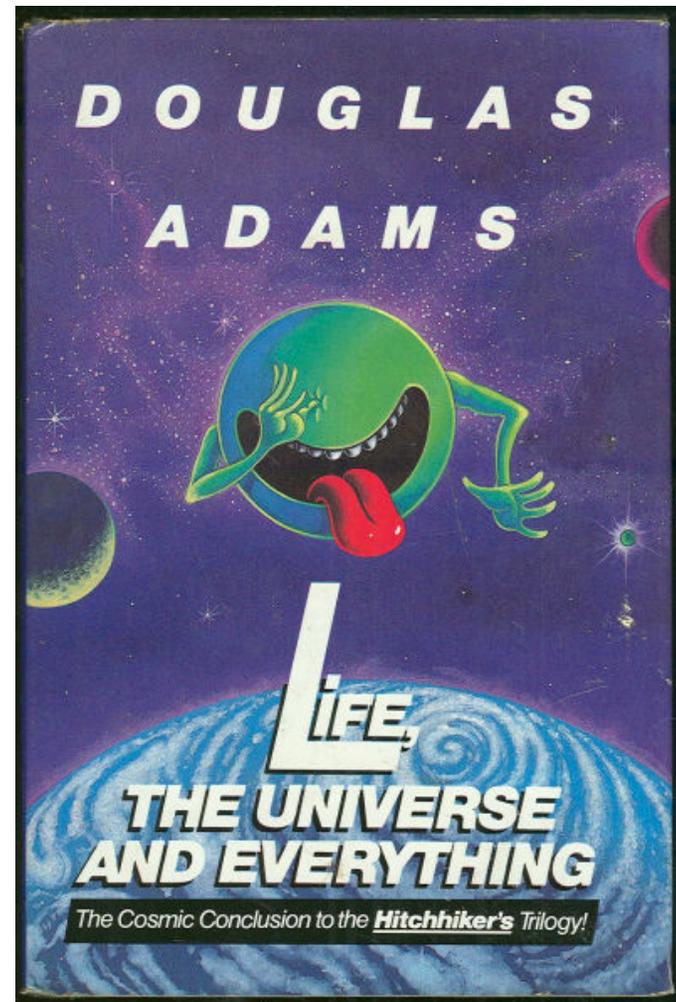


[26] Life in the Universe 1 (12/5/17)

Upcoming Items

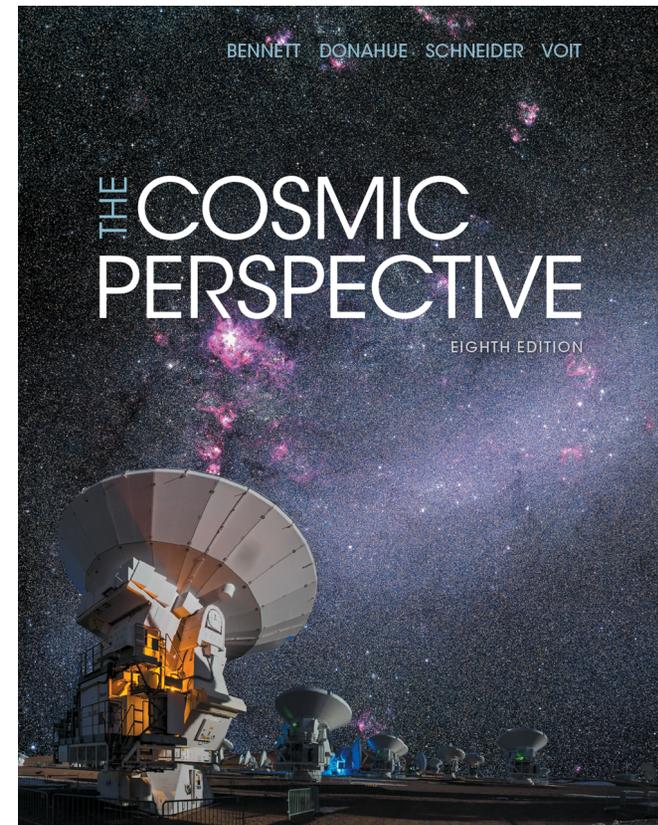
- Homework #12 due next class.
- Read chapters 24.4-24.5 for Thursday
- Have you done the course evaluation yet? **If not, please do so!**
- FINAL EXAM on **Wednesday, Dec 13** from 8-10 am in this room.



LEARNING GOALS

Chapter 24

For this class, you should be able to...
... outline broadly the conditions that may be needed for life to exist elsewhere in the universe;



Debate Next Time!

- The question:
Are there currently any interstellar civilizations in the Milky Way?
- Have fun!

Any astro questions?

In-Class Quiz

1. You have a time machine with a dial that you can spin to send you randomly to any time in Earth's history. If you spin the dial, travel through time, and walk out, what is most likely to happen to you?

