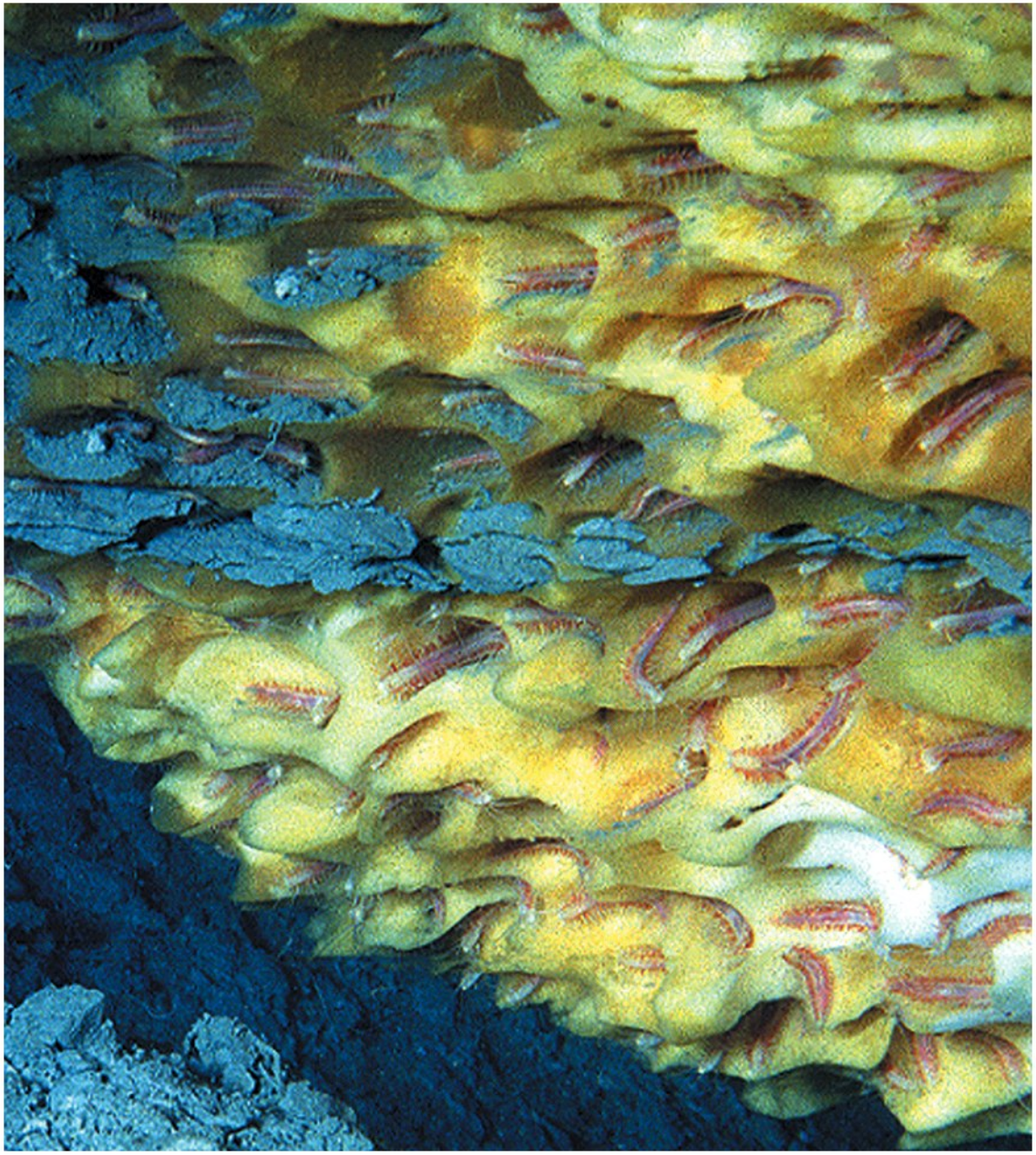
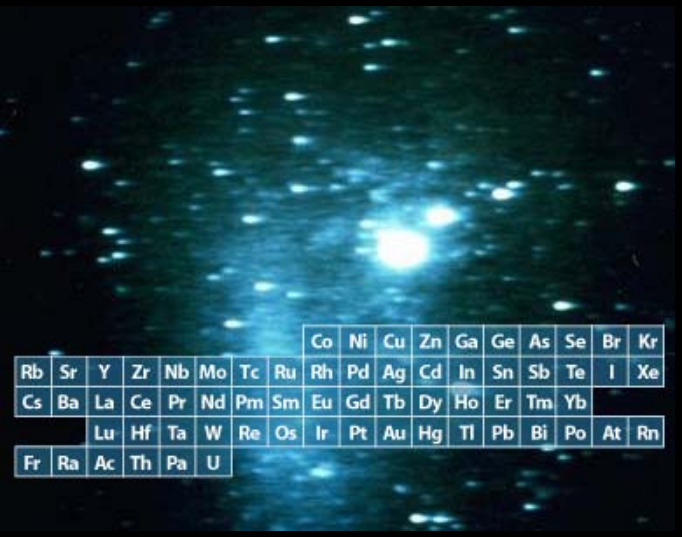


# The Search for Extraterrestrial Life

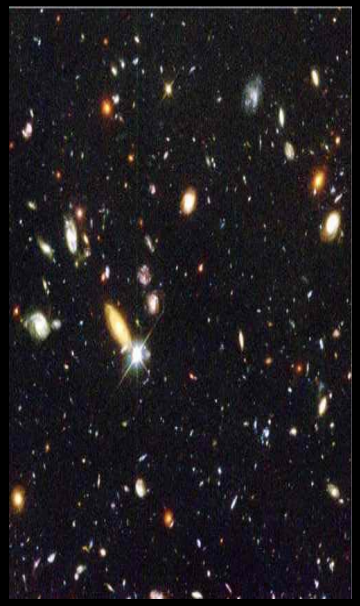
# Guiding Questions

1. What role could comets and meteorites have played in the origin of life on Earth?
2. Have spacecraft found any evidence for life elsewhere in our solar system?
3. Do meteorites from Mars give conclusive proof that life originated there?
4. How likely is it that other civilizations exist in our Galaxy?
5. How do astronomers search for evidence of civilizations on planets orbiting other stars?
6. Will it ever be possible to see Earthlike planets orbiting other stars?

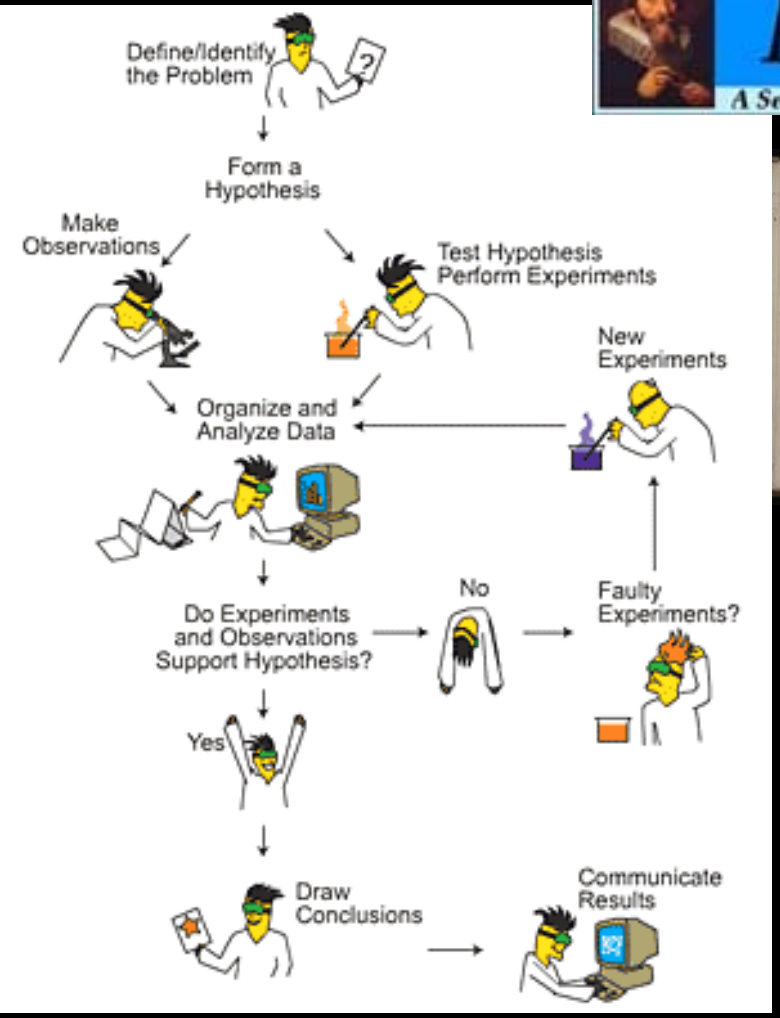
# A Universe of Life



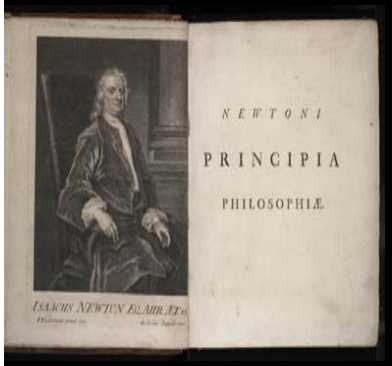

- Searching for life everywhere
- Planets, stars, galaxies, Big Bang
  - Conception of size and distance
- Stars and the origins of chemicals
- Formation of planets
- Defining astrobiology – the science



