Astronomy 330

This class (Lecture 13):

Life in the Solar System

Next Class:

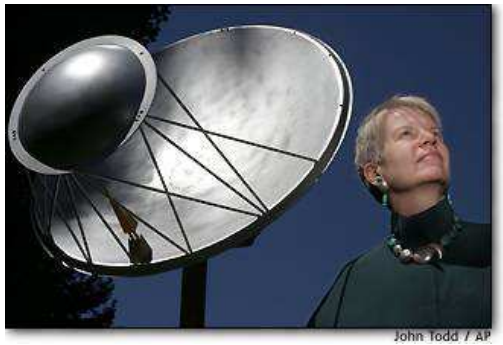
Life in the Solar System

HW 5 is due Thursday
Midterm is next week

Music: *Venus as a Boy* – Björk

Jill Tarter

- Director of SETI
- Giving a talk on the Allen Telescope Array for SETI on Thursday at 1600 (4pm!) in 141 Loomis.



Midterm

- 80 minute exam in this classroom.
- It will cover material up to, but not including, "Life in the Solar System"
- Will consist of 16 multiple choice/ true-false questions (worth 40 points) and 2 essay questions (25 and 40 points each) .
- A total of 105 points, so 5 extra credit points.
- You can bring a normal-sized sheet of paper with notes on both sides.

HW #3

- **Cheryl Cwik**: http://www.aliensandchildren.org
- **Dave Luedtke:** http://ezinearticles.com/?Plasma-Life-Forms---Dark-Panspermia&id=900017
- **Carol Regalbuto**: http://aliens.monstrous.com

Outline

- Simple alternative to life
- Life in our Solar System?
- Estimate of f_l

Life

- Life is based on cells
  - Protective enclosures formed from lipids
- Cells contain nucleic acids and protein enzymes
  - Instructions and catalysts that allow replication of nucleic acids
- Methods for acquiring energy
  - **Most** organism now on Earth get energy from the Sun– either directly or indirectly. But that requires pigments (e.g. chlorophyll).
  - Not sure if pigments are a primary need or if chemical sources of energy were used for early life.

http://www.internetcash.com/en/images/baby-crying.jpg

Protolife

If we assume that early life must have been protolife, then

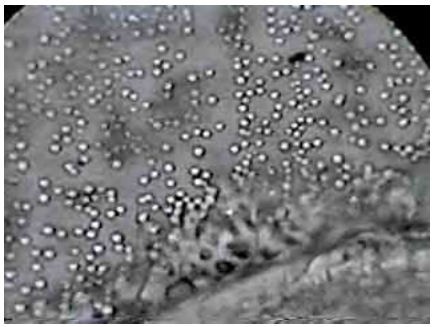
- Two protolife concepts based on nucleic acids or proteins.

1. Protein life
2. RNA life

http://www.perantivirus.com/sovirus/graficos/bilgates.jpg

1. Protein Protprotolife

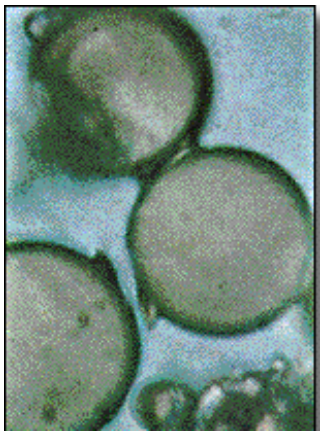
- Sydney Fox heated amino acids, droplets of protein formed when added to water– "proteinoids"
- Could have formed on the early Earth with tides.



http://leiwenwu.tripod.com/primordials.htm

1. Protein Protolife

- Sometimes they will grow and break into daughter spheres
- It is like cell reproduction, BUT there is no replication of nucleic acids, so not true reproduction.
- Nonetheless, they might be suitable for protocells.



http://www.biology.iupui.edu/biocourses/N100H/ch19life.html

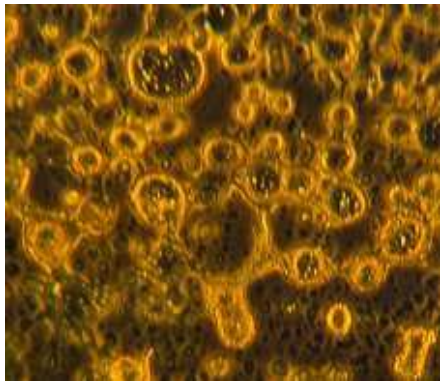
1. Protocells

- If so, how do nucleic acids come into play?
- Perhaps one proteinoid developed the capability to make its own protein from amino acids, then passed that on to its "offspring".
- Then, nucleic acids might have been used to store the amino acid information.

http://vcl.ctrl-c.liu.se/vcl/Artists/Juan-Crespo/Sydney-Fox-Lz.jpg

1. Protocells

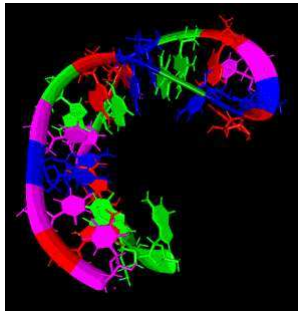
- And only later took over– revolt of the bookkeepers!
- Most biologist do not like the idea, as life without nucleic acid is hard to accept.



http://www.firstscience.com/home/articles/origins/genesis-by-comets-page-3-1_1383.html

2. The RNA World: Protolife

- The other camp believes that the transition to life was dominated by nucleic acids; the opposite problems of the Sydney Fox scenario.
- These genes are naked!
- A ecosystem of self-replicating RNA is nice, but without capability for protein synthesis, they could do little else.
- However, it's the most widely accepted concept due to numerous experiments.



http://www.bizspacebiotechnology.com/rna1.htm

2. RNA World

- The idea is that RNA is mutating away– eventually one RNA develops an enzyme function.
- This evolves to fill many of the niches that today's enzymes perform.
- At some point, the RNA encode and produce proteins through amino acid encoding, using one of the RNA enzyme functions.
- This would make better enzymes, which would replace the RNA versions.
- Is this possible?

2. RNA World: Experiments

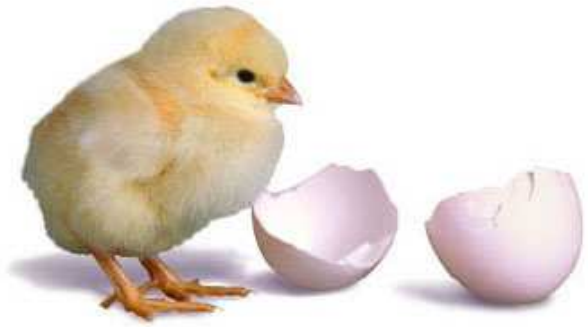
- Virus RNA is added to a test tube with replicase (an enzyme that catalyzes the synthesis of a complementary RNA molecule from an RNA template) and some activated nucleosides.
- The RNA was replicated without cell mechanisms.
- In one experiment, no RNA was added, and still RNA was produced.
- In fact, a number of variants were produced.
- The variant that replicated the fastest might win out.

Genetic Code and Origin of Translation

- One of the essential aspects of life is the synergistic interaction between proteins and nucleic acids– still the Chicken and egg problem.
- If protein-like polymers of amino acids formed, they would have to polymerize (create) the nucleotides.
  - The resulting nucleic acid would have to direct the synthesis of more protein, leading to more of the nucleic acid. Etc.
- Or in some RNA world ribozymes (RNA enzymes) began to construct the proteins– the favored view.

Neither Chicken nor Egg?

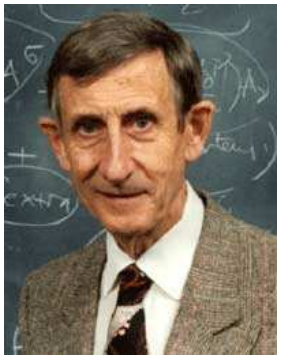
- While RNA world is favored, the difficulty is still in producing the nucleic acids on the early Earth.
- Freeman Dyson had argued that nucleic acid can not have been the first information carrying molecule.



http://www.antivegan.de/kochkurs/chicken-wings/chicken_egg2.jpg

Neither Chicken nor Egg?

