2. Gravity pulls hydrogen together and compresses it so intensely that it ignites *thermonuclear fusion* within the star and **lighter elements fuse together to form heavier elements like carbon, nitrogen and phosphorous** up to iron — and also heat and ***star light!***

3. When ***large*** stars explode, elements heavier than iron are formed (e.g., **gold, copper etc.)**


New Stars Re-Form When Gravity Collapses Nebulae Containing Hydrogen — and Heavier Elements That Were Made From Previous Star Explosions
Our Own Sun is Thought to Be a
3rd Generation Star
https://www.forbes.com/sites/startswithabang/2019/10/26/ask-ethan-how-many-generations-of-stars-formed-before-our-sun-did/?sh=408e80a91b84
https://www.nasa.gov/webbfirstimages

Star Formation

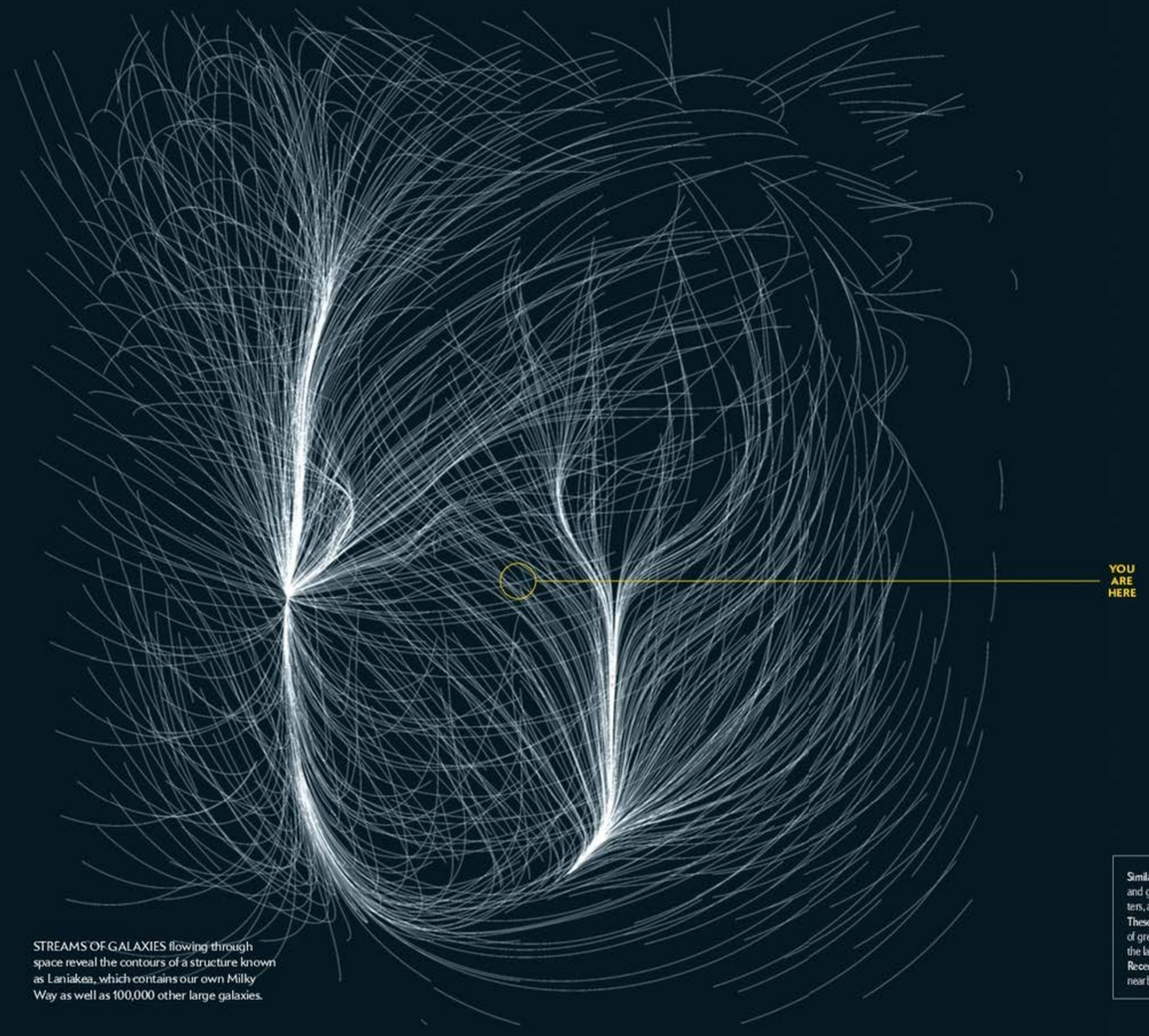
Simulation & visualization by Matthew Bate, University of Exeter

See: http://www.astro.ex.ac.uk/people/mbate/Cluster/cluster3d.html

Galaxy Formation

The first mini-galaxies formed when the universe was just a few hundred million years old. Over time, these small galaxies interacted and merged to build up ever larger galaxies, including big spirals like our own Milky Way.

Credit: NCSA/NASA/B. O'Shea (MSU) and M. Norman (UC San Diego). For more see: http://www.jwst.nasa.gov/videos_science.html



STREAMS OF GALAXIES flowing through space reveal the contours of a structure known as Laniakea, which contains our own Milky Way as well as 100,000 other large galaxies.

ASTRONOMY

Our Place in the Cosmos

The Milky Way turns out to be part of a massive supercluster of galaxies that forms one of the largest known structures in the universe. This discovery is only the beginning of a new effort to map the cosmos

By Noam I. Libeskind and R. Brent Tully

IN BRIEF

Similar to how stars clump together into star clusters and galaxies, galaxies themselves gather into clusters, and galactic clusters group into superclusters.

These galactic superclusters are the building blocks of great filaments, sheets and voids that constitute the largest measurable structures in the universe.

Recent studies of the motions of thousands of nearby galaxies have revealed that the Milky Way's home supercluster is far larger than previously thought. Astronomers call this newfound supersized supercluster "Laniakea."

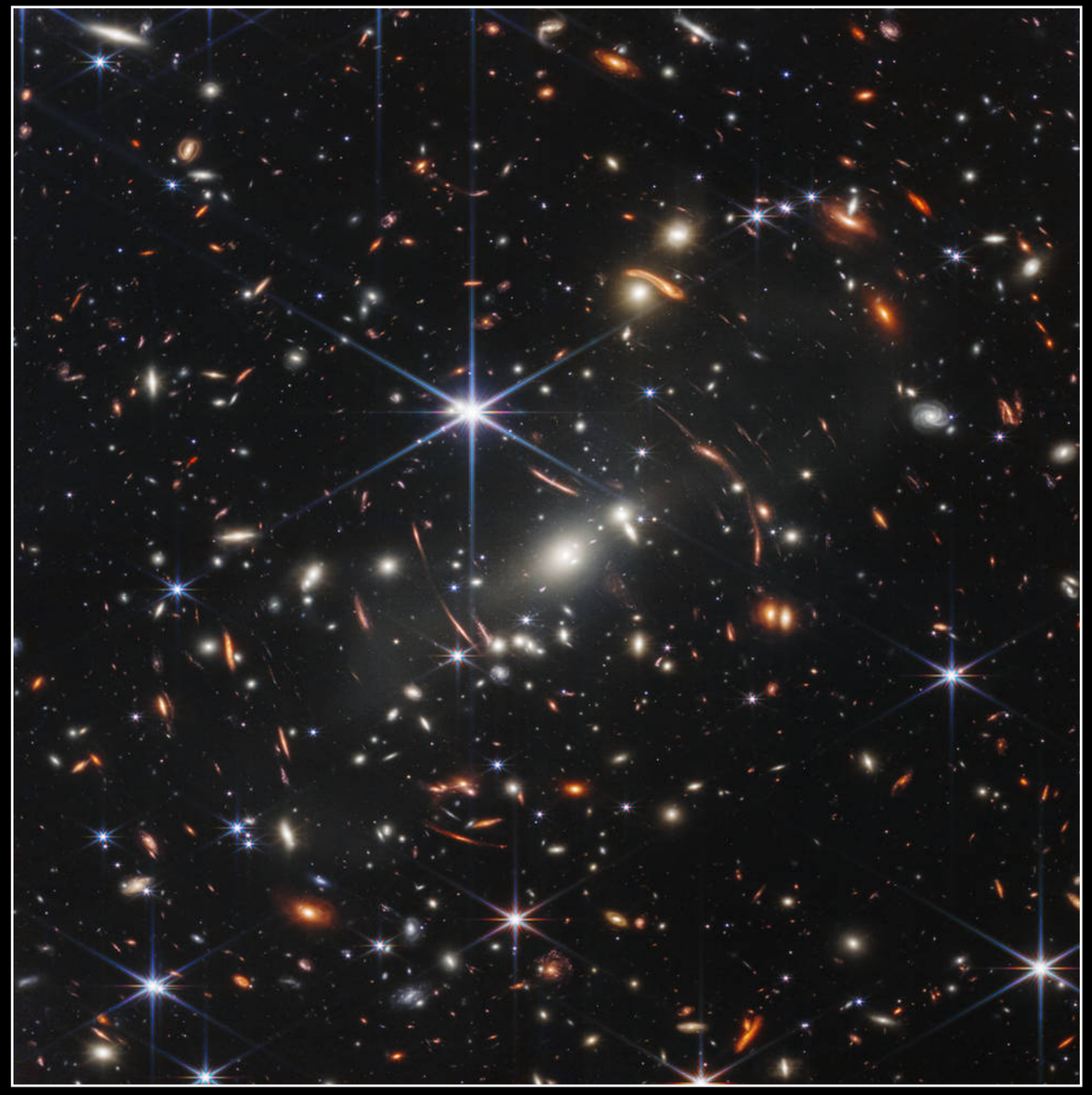
More detailed mapping of Laniakea and its neighboring superclusters could reveal new details about galaxy formation and help researchers solve the dual cosmological mysteries of dark matter and dark energy.

James Webb Space Telescope's Deep Field Image

The area observed in this image is equal to a patch of sky covered by a grain of sand extend at arms length.

