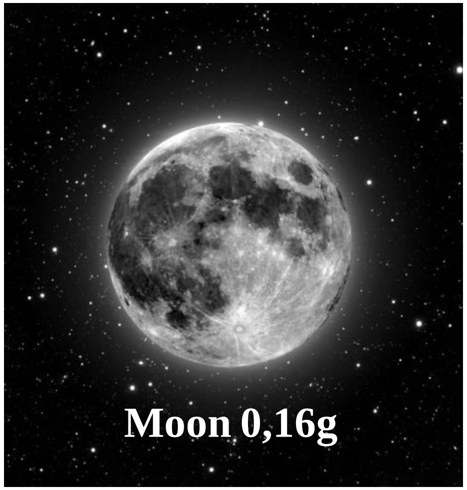
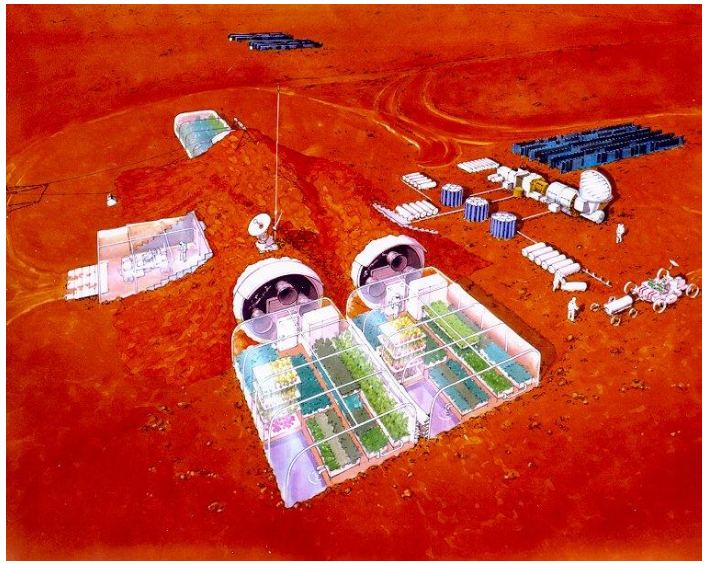
SPACE FARMING

