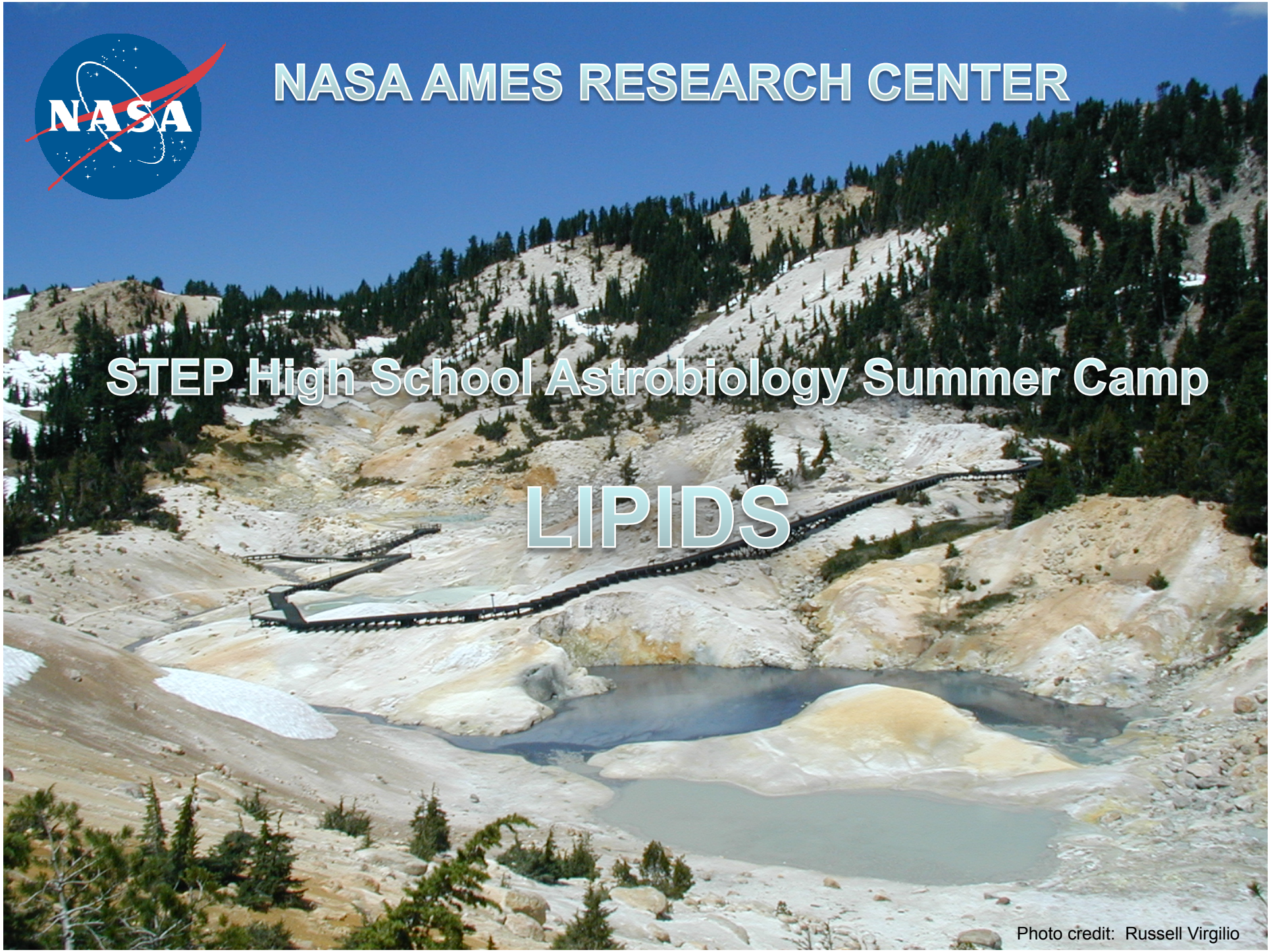
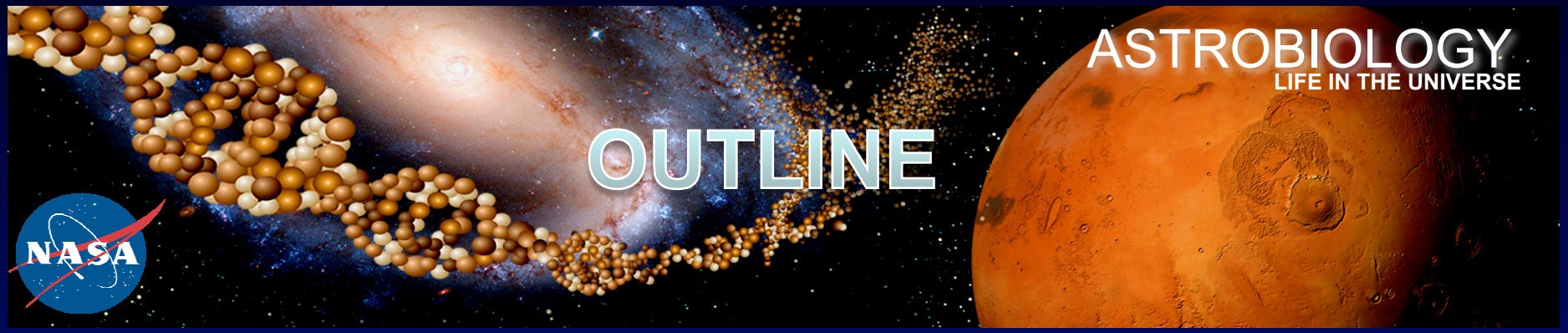

NASA AMES RESEARCH CENTER
STEP High School Astrobiology Summer Camp
LIPIDS
Photo credit: Russell Virgilio



1. What is Astrobiology?
    a) how does Astrobiology relate to Lassen?
2. What are lipids?
3. Lipids in microbes
    a) how can lipids help us to identify microbes in the environment?
    b) examples from Yellowstone and Lassen
4. Lipids in old rocks
5. Search for evidence of microbial life on Mars using lipids
    a) Mars Science Laboratory SAM instrument packageLipids in old rocks
6. Introduction to Lassen

What is Astrobiology?

Astrobiology is the scientific study of the origin, evolution, distribution, and future of life on Earth and in the universe.

- How does life originate and evolve?
- Is there life beyond Earth and, if so, how can we detect it?
- What is the future of life on Earth and in the universe?

http://astrobiology.nasa.gov

- Astrobiology is a collaborative effort
  - microbiology, ecology, astronomy, geology, paleontology, and chemistry
- Researchers begin by studying life on Earth
- Earth is the only planet that we know has life!
- Microbes have inhabited Earth for 9/10ths of its history
- It's likely that microbes will be the type of life we will find elsewhere in the universe
- Where do we find microbial ecosystems today?
- We study analog systems

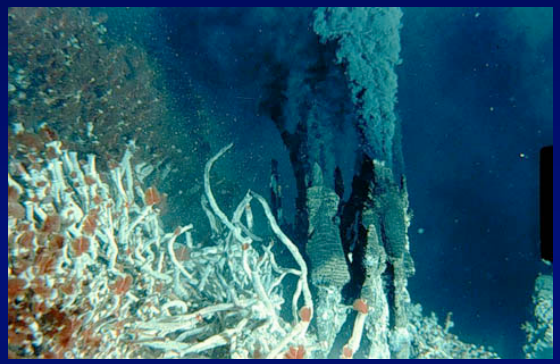
We hope to understand how life existed on early Earth and other planetary bodies

http://astrobiology.nasa.gov

ASTROBIOLOGY
LIFE IN THE UNIVERSE

ANALOG SYSTEMS

- Extreme environments on Earth
  - hot springs
  - deep sea hydrothermal vents
  - deep subsurface
  - polar regions
  - hypersaline ponds
  - arid environments
  - endolithic communities
  - high UV



Extremophiles

Thermophile = **heat-loving**

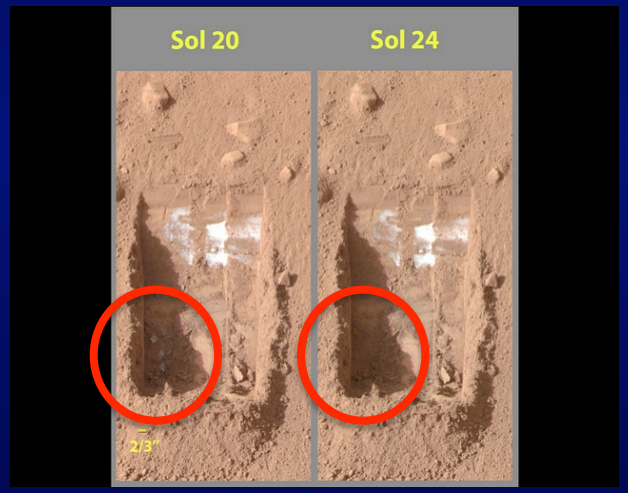
Acidophile = **acid-loving**

ASTROBIOLOGY
LIFE IN THE UNIVERSE

LIFE ELSEWHERE?

- Possible environments on other planetary bodies that could host microbial life
  - Follow the water!
  - Mars

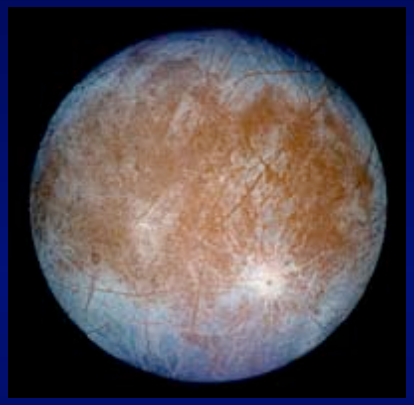
Spirit, Opportunity



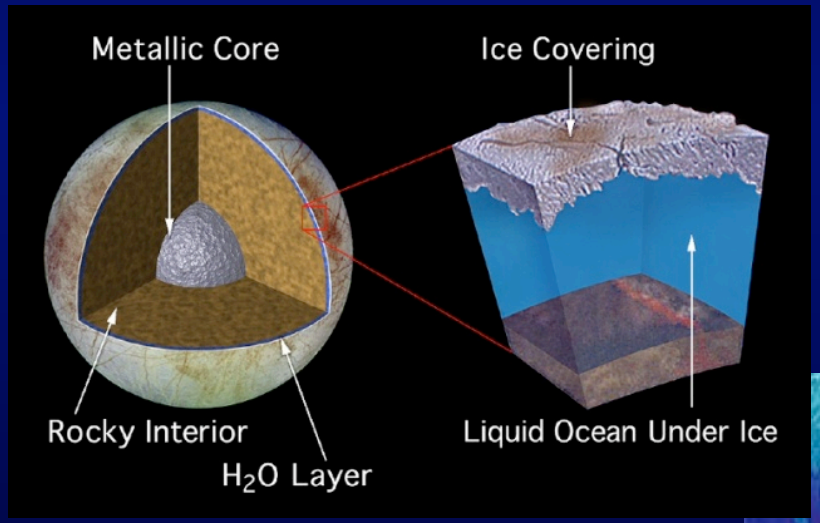
ASTROBIOLOGY
LIFE IN THE UNIVERSE

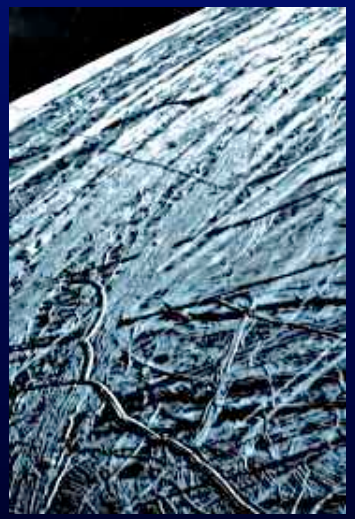
LIFE ELSEWHERE?

"ICY WORLDS"



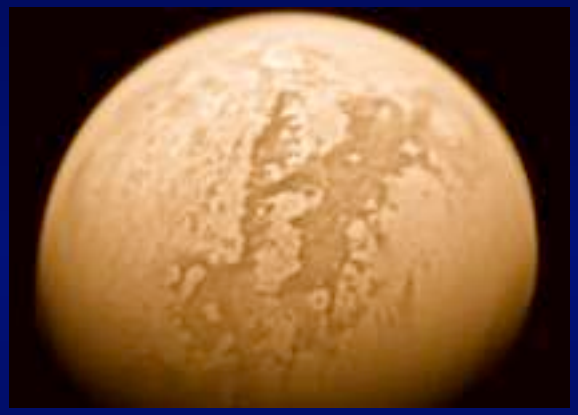
Jupiter's moon Europa





ASTROBIOLOGY
LIFE IN THE UNIVERSE

LIFE ELSEWHERE?

