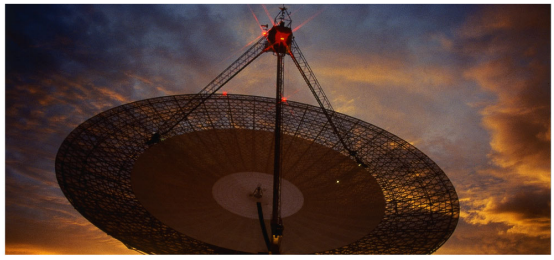
Chapter 24
Life in the Universe



Agenda

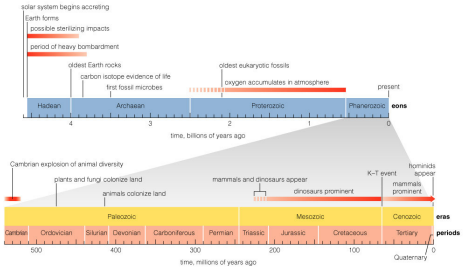
- Announce:
  - **Tuesday:** Finish Ch. 24; Extra Credit Presentations; Observation 8pm
  - **Thursday:** Review for Final; Crab Lab
  - **Tuesday:** Project Presentations
  - **May 8 1:50-4:30pm**: FINAL EXAM
- Evaluations
- Report from the APS
- Ch. 24
- *Life Beyond Earth* Part II

24.1 Life on Earth

Our goals for learning

- When did life arise on Earth?
- How did life arise on Earth?
- What are the necessities of life?

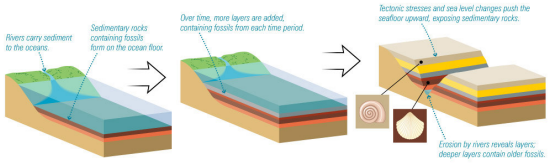
When did life arise on Earth?



Earliest Life Forms

- Life probably arose on Earth more than 3.85 billion years ago, shortly after the end of heavy bombardment
- Evidence comes from fossils, carbon isotopes.

Fossils in Sedimentary Rock



- relative ages: deeper layers formed earlier.
- absolute ages: radiometric dating

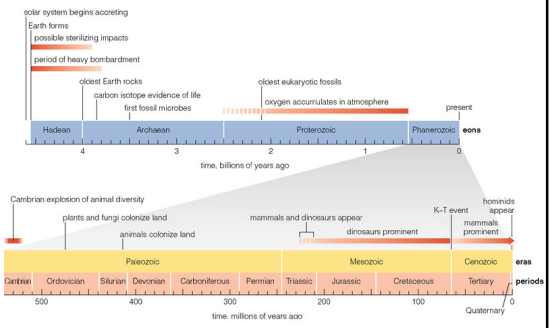
Fossils in Sedimentary Rock


- Rock layers of Grand Canyon record 2 billion years of Earth's history

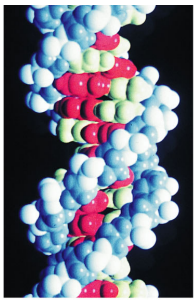
Earliest Fossils

- Oldest fossils show that bacteria-like organisms were present over 3.5 billion years ago
- Carbon isotope evidence pushes origin of life to more than 3.85 billion years ago

The Geological Time Scale



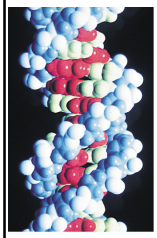
How did life arise on Earth?




Origin of Life on Earth

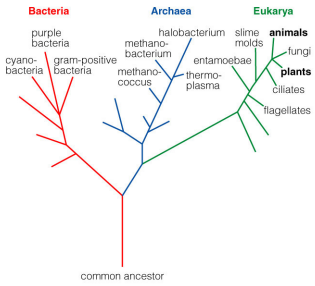
- Life evolves through time.
- All life on Earth shares a common ancestry.
- We may never know exactly how the first organism arose, but laboratory experiments suggest plausible scenarios.

The Theory of Evolution



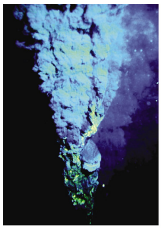

- The fossil record shows that evolution has occurred through time.
- Darwin's theory tells us HOW evolution occurs: through **natural selection**.
- Theory supported by discovery of DNA: evolution proceeds through **mutations**.

