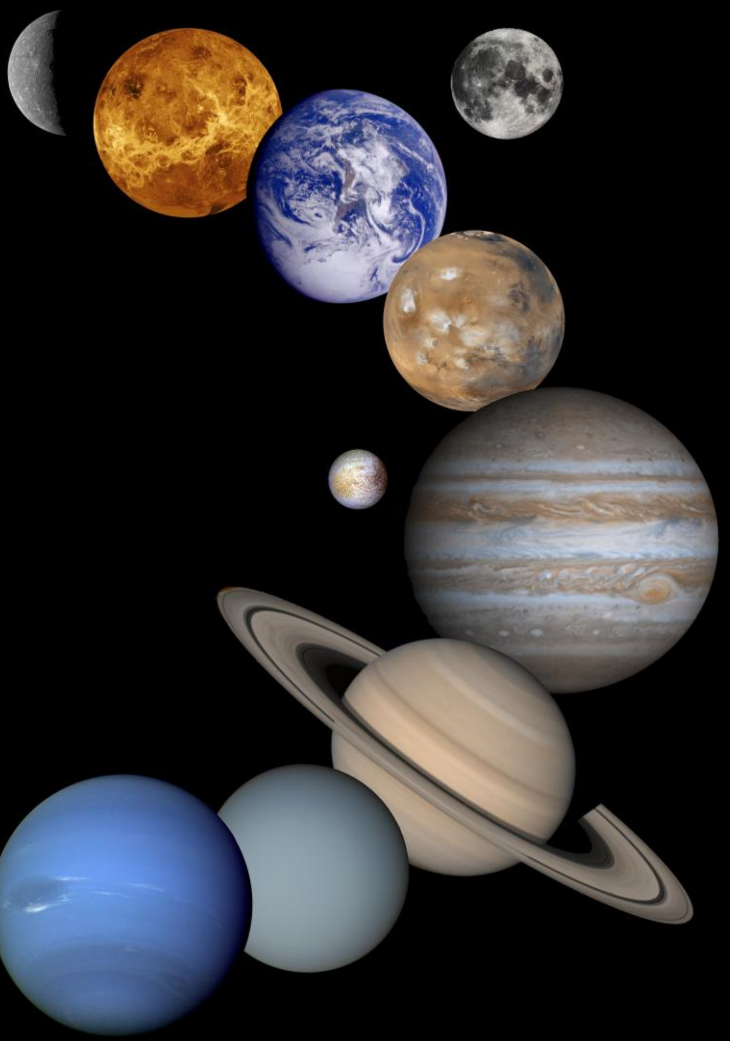
Planetary Protection: Policies and Practices

Session 1.1

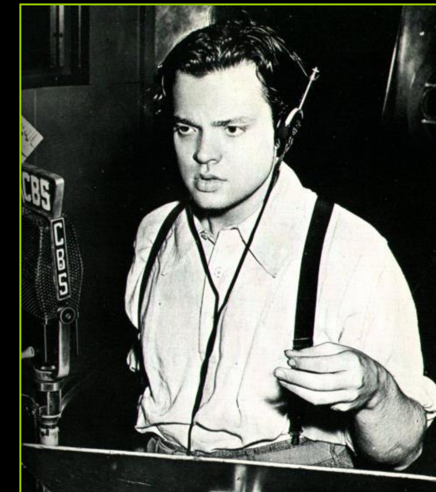


Planetary Protection and Astrobiology

Presenter: C. A. Conley, NASA PPO

In a Nutshell...

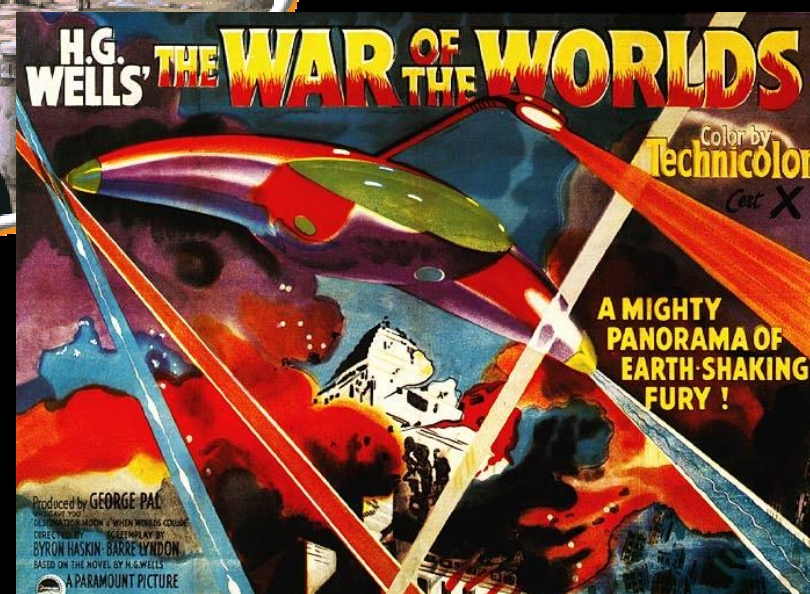
H.G. Wells
1898



Orson Welles
1938

**And scattered about...
were the Martians–dead!
–slain by the putrefactive
and disease bacteria against
which their systems were unpre-
pared; slain as the red weed was
being slain; slain, after all man's devices
had failed, by the humblest things that God,
in his wisdom, has put upon this earth.**

**...By virtue of this natural selection of our kind
we have developed resisting power; to no
germs do we succumb without a struggle...**



What are the origins, distribution, and future of life in the universe?

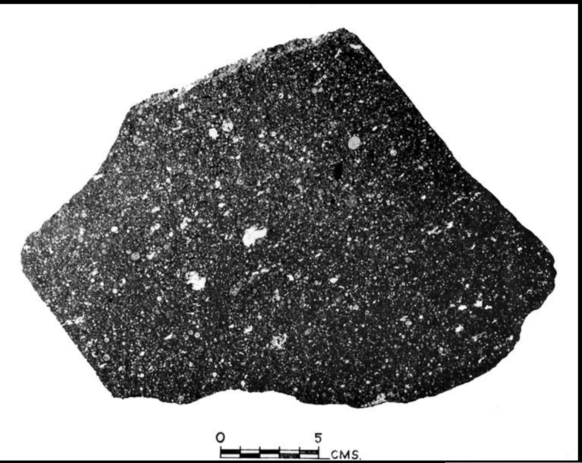
NASA Planetary Science Goals

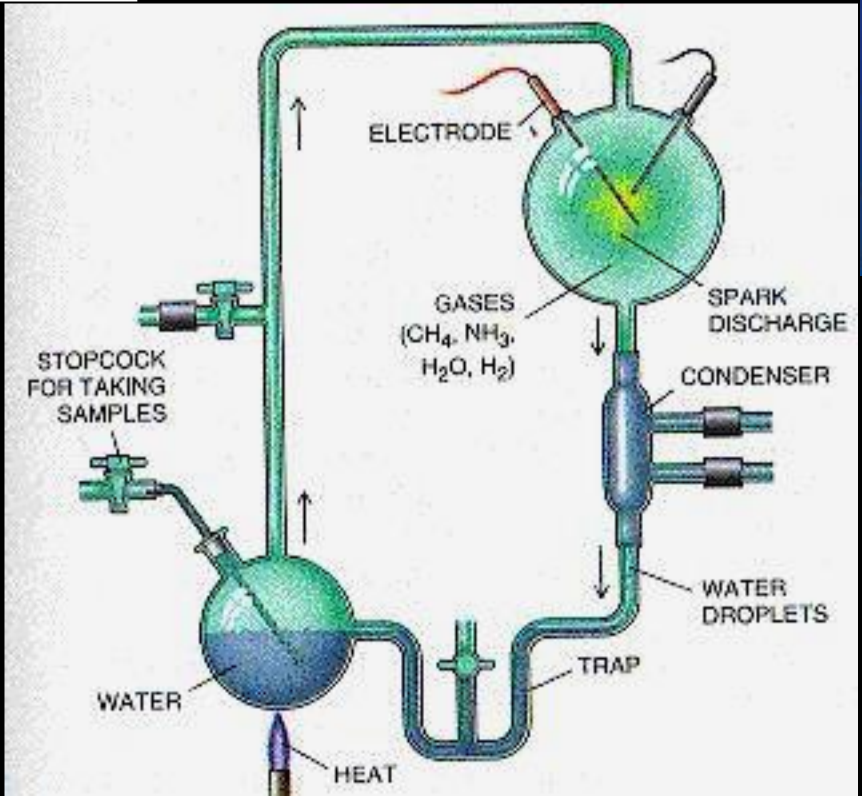
- What is the inventory of solar system objects and what processes are active in and among them?
- How did the Sun's family of planets, satellites, and minor bodies originate and evolve
- What are the characteristics of the solar system that lead to habitable environments?
- How and where could life begin and evolve in the solar system?
- What are characteristics of small bodies and planetary environments that pose hazards and/or provide resources?