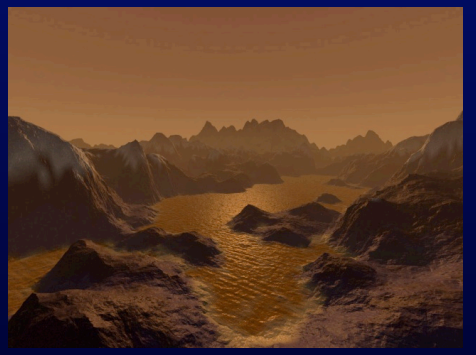


Saturn's moon Titan

-prebiotic chemistry

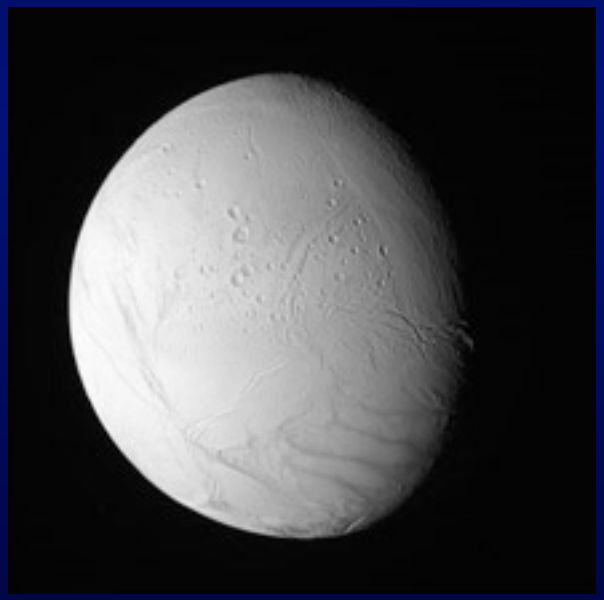
NASA Cassini mission
ESA Huygens probe

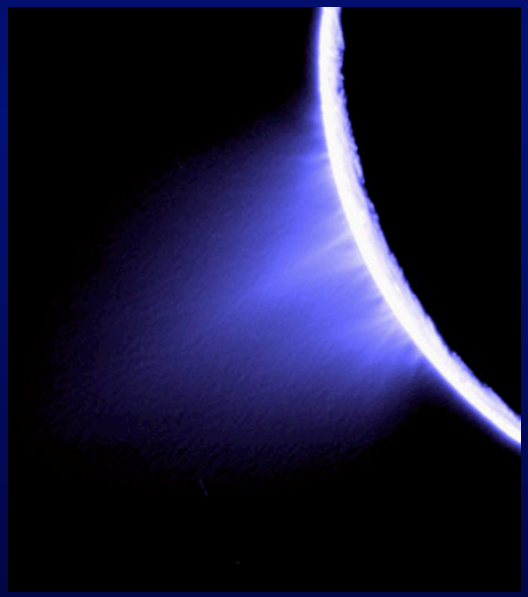
Ice volcanoes erupt liquid water



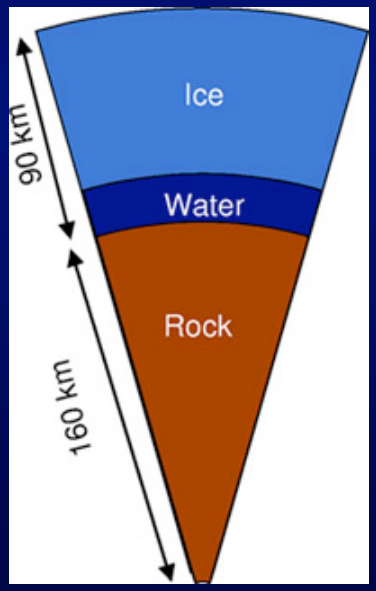
Ethane lakes

Saturn's moon Enceladus



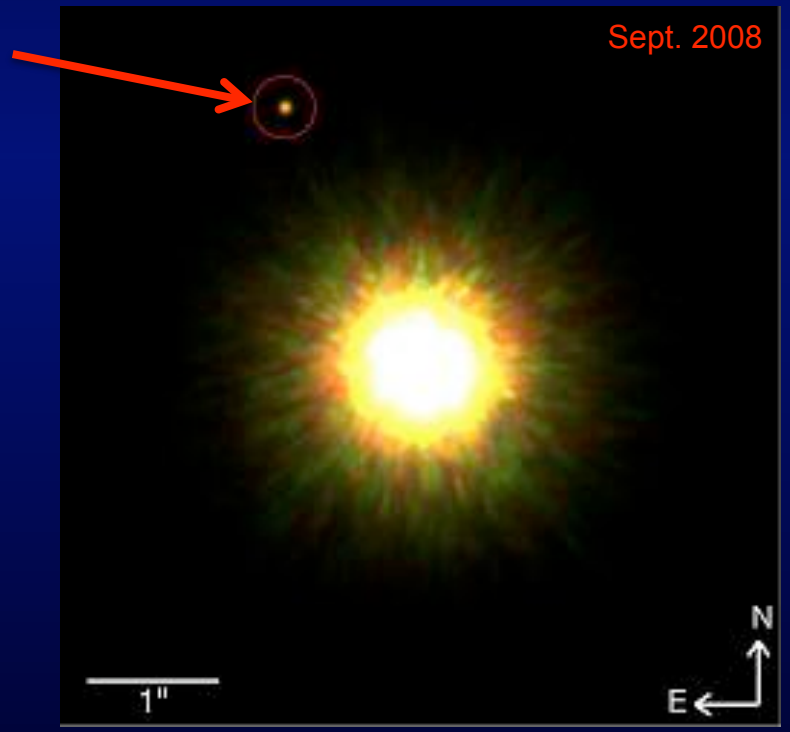


Plumes of H_2O vapor erupting



H_2O ocean?

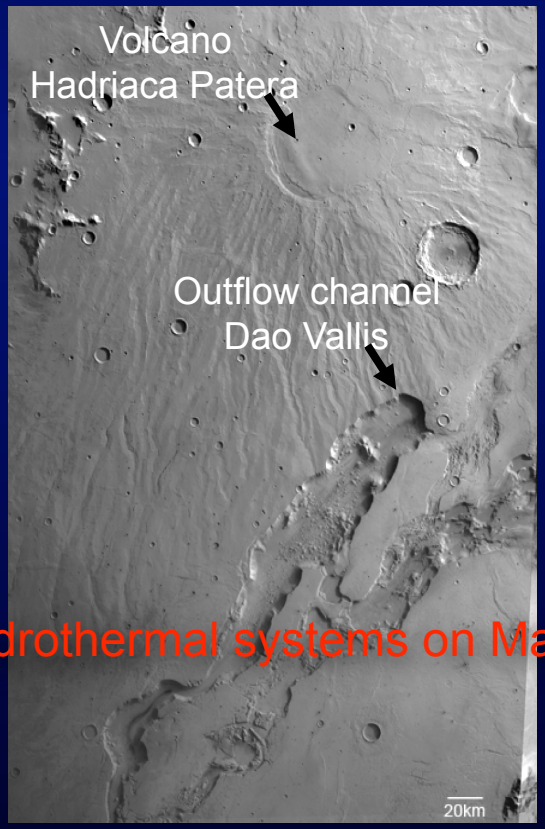
Extrasolar planets



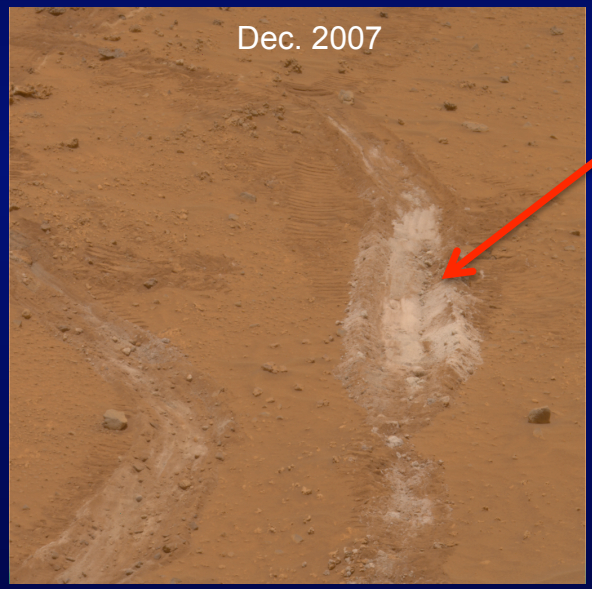
Gemini telescope, Hawai'i

first picture taken of a likely planet orbiting a distant, sun-like star

How does Astrobiology relate to Lassen?



Hydrothermal systems on Mars?



- Hot spring?
- *Fumarole?*

Was there a Lassen-type hydrothermal systems on Mars??

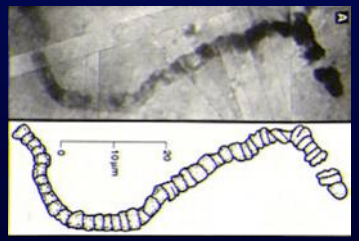
How do we look for evidence of life on Mars?

Biosignatures

BIOSIGNATURES

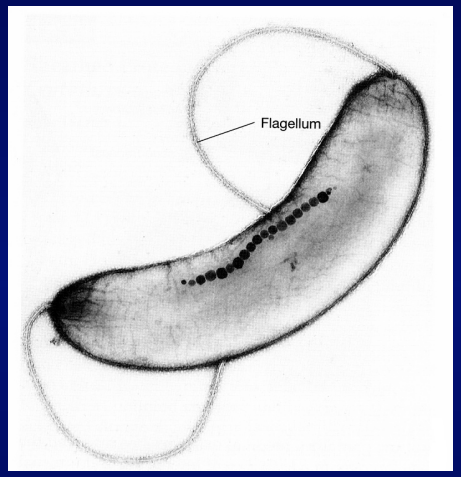
Microbially-influenced sedimentary structures
e.g., stromatolites