There are roughly 100 billion galaxies that contain roughly 100 billion stars in the observable universe.

https://www.nasa.gov/webbfirstimages



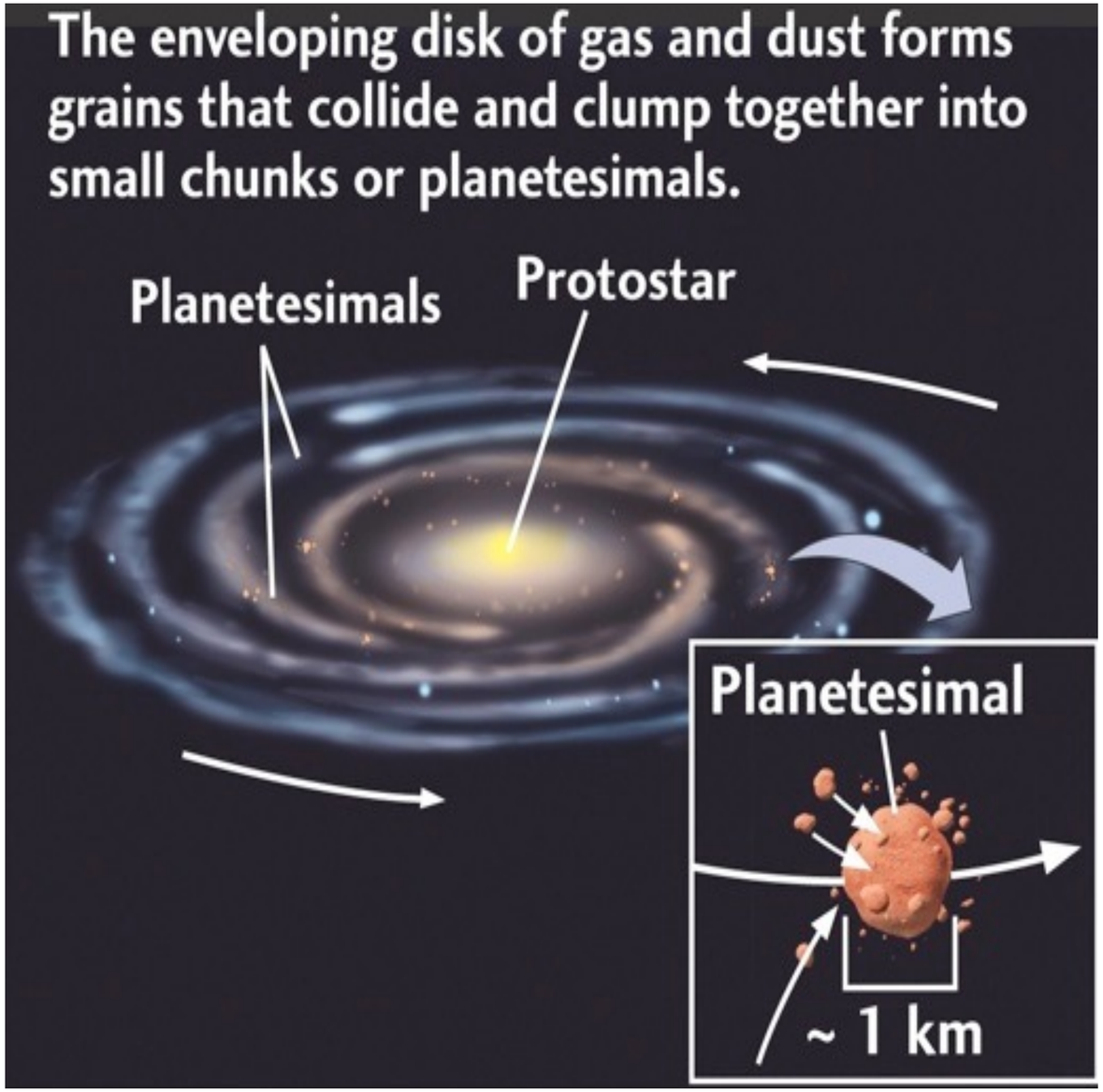
Summary of Universe/Galaxy/Star Formation

1. **Big Bang Happened About 14 Billion Years Ago:** All the mass of the universe expanded outward from a single point — hydrogen atoms formed as the universe began to cool. There was only hydrogen (and some helium) in the universe at this early stage.
2. Hydrogen gas was pulled together by gravity into large dense clouds
   - Temperature and pressure in the core of large dense hydrogen clouds increases due to compressional heating
   - When core temperatures reach 10 million degrees Kelvin, thermonuclear-fusion begins to form heavier elements - plus heat and visible light (*among other types of radiation*)
3. The only place in the universe where elements heavier than hydrogen or helium can be created is inside of stars where nuclear fusion of lighter elements creates heavier elements such as carbon (*with atomic number 12*) and on up to iron (*atomic number 26*). And elements heavier than iron are only formed when the largest stars explode.
4. New star formation continues today. We live in the age of stars!
5. When large stars explode, they form nebular clouds of gas and dust containing a mix of light and heavy elements that are available to be pulled back together by gravity to form new stars and new planets and new us!
6. Every single carbon atom making up YOUR physical body today was, at one point in the past, sitting in the center of a boiling hot star!!! **You very truly are made of star dust!!!**

Section II

1. Origin Of Our Solar System
2. Nothing Lasts Forever

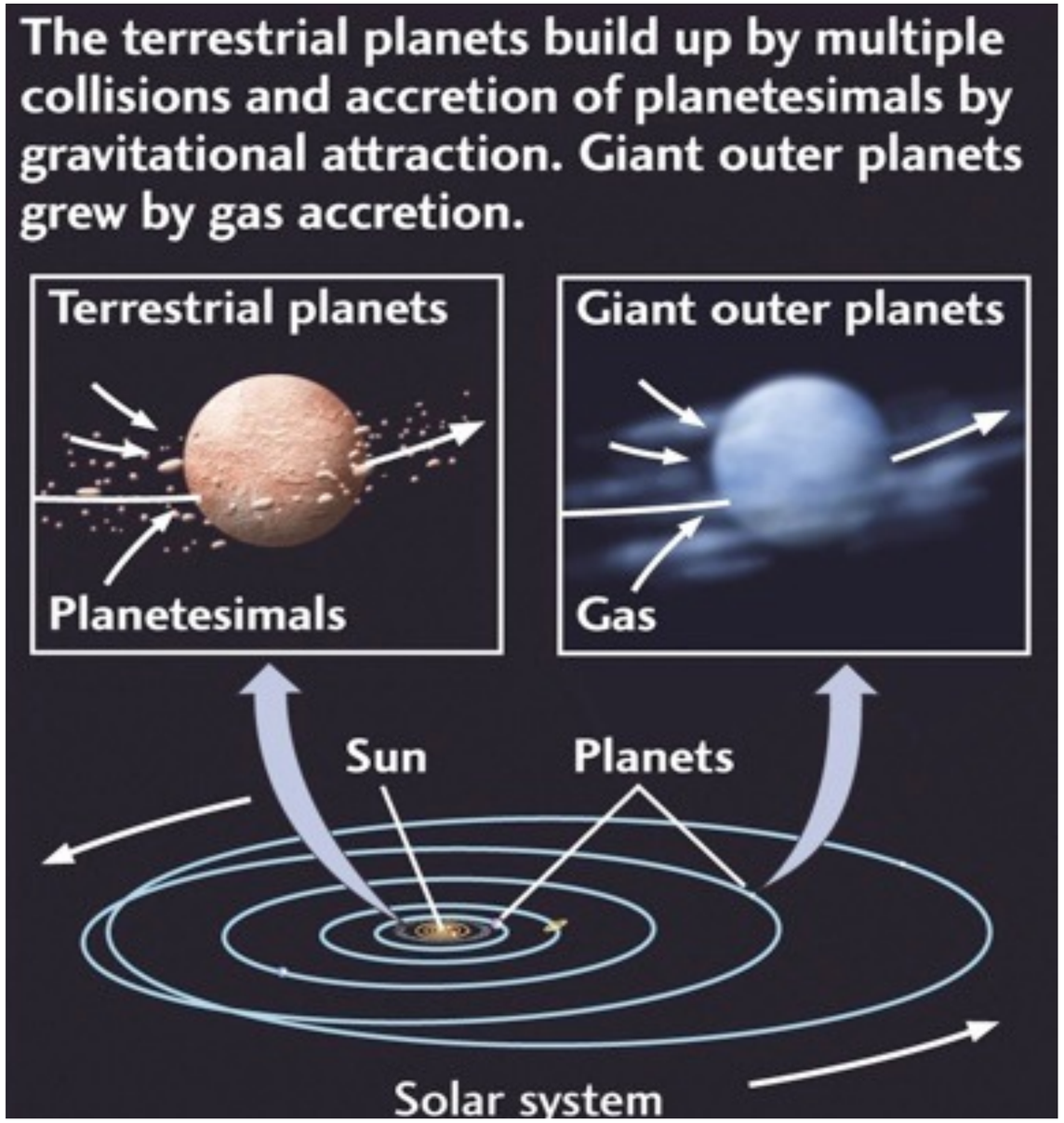
Formation of Solar System



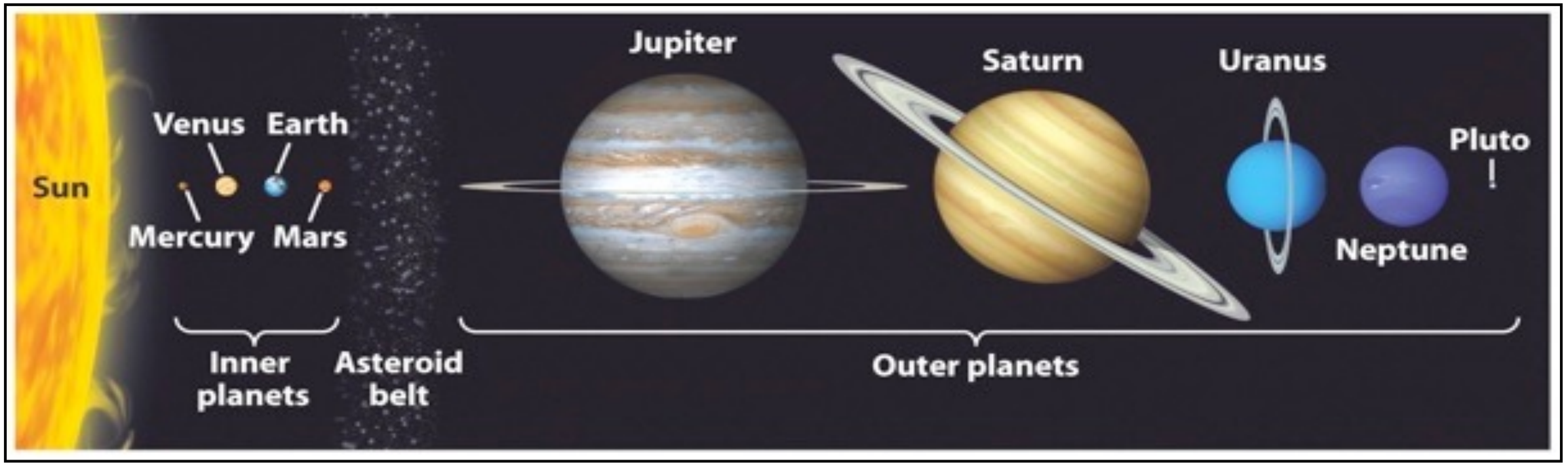
Formation of Solar System

Nearest to the Sun— only rocky material could withstand the heat when the solar system was young. The first four planets – Mercury, Venus, Earth, and Mars – are terrestrial planets.

Farther from the Sun — Ice, liquid, or gas settled in the outer regions of the young solar system. Gravity pulled these materials together. This is where we gas giants reside - Jupiter and Saturn, and the ice giants Uranus and Neptune.



Our Solar System



Terrestrial (inner)

- relatively small planets
- contains the heavier elements (Fe, Si, O)
- rocky shell over a metallic core
- accretion began 4.6 billion years ago

Gaseous (outer) Planets

- mostly volatile gases (H,He)
- same composition as the sun

Formation of Our Solar System

Nothing Lasts Forever…

1. Our Sun is 4.5 billions years old and in about 4 more billion years the sun will run out of hydrogen fuel and die.

2. But before the sun dies, it will expand in size beyond the orbit of earth and in so doing will vaporize the earth.

3. This is not a matter of maybe — this is an absolute certainty! **All** stars eventually run out of hydrogen fuel and our sun is no exception.

4. The full arc of earth history, from its initial formation through the evolution of all life, is at its midlife. —Eventually all of earth, and all of life on earth, will end – **for certain!**

5. But all the vaporized atoms that were once part of the sun and earth, and make up our bodies today, will eventually contract back to make new stars and new planets — and maybe even new life!

https://exoplanets.nasa.gov/what-is-an-exoplanet/stars/

Words of Wisdom…

“Look again at that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives.

