ASTR 380
Life at the Extreme

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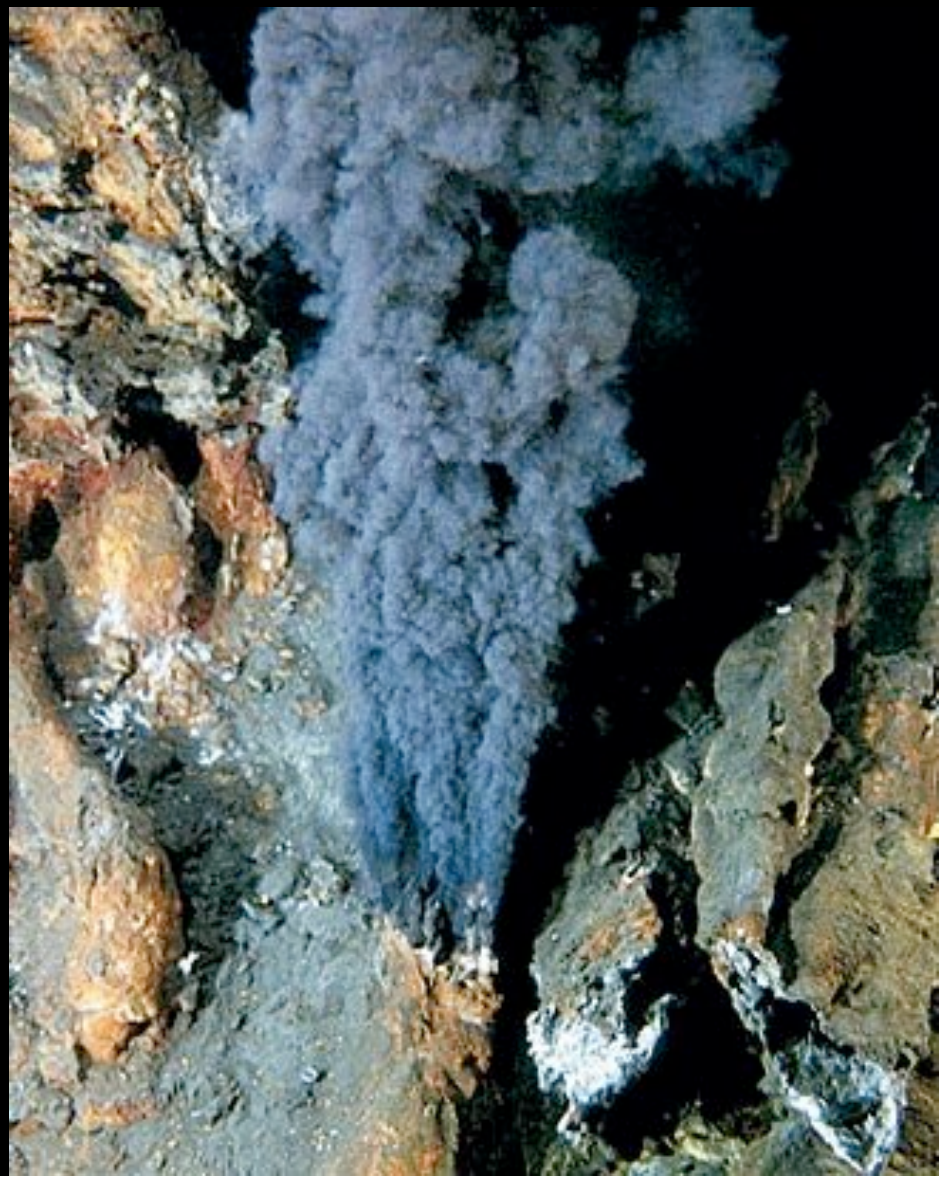
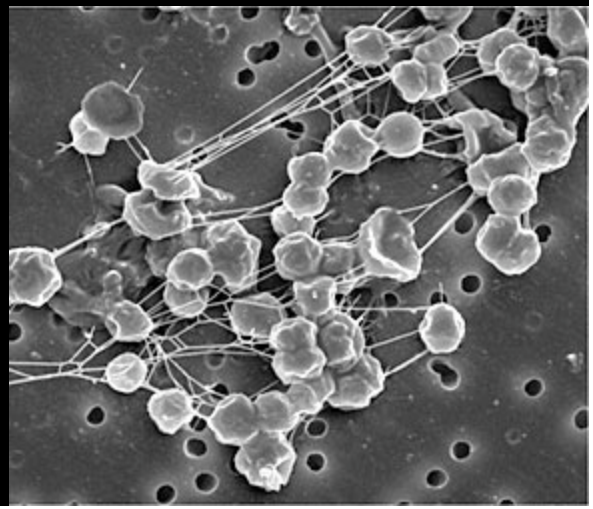


ASTR 380
Life at the Extreme

What types of extreme organisms exist?
What makes them special?
How do they fit into the tree of life?
How do they exist in so many places?
What can we learn from them?



Exam Review Session

- 7-9 PM, Thurs, Oct 9
  CSS 2400 (regular classroom)
- Discussion led by TA Vanessa Lauburg
- She will not prepare anything
  Completely driven by your questions
  End of questions = end of review!
- Vanessa doesn't know what is on exam
  Only forbidden question: "what is on exam?"
  (and variants of it)

What Environment Do We Need to Survive?

- Can't be too hot or too cold
- Can't be too dry
- Can't have too much salt or metals
- Can't be too acidic or too basic
- Can't have too much radiation
- Can't be too high-pressure
- Need enough oxygen in atmosphere

Geez, we're picky!

Life at the Extreme

A Shopping list of extreme organisms

Acidophile: An organism with an optimal growth at pH levels of 3 or below.

Alkaliphile: An organism with optimal growth at pH levels of 9 or above.

Endolith: An organism that lives in microscopic spaces within rocks within the Earth.

Halophile: An organism requiring at least 2M of salt for growth.

Hyperthermophile: An organism that thrives at temperatures of 80-121 °C in hydrothermal systems.

Hypolith: An organism that lives inside rocks in cold deserts.

Life at the Extreme

Lithoautotroph: An organism whose sole source of carbon is carbon dioxide. These organisms are capable of deriving energy from reduced mineral compounds like pyrites, and are active in the breakdown of bedrock to form soil.

Metalotolerant: An organism capable of tolerating high levels of dissolved heavy metals in solution, such as copper, cadmium, arsenic, and zinc.

Osmophile: An organism capable of growth in environments with a high sugar concentration.

Piezophile: An organism that lives optimally at high hydrostatic pressure. Common in the deep terrestrial subsurface and in oceanic trenches.

Polyextremophile: An organism that qualifies as an extremophile under more than one category.

Life at the Extreme

Psychrophile/Cryophile: An organism that grows better at temperatures of 15 °C or lower. Common in cold soils, permafrost, polar ice, cold ocean water, and in/under alpine snowpack.

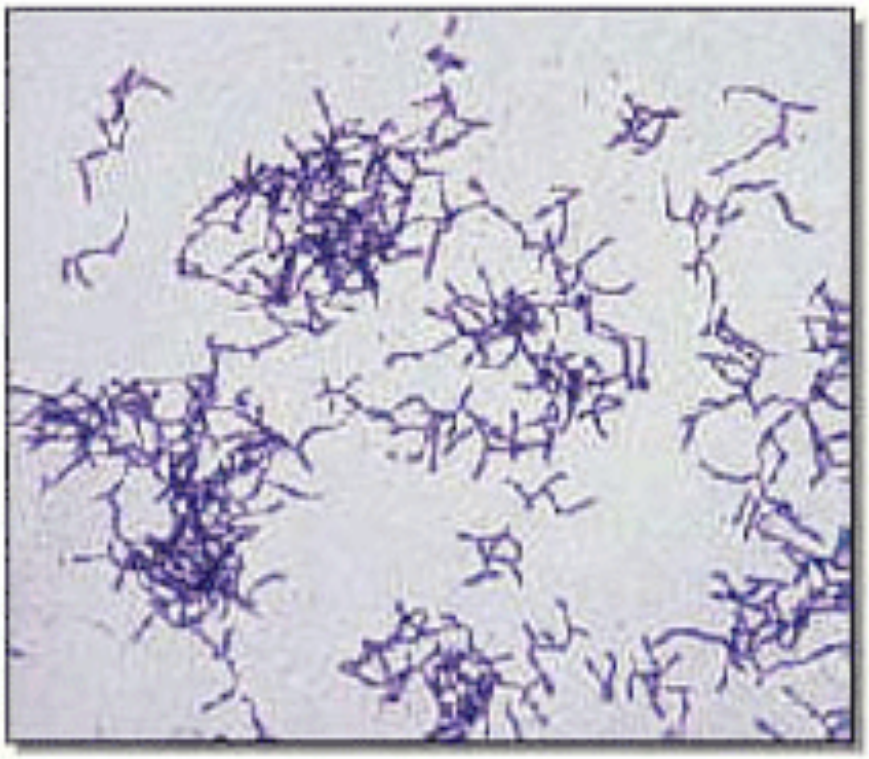
Radioresistant: resistant to high levels of ionizing radiation, most commonly ultraviolet radiation but also includes organisms resistant to nuclear radiation.

