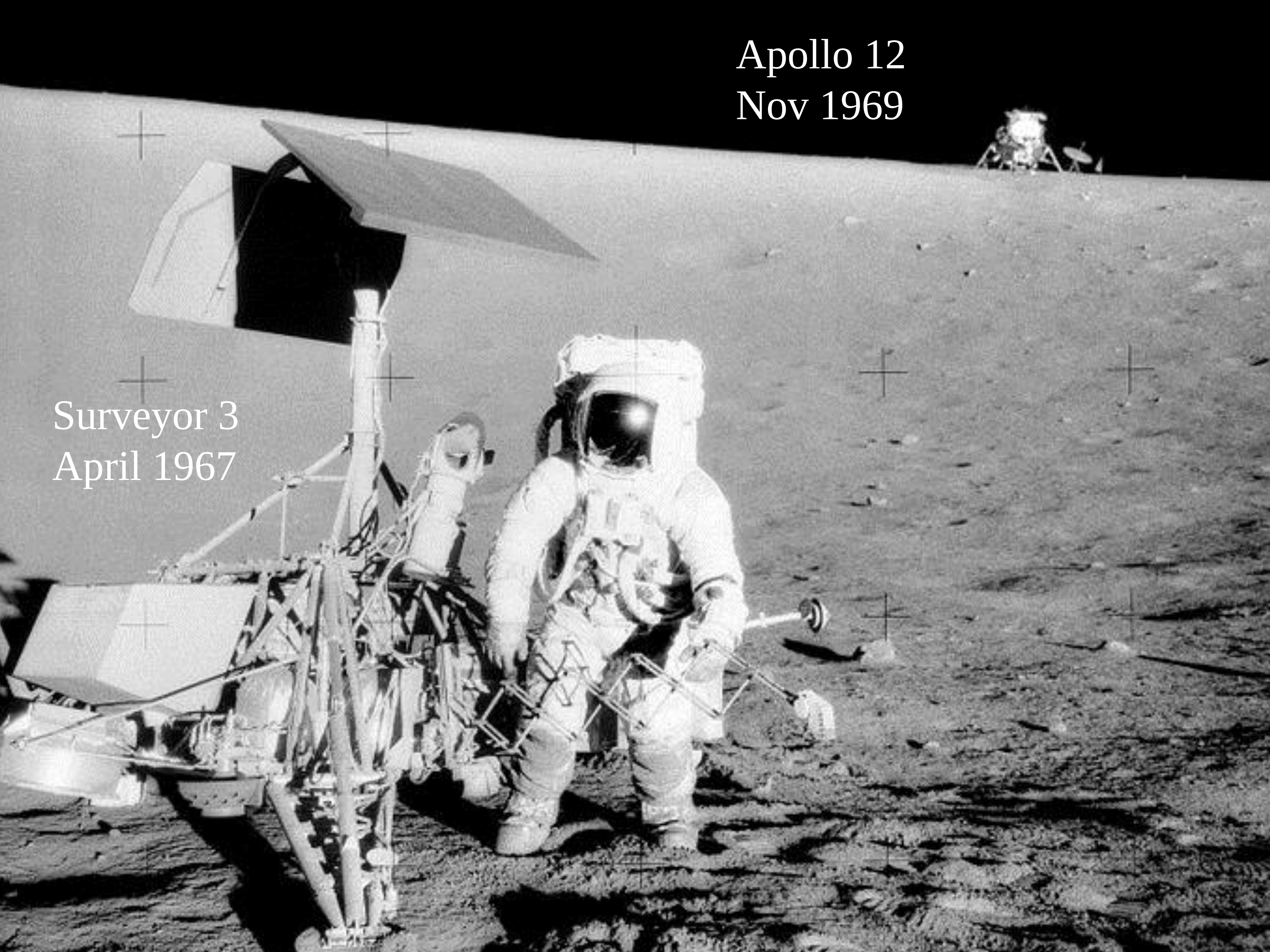
ASTR/GEOL-2040: Search for life in the Universe: Lecture 17

- Life on the edge
- Extremophiles
- Implications for
  - Origin of Life

Axel Brandenburg
(Office hours: Mondays 2:30 – 3:30 in X590 and
Wednesdays 11-12 in D230)


Apollo 12
Nov 1969
Surveyor 3
April 1967

Surveyor III: Bacterium isolated from lunar-retrieved TV camera

F. J. MITCHELL*
Lunar Receiving Laboratory, Manned Spacecraft Center, Houston, Texas 77058
and
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Brown and Root-Northrop, Manned Spacecraft Center, Houston, Texas 77058

(*Received* 9 *February* 1971; *accepted in revised form* 31 *March* 1971)

Abstract—Selected components of the unmanned Surveyor III spacecraft which had remained on the lunar surface for 2½ years were collected and returned to earth by the crew of Apollo 12. A bacterium, *Streptococcus mitis*, was isolated from a sample of foam taken from the interior of the retrieved TV camera. The available data suggests that the bacterium was deposited in the camera prior to the Surveyor III spacecraft launch. The authors suggest that lyophilizing conditions existing during prelaunch vacuum testing and later on the lunar surface may have been instrumental in the apparent survival of this microorganism.

Freeze-drying

Note: contamination possible, but ….