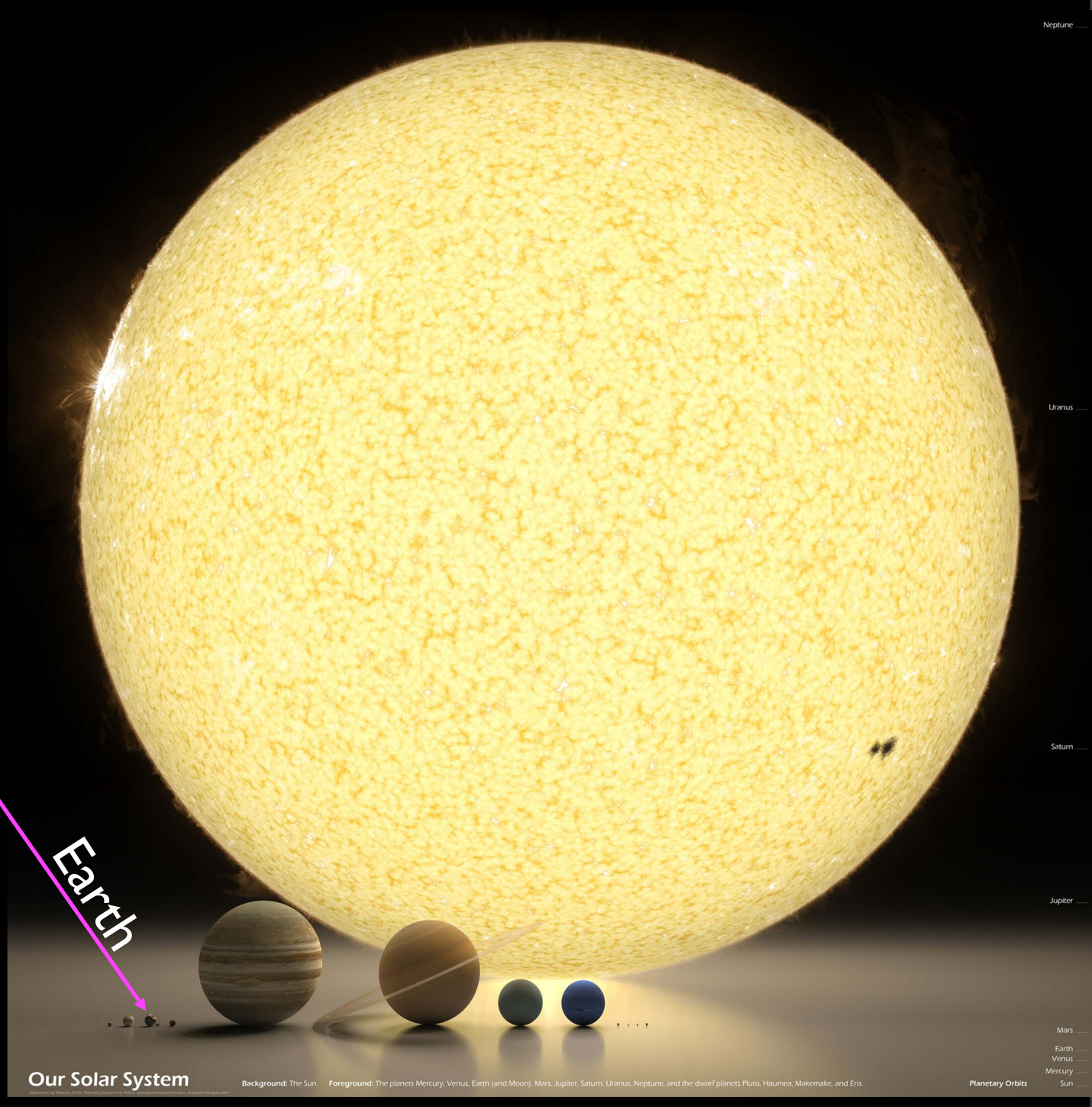
The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every "superstar," every "supreme leader," every saint and sinner in the history of our species lived there **- on a mote of dust suspended in a sunbeam.”** …

“…Our posturing, our imagined self-importance, the delusion that we have some privileged position in the Universe, are challenged by this point of pale light.

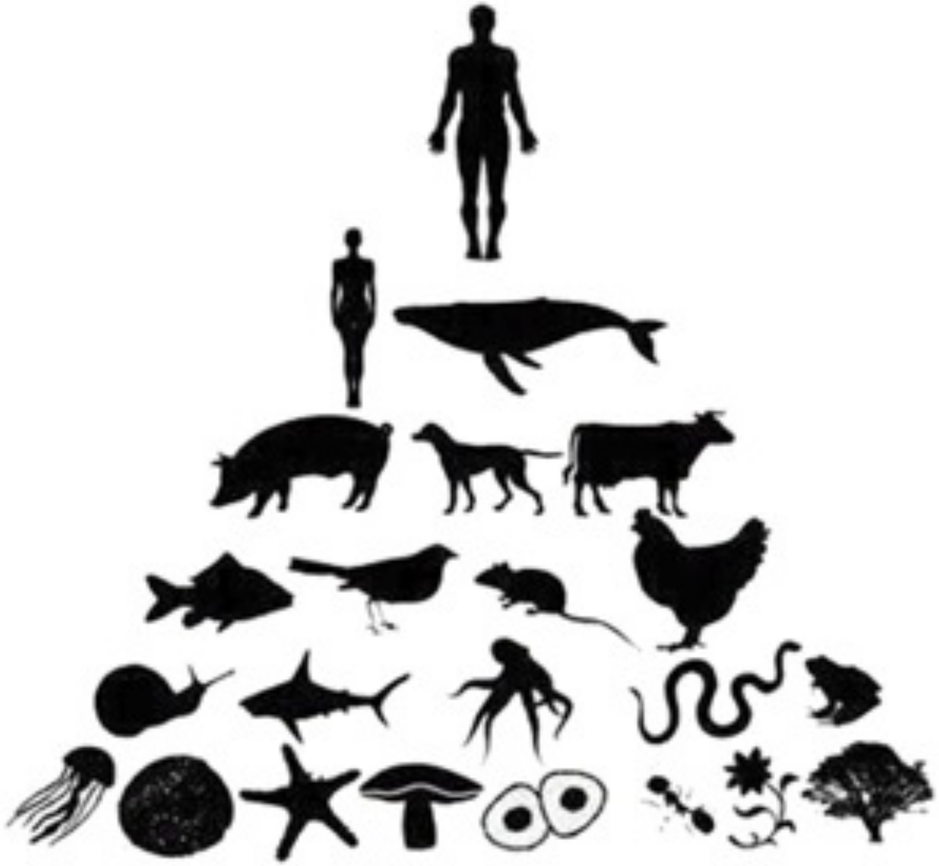
Our planet is a lonely speck in the great enveloping cosmic dark. In our obscurity, in all this vastness, there is no hint that help will come from elsewhere to save us from ourselves.”

Prof. Carl Sagan, Cornell University

For more Carl Sagan Quotes See: http://bit.ly/1f2kBhR



EGO



ECO

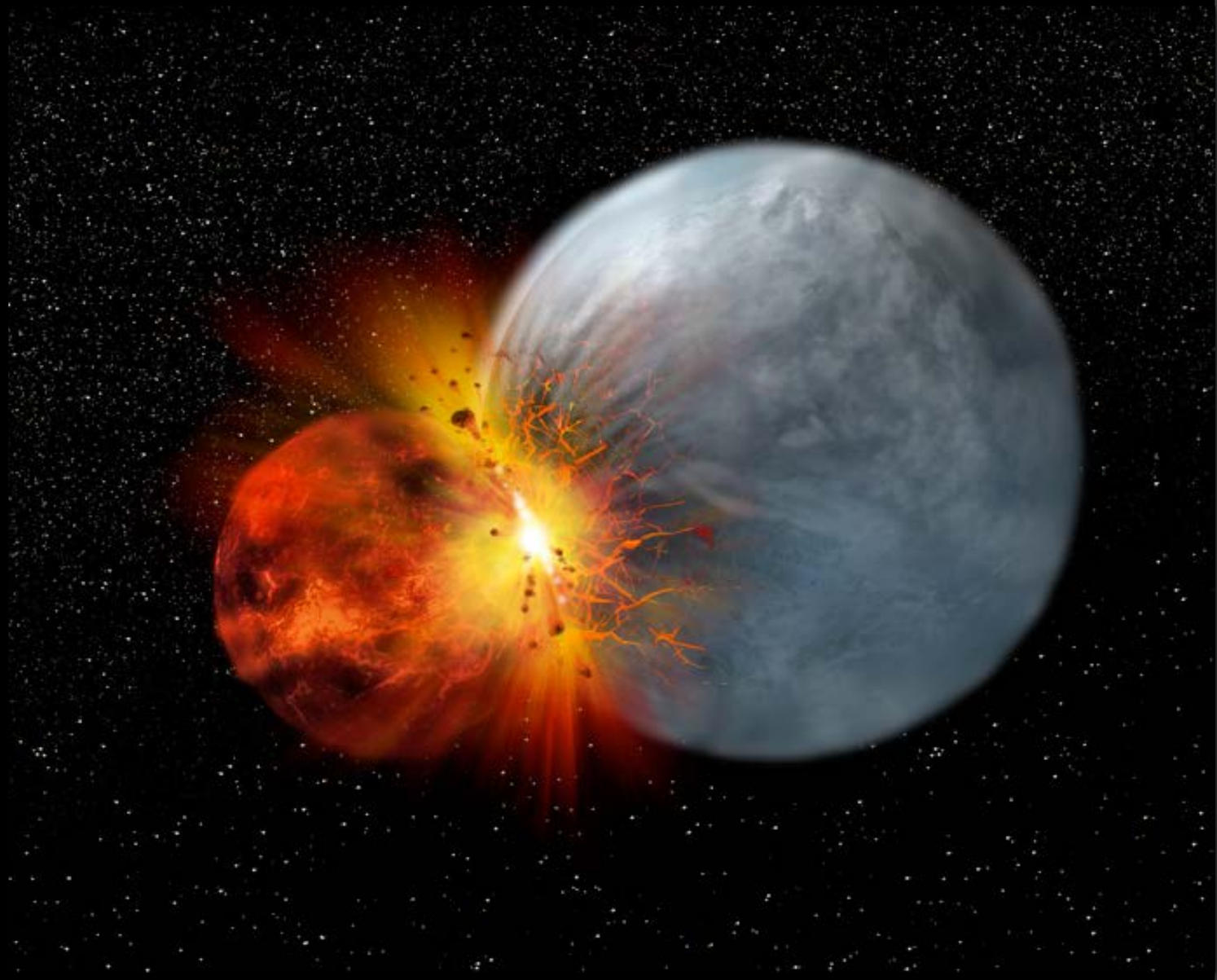
Summary of Solar System/Earth Formation

1. 4.6 billion years ago, rock-forming elements condensed into small solid grains as the nebula cooled.
   - *Grains accreted to planetesimals*
   - *Planetesimals accreted to form the Earth*
2. The sun (and earth) are at midlife
3. Earth and all of “us” are a very-very tiny part of the universe