- A. You'll be eaten by dinosaurs.
- B. You'll suffocate because you can't breathe the air.
- C. You'll be consumed by toxic bacteria.
- D. Nothing. You'll probably be just fine.

2. Roughly how long ago did life appear on Earth?

- A. ~40 billion years ago.
- B. ~4 billion years ago.
- C. ~400 million years ago.
- D. ~40 million years ago.

In-Class Quiz

1. You have a time machine with a dial that you can spin to send you randomly to any time in Earth's history. If you spin the dial, travel through time, and walk out, what is most likely to happen to you?

- A. You'll be eaten by dinosaurs.
- B. You'll suffocate because you can't breathe the air.**
- C. You'll be consumed by toxic bacteria.
- D. Nothing. You'll probably be just fine.

2. Roughly how long ago did life appear on Earth?

- A. ~40 billion years ago.
- B. ~4 billion years ago.**
- C. ~400 million years ago.
- D. ~40 million years ago.

What is Life?

- Which is alive?

A rock

A snowflake

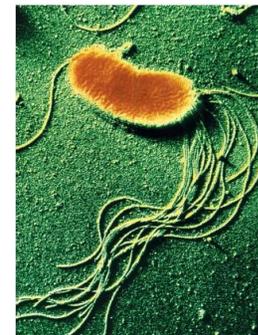
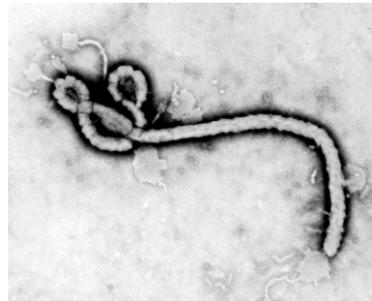
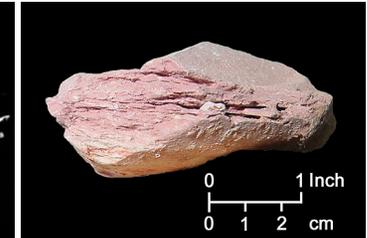
Clay