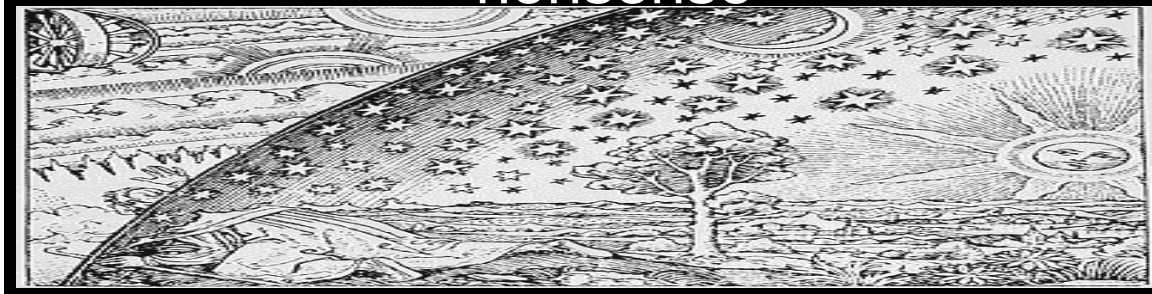
# The Science of Life in the Universe





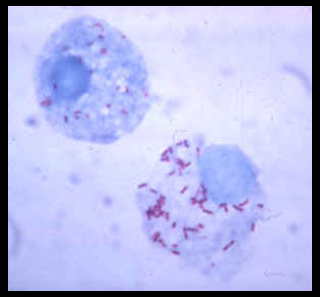


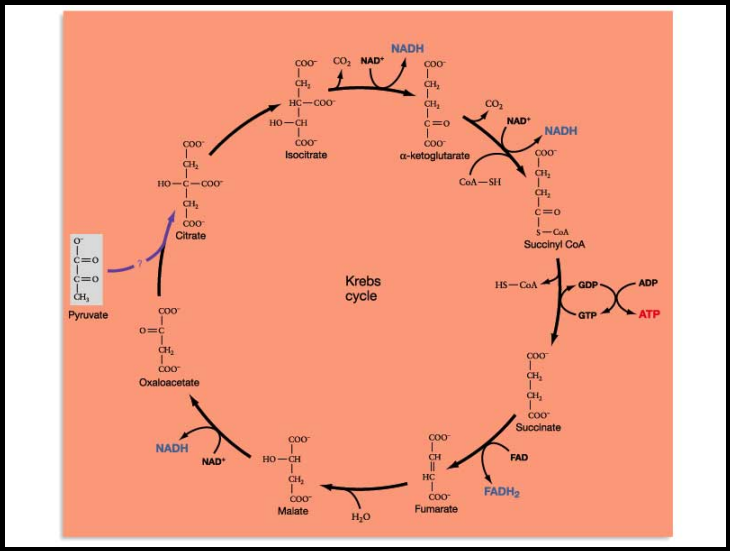

- Ancient cosmologies
- Science as a way of knowing
- Copernicus, Galileo, Kepler, Newton
- Pseudoscience and nonsense



# The Nature of Life

- What is it?
- Cells
- Metabolism
- DNA
- Extremophiles





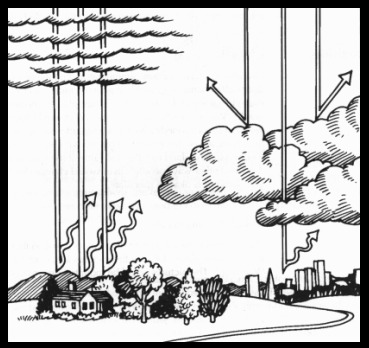

# The chemical building blocks of life are found throughout space

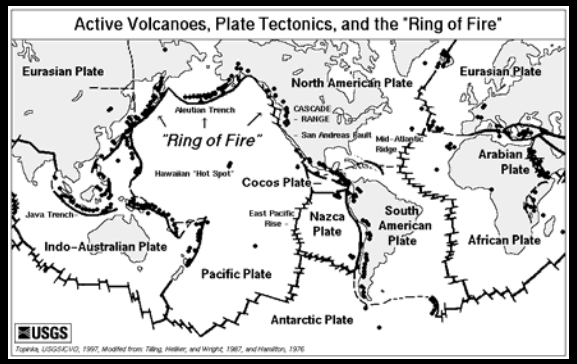
- All life on Earth, and presumably on other worlds, depends on organic (carbon-based) molecules
- These molecules occur naturally throughout interstellar space
- Organic molecules needed for life to originate were possibly brought to the young Earth by comets or asteroids, as well as being formed on Earth

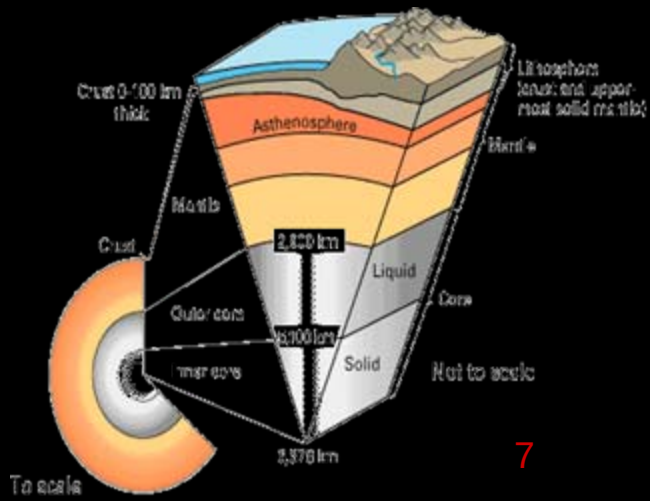
# The Geological History of the Earth

| EON | ERA | PERIOD | | EPOCH | | Ma |
|---|---|---|---|---|---|---|
| Phanerozoic | Cenozoic | Quaternary | | Holocene | | 0.01 |
| | | | | Pleistocene | Late | 0.8 |
| | | | | | Early | 1.8 |
| | | Tertiary | Neogene | Pliocene | Late | 3.6 |
| | | | | | Early | 5.3 |
| | | | | Miocene | Late | 11.2 |
| | | | | | Middle | 16.4 |
| | | | | | Early | 33.7 |
| | | | | Oligocene | Late | 28.5 |
| | | | | | Early | 33.7 |
| | | | Paleogene | Eocene | Late | 41.3 |
| | | | | | Middle | 49.0 |
| | | | | | Early | 54.8 |
| | | | | Paleocene | Late | 61.0 |
| | | | | | Early | 65.0 |
| | Mesozoic | Cretaceous | | Late | | 99.0 |
| | | | | Early | | 144 |
| | | Jurassic | | Late | | 159 |
| | | | | Middle | | 180 |
| | | | | Early | | 206 |
| | | Triassic | | Late | | 227 |
| | | | | Middle | | 242 |
| | | | | Early | | 248 |
| | Paleozoic | Permian | | Late | | 256 |
| | | | | Early | | 290 |
| | | Pennsylvanian | | | | 323 |
| | | Mississippian | | | | 354 |
| | | Devonian | | Late | | 370 |
| | | | | Middle | | 391 |
| | | | | Early | | 417 |
| | | Silurian | | Late | | 423 |
| | | | | Early | | 443 |
| | | Ordovician | | Late | | 458 |
| | | | | Middle | | 470 |
| | | | | Early | | 490 |
| | | Cambrian | | D | | 500 |
| | | | | C | | 512 |
| | | | | B | | 520 |
| | | | | A | | 543 |
| Precambrian | Proterozoic | Late | | | | 900 |
| | | Middle | | | | 1600 |
| | | Early | | | | 2500 |
| | Archean | Late | | | | 3000 |
| | | Middle | | | | 3400 |
| | | Early | | | | 3800? |

- Geologic Timescale
- Plate Tectonics
- Solid Earth
- Greenhouse Effect
- Relative/Absolute Dating