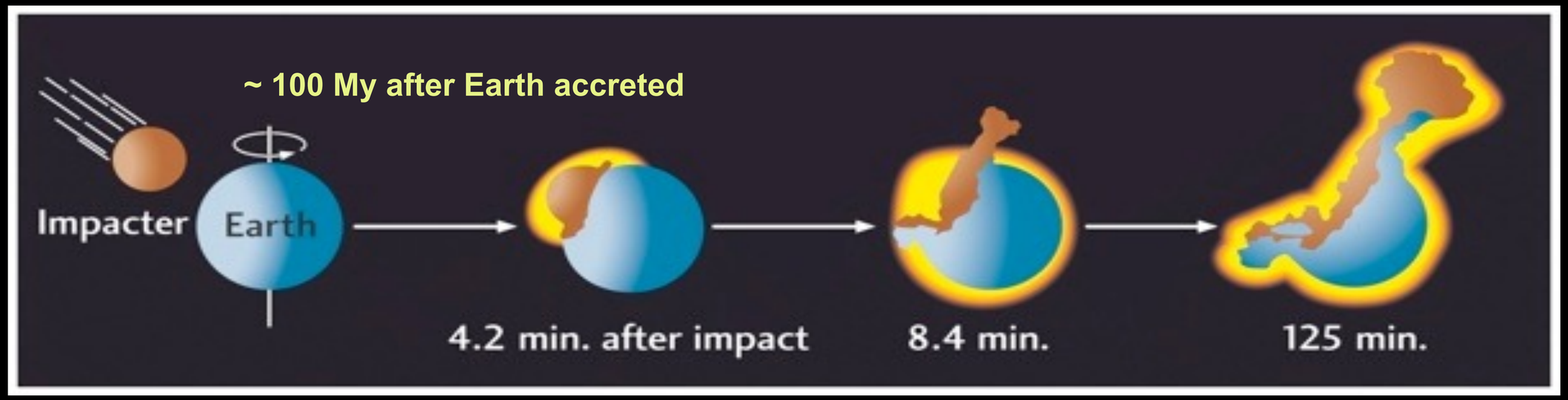
Section III

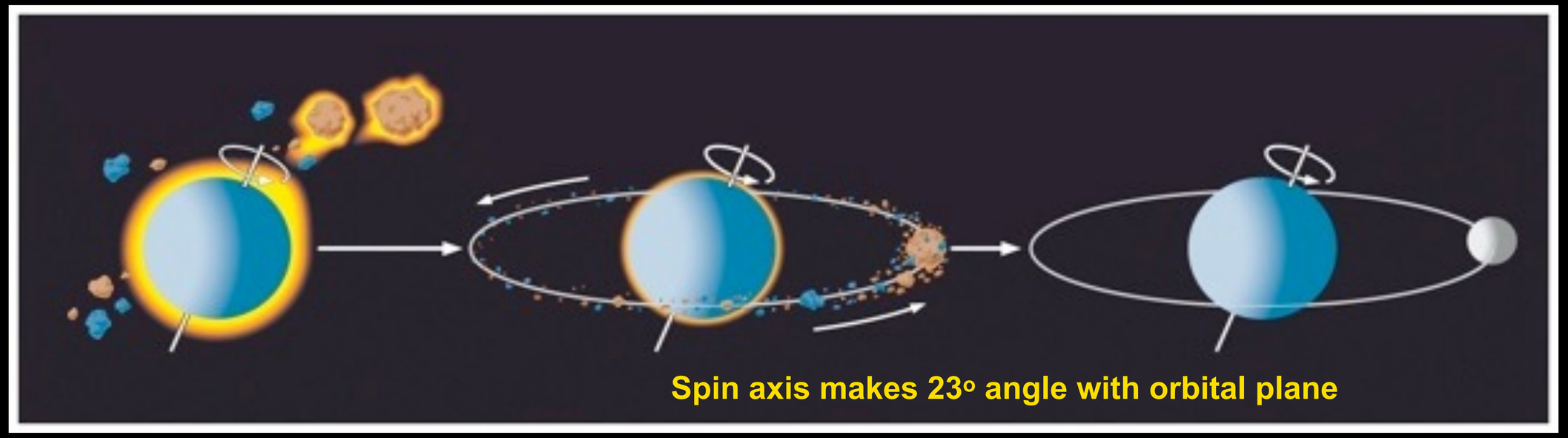
1. Formation of the Moon
2. Formation of the Atmosphere
3. Filling of the Ocean

The Moon Formed When Earth Was Hit By a Mars-Sized Object



Formation of Earth's Moon

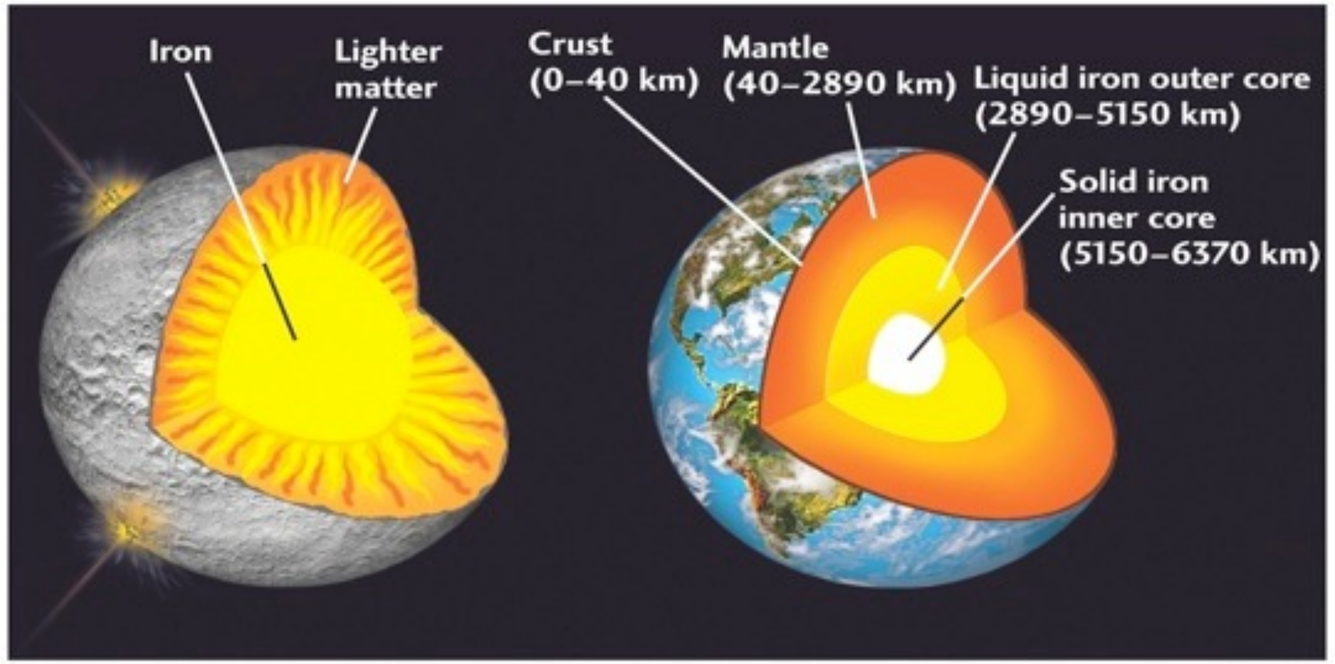




Early Earth and Formation of the Moon

Earth’s Atmosphere

Atmospheric Conditions of Early Earth versus Modern Earth



Early in Earth

1. Atmosphere consisted mostly of **hydrogen and helium** - gases abundant in the solar system.
2. Most of these gases were lost to space.

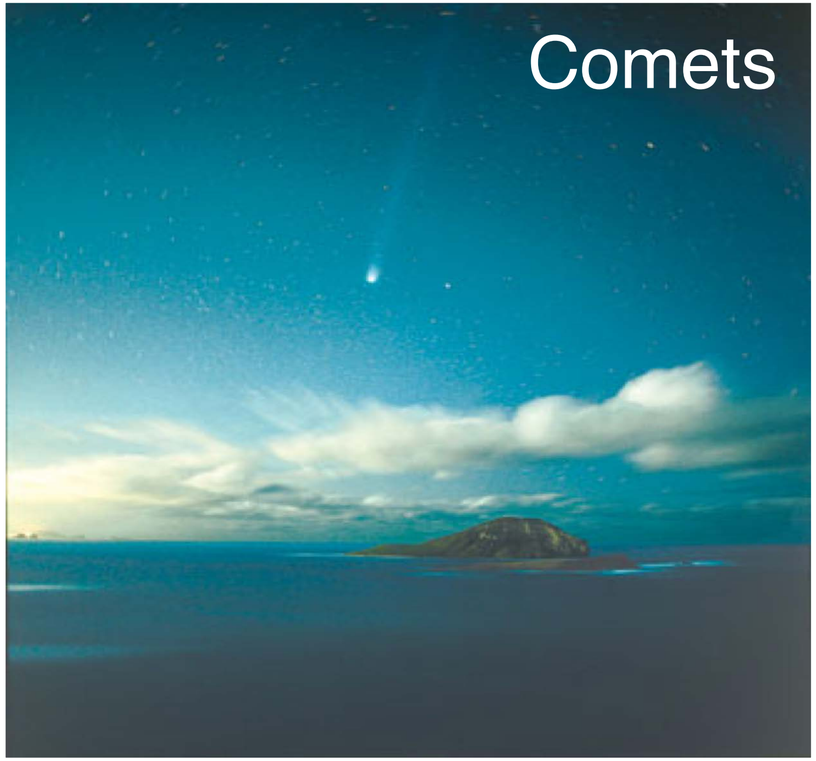
Today

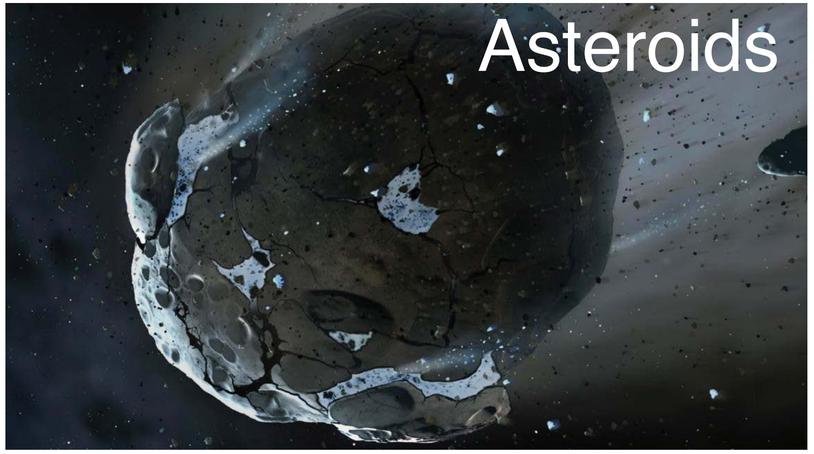
1. **Out-gassing from volcanoes releases: H_20, CO_2,** SO_2, N_2, H_2, Cl_2 into the Atmosphere
2. **Photosynthetic life then evolves much later and this produces a modern O_2-rich atmosphere!**

Where Did all the Water on Earth Come From?

The source of water on earth remains an issue of some significant scientific debate. Three theories are proposed