- Delay before culture began growing (consistent with dormant spores, not fresh)
- Microbes clung exclusively to foam
- Only a few bacteria found, not a whole population

Streptococcus from Surveyor 3

- 50 – 100 organisms discovered
  - Survived launch, space vacuum, radiation
- Deep freeze (20 K)
  - no nutrients, water, energy
- Freeze-dried
  - Not extremophiles, they merely survived
- Implications for panspermia

Astronomer Guillermo Gonzales:

The “where” depends on scientist’s discipline

- Science fiction writers: seeded from space
- Biochemist (e.g. Stanley Miller): tidal pool
- Astronomers (some): comets
- Geologists: hydrothermal vents
  - Russell: First Life (temp link: http://lcd-www.colorado.edu/~axbr9098/teach/ASTR_2040/material/Russell06_FirstLife.pdf)

SUBMARINE HYDROTHERMAL VENTS AND ASSOCIATED GRADIENT ENVIRONMENTS AS SITES FOR THE ORIGIN AND EVOLUTION OF LIFE

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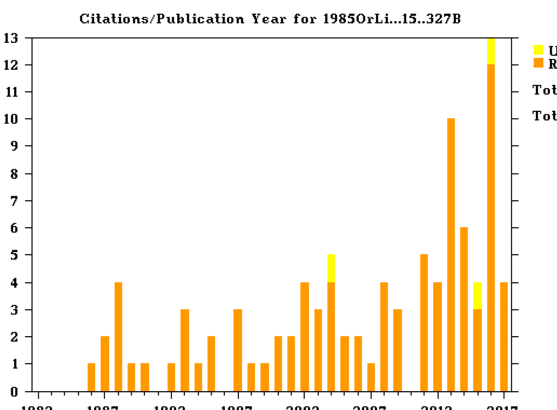
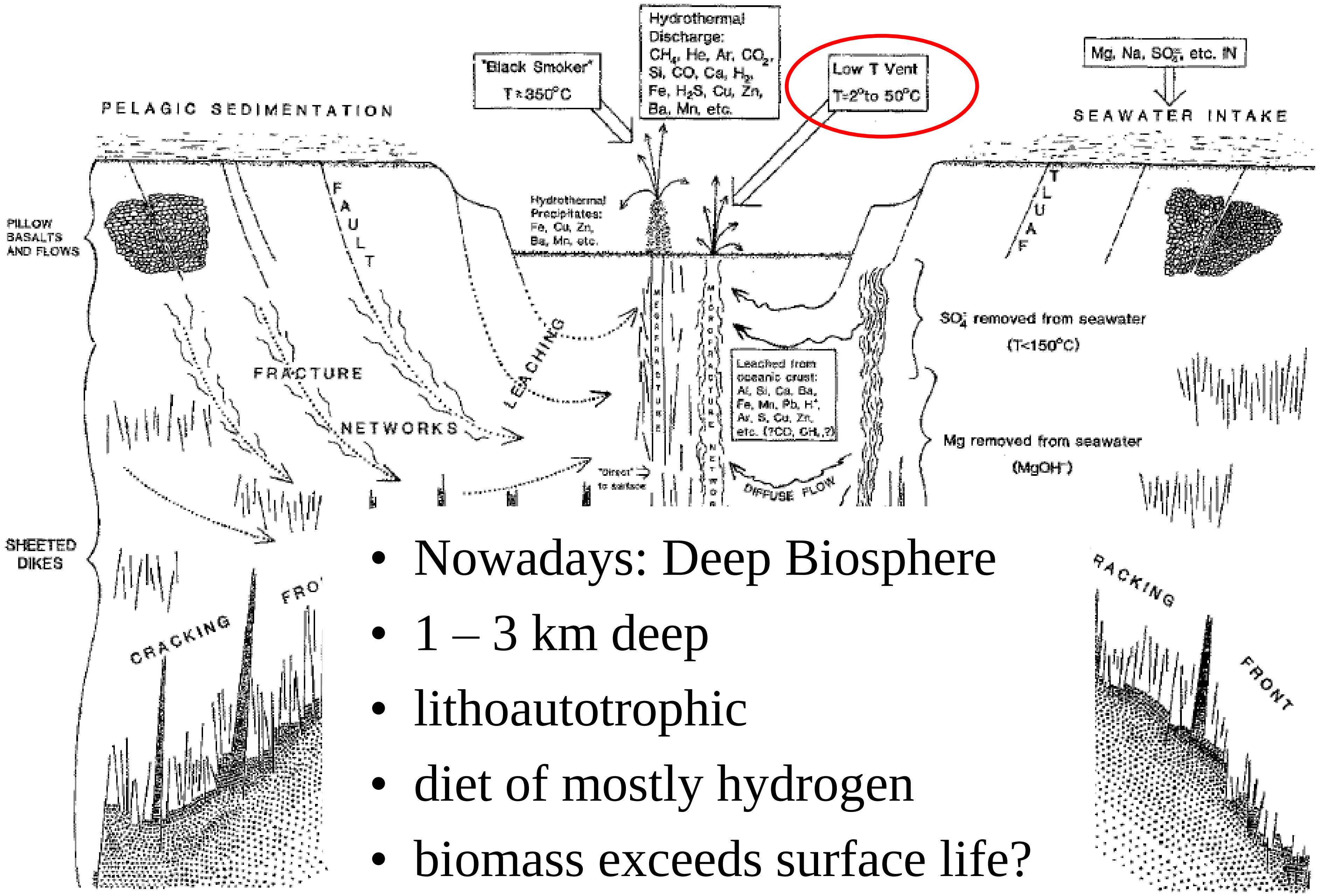
(Received 21 March; in revised form 16 April, 1985)

