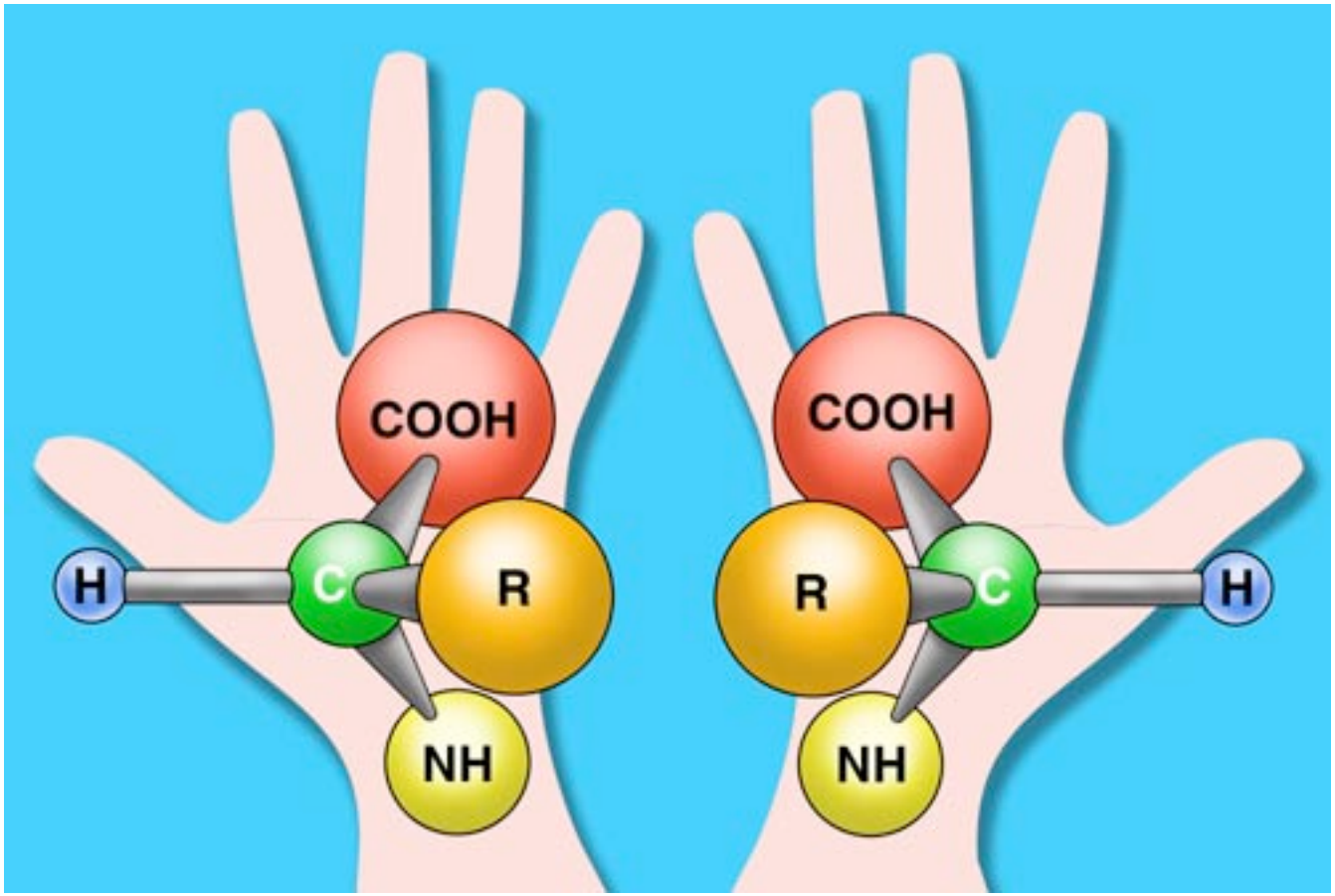
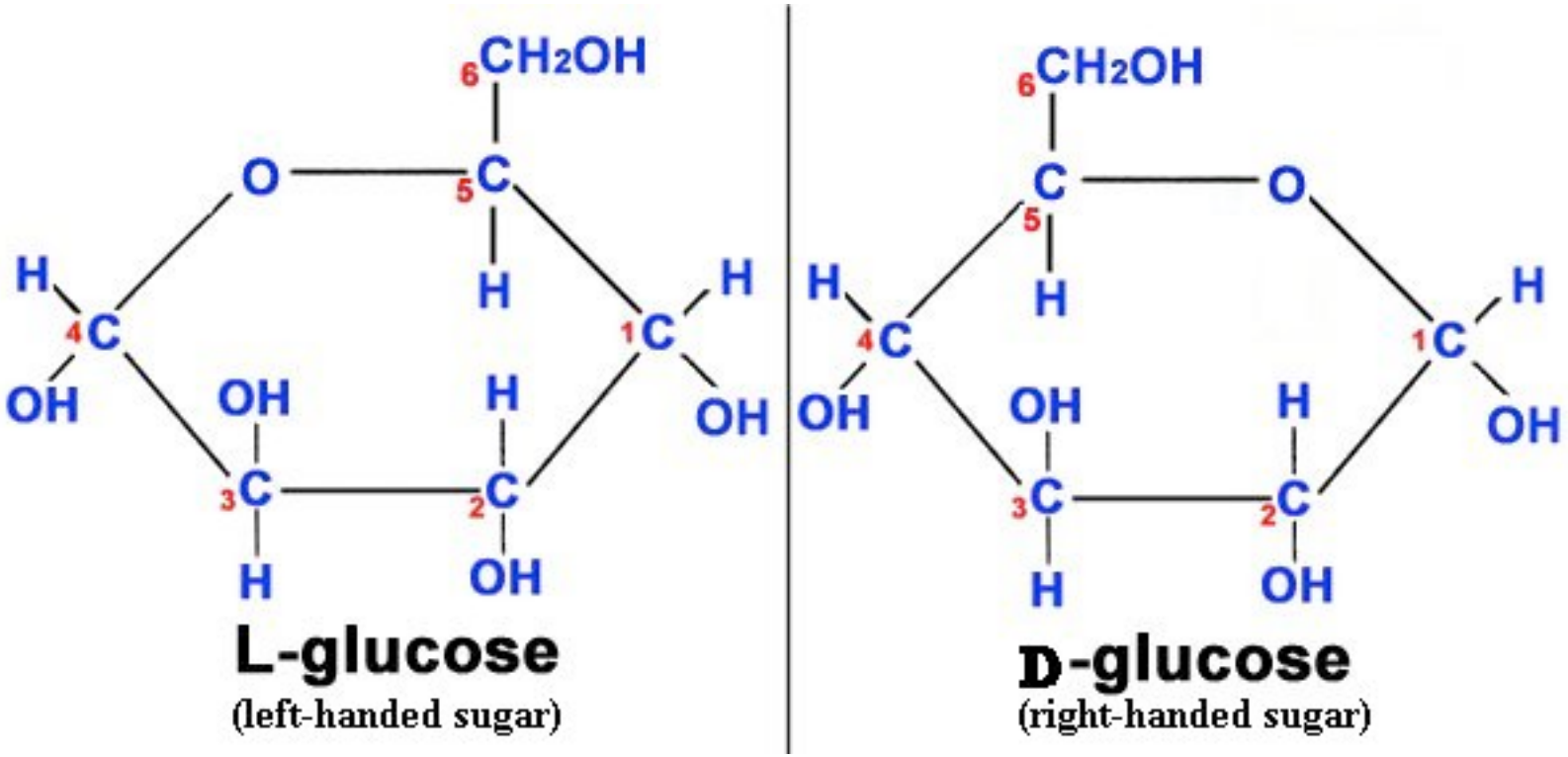
# Amino Acids have a “handedness”