Un ponte tra fantascienza e realtà della chimica agraria del terzo millennio

Giacomo Pietramellara

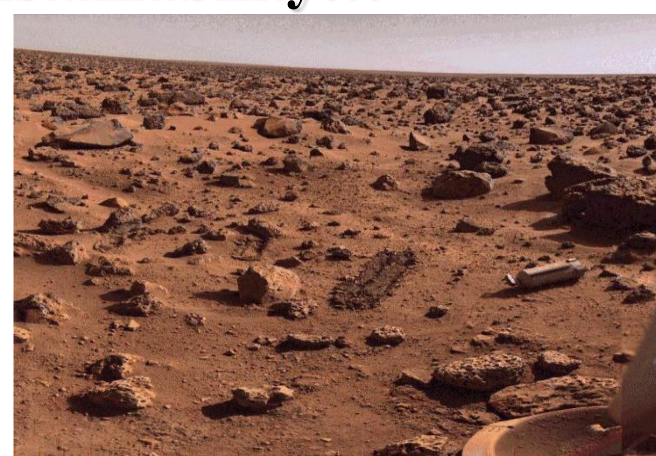


Smart soil and plant management…

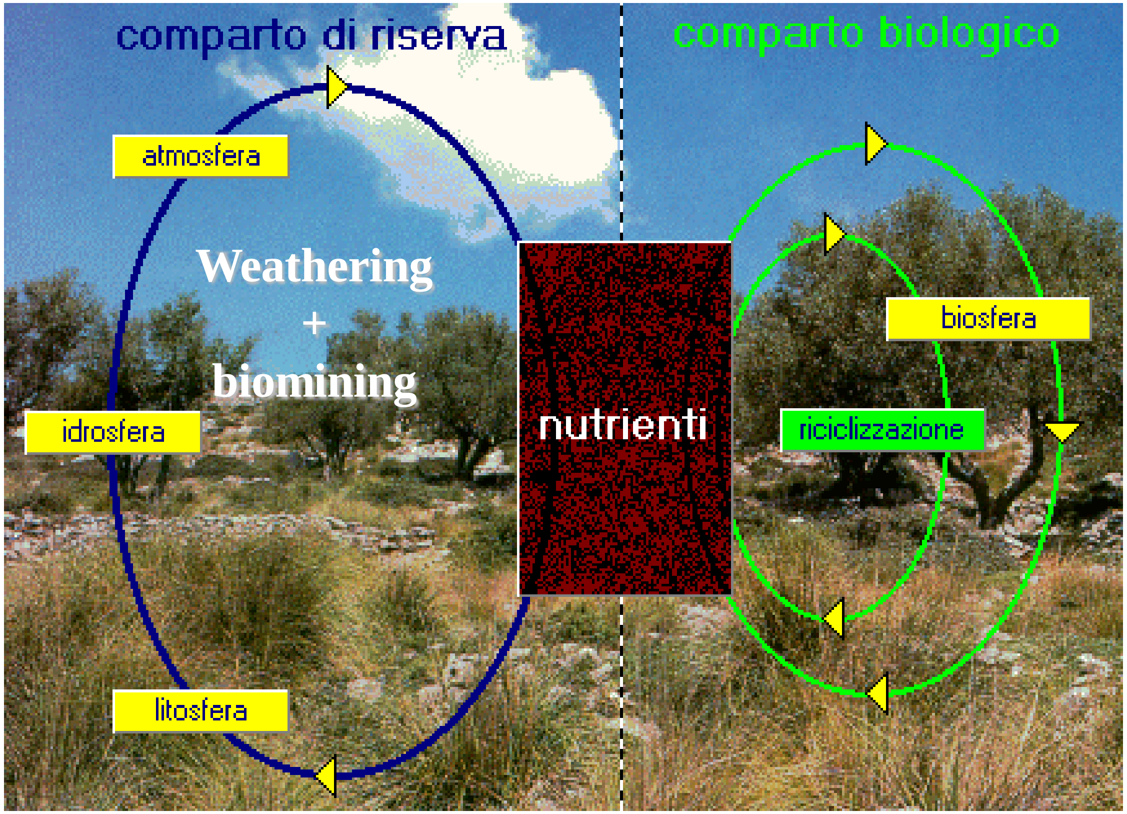


...for human extra-terrestrial base sustainability…

due to soil as a complex biological system



…in which microfauna + extracellular enzymes + plants confer to soil the capacity to degrade "almost" everything



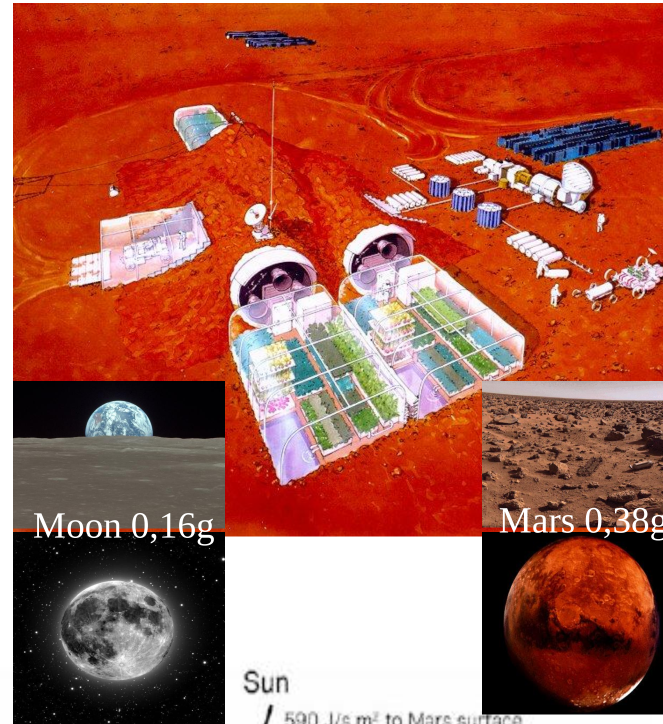
Sustaining life:
- **recycling nutrient substances**
- **purifying water**
- **storaging CO_2 and recycling O_2**

Space farming is not so easy to do

Earth 1g= 9.806 ms^{-2}

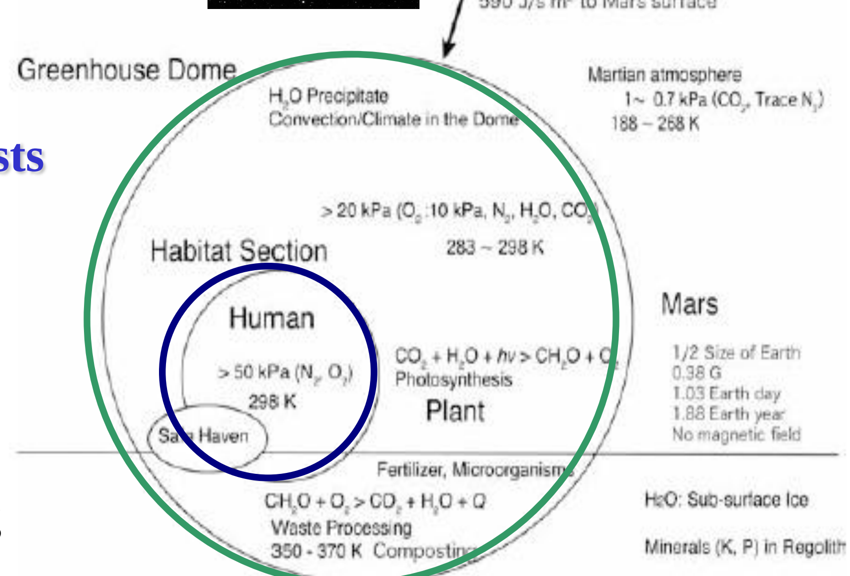
Environmental conditions

- Temperature
- Low gravity
- Atmosphere composition
- Soil characteristics
- Water circulation
- Nutrient availability
- Presence of toxic elements
- O_2 at boundary layers
- Plants adaptation