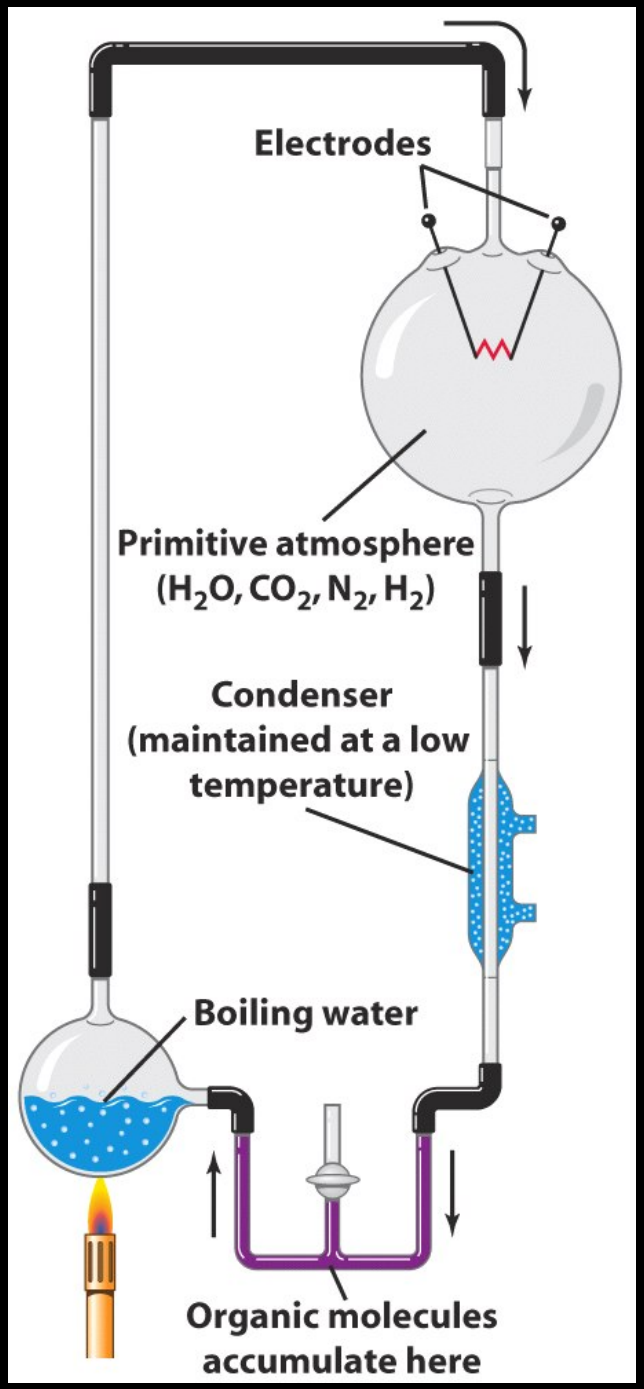




# The Origin and Evolution of Life on Earth

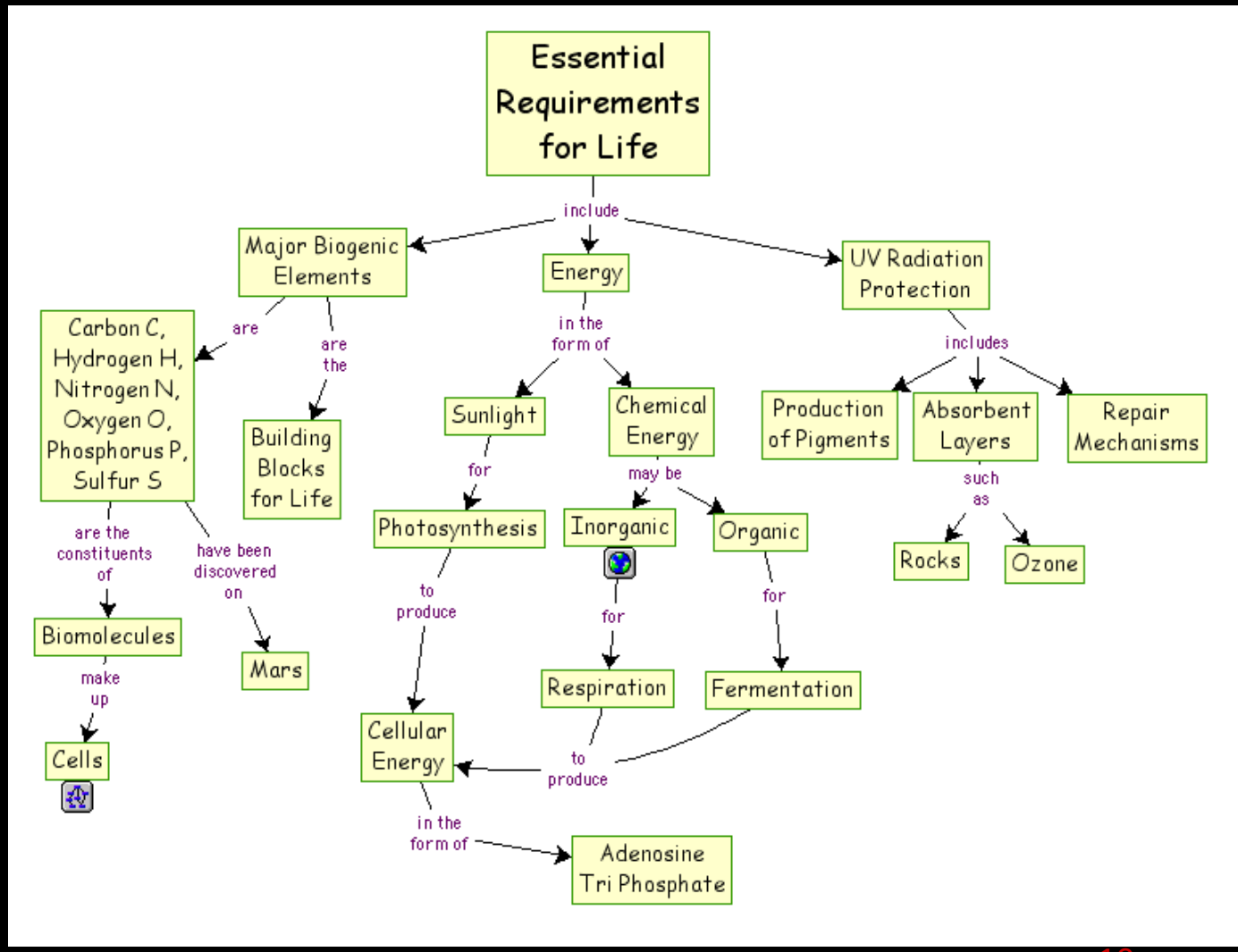
- Origin of Life
- Prokaryotes
- Eukaryotes
- Oxygen in Air
- Impacts & Extinctions
- Human Evolution




- Another likely source for organic molecules is chemical reactions in the Earth's primitive atmosphere
- Similar processes may occur on other worlds

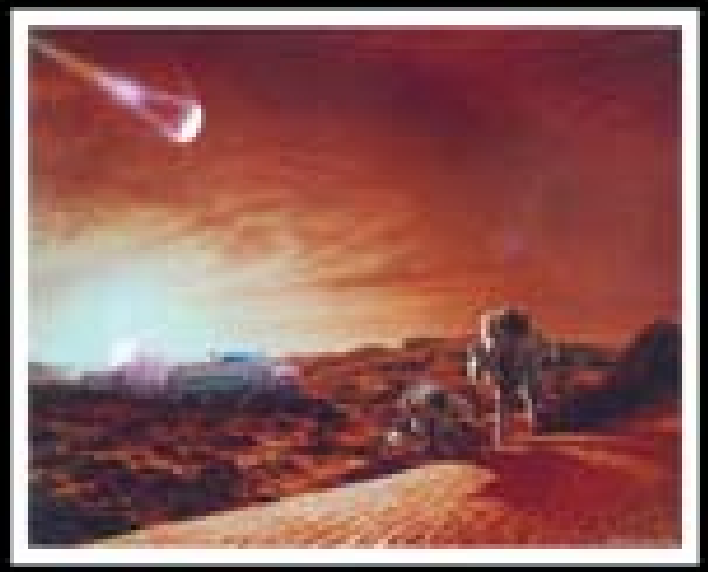
# Searching for Life in the Solar System

