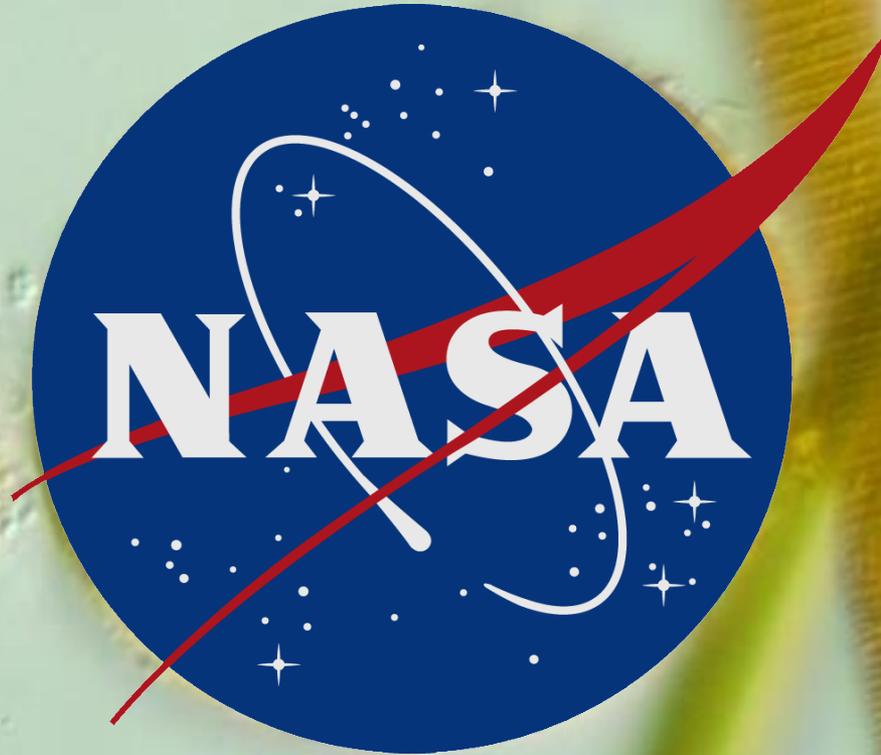


Microbes@NASA:

Why NASA Cares About Microbes

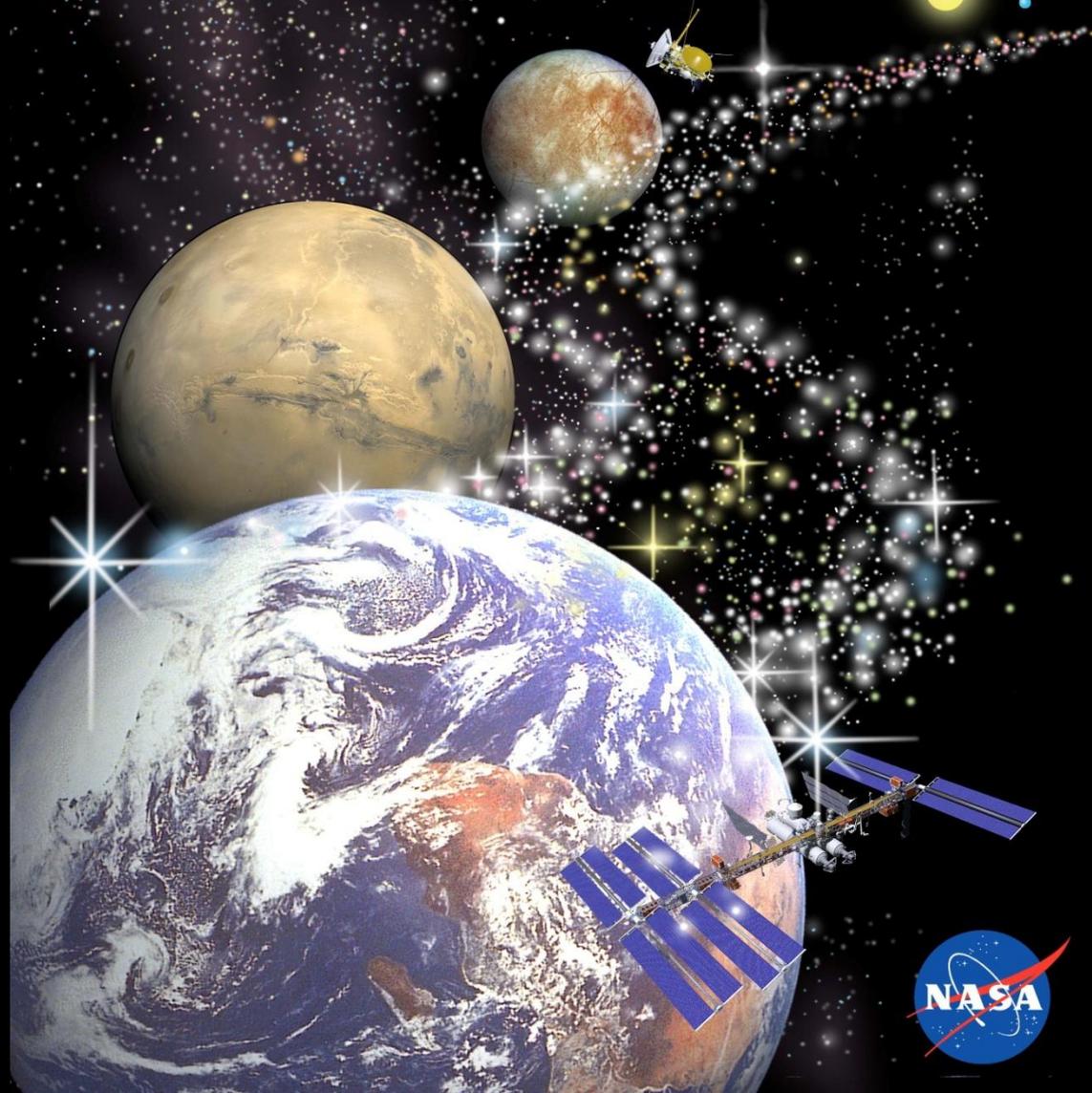


Brad Bebout, NASA Ames Research Center

Outline of Presentation

- Why should NASA care about microbes?
- Some stuff about microbes
- What are microbial mats and stromatolites?
- Why should NASA care about algae?
- Satellite experiments
- Other stuff about algae

Why Should NASA Care About Microbes?



I'll Give You Two Reasons.

1. Microbes are Germs:

Microbes:

- Will be with us when we leave the Earth whether we want them to be or not
- May become more virulent in space
- May produce toxins in a closed environment
- May degrade materials that are critical for safety (seals, etc.)

Maybe we should learn about microbes in space...

But NASA is All About Looking
for Life, Right?

2. Microbes Run Our Planet:

Microbes:

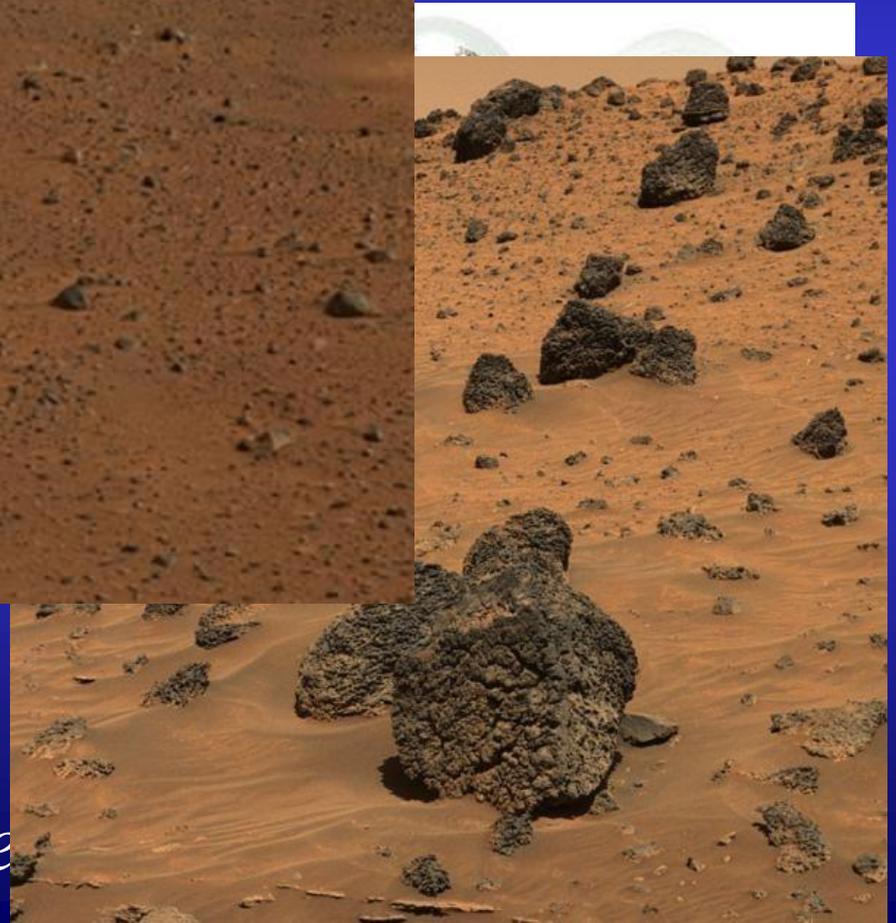
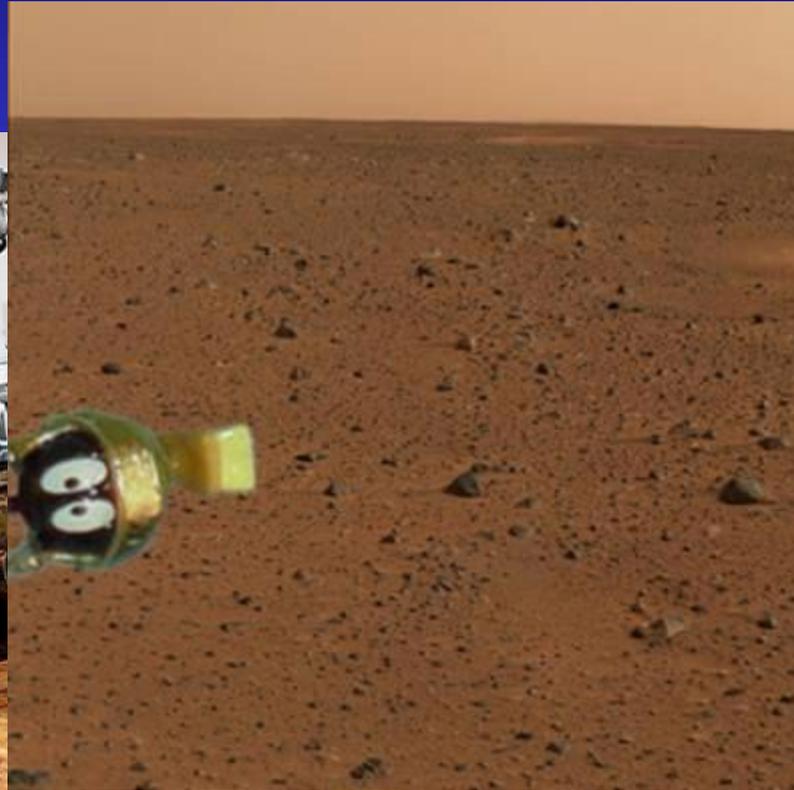
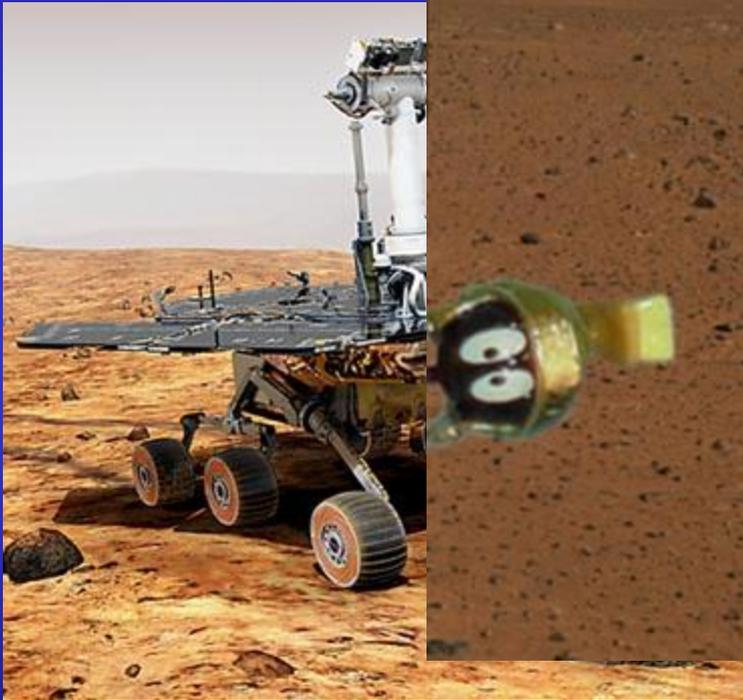
- Are the oldest forms of life, (had the planet to themselves for nearly 3 billion years)
- Have the greatest number, biomass, and diversity on Earth
- Most diverse metabolisms on Earth
- Control the cycling of (nearly?) all biologically important elements on Earth, and maybe on your spacecraft, as well

Maybe Microbes Run Other
So, We're Thinking...
Planets as Well...

*And maybe, just maybe, thinking about microbes as
NASA does might be a useful thing to do...*

Looking For Life

Local Edition (Our Solar System)



If Martians were big, we

How We're Looking for Life, Nearby:

Local Edition (Our Solar System)

Fossil
Organisms



Meteorites

Orbiting
Missions



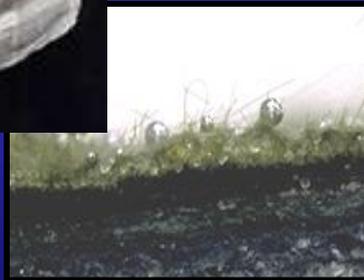
Biological
Molecules



Structures
Built by
Life



Chemistry
Performed
by Life



Landed
Missions



Looking For Life

Way Out There (Around Other Stars)



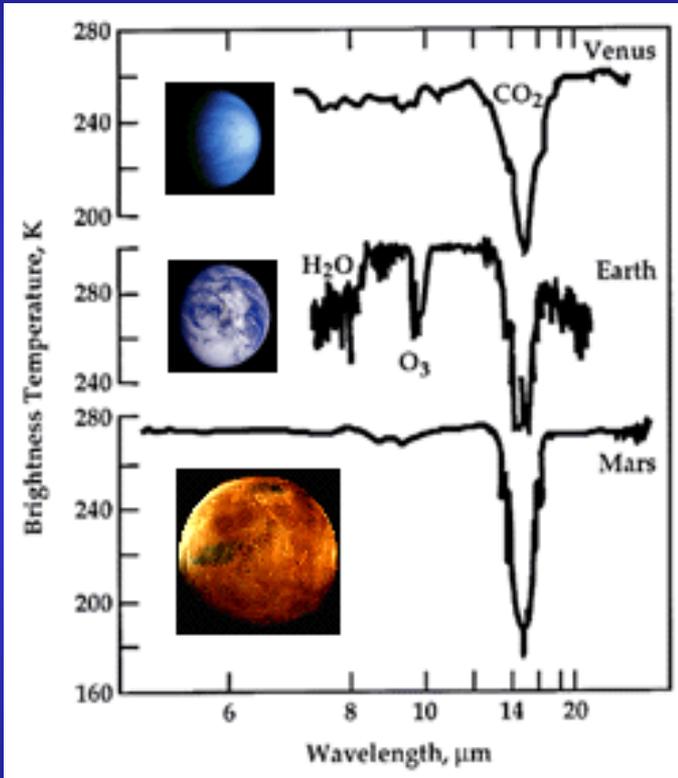
intelligent

∇

If life was out there, we should have heard from 'em...