Planetary protection is important to accomplishing each of these goals

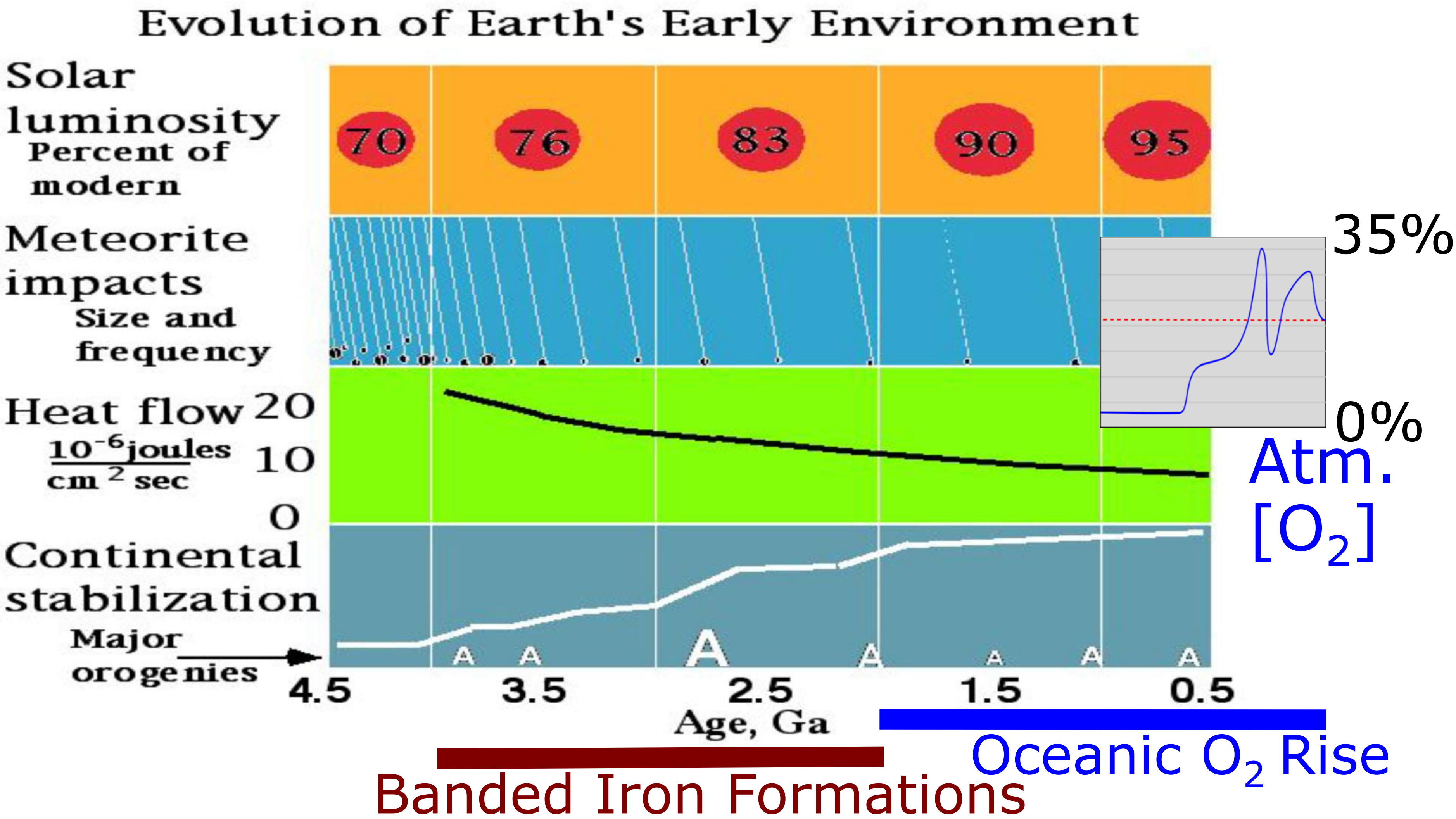
Chemistry of life comes from space...

and also from inorganic reactions on Early Earth



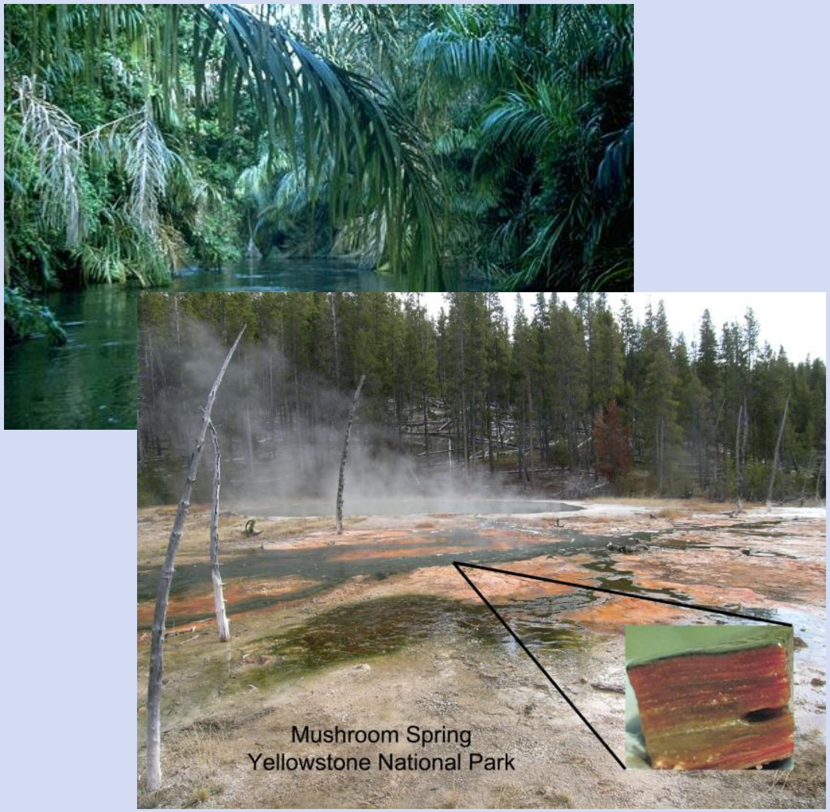


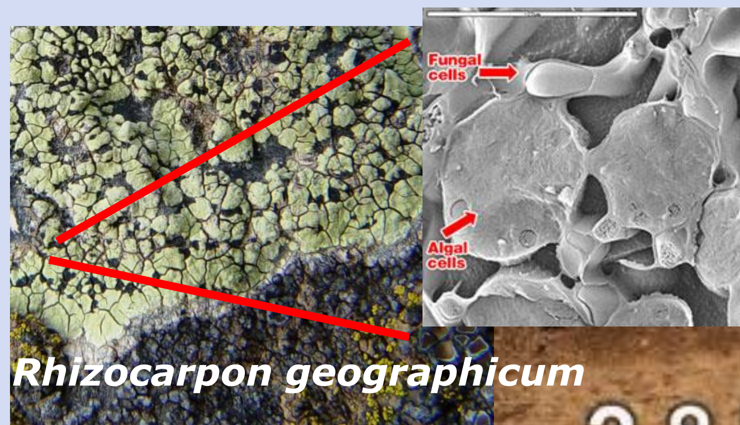
Life Affects the Evolution of Planets



Organisms Thrive in Strange Places...