Thermophile: An organism that can thrive at temperatures between 60-100 °C.

Xerophile: An organism that can grow in extremely dry, desiccating conditions. This type is exemplified by the soil microbes of the Atacama Desert.

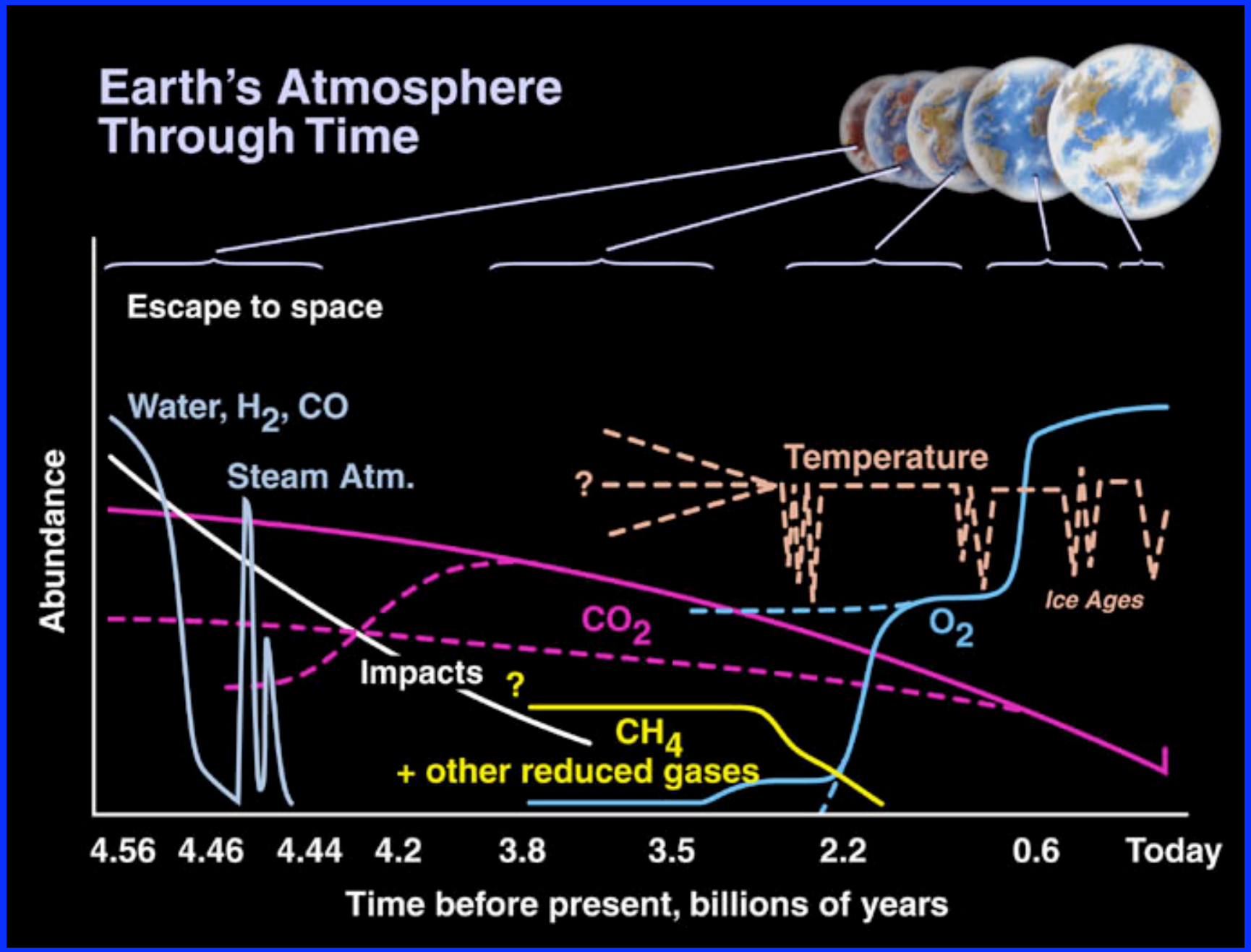
Life Without Oxygen

- Most life, for ~2 billion years
- Plenty of bacteria are still anaerobic
- Nasty ones
  Bad breath
  Botulism!
- Doesn't generate as much energy as with oxygen