## Life on Earth uses left handed amino acids

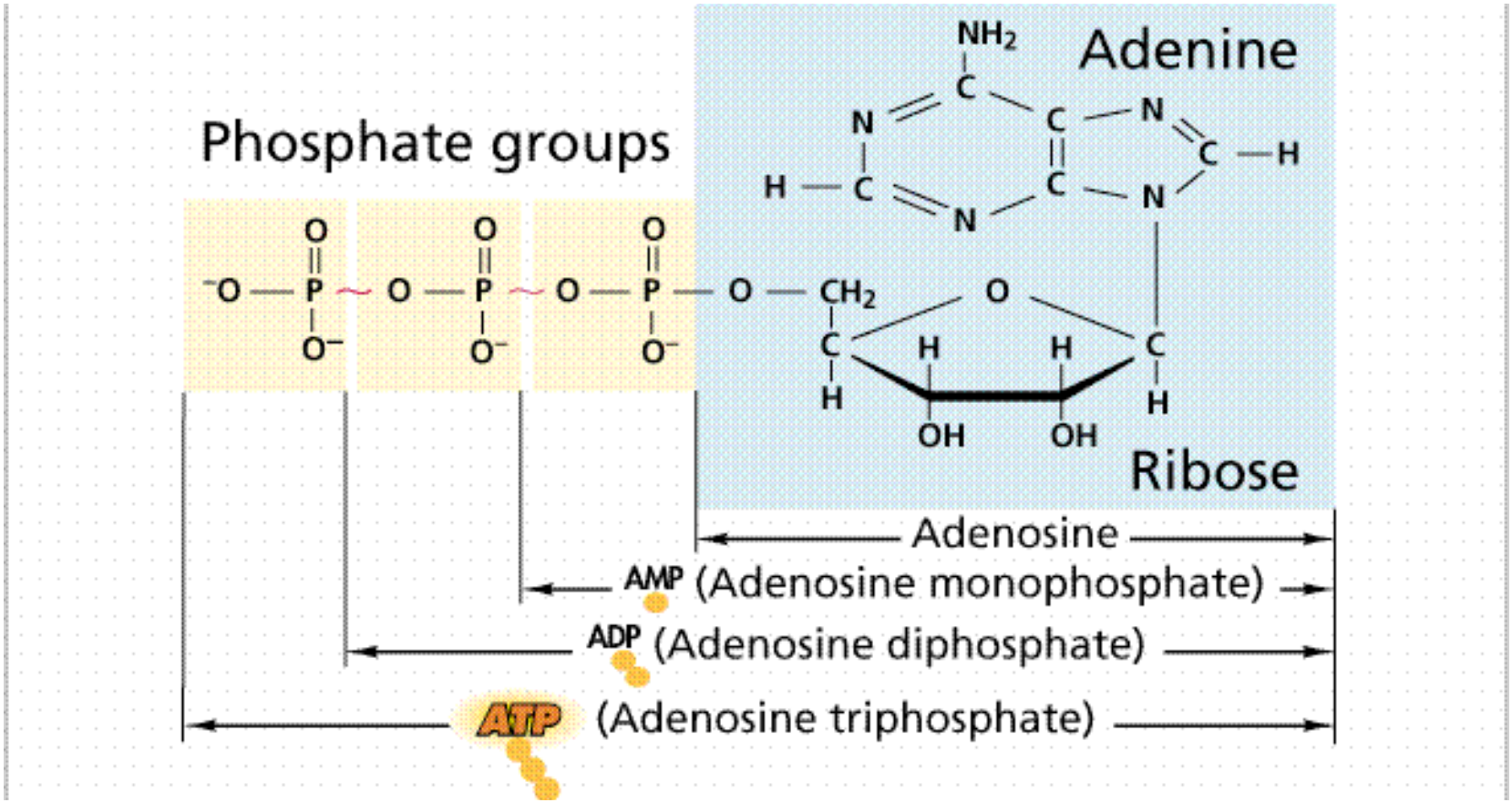


# Sugars may also have a “handedness”

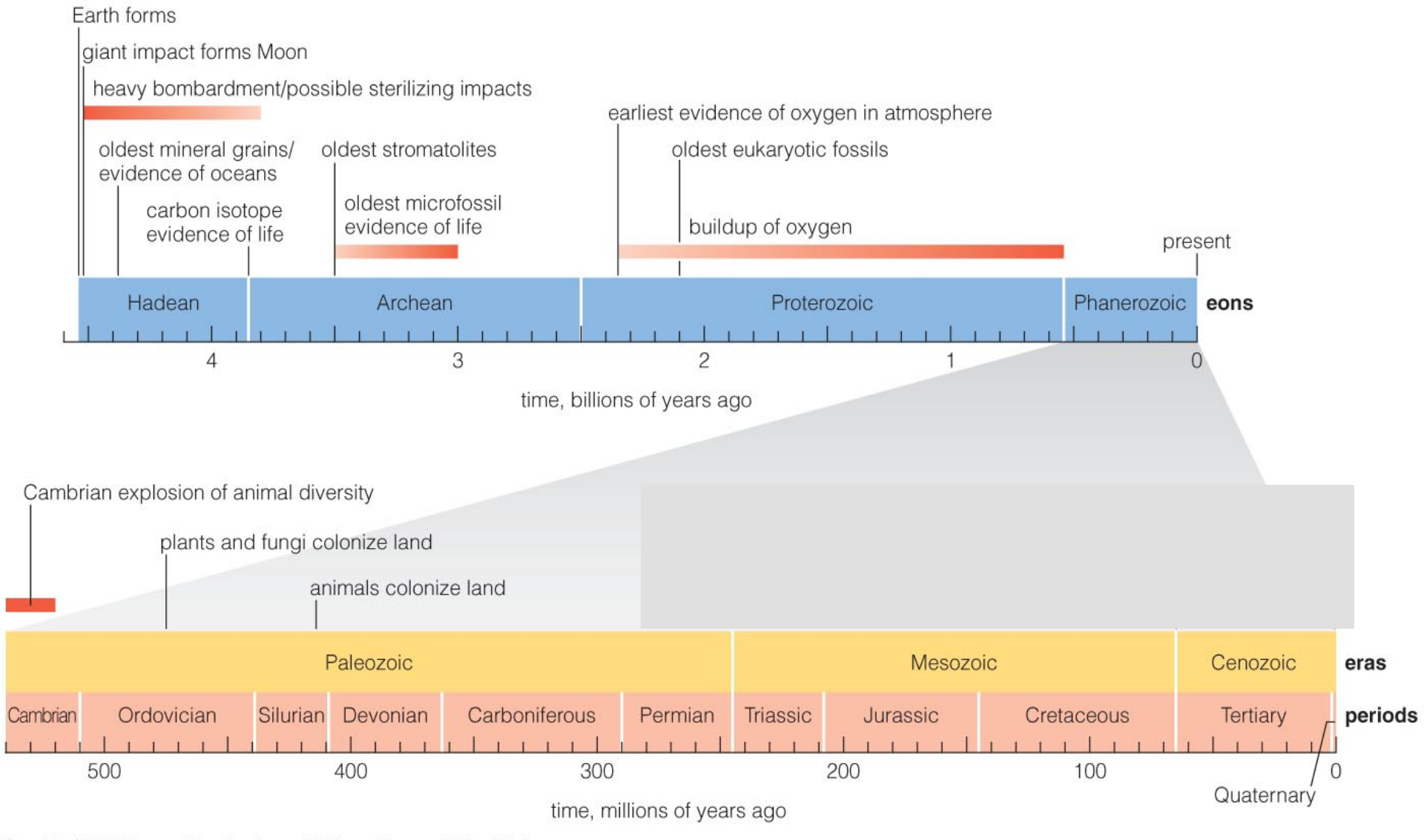
# Life on Earth uses right handed sugars

