"The Planets"
Astro/EPS C12 (CCN 17045 or 32505)

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LEC: 2 LeConte TWTh, 2:40–5:00pm
Office Hours: 419 Campbell Hall,
Mon 3–4 and Tue 5–6

STAR PARTY

- 10PM TUES 12 AUG
- attendance optional (this is just for fun)
- meet at 10pm in front of Campbell Hall
- don't be late
- my cell 510-207-2236
- may be cancelled if weather is bad

QUIZ 2

- tomorrow
- 1 double-sided sheet of notes
- comprehensive (covers the entire course) but weighted more toward material not yet tested

Aliens?

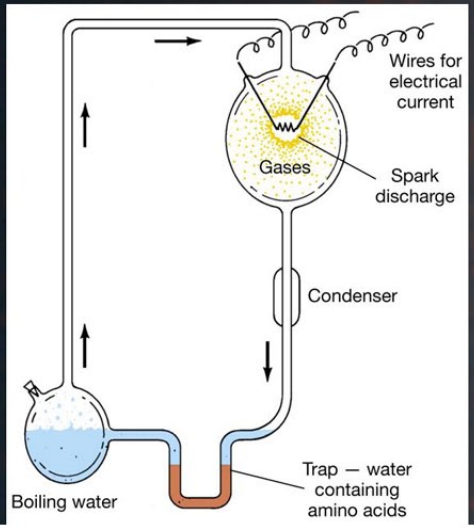
ASTROBIOLOGY

- the study of life in the Universe
- it is a relatively new, interdisciplinary science
  - biology
  - geology
  - astronomy
  - chemistry
  - physics
- just like planetary science was a new interdisciplinary science
  - geology
  - astronomy
  - chemistry
  - physics

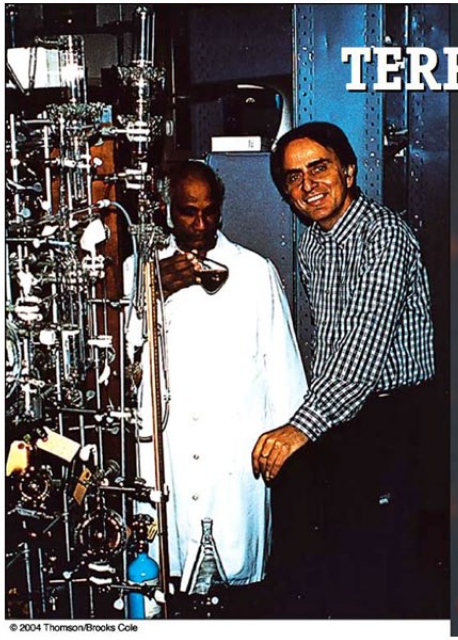
MORE PROBABLE ALIENS:

- cyanobacteria

RAW MATERIALS FOR LIFE



- terrestrial life is based on amino acids
  - compounds of C, H, N, O
  - building blocks of proteins
  - experiments mimicking early conditions have created amino acids



TERRESTRIAL LIFE

- Khare, Sagan (pictured), Miller, and Urey created amino acids out of gases simulating planetary atmospheres
- so far life is known only on Earth
- so we expect to find life in Earth-like places
- but chemical building blocks of life may be common elsewhere...

ORGANIC MOLECULES

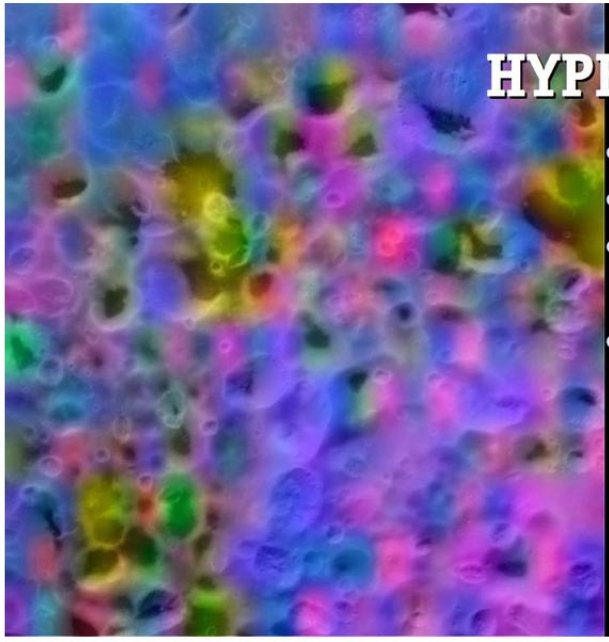
- organic means "containing C + H"
- complex organics common in interstellar dust, planetary nebulae...
- destroyed when material was heated and collapsed into protosolar disk

ORGANIC MOLECULES

- but complex organics common in comets, meteorites, interplanetary dust...
- are they easy to form?
- can be made using energy from electrical discharge, UV radiation, ion chemistry

HYPERION

- "regular" Saturnian satellite
- bright areas have water ice
- dark areas have organic material



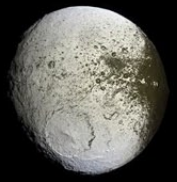
HYPERION

- R - CO_2
- G - CN?
- B - H_2O

- dark areas in craters have green and yellow (R+G) but not much blue

POLLUTED BY PHOEBE?

PHOEBE
- r ~ 220 km
- a ~ 215 R_S
- i ~ 173°



IAPETUS
- r ~ 1500 km
- a ~ 60 R_S
- i ~ 0.03°

HYPERION
- r ~ 220–360 km
- a ~ 25 R_S
- i ~ 0.43°

POLLUTED BY PHOEBE?

PHOEBE
- retrograde... captured KBO?

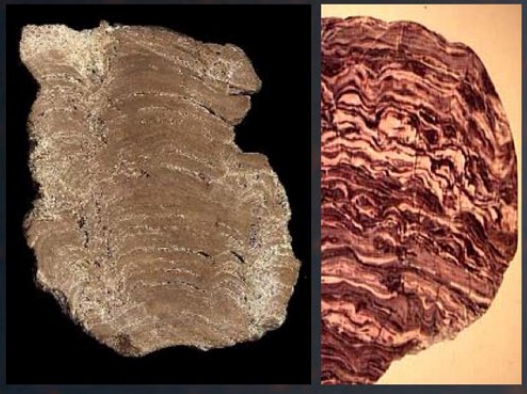
IAPETUS
- dark material on leading side

HYPERION
- dark material inside craters

MORE PROBABLE ALIENS:

- stromatolites
  - rock formations
  - created by colonies of microscopic cyanobacteria

OLDEST FOSSILS



- layers of sediment trapped in cyanobacteria colony mucous, eventually creating rock
- oldest are ~3.5 billion years old

MORE PROBABLE ALIENS:

- cyanobacteria

BIOLOGICAL CLASSIFICATION

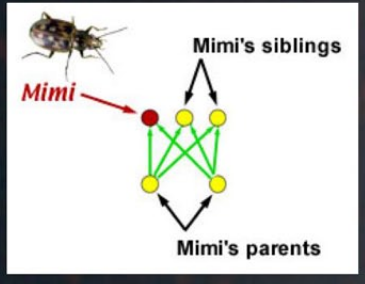
- the "old way" is based on physical characteristics of the organism
- developed in the 1700s by Carolus Linnaeus

Example classification: humans

As an example, consider the Linnaean classification for modern humans:

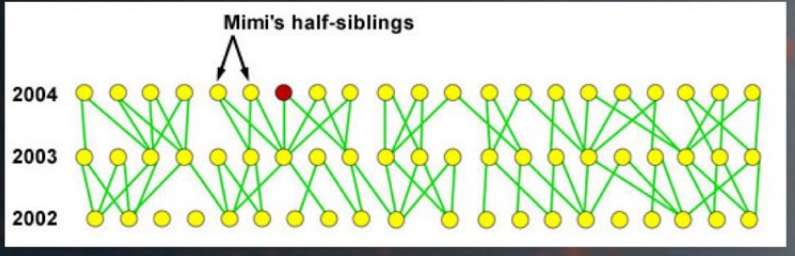
- **Kingdom:** Animalia (all animals, which are heterotrophs)
- **Phylum:** Chordata (all animals with a notochord)
- **Subphylum:** Vertebrata (all vertebrates, i.e., with a spinal column)
- **Class:** Mammalia (all vertebrates whose females secrete milk to nourish young)
- **Subclass:** Placentalia (Eutheria) (mammals who are nourished in utero through a placenta)
- **Order:** Primates (mammals with five opposable digits, binocular vision, and large brains)
- **Family:** Hominidae (all hominids, current and ancestral)
- **Genus:** *Homo* (upright primates; 'man')
- **Species:** *Homo sapiens* (humanity; 'wise man')
- **Subspecies:** *Homo sapiens sapiens*

BIOLOGICAL CLASSIFICATION

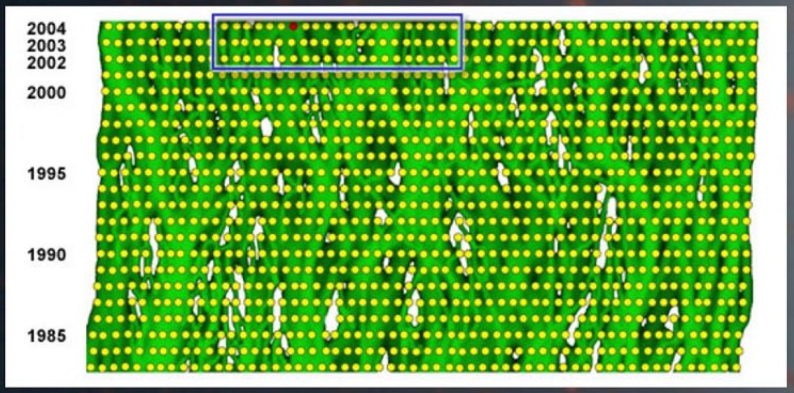


- newer schemes are based on genetic relationships
- all life on Earth is related
- these images are from tolweb.org (tree of life site)
- example: Mimi the beetle

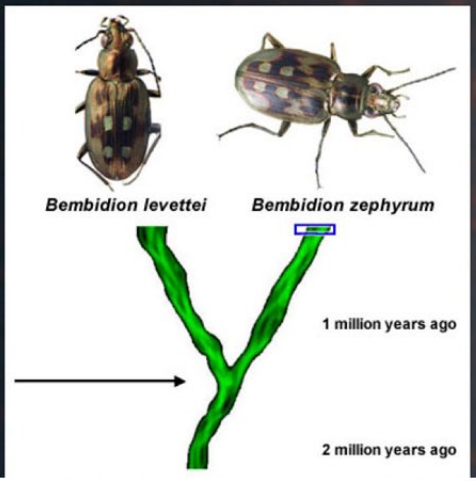
BIOLOGICAL CLASSIFICATION



BIOLOGICAL CLASSIFICATION

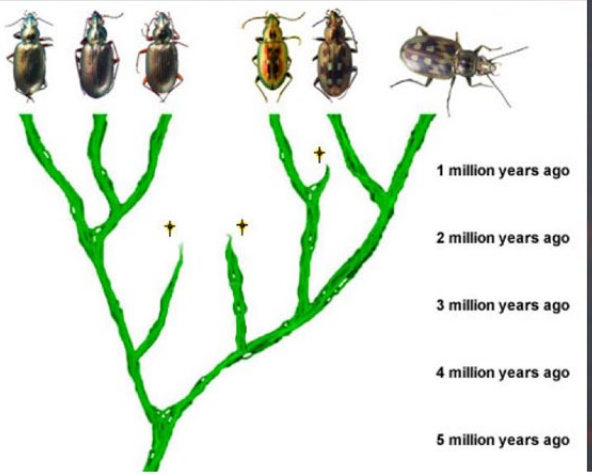


BIOLOGICAL CLASSIFICATION



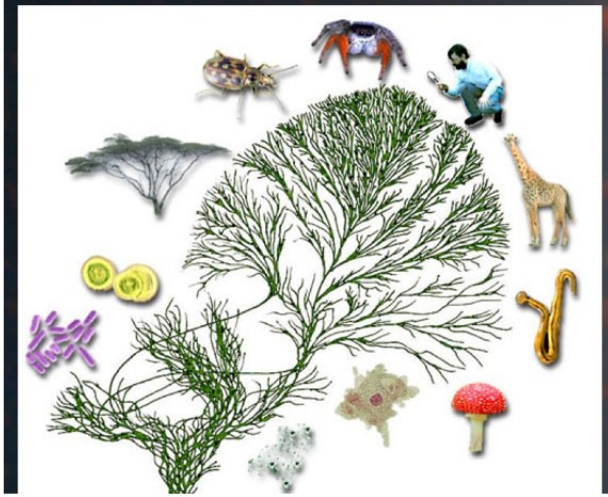
- two "species" are so different that they can't interbreed
- both descended from a common ancestor

BIOLOGICAL CLASSIFICATION



- branching is one-way
- diversity increases
- most successful survive: natural selection
- basis for evolution

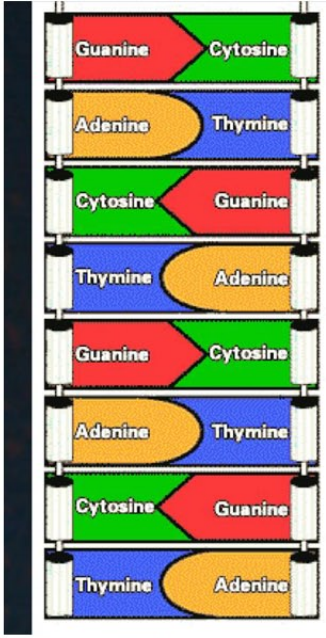
BIOLOGICAL CLASSIFICATION



- all life can be traced this way
- some rare exceptions to one-way branching, like mitochondria