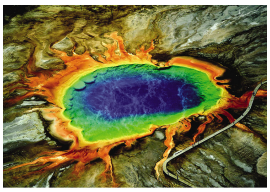
Tree of Life



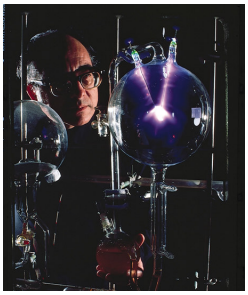
- Mapping genetic relationships has led biologists to discover this new "tree of life."
- Plants and animals are a small part of the tree.
- Suggests likely characteristics of common ancestor.

- These 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 .

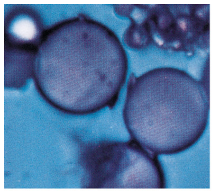


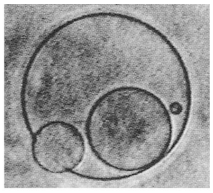


Laboratory Experiments



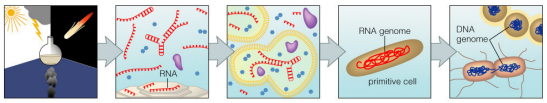
- Miller-Urey experiment (and more recent experiments) show that building blocks of life form easily and spontaneously under conditions of early Earth.





Microscopic, enclosed membranes or "pre-cells" have been created in the lab.

Chemicals to Life?



Could life have migrated to Earth?

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

Brief History of Life

- 4.4 billion years - early oceans form
- 3.5 billion years - cyanobacteria start releasing oxygen.
- 2.0 billion years - oxygen begins building up in atmosphere
- 540-500 million years - Cambrian Explosion
- 225-65 million years - dinosaurs and small mammals (dinosaurs ruled)
- Few million years - earliest hominids

Thought Question

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'll be unable to breathe the air.
C. You'll be consumed by toxic bacteria.
D. Nothing: you'll probably be just fine.

Thought Question

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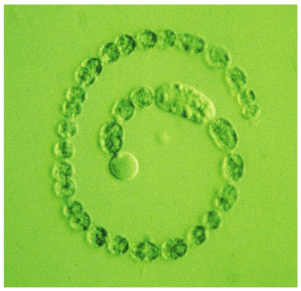
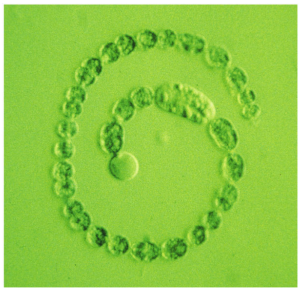
Origin of Oxygen



- Cyanobacteria paved the way for more complicated life forms by releasing oxygen into atmosphere via photosynthesis

What are the necessities of life?



Necessities for Life

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

Hardest to find on other planets

What have we learned?

- When did life arise on Earth?
  - Life arose at least 3.85 billion years ago, shortly after end of heavy bombardment
- How did life arise on Earth?
  - Life evolved from a common organism through natural selection, but we do not yet know the origin of the first organism
- What are the necessities of life?
  - Nutrients, energy, and liquid water

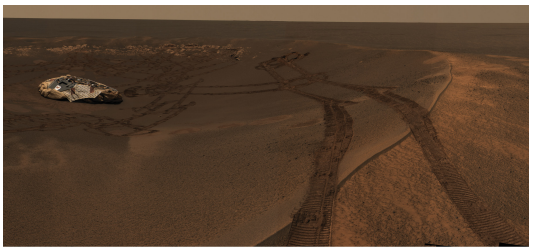
24.2 Life in the Solar System

Our goals for learning

- Could there be life on Mars?
- Could there be life on Europa or other jovian moons?

Could there be life on Mars?

Searches for Life on Mars



- Mars had liquid water in the distant past
- Still has subsurface ice; possibly subsurface water near sources of volcanic heat.

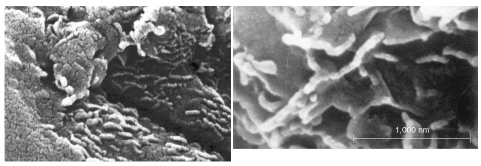
In 2004, NASA Spirit and Opportunity Rovers sent home new mineral evidence of past liquid water on Mars.

The Martian Meteorite debate

composition indicates origin on Mars.