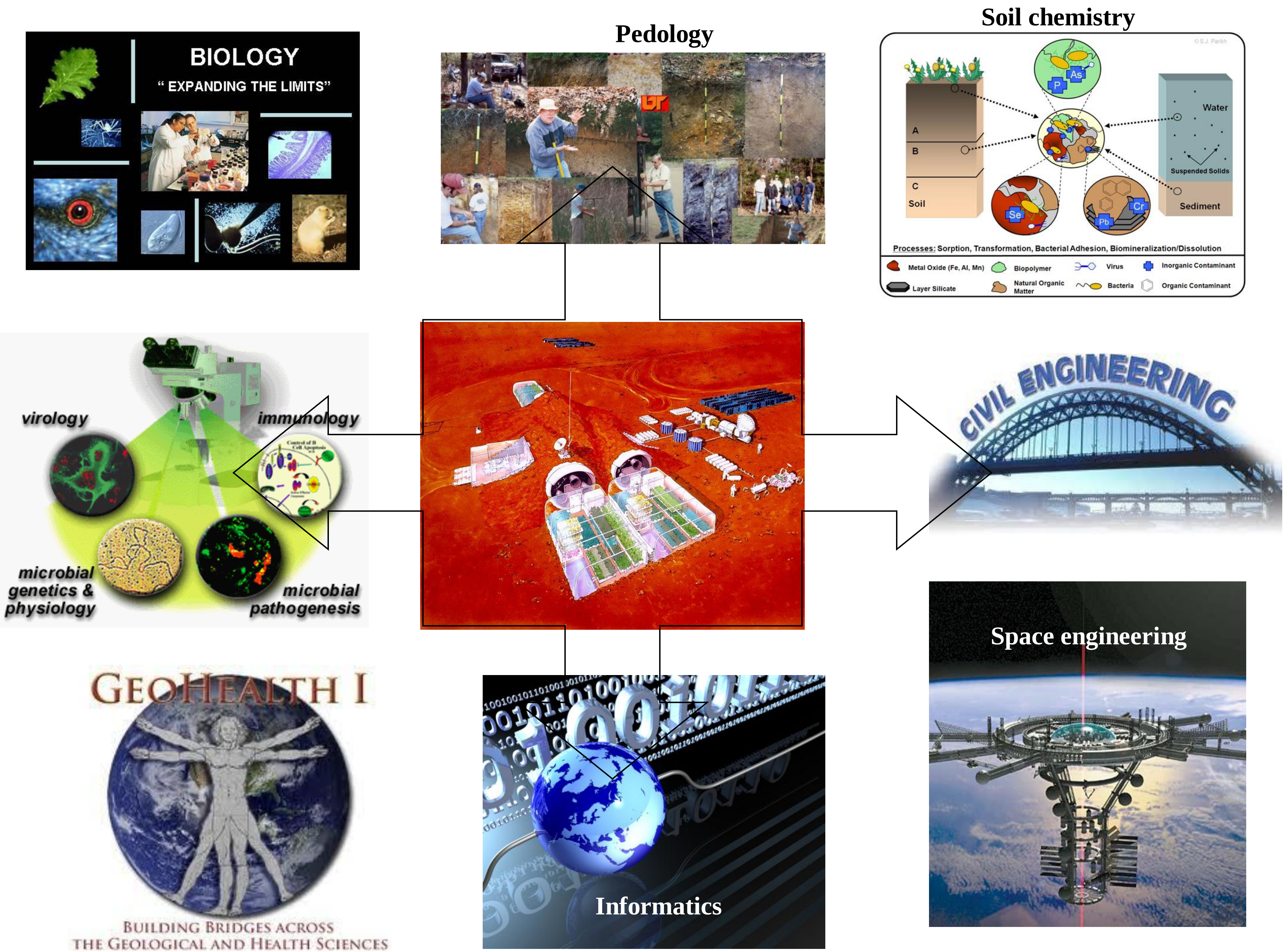


Human base requests

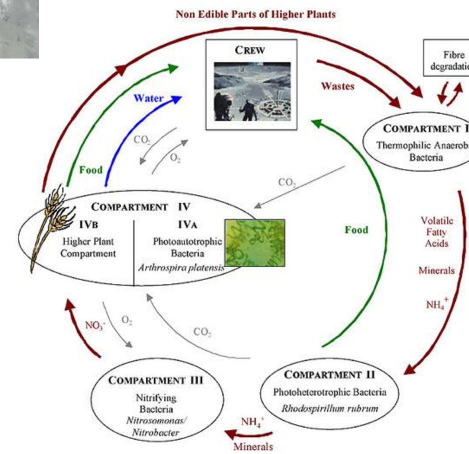
- Human adaptation
- Food requests
- Energy requests
- Safety waste recycling
- Air and water recycling



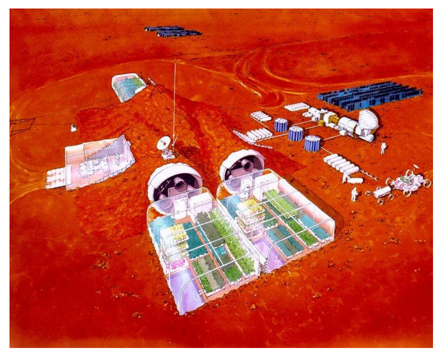
Avoiding cross contamination to preserve base biosystem and original forms of life


BIOLOGY
" EXPANDING THE LIMITS"
Pedology
Soil chemistry
A
B
C
Soil
Water
Suspended Solids
Sediment
P
As
Se
Cr
Pb
Processes: Sorption, Transformation, Bacterial Adhesion, Biomineralization/Dissolution
Metal Oxide (Fe, Al, Mn)
Biopolymer
Virus
Inorganic Contaminant
Layer Silicate
Natural Organic Matter
Bacteria
Organic Contaminant
virology
immunology
microbial genetics & physiology
microbial pathogenesis
CIVIL ENGINEERING
Space engineering
GEOHEALTH I
BUILDING BRIDGES ACROSS
THE GEOLOGICAL AND HEALTH SCIENCES
Informatics