Most organisms live in fairly complex communities, in which members share resources and improve community survival





Lichens survive space exposure

Some communities are made up of small numbers of species: frequently found in more ‘extreme’ environments

And Eat All Kinds of Things...

Many organisms use unusual energy sources: sulfate, perchlorate, photons...

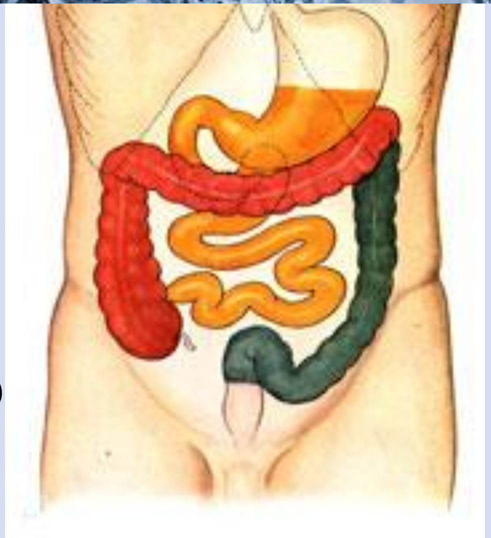
This community lives off radioactive decay of rocks around it: *no* input from the surface, or the sun

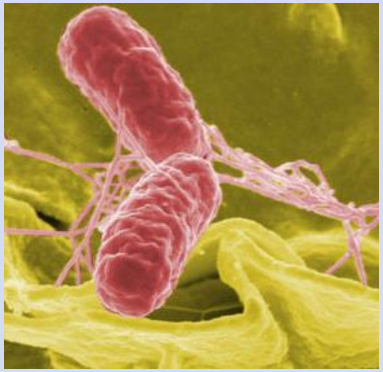
Organisms in Cueva de las Sardinas survive off the chemical energy from hydrothermal volcanism

Introduced Organisms Can Have Ecological Impacts

Stable communities are resistant to invasion by novel species

Salmonella typhimurium express more virulence genes after cultured in space

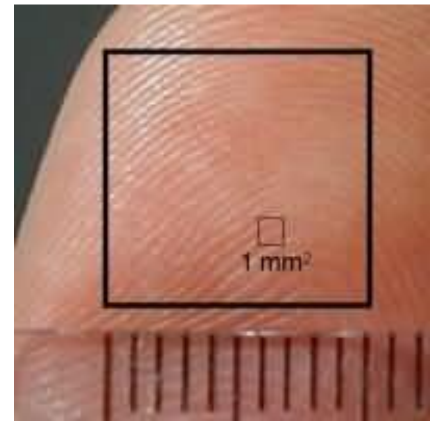




However, sometimes organisms with novel capabilities can sweep through a community

Life on us can grow elsewhere…

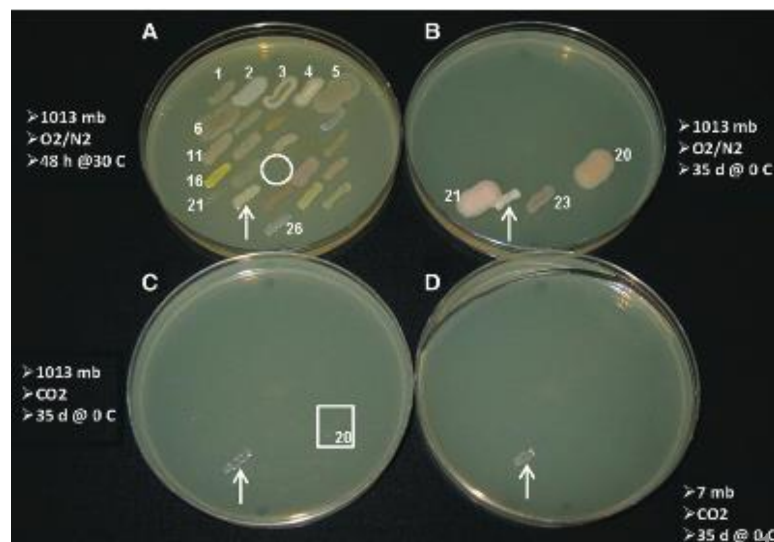
- Up to 10 000 microbes on 1 cm² of skin
- Up to 100 microbes on 1 mm² of skin



Can Earth life grow on Mars?

Microbes on cheese also grow

in Mars chambers on Earth...



The Basic Rationale for Planetary Protection Precautions

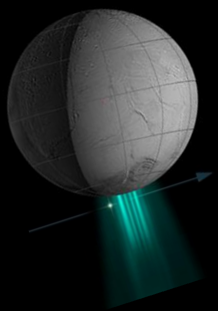
(as written by Bart Simpson, Dec. 17, 2000, "Skinner's Sense of Snow")

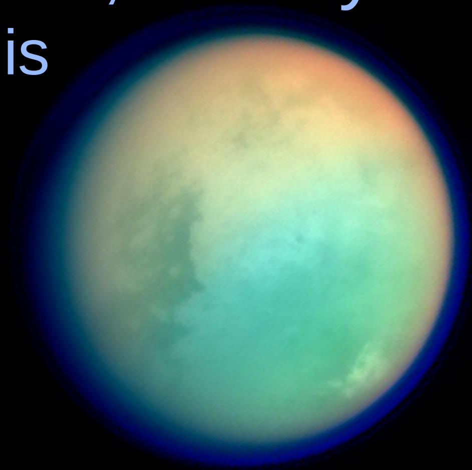
Science class should not end in tragedy....
Science class should not end in tragedy....
Science class should not end in tragedy....
Science class should not end in tragedy....
Science class should not

Planetary Environments are Diverse

The unaltered surfaces of most planets are cold, and by being cold, are dry

- spacecraft can change this

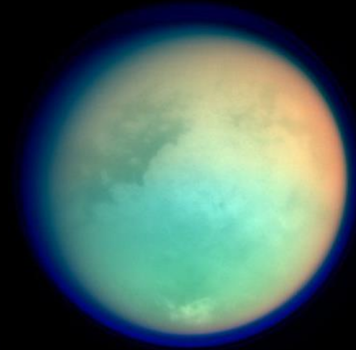


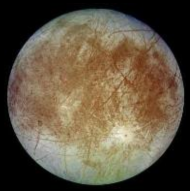


Interior environments may be more similar to Earth:

- possible subsurface oceans, both hot and cold
- subsurface rock, similar (?) to inhabited Earth rocks

What can we learn about searching for life, by studying life on Earth?