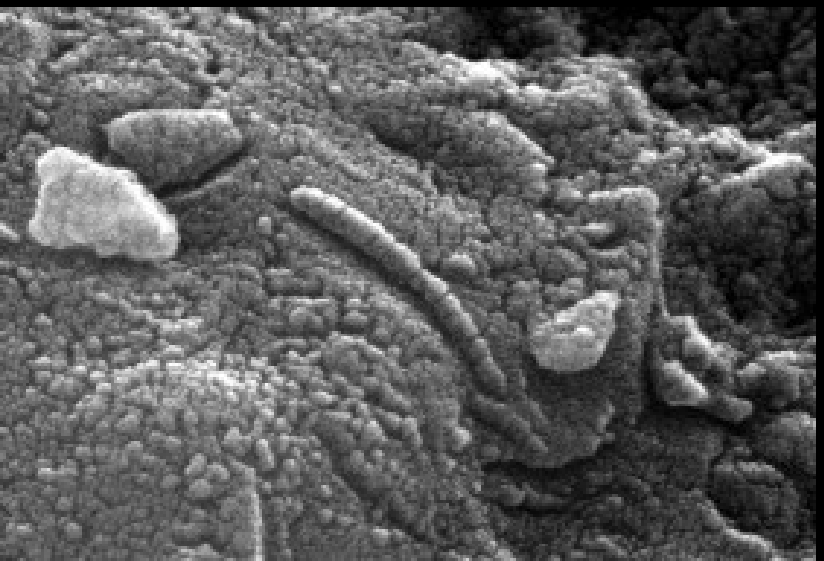
- Environmental Needs
- In the Solar System

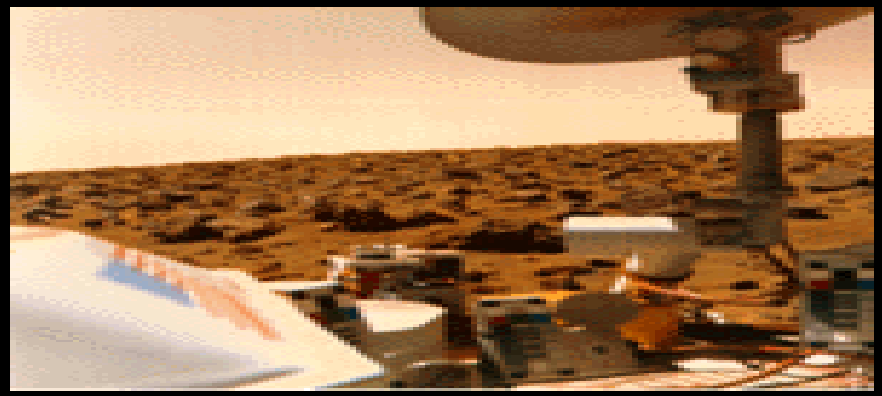



# Mars

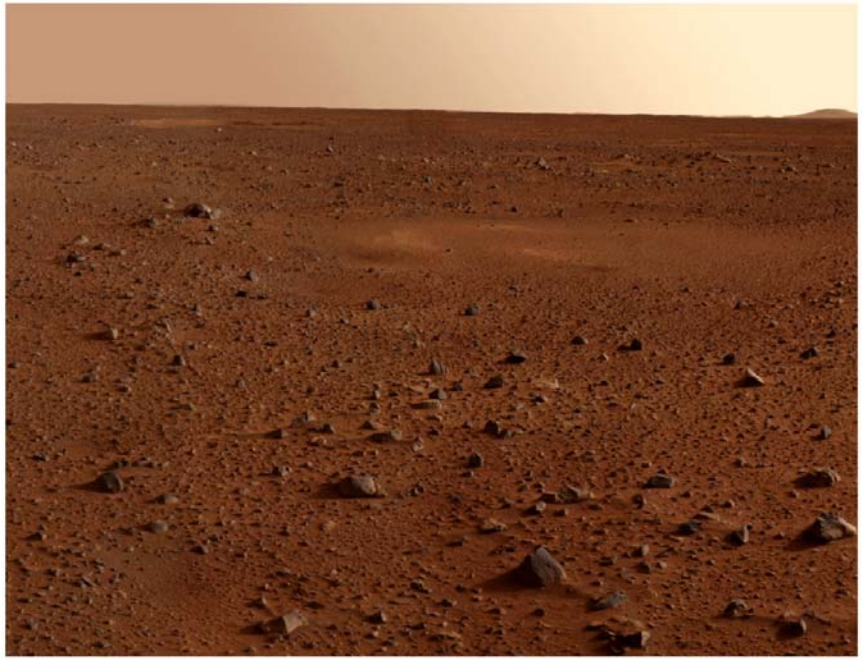
- Science Fiction
- Search for Life
- Martian Meteorites
- Exploration



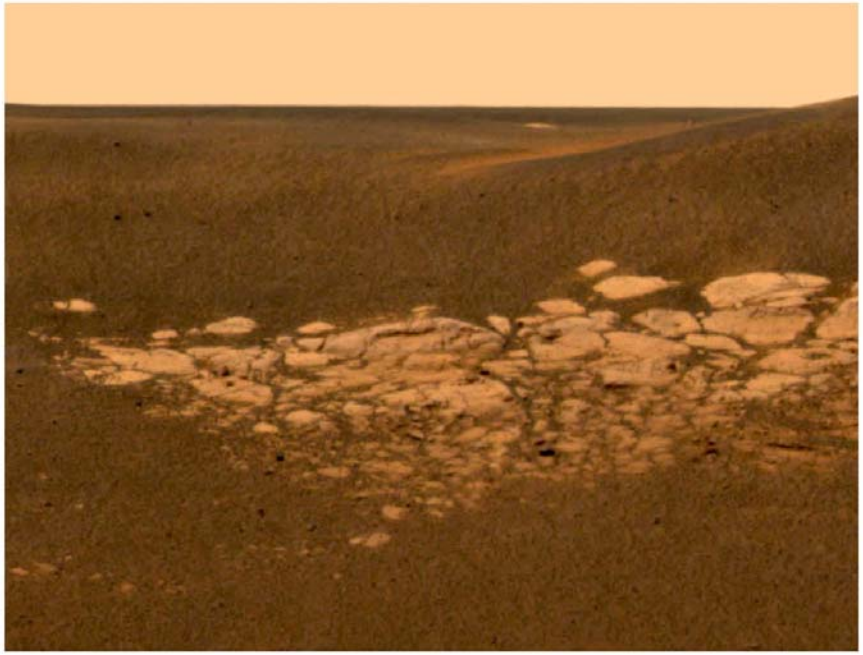




# NASA rovers that reached Mars in 2004 landed at locations that may once have been covered in water



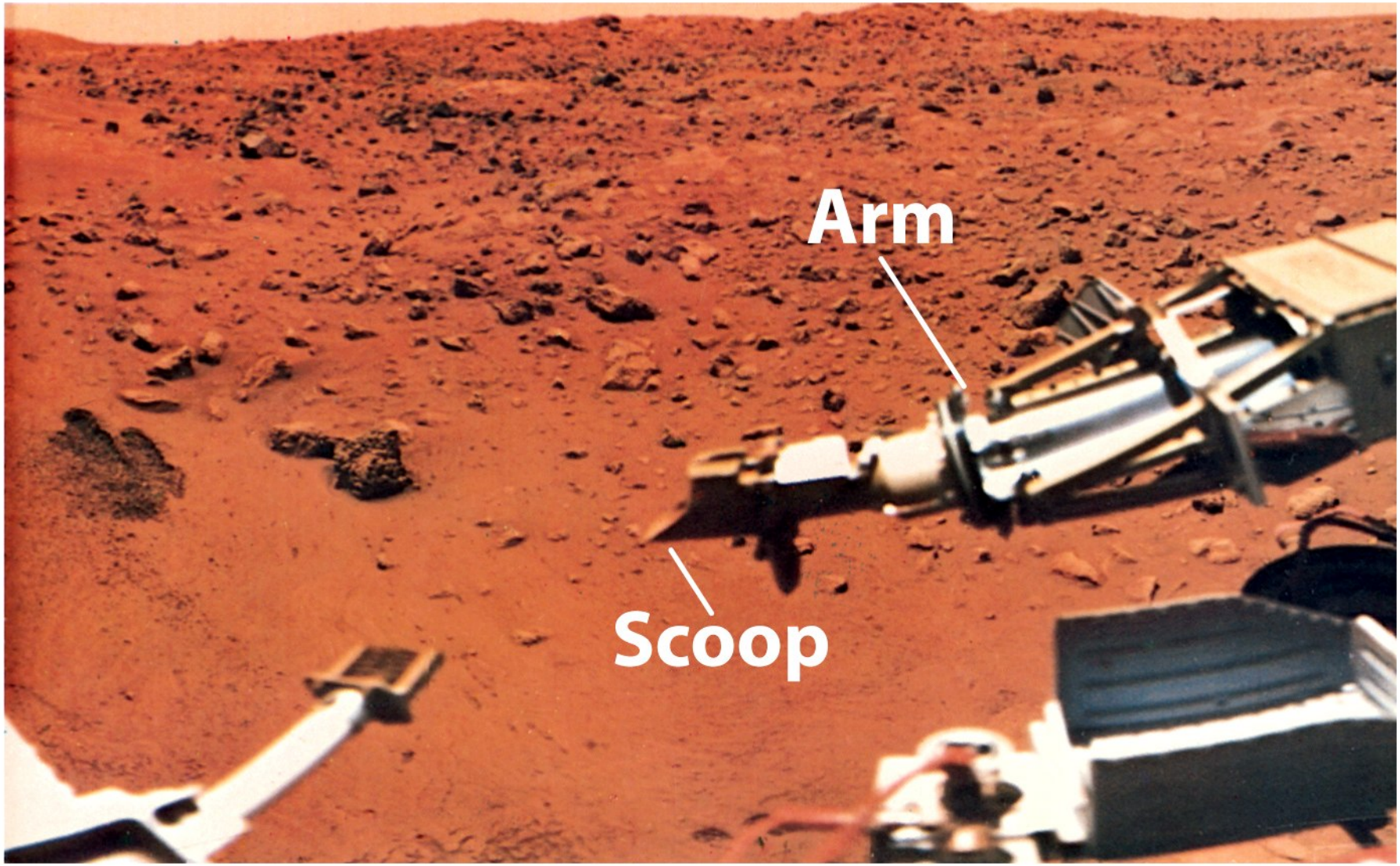
***Spirit*** **landing site in Gusev Crater**