A virus

A bacterium

A fly

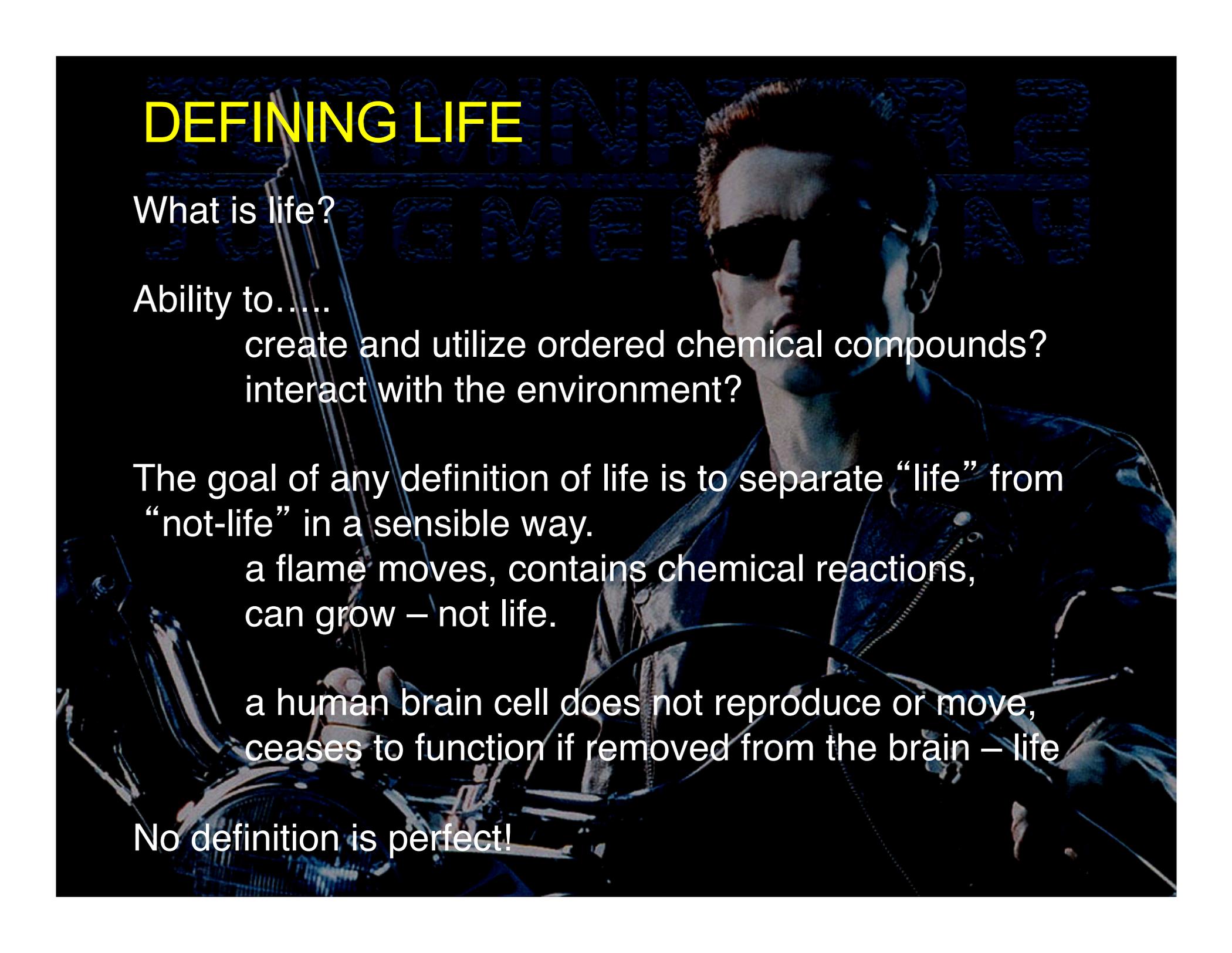
A person



Group Question: Definition of Life

- In your groups, try to come up with characteristics that:
*Apply to **all** life*
*And apply to **only** life*
- Good luck!

DEFINING LIFE



What is life?

Ability to.....

create and utilize ordered chemical compounds?
interact with the environment?

The goal of any definition of life is to separate “life” from “not-life” in a sensible way.

a flame moves, contains chemical reactions,
can grow – not life.

a human brain cell does not reproduce or move,
ceases to function if removed from the brain – life

No definition is perfect!

A Difficulty to Remember

- We only know of life on this planet
- Our inclination is to look for similar conditions
- But is this reasonable?