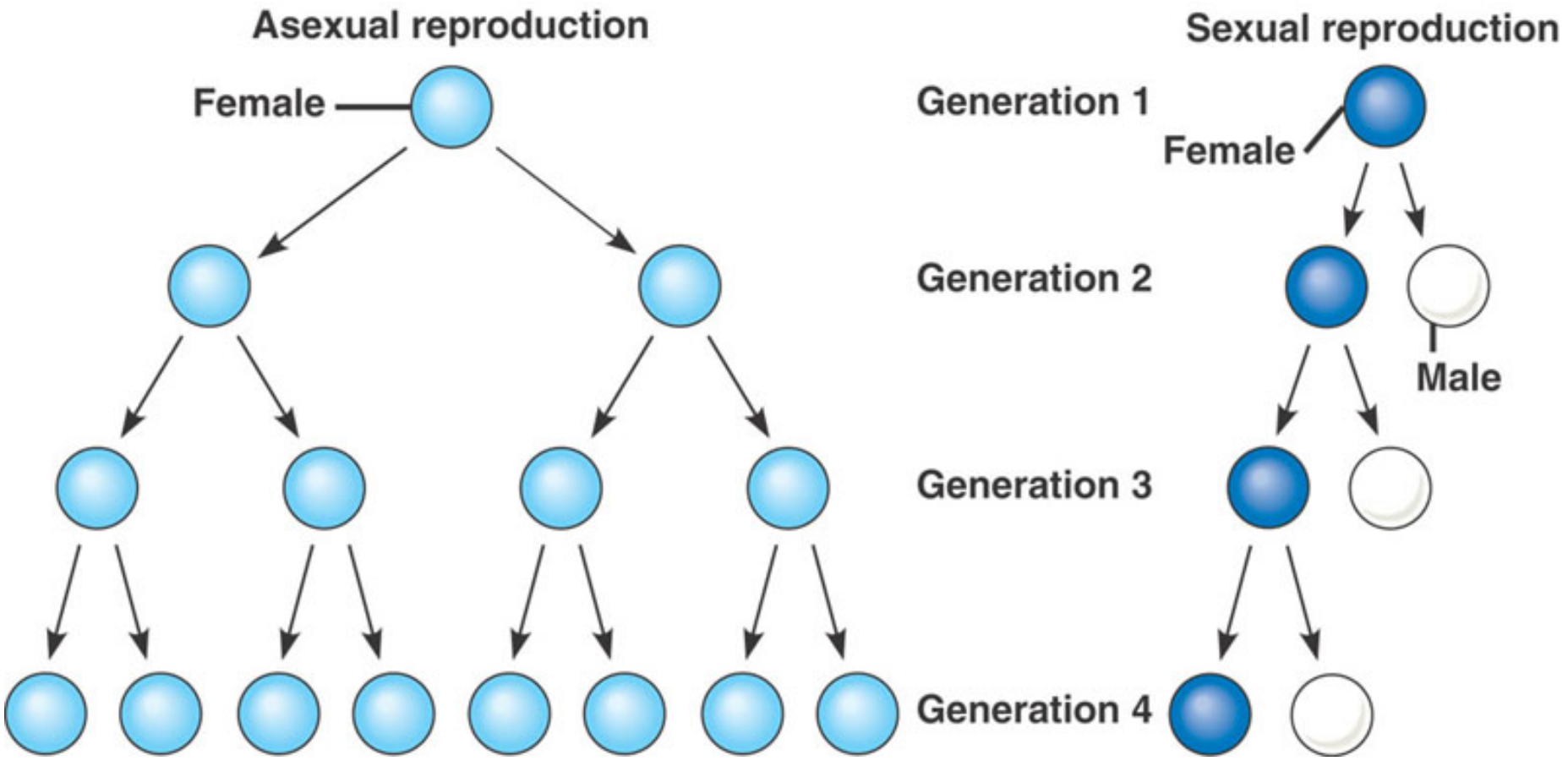


# ATP is a molecule common used to store and release energy in cells from bacteria to fungi to humans



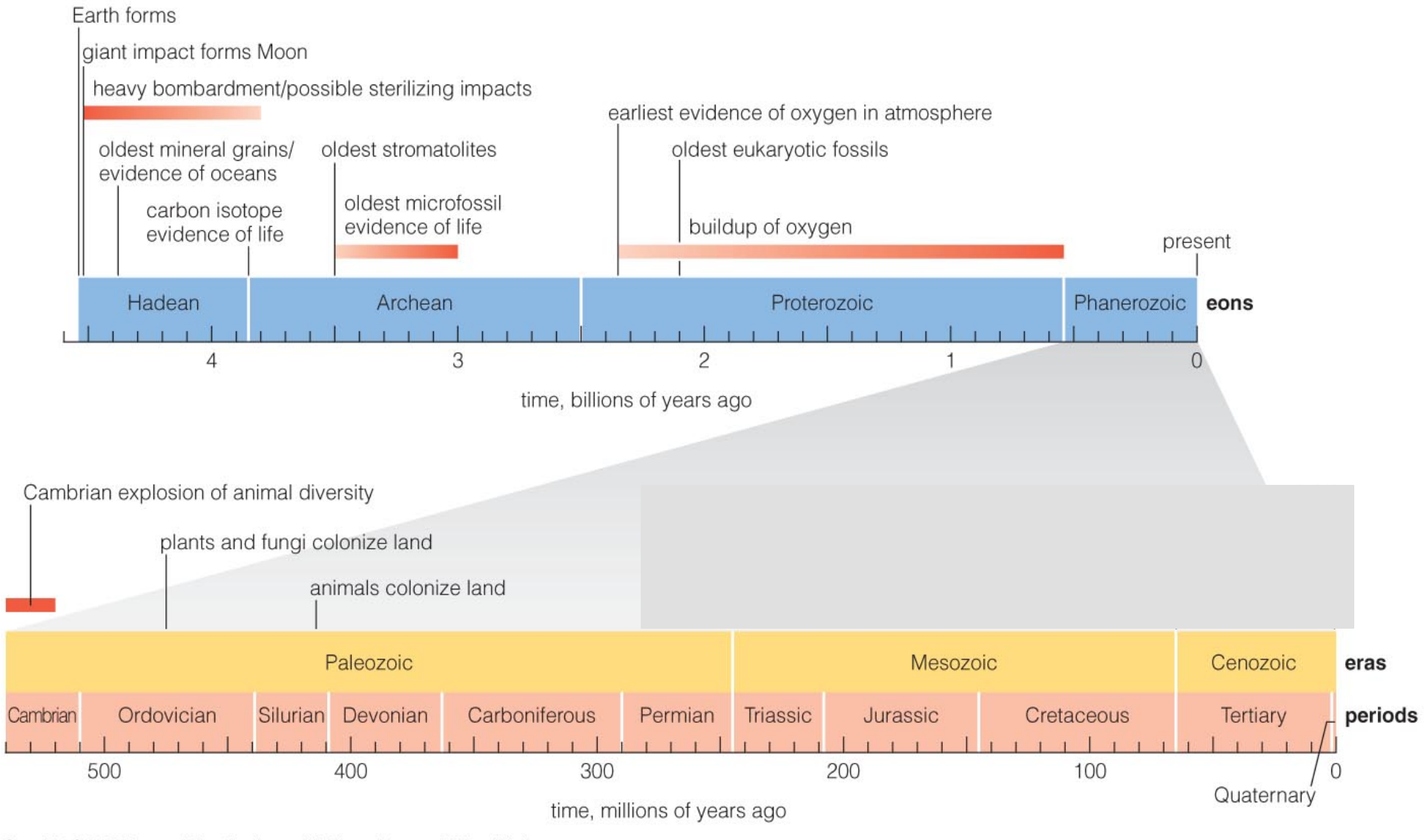
# EVOLUTION OF LIFE ON EARTH






The invention of sexual reproduction 1.2 billion years ago – apart from being a generally good thing – acts to accelerates evolution by mixing genetic material.

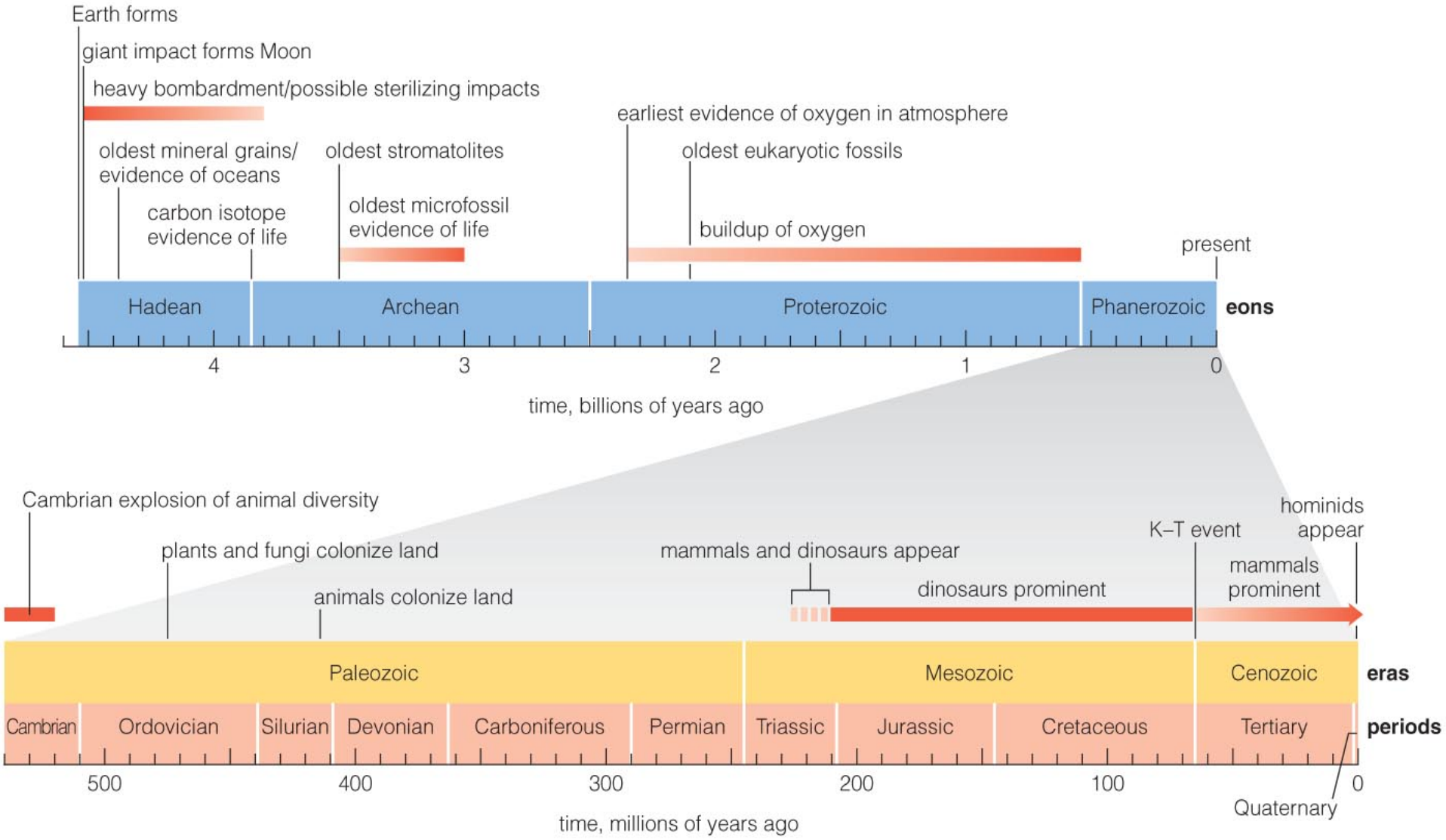
# EVOLUTION OF LIFE ON EARTH



After 3 billion years of no lifeform larger than the head of a pin, there is an explosion of diversity in the oceans 550 My ago – the Cambrian explosion.

Life moves onto the land 400 My ago and adapts to a much wider range of ecological niches. Evolution of plants raises the oxygen content of the atmosphere.

# EVOLUTION OF LIFE ON EARTH



**a** A dinosaur bone preserved in sandstone in Dinosaur National Monument, which straddles Utah and Colorado.

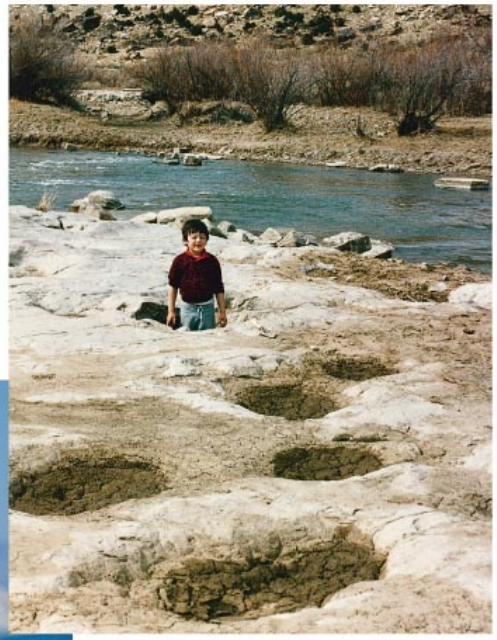
**b** A 190-million-year-old petrified (stone) tree in Arizona.

**c** These 375-million-year-old impressions are casts of dead organisms (called ammonites) made when minerals filled the empty space left after the organism decayed.