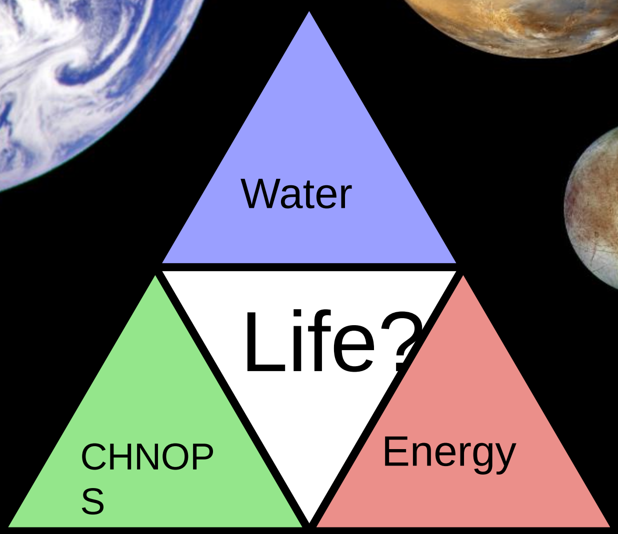




1. Life is tough
   (extremophiles)

2. Life is tenacious
   (long survival times)

3. Life is metabolically diverse
   (eats anything, breaths anything)

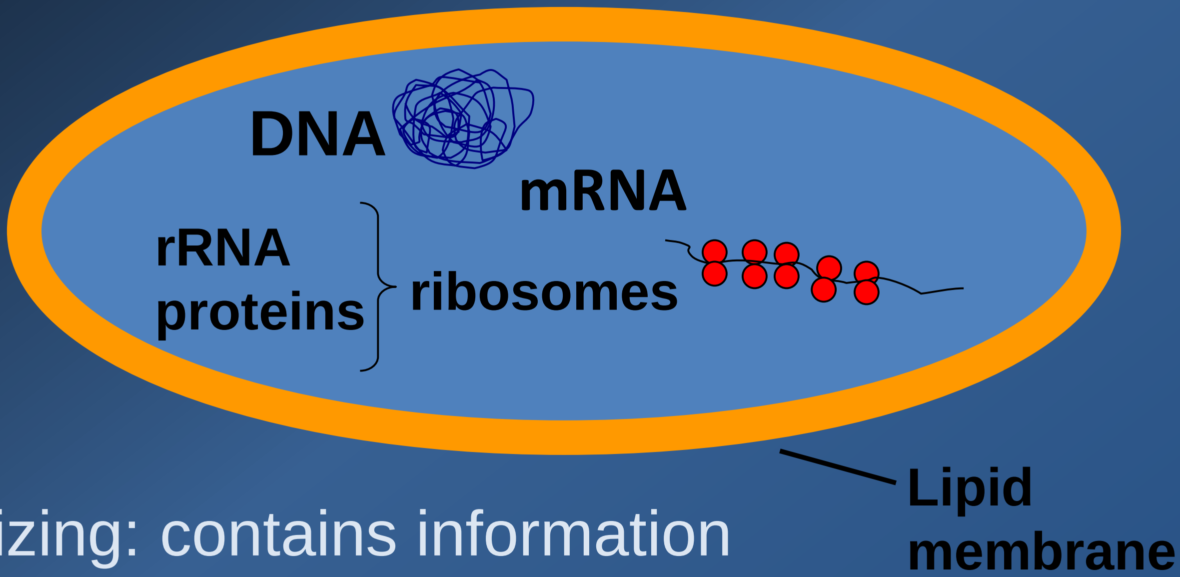


4. When conditions get tough, life moves inside the rocks

What is life?

May include elements of the following...

Life Has Structure



Self-organizing: contains information

Self-maintaining: can replicate (at least some of them)

Energy Flows: takes in energy and matter to maintain, grow and reproduce

SSU-rRNA Tree of Life

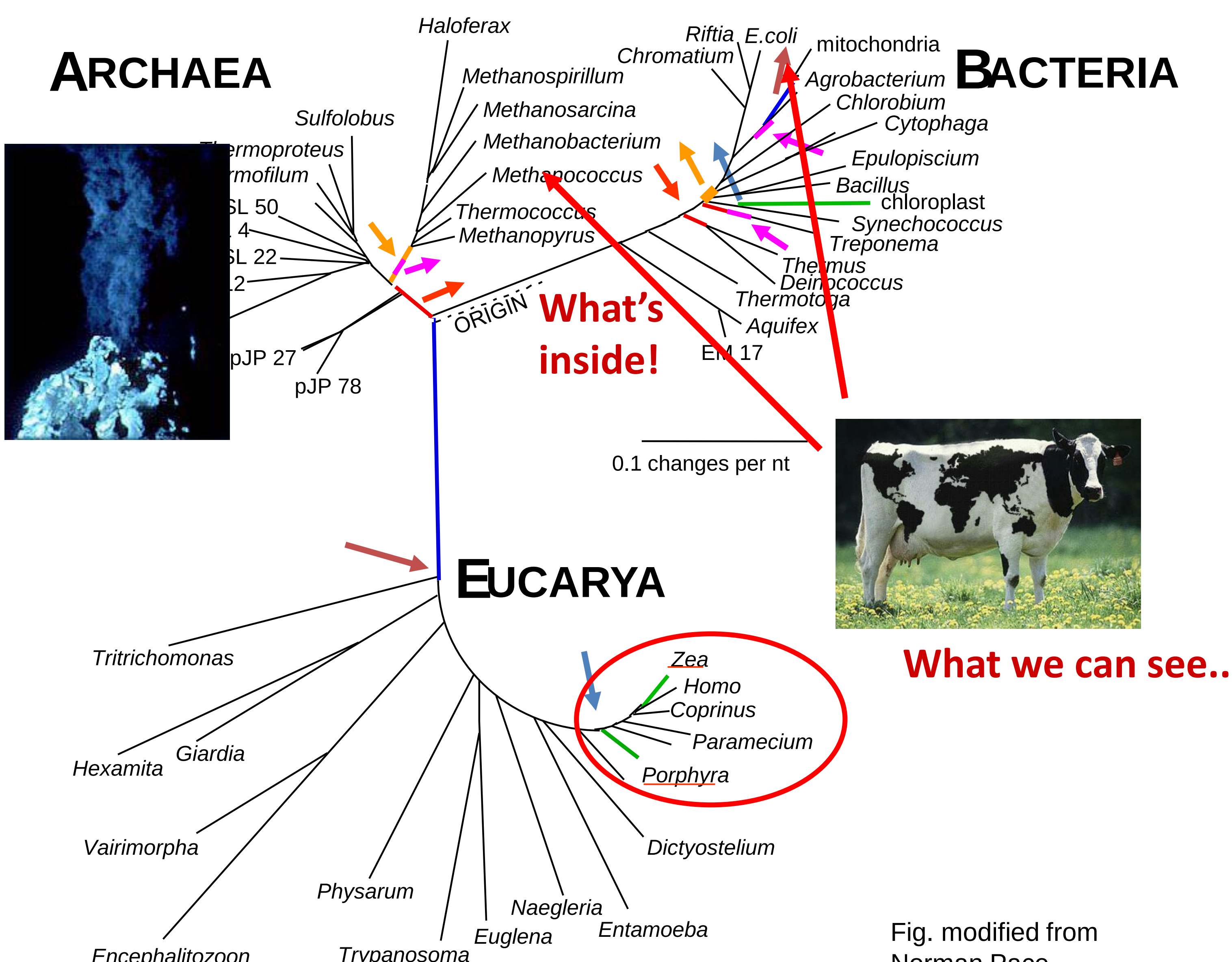
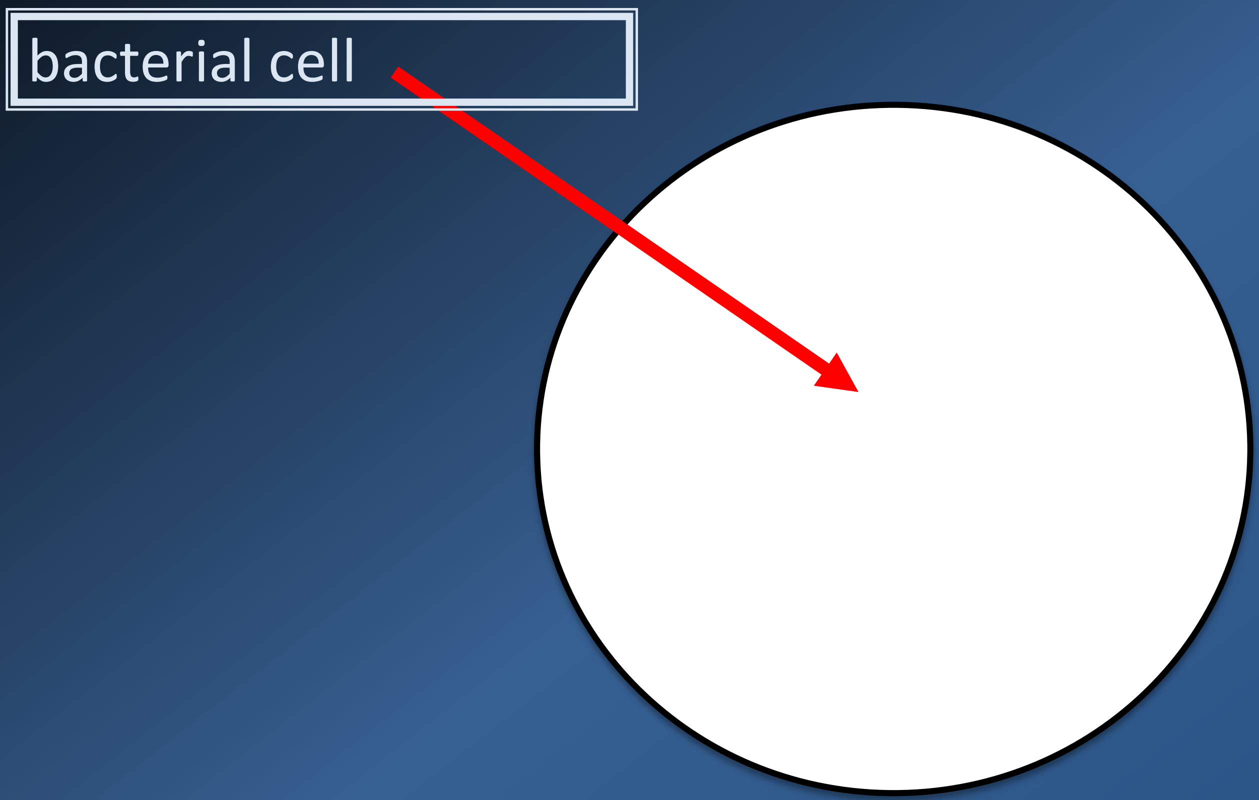