How We're Looking for Life

Way Out There (Around Other Stars)



Infrared and Far Infrared Absorption

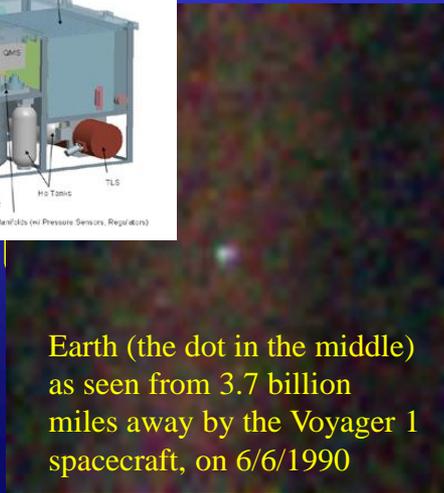
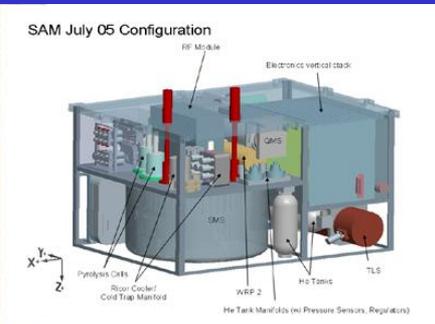
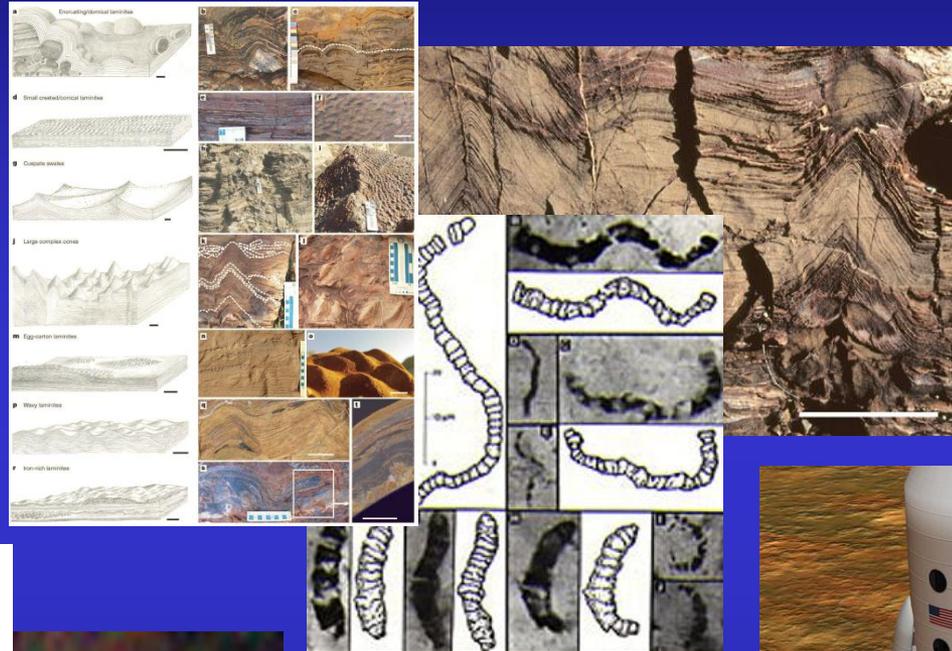
Terrestrial Planet Finder



So... Microbial Life is Extremely
Important in Life Detection
Strategies, In Fact...

Astrobiology's: Big Questions:

An (Admittedly) Microbe-Centric View



Earth (the dot in the middle) as seen from 3.7 billion miles away by the Voyager 1 spacecraft, on 6/6/1990

Maybe We Should Learn More
About Microbes?

What Do Microbes Need?

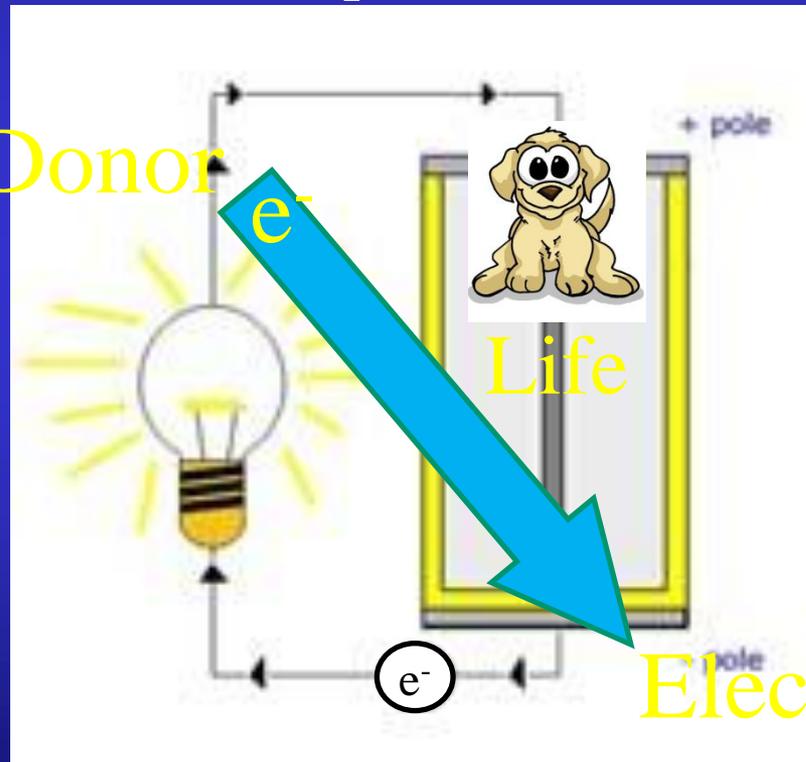
- Liquid water
- Food?
- A flow of electrons

A flow of electrons... Huh?

Life is a Battery, or... The Miracle of Life According to a Chemist

Electrons flow “downhill” from a donor to an acceptor, the flow of electrons is used to perform work (metabolism)

Electron Donor



Electron Acceptor

So... we should be looking for electrons?

Sources of Electrons for Microbes



Organic
Matter



Light!

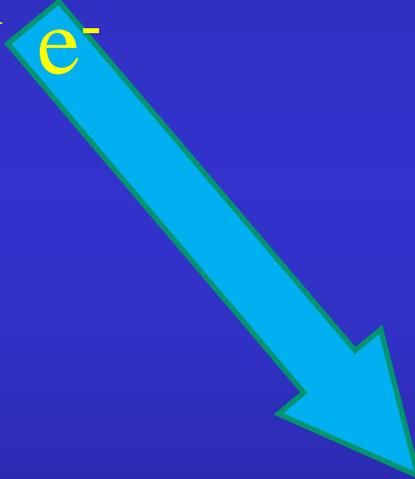
Inorganic
Matter



Electrons would be a good thing to look for...

Our Metabolism: a Chemist's View

Electron Donor



Electron Acceptor

It's pretty much the same for microbes, right?

Well, we then run smack dab into
microbial diversity...

Lots and lots of Electron Acceptors

oxygen, sure, but also:

organic C (fermentation)

nitrate

iron

manganese

sulfate

carbon dioxide

Electron acceptors would be a good thing to look for

Lots and lots of electron donors

organic carbon, sure, but also:

hydrogen sulfide

methane

iron

manganese

pyrite

ammonium

arsenic

selenium

Electron donors would be a good thing to look for

When in Doubt, Make up Names

Biologists classify organisms on basis of where their food comes from

- Heterotrophs: Organic carbon compounds are used as electron donors.
- Chemoautotrophs: Inorganic carbon compounds are electron donors. Organic carbon is synthesized.
- Photoautotrophs: Light energy (sun) is captured. Organic carbon is synthesized.

Don't tell the chemists that they are basically right

So we now know all these
wacky "electron" donors and acceptors

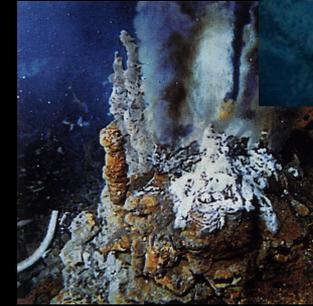
Microbes in Extreme Environments



Deep Sub-surface



Hypersaline



Deep Sea Vents

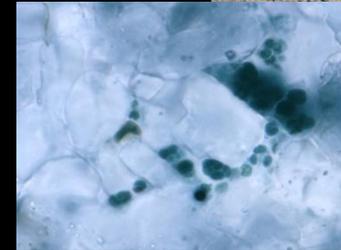
Thermal Features



Ice and Permafrost



Hot and Cold Deserts



Where in the ~~World~~ Universe
Would We Find Such Places?