***Opportunity*** **landing site in Meridiani Planum**

- The unsuccessful *Beagle 2* mission to Mars was to carry out a different set of biological experiments on samples taken from the interiors of rocks

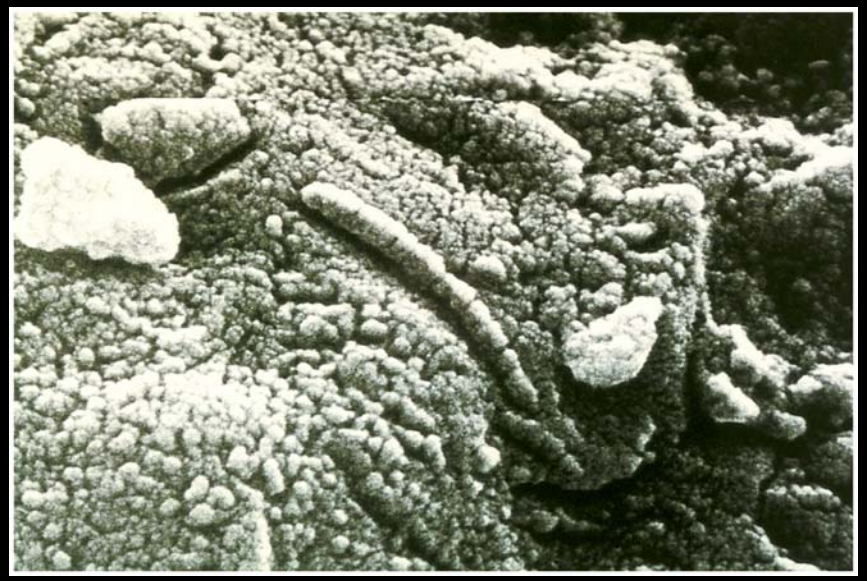
The *Viking Lander* spacecraft searched for microorganisms on the Martian surface, but found no conclusive sign of their presence



# A so-called “Face” on Mars

# A Happy Face?

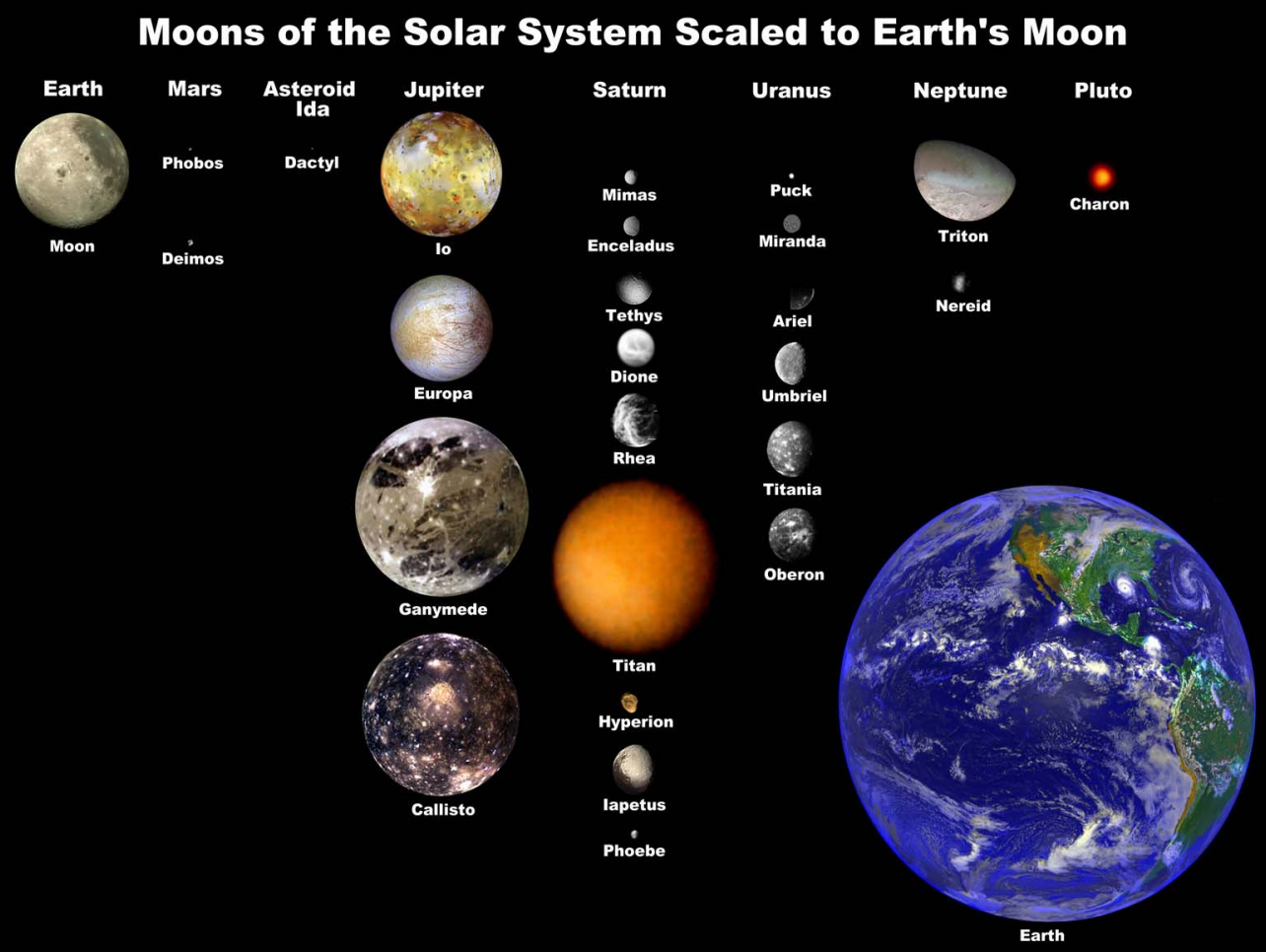
# Meteorites from Mars have been scrutinized for life-forms

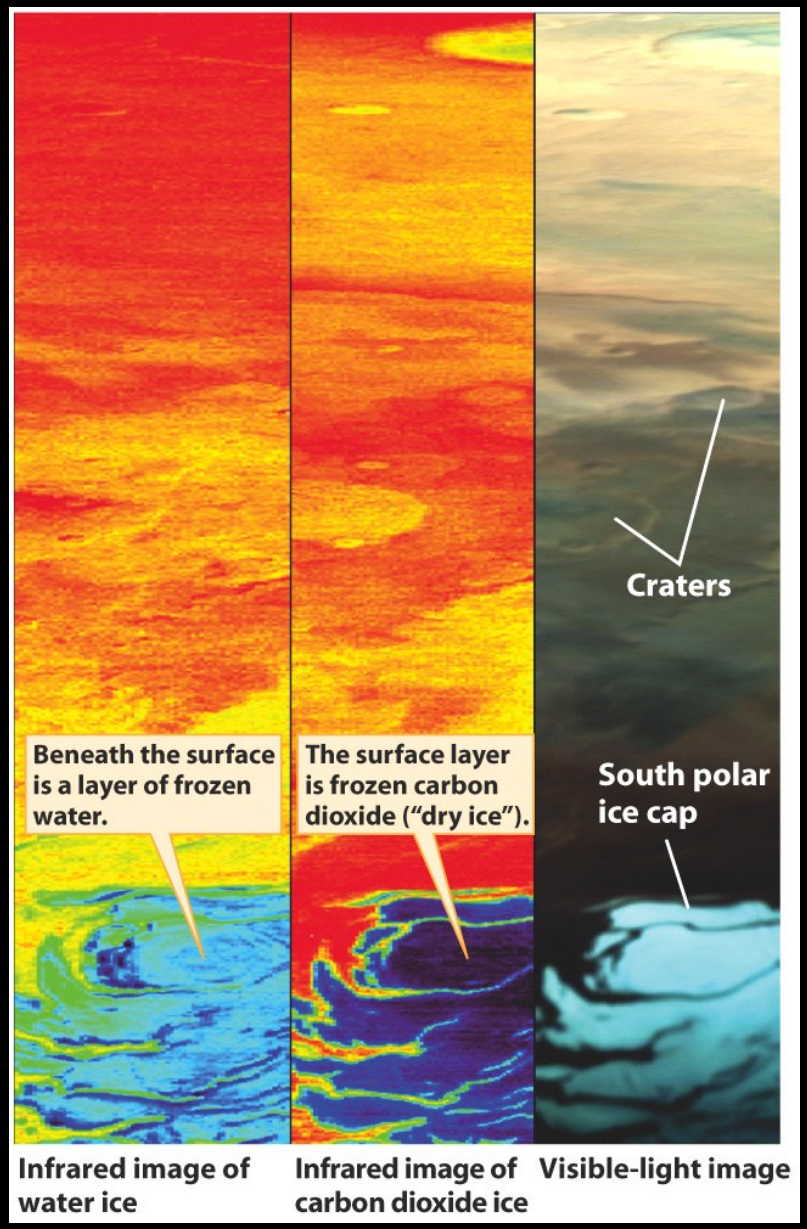
- An ancient Martian rock that came to Earth as a meteorite was examined for evidence that microorganisms once existed on Mars
- This has not been corroborated