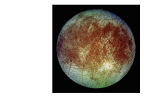
- 1984: meteorite ALH84001 found in Antarctica
- 13,000 years ago: fell to Earth in Antarctica
- 16 million years ago: blasted from surface of Mars
- 4.5 billion years ago: rock formed on Mars

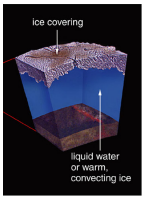
- Does the meteorite contain fossil evidence of life on Mars?



… most scientists not yet convinced

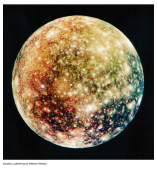
Could there be life on Europa or other jovian moons?





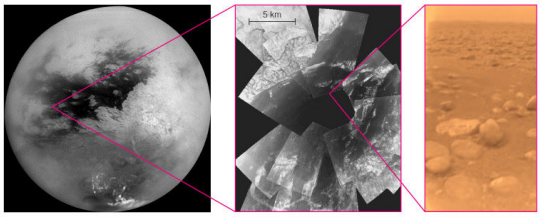
- Ganymede, Callisto also show some evidence for subsurface oceans.
- Relatively little energy available for life, but still…
- Intriguing prospect of THREE potential homes for life around Jupiter alone…

Ganymede



Callisto

Titan



- Surface too cold for liquid water (but deep underground?)
- Liquid ethane/methane on surface

What have we learned?

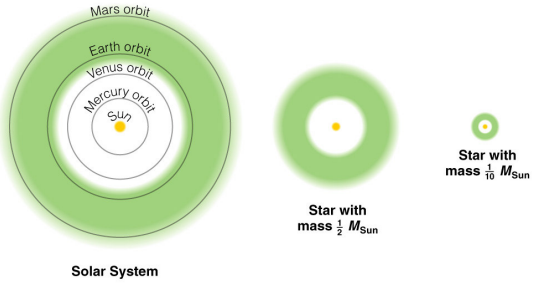
- Could there be life on Mars?
  - Evidence for liquid water in past suggests that life was once possible on Mars
- Could there be life on Europa or other jovian moons?
  - Jovian moons are cold but some show evidence for subsurface water and other liquids

24.3 Life Around Other Stars

Our goals for learning

- Are habitable planets likely?
- Are Earth-like planets rare or common?

Are habitable planets likely?



Habitable Planets

Definition:

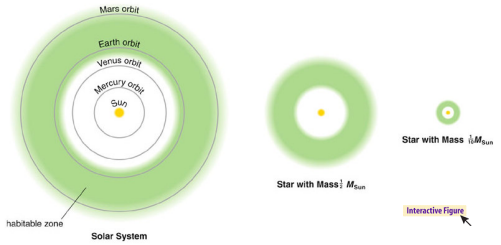
A **habitable** world contains the basic necessities for life as we know it, including liquid water.

- It does *not* necessarily have life.

Constraints on star systems:

1) Old enough to allow time for evolution (rules out high-mass stars - 1%)
2) Need to have stable orbits (*might* rule out binary/multiple star systems - 50%)
3) Size of "habitable zone": region in which a planet of the *right size* could have liquid water on its surface.

Even so… billions of stars in the Milky Way seem at least to offer the possibility of habitable worlds.

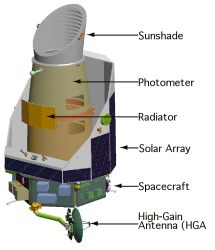


The more massive the star, the larger the habitable zone — higher probability of a planet in this zone.

Finding them will be hard

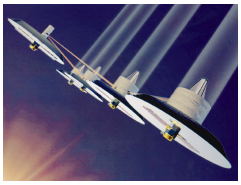
Recall our scale model solar system:

- Looking for an Earthlike planet around a nearby star is like standing on the East Coast of the United States and looking for a pinhead on the West Coast — with a VERY bright grapefruit nearby.
- But new technologies should soon show the way…



- Kepler (2007 launch) will monitor 100,000 stars for transit events for 4 years.

Later: SIM (2009?), TPF (2015?): interferometers to obtain spectra and crude images of Earth-size planets.