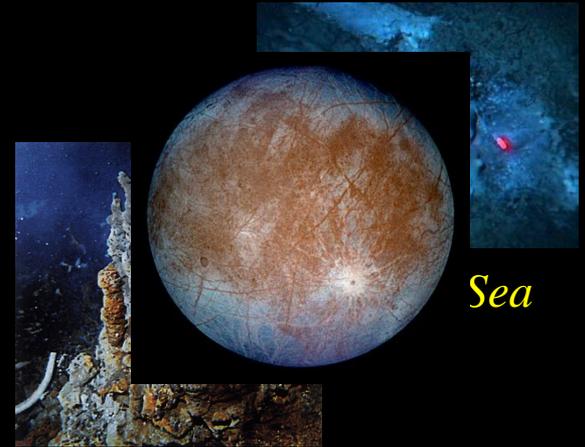
Microbes in Extreme Environments



Hypersaline

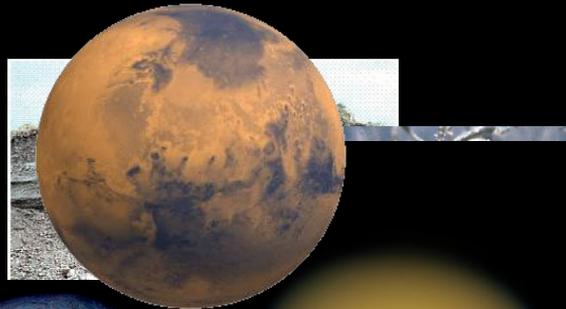
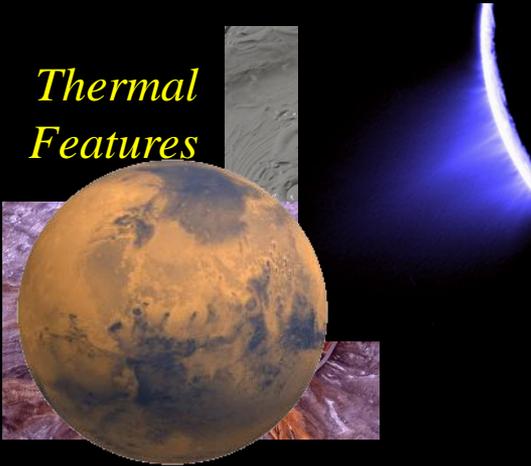


*Deep Sub-
surface*

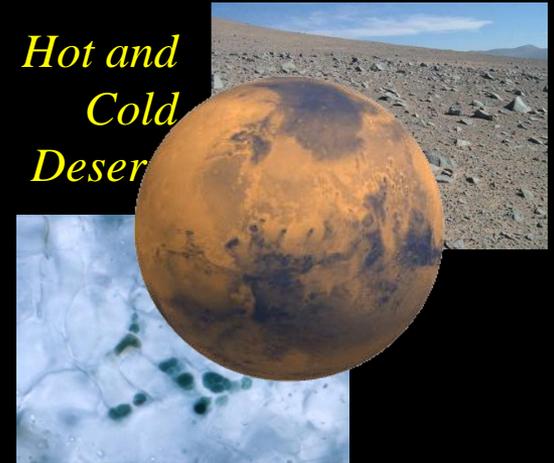


Sea

*Thermal
Features*



*Hot and
Cold
Desert*



The Universe-Wide Microbe Scavenger Hunt

Because There is So Much Energy
in a Star, Photosynthesis Results
in a Much Larger “Signal” for Life

Which is where we come in...



Microbial mats are found in hypersaline waters, deep sea vents, hot springs, ice and permafrost (not so much in the deep subsurface, but some...)

But photosynthetic microbial mats need light...

Microbial Mats and Stromatolites

Microbial mats are:

- Planar microbial communities, usually laminated, usually highly complex

Stromatolites are:

- Microbial mats incorporating a mineral component, can be bound and/or precipitated

Microbial Mats and Stromatolites

Microbial mats are:

- slime

Stromatolites are:

- Hard and/or lumpy slime

Going to talk mostly about photosynthetic mats



Three Billion, Five
Hundred Million
Years Ago...

Some Microbial Mats:



Some Stromatolites:



How Do I Understand What, if
~~Some of the Stuff We Do~~ With This
Glop of Stinky Stuff, or...

Look Under a Microscope

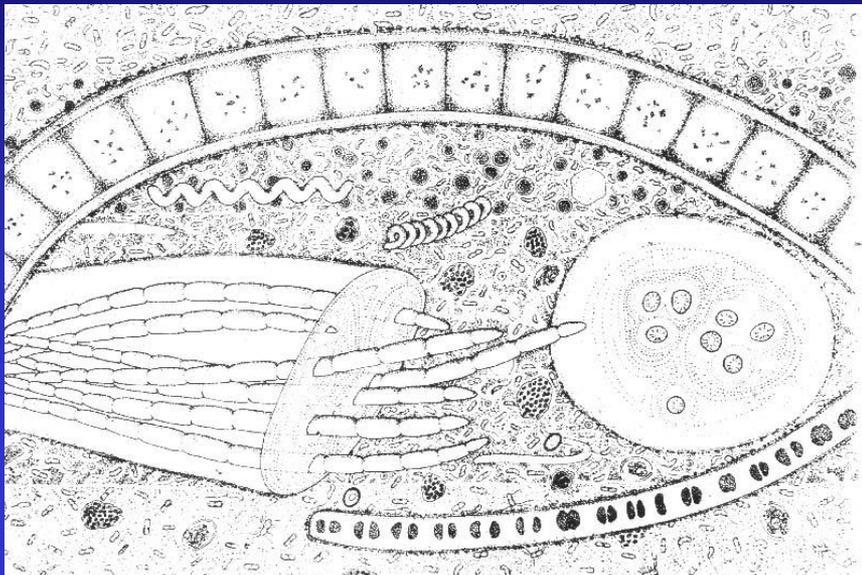
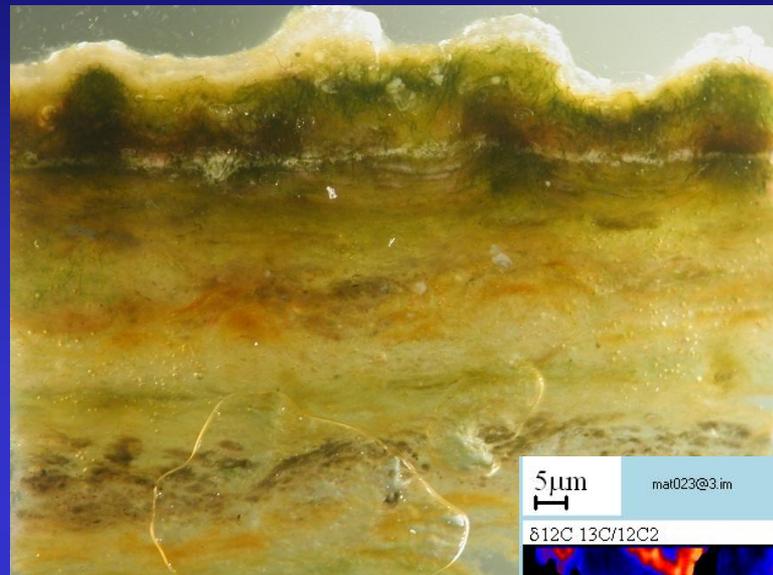
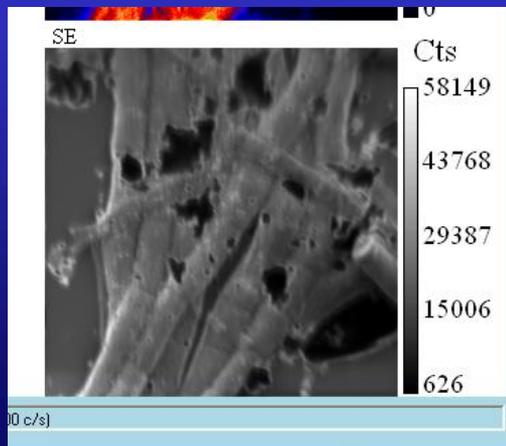
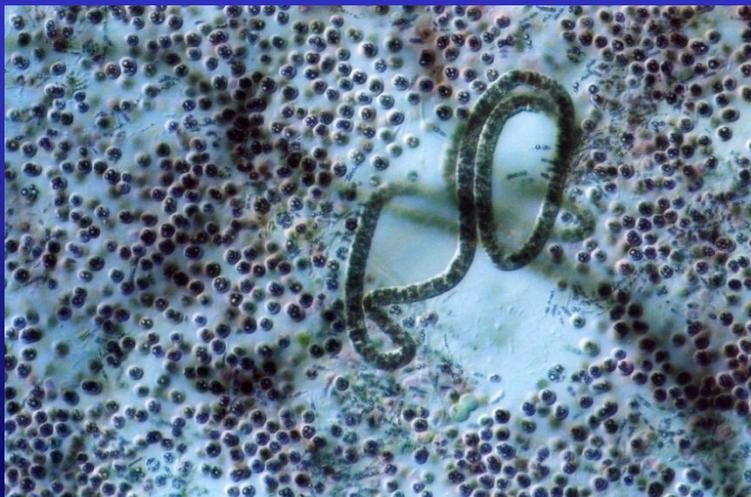
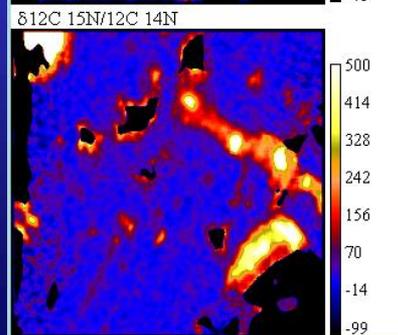
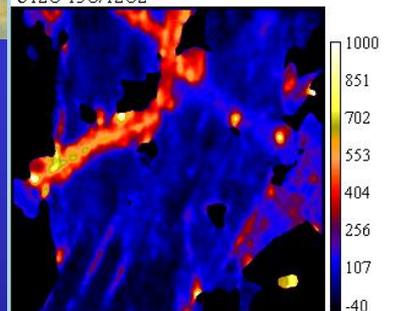