**e** An insect preserved in hardened tree resin (often called *amber*).

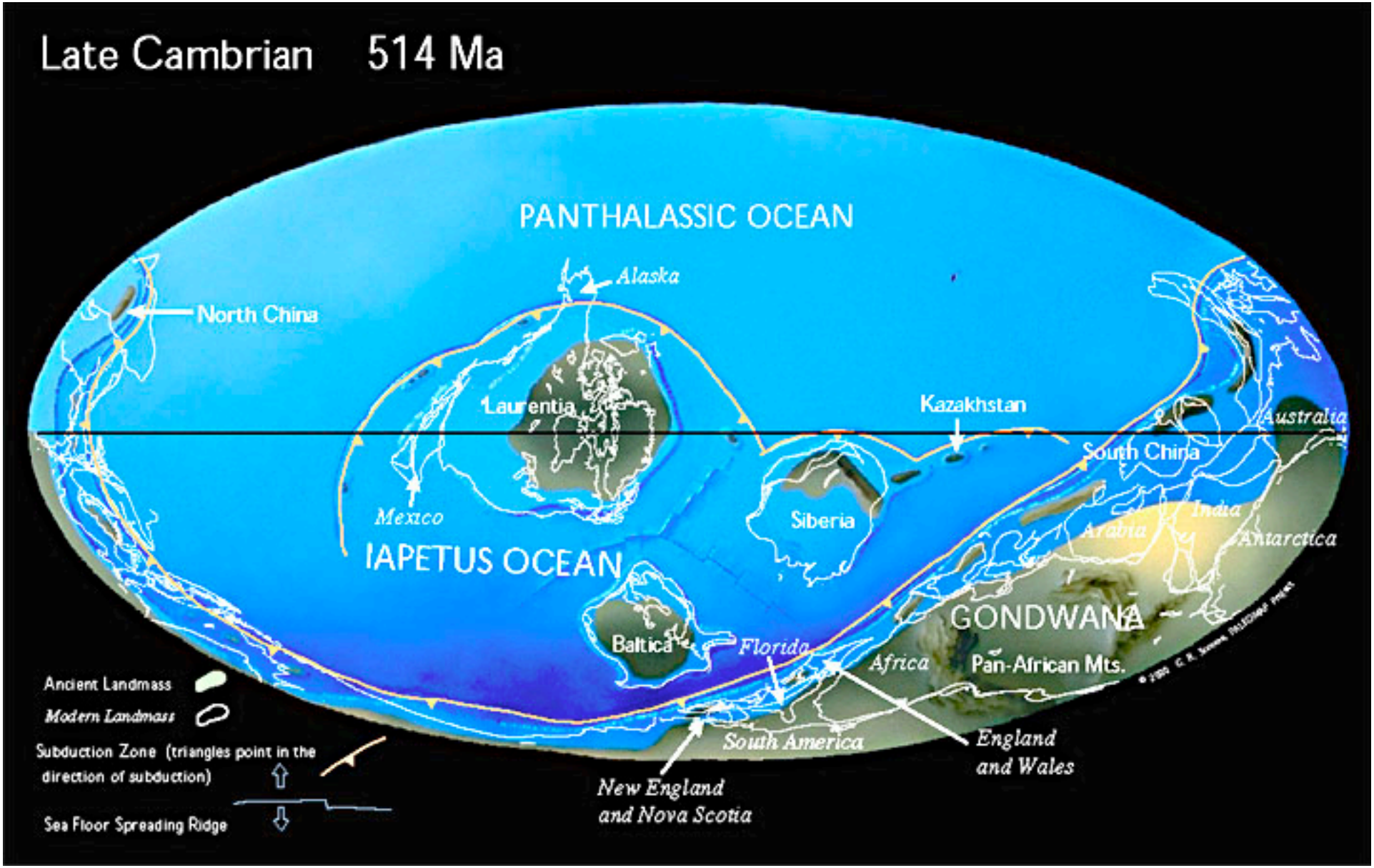
**d** This 40-million-year-old leaf still retains organic material, including DNA.

**f** These tusks belong to a whole 23,000-year-old mammoth discovered in Siberian ice in 1999.

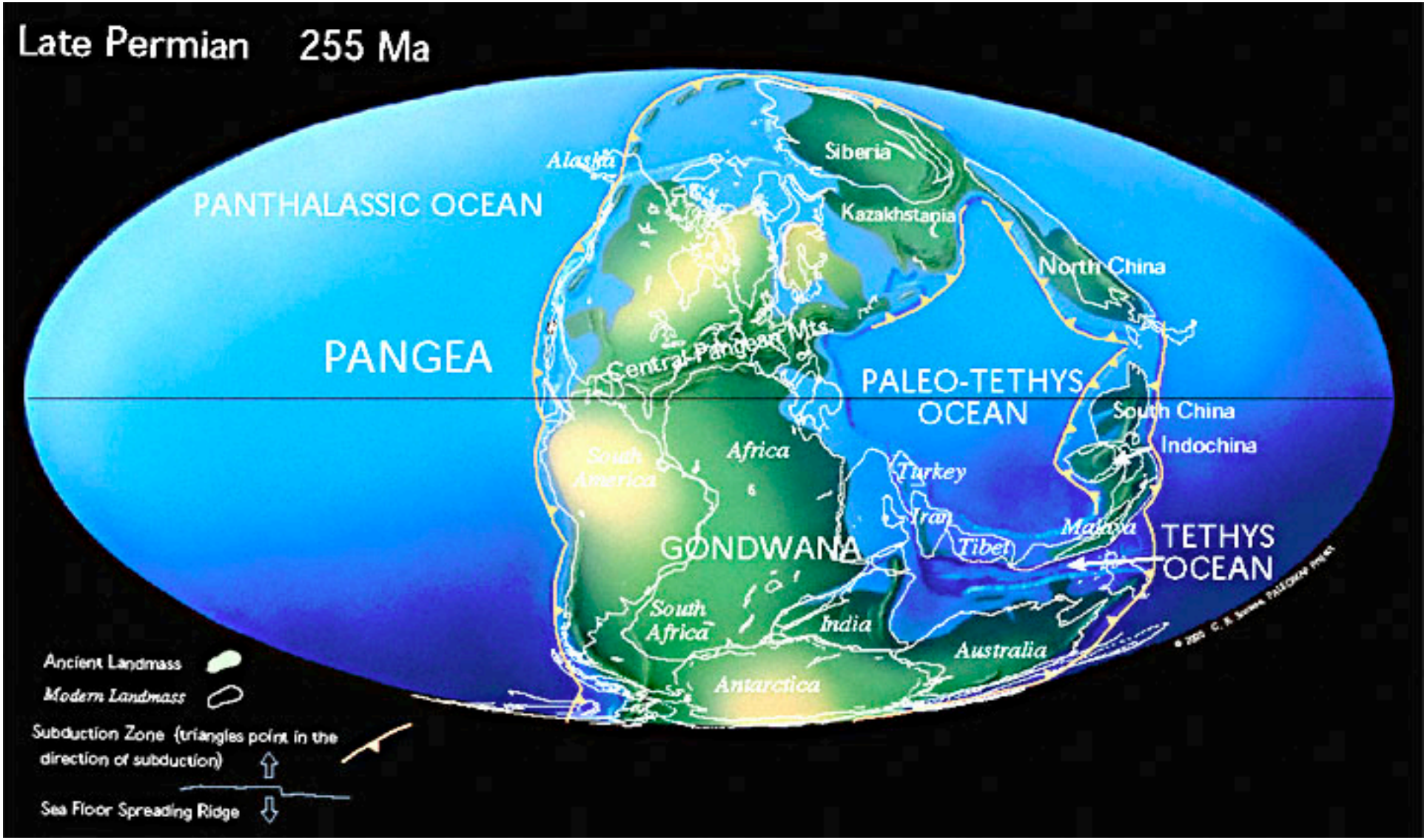


**g** This boy is standing in a 150-million-year-old dinosaur track in Colorado.

# Plate Tectonics



# Plate Tectonics



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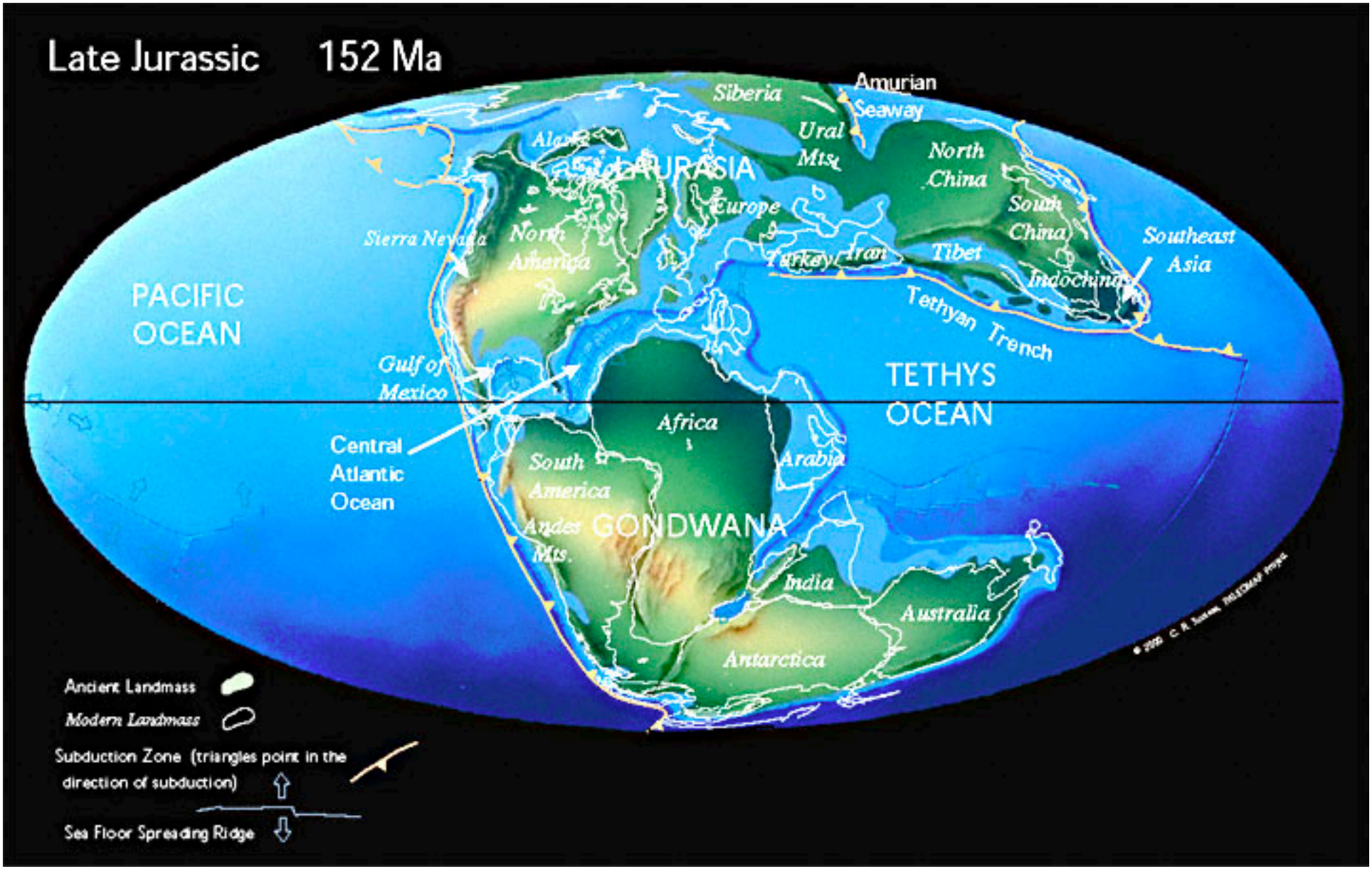