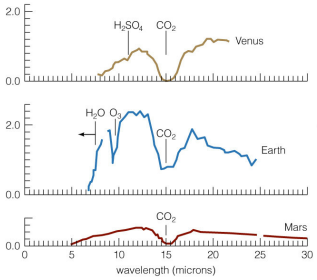


Spectral Signatures of Life

Venu

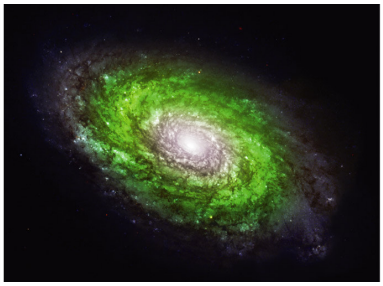
Earth

Mars

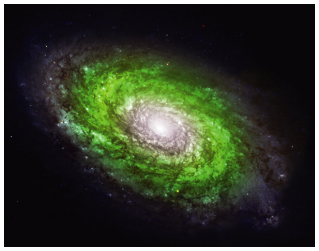


oxygen/ozone

Are Earth-like planets rare or common?

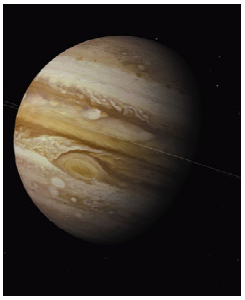


Elements and Habitability



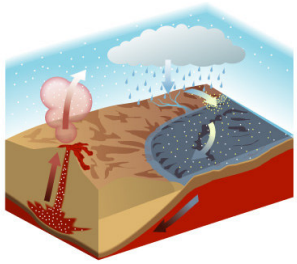
- Some scientists argue that proportions of heavy elements need to be just right for formation of habitable planets
- If so, then Earth-like planets are restricted to a galactic habitable zone

Impacts and Habitability



- Some scientists argue that Jupiter-like planets are necessary to reduce rate of impacts
- If so, then Earth-like planets are restricted to star systems with Jupiter-like planets

Climate and Habitability



- Some scientists argue that plate tectonics and/or a large Moon are necessary to keep the climate of an Earth-like planet stable enough for life

The Bottom Line

We don't yet know how important or negligible these concerns are.

What have we learned?

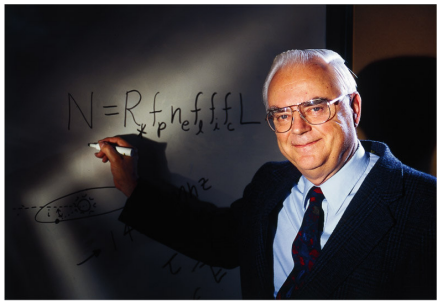
- Are habitable planets likely?
  - Billions stars have sizable habitable zones, but we don't yet know how many have terrestrial planets in those zones
- Are Earth-like planets rare or common?
  - We don't yet know because we are still trying to understand all the factors that make Earth suitable for life

24.4 The Search for Extraterrestrial Intelligence

Our goals for learning

- How many civilizations are out there?
- How does SETI work?

How many civilizations are out there?



The Drake Equation

Number of civilizations with whom we could potentially communicate

$$= N_{HP} \times f_{life} \times f_{civ} \times f_{now}$$

N_{HP} = total # of habitable planets in galaxy

f_{life} = fraction of habitable planets with life

f_{civ} = fraction of life-bearing planets w/ civilization at some time

f_{now} = fraction of civilizations around *now*.

We do not know the values for the Drake Equation

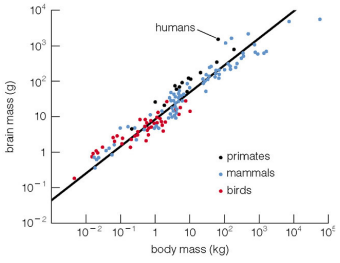
N_{HP} : probably billions.

f_{life} : ??? Hard to say (near 0 or near 1)

f_{civ} : ??? It took 4 billion years on Earth

f_{now} : ??? Can civilizations survive long-term?

Are we "off the chart" smart?

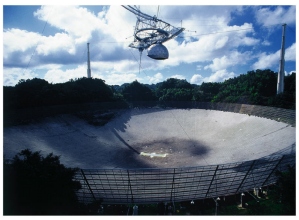


- Humans have comparatively large brains
- Does that mean our level of intelligence is improbably high?