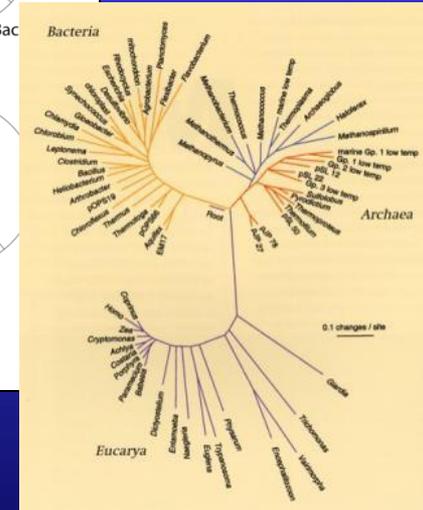
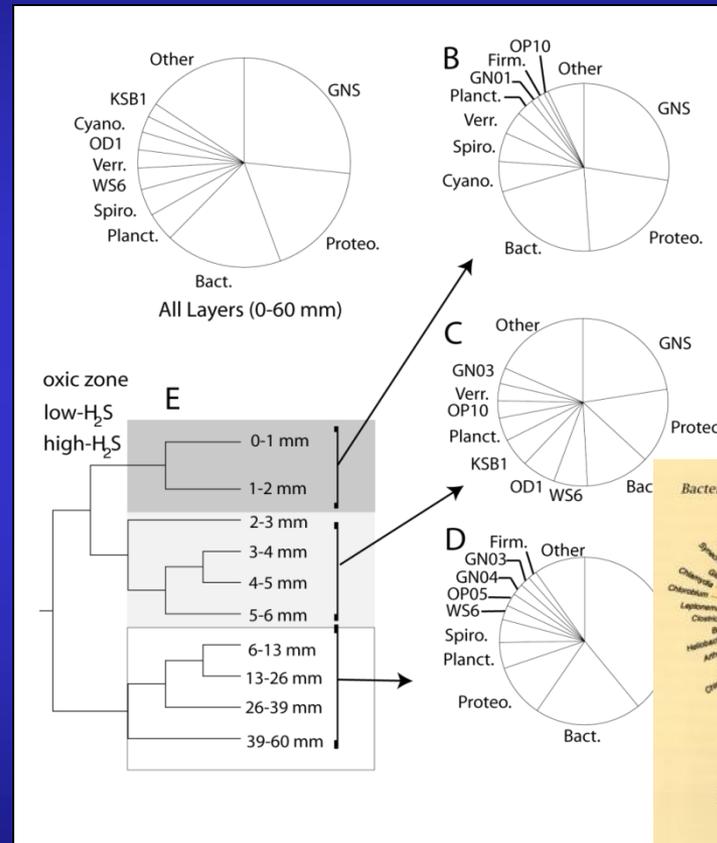
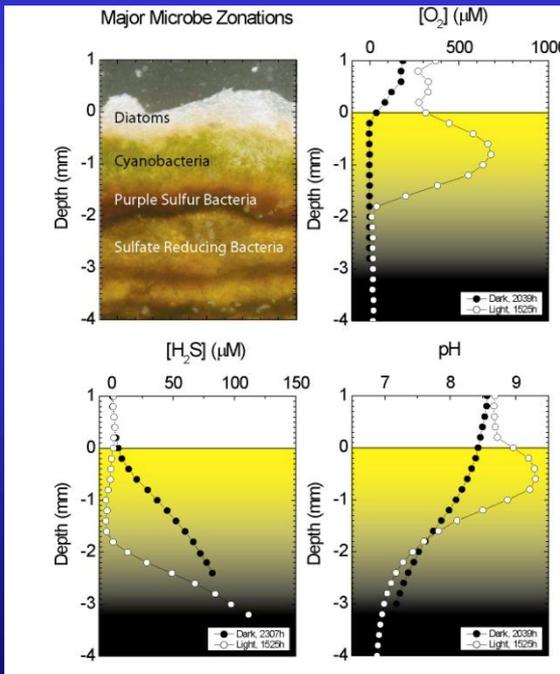
Illustration by Christie Lyons, in Sagan, D. *Science Teacher*, 1986



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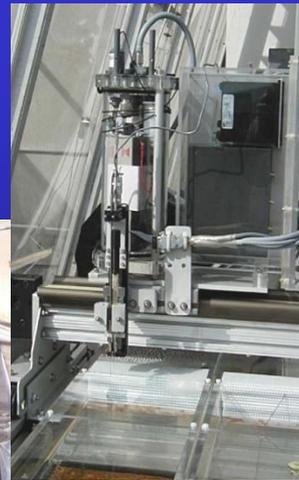
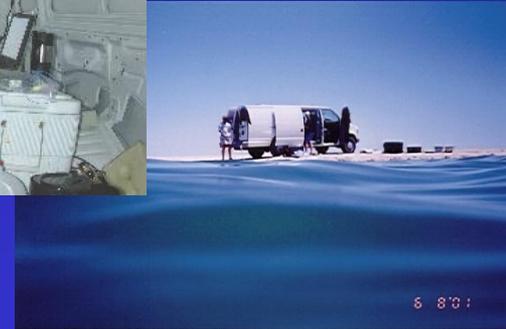
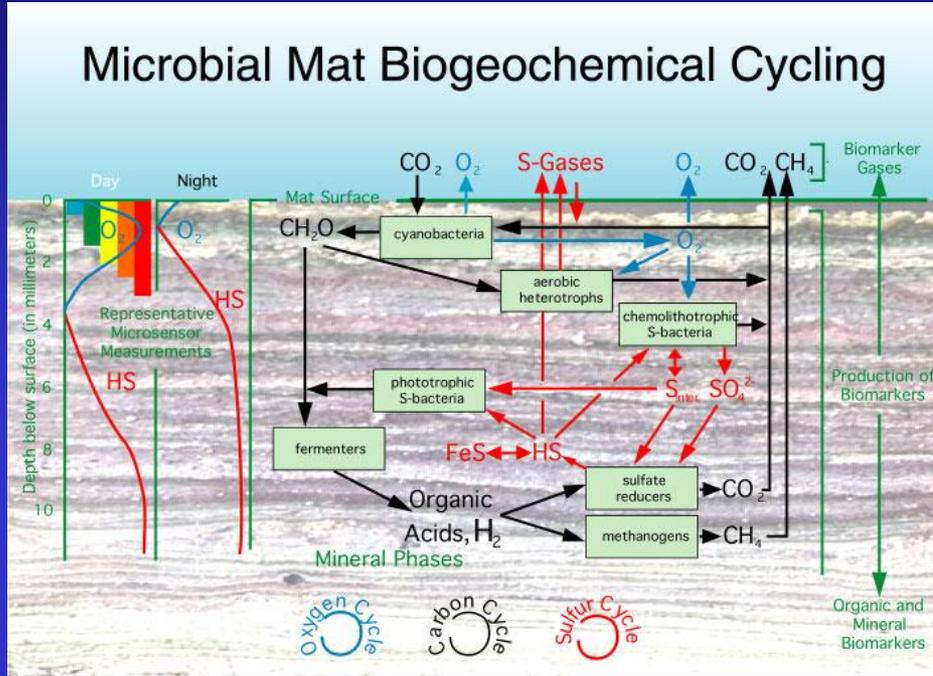