Abstract. Submarine hydrothermal vents are the only comtemporary geolo
called truly primeval; they continue to be a major source of gases and dissolv
as they were to the Archean ocean. Then, as now, they encompassed a mul
gradients as a direct result of interactions between extensive hydrothermal
the overlying oceanic and atmospheric environments. We have proposed t
necessary multiple pathways for the abiotic synthesis of chemical comp
'precells' and 'precell' communities and, ultimately, the evolution of free-liv
consistent with the tectonic, paleontological, and degassing history of the

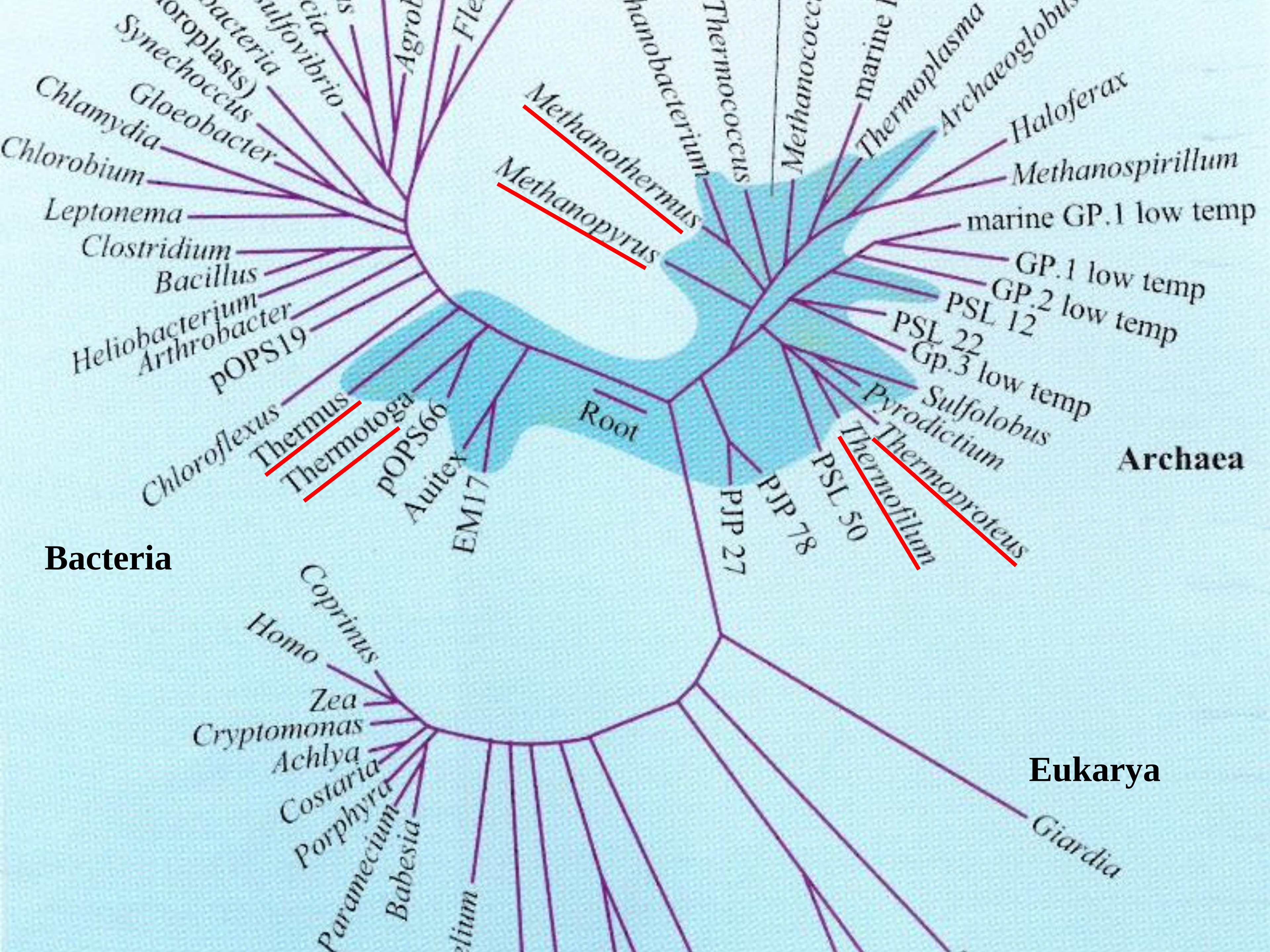




- Nowadays: Deep Biosphere
- 1 – 3 km deep
- lithoautotrophic
- diet of mostly hydrogen
- biomass exceeds surface life?