# Life on Jovian Moons

- Europa
- Titan
- Others

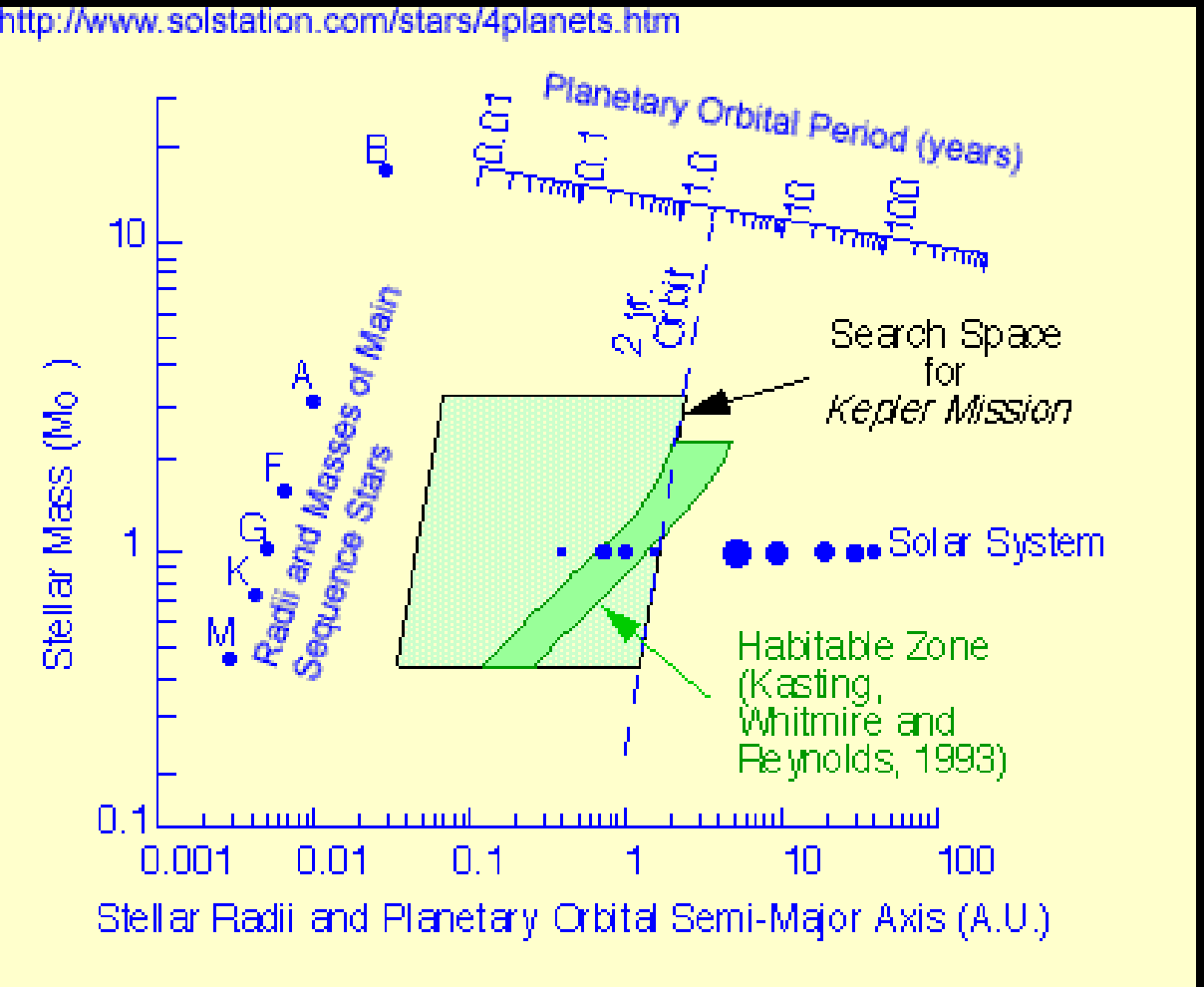


# Europa and Mars best potential for life to have evolved




- Besides Earth, only two worlds in our solar system—the planet Mars and Jupiter's satellite Europa—may have had the right conditions for the origin of life
- Mars once had liquid water on its surface, though it has none today
- Life may have originated on Mars during the liquid water era
- Europa appears to have extensive liquid water beneath its icy surface
  - Future missions may search for the presence of life

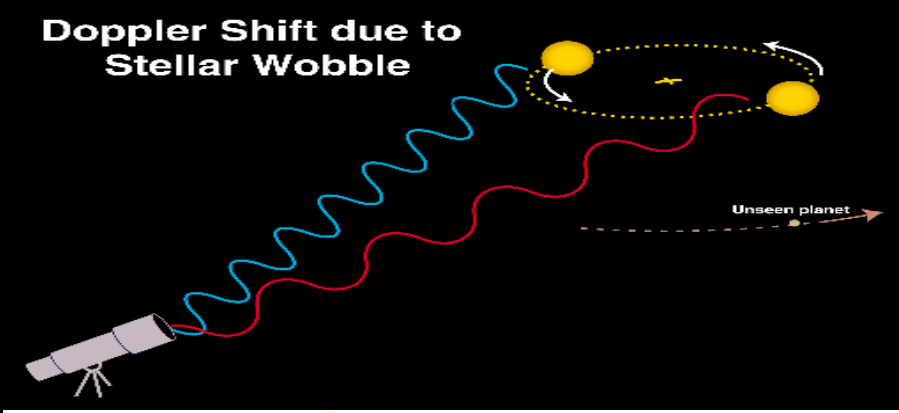
# The Nature and Evolution of Habitability