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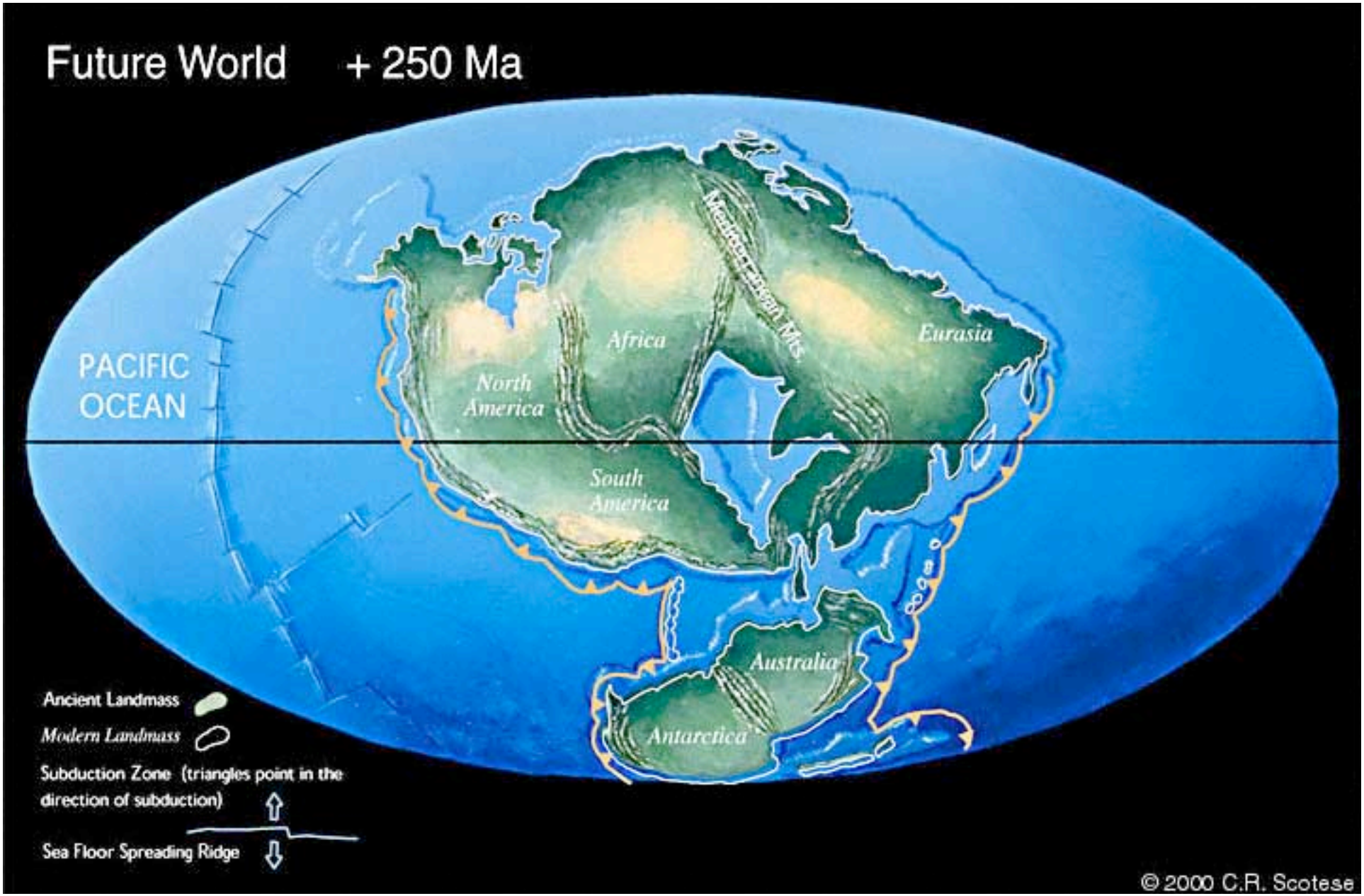
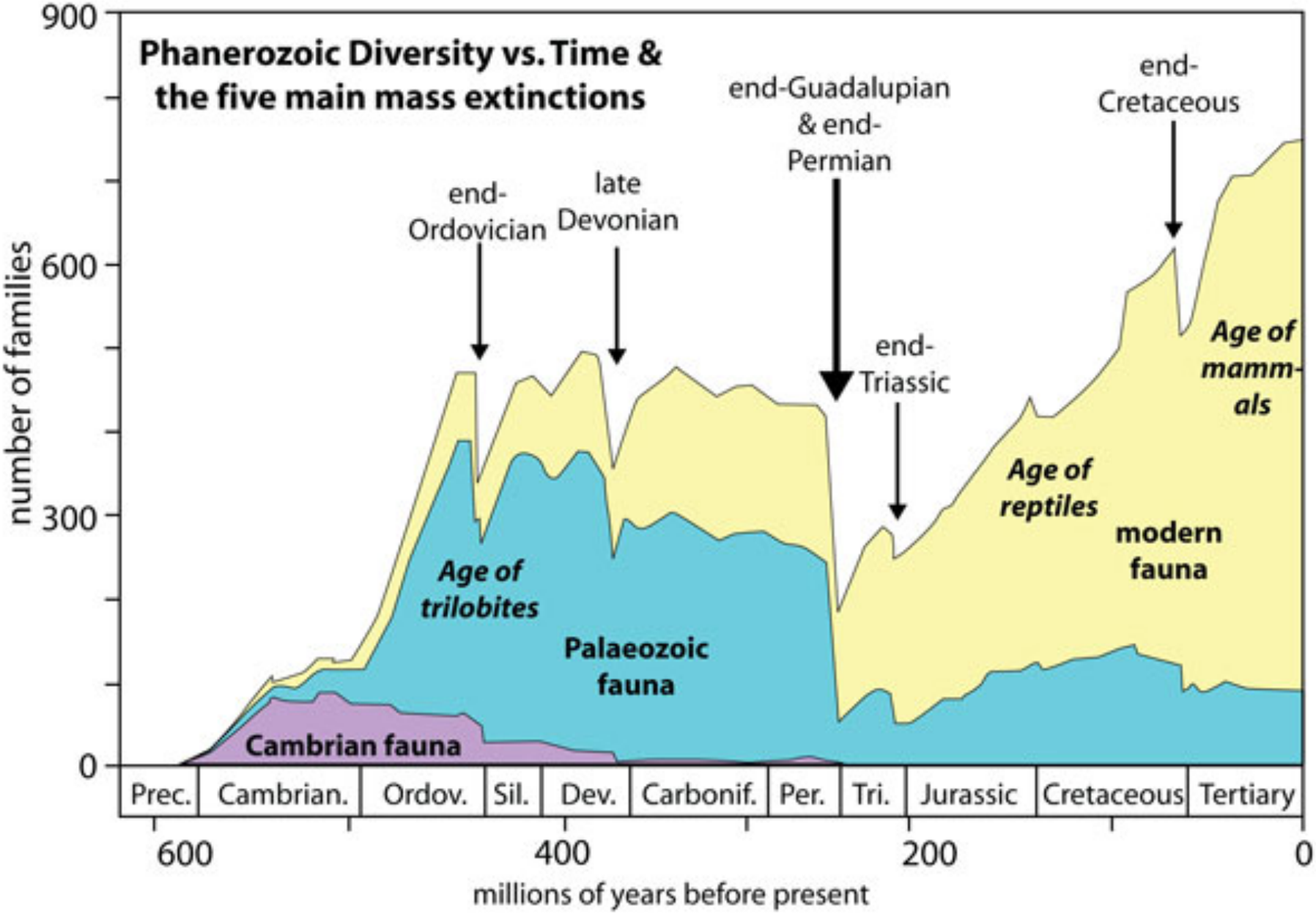
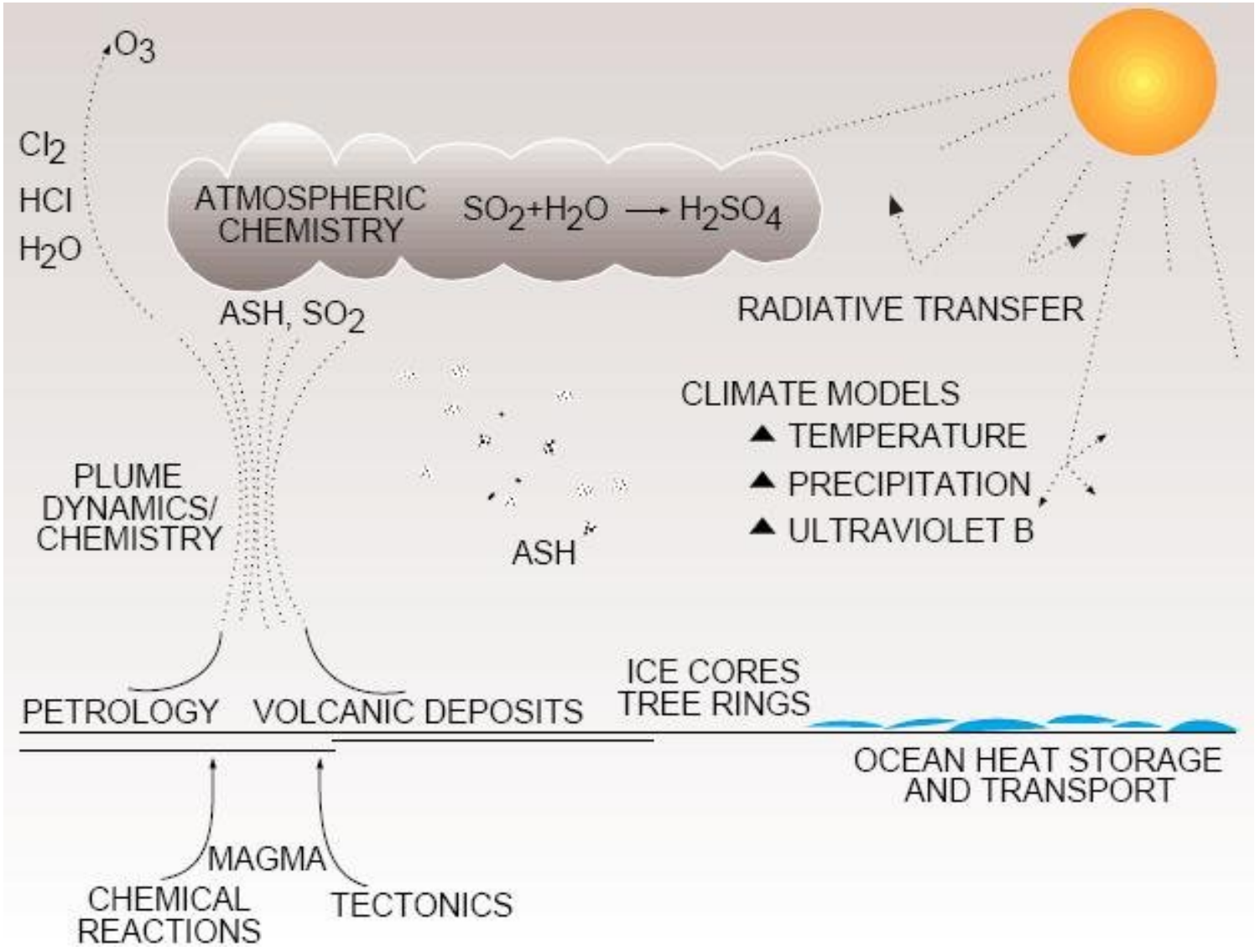