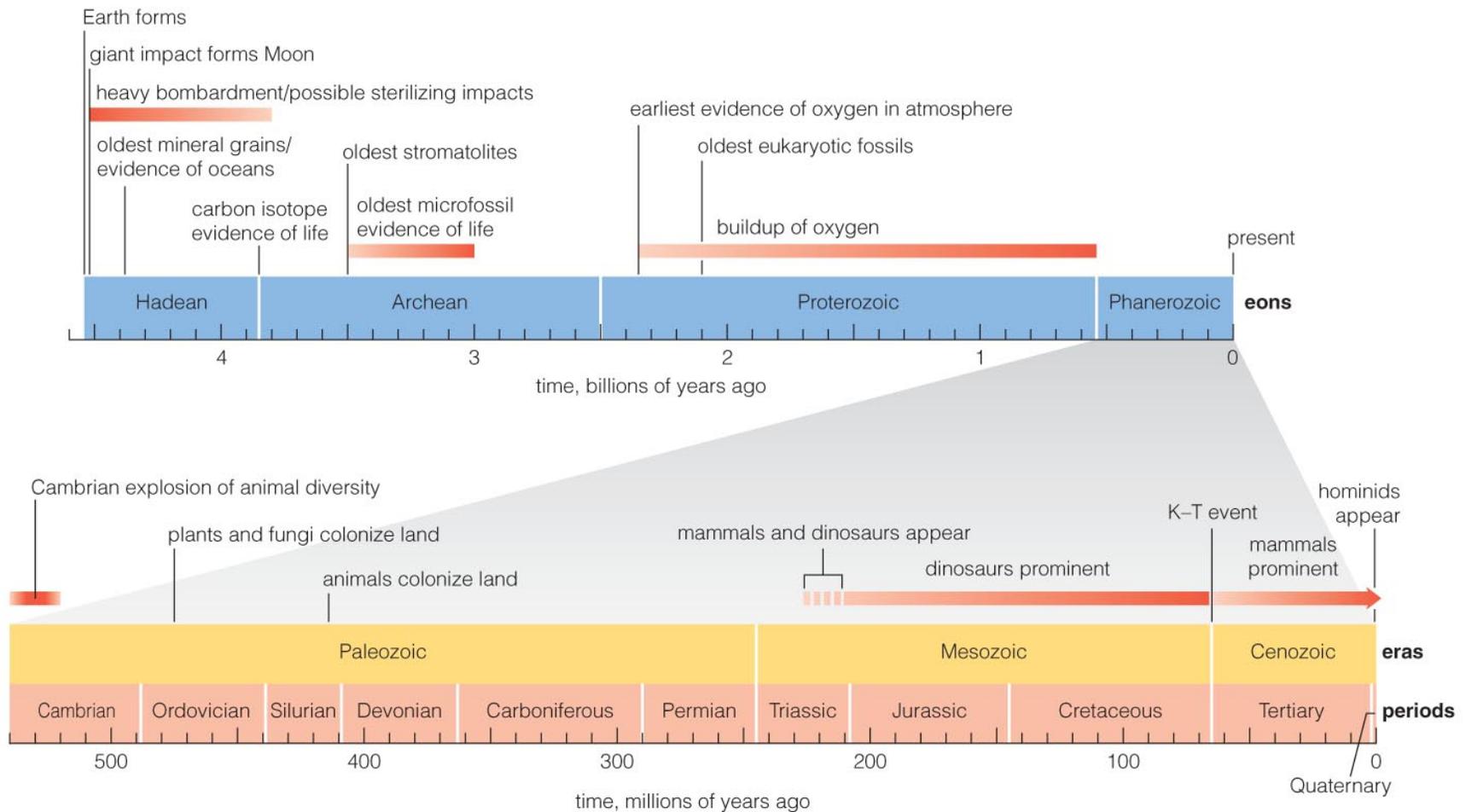
Life in the Universe

- Life arose early in Earth's history.
- Life may come from naturally occurring chemistry elsewhere.
- Microscopic living organisms survive harsh conditions.
- There appears to be liquid water elsewhere in our solar system...
- And there are exoplanets in "habitable zones"...
- But is intelligent life elsewhere likely?

The Facts

1. Life arose early in Earth's history.
 - Suggests life might develop quickly on other worlds too.
2. Complex organics can arise from early constituents.
 - Life may come from naturally occurring chemistry elsewhere.
3. Microscopic living organisms survive harsh conditions.
 - Necessities of life may be common in the universe.

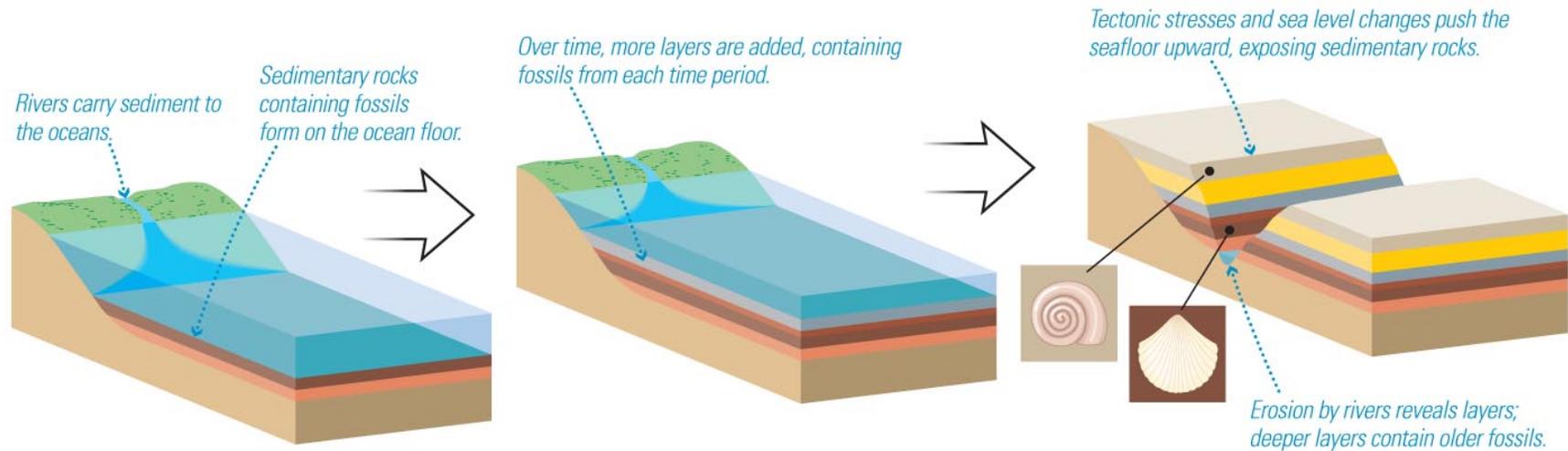
When did life arise on Earth?



Earliest Life Forms

- Life probably arose on Earth more than 3.85 billion years ago, shortly after the end of the heavy bombardment.
- Evidence comes from fossils (oldest 3.5 Gyr) and carbon isotopes (in rocks 3.85 Gyr old).

Fossils in Sedimentary Rock



- Relative ages: deeper layers formed earlier.
- Absolute ages: radiometric dating.

Fossils in Sedimentary Rock



- Rock layers of the Grand Canyon record 2 billion years of Earth's history.
- Dinosaur fossils are abundant at Dinosaur National Monument in the United States.

Earliest Fossils

- The oldest fossils show that bacteria-like organisms were present over 3.5 billion years ago.
- Carbon isotope evidence dates the origin of life to more than 3.85 billion years ago.