Microbial fossils



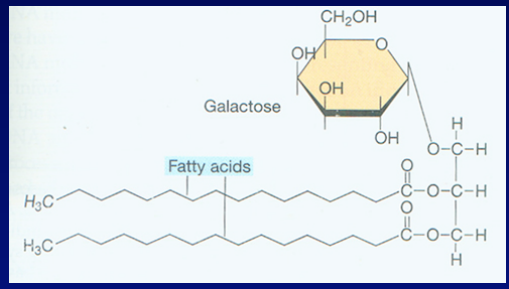
Chemofossils

Biominerals
a) BCM

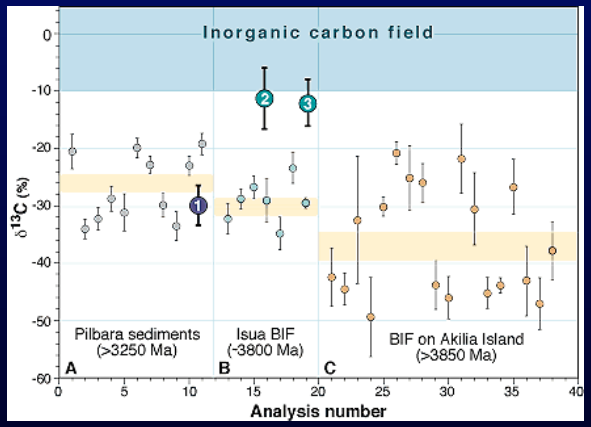


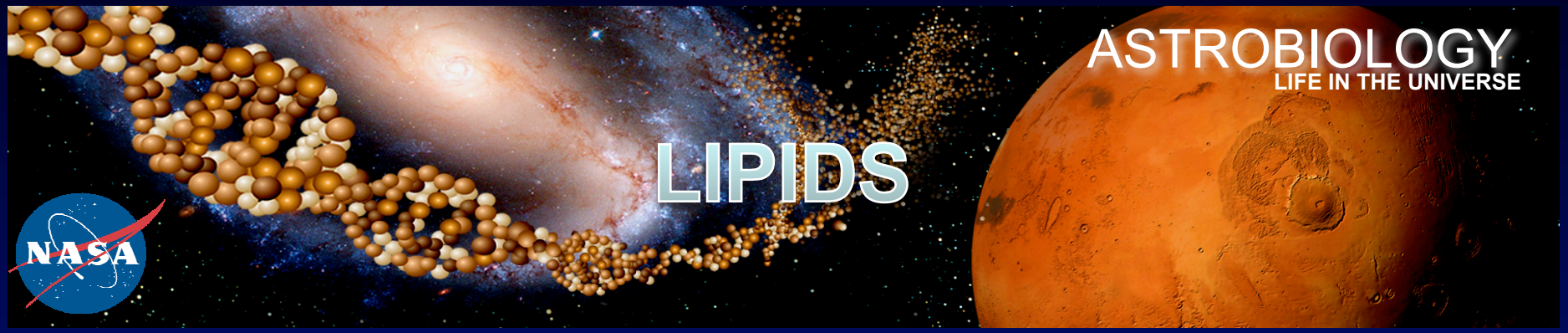
b) BIM

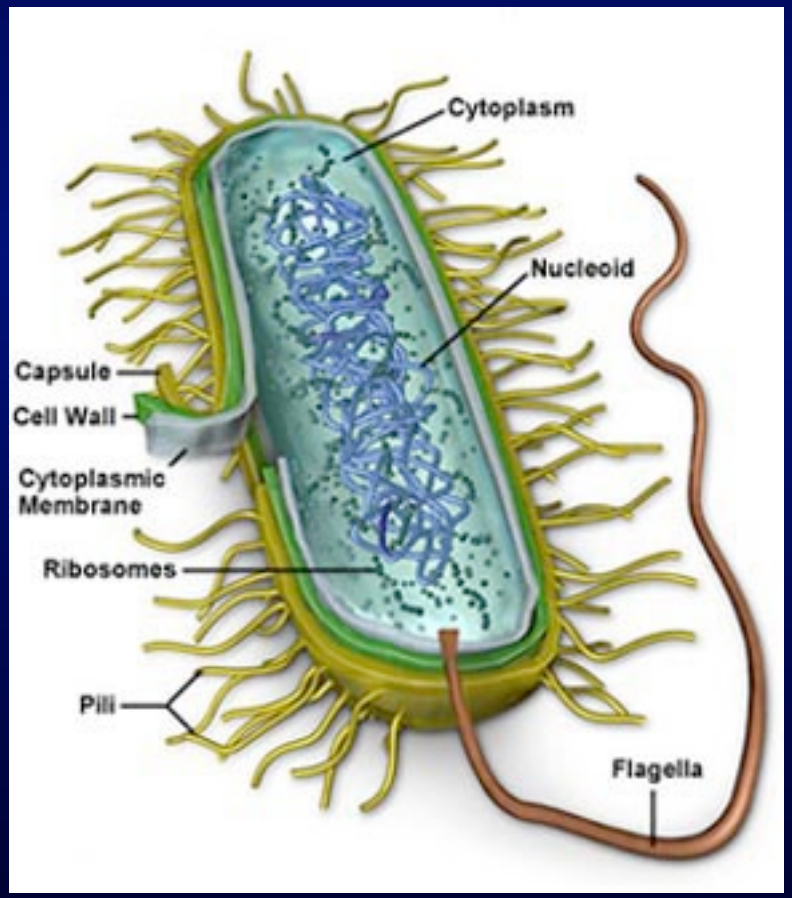
Lipid biomarkers



Stable isotopic fractionation



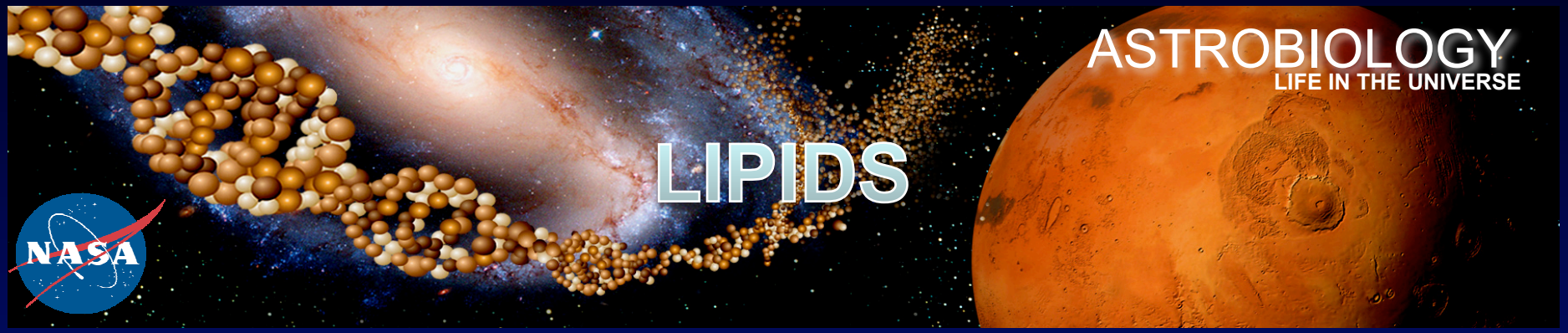


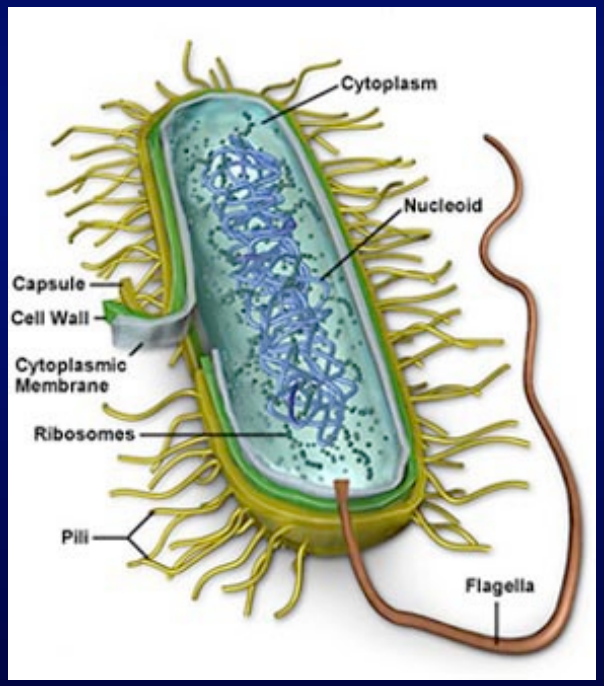


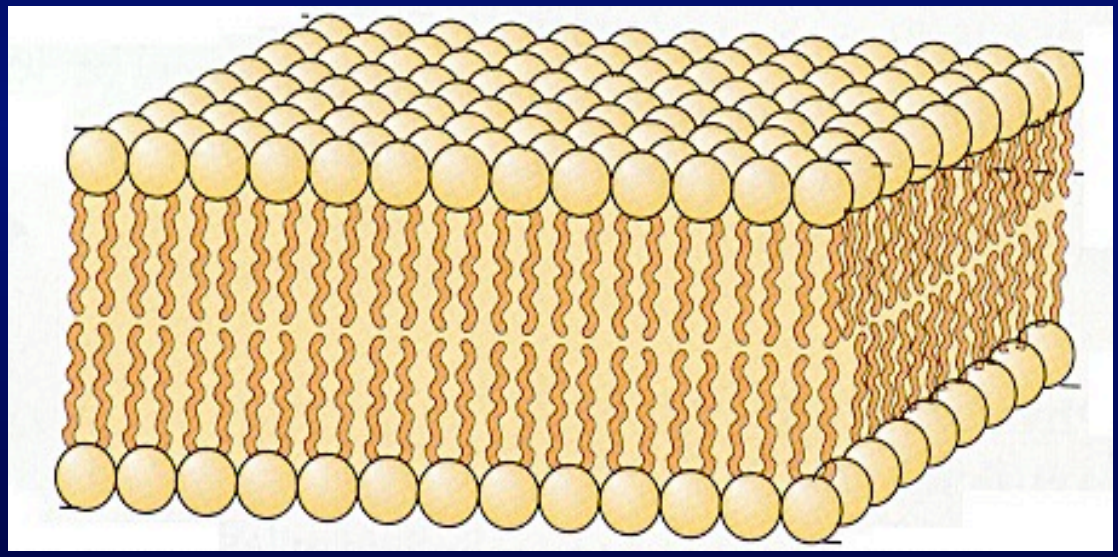
What are lipids?

Types:

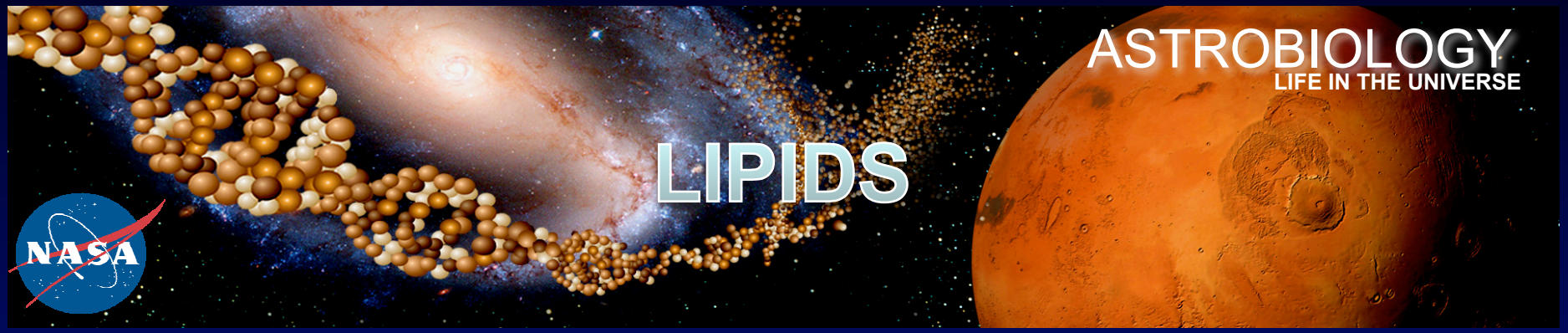
1. Oils, fats
2. Waxes
3. Sterols







Lipid bilayer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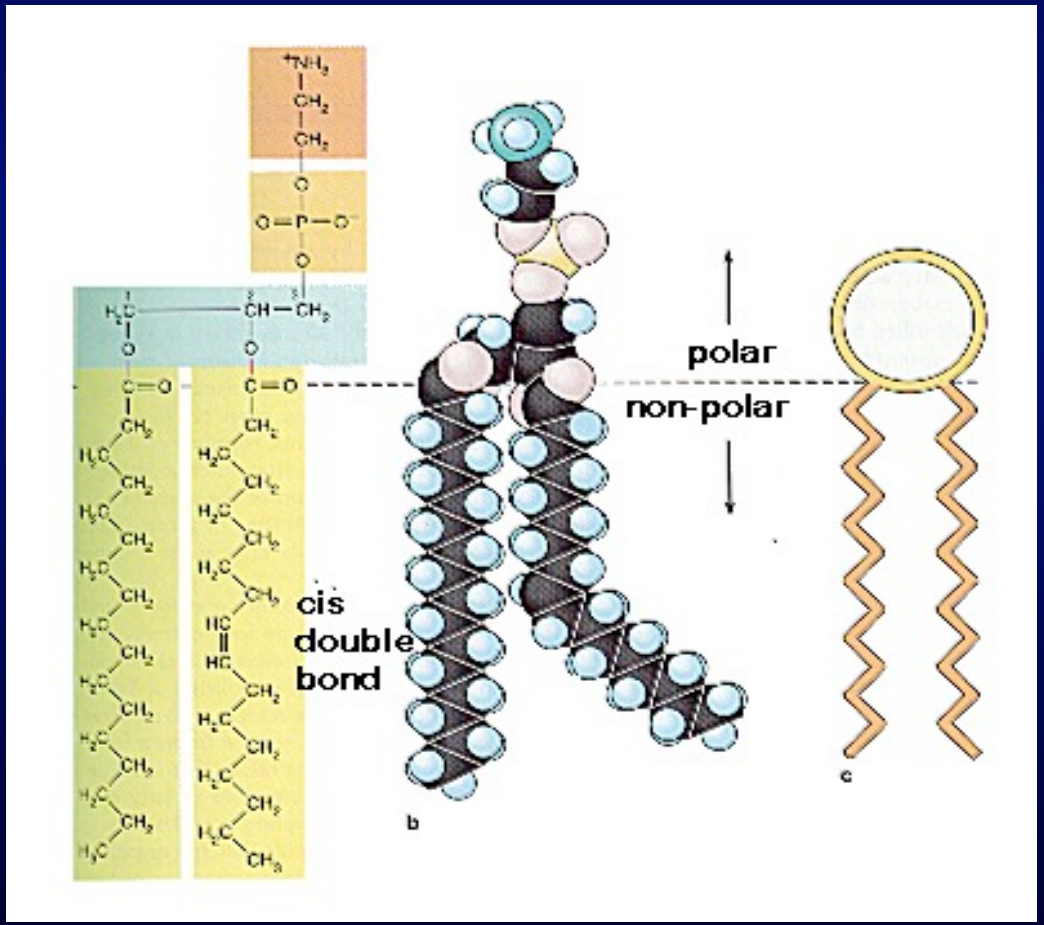
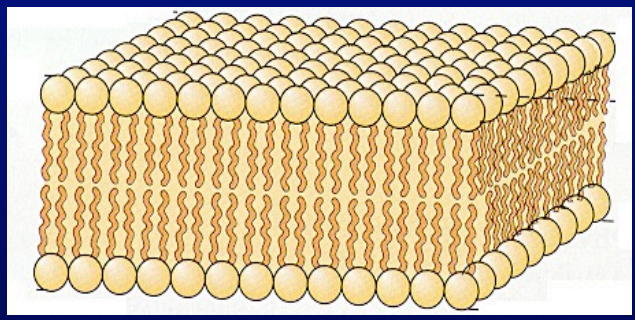
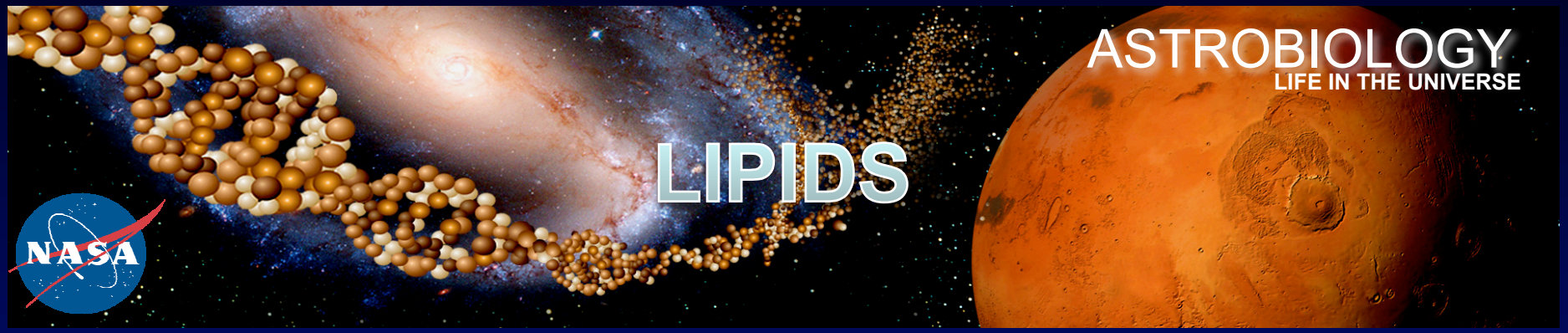
LIFE IN THE UNIVERSE
LIPIDS
NASA

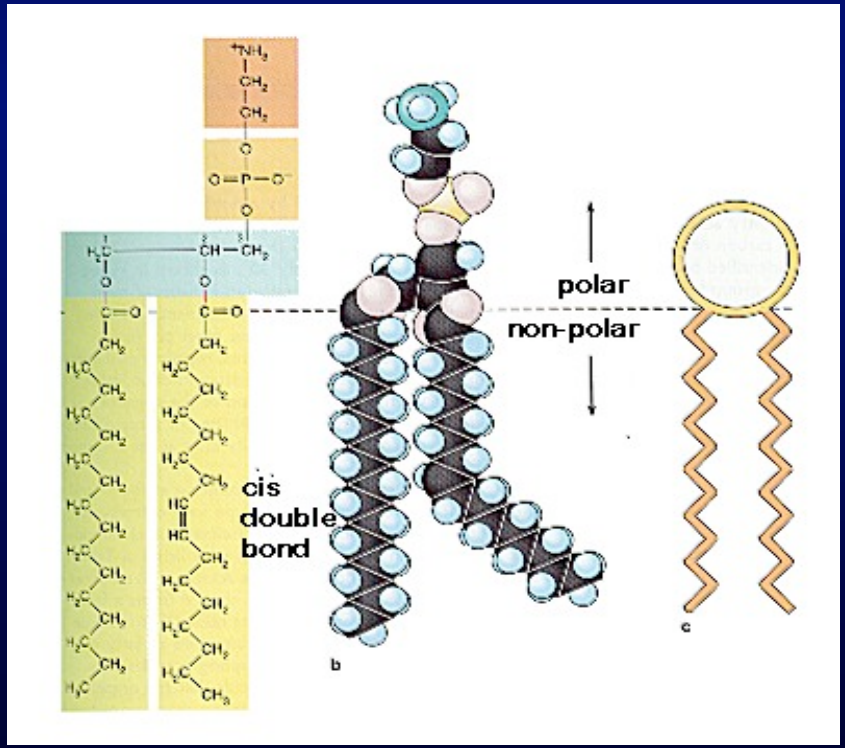

polar
non-polar
cis
double
bond
b
c

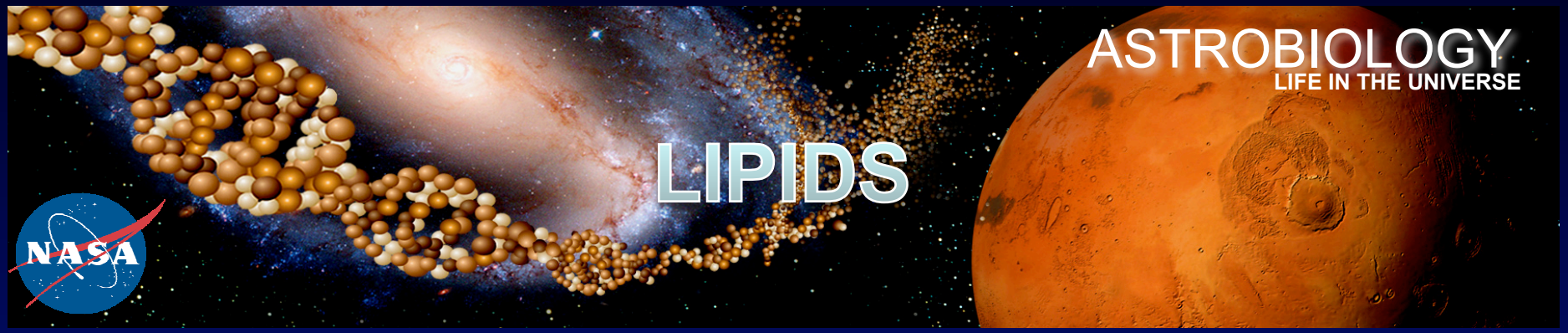
Fatty acids



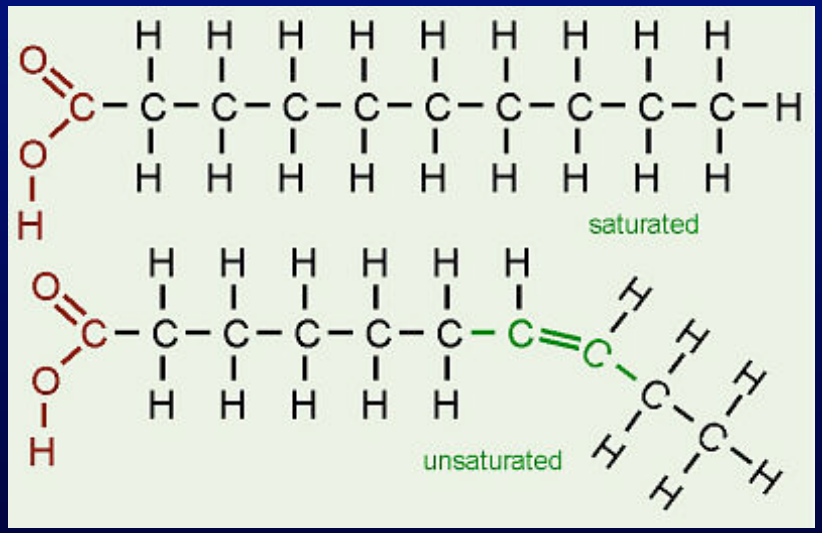


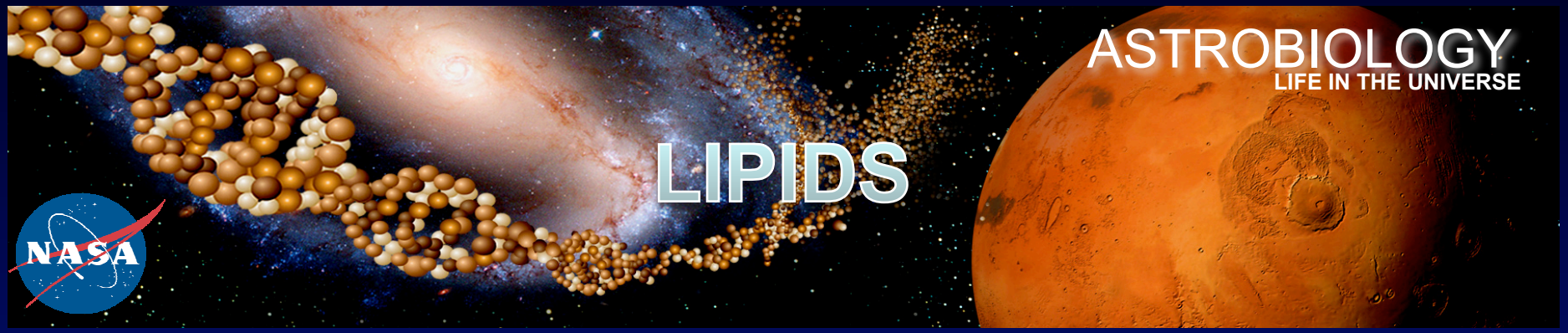
Mono-, Di-, and Tri-glycerides





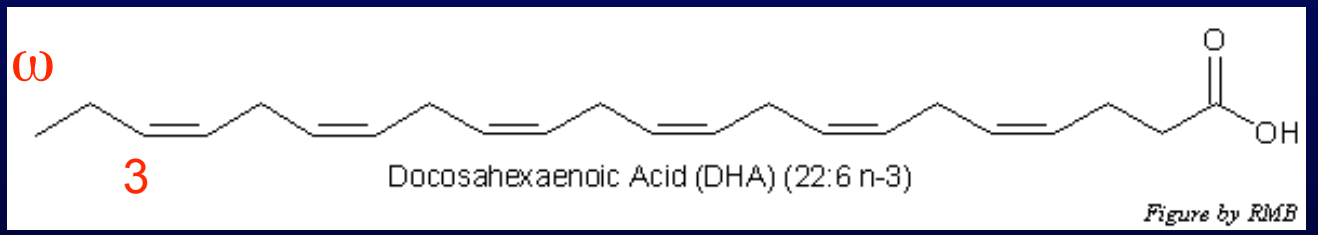
Saturated, mono-unsaturated, and poly-unsaturated