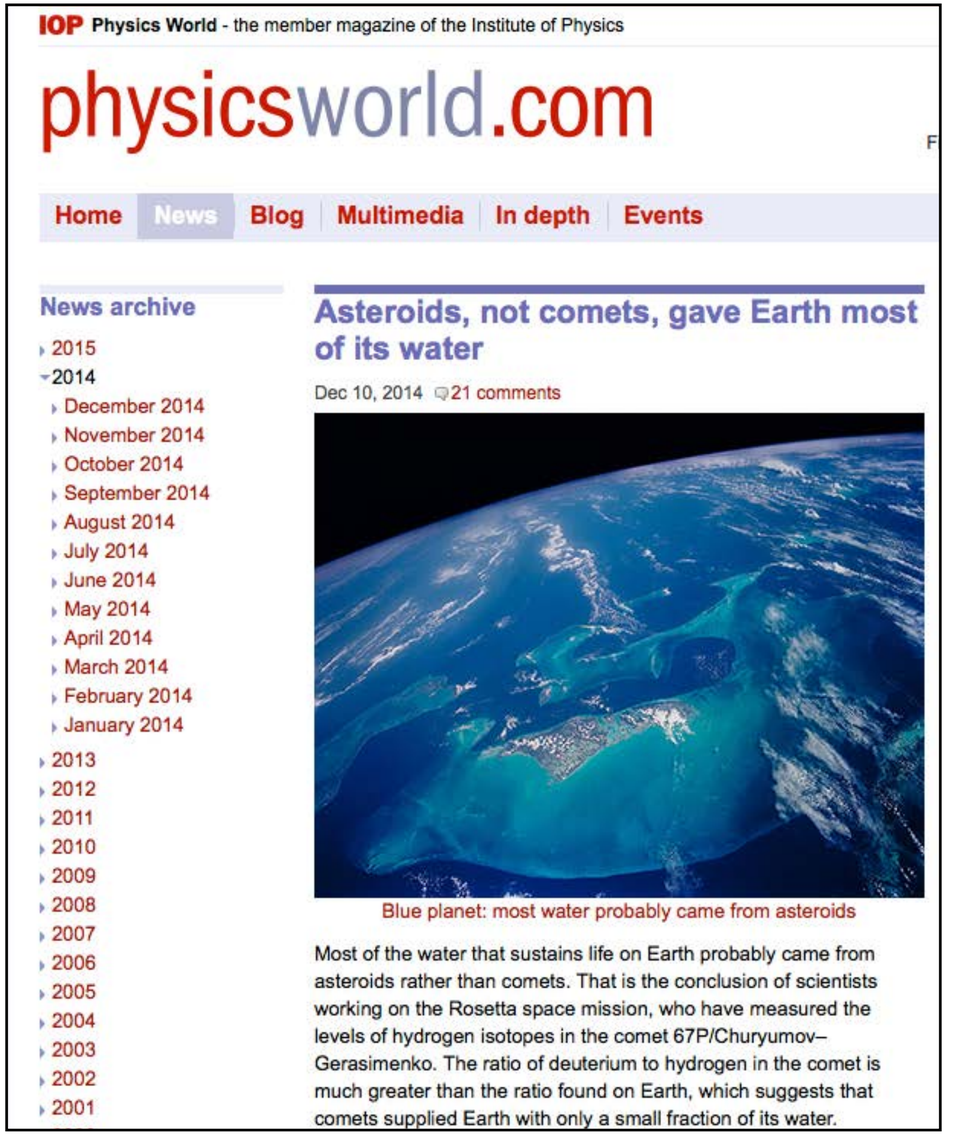
1. Water **formed in place** when the earth formed and then later out-gassed and condensed.
2. Water was **brought to earth by comets** after the earth formed and cooled.
3. Water was **brought to earth by ice-ladened asteroids** that bombarded the early earth.





In 2014 scientists who sent a space probe to a comet reported that the comet's water was isotopically very different from our own ocean water — **so as of today the astroids have the edge in being the source of earth water.**

But stay tuned… This could change as more information comes to light. See for Example: https://carnegiescience.edu/how-did-earth-get-its-water#:~:text=Washington, DC—Our planet's water,Edward Young and Hilke Schlichting)



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Asteroids, not comets, gave Earth most of its water

Dec 10, 2014 21 comments

Blue planet: most water probably came from asteroids

Most of the water that sustains life on Earth probably came from asteroids rather than comets. That is the conclusion of scientists working on the Rosetta space mission, who have measured the levels of hydrogen isotopes in the comet 67P/Churyumov–Gerasimenko. The ratio of deuterium to hydrogen in the comet is much greater than the ratio found on Earth, which suggests that comets supplied Earth with only a small fraction of its water.

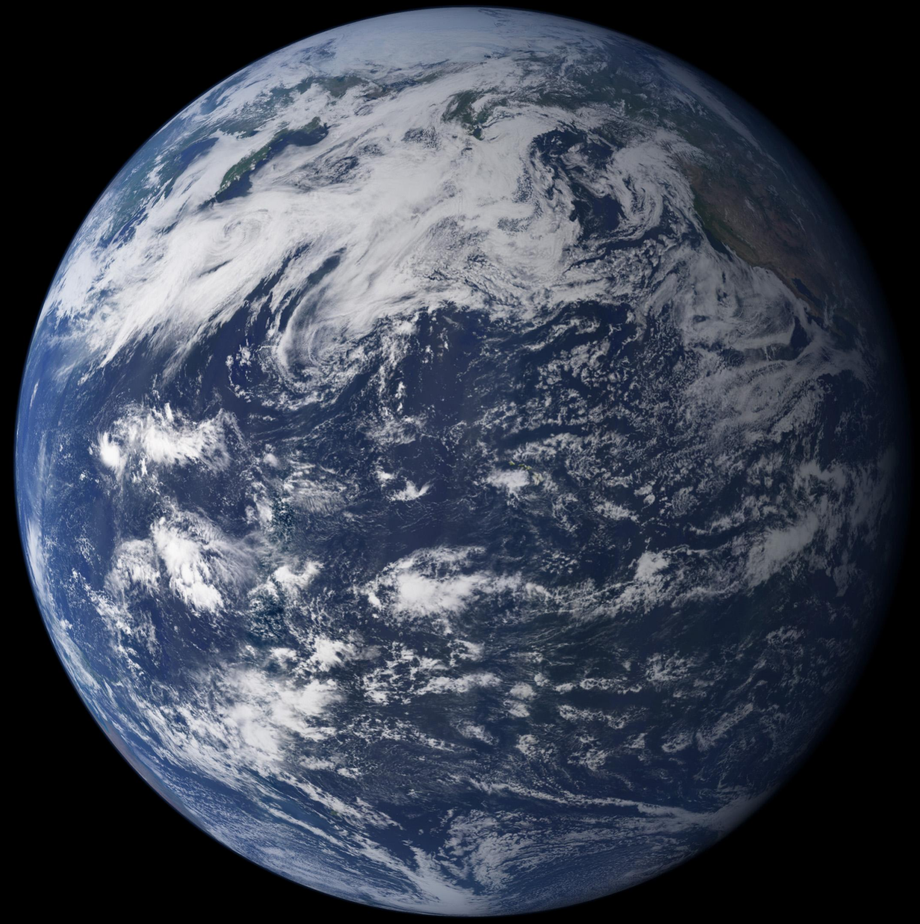
http://physicsworld.com/cws/article/news/2014/dec/10/asteroids-not-comets-gave-earth-most-of-its-water

http://www.smithsonianmag.com/science-nature/how-did-water-come-to-earth-72037248/?no-ist

Ancient Earth Was Likely a Water World

Recent evidence (2021) suggests that 3 billion to 4 billion years ago the earth's oceans held nearly twice as much water—enough water to submerge today's continents above the peak of Mount Everest.

Half of all this water was later sequestered into the Earth's Mantle.



https://www.sciencemag.org/news/2021/03/ancient-earth-was-water-world

Section IV

Evolution of Life

So Far…

1. Created the universe, the stars and all the atoms that make up YOU!
2. Created the earth, moon and atmosphere.
3. Filled the oceans with water.

And Now it is Time to Add Some Life!

A Few Key Points About the Evolution of Life on Earth

Origin of Life On Earth

Asteroid Impact

End of the Dinosaurs and Rise in Prominence of Mammals

65 million

(First - Land Plants, Land Animal, Bones, Vertebrates)

Cambrian Explosion

First Life on Land!!!

550 million

First Multicellular Life - Ocean Only!

2 billion

Oxygen Atmosphere Forms

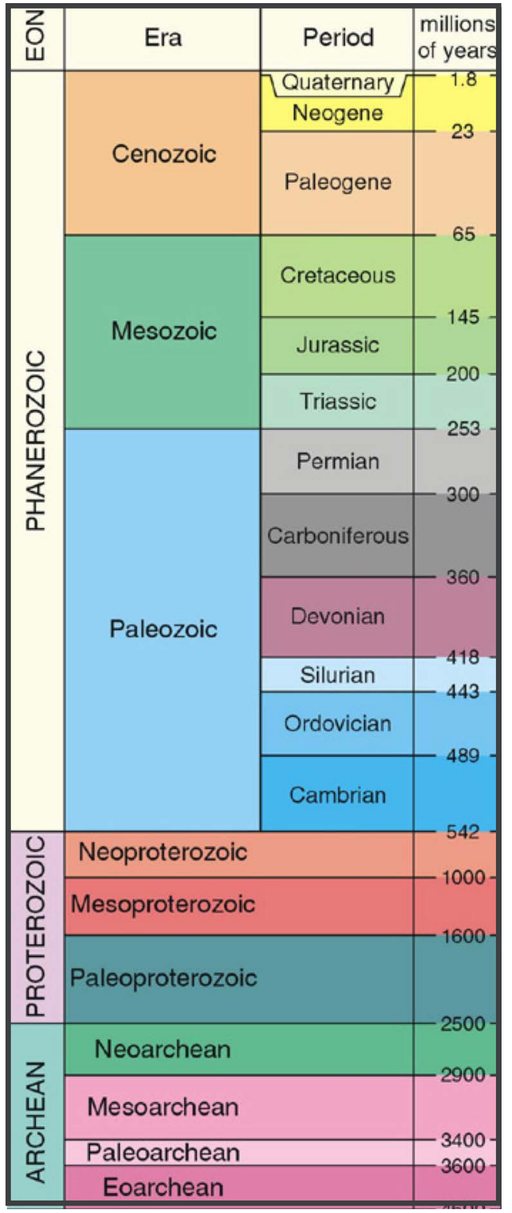
From the Actions of **Bacterial Photosynthesis** in the Ocean!

3 billion

Origin of First Life - Ocean Only!

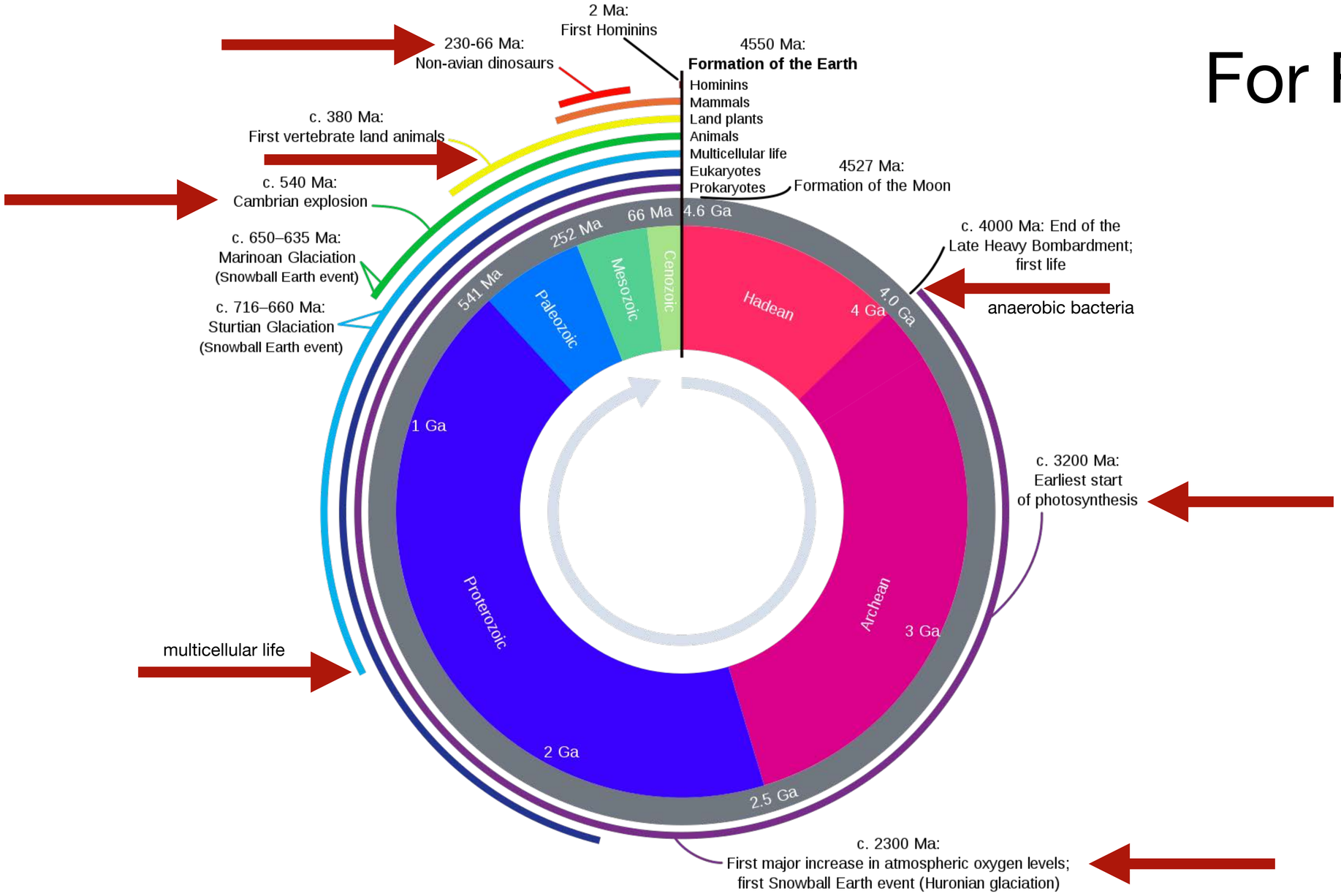
(Formed very soon after earth cooled and the oceans filled)