Arguments for hydrothermal vents

- Well protected from vaporizing impacts
- Energy-rich (H_2+CO → CH_2O)
- Reduced minerals interacting with sea water (2FeO + H_2O → Fe_2O_3 + H_2)
- Phylogeny suggests thermophile at root of tree


Synechoccus
Chlamydia
Gloeobacter
Chlorobium
Leptonema
Clostridium
Bacillus
Heliobacterium
Arthrobacter
pOPS19
Chloroflexus
Thermus
Thermotoga
pOPS66
Auitex
EM17
Root
Methanothermus
Methanopyrus
Thermococcus
Thermoplasma
Archaeoglobus
Haloferax
Methanospirillum
marine GP.1 low temp
GP.1 low temp
GP.2 low temp
PSL 12
PSL 22
Gp.3 low temp
Sulfolobus
Pyrodictium
Thermoproteus
Thermofilum
PSL 50
PJP 78
PJP 27
Archaea
Bacteria
Coprinus
Homo
Zea
Cryptomonas
Achlya
Costaria
Porphyra
Paramecium
Babesia
Giardia
Eukarya

Extremophiles: huge list

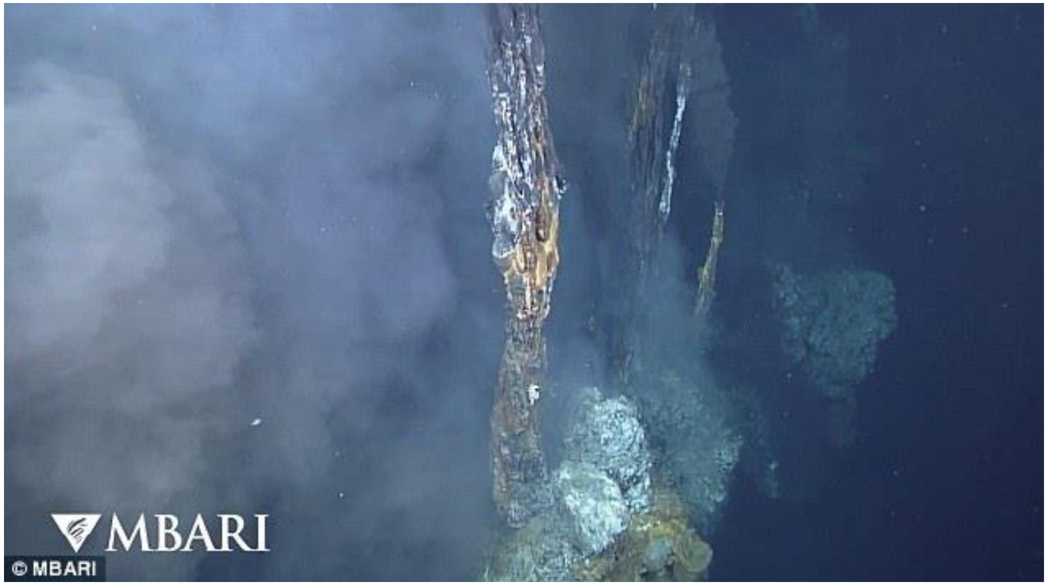
- Physical: temperature & pressure
  - Hyperthermophiles, thermophiles, mesophiles, psychrophiles, piezophiles, barophiles, …
- Chemical: NaCl, H_2O, pH, O_2, …
  - Halophiles, xerophiles (no H_2O), acidophiles, alkalophiles (pH), anaerobes, aerobes
- Radiation (also physical, but different):
  - radiophiles