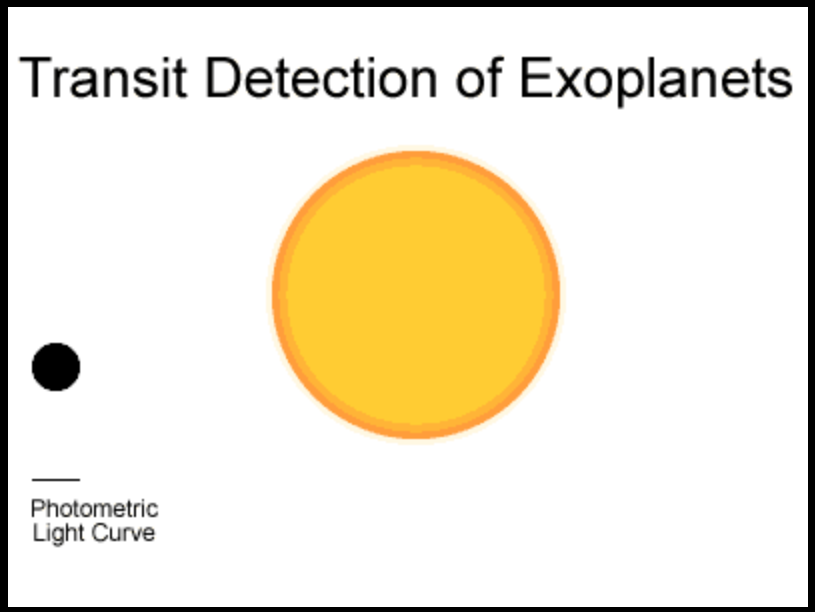


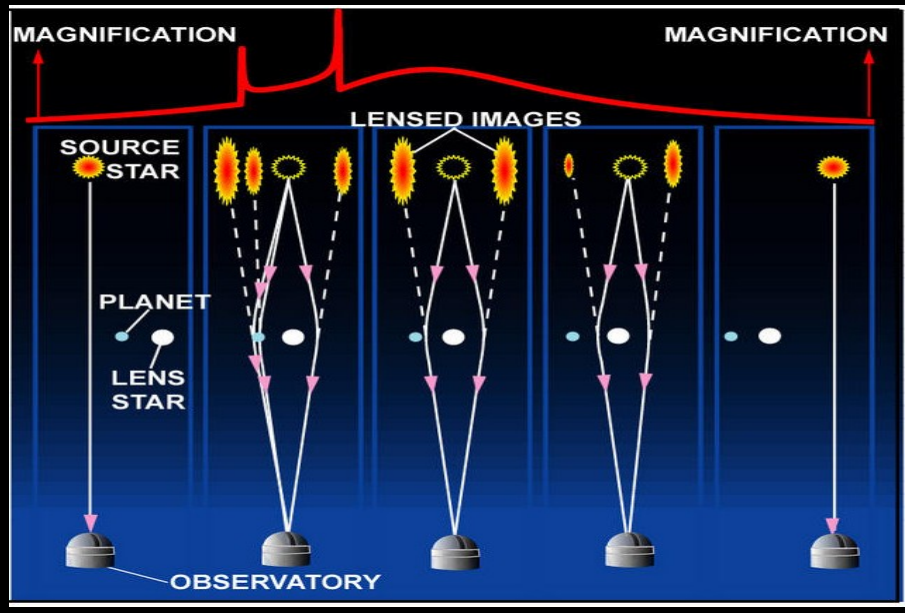

- Habitability Zone
  - Past, Present, Future

# The Search for Habitable Worlds

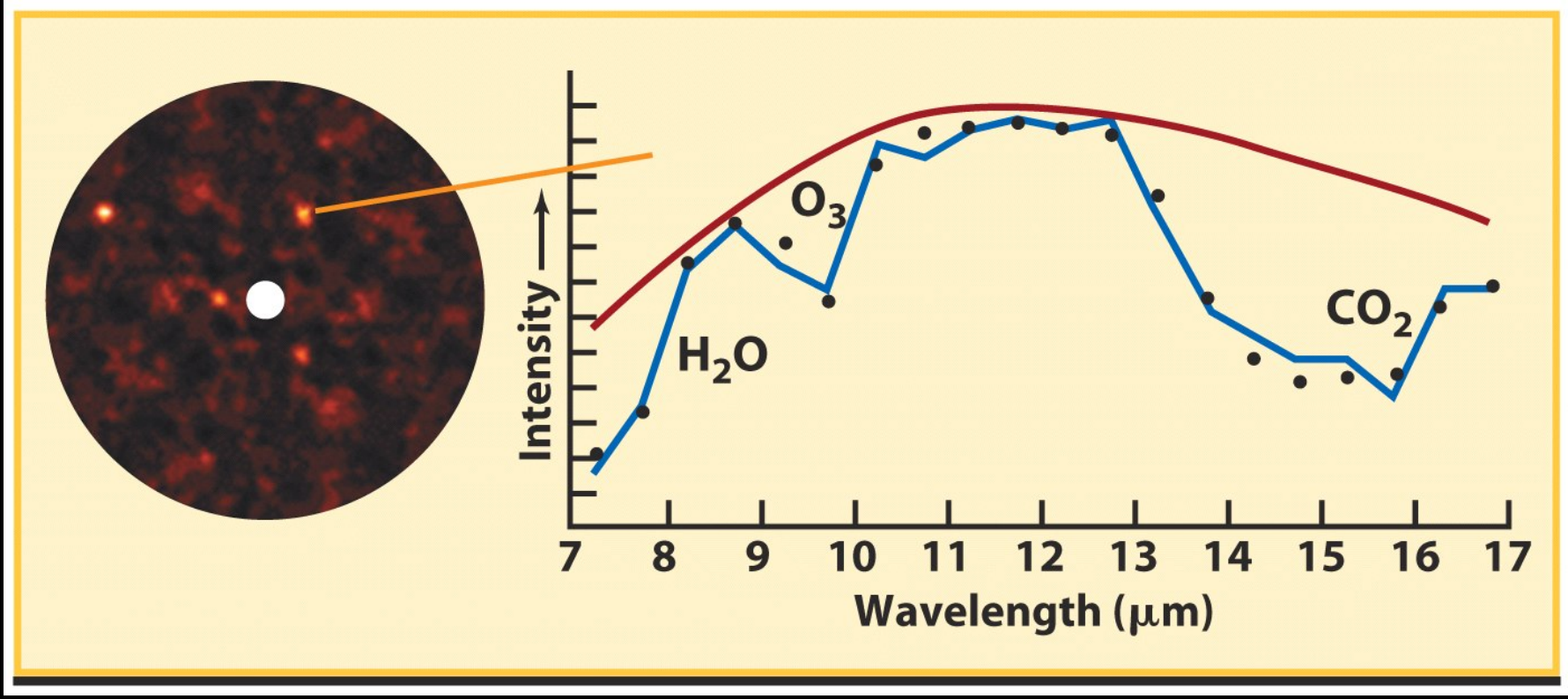
- Planet Formation
- Extrasolar Planets
  - Detection
- Earth-like Planets?



# Infrared telescopes in space began searching for Earthlike planets




- A new generation of orbiting telescopes may be able to detect terrestrial planets around nearby stars
- If such planets are found, their infrared spectra may reveal the presence or absence of life

# The Search for Extraterrestrial Intelligence

- SETI
- Drake Equation

$$N_0 = N^* \times f_P \times n_{EZ} \times f_L \times f_I \times F$$

*The Drake Equation*

$$N_T = R_* f_p n_e f_l f_i f_t t_l$$

- $N_T$ - number of communicative civilizations
- $R_*$ - mean rate at which suitable stars are born 1-10/y
- $f_p$ - fraction of stars with planetary systems 0.1-0.5
- $n_e$ - number of Earth-like worlds per planetary system 1-3
- $f_l$ - fraction of those Earths where life develops 0.1-1
- $f_i$ - fraction of these on which intelligence develops 0.01-1
- $f_t$ - fraction of intelligent beings who develop technology 0.1-1
- $t_l$ - lifetime of a civilisation with ability to communicate $10^3$-$10^6$

# The Drake equation helps scientists estimate how many civilizations may inhabit our Galaxy

$$N = R_* f_p n_e f_l f_i f_c L$$

$N$ = number of technologically advanced civilizations in the Galaxy whose messages we might be able to detect

$R_*$ = the rate at which solar-type stars form in the Galaxy

$f_p$ = the fraction of stars that have planets

$n_e$ = the number of planets per solar system that are Earthlike (that is, suitable for life)

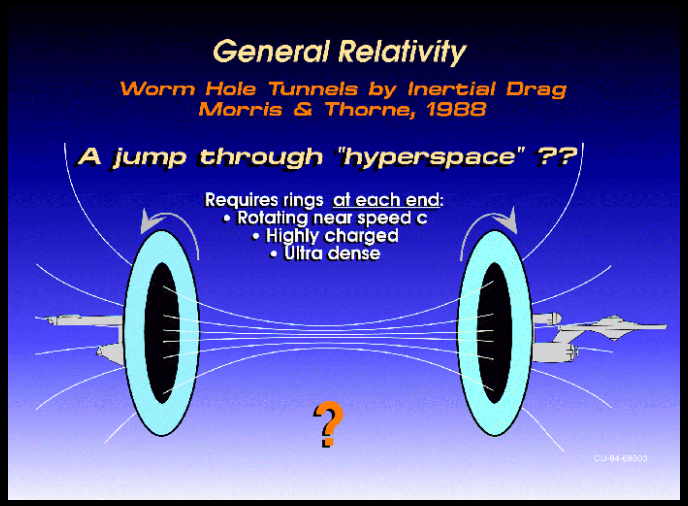
$f_l$ = the fraction of those Earthlike planets on which life actually arises

$f_i$ = the fraction of those life-forms that evolve into intelligent species

$f_c$ = the fraction of those species that develop adequate technology and then choose to send messages out into space

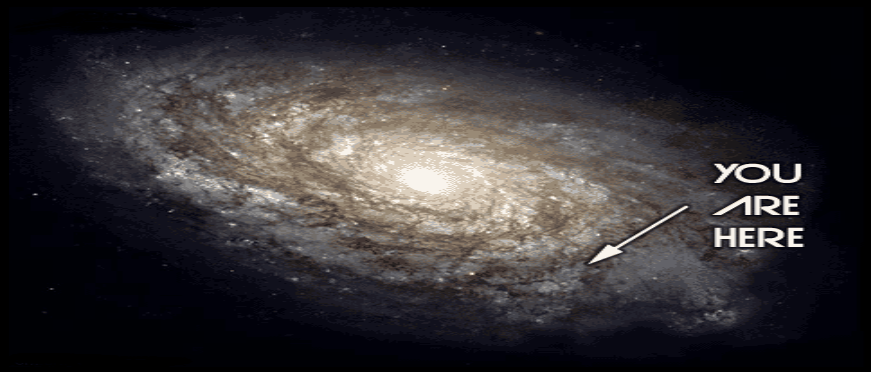
$L$ = the lifetime of a technologically advanced civilization

# Interstellar Travel

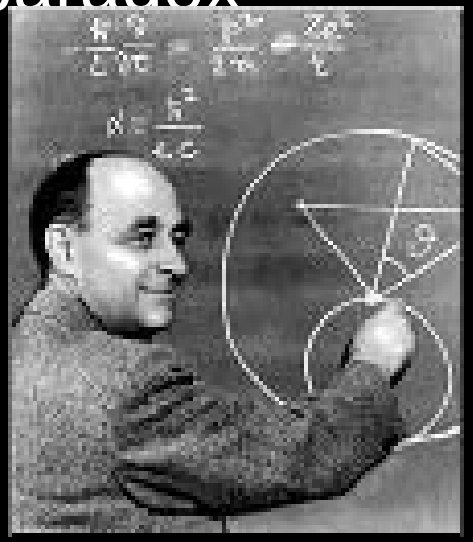



- How realistic?
  - Engineering
  - Limited by c
- Relativity and time dilation
- Wormholes and hyperspace?

