The Search for Intelligent Life in the Universe
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Mars is Peopled

and they want

Kirk's American Soap
Thus began the fascination with the idea that Mars contained life.
Mars

- Mass (1/10), radius (1/2) and atmosphere (.7–.9%) smaller than Earth’s.
- Rotation rate is nearly that of Earth’s.
- Reddish color due to iron oxide.
- Noachian epoch: before 3.5 Gyr; oldest surface features (Tharsis bulge) and late, extensive water flooding
- Hesperian epoch: between 1.8 and 3.5 Gyr; formation of extensive lava plains
- Amazonian epoch; after 1.8 Gyr; formation of Olympus Mons and other lava flows
Mars Geology

- Has craters and high volcanos (higher than on Earth due to lower gravity).
- No active volcanos or geologic activity for last 1–2 Byrs, due to low mass and therefore less radioactivity.
- Valles Marineres is a large canyon (7 km deep, 100 km wide, stretches 1/4 across planet), formed by cracking of crust as Mars cooled.
Mars Topography
Mars Atmosphere

- Polar caps (mostly H$_2$O with surface CO$_2$) which grow and shrink with seasons.
- Atmosphere only 0.7% of Earth’s, below the *triple point* of water, so no liquid water possible at any temperature.
- 95.7% CO$_2$, 2.7% N$_2$, 1.6% Ar, 0.2% O$_2$, 0.07% CO, 0.01% H$_2$O, 0.01% NO$_2$
Phases of Matter

- solid
- liquid
- gas

Pressure

Temperature

- melting
- freezing
- sublimation
- deposition
- vaporisation
- condensation
- critical point
- triple point
Phases and Heating/Cooling

- Heat of fusion
- Heat of vaporization

T (°C) vs. ∆Q/m (cal/g)

Ice
Ice + Water
Water
Water + Steam
Steam
Phase Diagrams of Water and Carbon Dioxide

![Phase Diagrams of Water and Carbon Dioxide](image)

- **Earth**

- **Mars**

- **0.006**

- **(374°C, 218 atm)**

- **(0.01°C, 0.00603 atm)**

- **Solid**

- **Liquid**

- **Gas**

- **H₂O**

- **Temperature**

- **90°C**

- **100°C**

- **Critical point**

- **(31°C, 73 atm)**

- **Triple point**

- **(-57°C, 5.1 atm)**

- **-125°C**

- **CO₂**

- **Temperature**

- **AST 248, Lecture 19**
Phases on Other Objects

Phase diagrams of H₂O, CH₄, and N₂

- Water vapor (steam)
- Liquid water
- Solid water (ice)
- Methane vapor
- Liquid methane
- Liquid nitrogen
- Solid methane
- Solid nitrogen

Critical point

Mars

Titan

Pluto/Triton

Temperature in Kelvin vs. Pressure in bars
Mars Dust Storms

- High velocity winds and giant dust storms on occasion. Winds caused by large temperature differences (day/night and pole/equator) and CO$_2$ condensation/evaporation. *Dust loading* catastrophically develops into storms like a super Dust Bowl (no vegetation to block it).
Mars and Water

- Evidence for water in past: *runoff* and *outflow* channels. Near-saturation of atmosphere with water indicates presence of subsurface ice (permafrost).
Mars and Water

Right: Spirit and Opportunity Mars Rovers confirmed past existence of liquid water by discovering 'blueberries' (nodules from leaching of minerals to rock surfaces) that formed in rocks which had been eroded and layered by water.

Below: New deposits in gullies suggest water carried sediment through them sometime between 1999 and 2005.
Sub-Glacial Water Lake

High salinity acts as an antifreeze.
Lake could absorb oxygen, making it more hospitable for life.

