

Today's Class: Search for Extraterrestrial Life

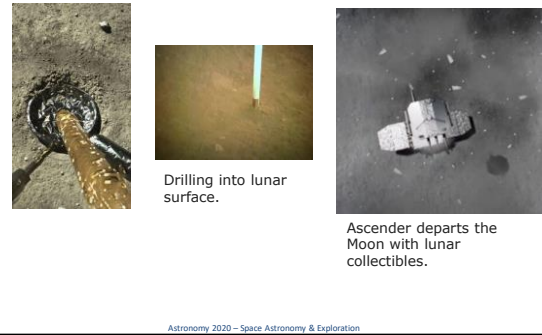


- Complete FCQ today!
- Final Paper due on Dec. 7.
- NASA Administrator visits class on Friday.

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Chinese Chang'e-5 Lands on Moon, Collects Samples, and Sends them home



Drilling into lunar surface.

Ascender departs the Moon with lunar collectibles.

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Landing on the Moon



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In the new spectrum of space law, will Biden favor the Moon Treaty?

Presented by Will Mihalich

- Moon treaty names natural resources on Moon "common heritage of mankind"
- Trump is a proponent for the treaty
- Biden favored "Law of the Sea Treaty" with similar "common heritage of mankind" concept
- Should Biden favor the Moon Treaty?



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Last Class

- Exoplanet detection
 - Doppler shift
 - Transits
- What properties can we measure?
 - Mass
 - Size
 - Density
 - Atmosphere composition

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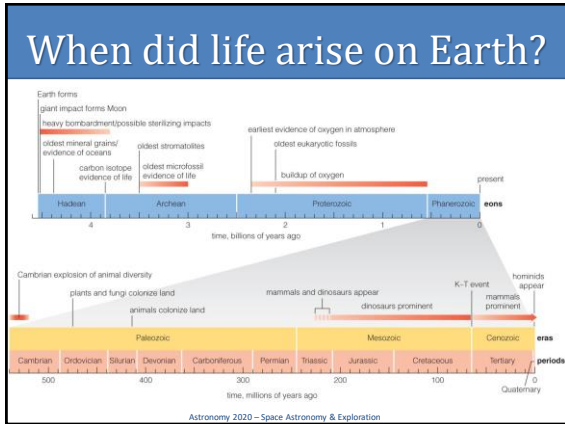
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Today's Class

- Life on Earth:
 - How did life arise on Earth?
 - What are the necessities of life?
 - What are the requirements for surface life?
- Life Elsewhere in the Solar System
 - Could there be life on Mars?
 - Could there be life on Europa or other jovian moons?
- Life on Extrasolar Planets
 - What kinds of extrasolar worlds might be habitable?
 - How could we detect life on extrasolar planets?

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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.

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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**.

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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

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Early Life on Earth

- Genetic studies suggest that the earliest life on Earth may have resembled the bacteria today found near deep ocean volcanic vents (*black smokers*).

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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.

Tardigrade, about 1 mm long, can survive in extreme conditions.

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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

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Class Exercise

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?

- You'll be eaten by dinosaurs.
- You'll suffocate because you'll be unable to breathe the air.
- You'll be consumed by toxic bacteria.
- Nothing. You'll probably be just fine.

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Class Exercise

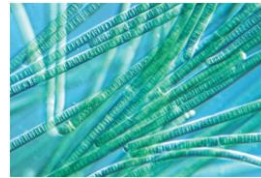
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Origin of Oxygen



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

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Necessities for Life

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

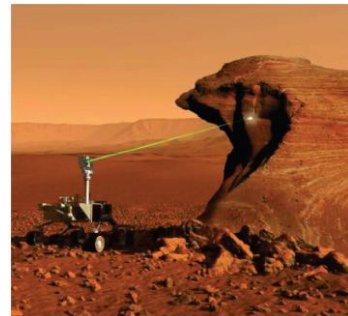


Hardest to find on other planets

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Could there be life on Mars?



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Searches for Life on Mars



- Mars had liquid water in the distant past.
- Still has subsurface ice and briny water.

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Could there be life on Europa or other jovian moons?



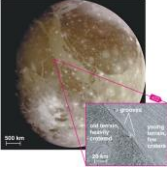
Europa may have a 100-km-thick ocean under an icy crust.
 Rising plumes of warm water rise upward: craters take within the ice, causing the crust above to crack. ...
 ... suggesting surface brines that look like a patchwork of colorings suspended in a place where liquid or slushy water flows.

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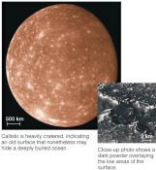
How about the other jovian moons?

- Ganymede, 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

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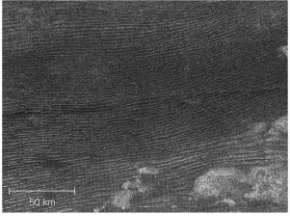


Callisto

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Titan



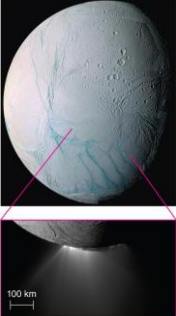
- The surface is too cold for liquid water (but there may be some deep underground).
- Has lakes of liquid ethane/methane on its surface.
- Has dunes, possibly made of hydrocarbon sediments.

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Enceladus

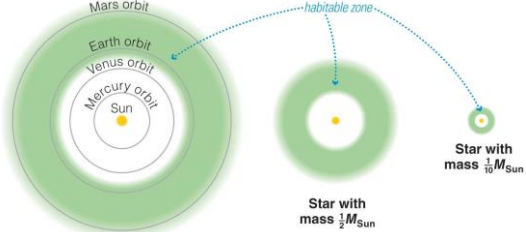
- Ice fountains suggest that Enceladus may have a subsurface ocean.



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What are the requirements for surface life?



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

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Ingredients for habitability?

- **Habitable zone**
 - The right distance from the star to maintain liquid water.
- **Volcanism**
 - For the creation of atmosphere and oceans.
- **Plate tectonics**
 - Carbon-dioxide cycle
- **Planetary magnetic field**
 - To protect the atmosphere from the solar wind.

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What kinds of extrasolar worlds might be habitable?



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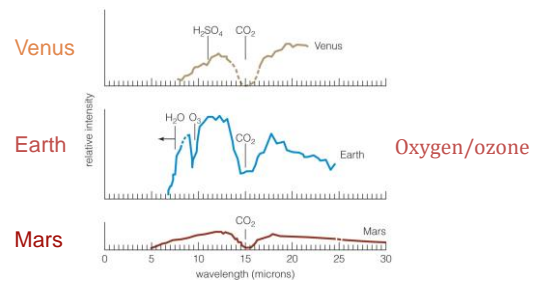
A wide variety of possibilities...

- Scientists are considering many possible locations for extrasolar life other than just the surfaces of Earth-like worlds.
 - Moons with habitable surfaces.
 - Super-Earths and water-worlds in extended habitable zones.
 - Sub-surfaces
 - Orphan planets

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Spectral Signatures of Life



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What did we learn today?

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