Space farming initial stage: one way system



MELiSSA



Biosphere

Biosphere 2 is a 3.14-acre (12,700 m2)[1] structure originally built to be an artificial materially closed ecological system in Oracle, Arizona (US) by Space Biosphere Ventures.

modular agricultural units (6 x 110 m^2) designed to:

- produce nutrients for 4 people
- recycling all air, water and waste
- Mars simulant soils (JSC Mars-1)

Soil management practices involved:

- minimal tillage
- mulching
- returning crop residues to the soil
- increasing soil biota
  (introduction of worms, soil bacteria and mycorrhizal fungi)
- pH control and texture ammelioration
  (addition of a peat moss, green sand, humates and pumice mix)
- increase nutrient availability

Results

Different experiments increased the capacity to satisfy crew diets but without reaching the 100%

(Silverstone et al. 2003 *Adv. Space Res*. 31: 69-75; 2005 *Adv. Space Res*. 35: 1544-1551)

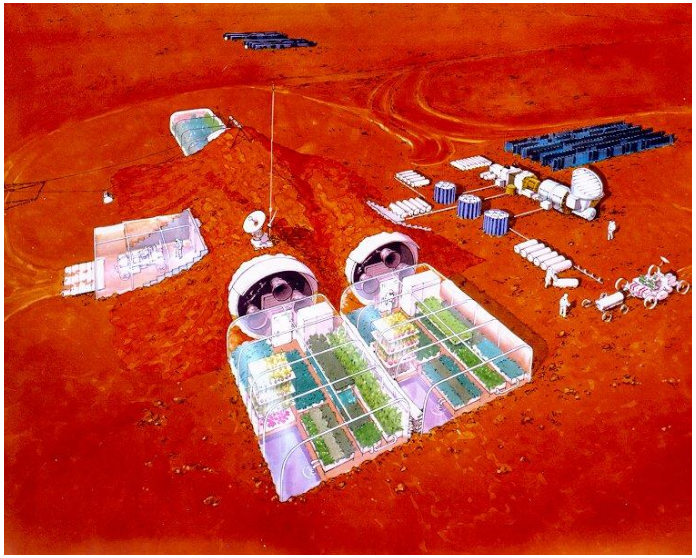
Crew energy-food, water and oxygen demand

Our space agriculture concept employs plants to (per person per day) regenerate 100 kg of water, revitalize 0.5 kg of oxygen from carbon dioxide, and produce 2 kg of food materials from human metabolic waste and inedible biomass (Katayama et al. 2008).

four major plant species
the farming area will be **200m²** per person

silkworm pupa
estimation of planting area required for mulberry trees to rear 18 kg of silkworm pupa is **64m²**.

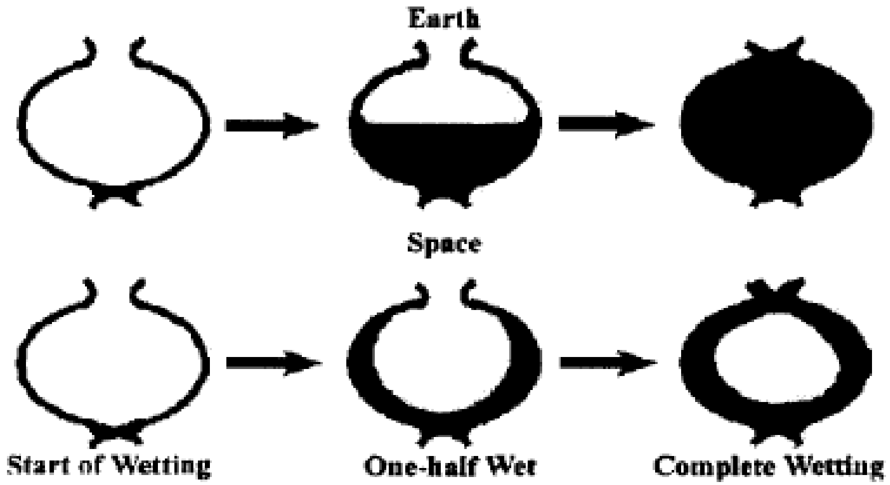
loach
Maximum production per unit water surface area is 10 kg/m², (1 year to rear adult loach). In order to produce 44 kg of loach per year, the minimum area for aquaculture is **4.4m²**.



Azolla
Since loach will be cultured in rice paddies with *Azolla* on their surface, we can manage all these items within the original farming area. The water surface area will be sufficient for *Azolla* as well.