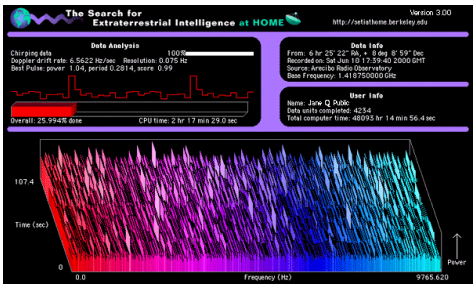
How does SETI work?

SETI experiments look for **deliberate** signals from E.T.

We've even sent a few signals ourselves…



Earth to globular cluster M13: Hoping we'll hear back in about 42,000 years!



Your computer can help! SETI @ Home: a screensaver with a purpose.

What have we learned?

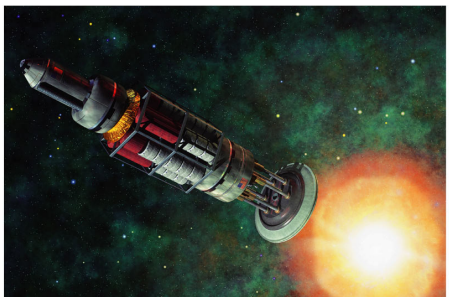
- How many civilizations are out there?
  - We don't know, but the Drake equation gives us a framework for thinking about the question
- How does SETI work?
  - Some telescopes are looking for deliberate communications from other worlds

24.5 Interstellar Travel and Its Implications to Civilization

Our goals for learning

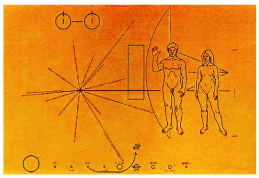
- How difficult is interstellar travel?
- Where are the aliens?

How difficult is interstellar travel?

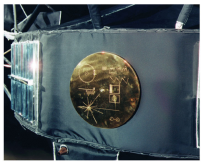


Current Spacecraft

- Current spacecraft travel at <1/10,000 c; 100,000 years to the nearest stars.

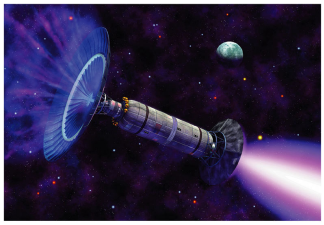


Pioneer plaque



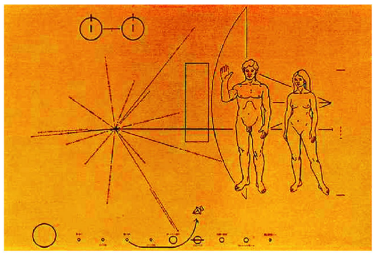
Voyager record

Difficulties of Interstellar Travel



- Far more efficient engines are needed
- Energy requirements are enormous
- Ordinary interstellar particles become like cosmic rays
- Social complications of time dilation

Where are the aliens?

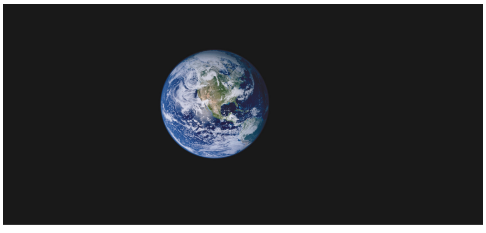


Fermi's Paradox

- Plausible arguments suggest that civilizations should be common, for example:
- Even if only 1 in 1 million stars gets a civilization at some time ⇒ 100,000 civilizations
- So why we haven't we detected them?

Possible solutions to the paradox

1) We are alone: life/civilizations much rarer than we might have guessed.
   - Our own planet/civilization looks all the more precious…



Possible solutions to the paradox

2) Civilizations are common but interstellar travel is not. Perhaps because:
   - Interstellar travel more difficult than we think.
   - Desire to explore is rare.
   - Civilizations destroy themselves before achieving interstellar travel

These are all possibilities, but not very appealing…

Possible solutions to the paradox

3) There IS a galactic civilization…
   … and some day we'll meet them…

What have we learned?

- How difficult is interstellar travel?
  - Interstellar travel remains well beyond our current capabilities and poses enormous diffculties
- Where are the aliens?
  - Plausible arguments suggest that if interstellar civilizations are common then at least one of them should have colonized the rest of the galaxy
  - Are we alone? Has there been no colonization? Are the colonists hiding?