4 billion



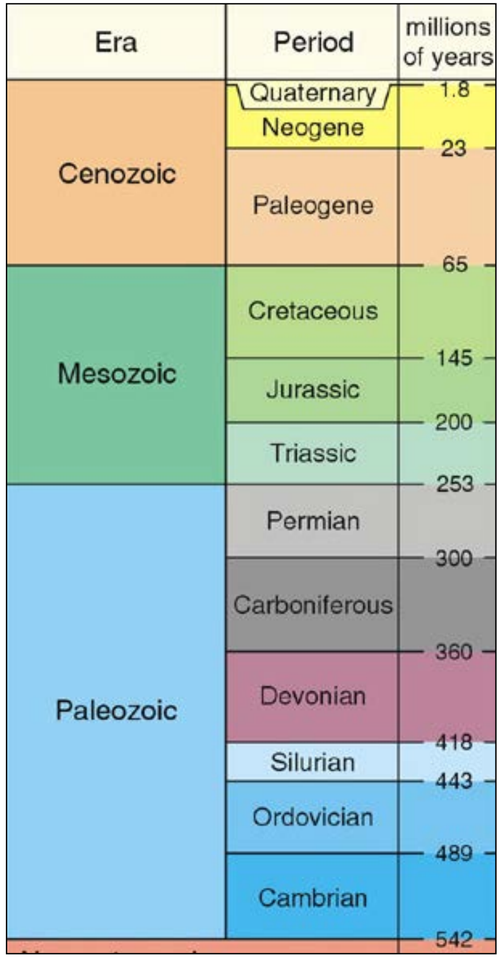
Ithaca!

For Fun...



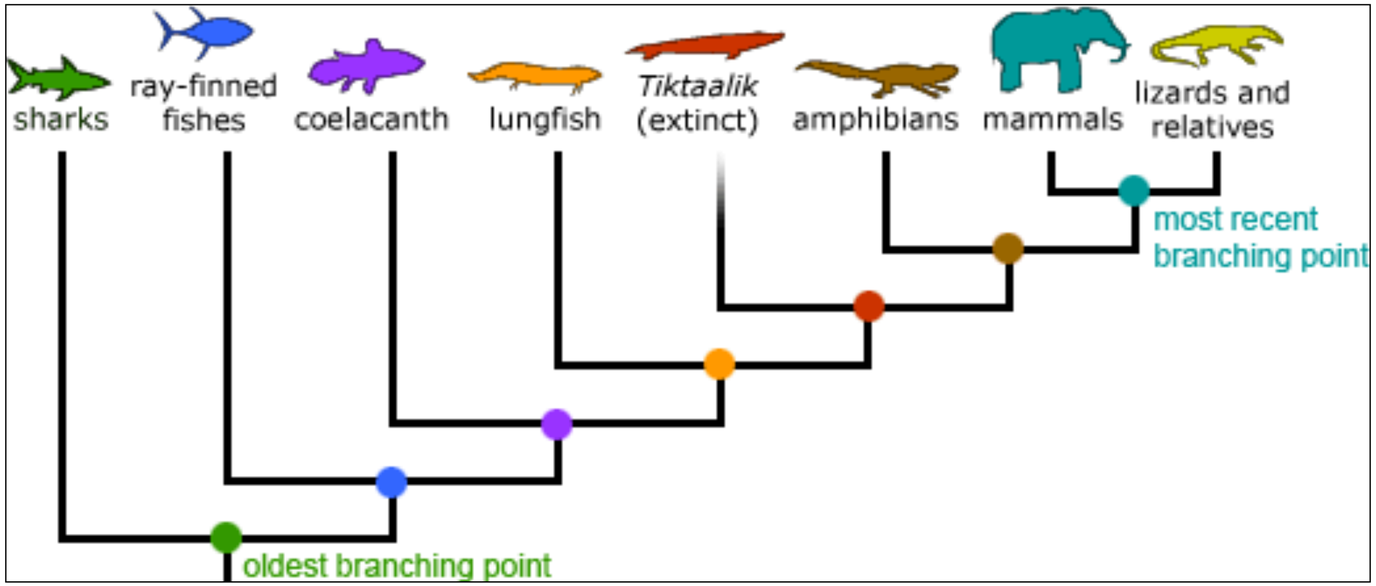
Milestones in Marine Vertebrates:

Post-Cambrian Explosion



- Marine Mammals
- Marine Reptiles
- Devonian – the “Age of Fishes” (Vertebrates)
- Origin of jaws
- Oldest known bone

Required Homework



Watch the Movie: Your Inner Fish (**Part I**)

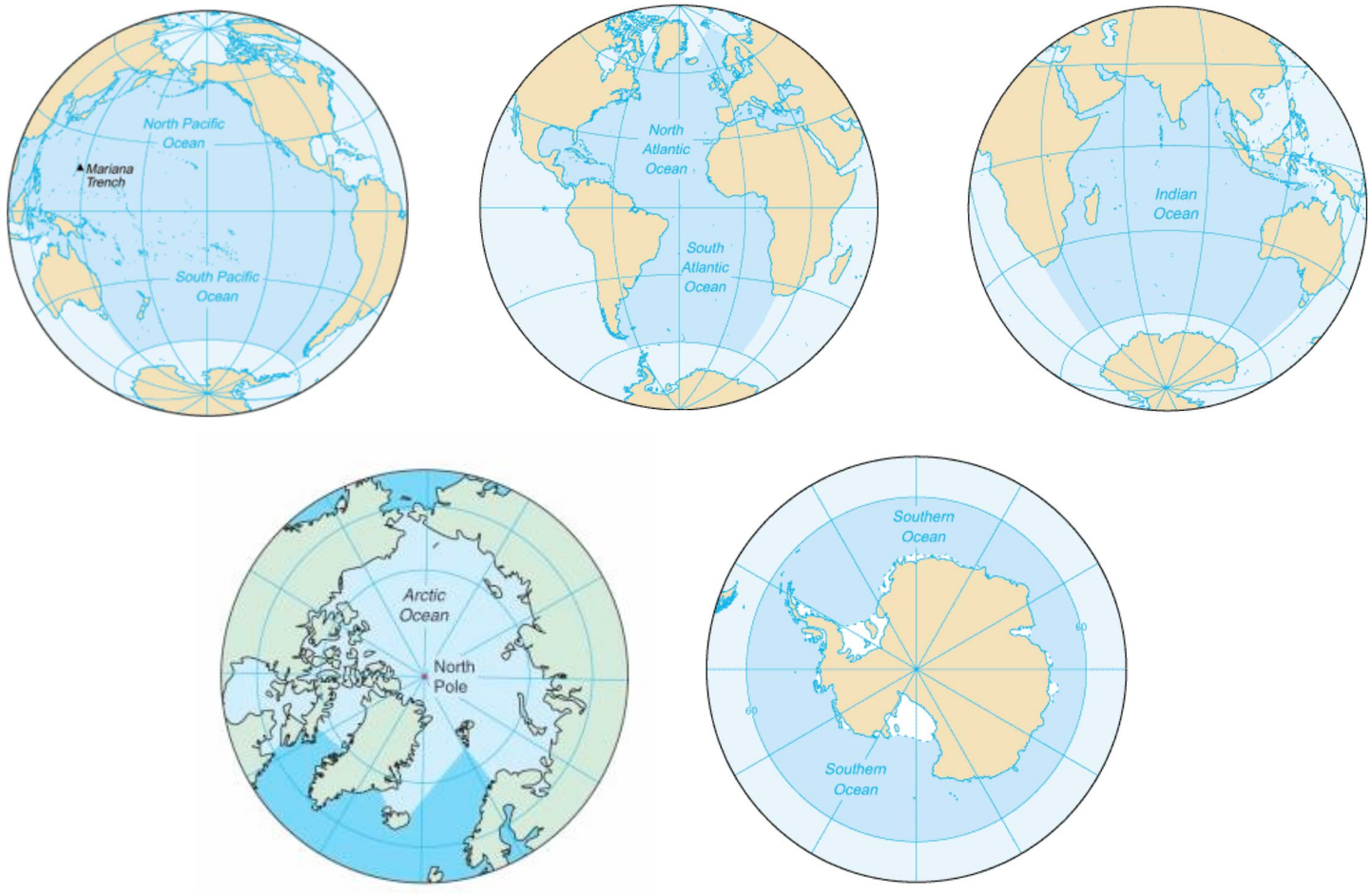
Streamed Through Canvas - Under the *Environmental Movies* Link