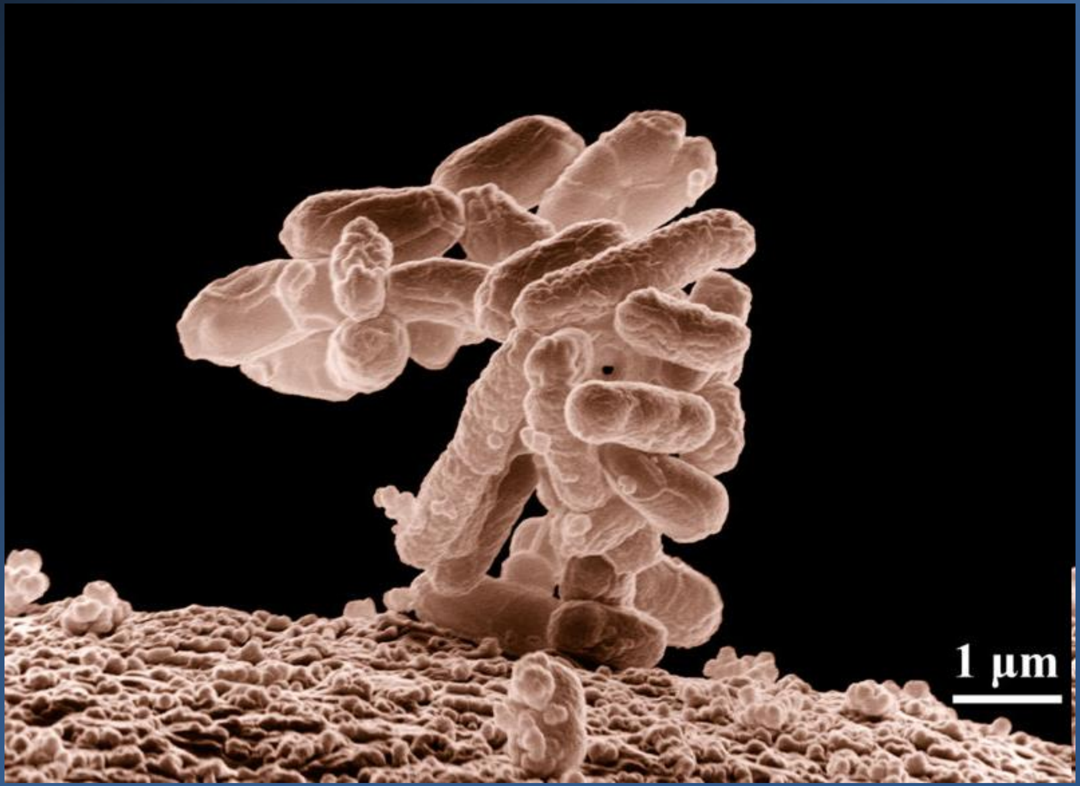
Fig. modified from Norman Pace

Size and distribution of microorganisms



A single bacterial cell is not visible to the naked eye!

How Big Are They?



A cluster of *Escherichia coli* bacteria magnified over 10,000 times

Where Do Contaminants Come From?

Sky

B. stratosphericus (above 24 km)

Soil

B. thermoterrestis
(egypt. soil, 55° C)

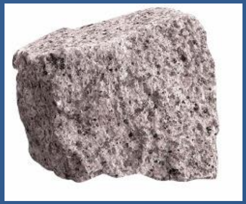
Hay

B. subtilis
(the „hay“-*Bacillus*)

Desert

B. sonorensis
(Sonoran Desert, Arizona)

Rocks



B. simplex
(500 spores/g rock)

Deep subsurface

B. infernus

SAF

B. pumilus SAFR

Food

B. cereus

Pathogens

B. anthracis
(the bioterrorist)

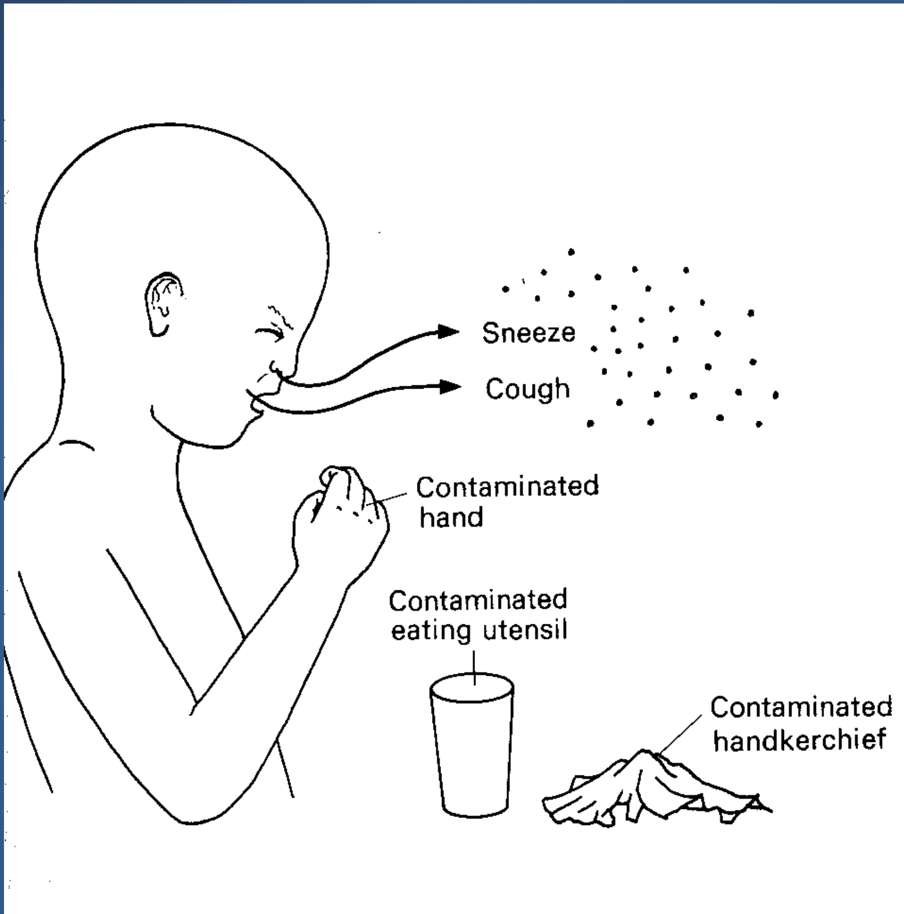
Insects

B. thuringiensis
(the exterminator)

Life is Everywhere...