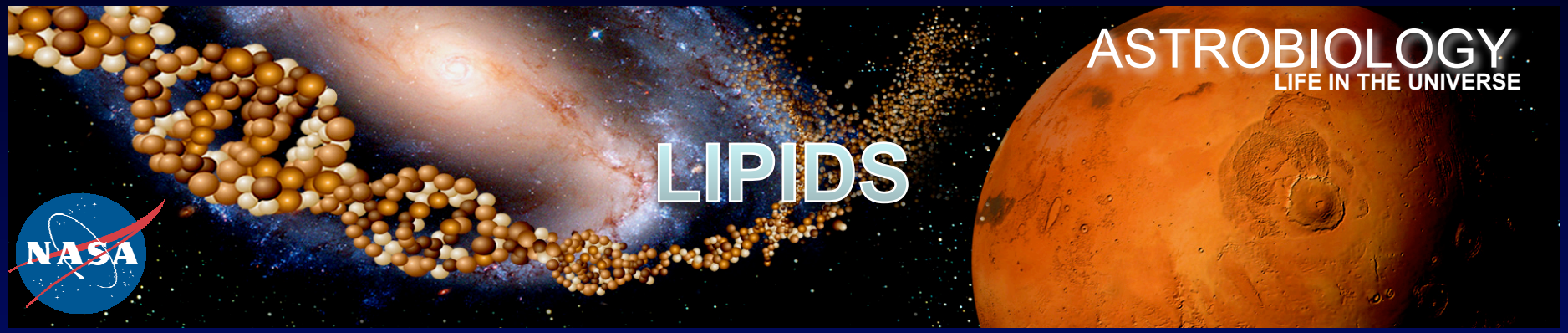




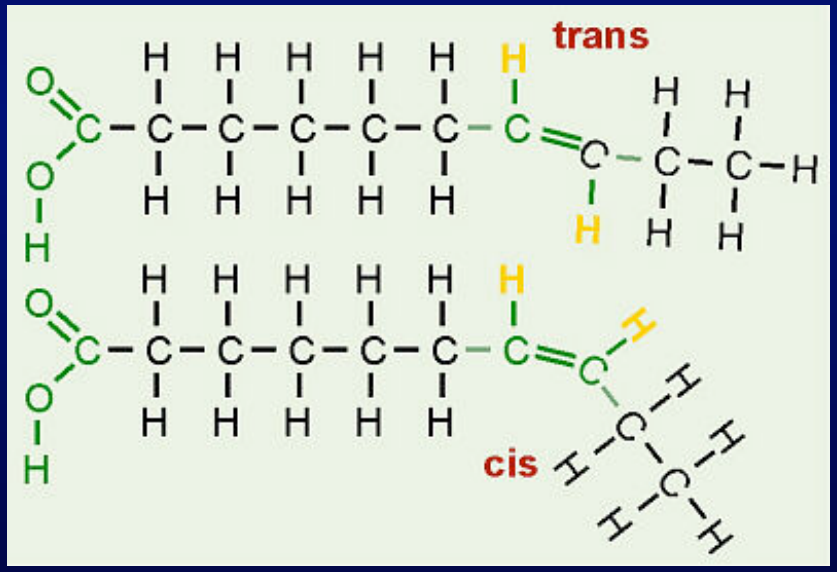
Saturated, mono-unsaturated, and poly-unsaturated

Fish oil: omega-3 fatty acids

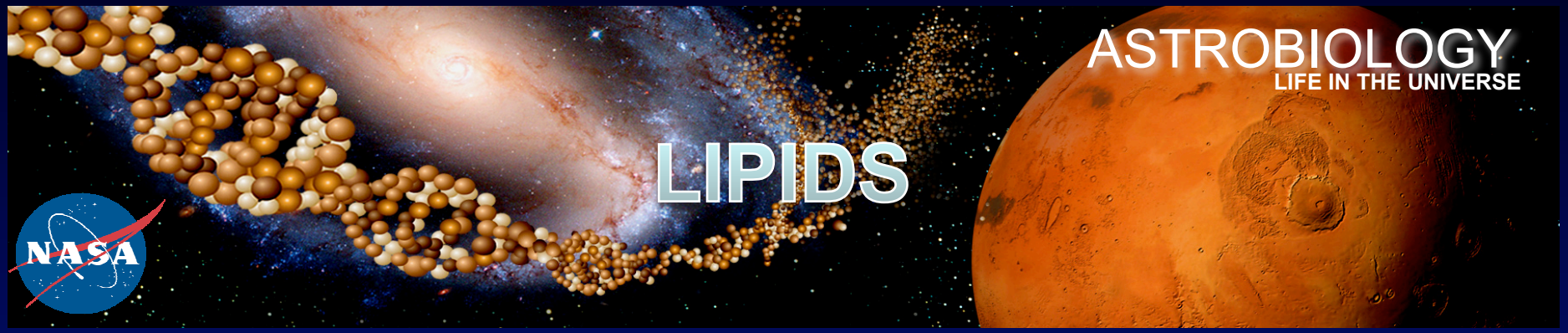




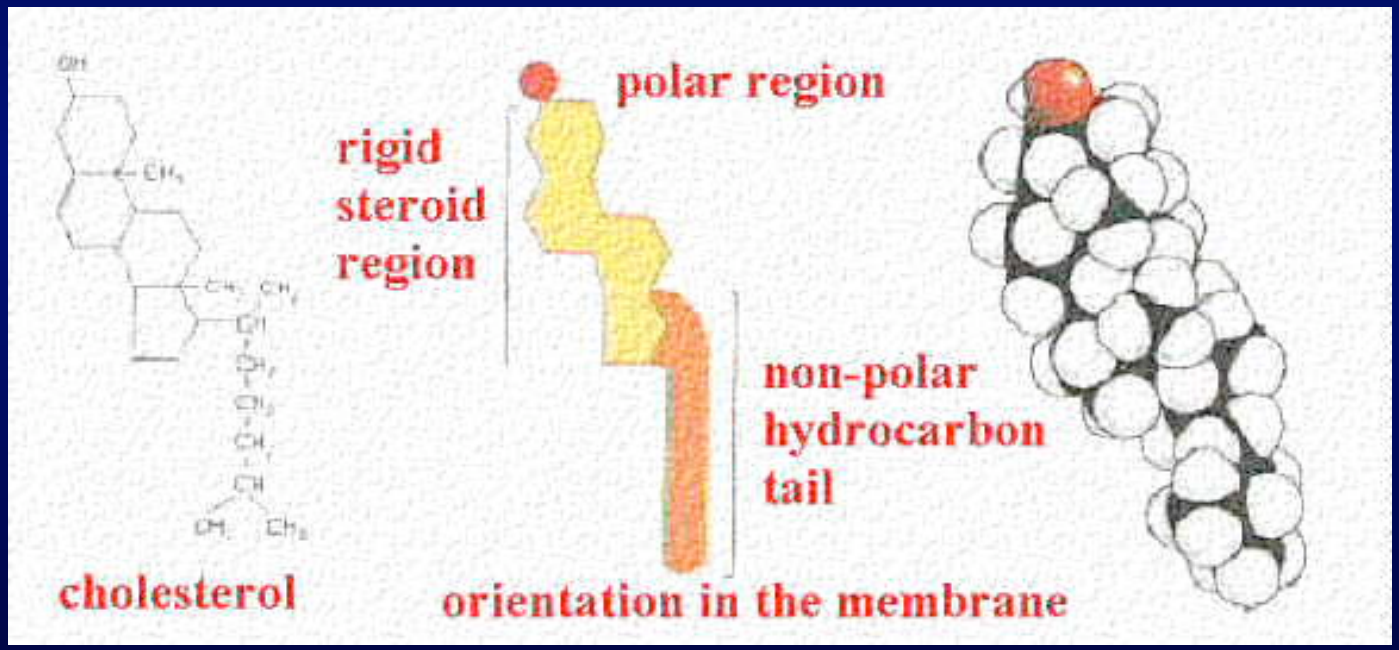
Trans fats



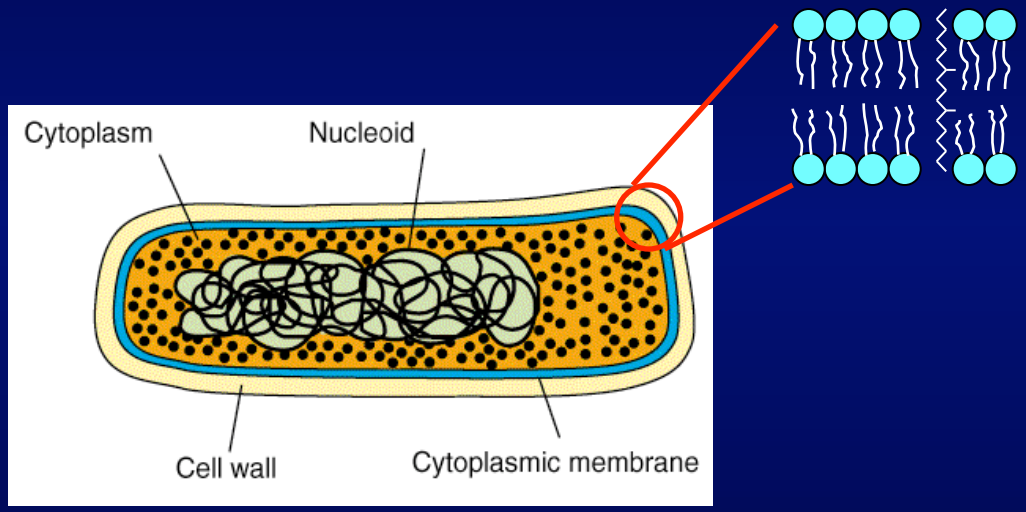
Cis bonds transform to trans upon heating
Trans fats = carcinogens!!

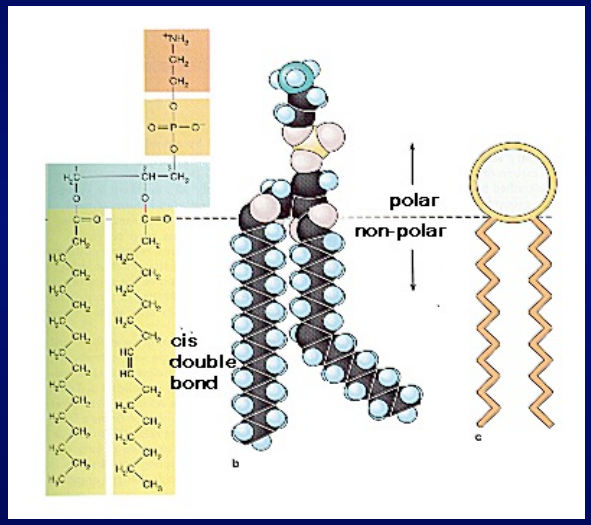


Cholesterol



Precursor to hormones (aka steroids!)
Vitamin D



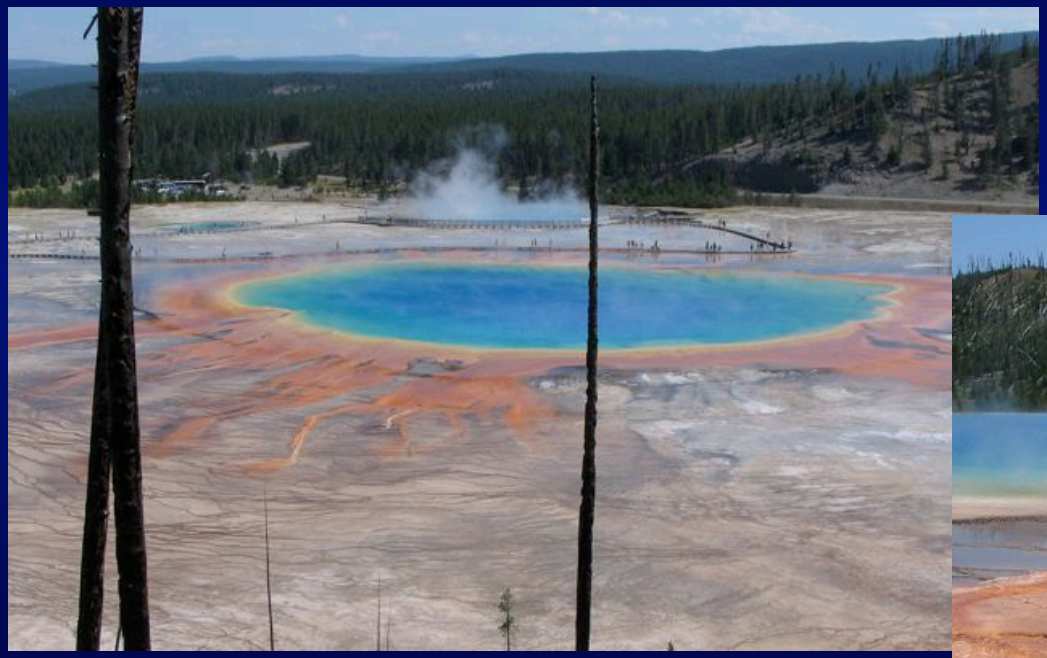


Ester-linked membrane fatty acids

Who's there?