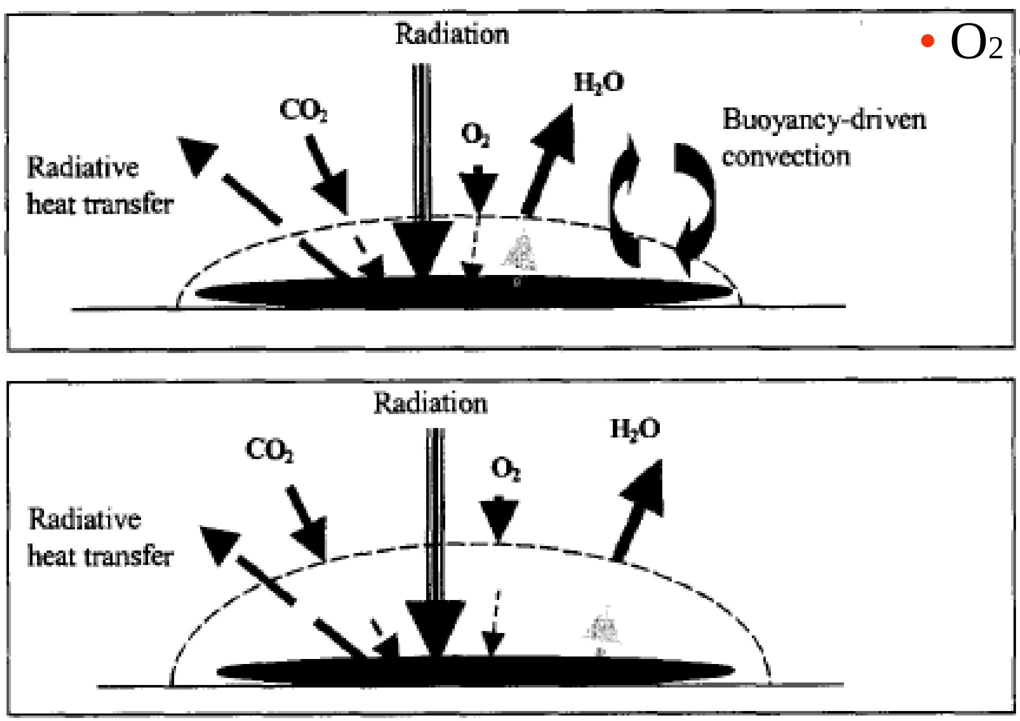
oxygen demand
Plant canopies produce 20–30g of O_2/m^2 per day, approximately **40 m²** area would be required for the maintenance of adequate oxygen level for each human crew member, about 1000 g/day

Microgravity effects



- soil water circulation

The trapped air would significantly reduce saturated hydraulic conductivity



- O_2 and temperature at boundary layers

At 1 g, the boundary layers are thin enough so that metabolic processes like respiration and transpiration are rarely diffusion-limited.

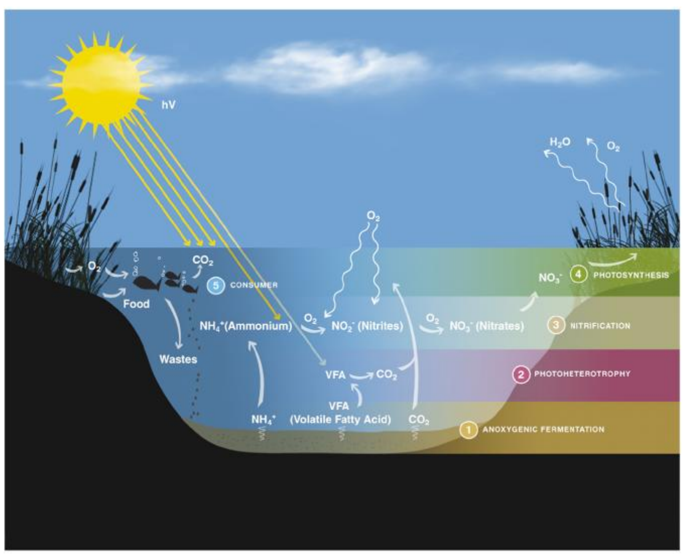
Inhibiting gravity-mediated oxygen transport may lead to severe biophysical limitations in O_2 availability, which may explain many hypoxic and physiological responses of plant tissues observed in past spaceflight experiments

Monje.et al. 2003. *Adv. Space Res.* 31 (1): 151-167

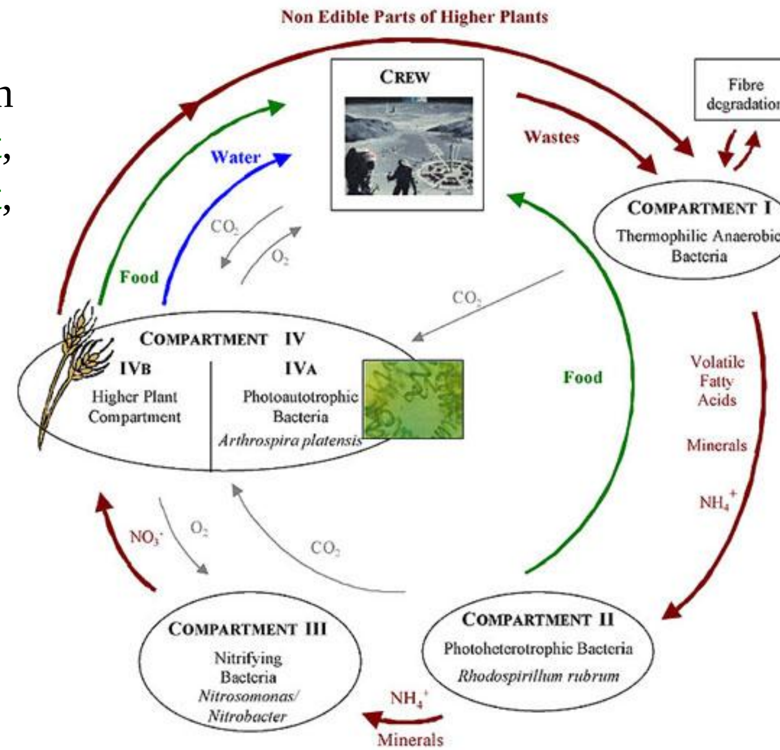
MELiSSA (Micro-Ecological Life Support System Alternative)