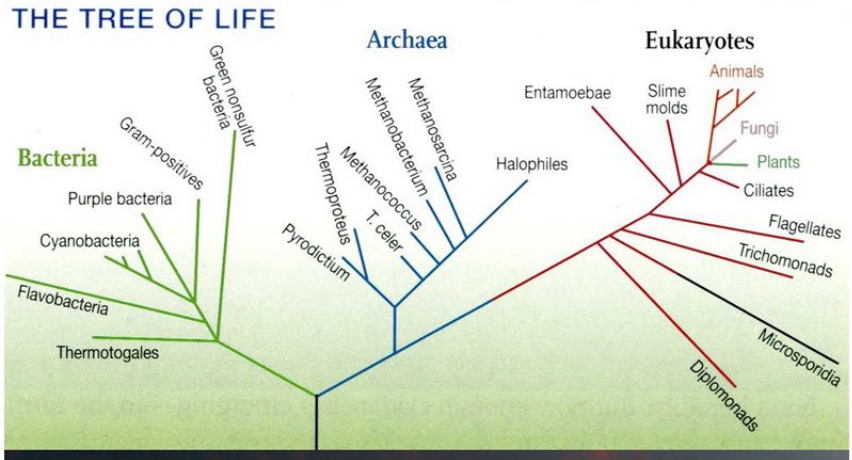
DNA

- DNA is a large molecule that can make copies of itself
- information is carried by the sequence of NUCLEOTIDES
- DNA sequences (genes) control what proteins cells make

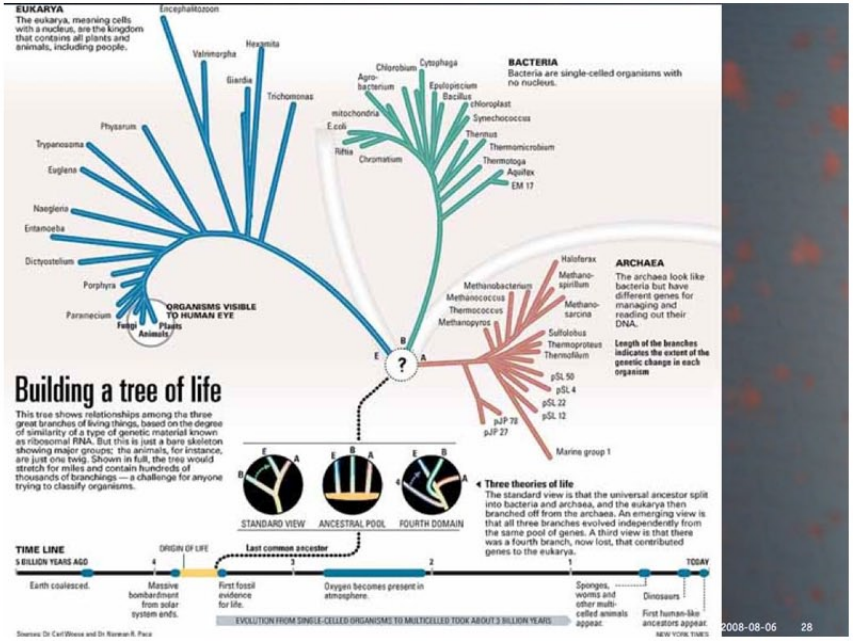


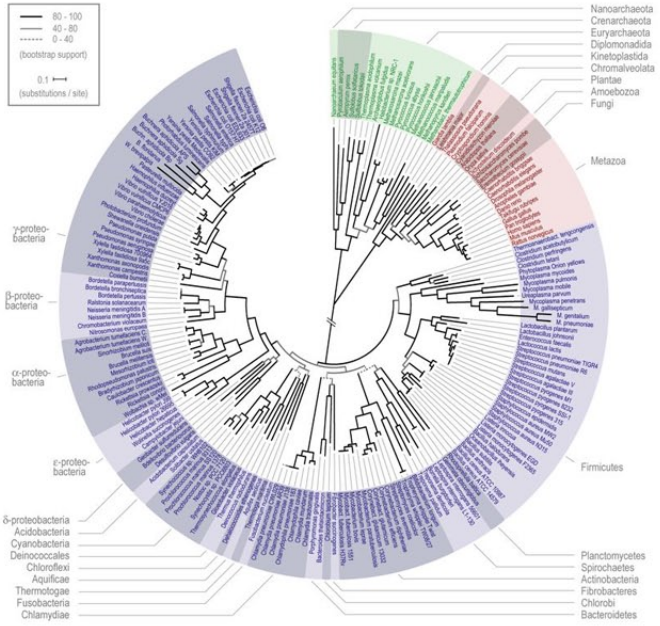
DNA/RNA

- the DNA "alphabet" includes only 4 nucleotides
- each nucleotide only fits together with is matching nucleotide
  - cytosine fits with guanine
  - thymine fits with adenine
- RNA is similar but has uracil instead of thymine

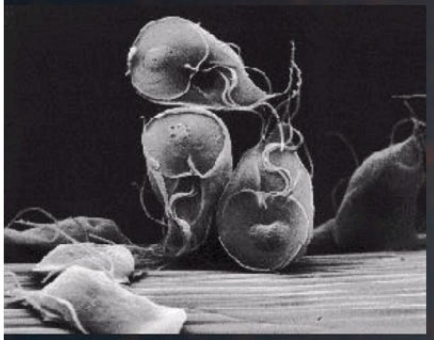


- organisms at end of branches
- distance between branches corresponds to genetic difference





DEFINITION OF LIFE



- reproduction
- metabolism
- ability to evolve

- but no firm definition can be made since there are always exceptions

REQUIREMENTS FOR LIFE

LIQUID WATER

- base for the chemical reactions of life

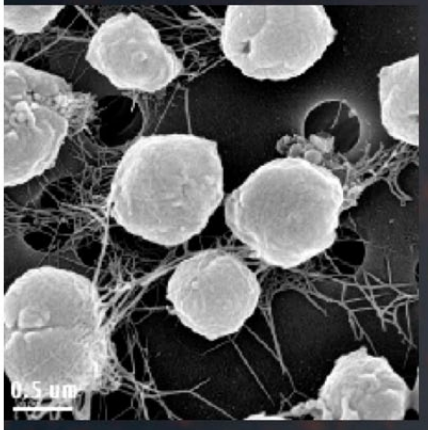
NUTRIENTS

- carbon
- nitrogen etc.
- to build proteins

ENERGY (food)

- sunlight
  - plants
  - photosynthesis
- chemical
  - we use oxygen
  - some microbes use metals
  - some METHANOGEN microbes use $H_2 + CO_2$ to make methane + water

EXTREMOPHILES



- deep-sea vent methanogen bacteria
- it is difficult or impossible to find an area on Earth with no life
- prokaryotes (microbes with no cell nuclei) are the largest biomass
- in your body they outnumber your own cells 10 to 1