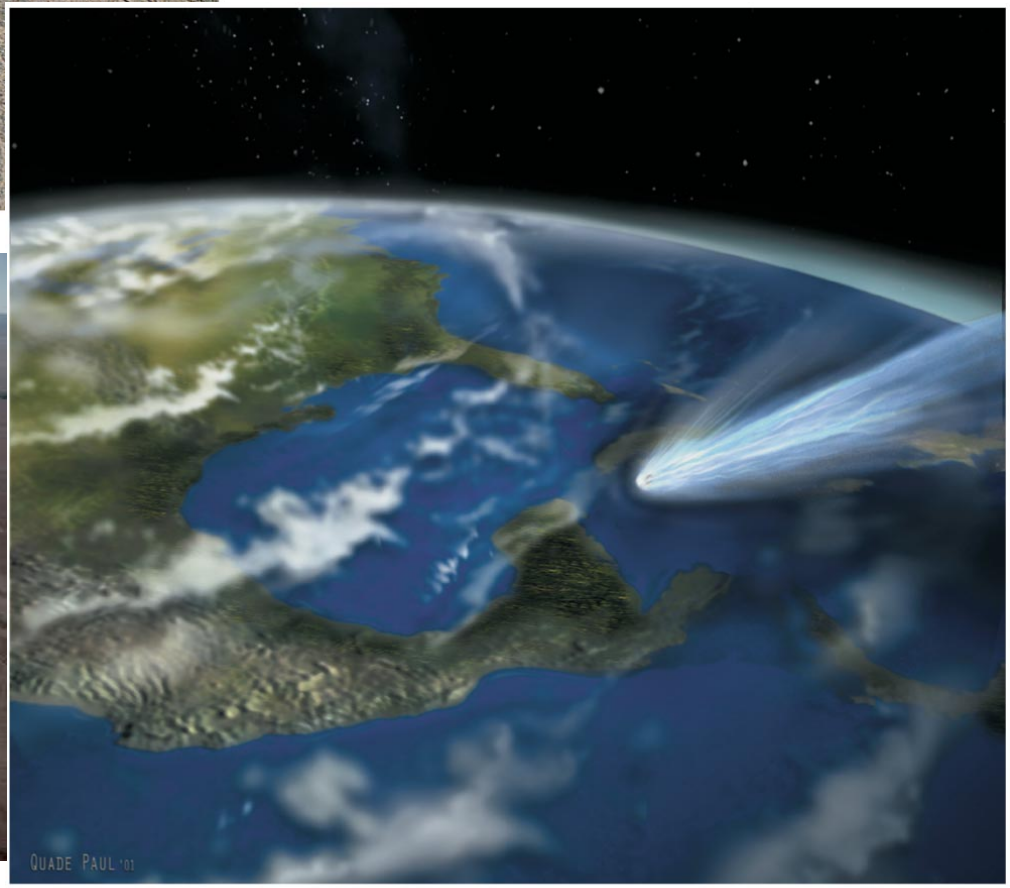
# Extinction History



Drastic climate change and ecological catastrophe can occur every 100,000 years or so due to supervolcanos. They blot out the Sun for decades.




A major impact event likely caused the mass extinction 65 million years



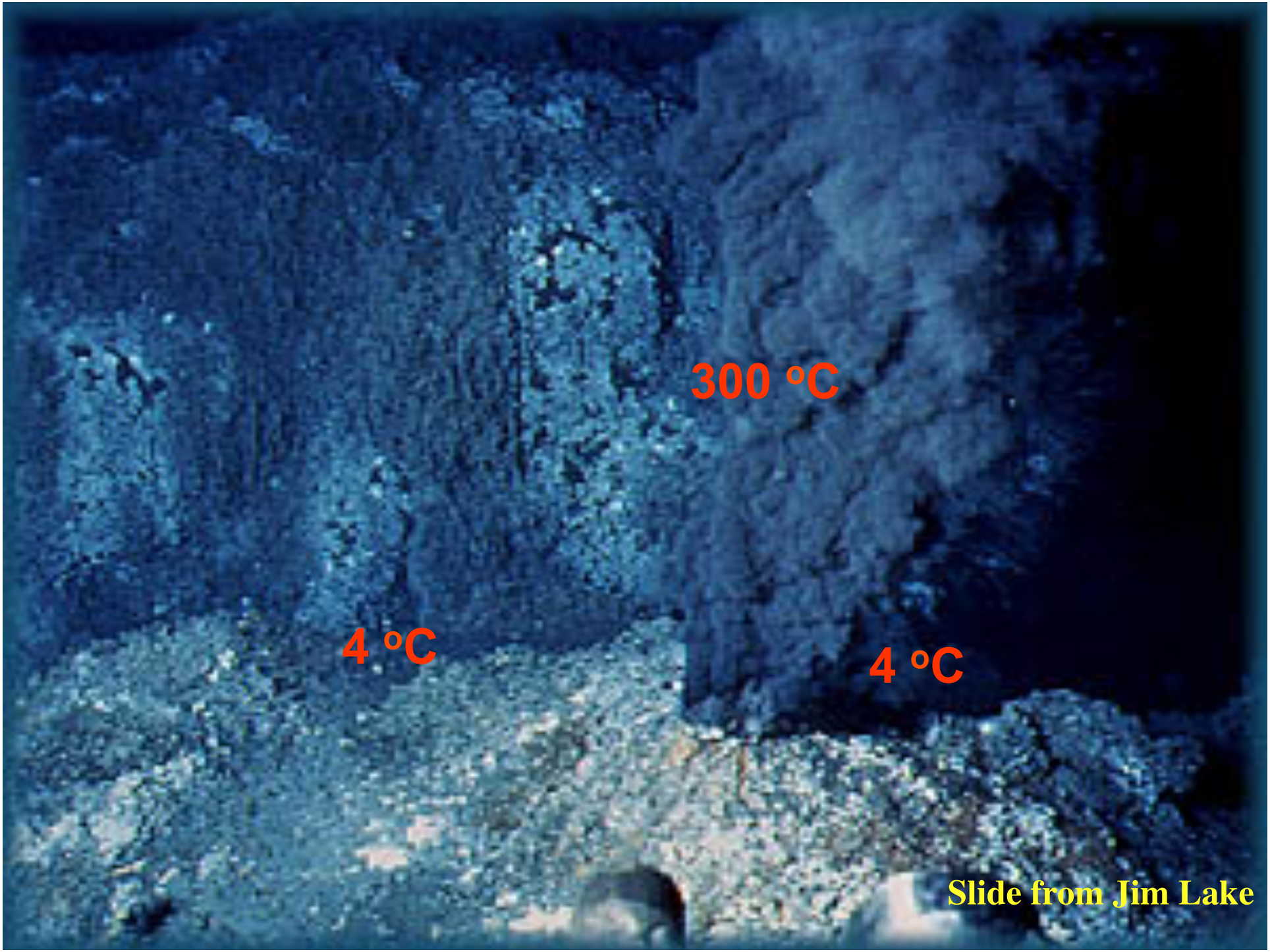
# Astrobiological Implications

- Earth had life soon after its origin, and maybe within 100 million years, under extreme conditions.
- Soon after the heavy meteorite bombardment ended, microbes as metabolically complex as now were widespread and abundant.
- So life arose and diversified rapidly, and occupied an amazing array of evolutionary niches.
- Planets with early but short-lived habitable windows (e.g. Mars, Venus) could have been lively.
- Intelligence does not rapidly follow evolution of complex cells (eukaryotes), so microbial life may be abundant while intelligence is rare.