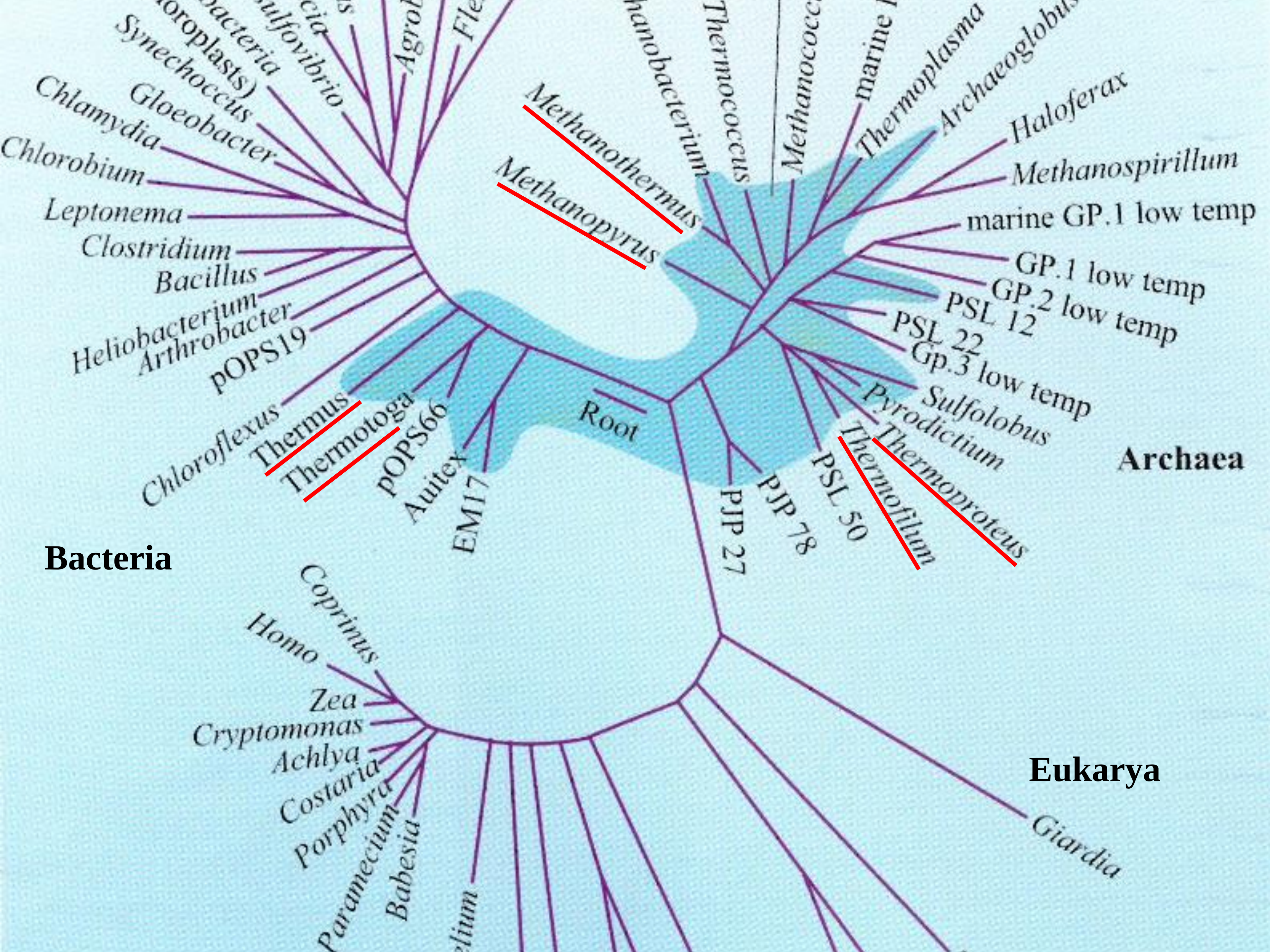
Life on the edge

- Extremophile (love extreme environments)
- Thrive in this environment
- Not merely survive

Example: thermophiles

- *Methanopyrus kandleri*
- Lives at 84 – 100 C (183 – 212 F)
- (in the lab reproduces even at 122 C = 252 F)
- Black smokers (Gulf of California)

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marine GP.1 low temp
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PSL 12
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Gp.3 low temp
Sulfolobus
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Thermoproteus
Thermofilum
PSL 50
PJP 78
PJP 27
Root
Archaea
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Homo
Zea
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Achlya
Costaria
Porphyra
Paramecium
Babesia
Giardia
Eukarya

How do they do it?

- Temperature: special proteins
  - Elevated G+C too A+T or A+U
  - More stable
- Low temperature: 2 methods
  - Depress freezing point (salts, glycerol)
  - Proteins binding to edges of ice crystals

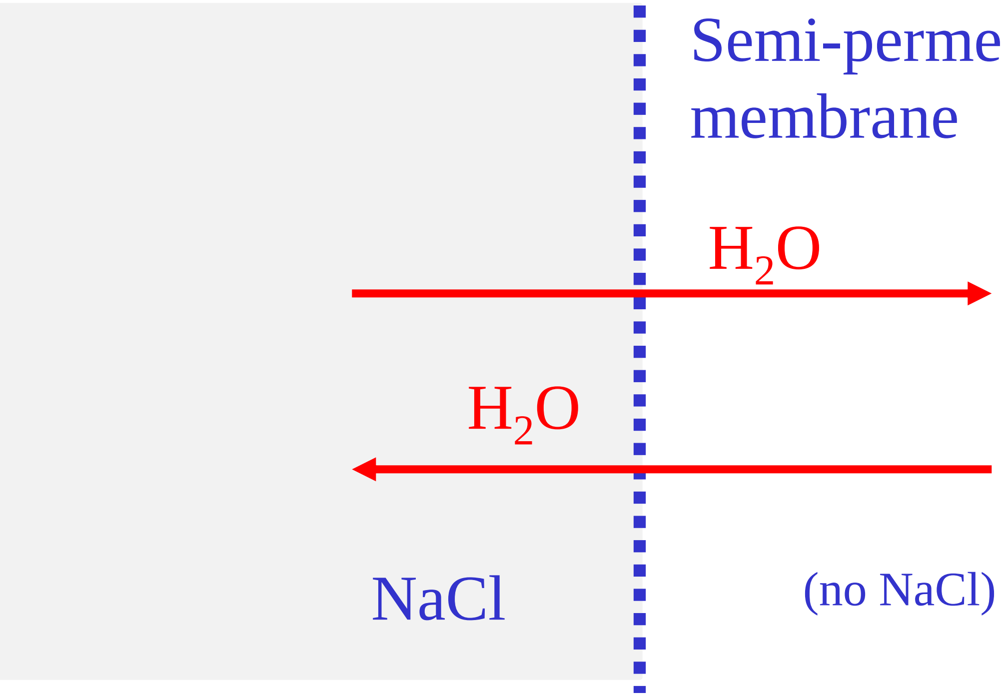
Extreme pH values

- pH measures fraction of H per molecule
  - pH=7 → 10^{-7} H atoms per H_2O molecule
- Acidophiles: thrive in pH = 0.7 – 4
  - Hydrothermal vents, black smokers
  - Survive by keeping acid out!
- Alkalophiles: thrive in pH = 9 – 12.5
  - Soda lakes
  - Neutrality inside cells

High & low salt concentrations

- Organisms can live within range of salinity
  - from destilled to saturated!
- Halophiles *require* high salinity to live
  - optimal range from 2x to 5x
  - E.g., in great salt lake, dead sea, salterns