THE DEEP OCEAN

(Robert A. Patzner, Salzburg, Austria)

- this fish still relies on (indirect) solar energy
- anaerobes (living without oxygen) populate seafloor vents
- superheated water temperatures can be ~120°C

METHANOGENS

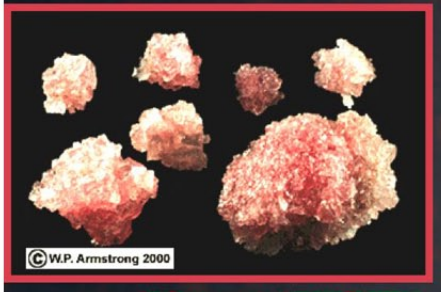
- do not tolerate oxygen
- type of archea

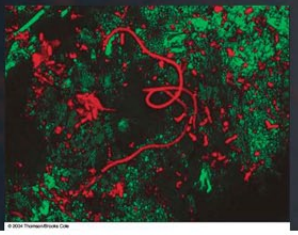
- found:
  - swamps
  - guts
  - seafloor vents
  - in rock km beneath the surface
  - ice

ACID, SALT

- organisms found "eating metal" in pure acid environments in abandoned mines
- halobacteria live in extremely salty environments

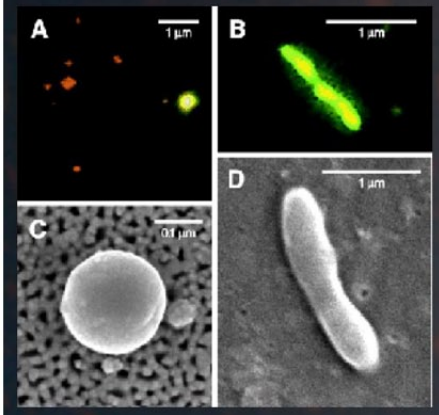
DEEP UNDERGROUND





- halobacteria have been revived from salt crystals underground in mines for 100s of thousands of years
- methanogen bacteria are found living kms below the surface

ICE



- 3.6 km deep ice core
- ice core yields climate data going back 400,000 years
- bacteria function at temperatures of −12°C to −17°C

TARDIGRADE

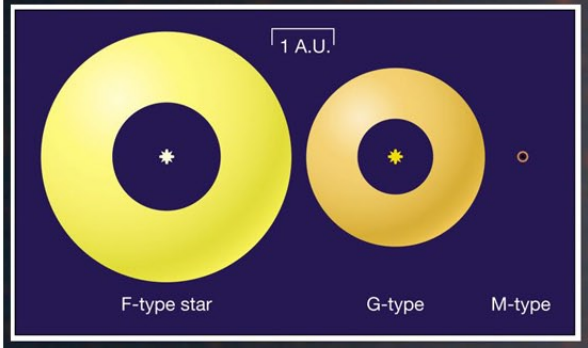
- "water bears" or "moss piglets"
- <1 mm long
- dormant ones have been revived after 120 years
- survive liquid helium (1 K), 151°C, xrays 250x lethal human dose, vacuum, 6000 bar pressures

PANDAGRADE

ECOSPHERES

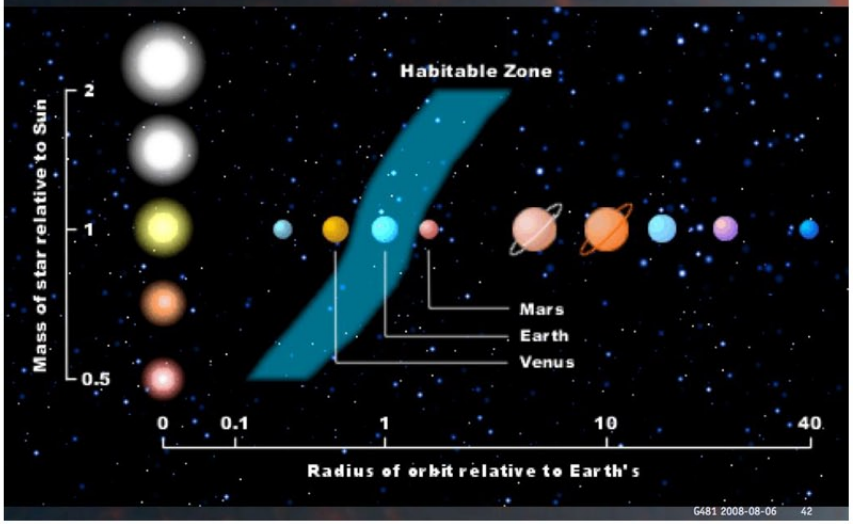
- places where life might exist
  - habitable zones around stars
  - habitable pockets
- requirements for life satisfied
  - liquid water
  - nutrients
  - energy

THE HABITABLE ZONE

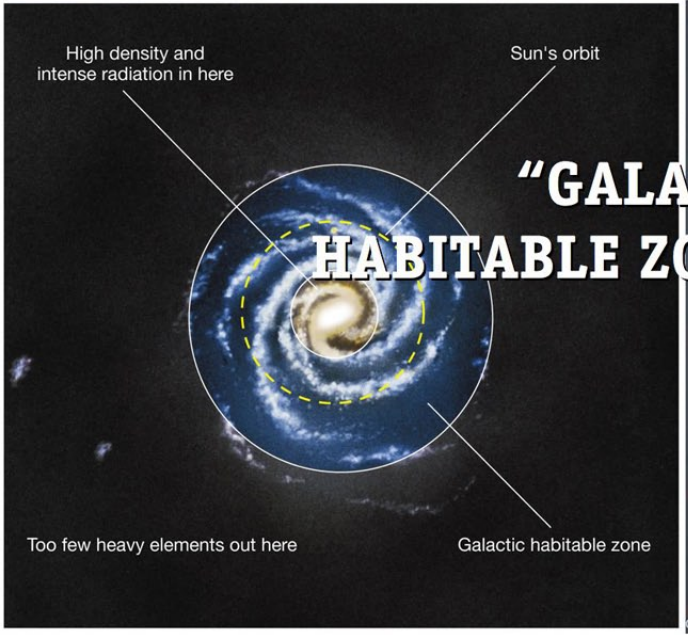


- planets must not be too hot or too cold to support life
- liquid water defines "too cold/too hot"
- habitable zone depends on stellar luminosity