- Transition between living and non-living requires a balance between order-preserving replication and error in replication.
- If too precise, nothing evolves.
- If too many errors, nothing consistent forms.
- He argues that RNA is not the easiest to start with, perhaps there were other polymers that preceded nucleic acids.



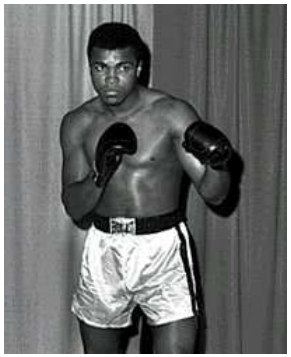
http://www.dartmouth.edu/~lhc/archive/sponsored/dyson.html

Alternatives: Clay

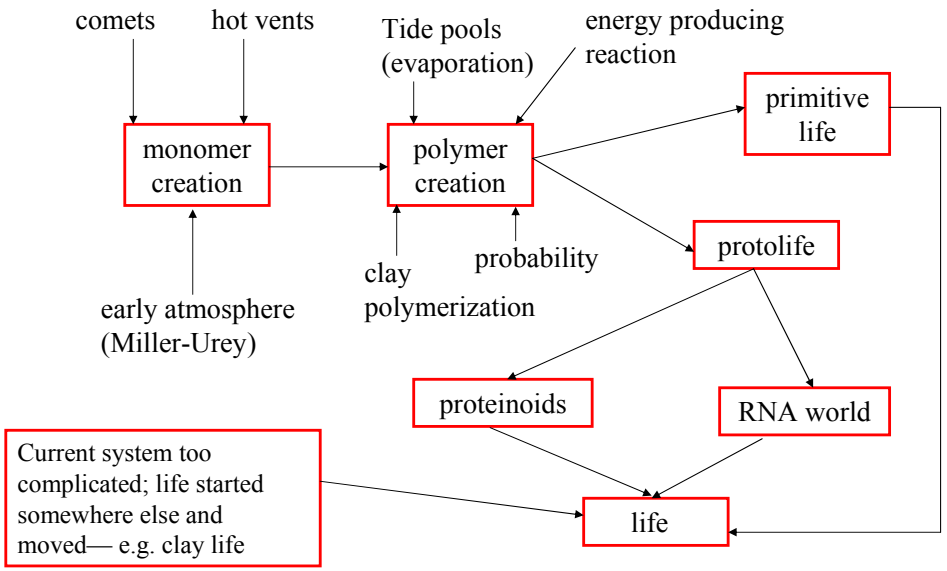
- Although the RNA world idea is widely accepted, there are issues concerning the prebiotic chemistry.
- Clay based genetic systems.
  - Layers of impurities in clay can produce patterns.
  - The layers can separate, settle elsewhere, and grow.
  - The patterns are not perfectly copied.

Alternatives: Clay

- Would not have been a big deal, BUT clays can capture and help polymerize amino acids.
- Maybe there was clay based life?
- Eventually the proteins make nucleic acids, which then provides a parallel genetic system that disregards the clay.
- Bottom line is that the step from molecules to life is so great that we are far from understanding it.



Pathways to Life on Earth



Exotic Life

- We have spent a long time with Earth Chauvinism, but ET life would be very different?
  Probably very alien!
- If other options are possible, then that gives a more optimistic value of f_l.
- As we just discussed, there are options for life based on other molecules than amino acids, some have been shown to sort of work in the lab.

http://www.itg.uiuc.edu/people/mcdowell/puppet-gallery/

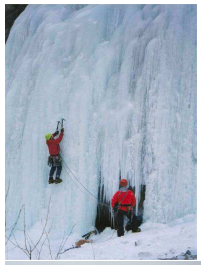
Silicon Based Life?

- Silicon makes 4 bonds like Carbon
- It is 135 times more abundant than carbon on Earth.
- But there are 4 arguments against it:
  - C-C bonds are twice as strong as Si-Si
  - Si-O or Si-H is stronger than Si-Si, so harder to make long stands
  - Si does not usually make multiple Si bonds
  - C with O makes CO_2, but Si with O makes silicates (SiO_2), which are large solid crystals.
- Still it is a possibility that can not be ruled out.

http://www.decipher.com/startrek/cardlists/mirrormirror/images/horta.gif
http://soundwavs.trekkieguy.com/25.html

Other Solvents

Molecule	*Freezes (K)*	*Boils (K)*
Water (H_2O)	273	373
Ammonia (NH_3)	195	240
Methyl alcohol (CH_3OH)	179	338
Methane (CH_4)	91	109
Ethane (C_2H_6)	90	184



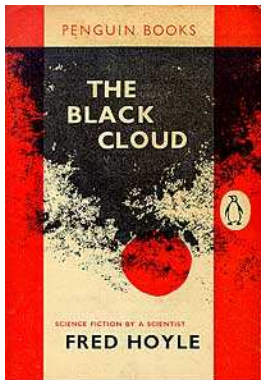
Water is about twice as good as ammonia or methyl alcohol. Water also has a high energy of vaporization, so it is very good at evaporative cooling (sweat).

http://www.talisman-activities.co.uk/winter/images/ice%20climbing.jpg
http://web.media.mit.edu/~fletcher/tags/boiling.jpg

Non-Chemical Life

Life is based on chemical energy. Thinking is an electrochemical activity. What about a life form that uses electromagnetic energy instead, perhaps without a body.

The Black Cloud (1957) by Fred Hoyle



The story describes a small interstellar molecule cloud that is alive. The organism is half a billion years old, as big as the orbit of Venus, and as massive as Jupiter. The brain is a complex network of molecules. Once it discovers the Earth it communicates with us:

The Black Cloud Speaks

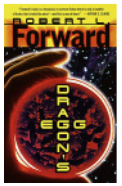
Paraphrased "badly"

- It is most unusual to find animals with technical skills inhabiting planets
- Living on a planet, greatly limits your size, thus the scope of your neurological activity.
- Living on a planet, forces you to possess muscular structures to promote movements.
- Your very largest animals have been mostly bone and muscle with very little brain.
- One only expects intelligent life to exist in a diffuse gaseous medium. At the moment, I myself am building basic chemicals at about 10,000,000,000 times the rate as your whole planet.

Cloud Problems

- How would such a cloud evolve?
- The most dense clouds are 10^{13} times less dense than our atmosphere, which makes molecule interactions very rare.
- In space, interstellar clouds are torn apart in about 10^7 years. It took 10^9 years for intelligent life to form on Earth.
- Still it is a cute idea.

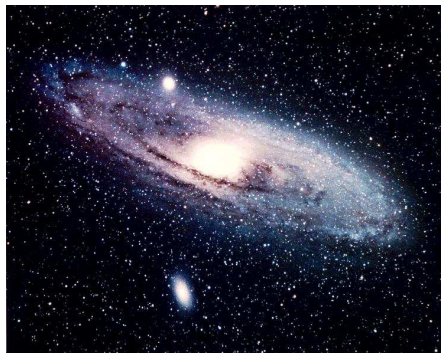
Other Voices, Other Energies



- Life based on nuclear energy (put forward by Drake)
  - Life on the surface of a neutron star?
  - Gravity and temperature too high for normal life.
  - Life made of closely packed nuclear matter instead of molecules
  - They interact quickly 10^{-21} seconds, much faster than chemical reactions.
- It has been fictionalized by Robert Forward in *Dragon's Egg*
  - Talking to these beings would be difficult.
  - Their Biology uses the strong nuclear force.
  - A time difference of a million to one.
  - In the time it takes to say "Hello" - would be the equivalent of a week to a star creature. It would hear "He . . . " on Sunday and ". . . lo" on the following Saturday.

Or Too Big

- Life based on gravitational energy?
- In this creature, the gravity force would dominate– very large!
- The monomer of life would have to be a star.
- Perhaps individual stars play the role of individual atoms or molecules in Earth life.