Section IV

Physiography of the Modern Oceans

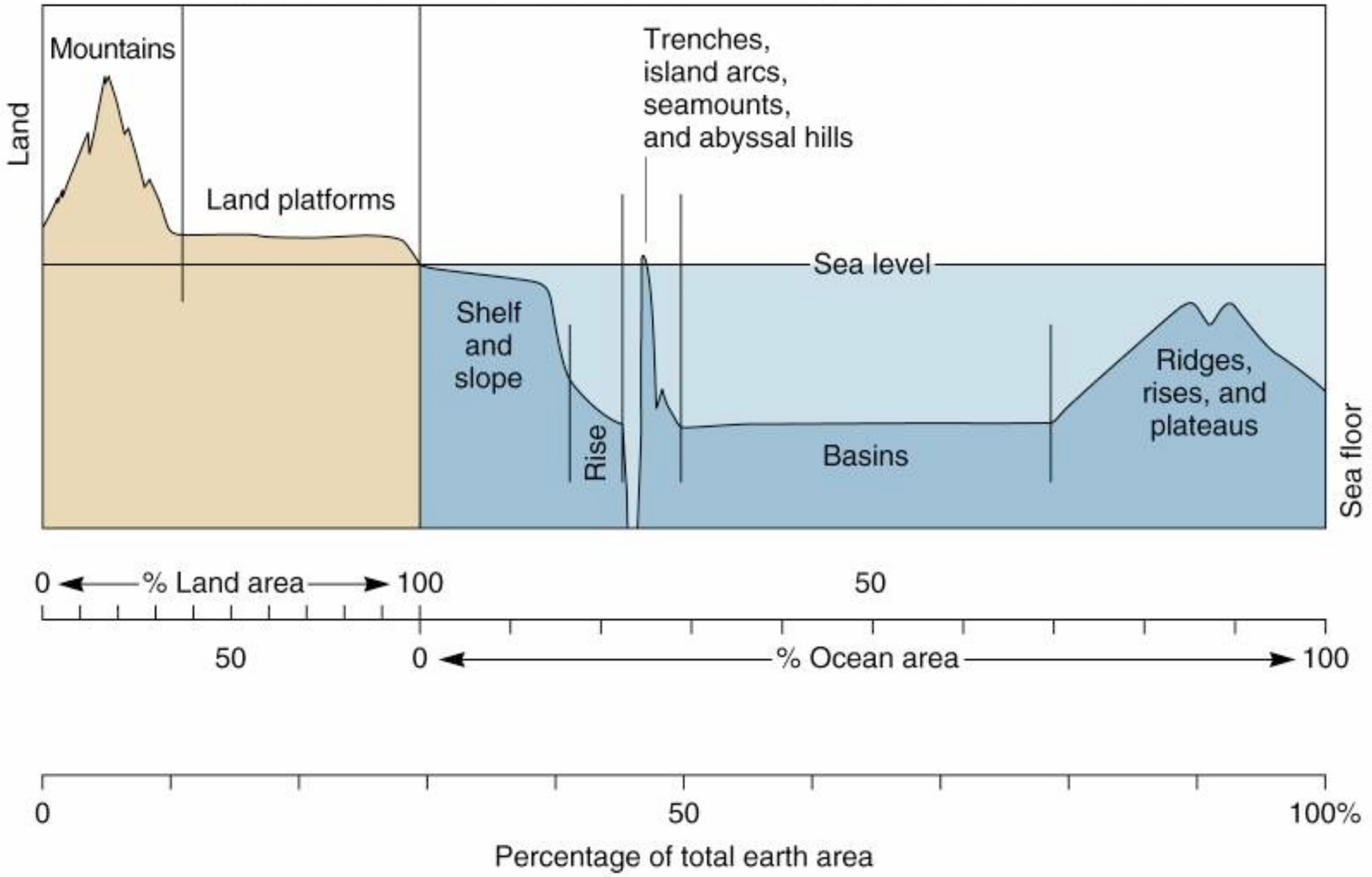
Five Officially Named Oceans

Pacific, Atlantic, Indian, Arctic and Southern



Ocean Depth, Surface Area and Volume…

Percent Area Covered by Physical Features

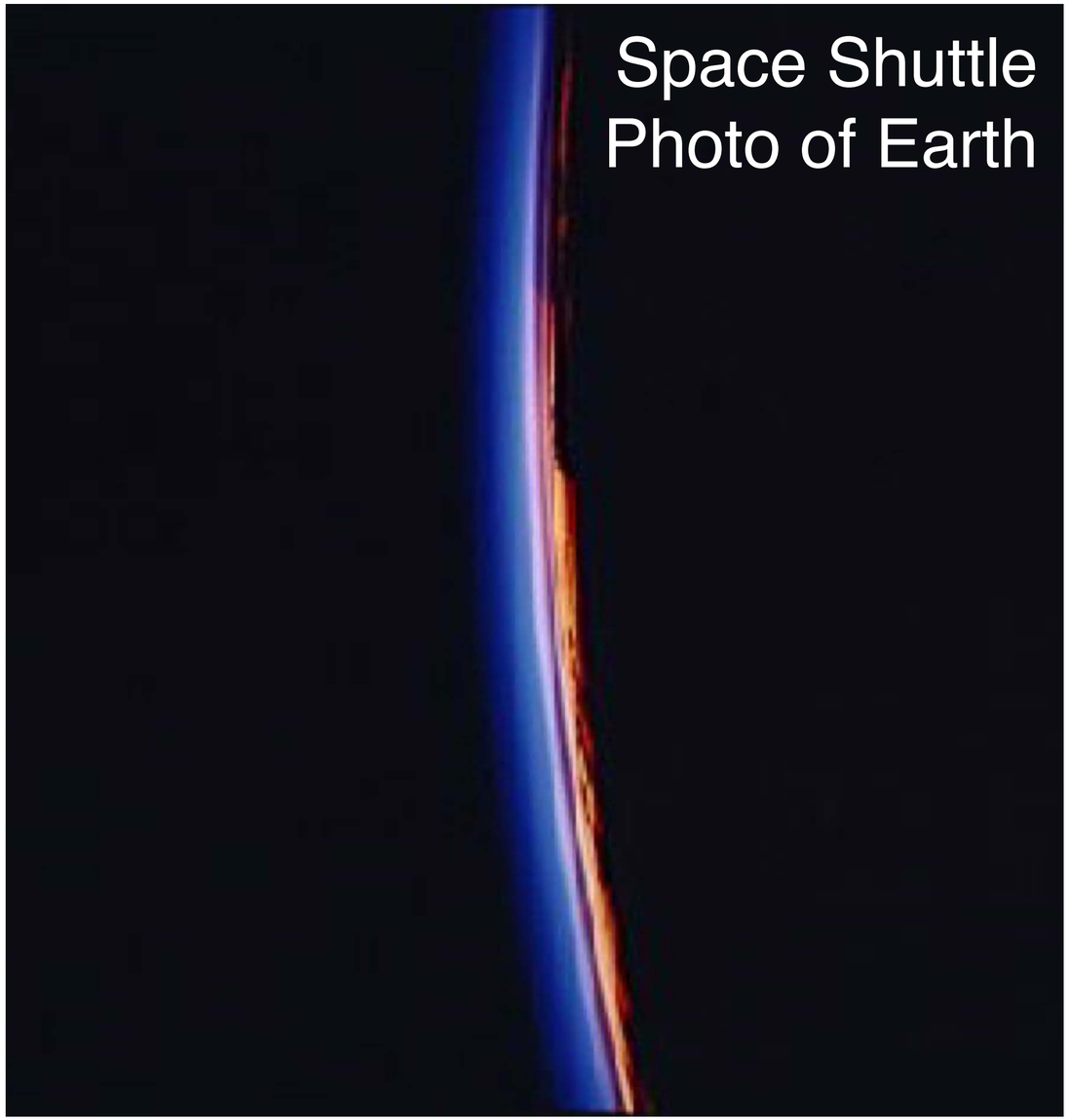


Average Depth: 4 km

The Remarkable Thinness of The Ocean and Atmosphere

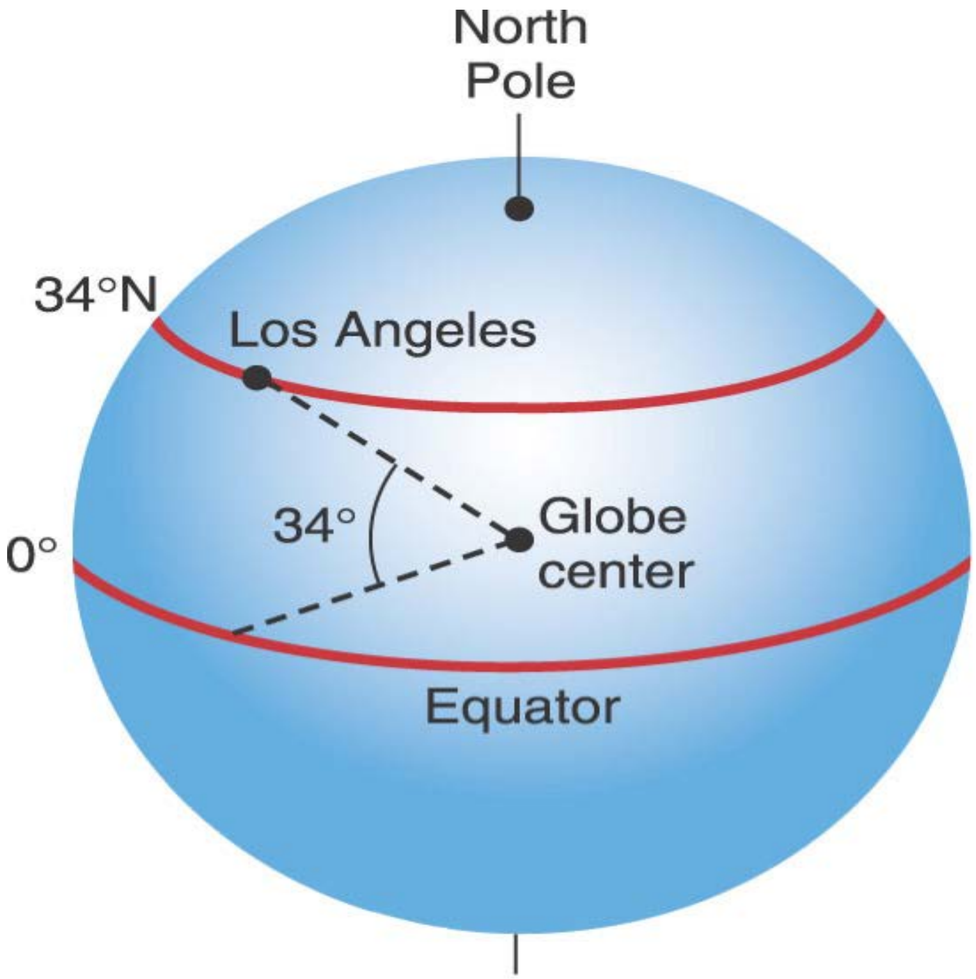
If you were to scale the earth down to the size of a beach ball *1/2 meter diameter*…