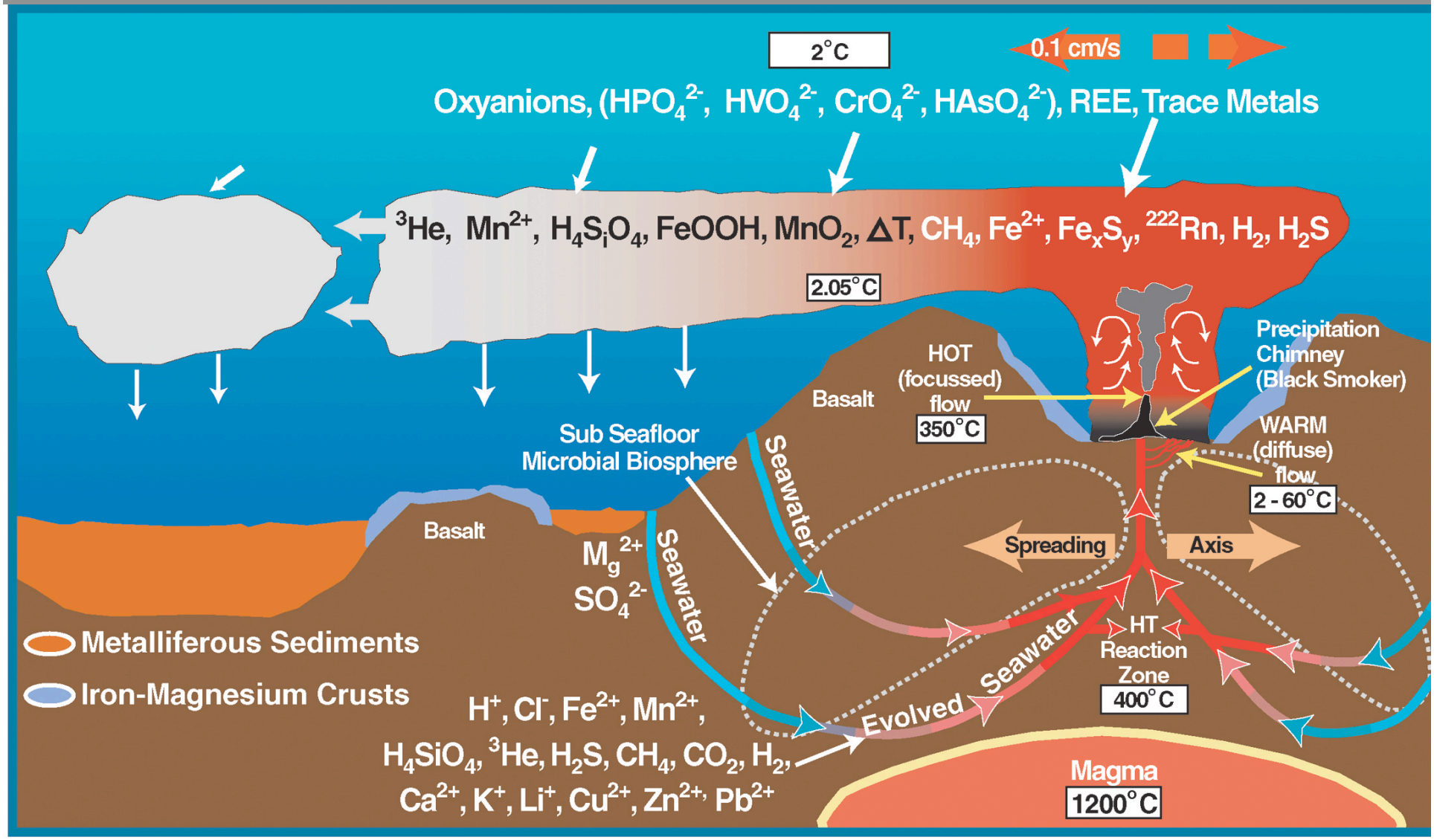
# Thermophiles

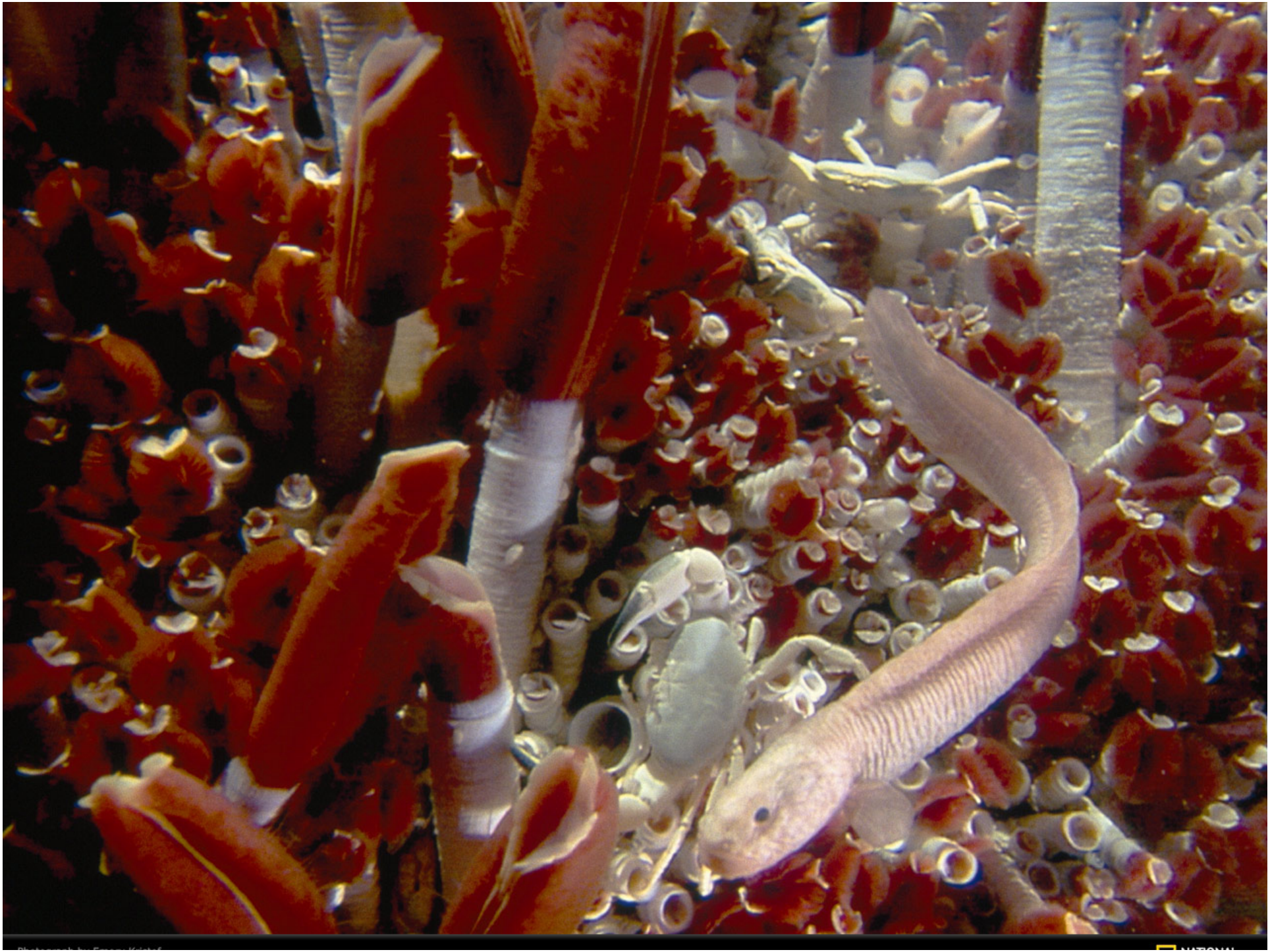
## "Heat-loving"

- Microorganisms that not only survive in high temperature, but that thrive there
- **Temperature Range:** 42°C to 121°C (well over the boiling point of water!)


300 °C
4 °C
4 °C
Slide from Jim Lake

# Complex Chemistry around a Deep Sea Vent






Bacteria up to 177 F (80C)

# Psychrophiles

## "Cold-loving"

- Microbes that prefer to live in cold temperatures that linger around the freezing point of water and sometimes lower!
- **Temperature Range:** -3°C to 20°C

# Researchers Discover Microbial Life in Mariana Trench

Mar 19, 2013 by Natali Anderson

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Mariana Trench



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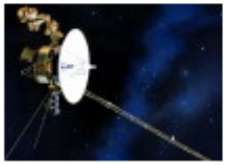