Thrombolites in Lake Clifton, Western Australia, along with a less advanced organism

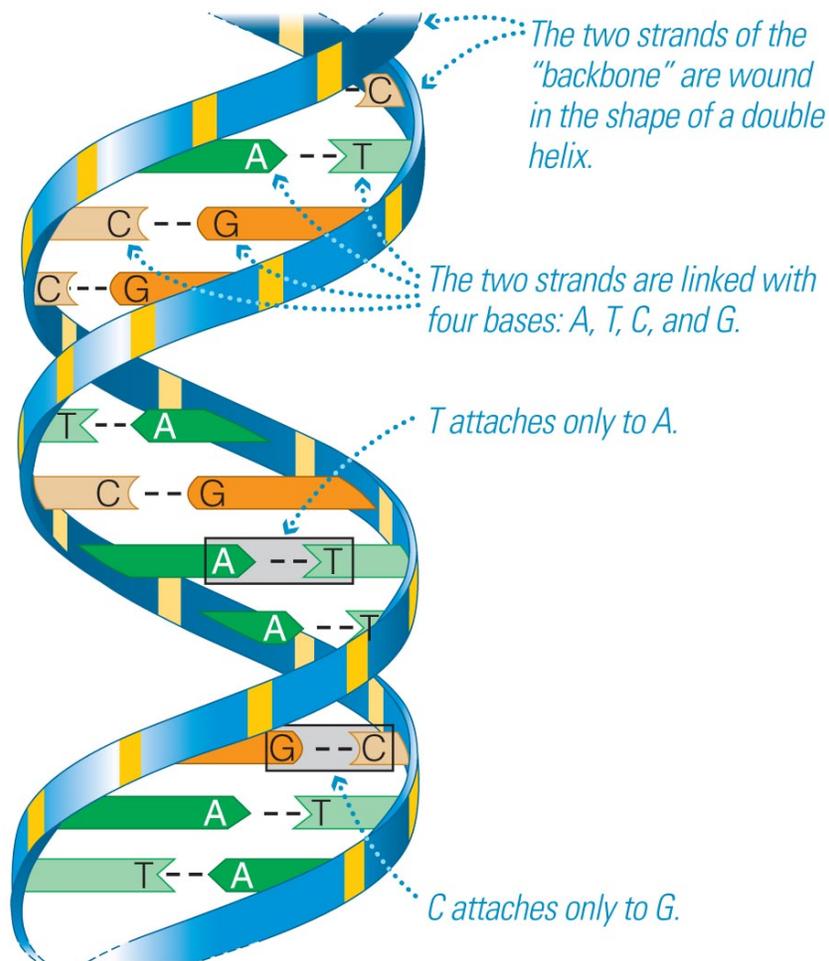
The Fact of Evolution

- Forms of life change over time, via descent with modification
- That's it!

The Theory of Evolution

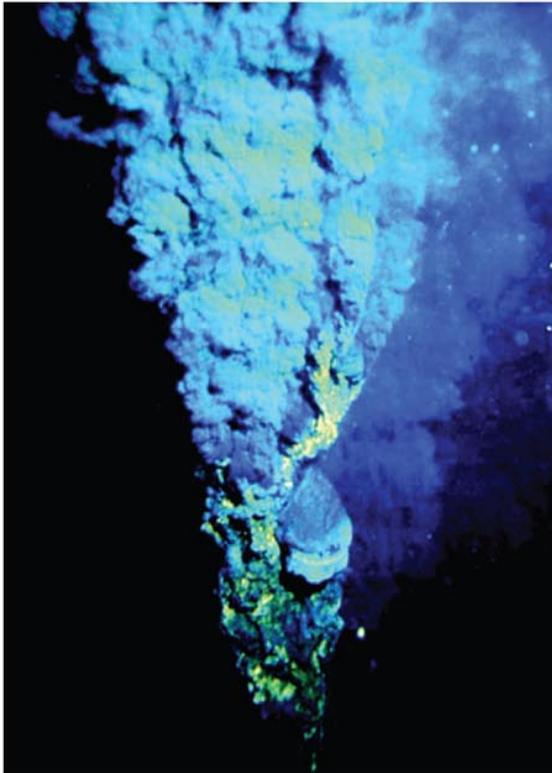
- Characteristics of population are most strongly influenced by individuals who leave the most viable offspring **Seems uncontroversial, even tautological!**
- Variation: mutation, sex, horizontal gene transfer, neutral drift, incorporation of cells
- Selection: natural/sexual