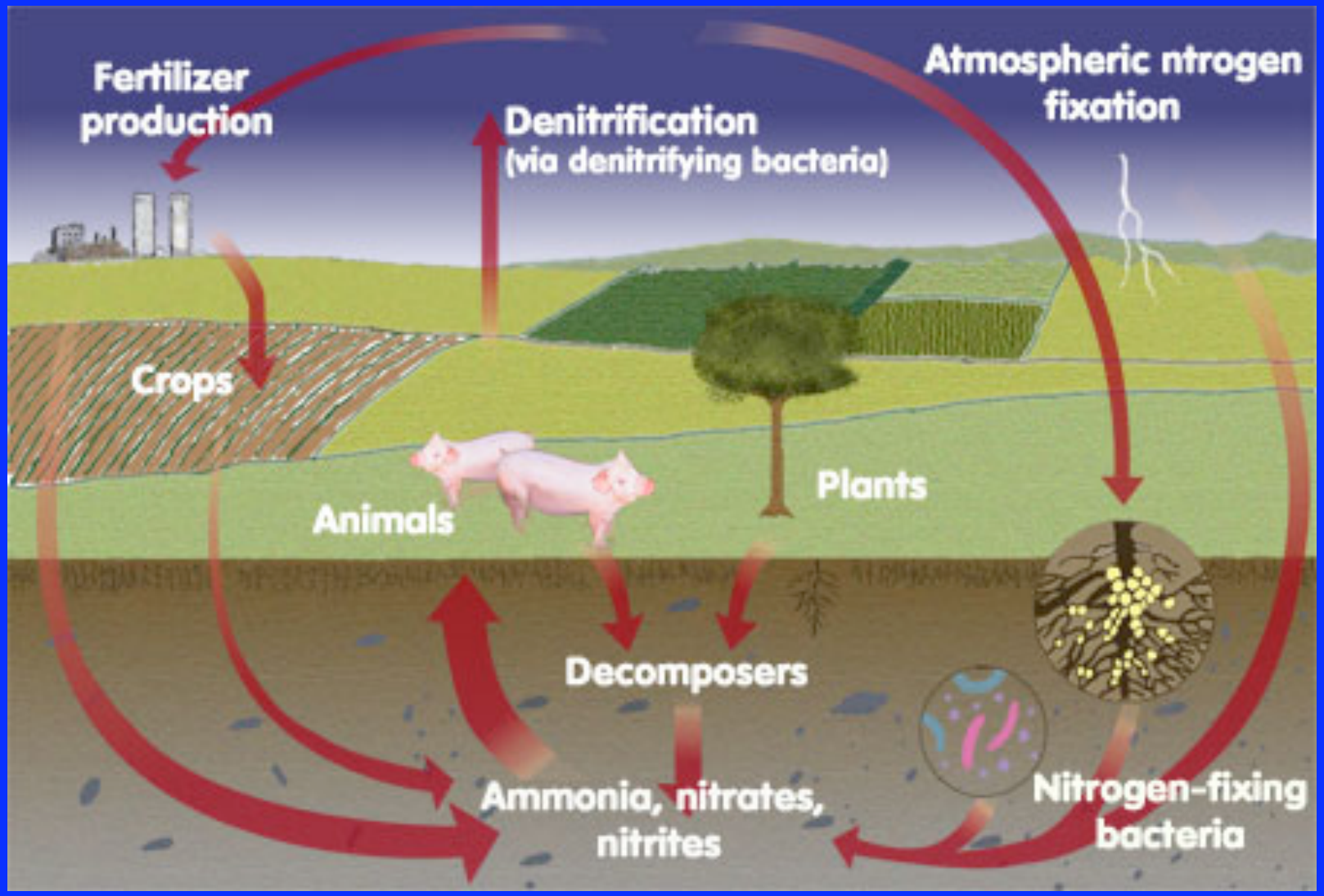
Anaerobic bacteria causes bad breath

http://breathappeal.com/images/causes_bacteria2.gif



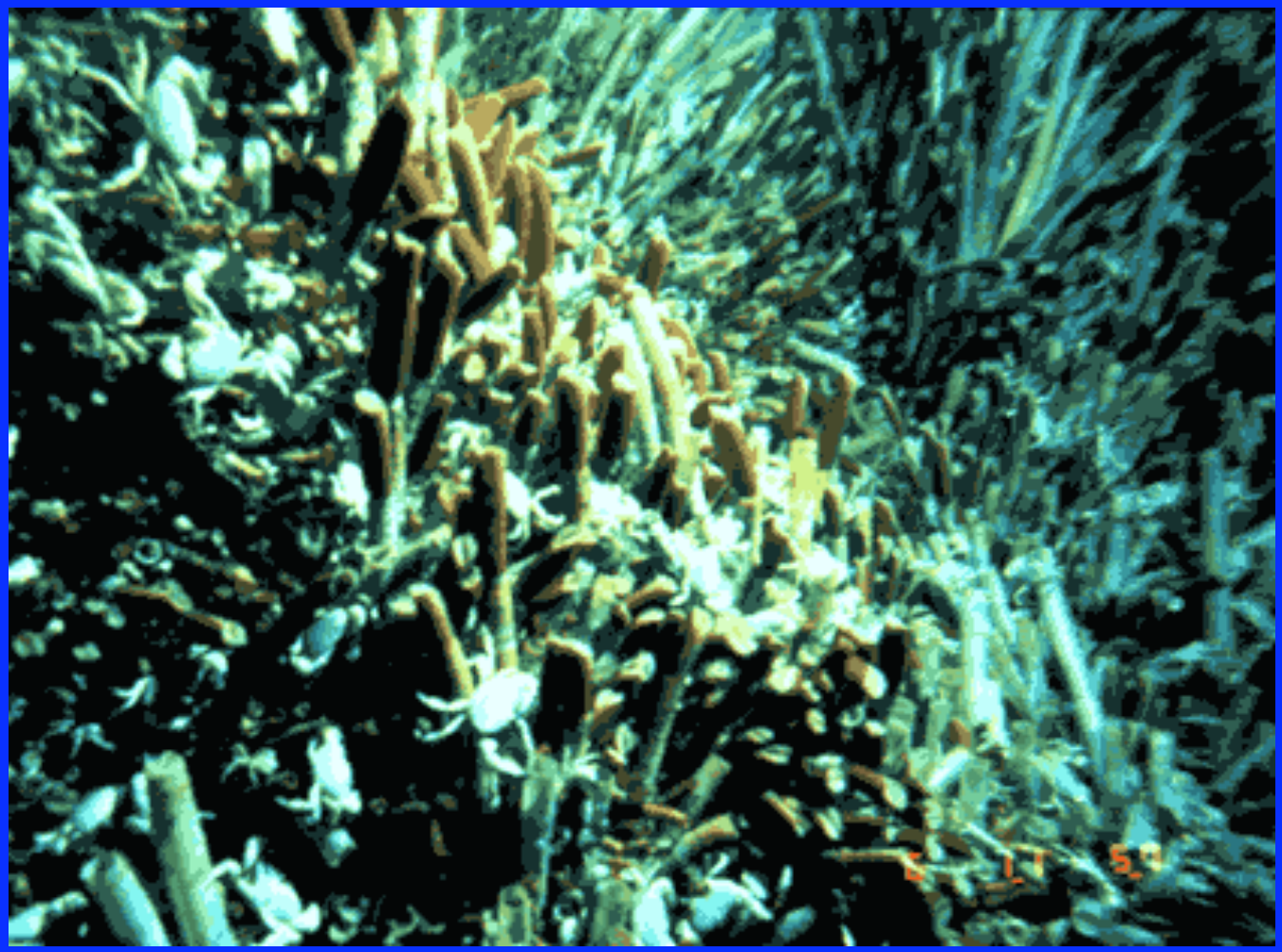
http://science.nasa.gov/headlines/y2002/images/exo-atmospheres/ATM_Time_Earths.jpg

Nitrogen-Fixing Bacteria



http://peer.tamu.edu/curriculum_modules/Environ_Hazard/images/nitrogencyclesmall.jpg

Sulfur-Fixing Bacteria (as food)



http://earthsci.org/mineral/energy/geomin/tube_worms.gif

Life at the Extreme

Thermophiles: microbes that love heat
temperatures from 45 to 105 C

found in hot pools associated with geothermal activity
deep ocean volcanic vents
decomposing plant matter

Hot pool in Yellowstone National Park

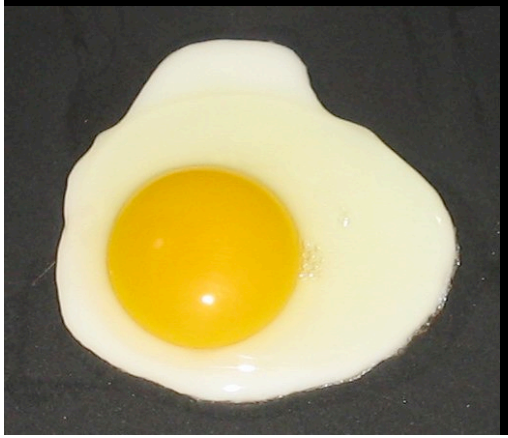
Life at the Extreme

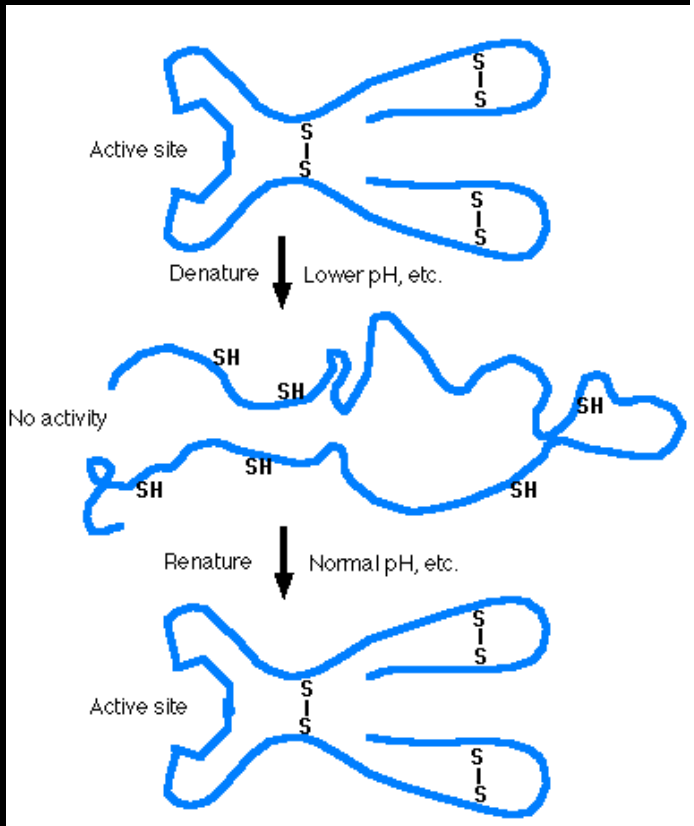
Thermophiles: microbes that love heat

In normal life, high temperature denatures proteins – changes the shape of the protein which changes its functionality.

Cooking denatures proteins in eggs to create the “white”.

Excessive fevers can denature proteins in people causing death.





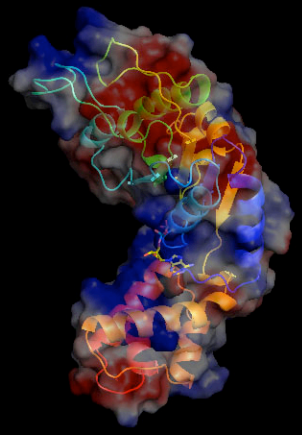
Life at the Extreme

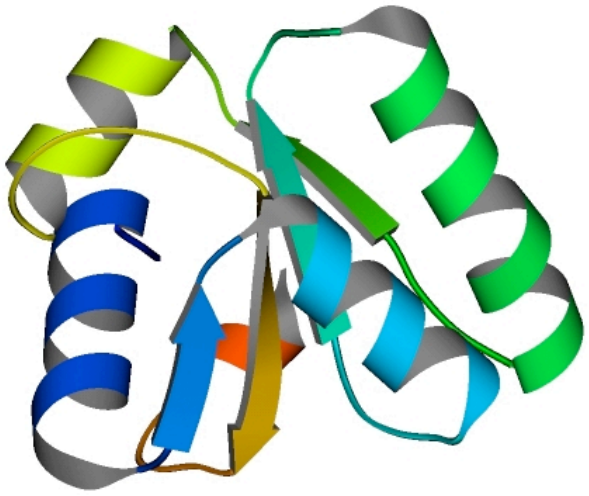
Thermophiles: microbes that love heat
temperatures from 45 to 105 C

Thermophile proteins are more densely packed and exclude water from their interiors.