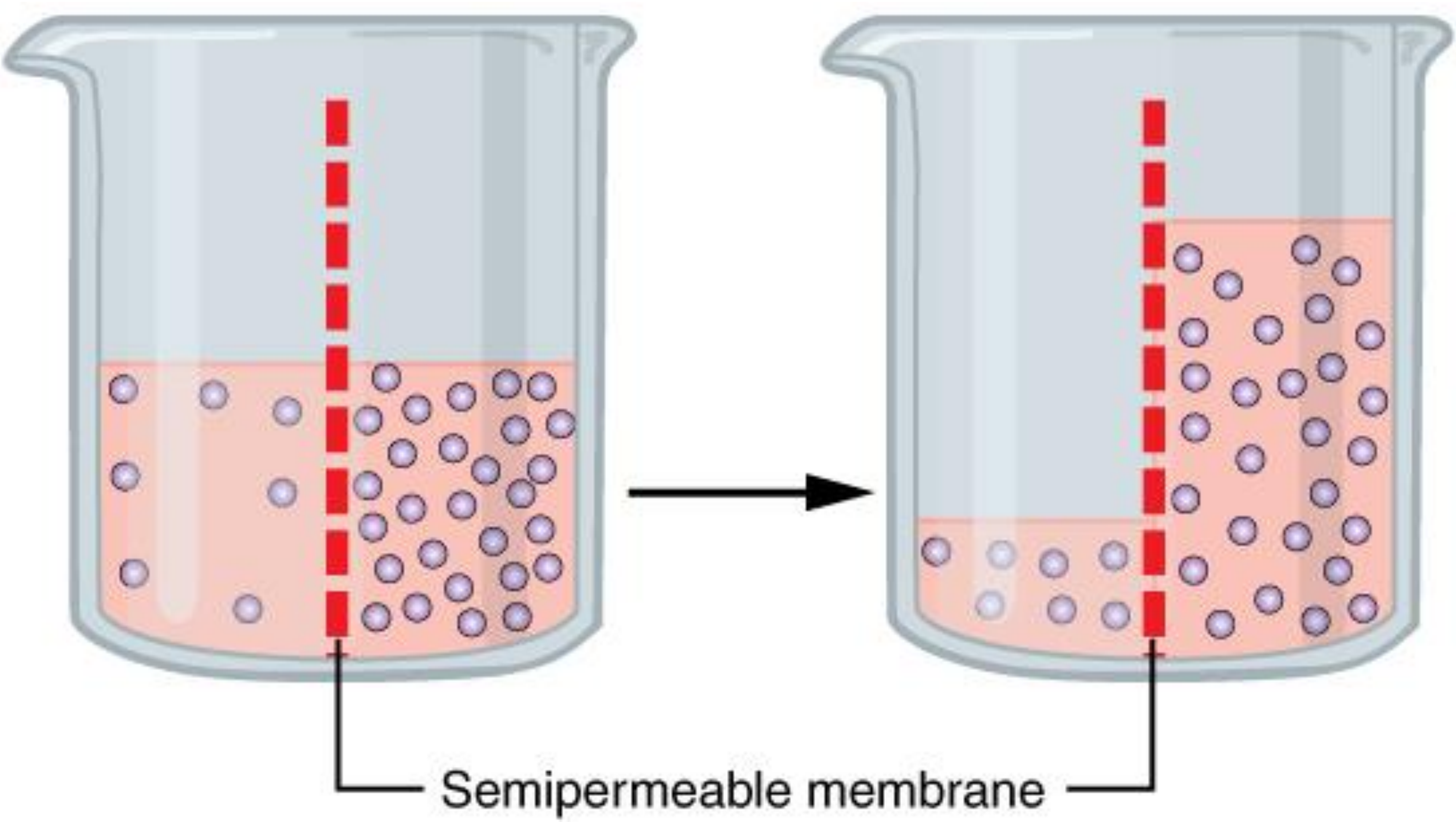
The problem for halophiles



A. Water flows out of salty region
B. Water flows into salty region

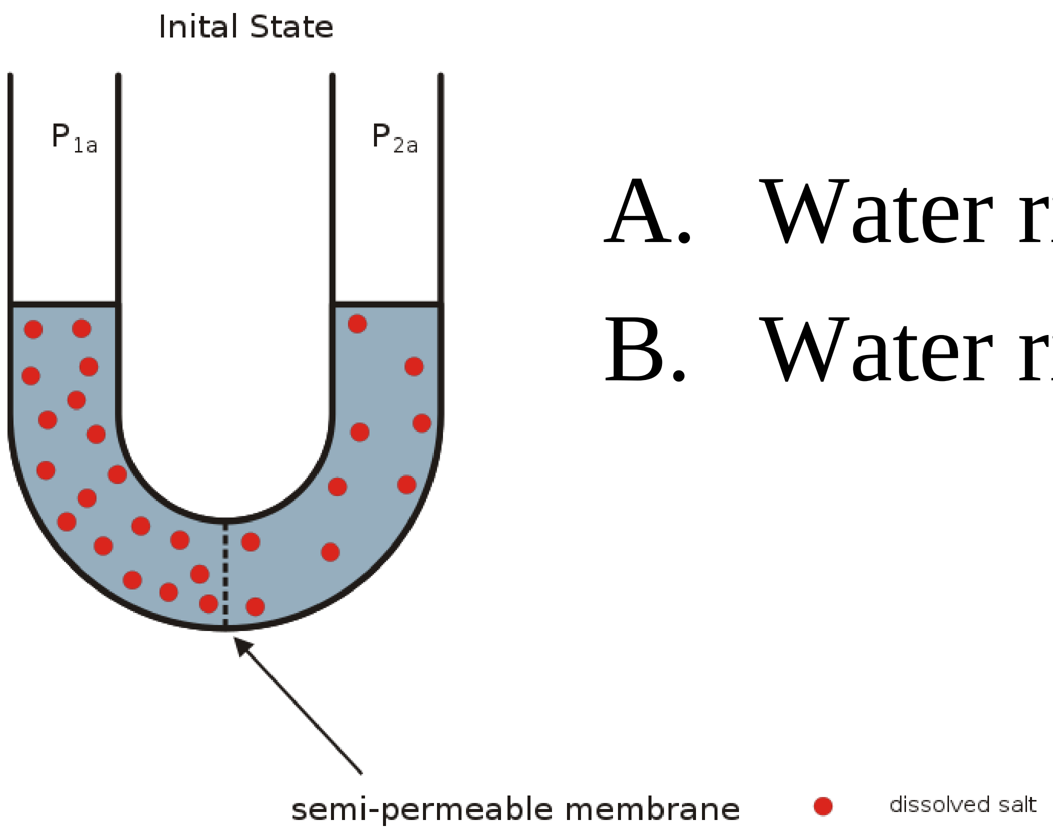
- More salty on one side of the membrane
- Which side gets dehydrated?

Osmosis



- Tendency to equilibrate density of molecules