MELiSSA is a bioregenerative life support system designed by the European Space Agency (ESA) for the complete recycling of gas, liquid and solid wastes during long distance space exploration. The system uses the combined activity of different living organisms: microbial cultures in bioreactors, a plant compartment and a human crew

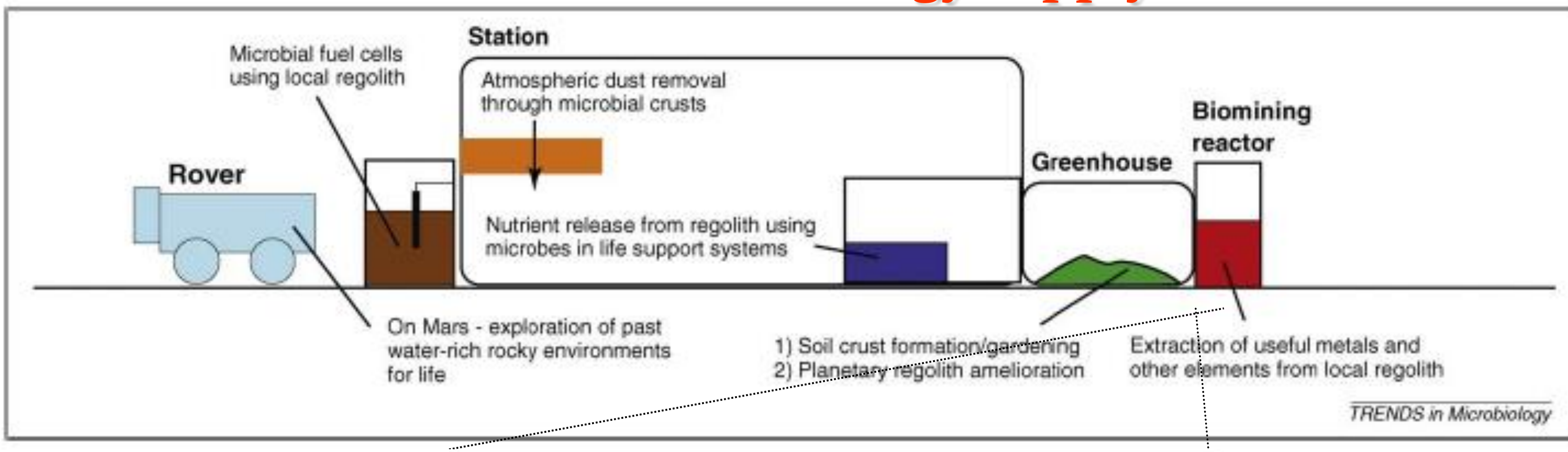
Principally, life support systems can be divided into five main areas: (i) **atmosphere management**, (ii) **water management**, (iii) **food production and storage**, (iv) **waste management**, and (v) **crew safety**