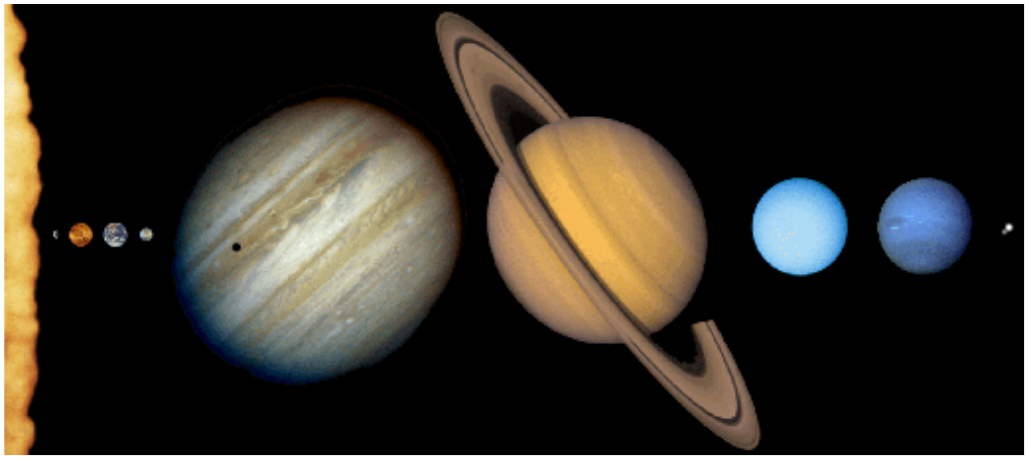
Or Too Big

- Could galaxies be alive?
- Stars interact with one another on a time scale of many millions of years, so if life is to originate from such interactions it would take longer than the age of the Universe.
- If life is occurring, it is only at the stage where life was when the Earth was a few years old.

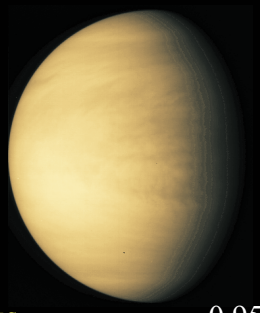
http://www.astro.cz/cz/wallpapers/index.php?id=15

Life in the Solar System?

- We want to examine in more detail the backyard of humans.
- What we find may change our estimates of f_l.



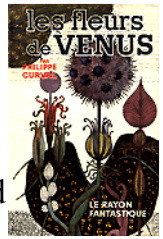
Earth – Venus comparison



Venus is the hottest planet, the closest in size to Earth, the closest in distance to Earth, and the planet with the longest day.

Radius	0.95 Earth
Surface gravity	0.91 Earth
Mass	0.81 Earth
Distance from Sun	0.72 AU
Average Temp	475 C
Year	224.7 Earth days
Length of Day	116.8 Earth days
Atmosphere	96% CO_2

What We Used to Think



Venus must be hotter, as it is closer the Sun, but the cloud cover must reflect back a large amount of the heat.

In 1918, a Swedish chemist and Nobel laureate concluded:

- Everything on Venus is dripping wet.
- Most of the surface is no doubt covered with swamps.
- The constantly uniform climatic conditions result in an entire absence of adaptation to changing exterior conditions.
- Only low forms of life are therefore represented, mostly no doubt, belonging to the vegetable kingdom; and the organisms are nearly of the same kind all over the planet.

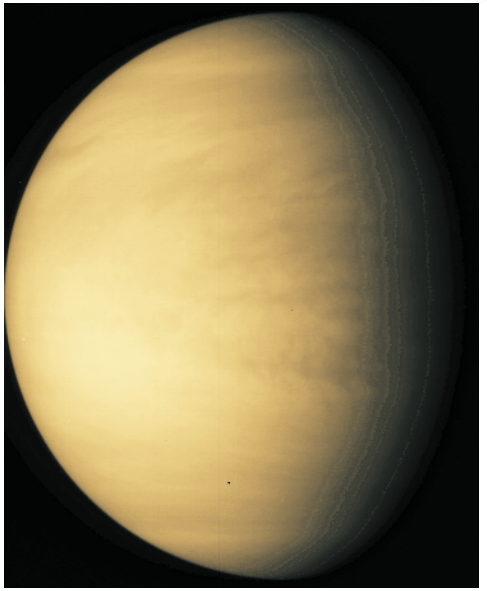
http://www.daviddarling.info/encyclopedia/V/Venuslife.html

Turns Out that Venus is Hell

- The surface is hot enough to melt lead
- There is a runaway greenhouse effect
- There is almost no water
- There is sulfuric acid rain
- Not a place to visit for Spring Break.

Our "Twin"

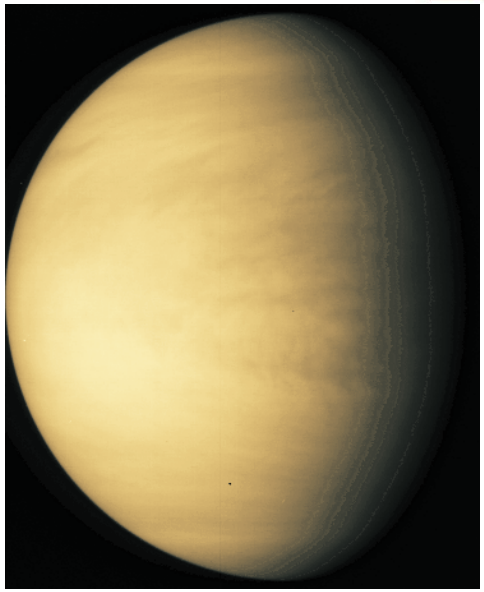
- Always covered in thick clouds of CO_2, which make it the hottest planet in the Solar System.
- Pressure on surface is 90 times that on Earth– like 1 km under the sea



http://antwrp.gsfc.nasa.gov/apod/ap960923.html

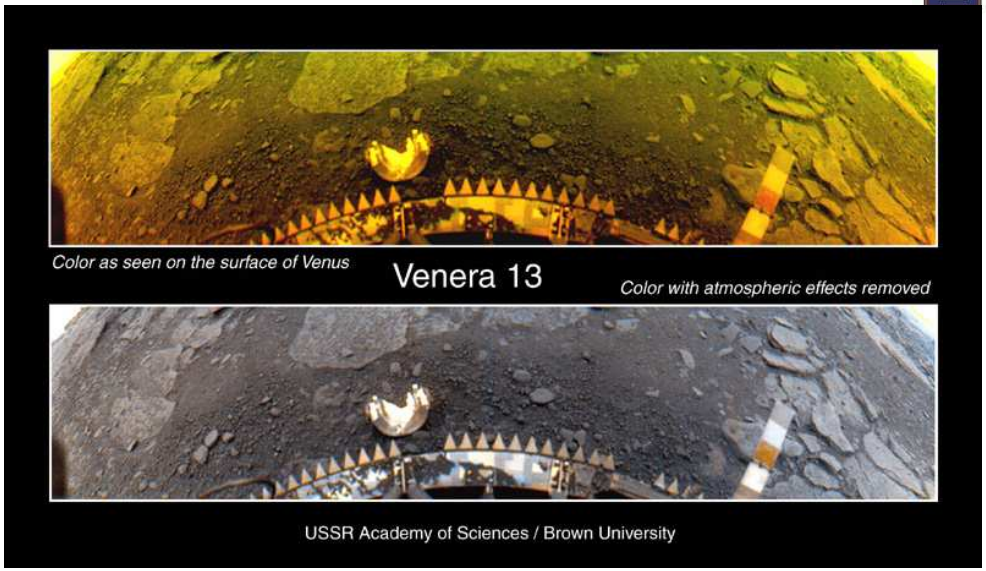
Our "Twin"