Stronger cross connections which help the protein keep its shape.

It appears to be an adaptation.





Life at the Extreme

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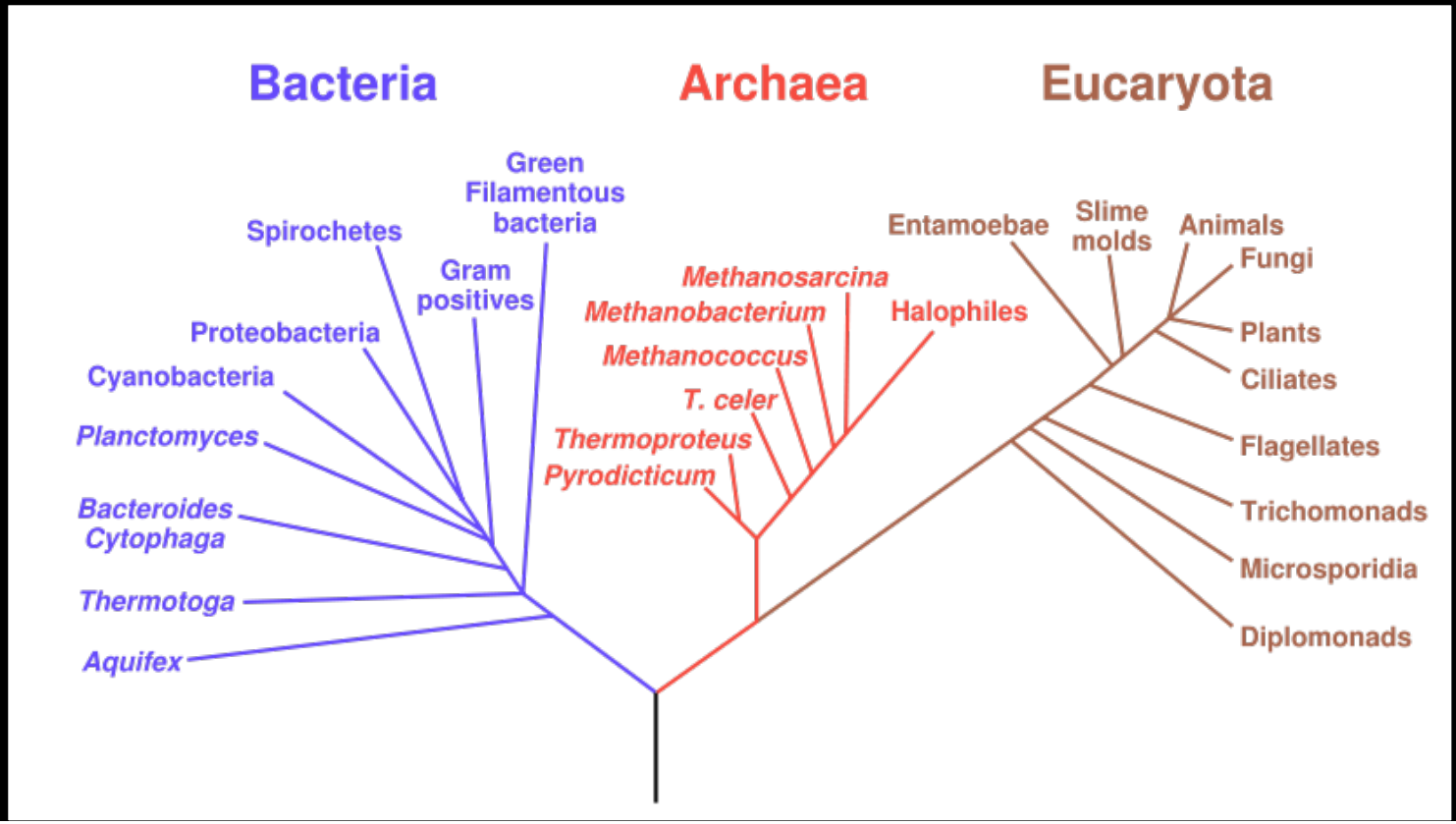
Life at the Extreme

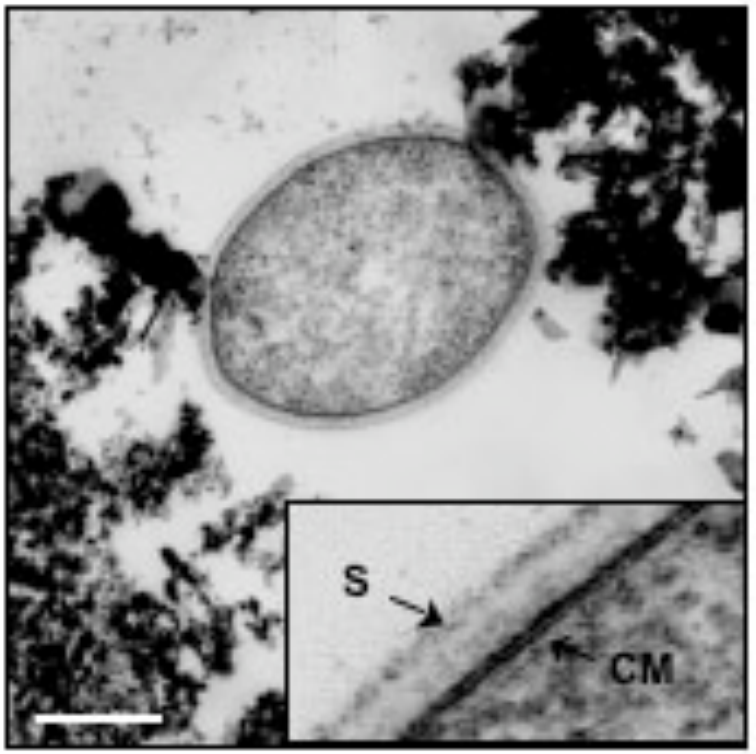
Thermophiles: microbes that love heat
temperatures from 45 to 105 C

Most thermophiles are archaebacteria – single cell organisms with no distinct nucleus.



The Record Holder

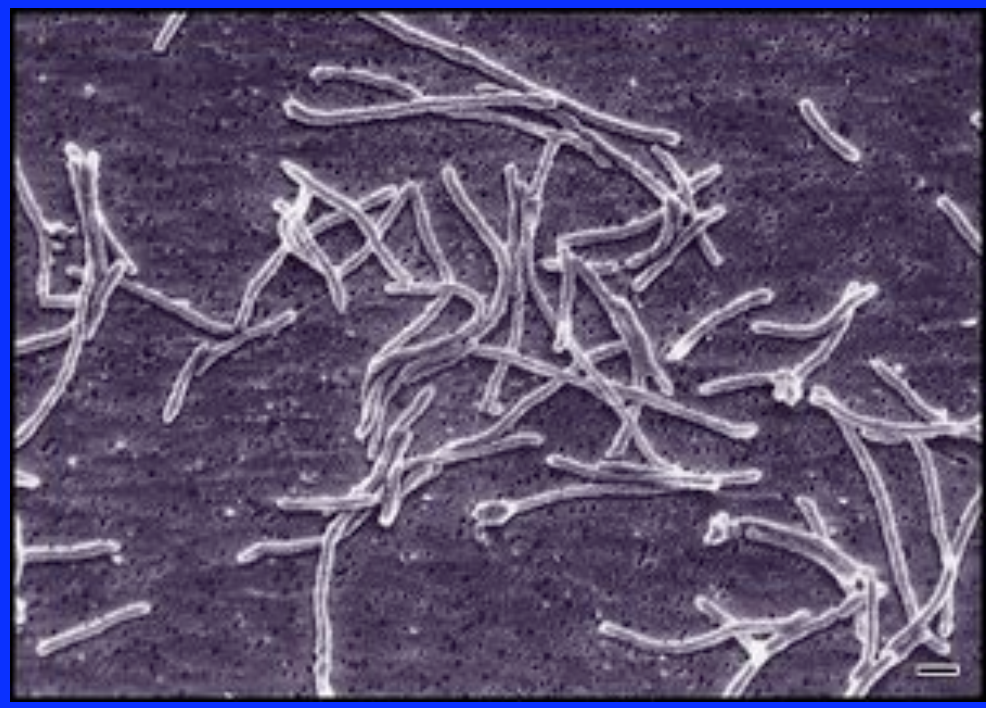
- Strain 121
- Doubled population in 24 hours at 121 C!!
- Even tougher organisms might await discovery



http://www.nsf.gov/od/lpa/news/03/images/strain121_thin.jpg

An Unexpected Benefit

- Thermus aquaticus
- Bacterium, has heat resistant enzyme
- Critical in PCR
  Forensics, disease, ...
- One of many examples of benefits from basic research!