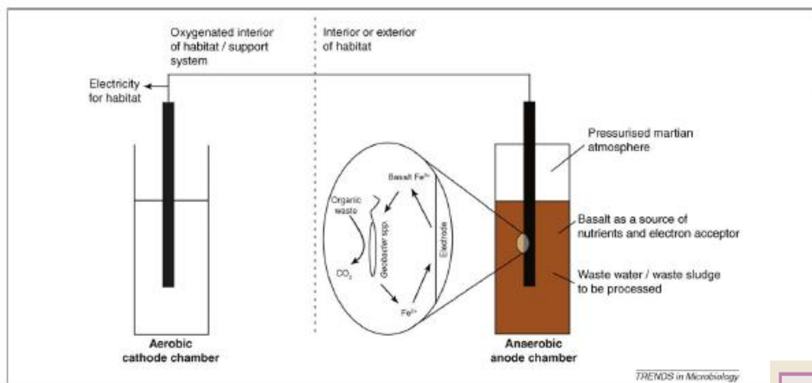


Current Opinion in Microbiology

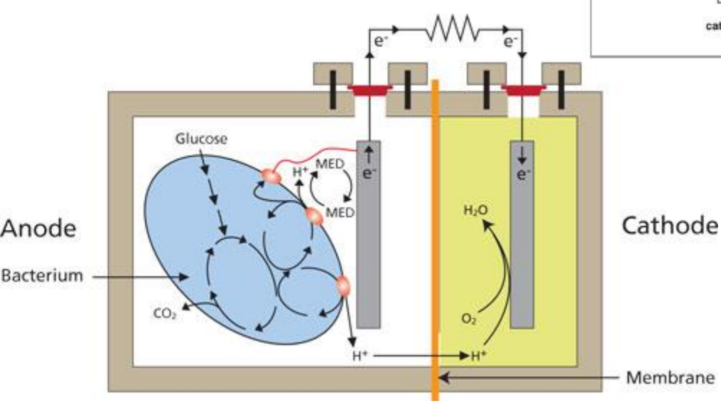


Extraterrestrial energy supply



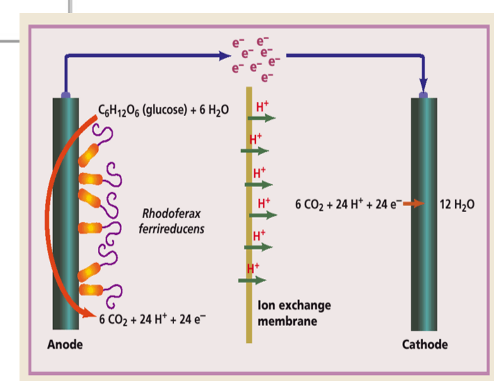


- Geomicrobiolgy
- Biomining
- Microbial fuel cells

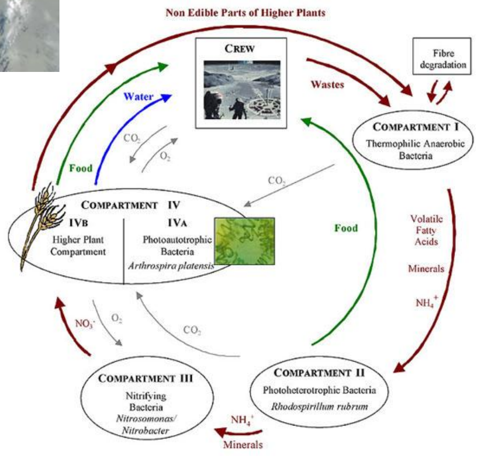


Extraterrestrial MFC.

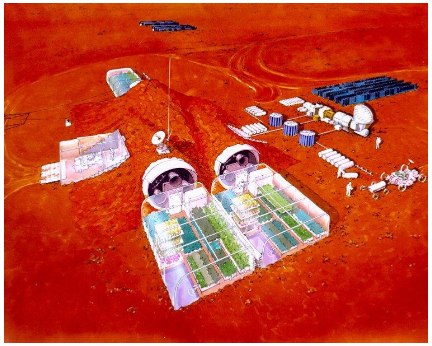
This concept uses microbe–mineral interactions to drive the production of energy and processing of organic waste using local atmospheric and regolith resources on the surface of Mars.



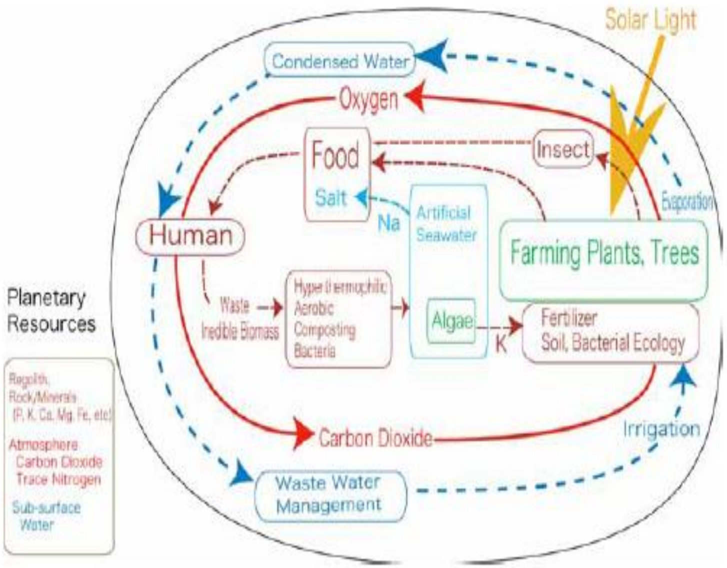
Space farming evolution: two way system

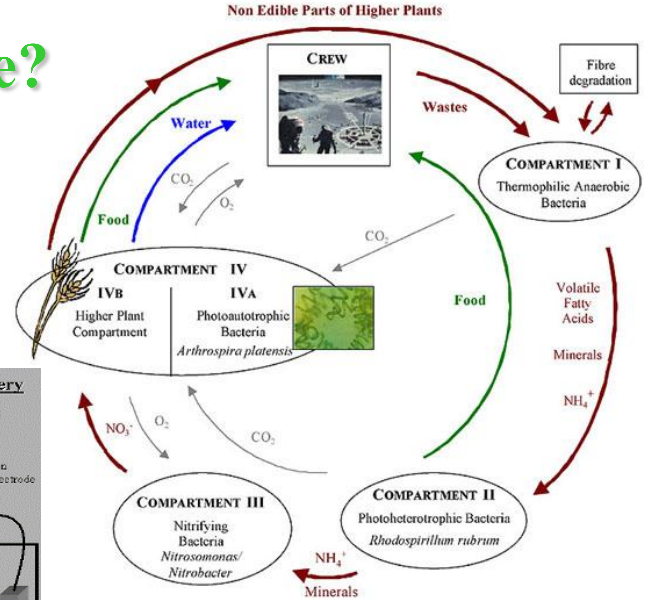


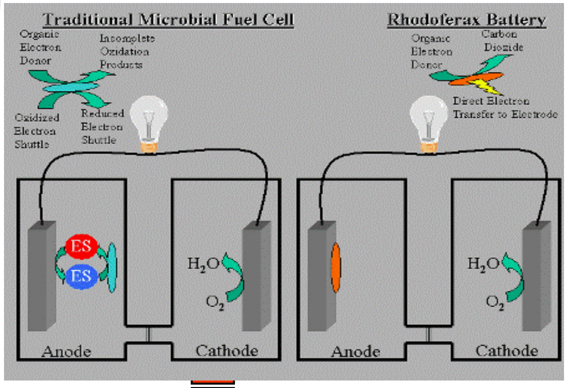
MELiSSA



…it will be possible?