The Theory of Evolution

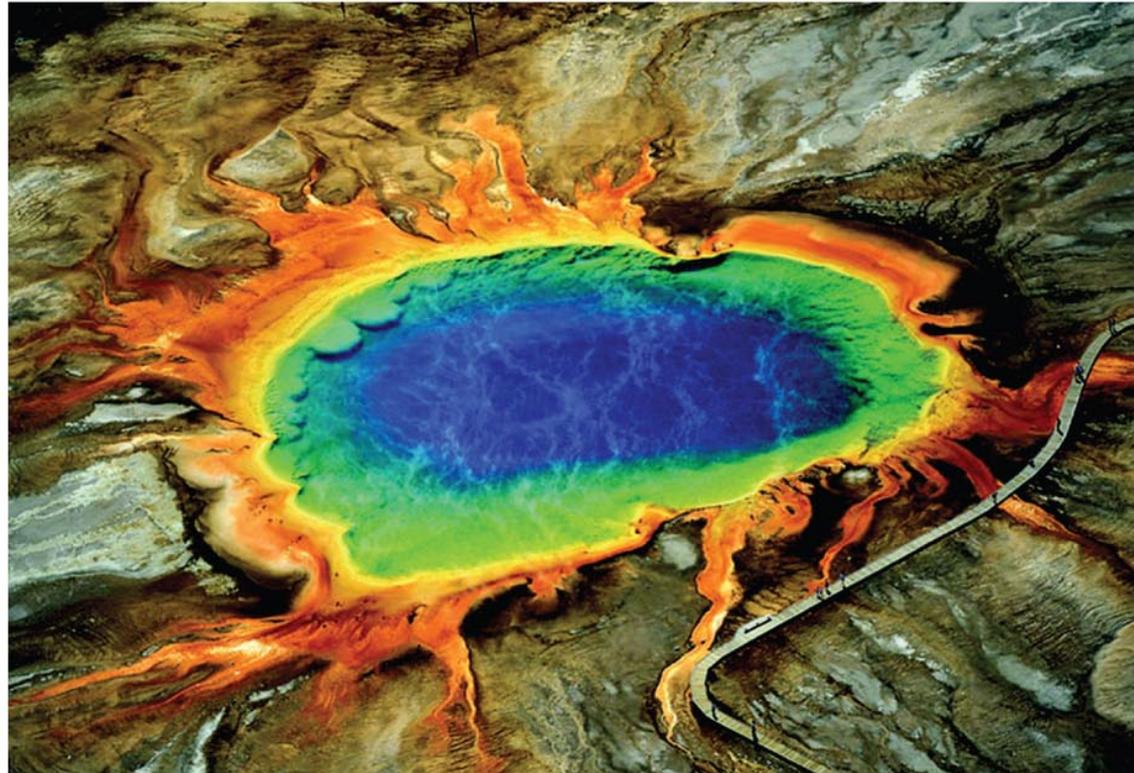


- The fossil record shows that evolution has occurred through time.
- Darwin's theory tells us HOW evolution occurs: through **natural selection**.
- Theory supported by discovery of DNA
- All life on Earth is related

- Some genetic studies suggest that the earliest life on Earth may have resembled the bacteria today found near deep ocean volcanic vents (black smokers) and geothermal hot springs.



a This photograph shows a black smoker—a volcanic vent on the ocean floor that spews out hot, mineral-rich water.



b This aerial photo shows a hot spring in Yellowstone National Park. The different colors are from different microbes that survive in water of different temperatures. For a sense of scale, note the walkway winding along the lower right.