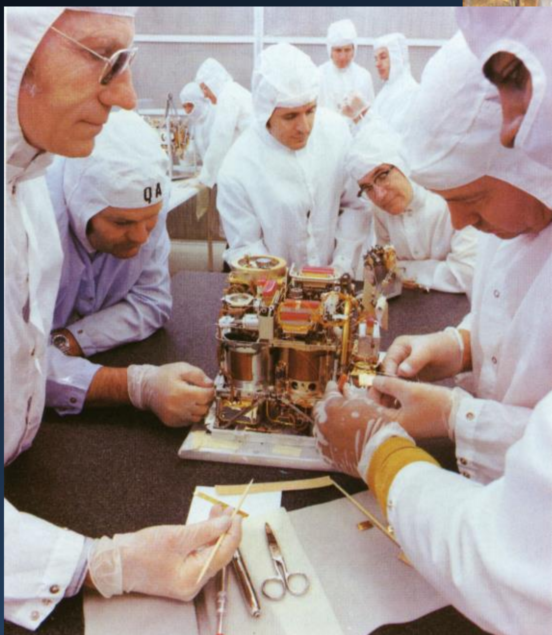
Occurrence of microorganisms:

- Total: 10^{30} cells à $5x10^{-13}$g ~10^{11} tons
- In air: desiccation resistant species
- In drinking water: < 100cells/ml
- In soil: up to 10^8 cells/g soil
- On human skin: 10^{12} cells
- In human mouth: 10^{10} cells
- In gastrointestinal tract: 10^{14} cells

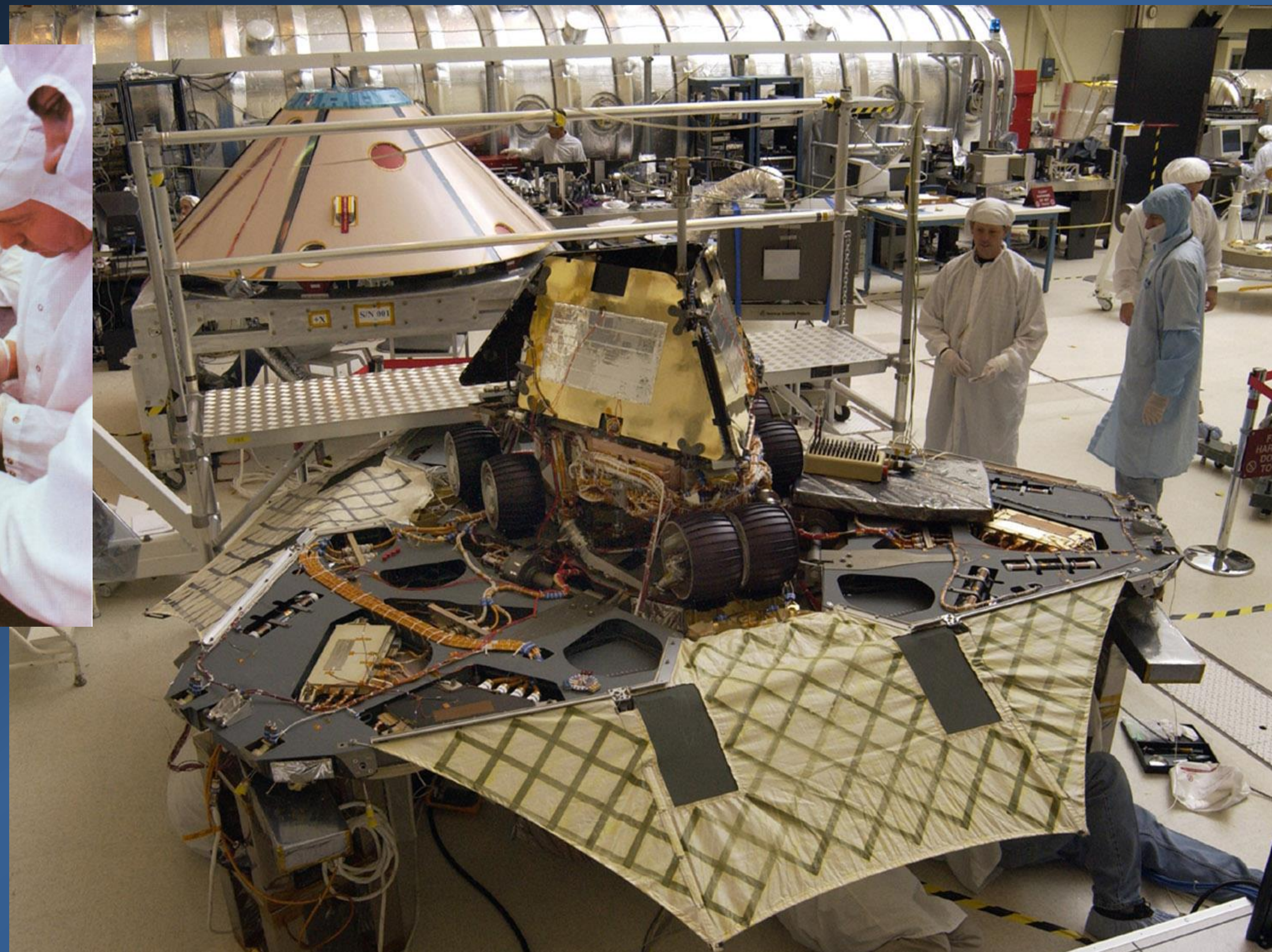


Total human microflora:
Orders of magnitude more microbial cells than human cells!

This Means Also In Spacecraft Cleanrooms!



Viking Life Detection Package



MER-1 in SAF

What Organisms Do We Worry About?

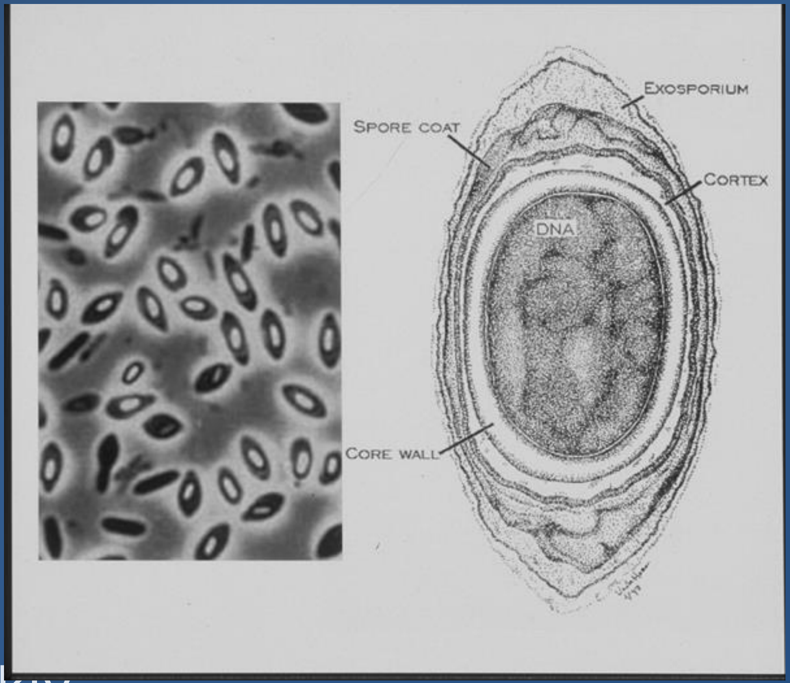
Bacterial Endospores (Spores) are the most resistant organisms to heat sterilization

Subcellular body formed when conditions not favorable for growth

Resistant to harsh conditions (temperature, heat, drying, radiation, acids, disinfectants etc)