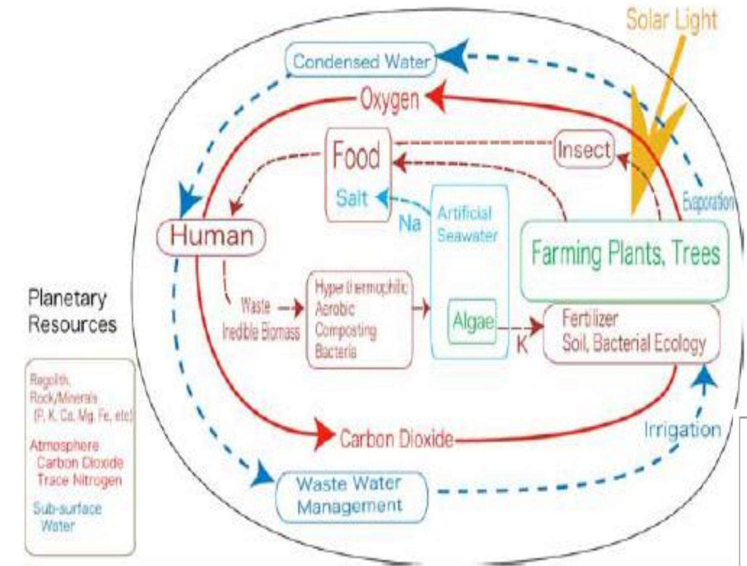


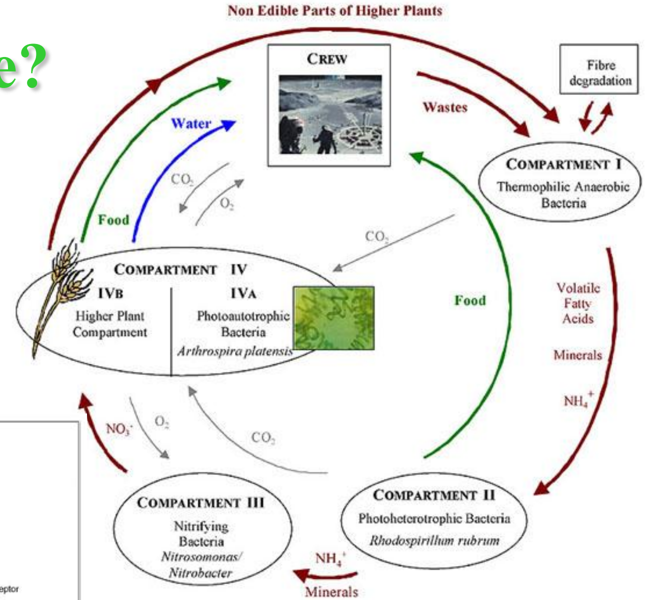


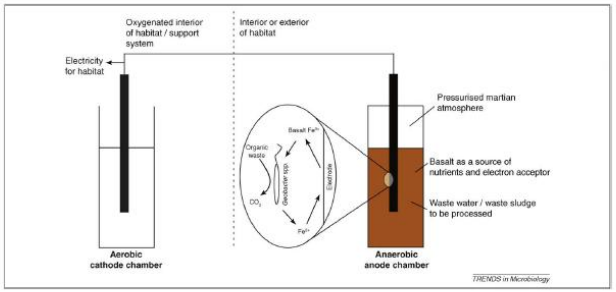


..”yes we can!..:

…it will be possible?







..”yes we can!..:

Model food materials to meet the nutritional requirements for one person/day

Rice 300g, soybean 100g, sweat potato 200g, green-yellow vegetable (Komatsuna) 300g, silkworm pupa 50g, loach fish 120g, *Azolla filiculoides*, and sodium salt 3g (Yamashita et al. 2007).

Azolla filiculoides

silkworm pupa

Loach fish

Macrotermes subhyalinus

Lentinula edodes

Auricularia auricula

Wooden biomass can be converted to edible biomass, i.e., insect meat, by termites (*Macrotermes subhyalinus*).
Culturing of wood-degrading fungi, Japanese mushroom (*Lentinula edodes*) or Jew's ear fungus (*Auricularia auricula*), could enrich diet in vitamin D, a component deficit in the plant-based diet, especially after the drying process and irradiation by ultraviolet light.

Smart green management in human abitative constructions

In 1973, NASA scientists identified 107 volatile organic compounds (VOCs) in the air inside the Skylab space station. Synthetic materials, like those used to construct Skylab, give off low levels of chemicals (formaldehyde, benzene, and trichloroethylene)

Sick Building Syndrome

When toxins become concentrated inside sealed buildings, due to keeping temperature-controlled air in place.

BioHome

One of the NASA experiments testing this solution was called "**closed ecological life support systems**." The **BioHome** was designed as suitable for persons to live in, with a great deal of the interior occupied by houseplants.

(Francesca Rapparini - f.rapparini@ibimet.cnr.it)

Dracena compacta

Dracena marginata

Edera

Ficus benjamina

Spatiphillum

Terraforming

Terraforming: a process of planetary engineering, specifically directed at enhancing the capacity of an extraterrestrial planetary environment to support life as we know it.

The ultimate achievement in terraforming would be to create an open planetary biosphere emulating all the functions of the biosphere of Earth, one that would be fully habitable for human beings.

Mars is considered by many to be the most likely candidate for terraforming.

Much study has been done concerning the possibility of heating the planet and altering its atmosphere, and NASA has even hosted debates on the subject.

...it will be possible?

..”yes we can!...

..or..

In conclusion present and future perspective

Today…..

…**from the stables to the stars**

..but tomorrow…..

…**from the stars to the stables**

we hope with a positive meaning!