Clone and Sequence, Try to Make Sense of It



Ley, R. E., et al. 2006. *Appl. Environ. Microbiol.* 72:3685-3695

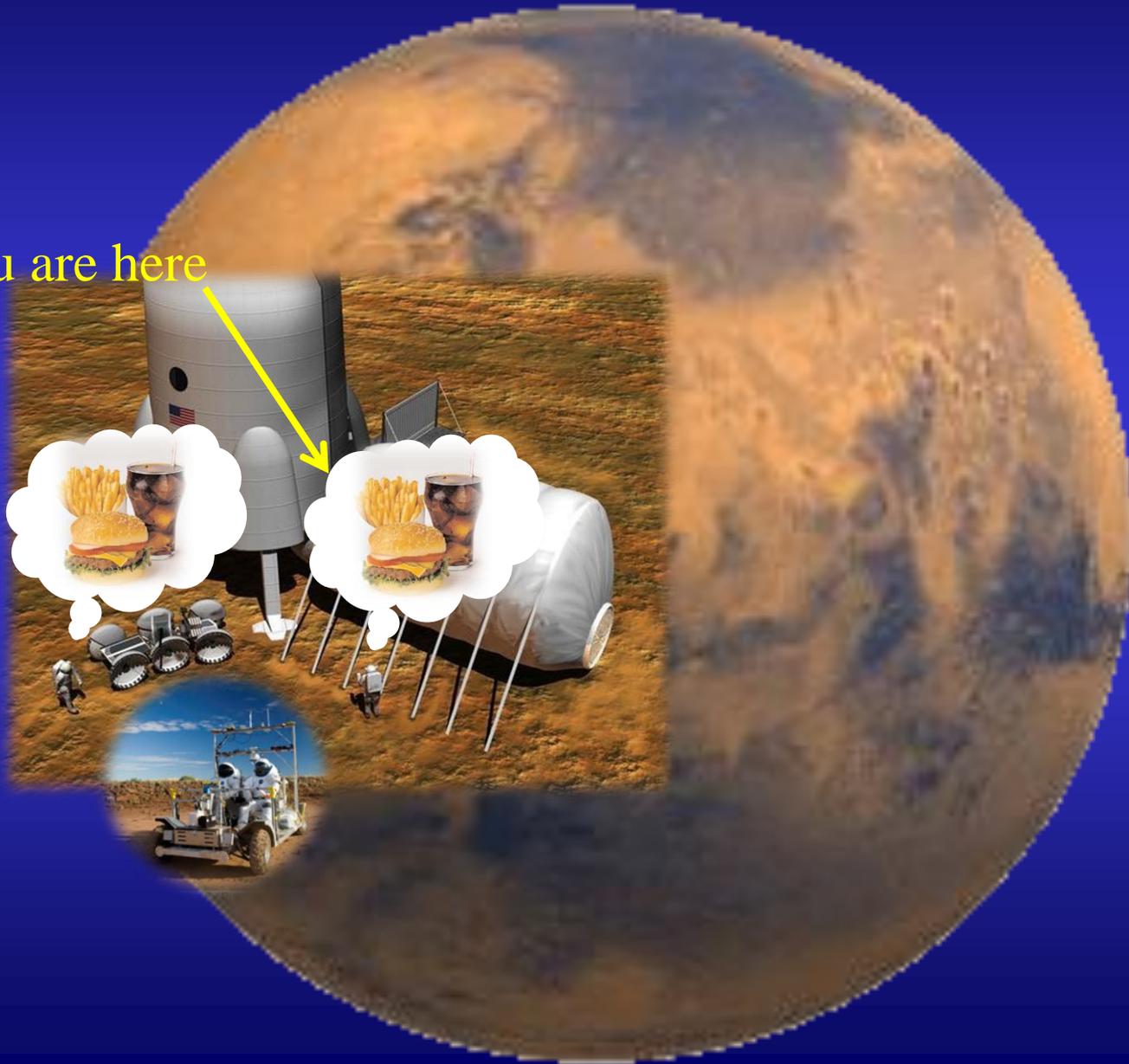
Measure Functions Performed by Mats



For What Other Reasons Would
NASA Care About Algae?

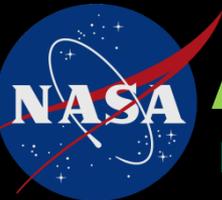
Imagine...

You are here



Algae: It's
what's for
dinner (and
Lunch, and
Breakfast...)