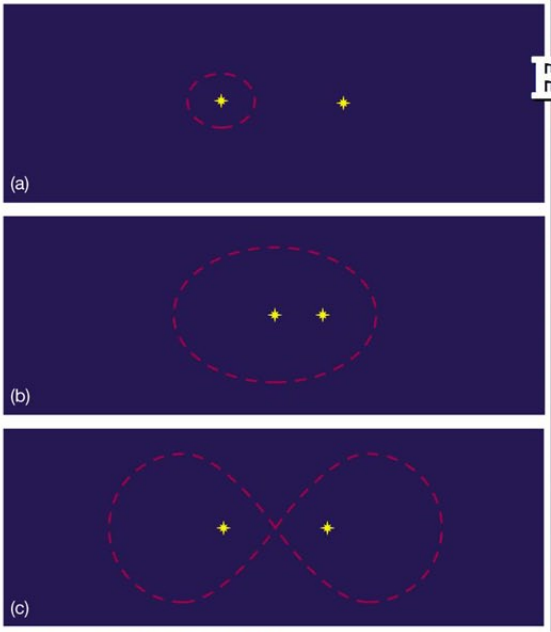
THE HABITABLE ZONE



- orbits too close to the star could result in synchronous rotation

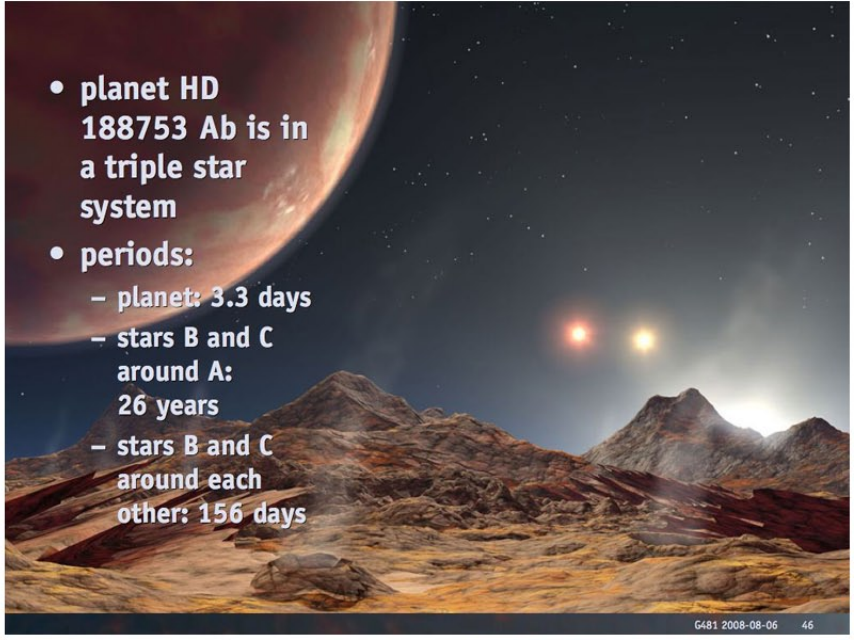


"GALACTIC HABITABLE ZONE"



BINARIES

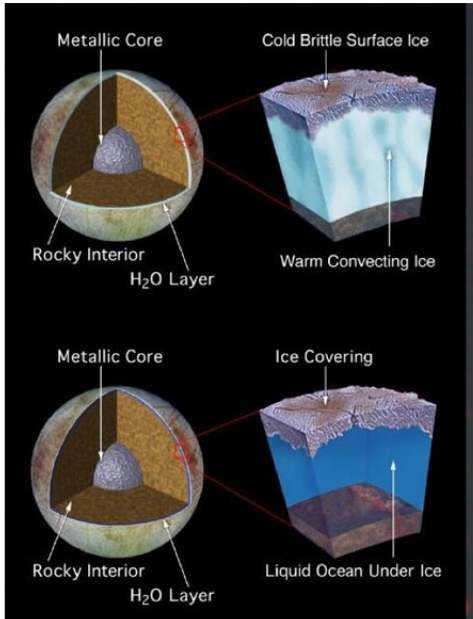
- a habitable planet might have orbit A or B
- orbit C would probably not be stable, so not good for life



- planet HD 188753 Ab is in a triple star system
- periods:
  - planet: 3.3 days
  - stars B and C around A: 26 years
  - stars B and C around each other: 156 days

"HABITABLE POCKETS"

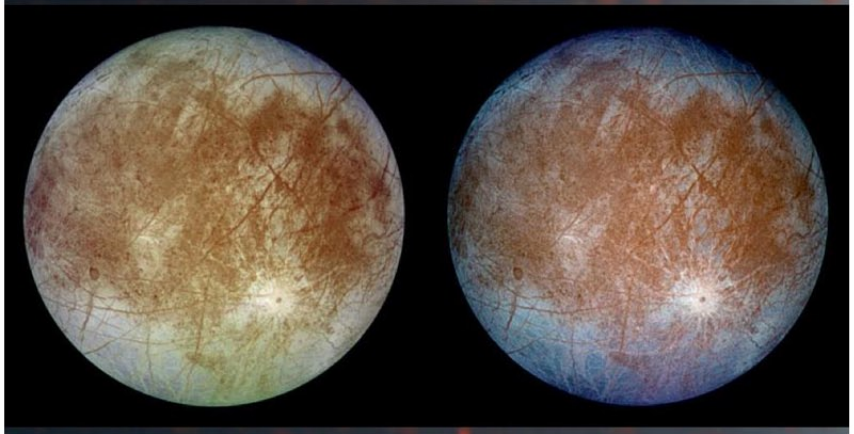
- Jupiter system is too far from the Sun to be in the habitable zone
- tidal forces on the Galilean satellites heat their interiors; some can maintain LIQUID water inside
- Enceladus, Titan, other icy bodies may provide more habitable pockets

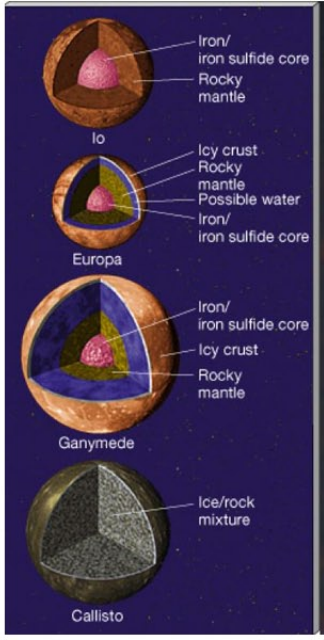


EUROPA

- ice crust thickness unknown, 5-20 km

EUROPA



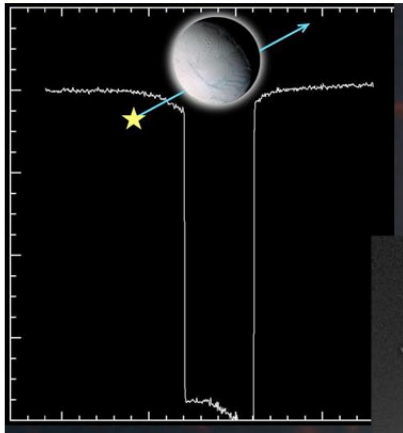


GANYMEDE

- ice crust ~100 km thick
- larger ocean than Europa, but sandwiched between ice layers
- only Europa likely to have a water-rock interface
- (indirect evidence for ocean beneath Callisto's surface also)