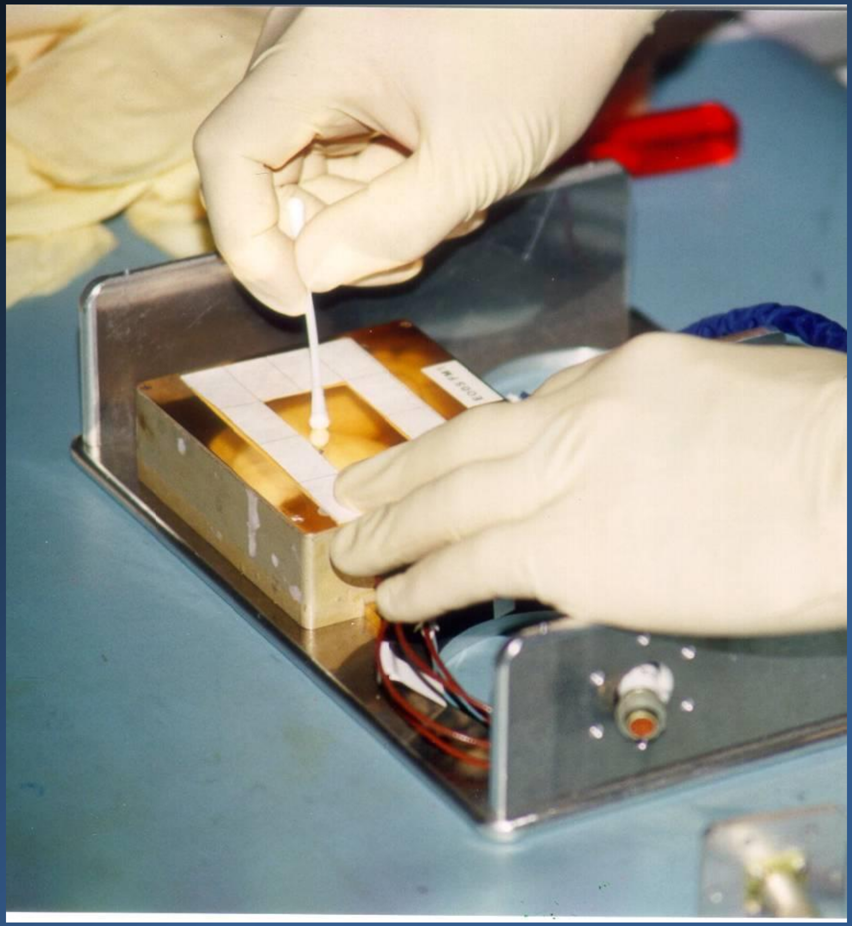
Can remain dormant for $>10^7$ years

Convert back to vegetative cells quickly



Bacillus spores

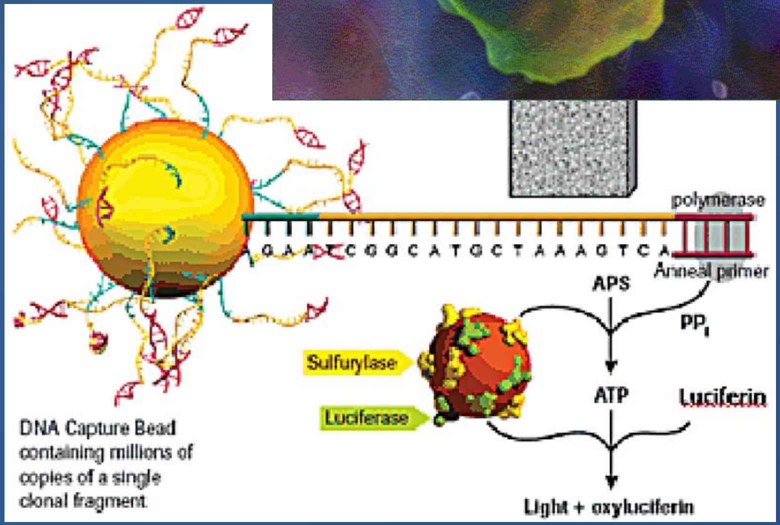
How Do We Find Out What's There?



Collect samples...

- Swabs are used on an area (5 by 5 cm^2) of a spacecraft subunit
- Wipes are used to sample larger areas (up to 1 x 1 m^2)
- May sample air through a filtering system

Then Evaluate Them:

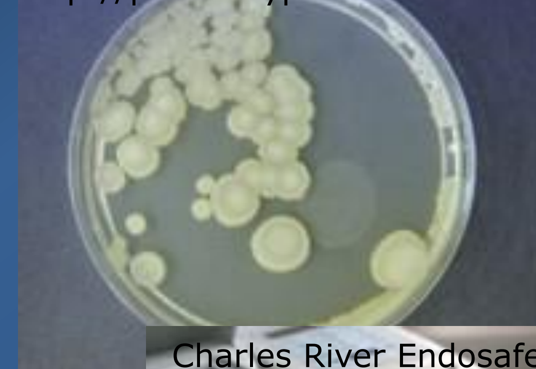


Culture studies identify or count some organisms in samples taken from spacecraft

Molecular biology can be used to identify more organisms, but counting is challenging

The Standard Assay and Supplements

http://planetaryprotection.nasa.gov



- Standard assay: count heat-resistant organisms that grow on culture medium at 32C in 72 hours.
  Rapid Spore Assay may be equivalent but faster; terbium Germination Assay in future

Charles River Endosafe

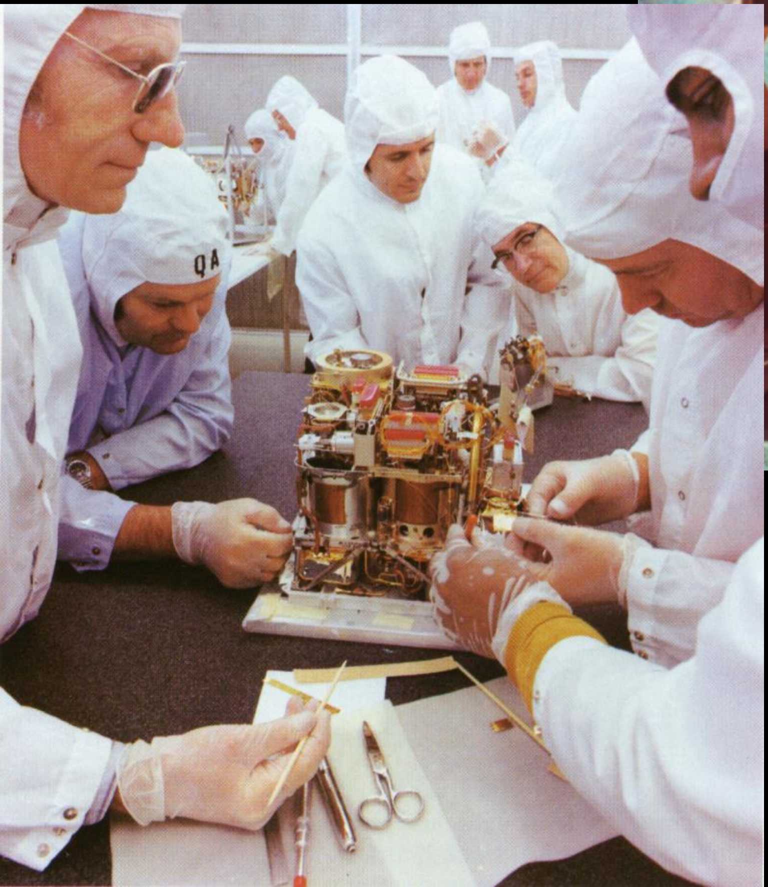
- Limulus Amoebocyte Lysate (LAL): measure levels of a particular bacterial cell wall protein.
  Counts a different subset, includes dead and living.

- Total Adenosine Triphosphate (tATP): measure levels of a small labile molecule present in all organisms.
  Counts human and microbial contamination.

