ExoBiology

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Lecture 10
Life (def): a “self-sustained chemical reaction capable of undergoing neo-Darwinian evolution”; i.e., one capable of replication with mutations which are able to be culled by natural selection.

In some definitions, anti-entropic, complex organization is also required.
Requirements for Evolution of Life

1. Complex organic molecules; e.g. amino acids and nucleic acids

2. Energy source. e.g. peptide bond formation is energetically uphill

3. Liquid environment in which to carry out the necessary chemistry.
Organic Molecules

1. Carbon, Hydrogen, Oxygen
   - CH₄ Methane
   - CH₃-CH₃ Ethane
   - CH₃-OH Methanol
   - CH₃CH₂-OH Ethanol

2. May also include N, S, P
   - Amino Acids
     - Glycine NH₃⁺-CH₂-COO⁻
     - Cysteine NH₃⁺-CH(CH₂SH)-COO⁻
The Voyager program is an American scientific program that launched two unmanned space missions, the probes Voyager 1 and Voyager 2. These were launched in 1977 to take advantage of a favorable alignment of the planets during the late 1970s.
The four moons were discovered sometime between 1609 and 1610 when Galileo made improvements to his telescope, which enabled him to observe celestial bodies more distinctly than had ever been possible before.

<table>
<thead>
<tr>
<th>Spacecraft</th>
<th>Closest approach</th>
<th>Distance</th>
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<tbody>
<tr>
<td>Pioneer 10</td>
<td>December 3, 1973</td>
<td>130,000 km</td>
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<tr>
<td>Pioneer 11</td>
<td>December 4, 1974</td>
<td>34,000 km</td>
</tr>
<tr>
<td>Voyager 1</td>
<td>March 5, 1979</td>
<td>349,000 km</td>
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<tr>
<td>Voyager 2</td>
<td>July 9, 1979</td>
<td>570,000 km</td>
</tr>
<tr>
<td>Ulysses</td>
<td>February 8, 1992²</td>
<td>408,894 km</td>
</tr>
<tr>
<td></td>
<td>February 4, 2004²</td>
<td>120,000,000 km</td>
</tr>
<tr>
<td>Cassini</td>
<td>December 30, 2000</td>
<td>10,000,000 km</td>
</tr>
<tr>
<td>New Horizons</td>
<td>February 28, 2007</td>
<td>2,304,535 km</td>
</tr>
</tbody>
</table>

A composite Cassini image of Jupiter. The dark spot is the shadow of Europa.

² [91]
The dark spot just left of center is the erupting volcano Prometheus. Whitish plains on either side of it are coated with volcanically emplaced sulfur dioxide frost, while yellower regions are encrusted with a higher proportion of sulfur.

**Discovery**

- **Discovered by**: Galileo Galilei
- **Discovery date**: January 8, 1610 [1]

Active lava flows in volcanic region Tvashtar Paterae (blank region represents saturated areas in the original data). Images taken by Galileo in
Europa

Europa’s trailing hemisphere in approximate natural color. The prominent crater in the lower right is 
Pwyll and the darker regions are areas where Europa’s primarily water ice surface has a higher mineral content. Imaged on September 7, 1999 by Galileo spacecraft.

**Discovery**

| Discovered by | Galileo Galilei
|               | Simon Marius
| Discovery date | January 8, 1610[^1]
Images of several moons of Saturn. From left to right: Mimas, Enceladus, Tethys, Dione, Rhea; Titan in the background; Iapetus (top) and irregularly shaped Hyperion (bottom). Some small moons are also shown. All to scale.
Cassini Mission: Cassini–Huygens is a robotic spacecraft sent to the Saturn system. It has studied the planet and its many natural satellites since arriving there in 2004.

Cassini has seven primary objectives:[citation needed]

• Determine the three-dimensional structure and dynamic behavior of the rings of Saturn
• Determine the composition of the satellite surfaces and the geological history of each object
• Determine the nature and origin of the dark material on Iapetus's leading hemisphere
• Measure the three-dimensional structure and dynamic behavior of the magnetosphere
• Study the dynamic behavior of Saturn's atmosphere at cloud level
• Study the time variability of Titan's clouds and hazes
• Characterize Titan's surface on a regional scale
Video –
Chapter 6
Volcanism on a Moon
Video – Chapter 7
Volcanism on a Moon

Io – moon of Jupiter

Major volcanic activity.

Gravitational Distortions can create molton core or volcanisms. Source of energy
Galileo spacecraft image of Io. The dark spot just left of center is the erupting volcano Prometheus. Whitish plains on either side of it are coated with volcanically emplaced sulfur dioxide frost, while yellower regions are encrusted with a higher proportion of sulfur.

**Discovery**

- Discovered by: Galileo Galilei
- Discovery date: January 8, 1610 [1]

Galileo image showing a dark spot (interrupting the red ring of short-chain sulfur allotropes deposited by Pele) produced by a major eruption at Pillan Patera in 1997.

Active lava flows in volcanic region Tvashtar Paterae (blank region represents saturated areas in the original data). Images taken by Galileo in 1997.
Video –
Chapter 8 - Water World

Europa – moon of Jupiter

Ocean of salty water.
2x more liquid water than earth
Can anything live in this ocean?

Life in underwater Volcanic Vents
Europa

Europa's trailing hemisphere in approximate natural color. The prominent crater in the lower right is Pwyll and the darker regions are areas where Europa's primarily water ice surface has a higher mineral content. Imaged on September 7, 1999 by Galileo spacecraft.

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Video –
Chapter 9 Space Snow
Video –
Chapter 9 Space Snow

Rings of Saturn – lots of Water

Enceladus – moon of Saturn

“Tiger Stripes”. Jets of Ice

Excess heat due to gravitational distortions

Organic molecules on Enceladus
Enceladus is the sixth-largest of the moons of Saturn. It was discovered in 1789 by William Herschel.

Enceladus seems to have liquid water under its icy surface.

Cryovolcanoes at the south pole shoot large jets of water ice particles into space. Some of this water falls back onto the moon as "snow", some of it adds to Saturn's rings, and some of it reaches Saturn.

Because of this apparent water at or near the surface, Enceladus may be one of the best places for humans to look for extraterrestrial life.
Ammonia discovery. In July 2009 it was announced that ammonia had been discovered during flybys in July and October 2008.
Video –
Chapter 10 Land of Lakes
Expanding the Limits of where life can live

Titan – moon of Saturn

Planets form around Most Stars

Exoplanets

Goldilocks Zone
Video –
Chapter 11 Search for Life
Video –
Chapter 11 Search for Life

Kepler Space Telescope
Rocky planets. Grains of sand.

James Webb Space Telescope
Search for O$_2$

Billions of Stars, many have planets
Billions of Galaxies
“life should be an easy start on another word”