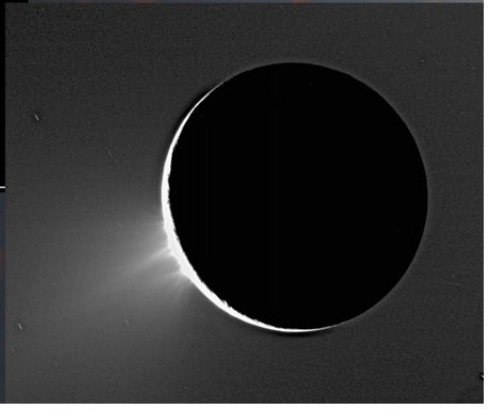
HEATING PLANETARY INTERIORS

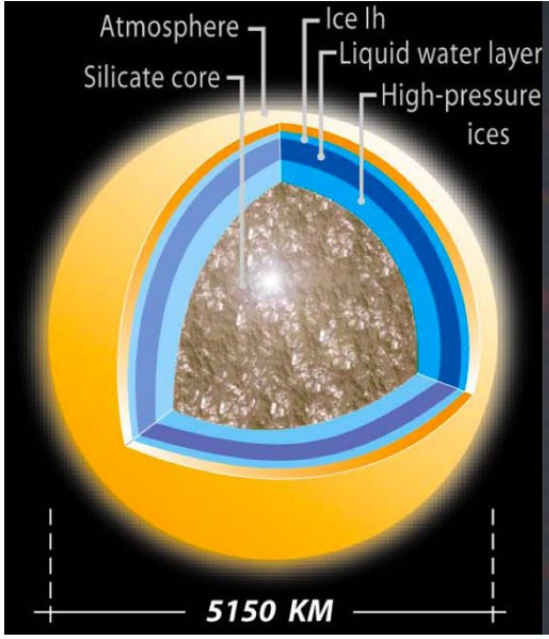
- gravitational energy from formation
  - impacts
  - differentiation
- tidal heating
- nuclear energy
  - radioactive decay (fission, not fusion)
  - uranium, thorium, potassium
  - aluminum-26 was important for some asteroids



ENCELADUS

- where is the water coming from?

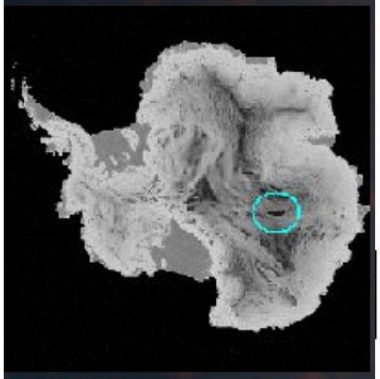


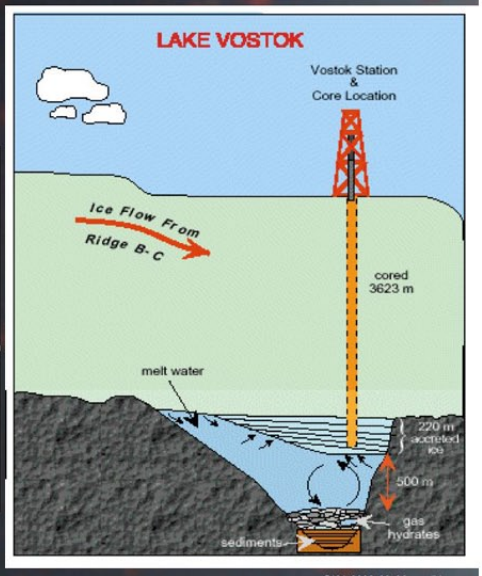


TITAN TOO?

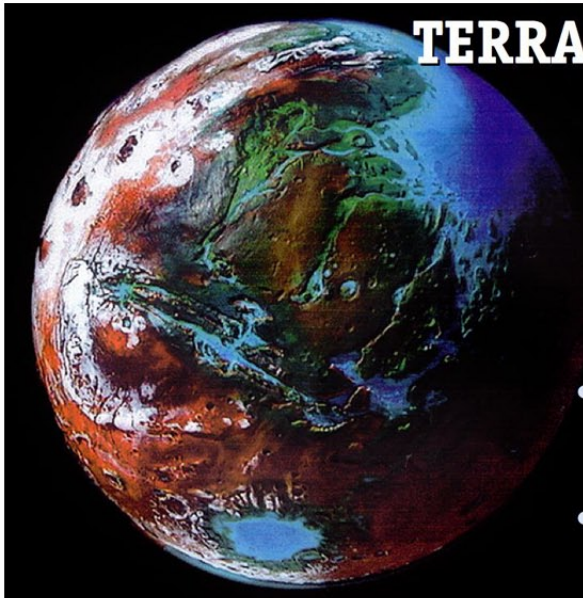
- ocean predicted by models of Titan's evolution
- positions of landmarks shifted 30km betw 2004, 2007 (radar)

LAKE VOSTOK





TERRAFORMING MARS



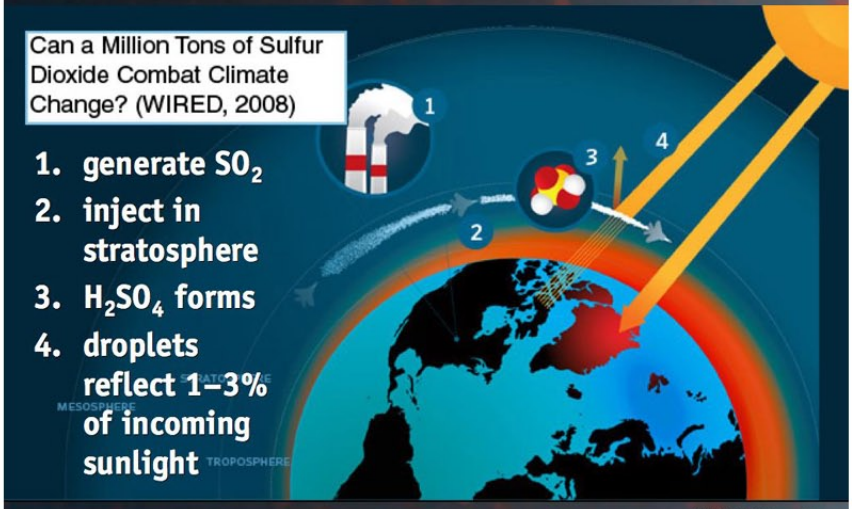
- terraforming = making it earthlike
- ethical issues

Model by Chris Wayan 2004

ALTERING EARTH'S CLIMATE

Can a Million Tons of Sulfur Dioxide Combat Climate Change? (WIRED, 2008)