# The Fermi Paradox




- Where are the aliens?
- Galactic colonization
- Resolving the paradox

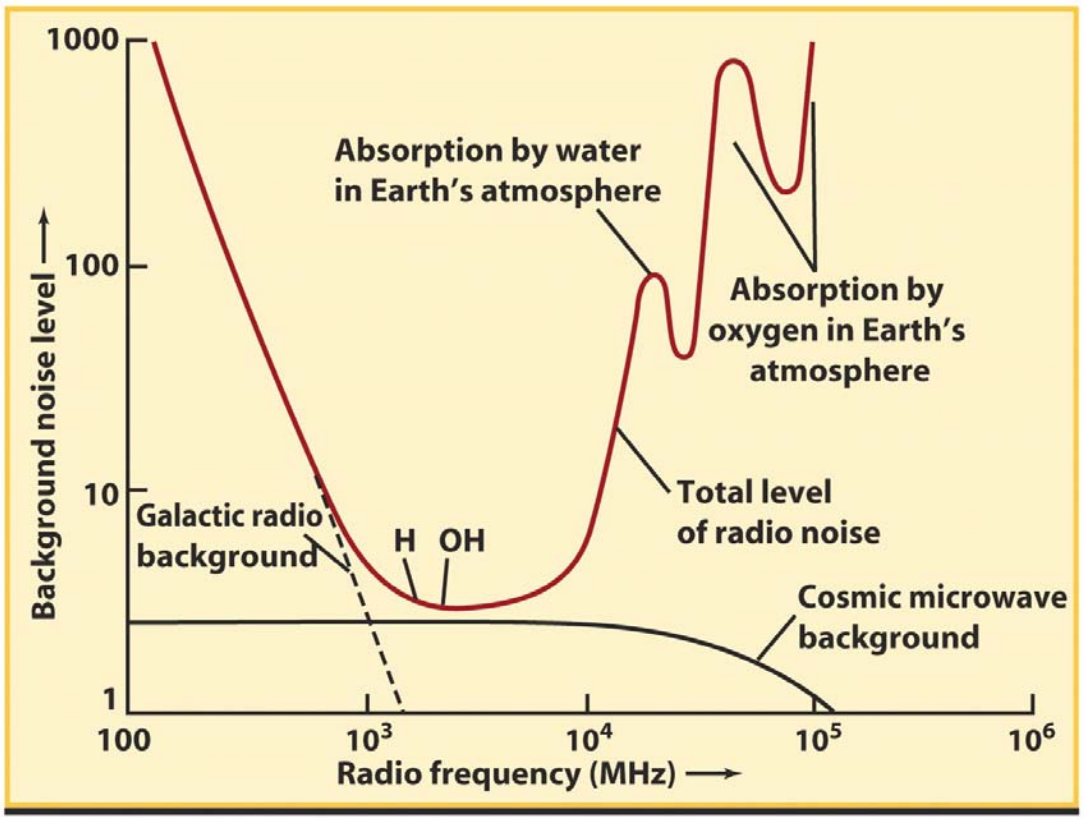
# Contact – Implications of the Search and Discovery

- Can we make contact
  - Which kind 1st, 2nd, 3rd
- Contact implications

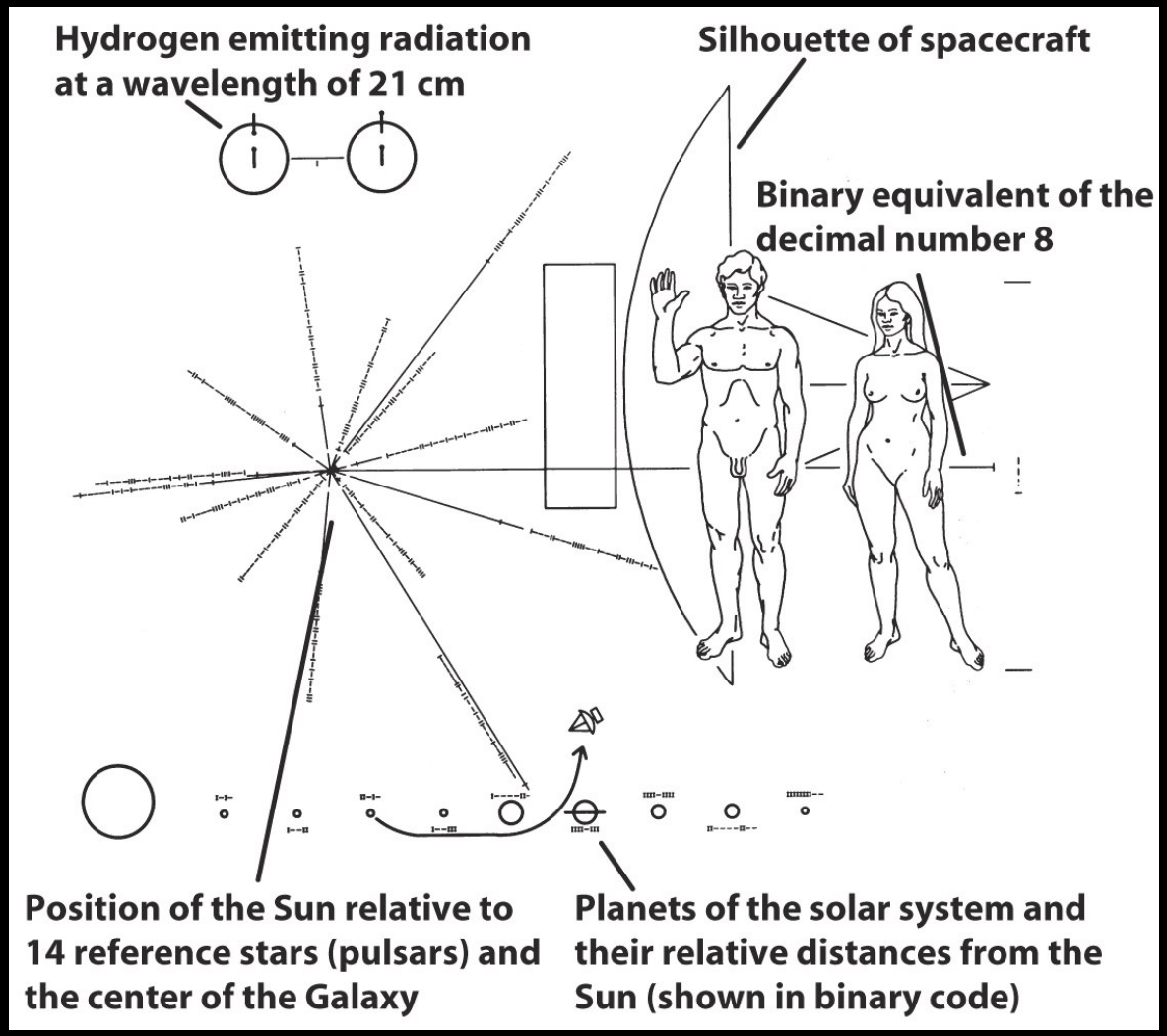



# Radio searches for alien civilizations are under way

- No signs of intelligent life have yet been detected
  - searches are continuing and using increasingly sophisticated techniques
- The so-called water hole is a range of radio frequencies in which there is little noise and little absorption by the Earth's atmosphere
  - scientists suggest that this noise-free region would be well suited for interstellar communication



# If an alien civilization were someday to find this message, which of the features on the plaque do you think would be easily understandable to them?



# Astrobiology in One Sentence

- The universe is unimaginably large, and alive; you are not at the center of the universe; and, the way to know the universe is through science.
  - » Dr. Harold Geller

HAVE A GREAT SUMMER