- Often called the morning star or the evening star. 3rd brightest object in the sky.
- Often mistaken for a UFO.
- Retrograde rotation – Sun rises in west
- No moons, no magnetic field



http://antwrp.gsfc.nasa.gov/apod/ap960923.html

Soviet Satellites on Venus

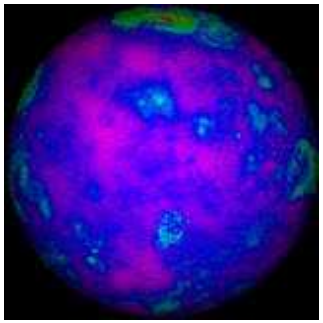


Mostly Basalts-like rocks, indicative of volcanoes

The Venusian Surface Revealed

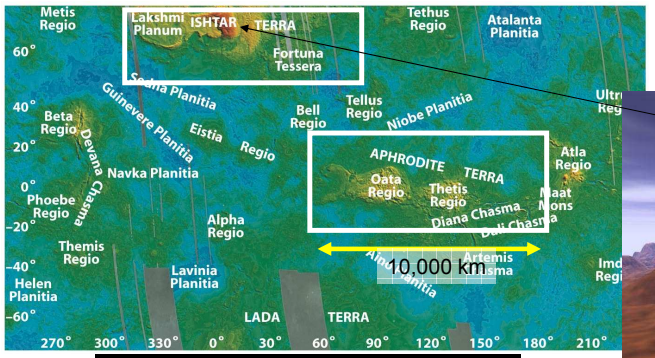
- We can't see Venus' surface in visible light, clouds block the view
- Magellan's Radar showed the surface
- Most of surface is smooth lava flows
- Many large volcanoes
- Probable ongoing volcanism

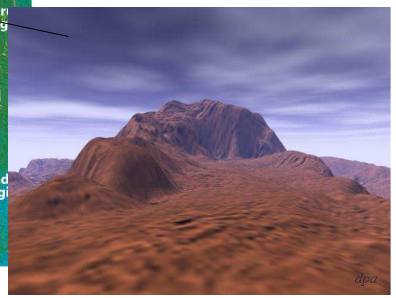
Surface of Venus: Radar



http://www.solarviews.com/raw/venus

Venus: surface features





Images of Venus

from radar data collected by the

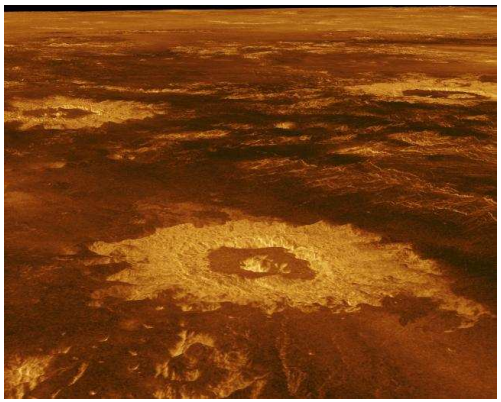
NASA Magellan Spacecraft

Maxwell Montes (65N 5E)
(Highest mountain range in the solar system
11km high– Everest is 8km)

http://www.geology.smu.edu/~dpa-www/venus.html

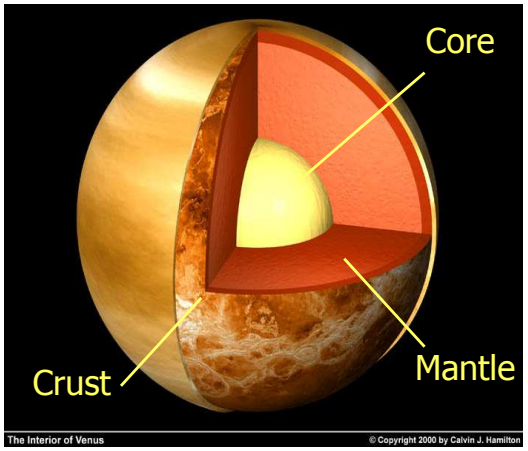
Impacts on Venus

- Venus has about 1,000 craters, often clustered
- No trace of heavy bombardment
- Cratering rate indicates Venus' surface about 500 million yrs old
- Why?
  - Possibility: Extreme temperatures soften rock, making the surface subject to catastrophic volcanic upheaval



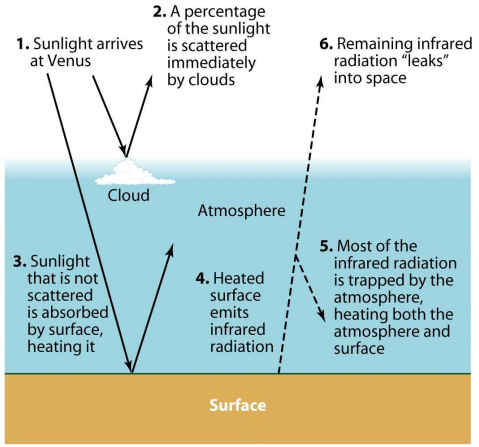
Venus' Interior

- Venus' size and density are roughly equal to Earth's
  - Indicates iron core of similar size
- No magnetic field
  - Very slow rotation - 243 Earth days



Runaway Greenhouse

- On Earth, greenhouse gasses insulate us
  - Keep Earth 35 K warmer than it would be otherwise
- On Venus, massive amounts of CO_2 keep it incredibly hot
  - Almost 300 K warmer!
  - The hottest planet in the Solar System



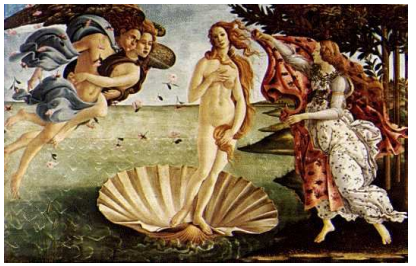
What Happened to Venus?

- It really should have been more like Earth, but the atmosphere is much different.
- Earth's atmosphere is mostly O_2 from life, but early Earth was N.
- Earth and Venus have similar amounts of carbon & nitrogen, but…

http://www.digitalart.ab.ca/art/ren/images/birth-of-venus.jpg

Why So Different?

- Earth's carbon is locked up
  - Dissolved in the oceans
  - Locked into rocks and life

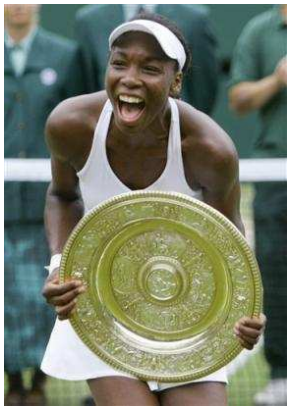


- Venus' carbon is in its atmosphere
  - Too close to the Sun for liquid water
  - No oceans to trap the carbon dioxide
  - No life to process the carbon into sedimentary rocks

http://www.edgechaos.com/MECA/WALLART/VR89/venus.jpeg

What Happened to Venus?

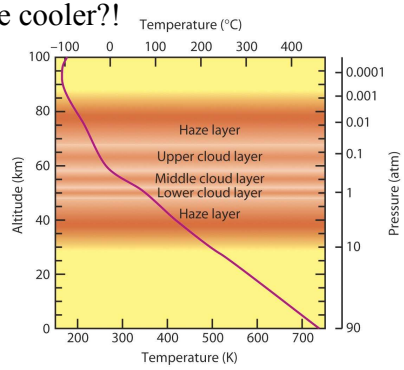
- Apparently Venus lost its H_2O– no oceans and no sediments.
- Probably the atmospheric temperature was hot enough for water to travel high enough to be broken apart by UV radiation, the H was lost and the O reacted with something else.
- Irreversible procedure!
- Which is why greenhouse effect is worrisome here too!
- The Earth traps water vapor in the cool tropopause at 14km.



http://photos1.blogger.com/blogger/4103/1148/1600/Venus%20Wimbeldon05.jpg

Life on Venus?

- Surface is far too hot
  - If lead is liquid, think of what heat would do to complex organic polymers
  - No cooler polar regions exist
    - Heat is uniform!
    - But, high in the clouds it should be cooler?!
- Maybe life can still exist in the clouds?
- At 50 km up, the temperature is not too hot and the pressure is 1 atmosphere.