http://upload.wikimedia.org/wikipedia/commons/thumb/4/48/Thermus_aquaticus.JPG/300px-Thermus_aquaticus.JP

Life at the Extreme

Thermophiles: microbes that love heat

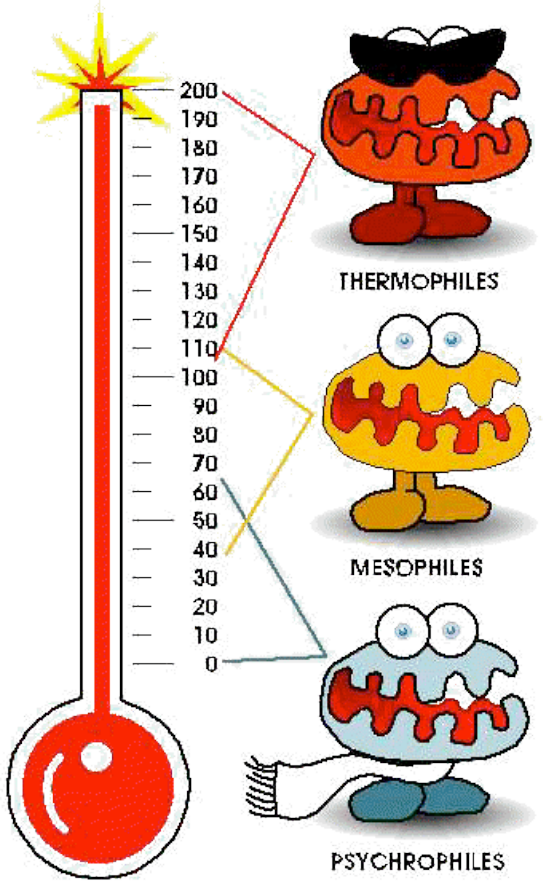
But not all thermophiles are single celled.

The Pompeii Worm can survive temperatures of 176 F – nearly boiling water from undersea geothermal jets

It is a member of the Animal kingdom but lives symbiotically with thermophilic bacteria which may protect it from the heat.

Cold-Lovers

- Cryophiles, or psychrophiles
- Membranes stiffen, ice crystals can puncture cell walls
- Have evolved antifreeze!
- Also resistant membranes
- But, still need liquid water
- Most bacteria can be stored and revived from cold



http://www.compostinfo.com/images/Tutorial/microbes.gif

Human Cryogenics?

Maybe a way to allow us to travel large distances in spacecraft?

Many technical issues

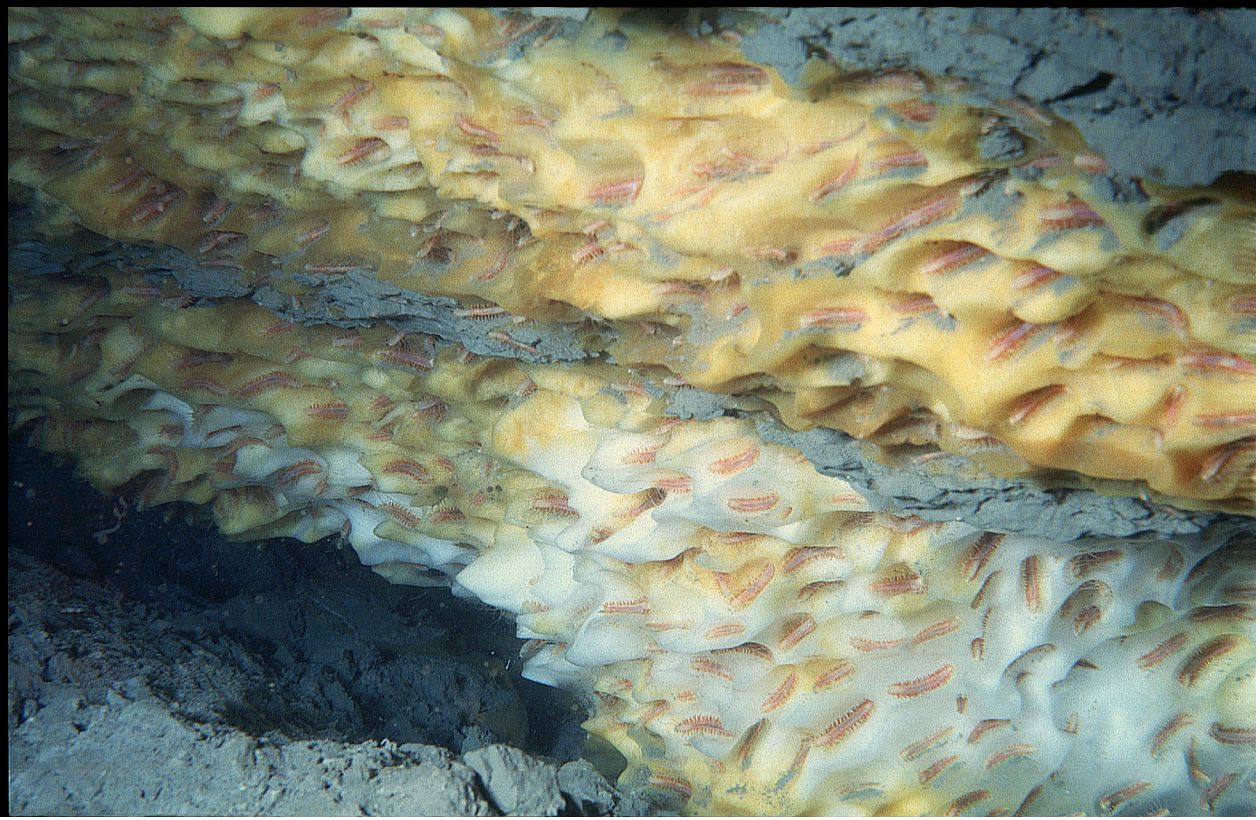
Long-term future if at all

Life at the Extreme

And then there is really weird….

Methane Ice Worms… 1-2 inch long pink worms that live on methane ice on the ocean floor in special areas called cold seeps.

It is unclear if they feed off the methane ice, or bacteria that might live on the ice