Turner Biosystems

LAL and ATP assays measure cleanliness and bioburden, but do not correlate directly with spore counting.

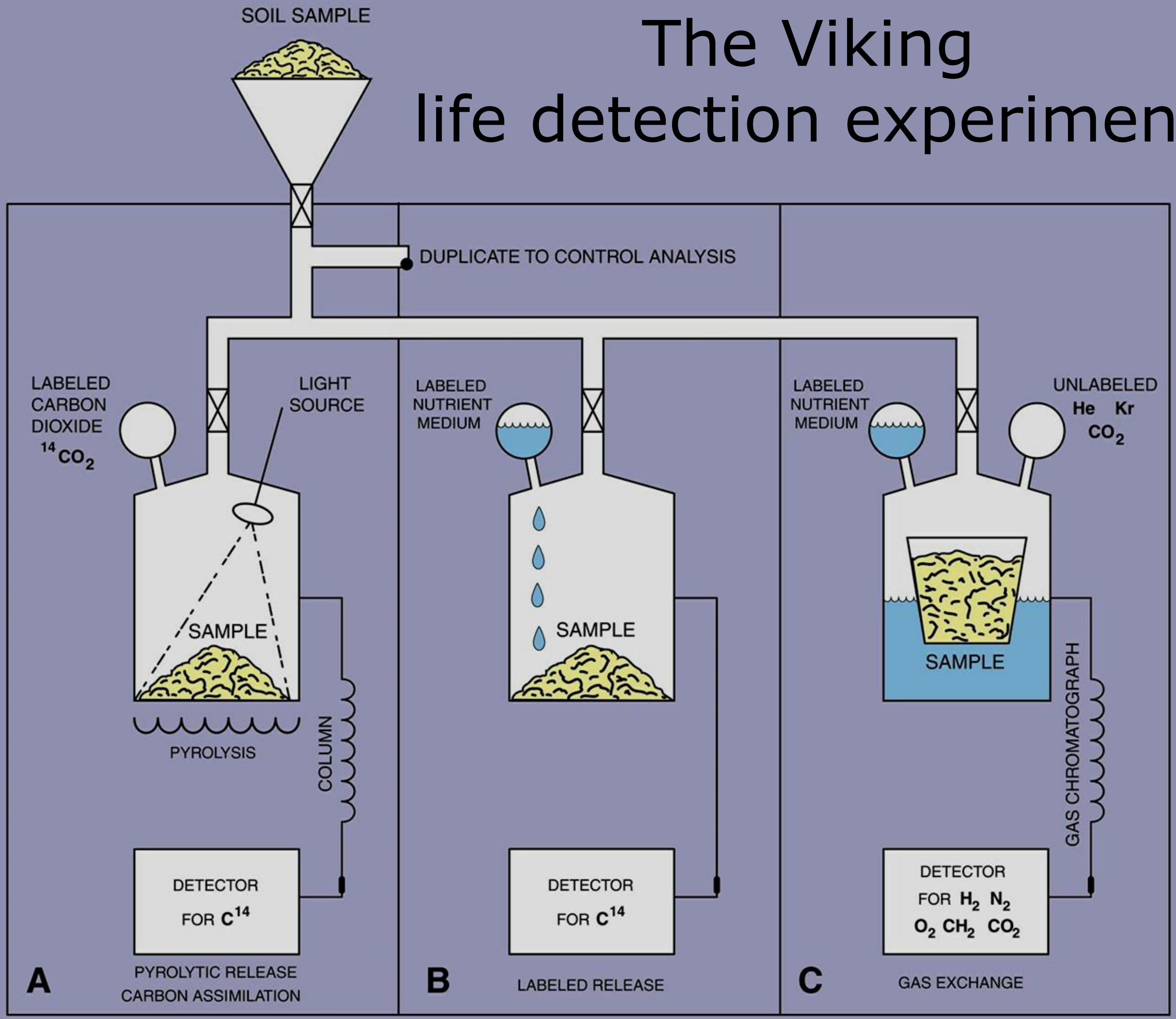
The Inquisition Approach



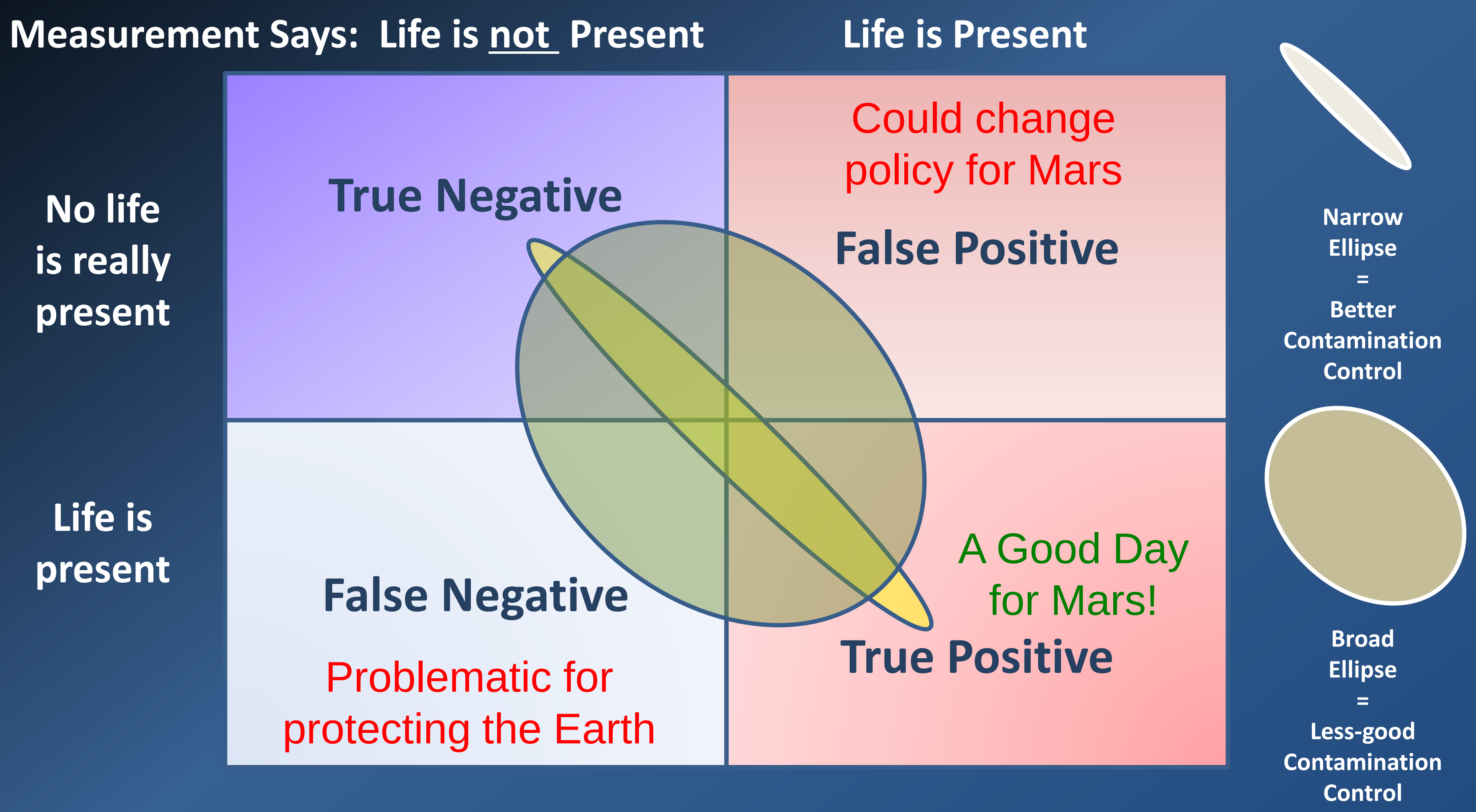
Viking
Life Detection
Package

Terminal
Sterilization
Works

The Viking life detection experiment



Organic Contamination and Life Detection




Don't spill
it!
Campbell's
Primordial
SOUP