ASTROBIOLOGY
LIFE IN THE UNIVERSE

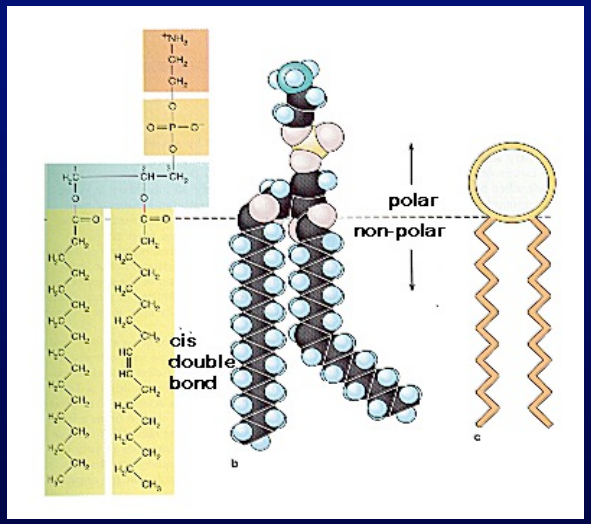
LIPIDS IN MICROBES

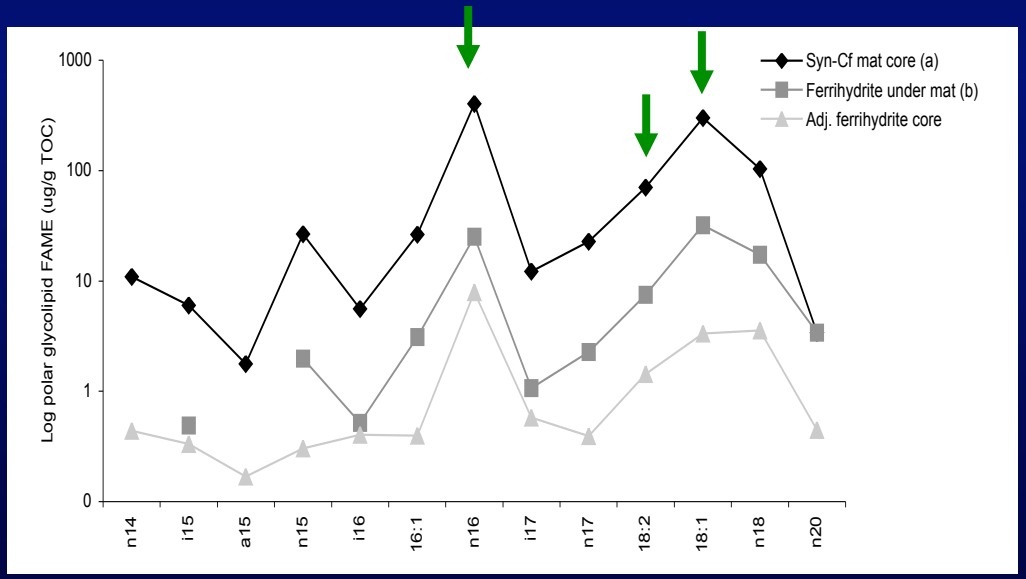


Grand Prismatic hot spring
Yellowstone

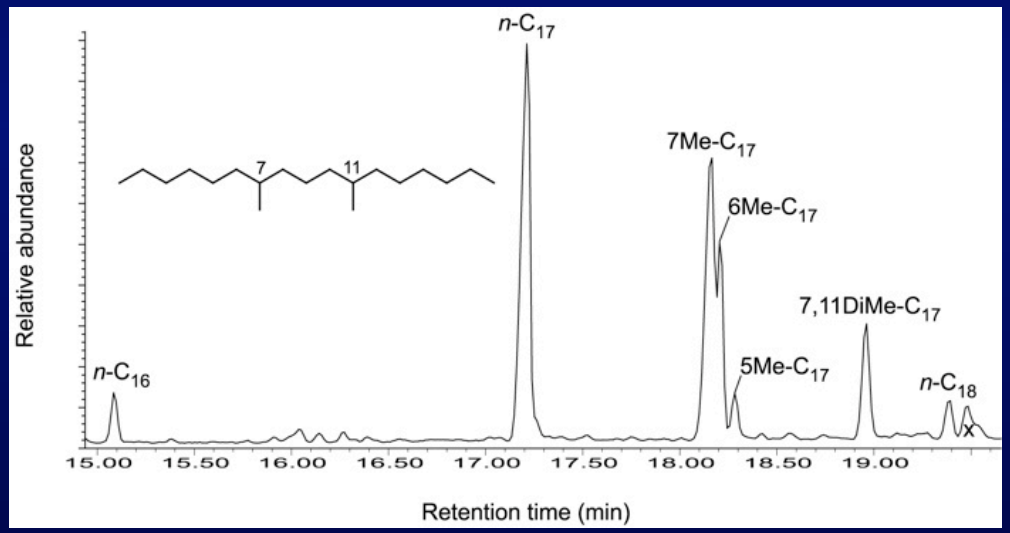

ASTROBIOLOGY
LIFE IN THE UNIVERSE
LIPIDS IN MICROBES
NASA

Who's there?


polar
non-polar
cis
double
bond


Log polar glycolipid FAME (ug/g TOC)
1000
100
10
1
0
Syn-Cf mat core (a)
Ferrihydrite under mat (b)
Adj. ferrihydrite core
n14
i15
a15
n15
i16
16:1
n16
i17
n17
18:2
18:1
n18
n20