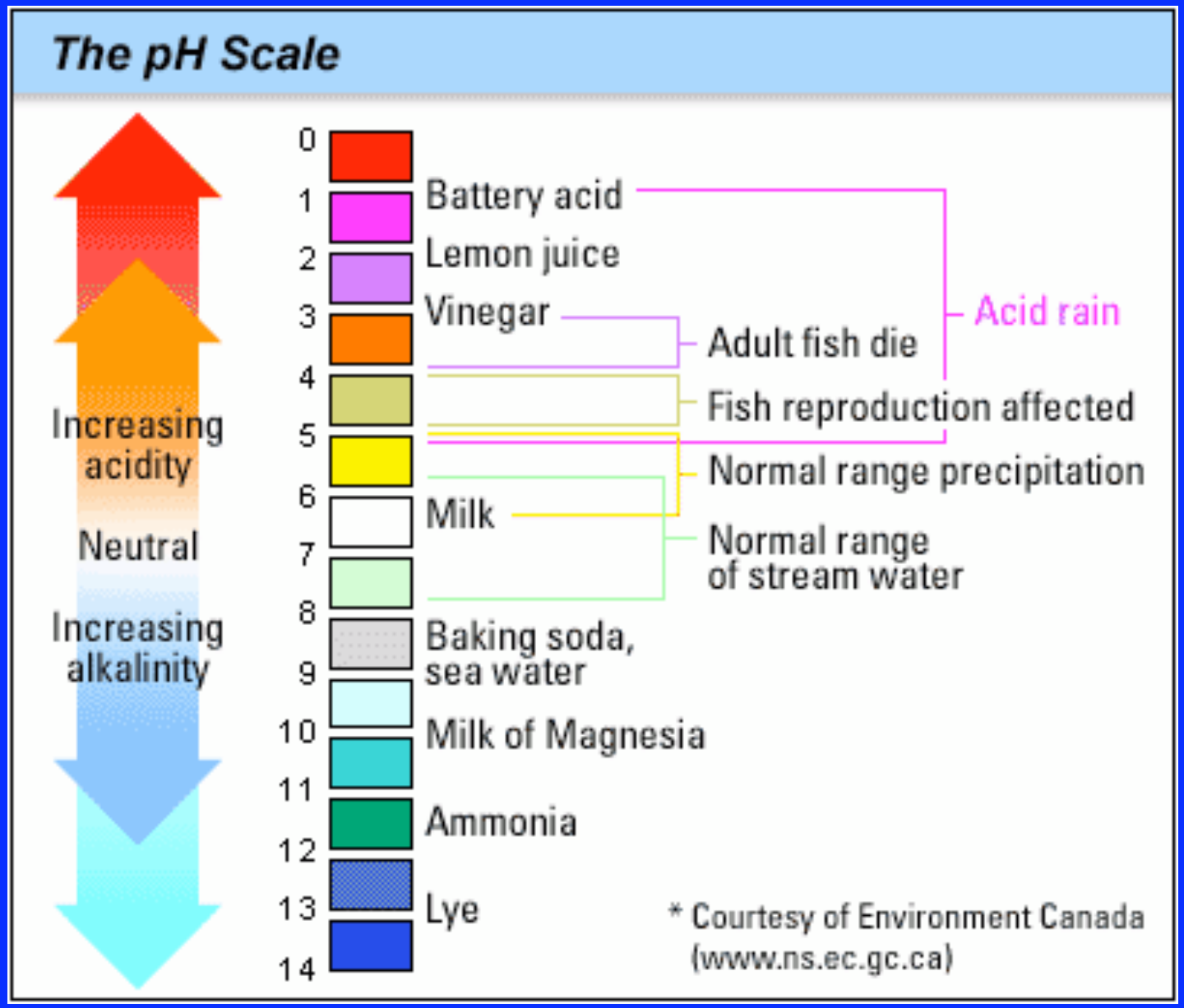


Life at the Extreme

And then there is really weird….

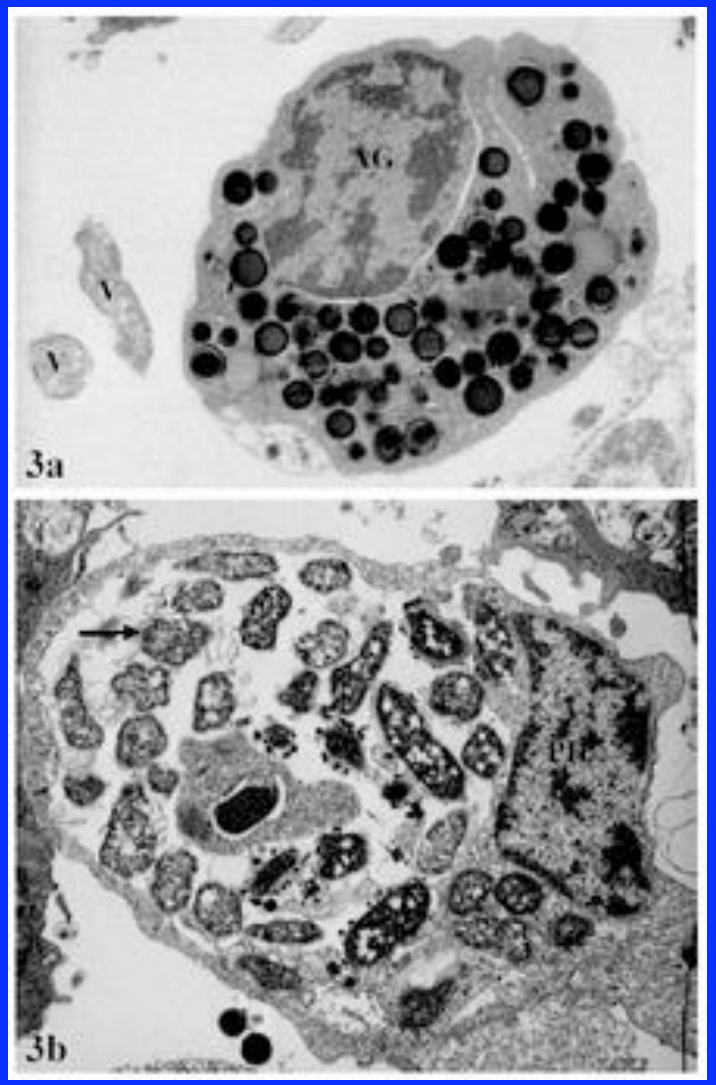
Glacial Ice Worms…. Live in the ice of glaciers
members of the segmented worm family
eat snow algae
proteins denature, cell walls melt, and worm liquifies
at around 5 C.

Acids and Bases



Acid and Base Lovers

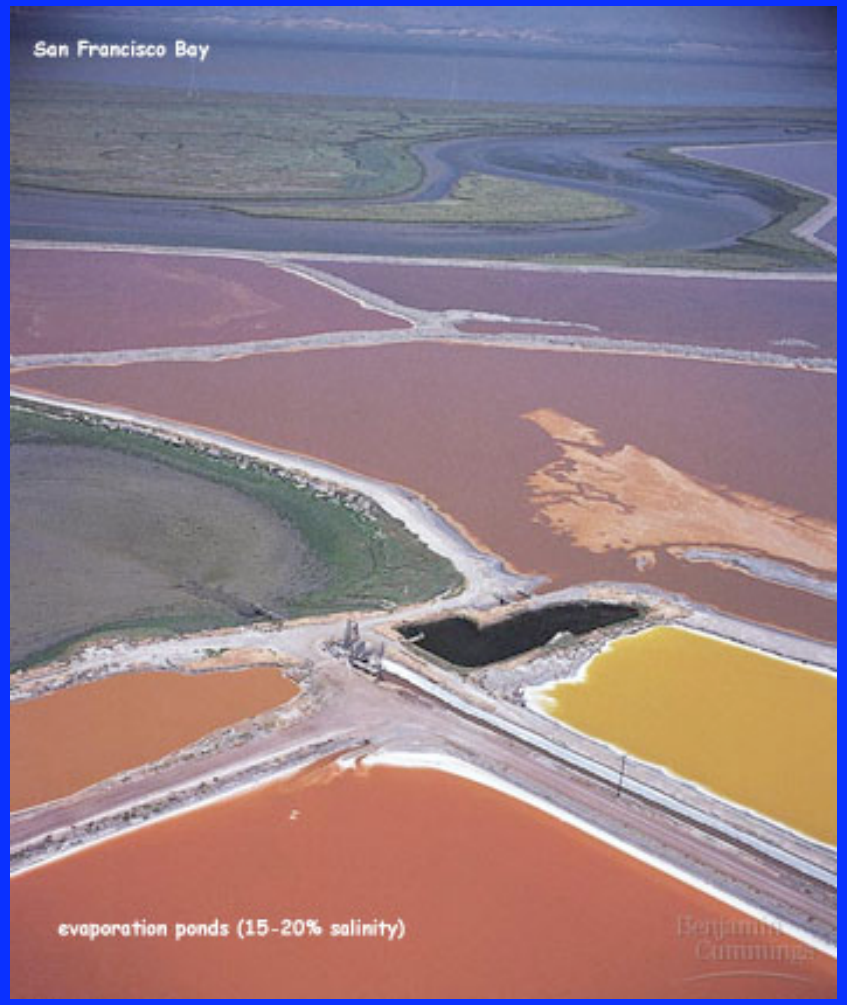
- Acidophiles: optimal pH<2.0
  Some grow at pH=0!
- Alkaliphiles: pH>9
- Most "cheat" by maintaining normal pH inside cell
- Some have evolved special proteins