Found by Mars Express
Some Previous Evidence of Water is Suspect

Analysis shows that the flows all end at approximately the same slope, which is similar to the angle of repose for sand.
“Tough” organic molecules discovered in martian sedimentary rocks. Concentrations of organic carbon are 10 parts per million, the same as exists in martian meteorites, and a thousand times greater than previously detected on martian surface. Seasonal variations in methane discovered, peaking in summer; likely due to water-rock chemistry and not life.
Evolution of Mars

- Original atmosphere of Mars was 600 times as dense, similar to present thickness of Earth’s atmosphere, and mostly CO\(_2\). Where did this gas go?
- Water on Mars’ surface dissolved some CO\(_2\), some froze into polar caps, some lost to catastrophic impacts.
- Lack of ozone layer led to UV dissociation of N\(_2\) and H\(_2\)O and their loss from atmosphere.
- Cooling and solidification of iron core led to loss of magnetic field and solar-wind stripping of atmosphere.
- Net result: *Runaway Refrigerator effect.*
- Mars is not necessarily too far from Sun to be Earth-like, but it is too small (not enough gravity, too rapid cooling) to retain atmosphere and liquid water.
Viking Experiments

- Gas exchange (GEX) — Soil sample placed in contact with a nutrient ("chicken soup"), Gas chromatograph analyzes the atmosphere for changes.

- Labeled release (LR) — Soil sample placed in contact with radioactive C\textsuperscript{14} nutrient. Radiation detectors monitors the atmosphere for changes.

- Pyrolitic release (PR) — Soil sample incubated with radioactive CO and CO\textsubscript{2}, then heated to 1023 K. Organic gases trapped, checked for radioactivity.

**PR experiment designed without H\textsubscript{2}O/nutrient:**

- Liquid water cannot exist on Mars today, so it could trigger a variety of reactions that mask biological activity.

- The "chicken soup" might end up being poisonous to organisms.
Results of Viking Experiments

- **GEX** — Large amounts of O released, later attributed to inorganic reactions of soil and H$_2$O.

- **LR** — Wetting produced rise in radioactivity, greater than observed on Earth. Second wetting produced no further response, suggesting that organic molecules in nutrient reacted with O-rich soil and produced CO$_2$.

- **PR** — Radioactive C became part of the compounds in the soil sample. However, when soil sample pre-heated at high temperatures, same effect observed, although microorganisms should already have been killed.
Other Missions up to the Present

- Phobos 1 and 2 – 7 and 12 July 1988; orbited but failed to land
- Mars Observer – 25 September 1992; failed orbiter
- Mars Global Surveyor – 7 November 1996; orbiter
- Mars 96 – 16 November 1996; failed orbiter/lander
- Nozomi (Planet-B) – 3 July 1998; orbiter
- Mars Climate Orbiter – 11 December 1998; failed orbiter
- Mars Polar Lander 00 – 3 January 1999; failed lander
- Deep Space 2 – 3 January 1999; failed penetrator
- Mars Odyssey – 7 April 2001; orbiter (active)
- Mars Express – 2 June 2003; orbiter (active), lander Beagle 2 failed
- Spirit – 10 June 2003; rover
- Opportunity – 8 July 2003; rover (active)
- Mars Reconnaissance Orbiter – 12 August 2005; orbiter (active)
- Phoenix – 4 August 2007; Mars Scout lander
- Phobos-Grunt – 8 November 2011; failed lander
- Yinghuo-1 – 8 November 2011; failed orbiter
- Curiosity – 26 November 2011; rover (active)
- Mangalyaan – 5 November 2013; ISRO (India) orbiter (active)
- Maven – 18 November 2013; Mars Scout orbiter (active)
- ExoMars 2016 – 14 March 2016; ESA orbiter/lander (active)
Disadvantages of manned missions:

- Tremendously increased costs of transporting astronauts’ weight including food and life-support, including radiation shielding and water extraction and recycling
- Risks astronaut’s lives; history shows that a large fraction of missions to Mars fail.
- Danger of contamination both ways
- History shows they will be based on political, not scientific, considerations
Some Recent Mars Missions