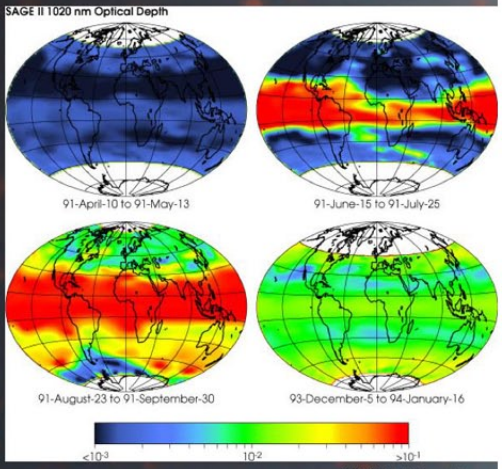
1. generate SO_2
2. inject in stratosphere
3. H_2SO_4 forms
4. droplets reflect 1–3% of incoming sunlight



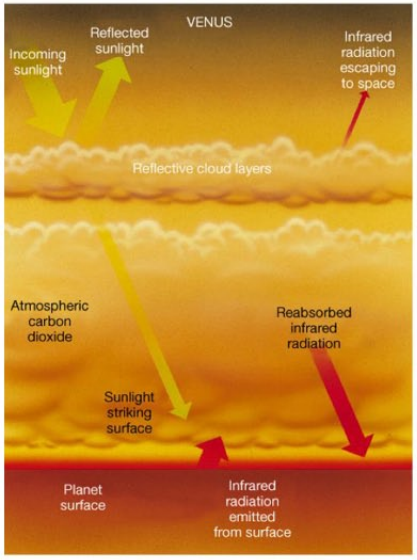
MT. PINATUBO

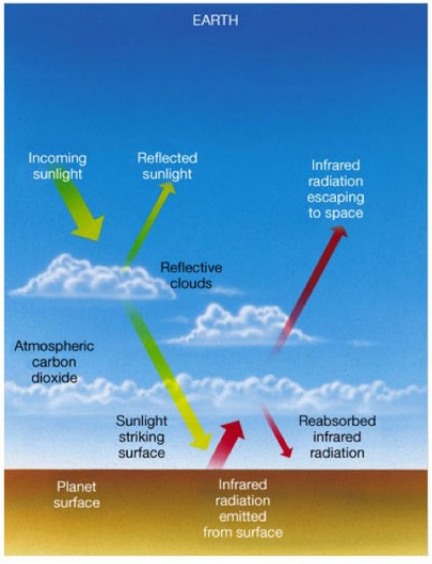
MT. PINATUBO

- injected SO_2 into stratosphere
- $SO_2 + H_2O$ --> sulfuric acid
- Earth's temperature was lowered for 2 years

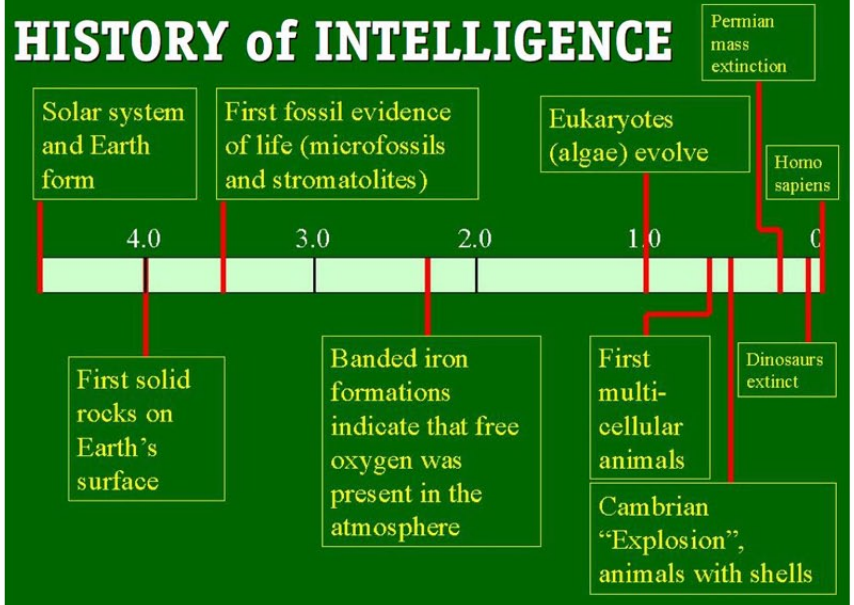


VENUS vs. EARTH





HISTORY of INTELLIGENCE



The Drake Equation

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

Where,

N = The number of civilizations in The Milky Way Galaxy whose radio emissions are detectable.

R_* = The rate of formation of stars suitable for the development of intelligent life.

f_p = The fraction of those stars with planetary systems.

n_e = The number of planets, per solar system, with an environment suitable for life.

f_l = The fraction of suitable planets on which life actually appears.

f_i = The fraction of life bearing planets on which intelligent life emerges.

f_c = The fraction of civilizations that develop a technology that releases detectable signs of their existence into space.

L = The length of time such civilizations release detectable signals into space.

- **number of detectable intelligent civilizations in the galaxy depends on several necessary factors**

THE DRAKE EQUATION

All stars in the Milky Way

Star systems:

With planets
with planetary habitats
With simple life
With intelligence
With technical society
With long-lasting technology

SETIs

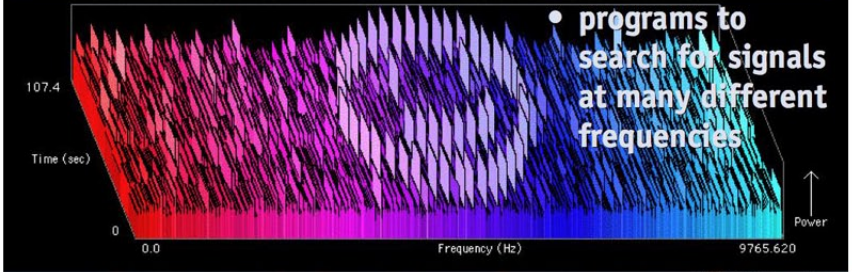
The Search for Extraterrestrial Intelligence at HOME

Version 1.0
http://setiathome.ssl.berkeley.edu

Data Analysis
Chirping data 100%
Doppler drift rate: 2.2460 Hz/sec
Frequency resolution: 0.074506 Hz
Strongest Peak: power 156.39
(2887.2 Hz at 67.11 seconds, drift rate 0.349 Hz/sec)
Strongest Gaussian: power 1.51, fit 25.491
(2150.5 Hz at 43.62 seconds, drift rate 1.775 Hz/sec)
Overall: 17.960% done
CPU time: 4 hr 49 min 37.9 sec

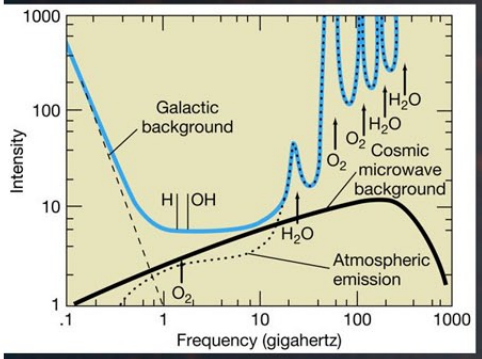
Data Info
From: 10 hr 32 min 45 sec RA, + 20 deg 12 min 35 sec Dec
Recorded on: Fri Jan 8 07:07:30 1999 GMT
Source: Arecibo Radio Observatory
Base Frequency: 1.41888671 7GHz