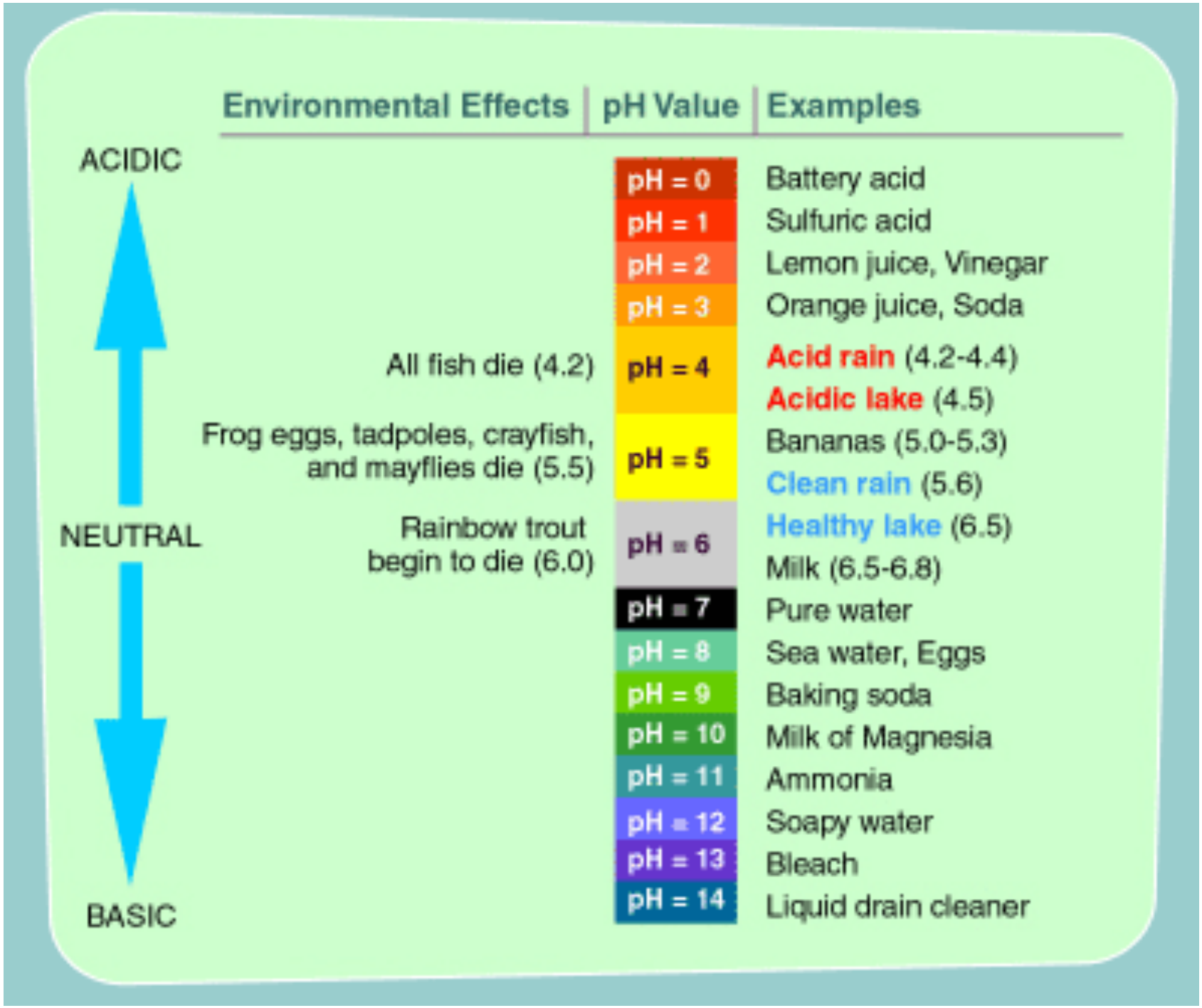
Scientists: Voyager 1 Has Left the Solar System

New Wasp

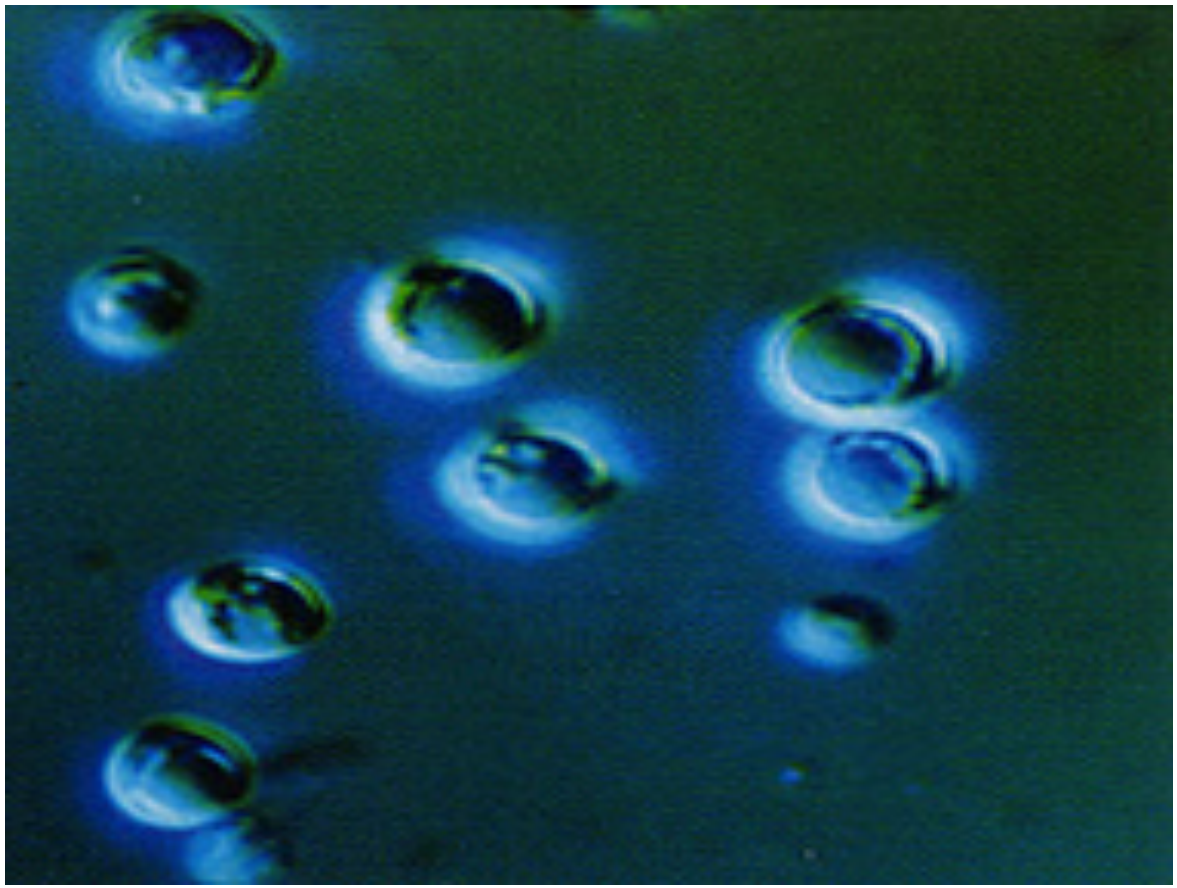
**An international team of scientists has discovered a surprisingly huge and active bacterial community living on the sea floor at the deepest site on Earth, the Mariana Trench.**

Photo of the sediment surface at Challenger Deep – 6.77 miles water depth (Ronnie N. Glud et al)

According to their study, published in the journal *Nature Geoscience*, a highly active bacteria community exists in the sediment of the trench – even though the environment is under extreme pressure almost 1,100 times higher than at sea level.


Environmental Effects
pH Value
Examples
ACIDIC
NEUTRAL
BASIC
All fish die (4.2)
Frog eggs, tadpoles, crayfish, and mayflies die (5.5)
Rainbow trout begin to die (6.0)
pH = 0
pH = 1
pH = 2
pH = 3
pH = 4
pH = 5
pH = 6
pH = 7
pH = 8
pH = 9
pH = 10
pH = 11
pH = 12
pH = 13
pH = 14
Battery acid
Sulfuric acid
Lemon juice, Vinegar
Orange juice, Soda
Acid rain (4.2-4.4)
Acidic lake (4.5)
Bananas (5.0-5.3)
Clean rain (5.6)
Healthy lake (6.5)
Milk (6.5-6.8)
Pure water
Sea water, Eggs
Baking soda
Milk of Magnesia
Ammonia
Soapy water
Bleach
Liquid drain cleaner

# Acidophiles



This is a picture of *Cyanidium caldariam*, an organism that can live in a pH as low as ZERO!!!

# Anaerobes

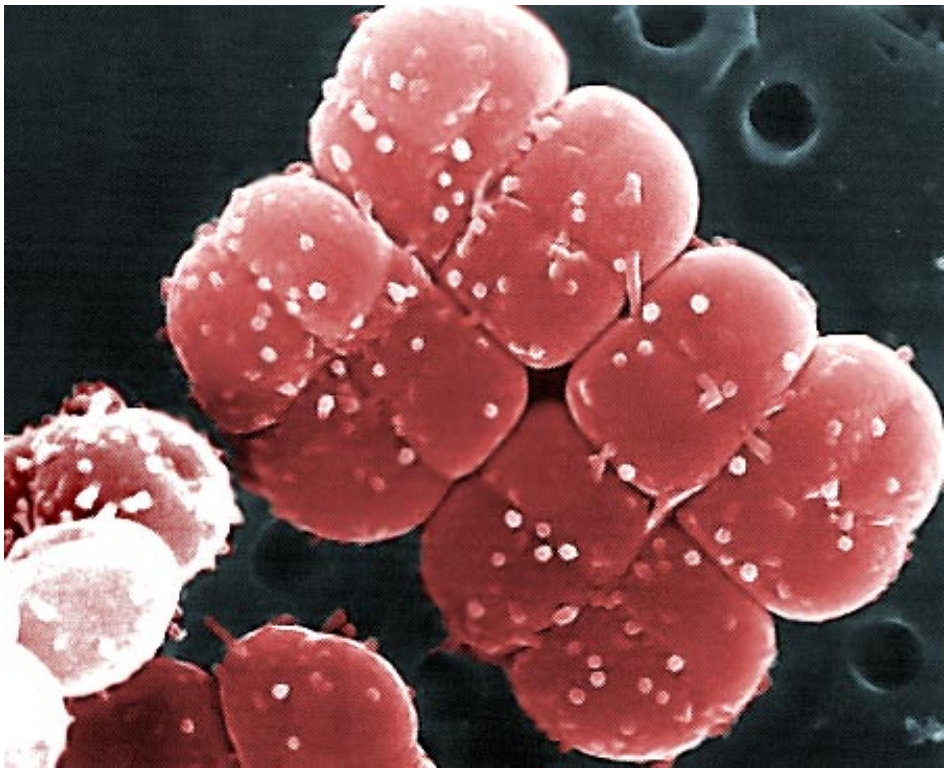
## "Hate Oxygen"

- These are microbes that don't like to function with oxygen in the environment.
- May use gases other than oxygen in order respire

# Methanogen?!?!

**Methane ice (crystallized structures of methane & water) that can form under conditions of low temperature and very high pressure. This methane hydrate mound in the Gulf of Mexico has thousands of polychaete worms on its exposed surface.**

# Conan the Bacterium



**Deinocuccus radiodurans is a microbe that can withstand 1000 times the radiation dose that would kill a human in minutes. It keeps 5 stacked copies of its DNA ready for very quick repairs.**

# The Amazing Tardigrade

**The tardigrade or water bear is a fully functioning microscopic animal that can go into a freeze-dried wait state for centuries and reanimate in water. It is found in all Earth's ecosystems.**

# Tardigrades have been revived after exposure to 10 days in space!