- Only the water level can adjust

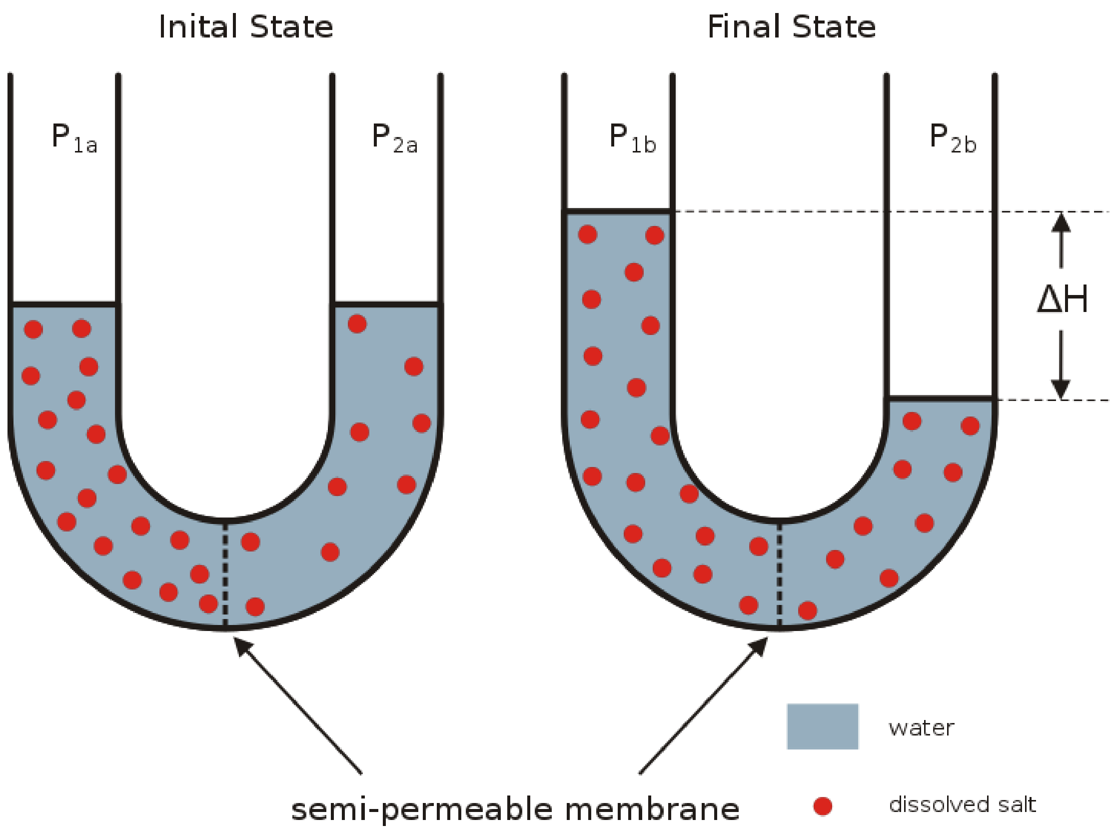
What happens to the water?



A. Water rises on the left

B. Water rises on the right

What happens to the water?



A. Water rises on the left

B. Water rises on the right

How do halophiles survive?