Chemical Disequilibrium

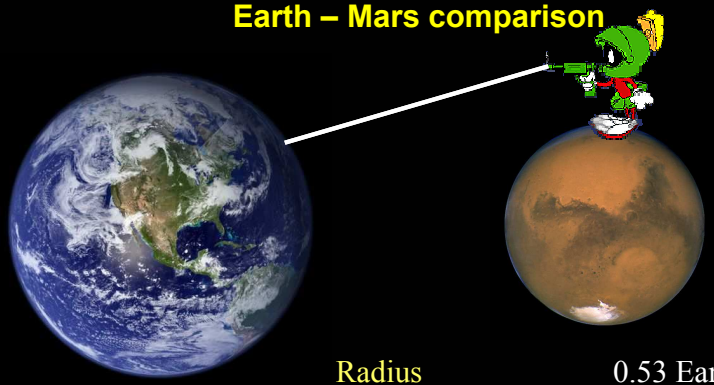
- High clouds in the atmosphere contain chemicals that hint at the presence of some kind of biological activity.
- Hydrogen sulfide and sulfur dioxide - two gases that react with each other– exists in the clouds.
- Something is probably producing them.
- Hardly any carbon monoxide. So something is perhaps removing the gas.

http://www.manson-valley.de/fotogalerie/manson/images/acss/acss_32.jpg

Life on Venus?

- One possibility is that microbes living in the clouds could be combining sulfur dioxide with carbon monoxide and possibly hydrogen sulphide or carbonyl sulphide in a metabolism similar to that of some early terrestrial micro-organisms.
- Given that the temperature on Venus was once much cooler, there may once have been oceans on the planet. Life could have started there and retreated to stable niches once the runaway greenhouse effect began.
- Maybe a mission to scoop up some atmosphere?

Earth – Mars comparison



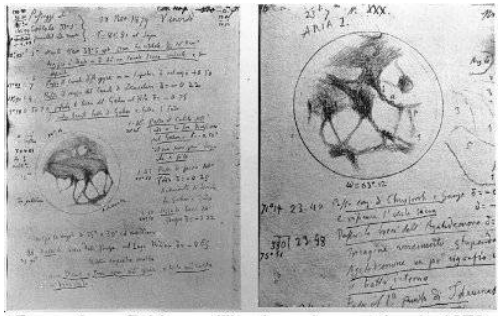
Radius	0.53 Earth
Surface gravity	0.38 Earth
Mass	0.11 Earth
Distance from Sun	1.5 AU
Average Temp	-63 C
Max Temp	20 C
Year	687 Earth days
Length of Day	24 hours 39 minutes
Atmosphere	CO_2 95%

Mars has the Solar System's largest Volcano, Olympus Mons – 27 km tall.

What we used to think.

Giovanni Virginio Schiaparelli

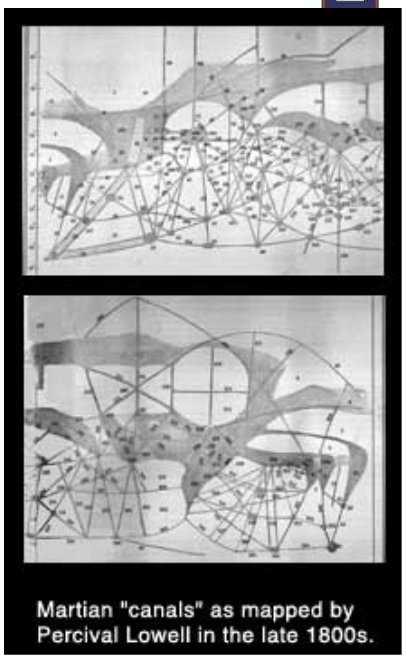
- Was thought to be similar to the Earth in many ways.
- Life was argued to exist on Mars by many astronomers.
- The astronomer Schiaparelli announced that he saw regular linear markings on the surface, which he named *canali*.
- Technically, in Italian means channels, but it was mistranslated to canals.



Pages from Schiaparelli's observing notebook, 1879

Percival Lowell's Canals

- Evidence for intelligent life?
- Mapped the civilization.
- Influenced culture.

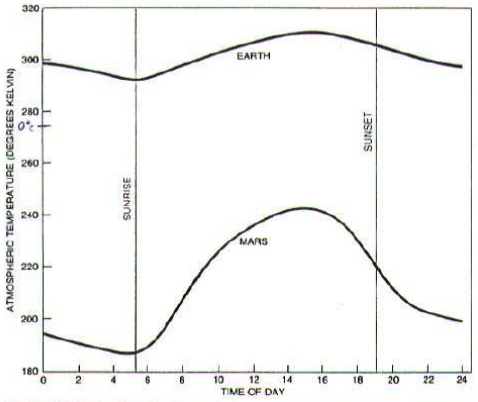


Martian "canals" as mapped by Percival Lowell in the late 1800s.

The Martian Atmosphere

- 95% carbon dioxide
- Atmospheric pressure 0.6% of Earth's – like 40 km altitude on Earth
- But too thin for significant greenhouse effect.
- Pressure is too low for liquid water.
- Not protected by a global magnetosphere like Earth's

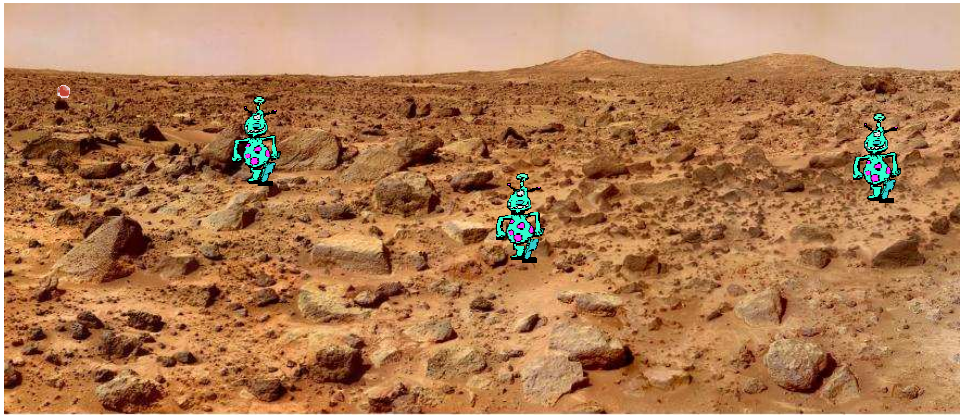
- Large daily and seasonal swings in surface temperature



DAILY VARIATIONS IN ATMOSPHERIC TEMPERATURE at the *Viking 1* landing site (*color*) are qualitatively similar to those at China Lake, Calif., a desert site (*black*). In both cases the temperature touches a minimum around sunrise and reaches a peak about 10 hours later. The daily range, however, is about three times greater on Mars than it is on the earth. At Viking site range is 55 degrees, from about 187 to 242 degrees Kelvin (−86 to −31 degrees Celsius). At China Lake range is 18 degrees, from 292 to 310 degrees K. (19 to 37 degrees C.).

The Surface of Mars

- Mars is a desert!
- Iron oxide in soil gives reddish cast.