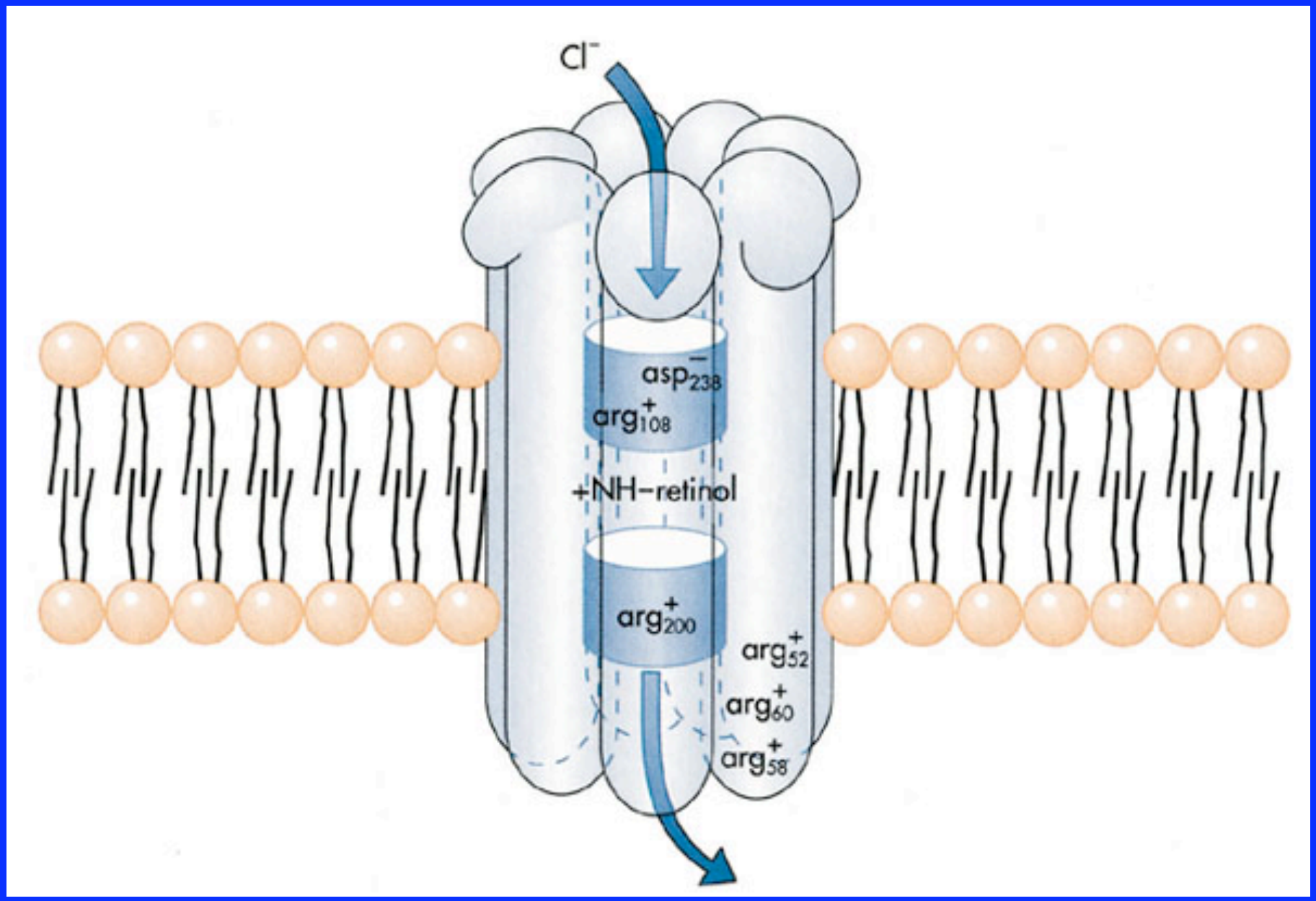
http://www.biologicalprocedures.com/bpo/arts/1/81/m81f3sm.jpg

Salt Lovers

- Require salt conc. at least 5x that of ocean
  Great Salt Lake
  Dead Sea
  Evap. ponds
- Pump out salt vigorously