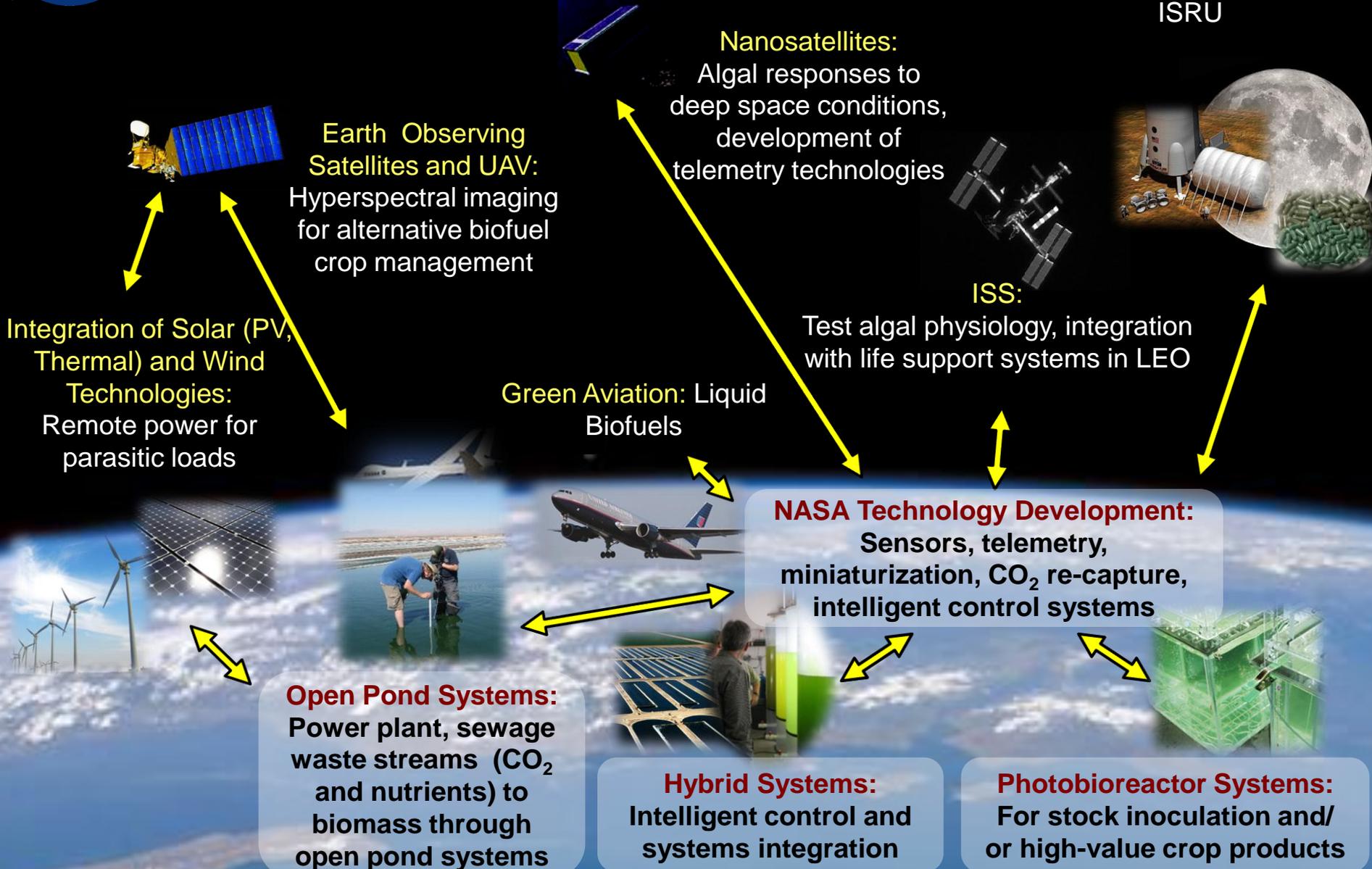




Algae: Why NASA?

Integrating Green and Space Technologies

Moon, Mars, and NEO Life Support and ISRU: Algae for food, fuels, nutrient and carbon recycling and ISRU



Earth Observing Satellites and UAV:
Hyperspectral imaging for alternative biofuel crop management

Nanosatellites:
Algal responses to deep space conditions, development of telemetry technologies

ISS:
Test algal physiology, integration with life support systems in LEO

Green Aviation: Liquid Biofuels

Integration of Solar (PV, Thermal) and Wind Technologies:
Remote power for parasitic loads

NASA Technology Development:
Sensors, telemetry, miniaturization, CO₂ re-capture, intelligent control systems

Open Pond Systems:
Power plant, sewage waste streams (CO₂ and nutrients) to biomass through open pond systems

Hybrid Systems:
Intelligent control and systems integration

Photobioreactor Systems:
For stock inoculation and/or high-value crop products

If Maybe We Should Hear How
Well They Do Find Space?

Microbial Assay Technology for Space (MATs)



Terrestrial Life always operates in complex ecosystems:

We must understand these to interpret early life and to move beyond



Early Earth – Modern Earth

Biological and Planetary Evolution

Terrestrial Planet Finder

Extra-terrestrial Life

Biological and chemical interactions sustaining life operate through microbial pathways



Technology - Life in Space

Advanced life support

Closed system recycling

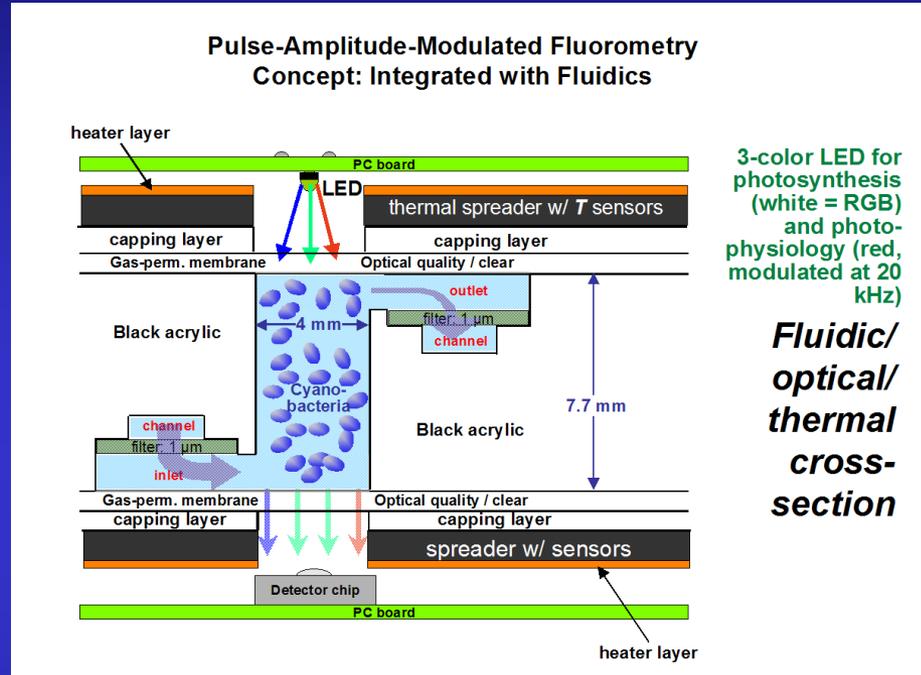
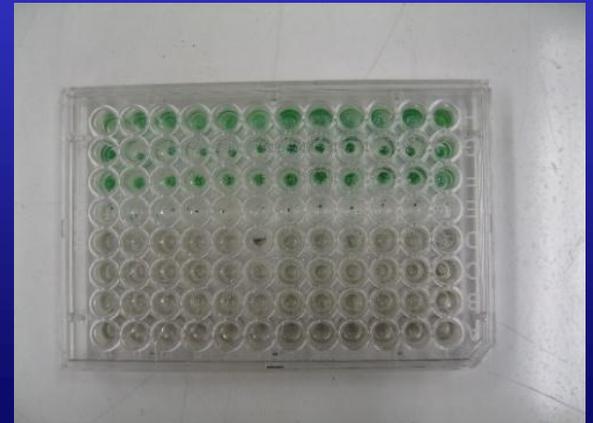
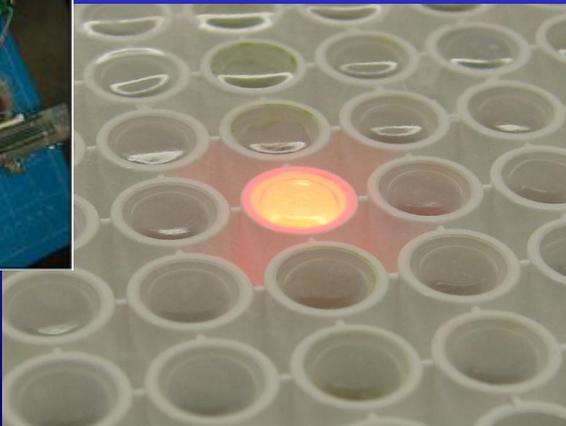
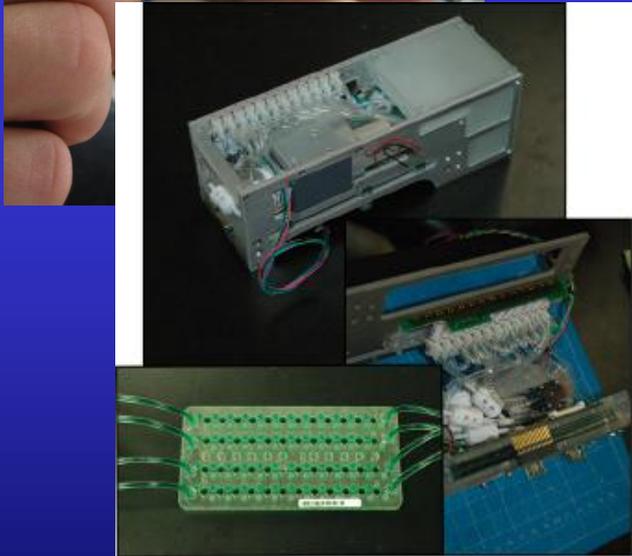
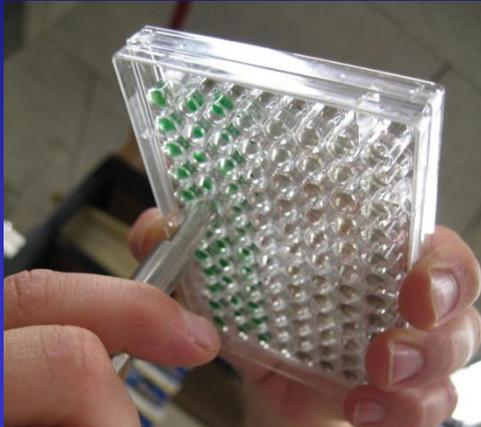
Production of useful byproducts