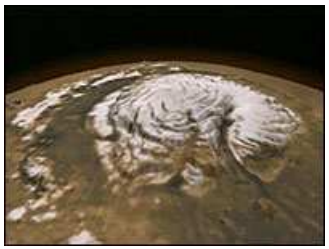


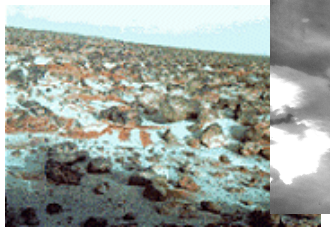
View of "Twin Peaks" from Mars Pathfinder

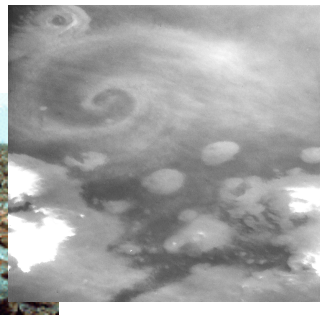
http://www.grc.nasa.gov/WWW/PAO/html/marspath.htm

Water on Mars

- There **is** water on Mars
  - North and south polar caps (some CO_2)
  - Some water vapor in the air
  - Frost on rocks
  - Clouds (ice crystals)
- No *liquid* water now

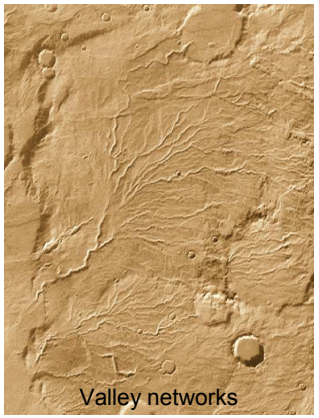


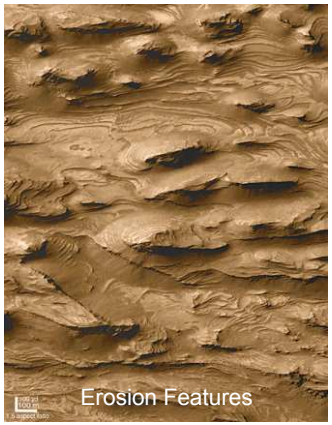


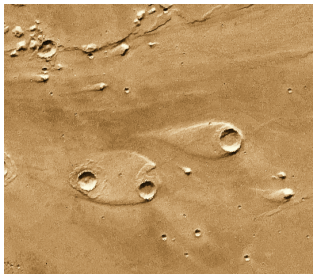


Liquid water on Mars?

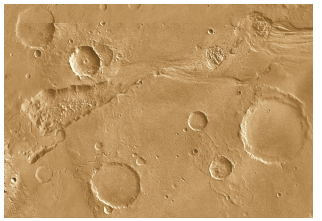
- Water erosion features visible from space
- Atmospheric pressure too low for liquid water to exist
- Perhaps at some point in the past?





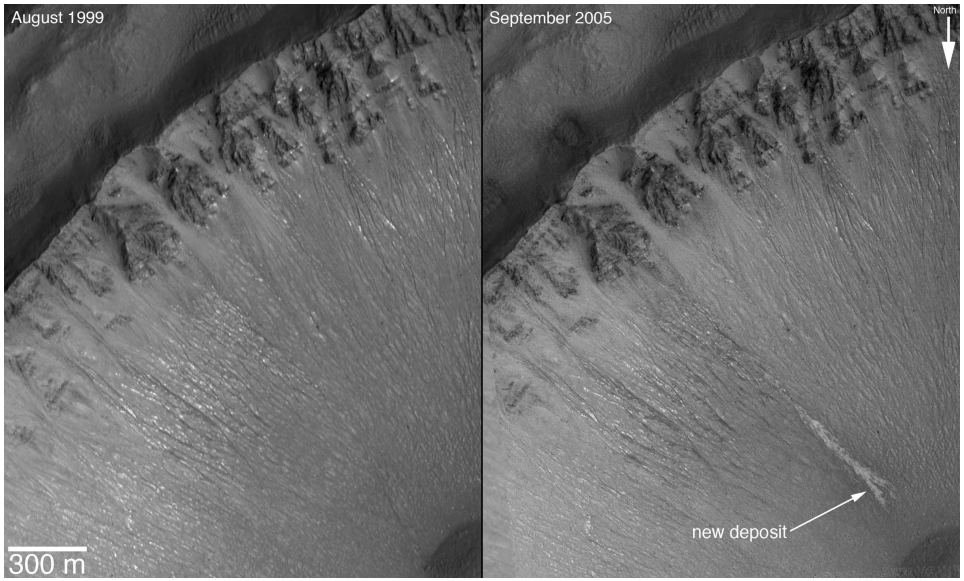


"Islands"

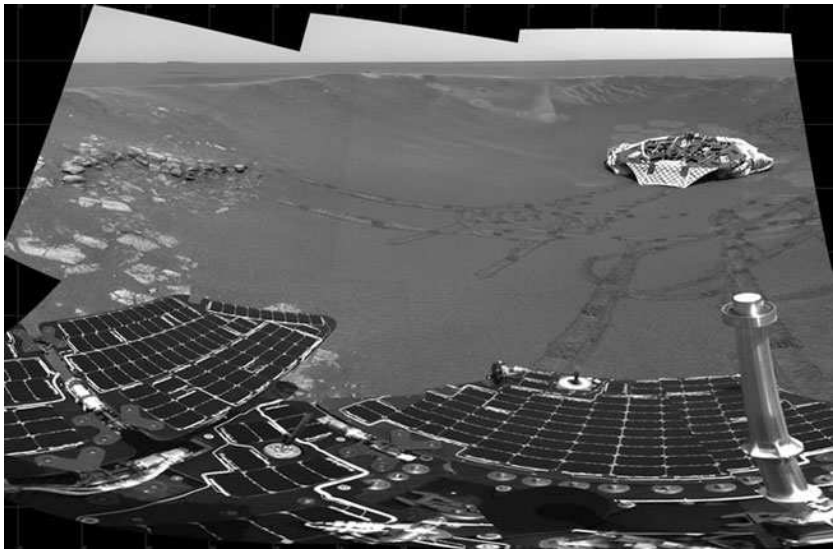


Flood erosion

New Water?

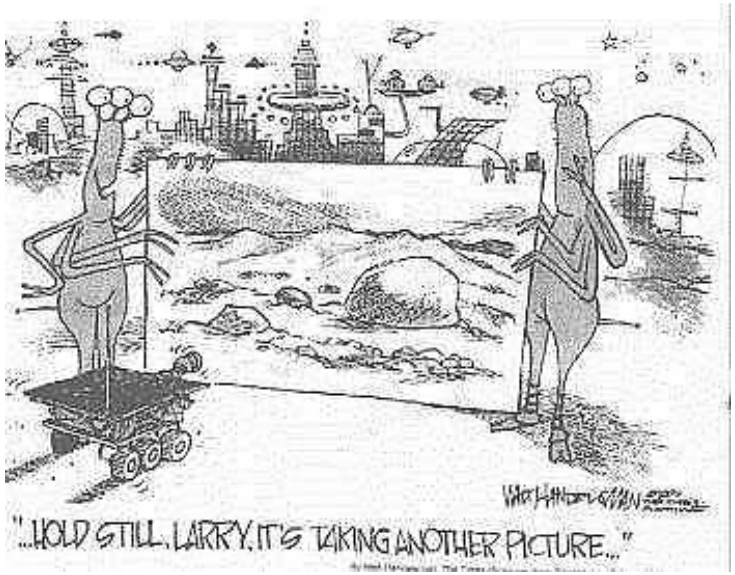


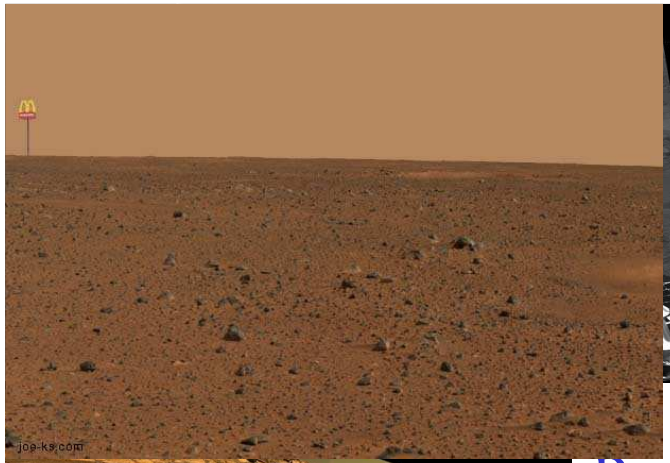
The Surface of Mars: Opportunity

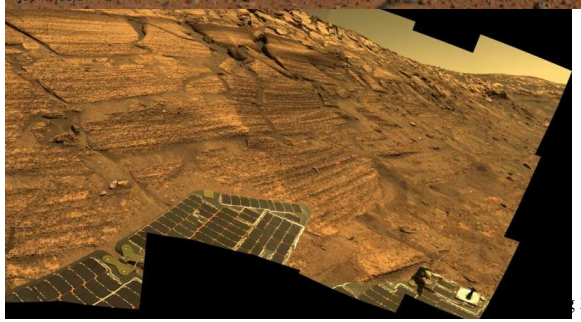


 http://antwrp.gsfc.nasa.gov/apod/ap040303.html

Roving on Mars







Roving on Mars:

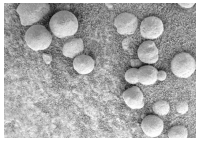
Spirit and Opportunity find evidence of ancient liquid water

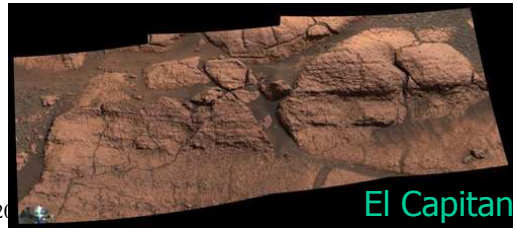
http://antwrp.gsfc.nasa.gov/apod/image/0403/emptynest_opportunity_big.jpg

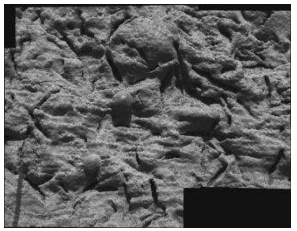
2008

Standing Water on Mars

- The new data from the rovers are highly suggestive of ancient standing water on the Meridiani Planum.
- 3 pieces of evidence:
  - Physical appearance of rocks
  - Rocks with niches where crystals appear to have grown
  - Rocks with sulfates left after the water evaporated
- Is it a former sea floor or just an area that had ground-water?



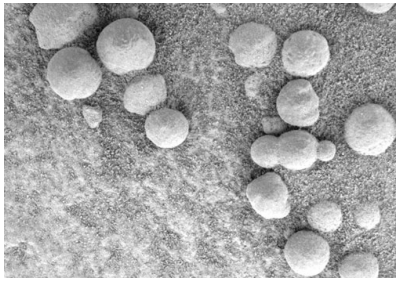


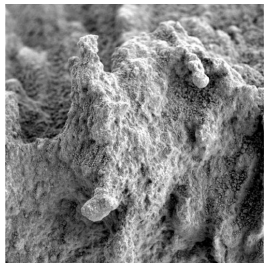


Mars' Watery Past

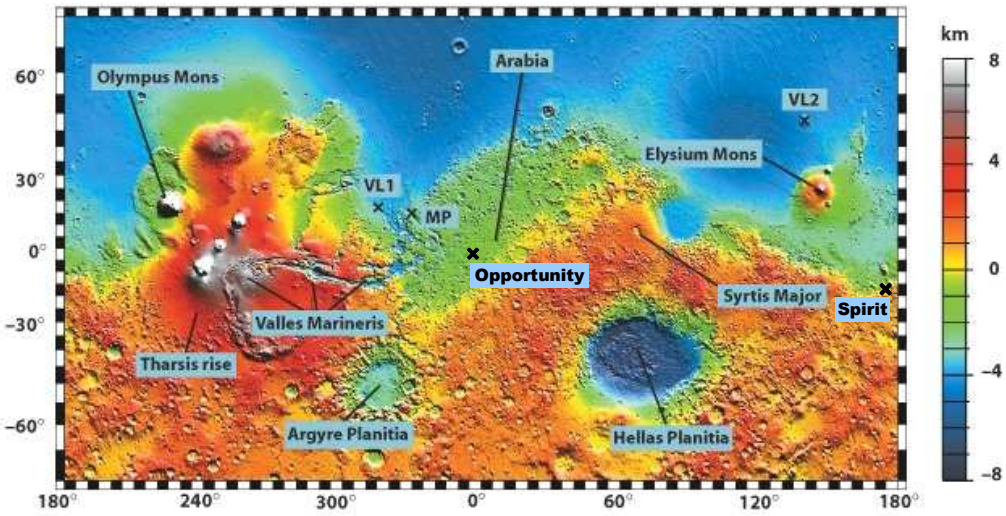
What Happened to the Water?

- That is the big question
  - Both Opportunity and Spirit have found evidence of water
  - Did the water escape to space with the air?
  - Is it frozen beneath the surface?
- The rovers are continuing their exploration
- More missions are planned

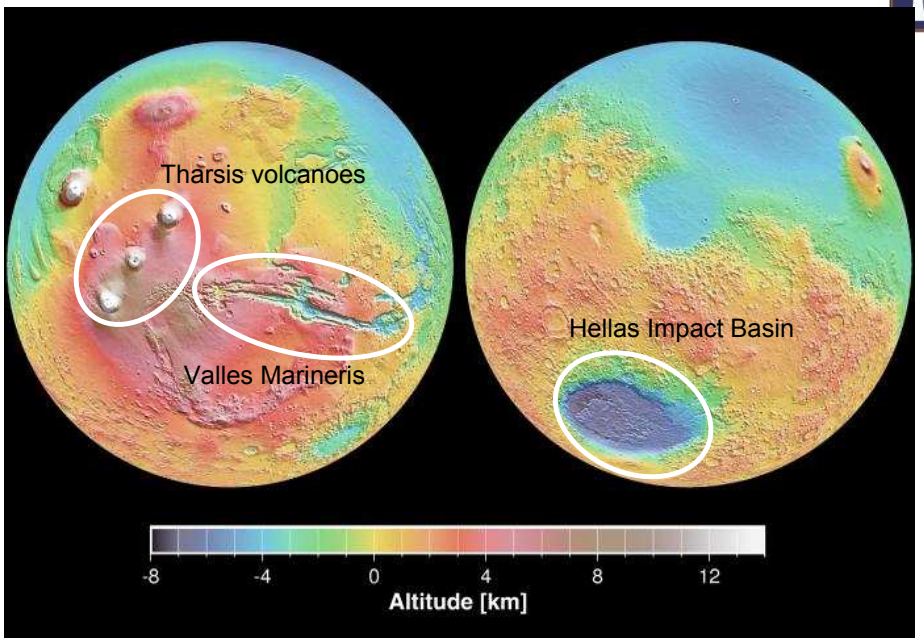




The Geology of Mars



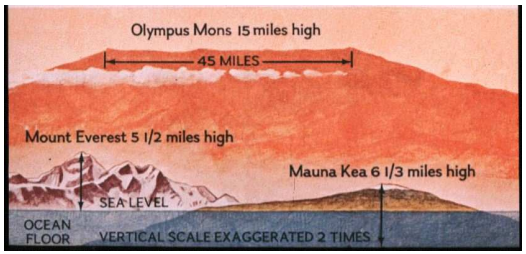
The Surface of Mars



Mars Global Surveyor

Olympus Mons

- The largest mountain in the Solar System rising 26 km high
- A shield volcano, like Hawaii on Earth
- Its caldera is 90 km across

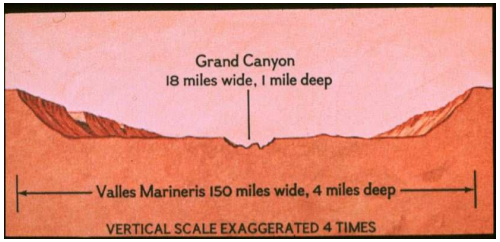


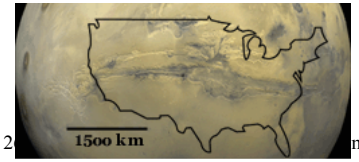
Olympus Mons

- Its base is more than 500 km in diameter
- As long as the entire Hawaiian island chain
- Rimmed by a 6 km high cliff
- Last erupted 25 million years ago
- Probably so big, due to lack of plate tectonics