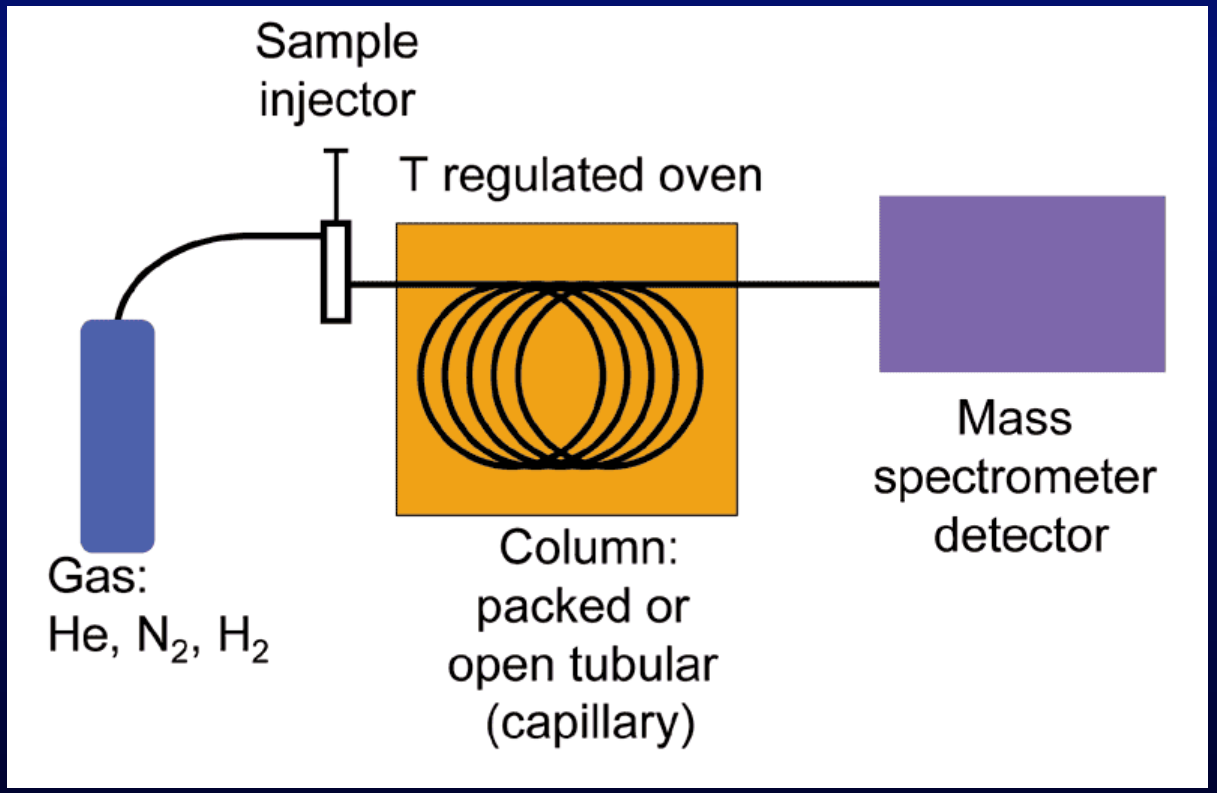
cyanobacteria

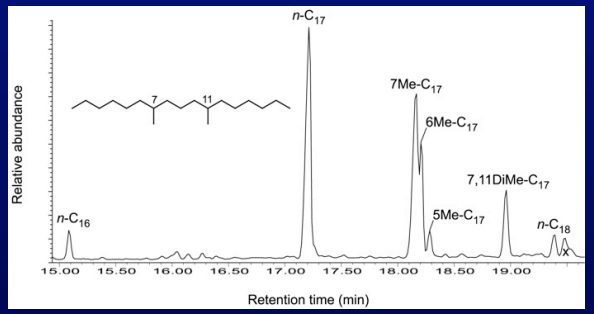


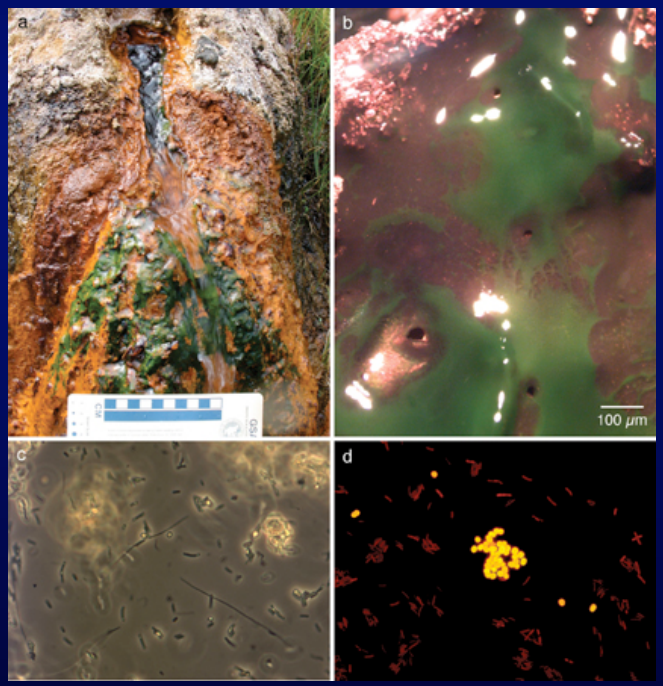
Gas chromatography-mass spectroscopy

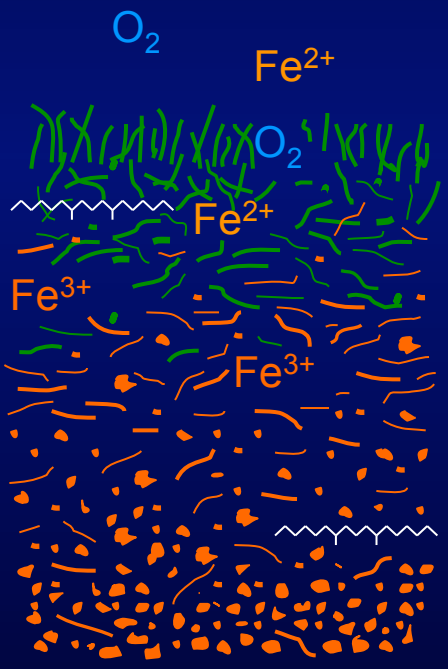
Hydrocarbons: mono- and dimethylalkanes

Gas chromatography-mass spectroscopy

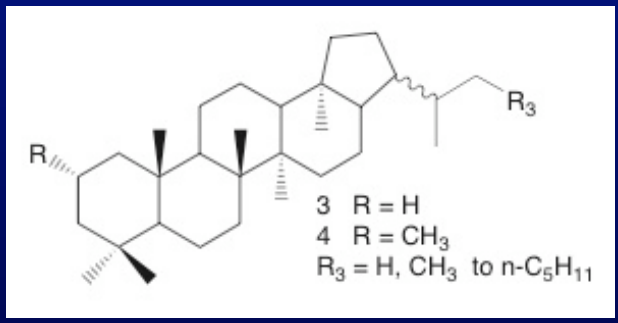






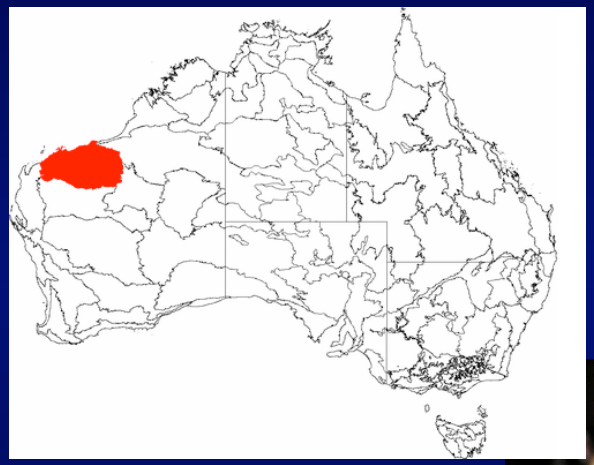


Cyanobacteria



2α-methylhopane

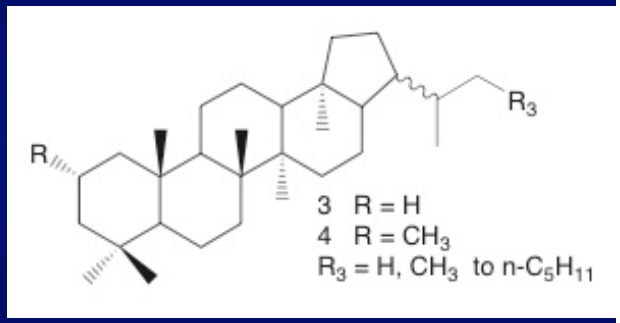
Brocks et al., 1999



Pilbara Craton, Australia

2.7 Billion years old!

Cyanobacteria



2α-methylhopane

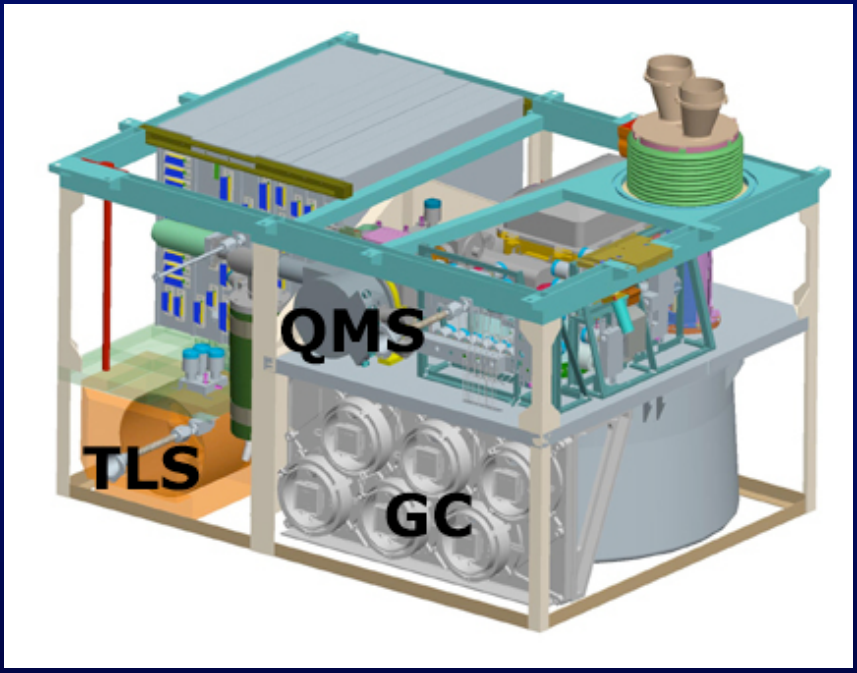
ASTROBIOLOGY
LIFE IN THE UNIVERSE

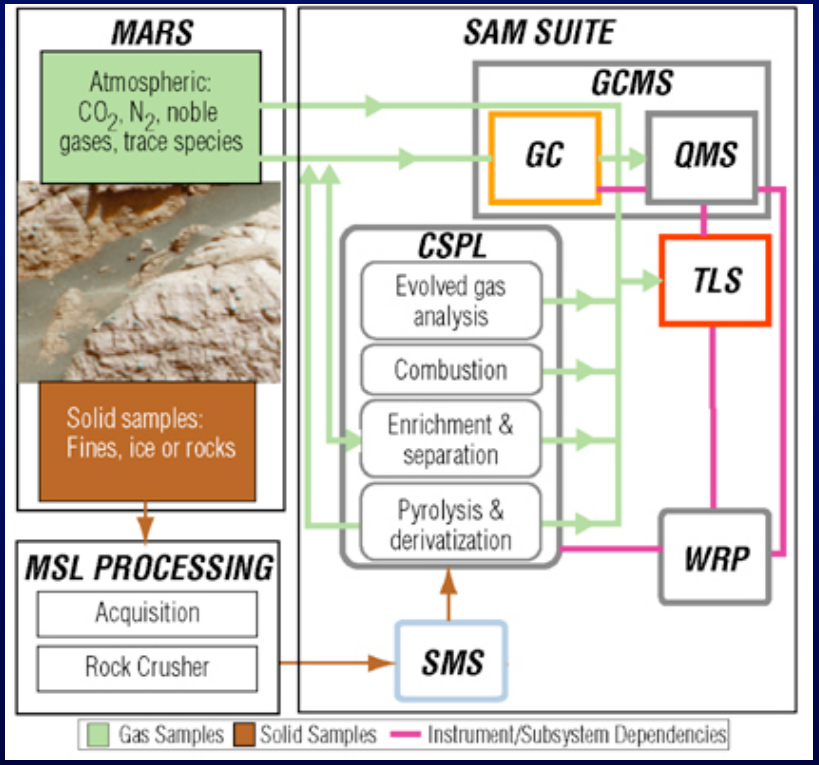
SEARCHING FOR LIPIDS ON MARS

Mars Science Laboratory mission launching 2011

ASTROBIOLOGY
LIFE IN THE UNIVERSE

SEARCHING FOR LIPIDS ON MARS





ASTROBIOLOGY
LIFE IN THE UNIVERSE

FIELD WORK - YELLOWSTONE

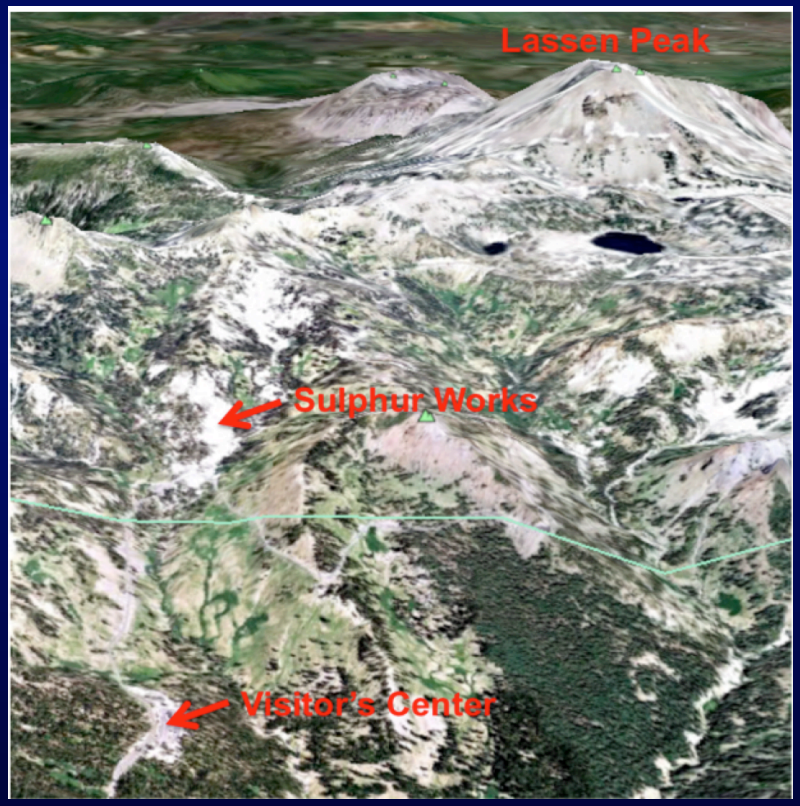
ASTROBIOLOGY
LIFE IN THE UNIVERSE

FIELD WORK - LASSEN

Lassen Volcanic National Park
Astrobiology Student Interns - Red Bluff High School

Cyanidia


ASTROBIOLOGY
LIFE IN THE UNIVERSE
LASSEN
NASA


Lassen Peak
Sulphur Works
Visitor's Center

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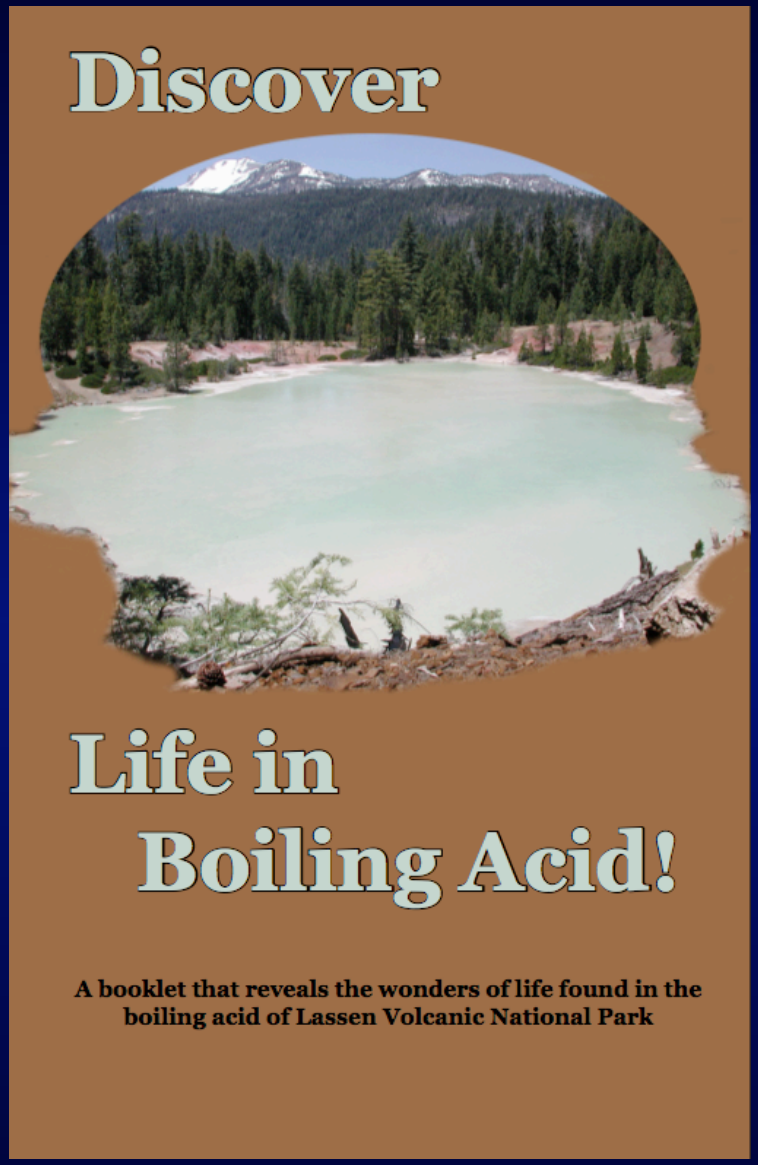
A brief tour of Sulphur Works