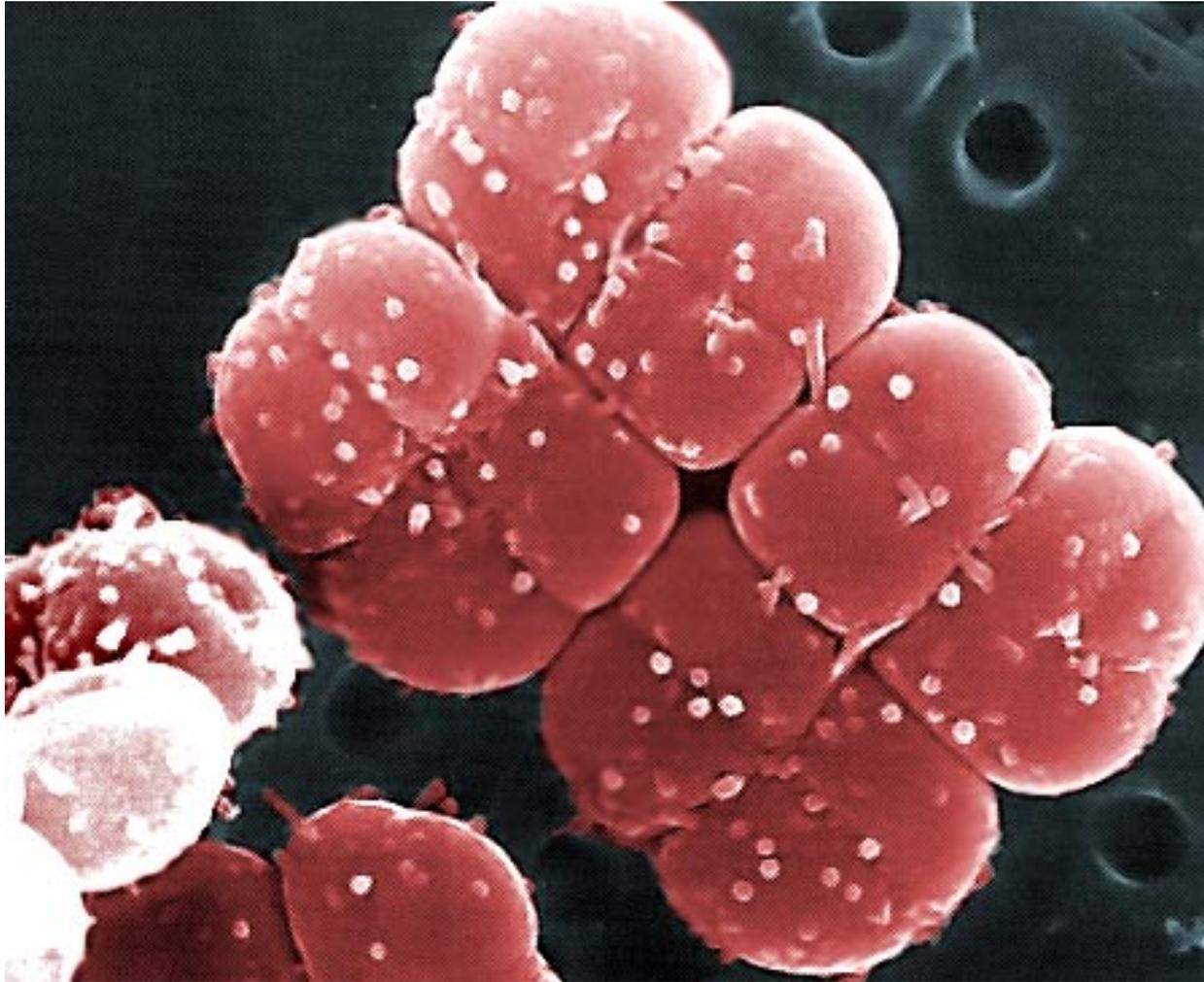
Could life have migrated to Earth?

- Venus, Earth, Mars have exchanged tons of rock (blasted into orbit by impacts).
- Some microbes, and even larger organisms, can survive years in space.



A tardigrade,
one of the
most resilient
animals known

Radiation Resistance



Deinococcus radiodurans

Can withstand
500x fatal rad
dose for humans

Can also resist
heat, cold, dry,
acid, vacuum, ...

Could this
survive an
interstellar trip?

Conan the Bacterium

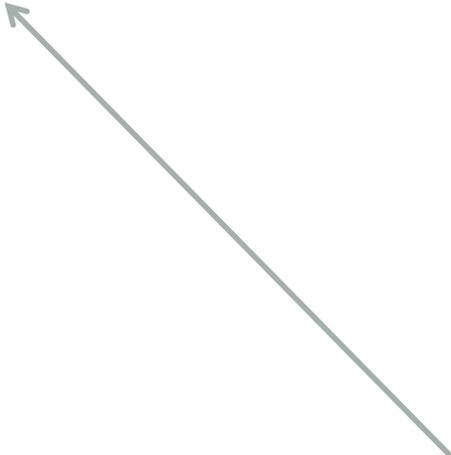
- Radiodurans, again
- How can it survive radiation, cold, vacuum, dormancy, acid, oxidation, ... ?
- Redundancy!
- Genetic code repeats itself many times
- Damage in an area can be recognized and repaired quickly

What are the necessities of life?