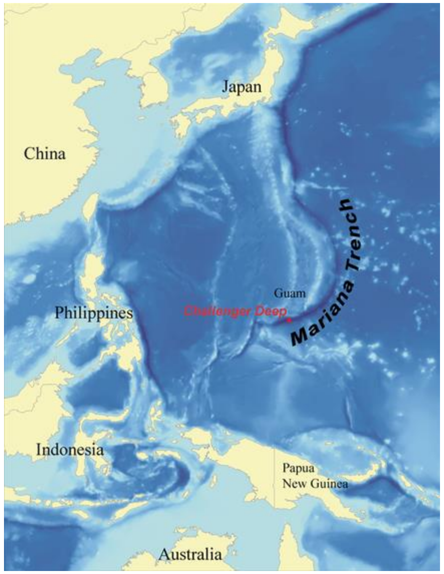
- Have to balance the concentrations
  - Either by producing internal solute
  - Or by retaining solute extracted from outside
- Halobacterium salinarum: KCl
  - Cannot survive in normal waters

Desiccation: xerophiles

- No H_2O for days, weeks, years, …
- But H_2O essential for life
- Can only tolerate (not thrive/replicate) desiccation
- Survive by entering state of suspended animation (little/no metabolism)

Pressure: piezophiles (barophiles)

- 10 km height: ¼ of usual pressure
- Mariana trench 1000 times usual
- Don’t grow <500x
- High pressure:
- molecules packed tightly



Organism in Great Salt Lake?

A. Psychrophile?
B. Thermophile?
C. Halophile?
D. Xerophile?
E. Piezophile?

Organism in Great Salt Lake?

A. Psychrophile?
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Organism in Mariana Trench?

A. Psychrophile?
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Organism in Mariana Trench?

A. Psychrophile?
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Organism in Atacama Desert?

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B. Thermophile?
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Organism in Atacama Desert?

A. Psychrophile?
B. Thermophile?
C. Halophile?
D. Xerophile?
E. Piezophile?

Organism at North Pole?

A. Psychrophile?
B. Thermophile?
C. Halophile?
D. Xerophile?
E. Piezophile?

Organism at North Pole?

A. Psychrophile?
B. Thermophile?
C. Halophile?
D. Xerophile?
E. Piezophile?

Radiation: radiophiles

- *Deinococcus radiodurans*
  - Often survives also other extremes
  - Desiccation, low pressure, …
- Rebuilds DNA from radiation-damaged fragments within hours after coming back to life

FIGURE 5.24
It almost doesn't look real, but the tiny animal in this photograph is a tardigrade (also called a "water bear"); it is about a millimeter long. Tardigrades can survive an incredible range of extreme conditions, including at least some time in the near-vacuum of space.

Tardigrade

- Multicellular
- Technically not extremophile
  - Survives better under ordinary conditions
- Also found in Lake Vostok (Antarctica)
  - 3.7 km under the ice, since 15 Myr

Lession for planet Earth

- Life is difficult to wipe out
- Might survive at leads as endoliths (in rocks)

DIRECT CONTACT AMONG GALACTIC CIVILIZATIONS BY RELATIVISTIC INTERSTELLAR SPACEFLIGHT*

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Department of Genetics, Stanford University Medical Centre,
Palo Alto, California

(*Received* 16 *December* 1962)

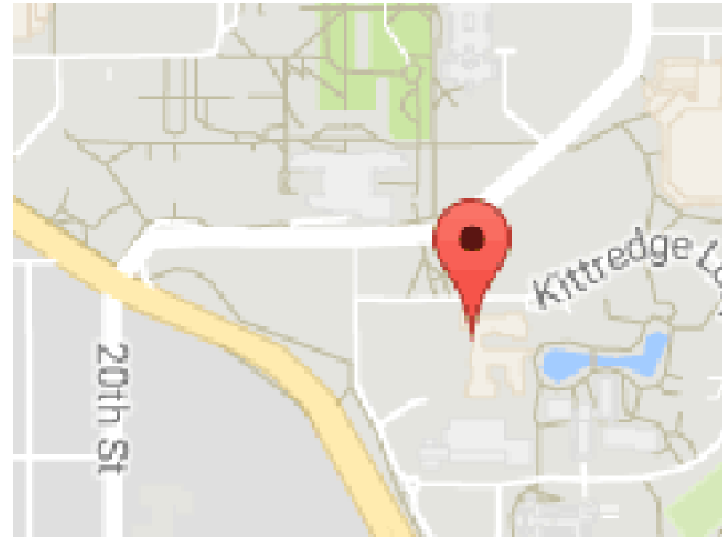
Abstract—An estimate of the number of advanced technical civilizations on planets of other stars depends on our knowledge of the rate of star formation; the frequency of favorably situated planets; the probabilities of the origins of life, of intelligence and of technical civilization; and the lifetimes of technical civilizations. These parameters are poorly known. The estimates of the present paper lead to $\sim 10^6$ extant advanced technical civilizations in our Galaxy. The most probable distance to the nearest such community is then several hundred light years.

Could multicellular life get reinvented?

- What did we learn about it on Earth?
  - Endolithic life ok? (chemoautotrophic)
  - Oceans? Nutrients (ferrous Fe, FeO)
- Multicellular: needed to wait for O_2
  - Snowballs Earths (mass extinctions)
  - Other mass extinctions? (no LHB)
- Does Earth provide enough resources?
  - And is there enough time? (3 Gyr)

On Wednesday

- Fiske Planetarium
  - Compulsory
  - bring clickers!
- Midterm on *Friday*
  - see sample+solutions
  - includes Quiz 1 topics!



Fiske Planetarium

4.3 ★★★★★ 34 reviews

Museum in Boulder, Colorado