1. The ocean thickness would be 0.15 mm
2. The atmospheric thickness would be about 0.45 mm

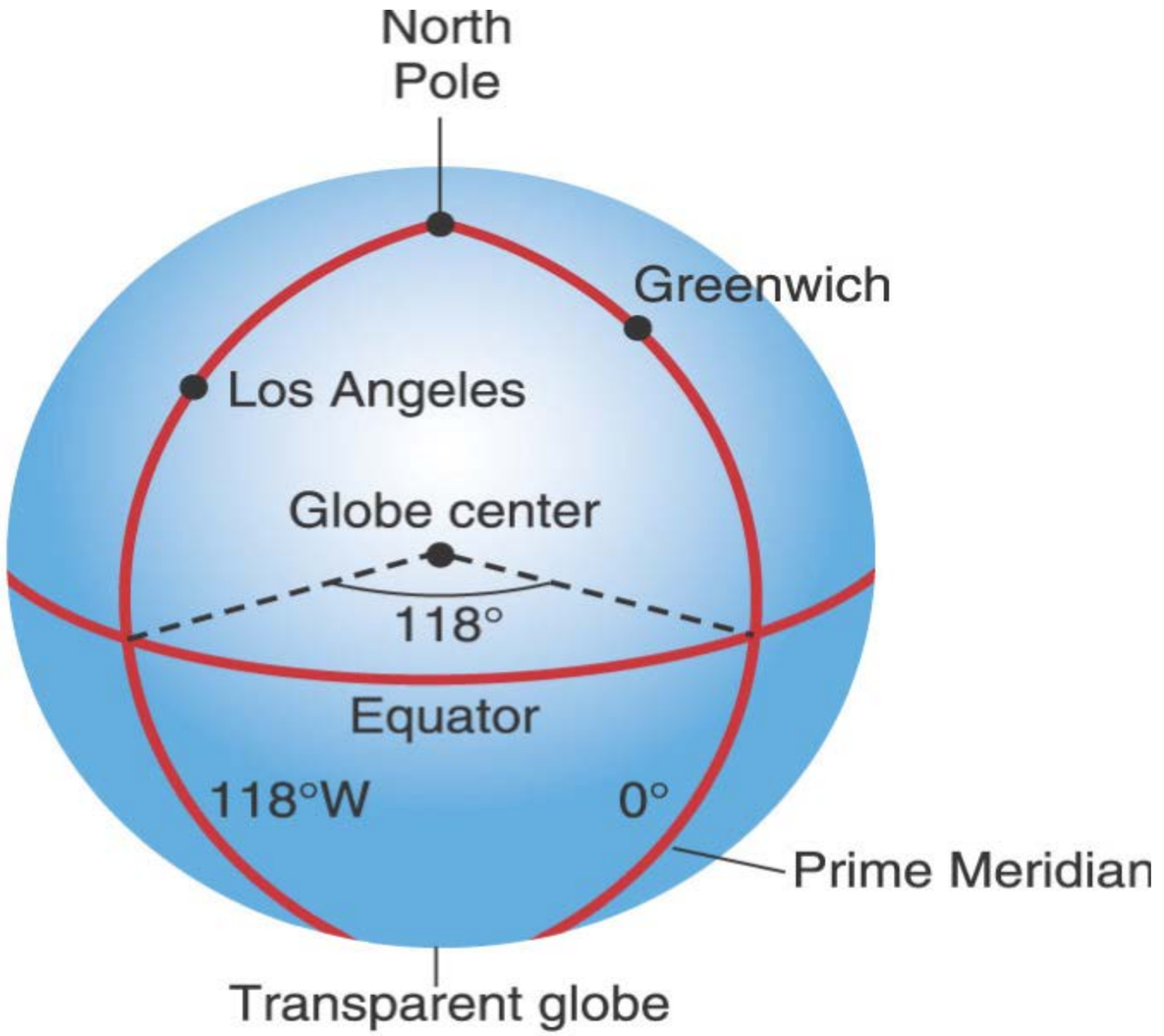


Understanding Latitude and Longitude and Contour Plots

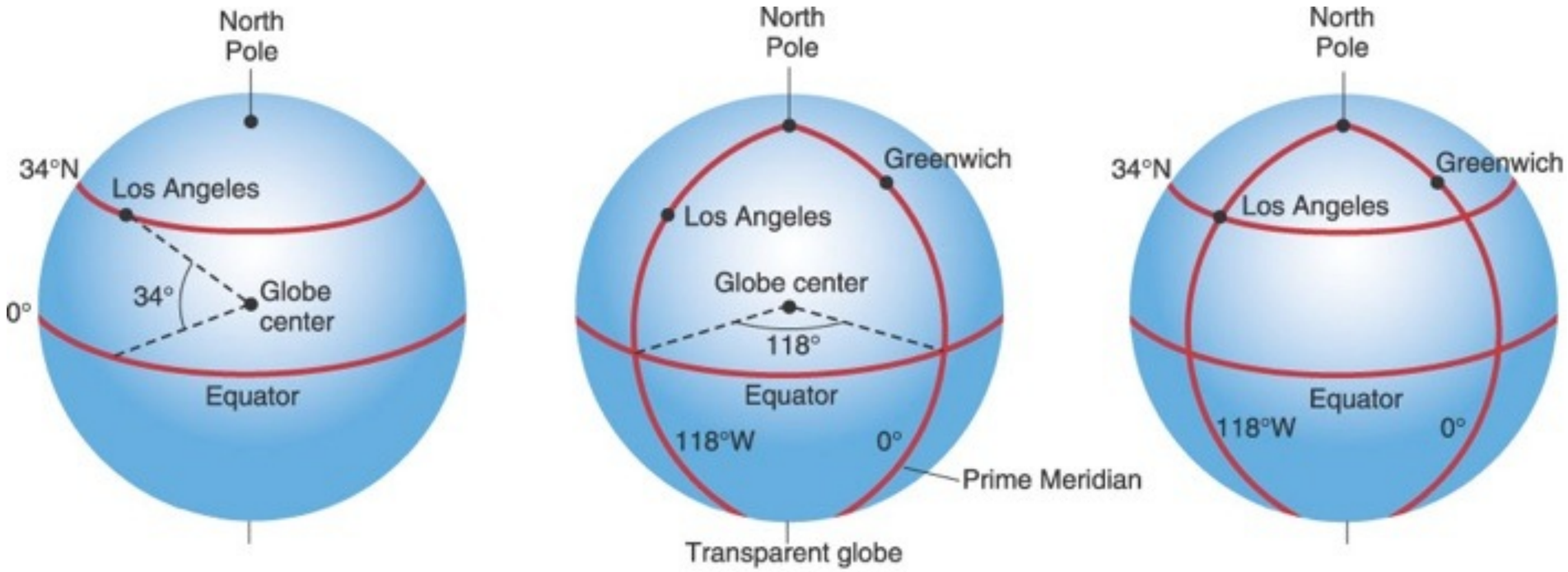
Latitude



Longitude



Latitude / Longitude



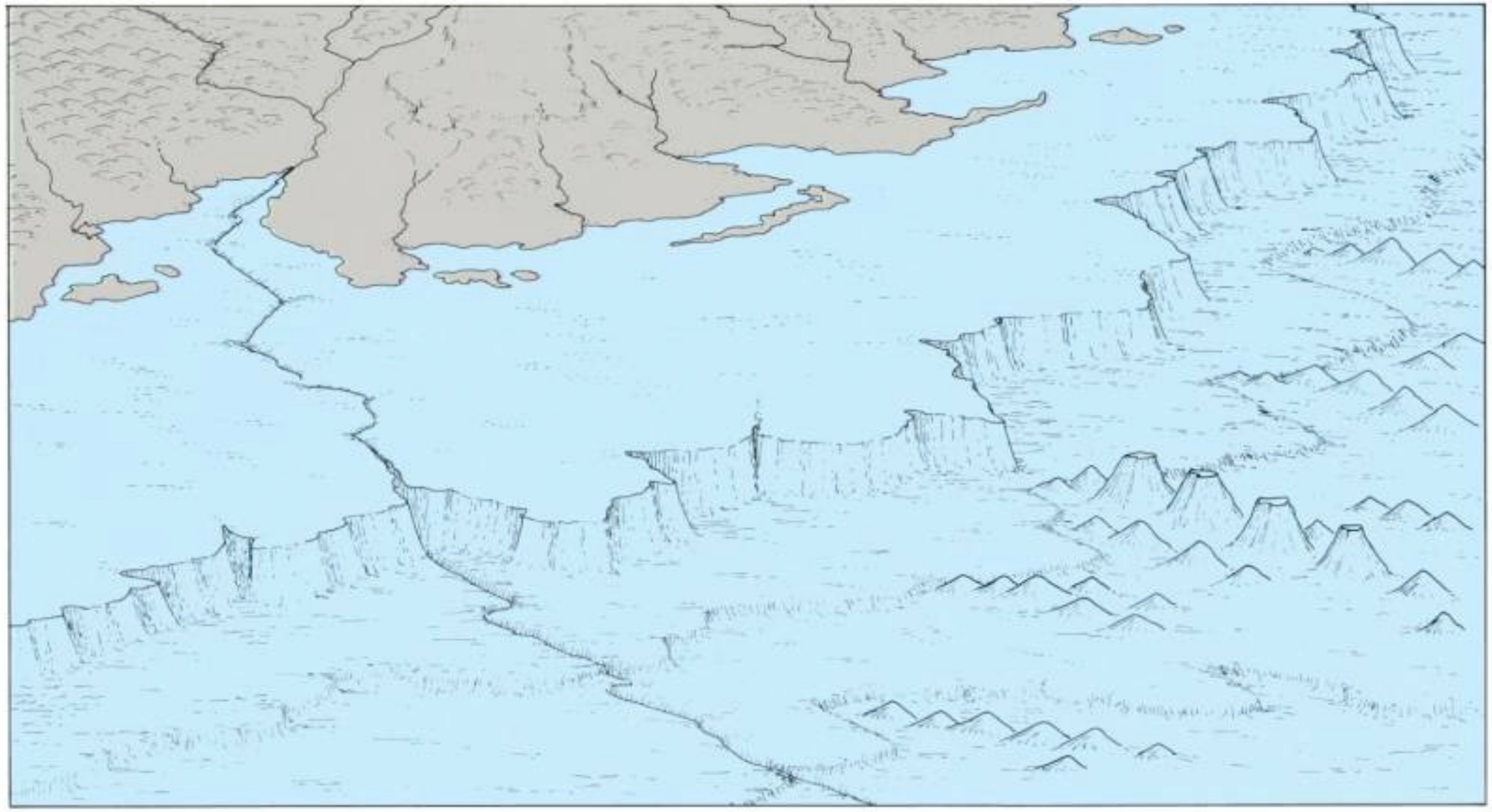
Los Angeles is at: 34º N, 118º W

Or Equally (using +/- convention)*:* +34º Latitude, -118º Longitude

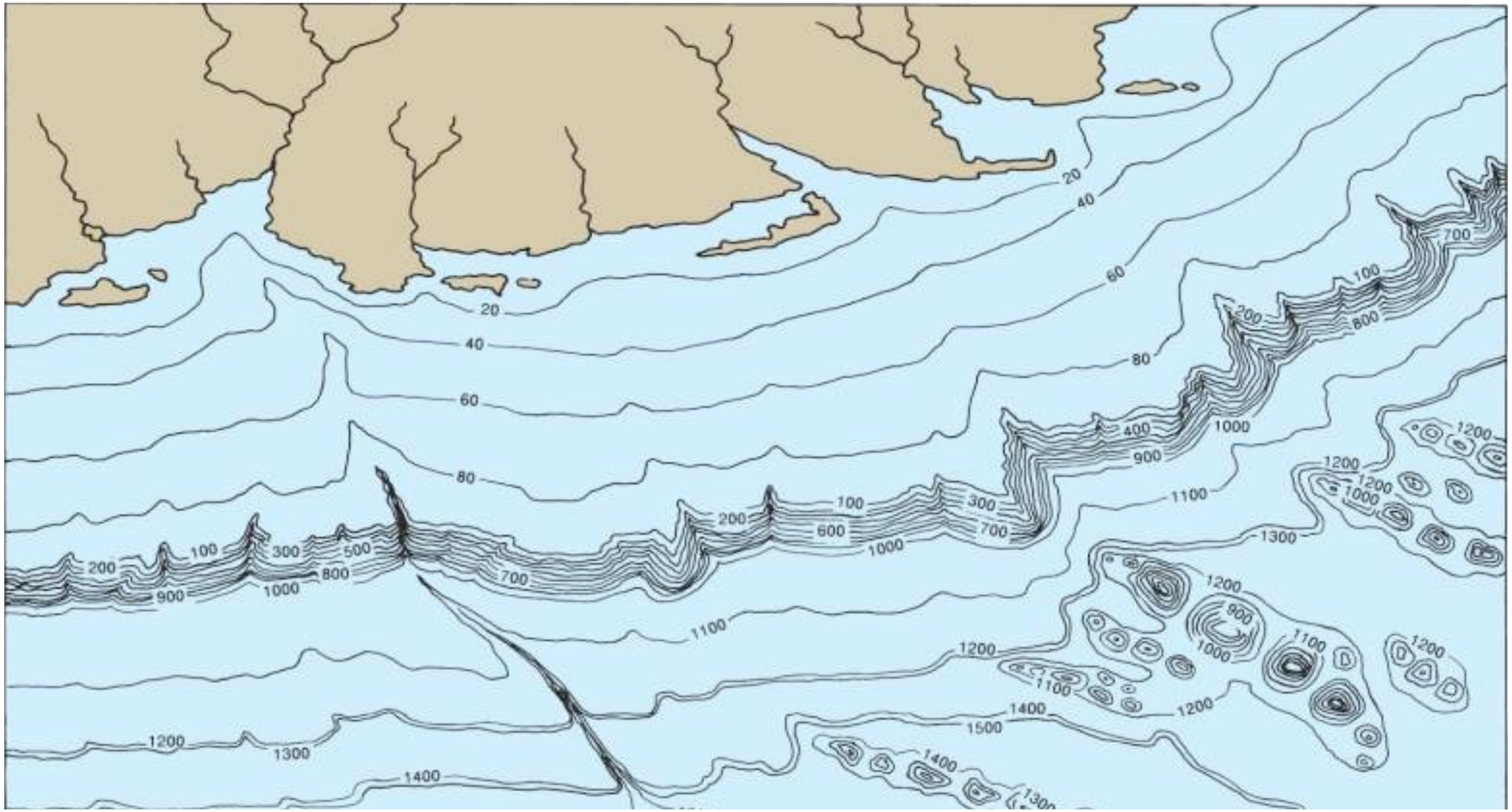
Contour Plots

Bathymetry Maps, Meridional and Zonal Sections

3-D Drawing of Ocean Seafloor



Contour Plot of Ocean Seafloor



Equivalent Contour Plots

(Lines with Numerical Labels or Filled with Color Bar)