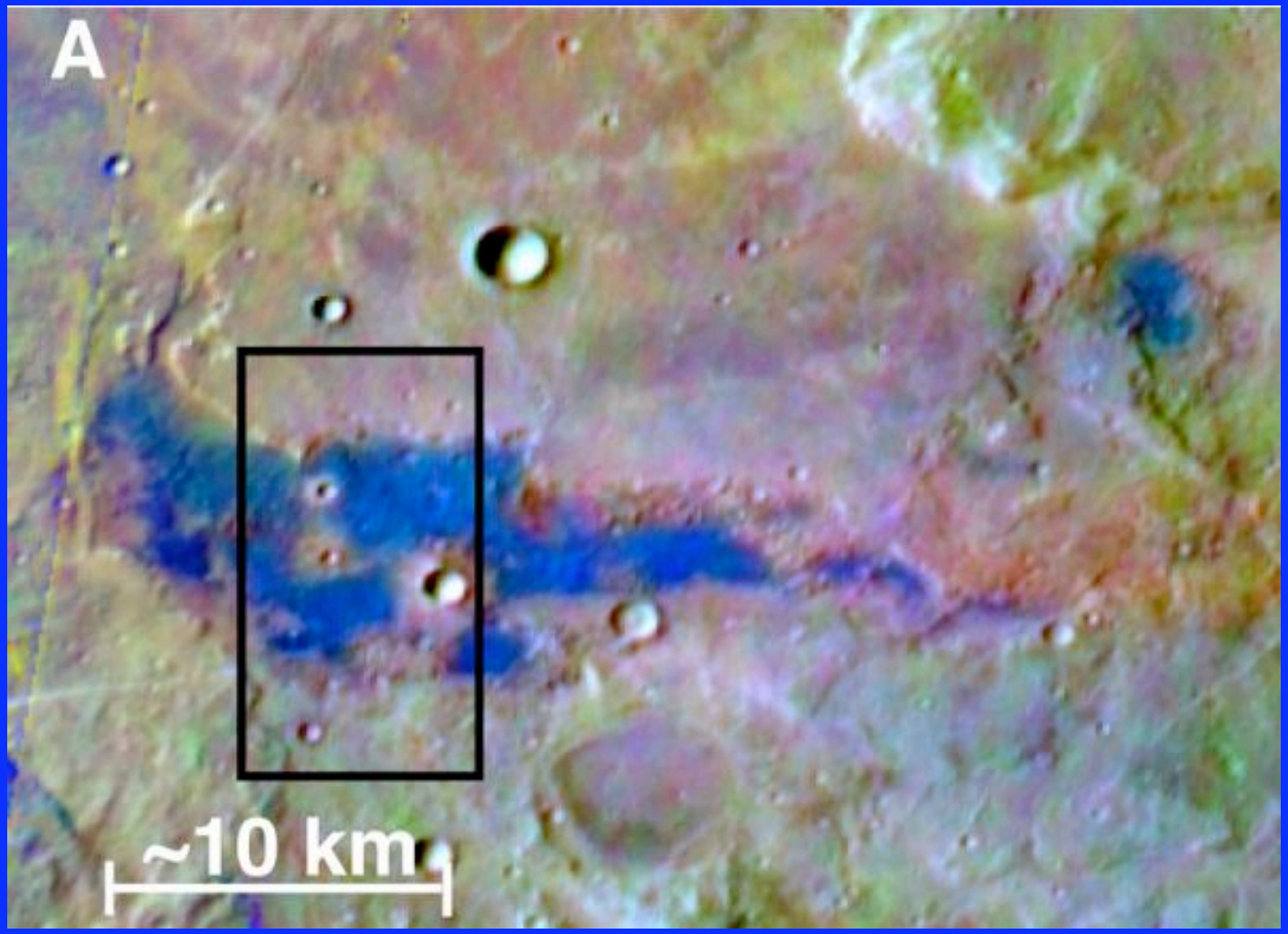


http://fig.cox.miami.edu/~cmallery/150/proceuc/c27x14halophiles.jpg



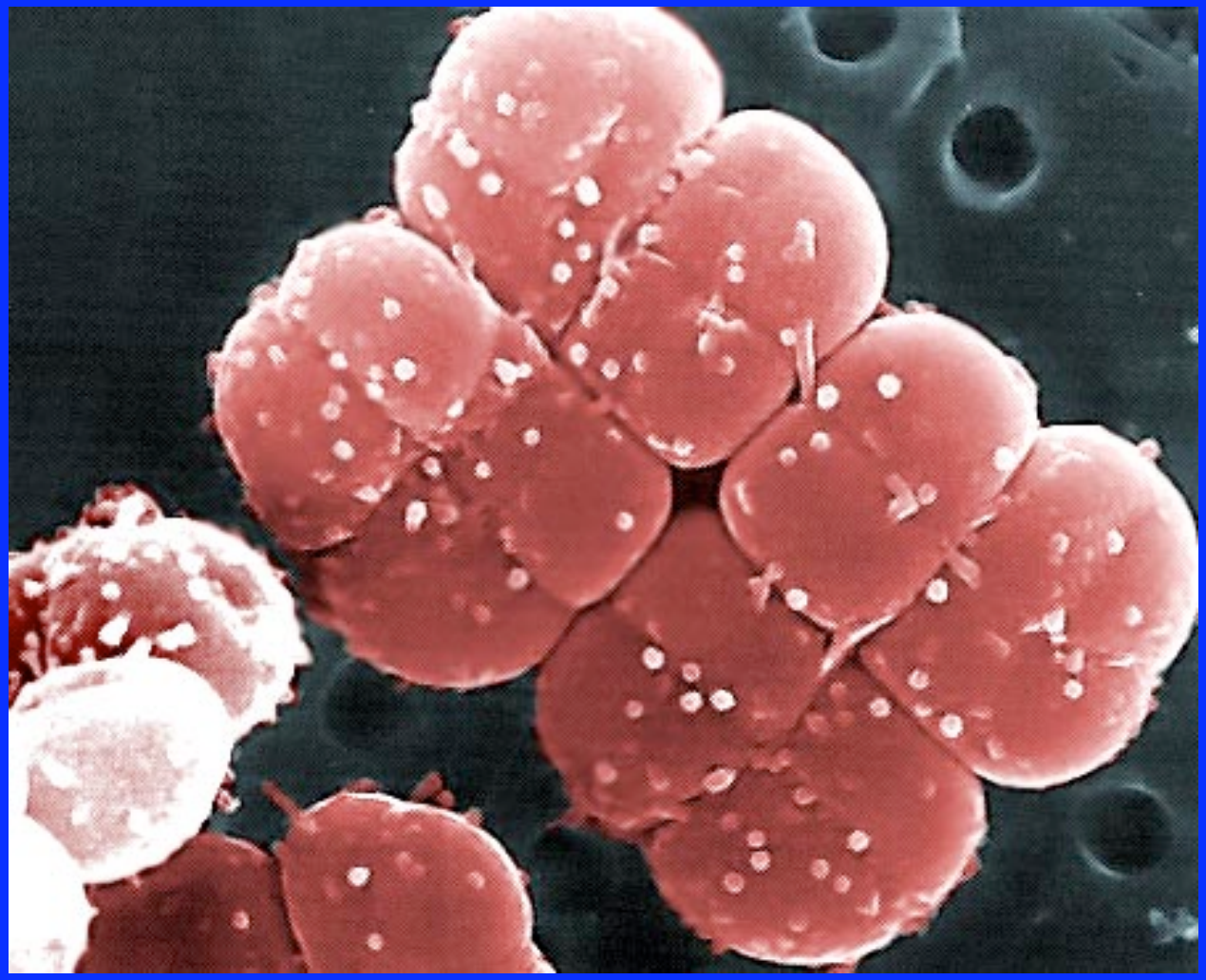
http://www.mhhe.com/biosci/genbio/raven6b/graphics/raven06b/enhancementchapters/images/30e-06.jpg

Salty Conditions on Mars?



http://www.sciencedaily.com/images/2008/03/080320150042-large.jpg

Radiation Resistance



http://www.scifun.ed.ac.uk/card/images/facts/d_radiodurans.jpg

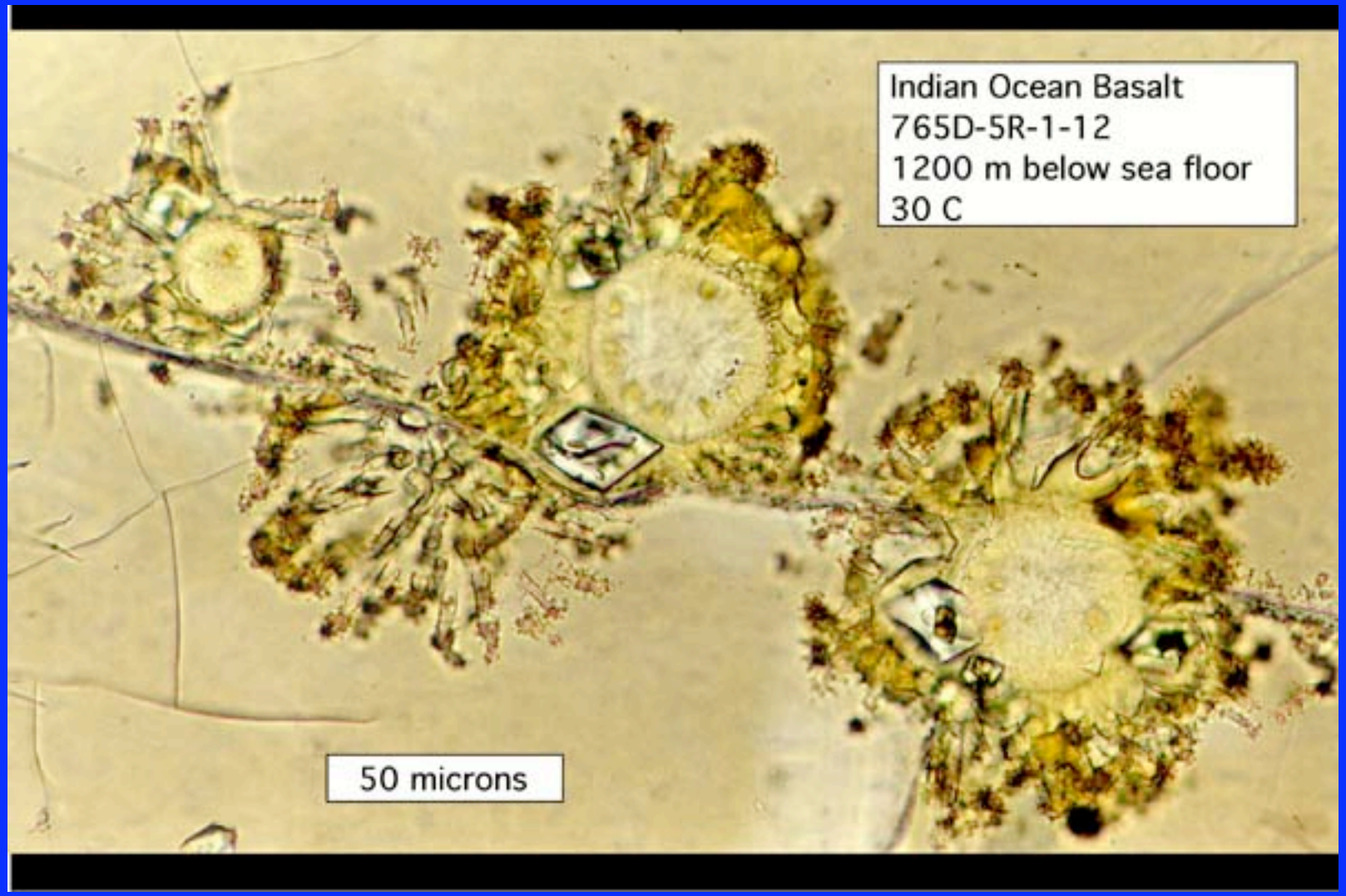
Deinococcus radiodurans

Can withstand 500x fatal rad dose for humans

Can also resist heat, cold, dry, acid, ...

Could this survive an interstellar trip?

Endoliths: Life Deep in Rocks



http://serc.carleton.edu/images/microbelife/extreme/endoliths/rockeatingmicro.jpg

Life Deep in Rock

- Probably most of the biomass on Earth!
- So far, record is almost three miles below the surface
- Also found miles below seafloor
- Live in rock cracks; can remain in stasis for many years (thousands? more?) until there is some water

Wild Speculation

- Depth limited by heat
  Need liquid water
- Mars is smaller, has cooled off faster
- Probably much thicker part of crust that can harbor life
- Might there now be more living biomass on Mars than on Earth?

http://www.windows.ucar.edu/mars/images/mars1.gif

Undersea Thermal Vents

- Near volcanic vents
- Rich with minerals
- Bacteria/archea use the nutrients
- Other things eat them
- Whole ecosystem!

http://ocean-ridge.ldeo.columbia.edu/courses/subgeol/hot_springs/smokers.gif

Bdelloid Rotifers

- Multicellular
- Are everywhere: fresh water, moist soil, ...
- Super-resistant to radiation, heat, cold, ...
- Can go into spore state for a long time

http://farm2.static.flickr.com/1140/1472260957_406970e305.jpg

Life at the Extreme

How do these specialized organisms exist in so many places?

Volcanic hot spots come and go on 1,000 – 100,000 year live times.

High acid, high salt, nearly all extreme environments are island oasis for these organisms….

Unique evolution?

Co-evolution?

Life at the Extreme

What can we learn from them?

Without doubt, life, once established, can evolve to thrive in a wide range of environments.

All organisms discovered to date on Earth appear consistent with a single original ancestor.

--- “to date” and “consistent”– is science speak for the possibility that future discoveries could challenge the story.

One life takes hold, it can continue in unlikely environments: both hot and cold.

Summary

- Life is everywhere on Earth that has liquid water at least part of the time
- Suggests that microbial life is amazingly robust
- Complex life not as clear; more restricted
  Because can't evolve?
  Or because outcompeted by others?