User Info
Name: Bob van de Walle
Data units completed: 4
Total computer time: 247 hr 56 min 26.7 sec



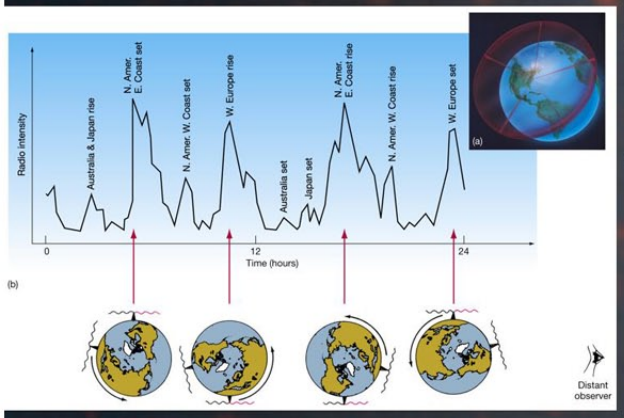
- **programs to search for signals at many different frequencies**

RADIO, 18-21cm

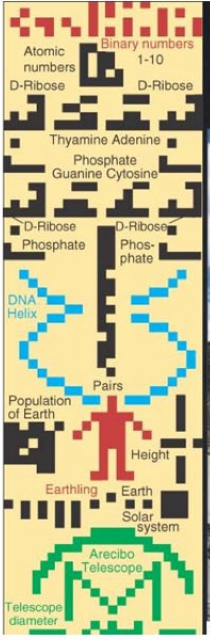


- **certain radio wavelengths seem more likely to be used**
- **minimum galactic background**
- **minimum atmospheric interference**

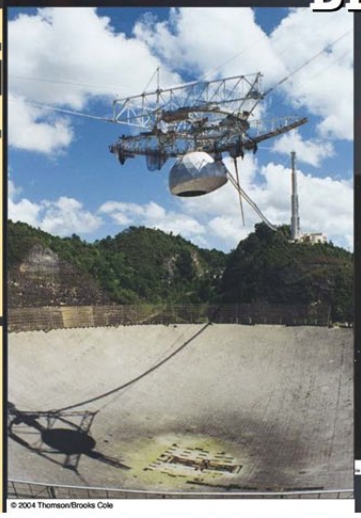
ARE THEY WATCHING TV?

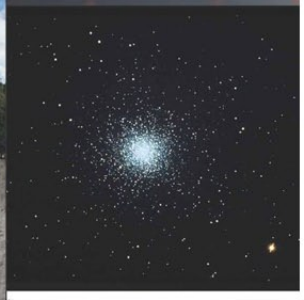


- radio & TV broadcasts for 70 years
- signals would have reached stars 70 light-years away

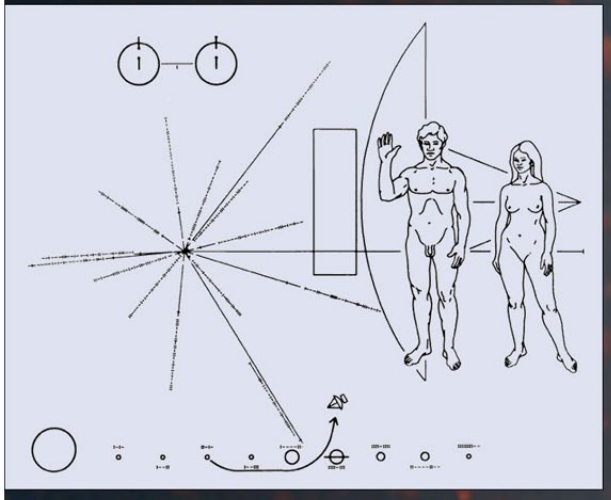


INTENTIONAL BROADCAST





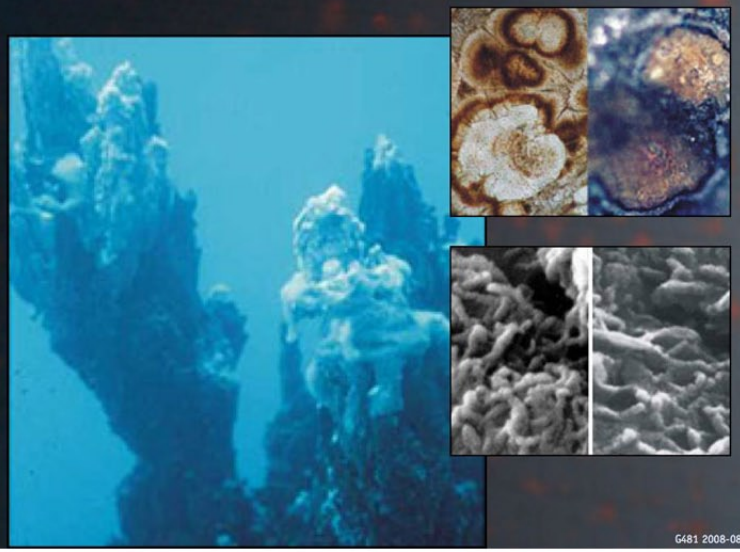
PIONEER 11 PLAQUE



MARS METEORITE ALH84001

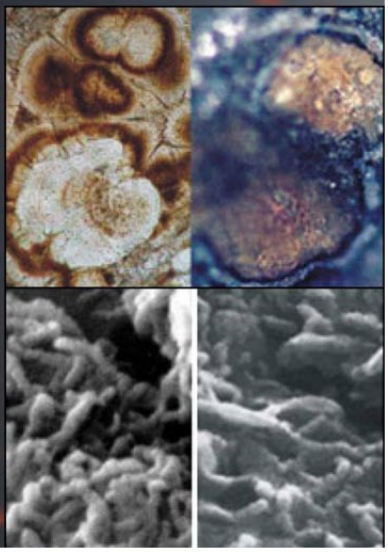
- rock contains 3.6-billion year old features
- carbonates
  - formed in the presence of water
- "nano-bodies"
  - possible micro-fossils?

LAKE VAN vs. ALH84001



LAKE VAN vs. ALH84001

- Earth features on left, Mars features on right
- cyanobacteria grow in calcium-rich Lake Van in Turkey
- structures may be too small to be fossil organisms
- unknown if they are from biological or mineral processes



CHEMICAL "BIOMARKERS"

- Viking Mars mission baked soil and searched for organic molecules
- Phoenix lander currently doing chemistry experiments
- CH_4 (methane) on Mars/Titan is not stable over long timescales; what is the source?
- other advanced chemical signs may work: isotopic signatures, chirality

CHEMICAL "BIOMARKERS"

- MSL in 2010 is planned to do the search again with improved technology