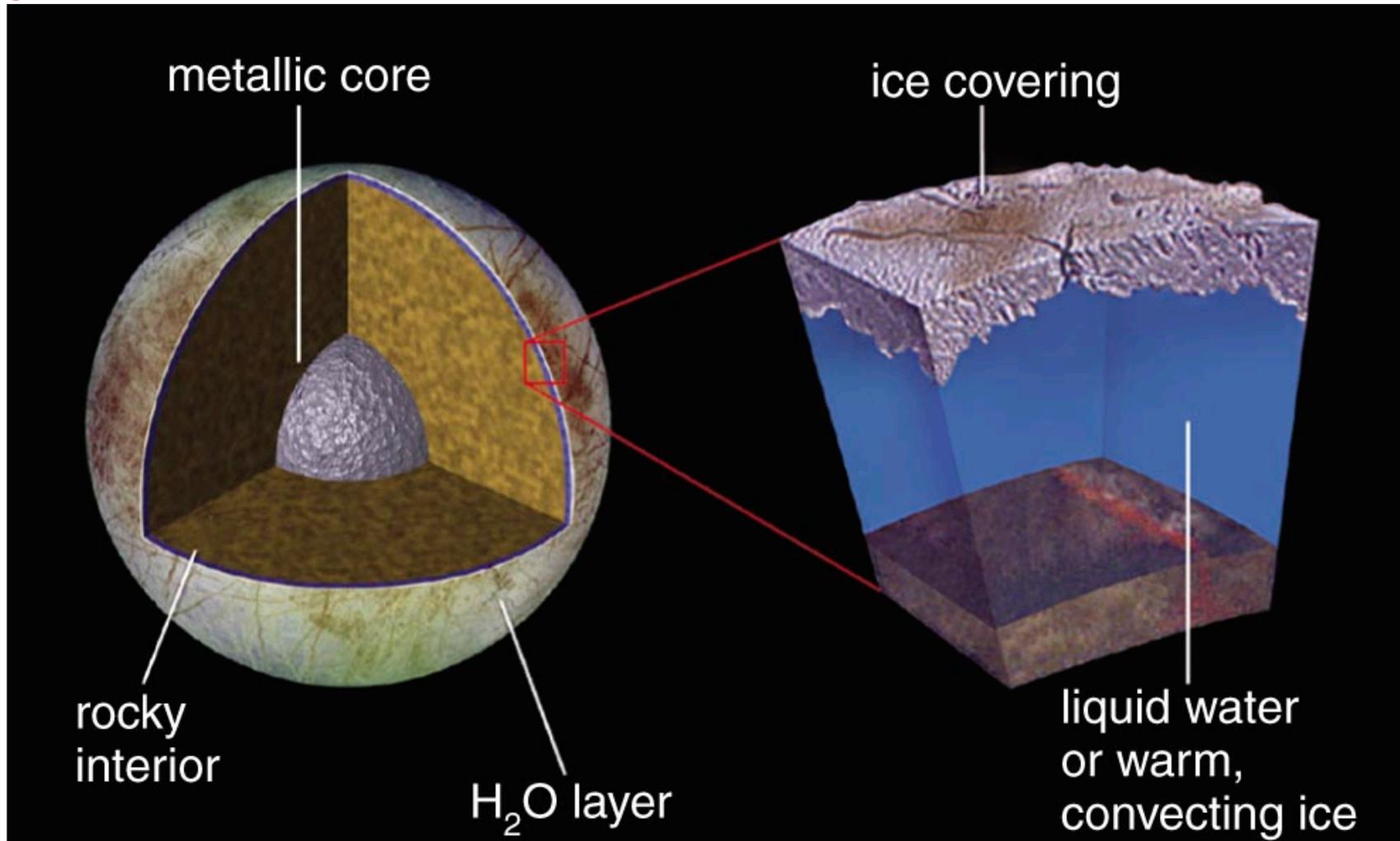
Necessities for Life

- A nutrient source.
- Energy (sunlight, chemical reactions, internal heat).
- Liquid water (or possibly some other liquid).



Hardest to find on
other planets...?

Could there be life on Europa or other jovian moons?

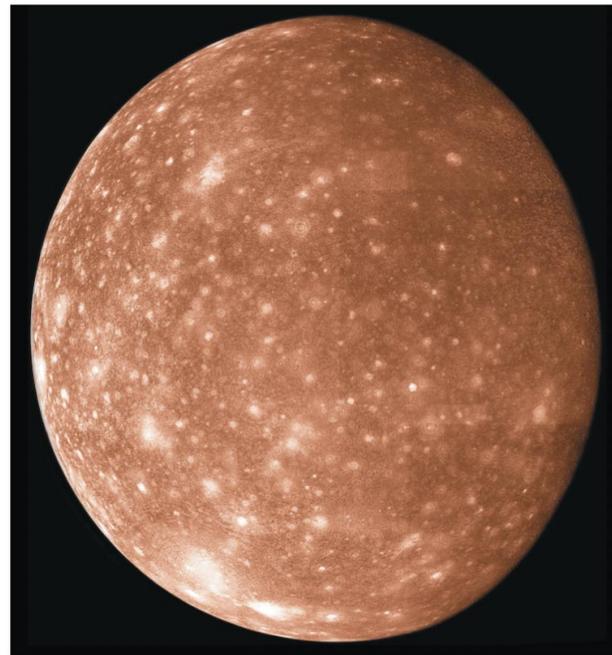


- Ganymede and Callisto also show some evidence for subsurface oceans.
- Relatively little energy available for life, but there still may be enough.
- Intriguing prospect of **THREE** potential homes for life around Jupiter alone.

Ganymede



Callisto



Could there be life on Mars?