- **Mars Global Surveyor**
  - Thermal emission spectrometers
- **Mars Pathfinder, Sojourner rover**
  - Mars was in its past warm and wet, with water existing in its liquid state and a thicker atmosphere.
- **Mars Odyssey, Mars Surveyor Orbiter**
  - Mars weather and climate
  - radiation hazards (martian radiation environment experiment)
  - gamma-ray spectrometer subsurface chemistry and water
  - thermal emission imaging system for detecting past water (hematite)
- **Spirit and Opportunity, Mars rovers**
  - Exploration for evidence of water
- **Rosetta**
  - Mars and asteroid flyby
- **Mars Express**
<table>
<thead>
<tr>
<th>Country</th>
<th>Launched</th>
<th>Outcome</th>
</tr>
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<tbody>
<tr>
<td>Pathfinder</td>
<td>U.S.</td>
<td>1996 Landed successfully July 4, 1996. Rover Sojourner drove about 1,640 feet (500 m) from the lander, took photographs and analysis data.</td>
</tr>
<tr>
<td>Mars Climate Orbiter*</td>
<td>U.S.</td>
<td>1998 Due to a mix-up of measurement units attributed to human error, orbiter crashed on Mars’ surface.</td>
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<tr>
<td>Mars Polar Lander</td>
<td>U.S.</td>
<td>1999 Radio contact was lost before landing; presumed crashed due to software error which went undetected during pre-launch tests.</td>
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<tr>
<td>Curiosity</td>
<td>U.S.</td>
<td>2011 Rover scheduled to land on Mars Aug. 6, 2012. Instrumetal analysis will investigate the possibility of life and will study soil samples.</td>
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Planned Missions

- InSight - 5 May 2018; lander to arrive January 2019
- ExoMars 2020 (2018 launch) ESA rover and Russian surface platform to arrive 2019
- Mars 2020 (July/August 2020) Curiosity-style rover to arrive March 2021
Did Life Once Exist on Mars?

SNC meteorites: unusually young ages, formed on a planet, blasted into space and exposed to cosmic rays after formation. Hard to blast matter off Mercury, Venus or Earth into Earth-crossing orbit, implying Mars or Moon origin. Trapped gases nearly identical to atmospheric composition of Mars.

Three groups of SNC meteorites:

1. formation age 4.5 Gyr, impact (transit) age 15 Myr
2. formation age 1.3 Gyr, impact (transit) age 12 Myr
3. formation age 170 Myr, impact (transit) age 3 Myr
Did Life Once Exist on Mars?

Recently, a NASA team announced possibly detecting evidence of former life in ALH 84001, which landed in Antarctica 13,000 yrs ago. Evidence associated with carbonate globules, spherical crystals formed as carbonate precipitates from liquid water permeating the rock 3.6 Gyr ago:

▶ Carbonate grains with layered structure, indicating biological activity.
▶ Carbonate grains with shapes resembling Earth bacteria, 1/100 thickness of human hair, the same as smallest known Earth bacteria.
▶ Carbonate grains contain biominerals, possibly formed as a result of biological activity (magnetite, pyrrhotite, and greigite).
▶ Carbonate grains contain complex polyaromatic hydrocarbons (PAH) whose concentration increases with depth, implying terrestrial contamination unlikely. These PAHs differ from those observed in other meteorites or cosmic dust.
▶ Coincidence of 3.6 Gyr globule age with liquid water on Mars.

BUT:

▶ There are nonbiological ways to produce layered carbonates.
▶ Extremely small size of nanobacteria-like shapes disturbs biochemists, as there is no evidence of cell walls, reproduction, growth, or cell colonies.
▶ $^{32}\text{S}/^{34}\text{S}$ higher than in Earth life.
▶ Discovery of terrestrial microorganisms in meteorite shows that some contamination has occurred, and could explain the PAH evidence.
▶ Previous claims of “life” in meteorites have always proved false.