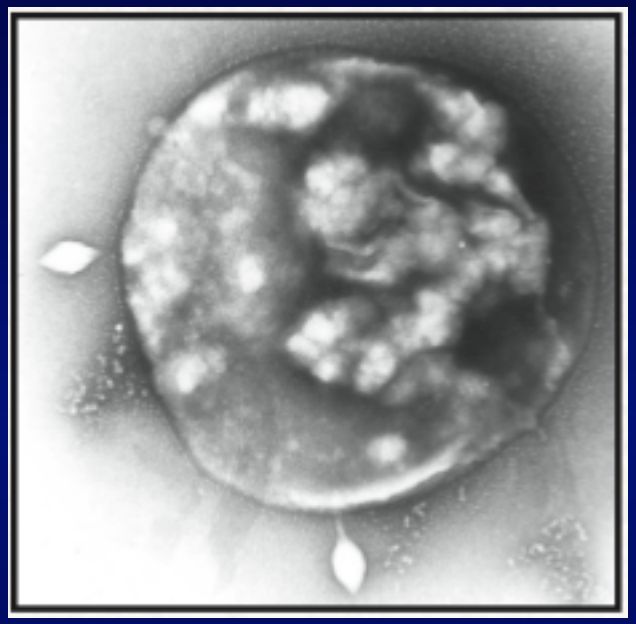
Mud pot on the side of the main road

Summer

Winter

75.2 °C pH 2.6

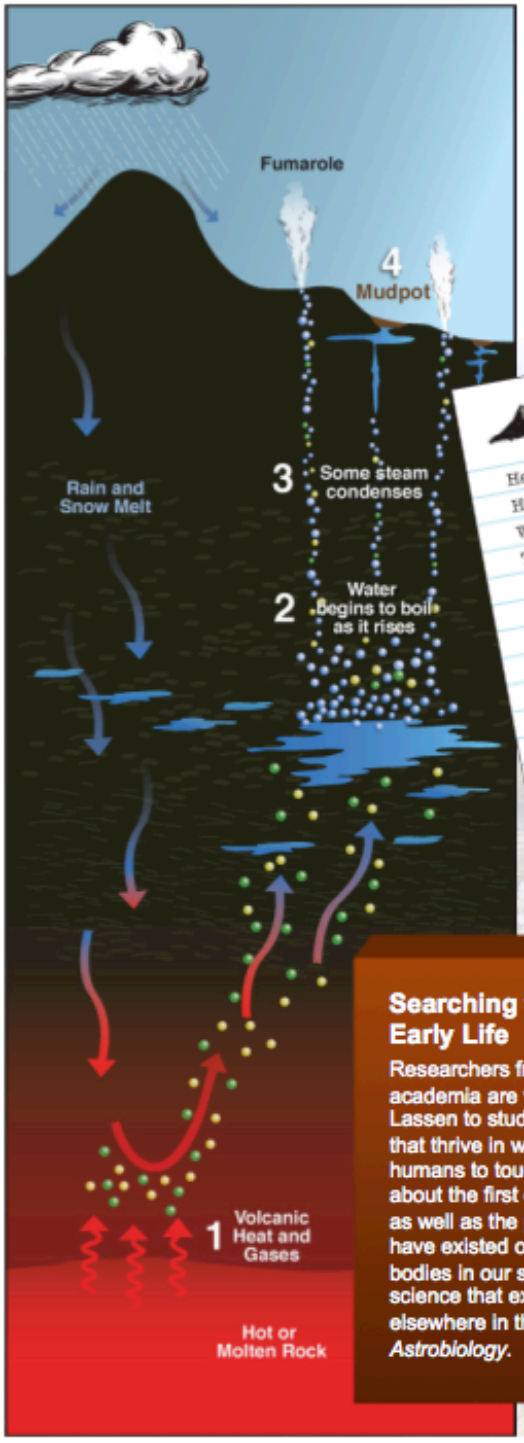




A virus attacking *Sulfolobus*

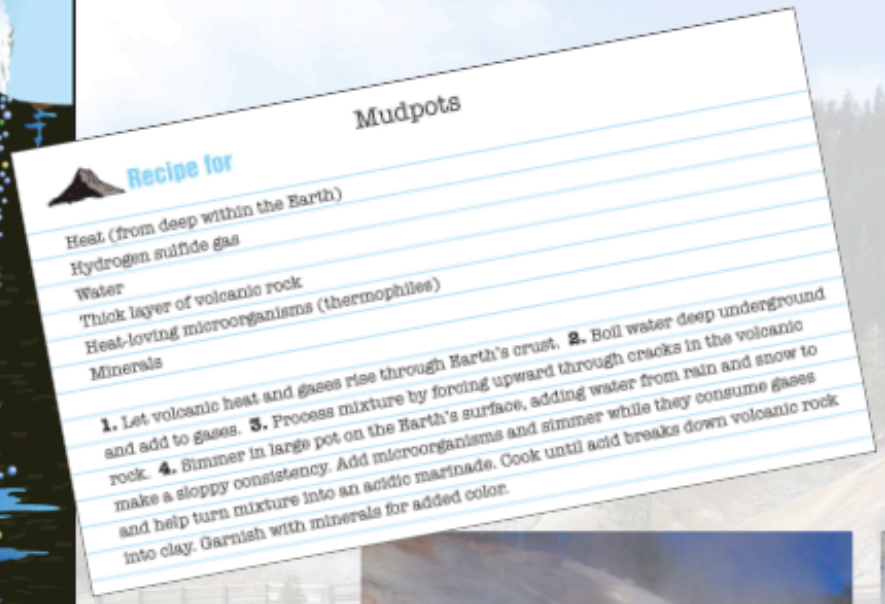
Dr. Ken Stedman, Portland State; Drs. Patty Siering and Mark Wilson, Humboldt State, Dr. Gordon Wolfe, Chico State

Sulphur Works



Making Mud

This vat of bubbling mud contains the perfect mix of ingredients to create mudpots: heat, gases, water, volcanic rock, minerals, acid, and thermophiles – heat-loving microorganisms too small to be seen by the naked eye. These thermophiles consume some of the gases and help convert them into sulfuric acid. The acid breaks down rock to form clay, which mixes with water to create mudpots.



Mudpots

Recipe for

Heat (from deep within the Earth)
Hydrogen sulfide gas
Water
Thick layer of volcanic rock
Heat-loving microorganisms (thermophiles)
Minerals

1. Let volcanic heat and gases rise through Earth's crust. **2.** Boil water deep underground and add to gases. **3.** Process mixture by forcing upward through cracks in the volcanic rock. **4.** Simmer in large pot on the Earth's surface, adding water from rain and snow to make a sloppy consistency. Add microorganisms and simmer while they consume gases and help turn mixture into an acidic marinade. Cook until acid breaks down volcanic rock into clay. Garnish with minerals for added color.

Searching for Clues of Early Life

Researchers from NASA and academia are working together in Lassen to study microorganisms that thrive in water too hot for humans to touch. They can tell us about the first organisms on Earth, as well as the potential for life to have existed on Mars or other bodies in our solar system. The science that explores for life elsewhere in the universe is called *Astrobiology*.

Mudpots change with the seasons. In the late summer when there is very little precipitation, mudpots are dry and dominated by steam, as seen in the image on the left. The image on the right shows the same mudpot in the spring, when the snow melts and water mixes with clay to form a bubbling cauldron of mud.

Exhibit made possible by support from NASA Astrobiology Institute and Lockheed Martin Exploration and Science

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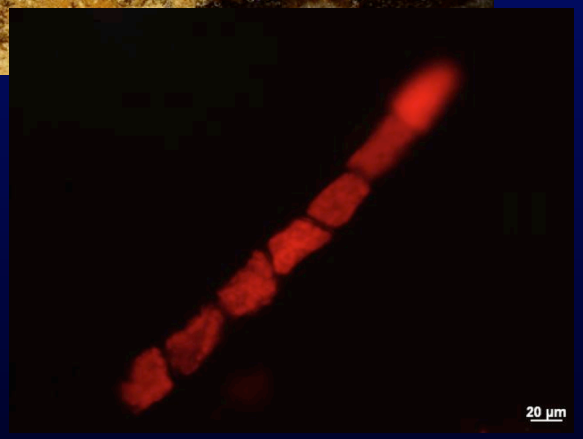
A brief tour of Sulphur Works

Hydrothermal outflow channel near the road



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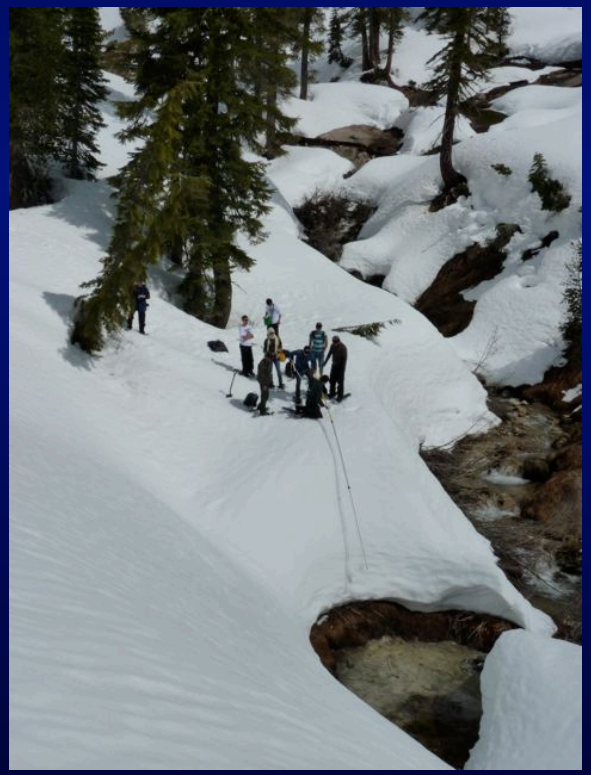
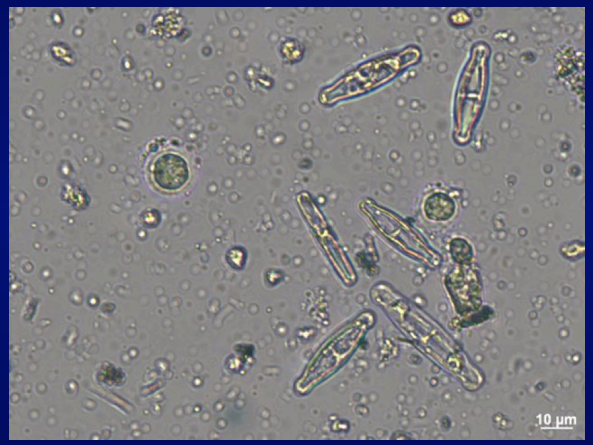
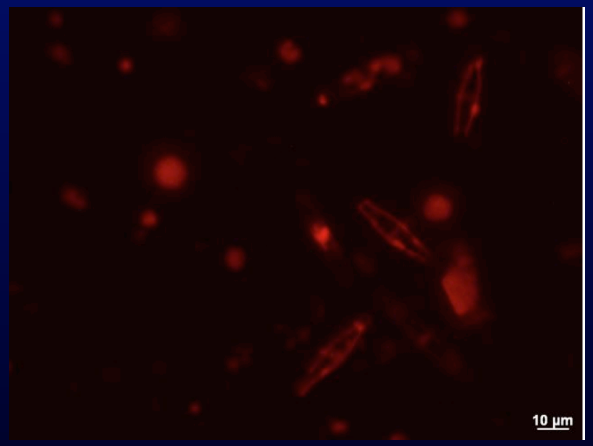
A brief tour of Sulphur Works

Hydrothermal pool along the Ridge Lakes Trail, Upper Sulphur Works



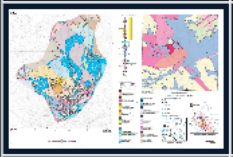
23 May 2011





http://microbes.arc.nasa.gov/STEP/htm_files/Lassen_Trip__resources.htm

Science, Technology and Exploration Program (STEP)

Lassen Volcanic National Park Field Trip Resources			
	National Park Service Web Site	Useful information about Lassen Volcanic National Park	Link
	USGS Geologic maps	Geologic maps of Lassen Volcanic National Park	Link
	Discover Life in Boiling Acid!	Booklet about microbes that live in the boiling acid of Lassen Volcanic National Park	Download
	Sulfur Works Field Guide	Information about one of the field sites we will visit	Download
	"Hot Water" in Lassen Volcanic National Park	USGS publication about the thermal features in Lassen Volcanic National Park	Download

1. What is Astrobiology?
    a) how does Astrobiology relate to Lassen?
2. What are lipids?
3. Lipids in microbes
    a) how can lipids help us to identify microbes in the environment?
    b) examples from Yellowstone and Lassen
4. Lipids in old rocks
5. Search for evidence of microbial life on Mars using lipids
    a) Mars Science Laboratory SAM instrument packageLipids in old rocks
6. Introduction to Lassen