Biohazard testing

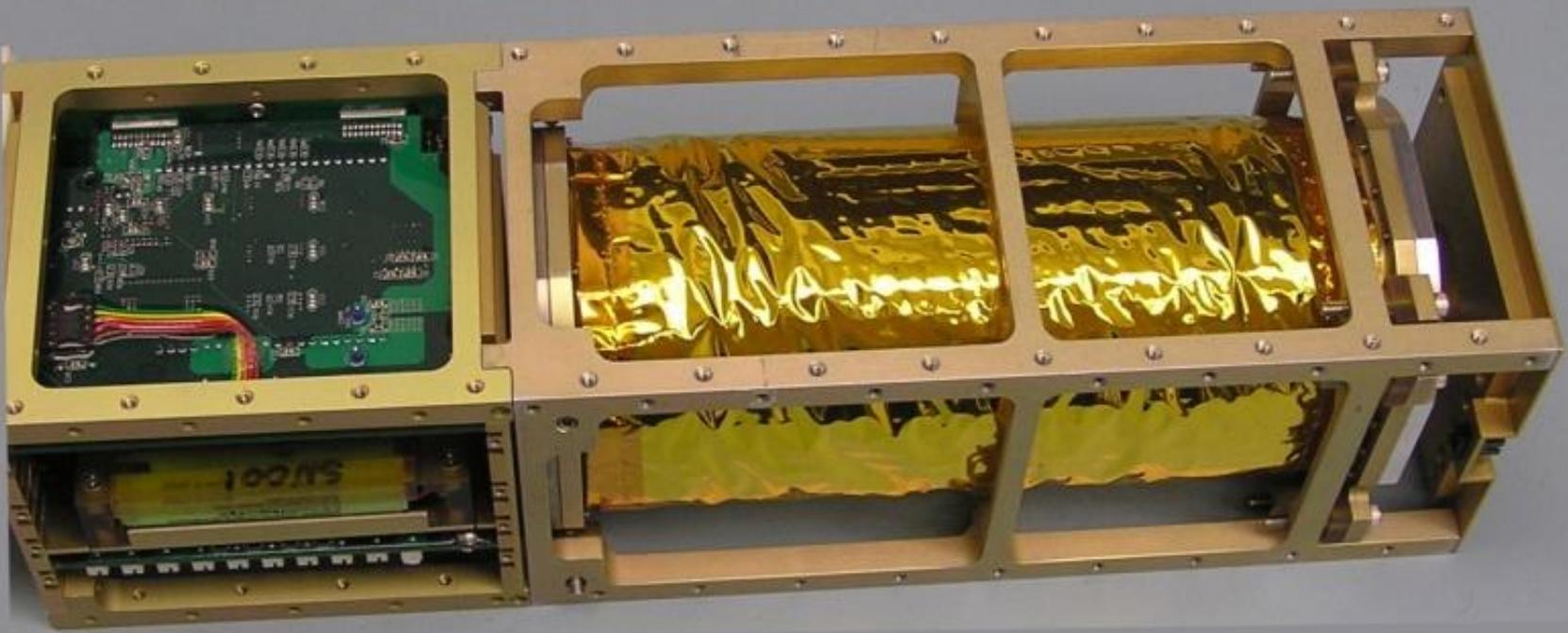
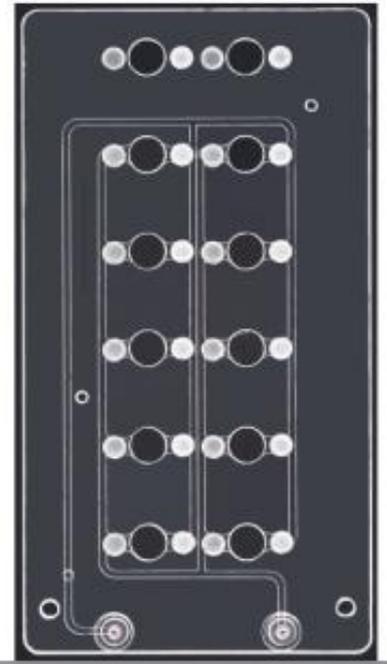
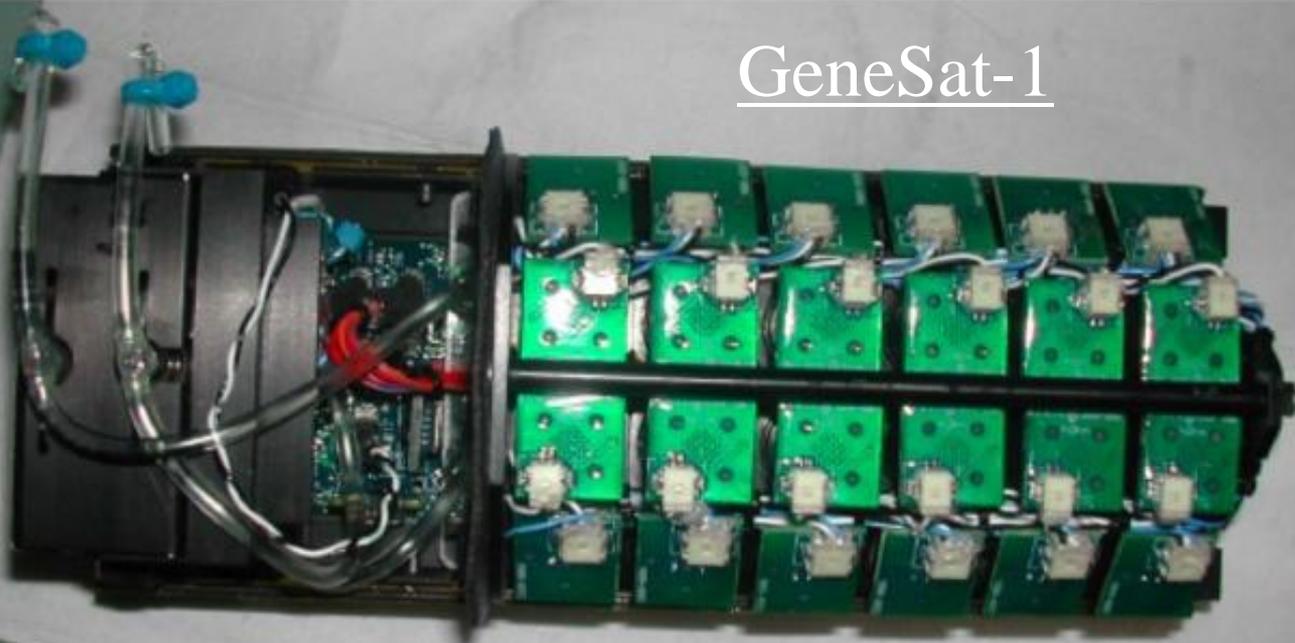
Bioremediation

Planetary Protection

(SLIMESat = Space Laboratory for Investigations of Microbial Ecophysiology)



GeneSat-1



© <http://www.powerlabs.org/>



Green Technology Development

- We (and the algae we know) can function in extreme environments
- We do lipid extraction and analysis
- We do bioreactor research and development
- Collaborations with private and public organizations starting



Microbial Mats: Relevance to NASA

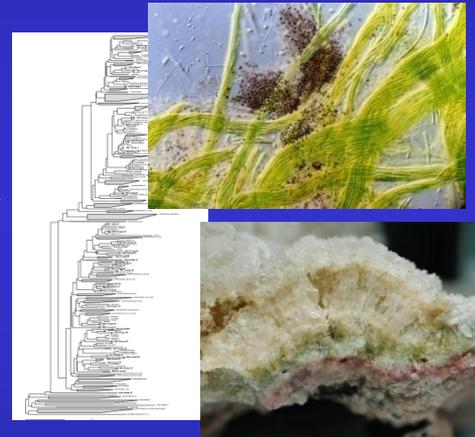
Some of the earliest and most widespread evidence of life on Earth



Have shaped the atmosphere and climate of Earth over geologic time



Related to the communities in which microbial diversity evolved



May be important in the search for life both within our solar system and on extrasolar planets



Useful for space flight experiments and planetary protection applications?