Valles Marineris

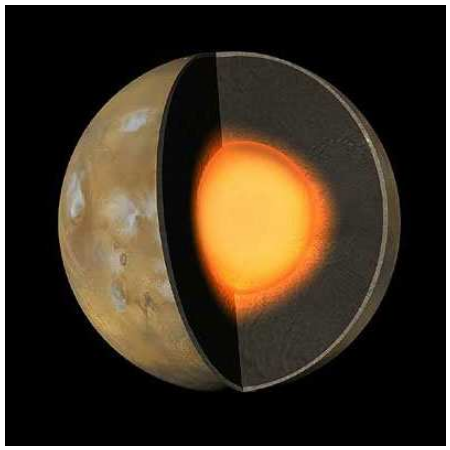
- A series of fault canyons
- 5000 km long
  - A big as the U.S.!
- A giant crack in the crust of Mars
  - Formed as the planet cooled
  - Expanded by water flow





Mars' Interior

- Like Earth, Mars has an iron core
  - About half of the planet's radius in size
  - Heavily contaminated with sulfur
  - Weak magnetic field suggests a thin layer of liquid iron, mostly solid



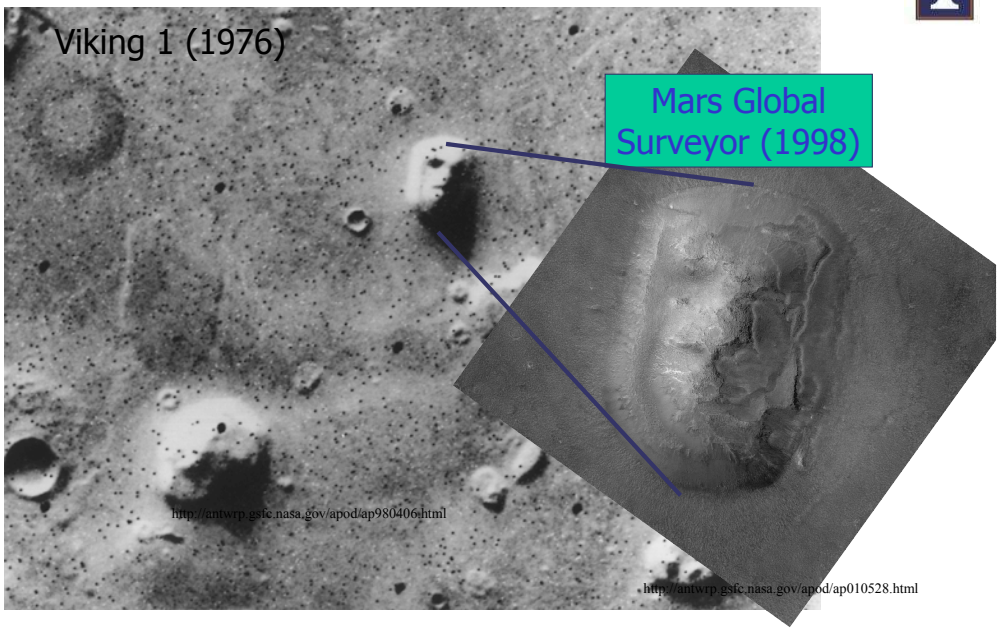
Mars' Past

- Early in Mars' history it was likely more Earth-like
  - Geologically active
  - Volcanic eruptions created a thick carbon dioxide, nitrogen atmosphere
  - Greenhouse effect made it warm enough for liquid water
  - Oceans? Rivers? Glaciers by the poles?
  - Life?

What Happened?

- Mars was too small
  - Not enough internal heat
- Plate tectonics stopped
  - Volcanoes sat over "hotspots" grew to immense sizes
- Volcanic activity slowed as the interior cooled
- The atmosphere escaped
- The planet froze
- Did life move underground?

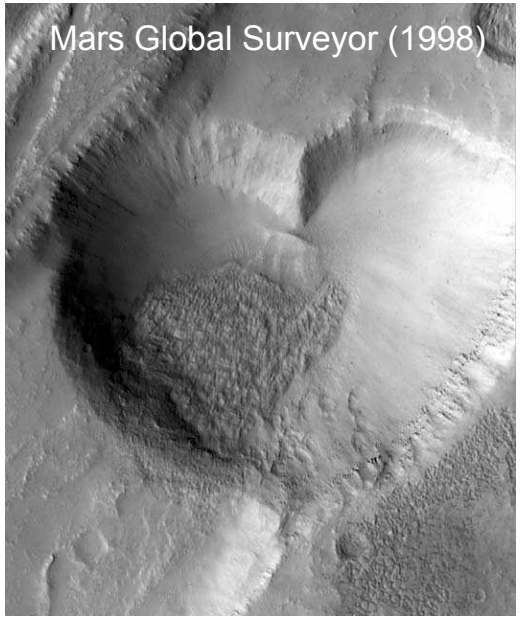
The "Face" of Mars?



Other Faces

 http://antwrp.gsfc.nasa.gov/apod/ap990315.html

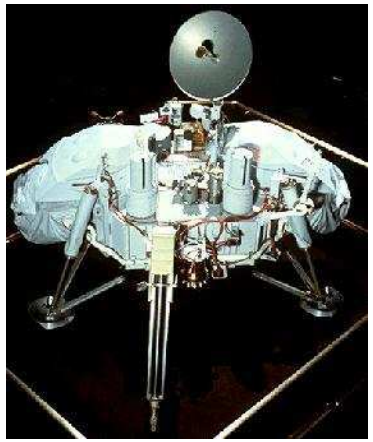
Other Places



 http://www.solarviews.com/cap/mgs/heart.htm

The Search for Mars Life

- Viking 1 and 2 carried several experiments to detect life
- The results were ambiguous. The soil reacted vigorously with the Viking nutrients, then tapered off in activity.
- The conclusion of most scientists is that the reactions were due to inorganic chemical reactions.



Martians?

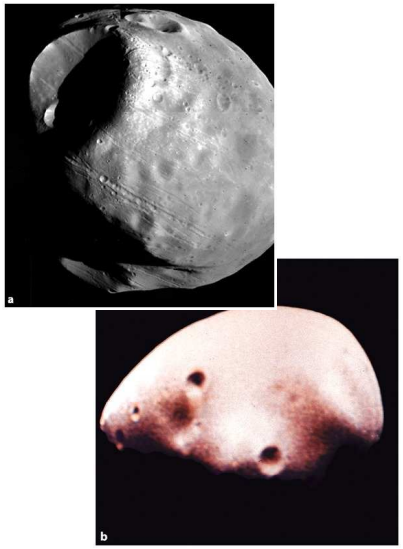
- In August 1996, evidence for microbial life was found in a Martian meteorite.
  - ALH84001 (3Gyrs): Found in Antarctica, composition suggests it was knocked from Mars
  - About 14 such Mars rocks have been found on Earth
- David McKay *et al.* suggested that there was fossil evidence for bacteria in the meteorite.

Martian Microbe Fossils?

- Microscopic shapes that resemble living and fossil bacteria on Earth– nanobacteria, but much smaller than on Earth.
- Microscopic mineral grains like some produced by living and fossil bacteria on Earth
- Organic chemical compounds that resemble the decay products of bacteria on Earth.
- In the end, not impelling enough. Non-biological processes can probably produce the observed features

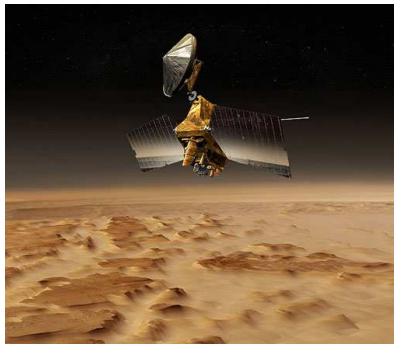
Phobos & Deimos

- Mars' moons
- Likely captured asteroids
- Very small
  - About 15-25 km in size
  - Shaped like potatoes



Mars Missions

- Mars Reconnaissance Orbiter (now)
  - Will study the geology and climate of Mars
  - Look for ancient sea shores
  - Survey potential landing sites
- Phoenix (2007)
  - Will analyze water ice at Mars' north pole



Manned Mars Exploration

- NASA's plans to send a manned expedition to Mars
- Timetable:
  - Complete Space Station by 2010
  - Return to Moon by 2020
  - Then, on to Mars (no date)
- No cost estimates
  - Some funds from to-be-retired shuttle fleet