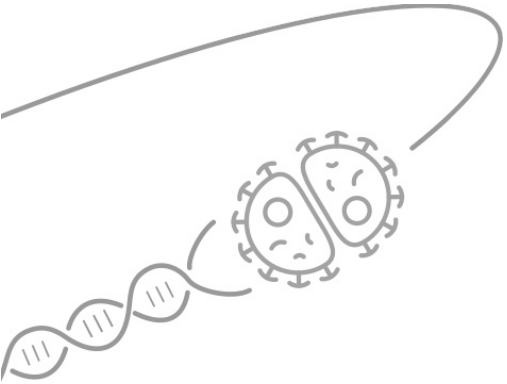
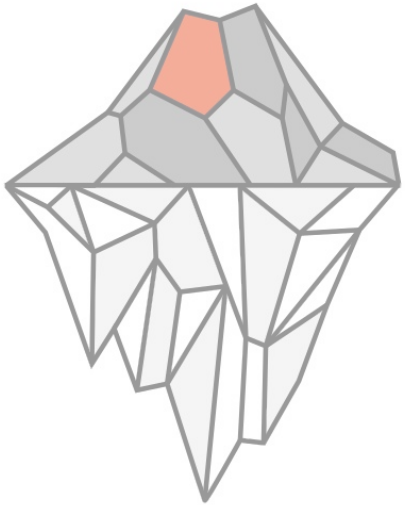


MICROBIAL METABOLISM AND PLANETARY HABITABILITY

INTRODUCTION – HABITABILITY AND GEOENGINEERING



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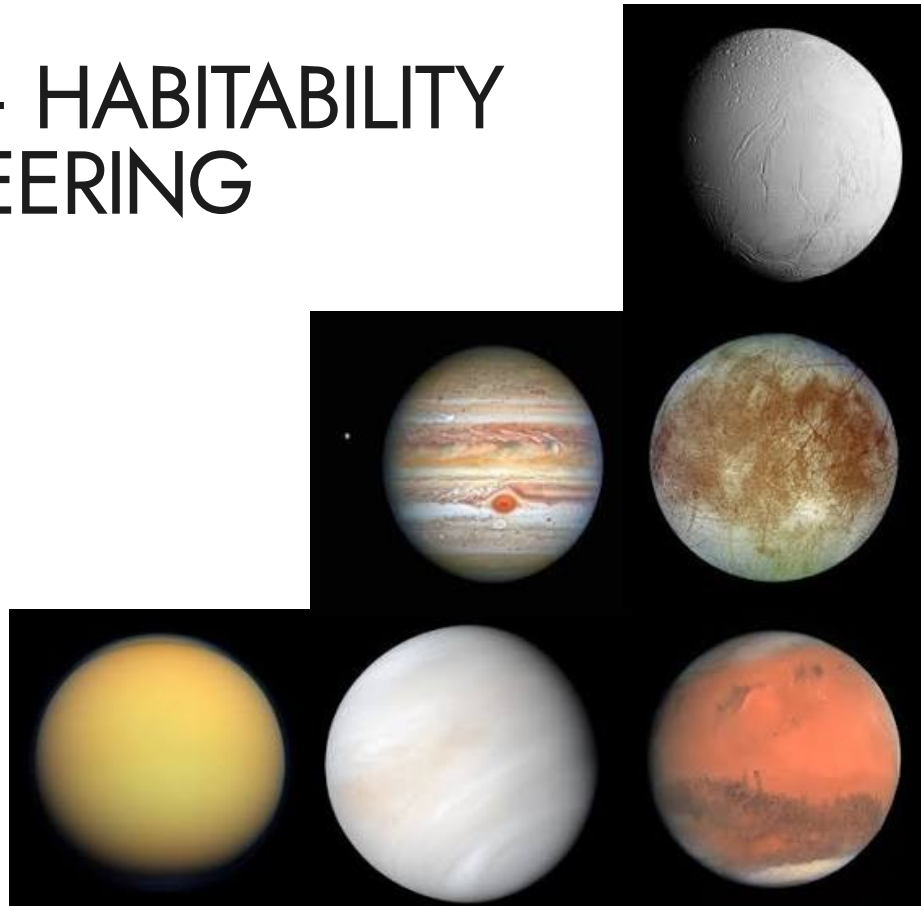

GIOVANNELLI LAB
UNIVERSITY OF NAPLES FEDERICO II

BIOLOGY OF EXTREME ENVIRONMENTS

DIPARTIMENTO DI BIOLOGIA

INTRO POLL

https://forms.gle/hRZvqswAjnnFKbu56

AN INTERACTIVE COURSE

This will be a highly interactive course. This will be a course designed with a learn-by-doing approach

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Frontal lectures will be reduced to a minimum

Often you will be required to carry out group exercises during class

Bring your laptop/tablet/cell phone

EXPECTATIONS

I expect active participation in the class activities

I expect full collaboration and an inclusive attitude

Groups for in class activities will be constantly changed

As part of this class I will also introduce a number of general and soft-skill lectures regarding the approach to science and research

MAIN COURSE PROJECT

- *Form groups of 2-3 students (international!)*

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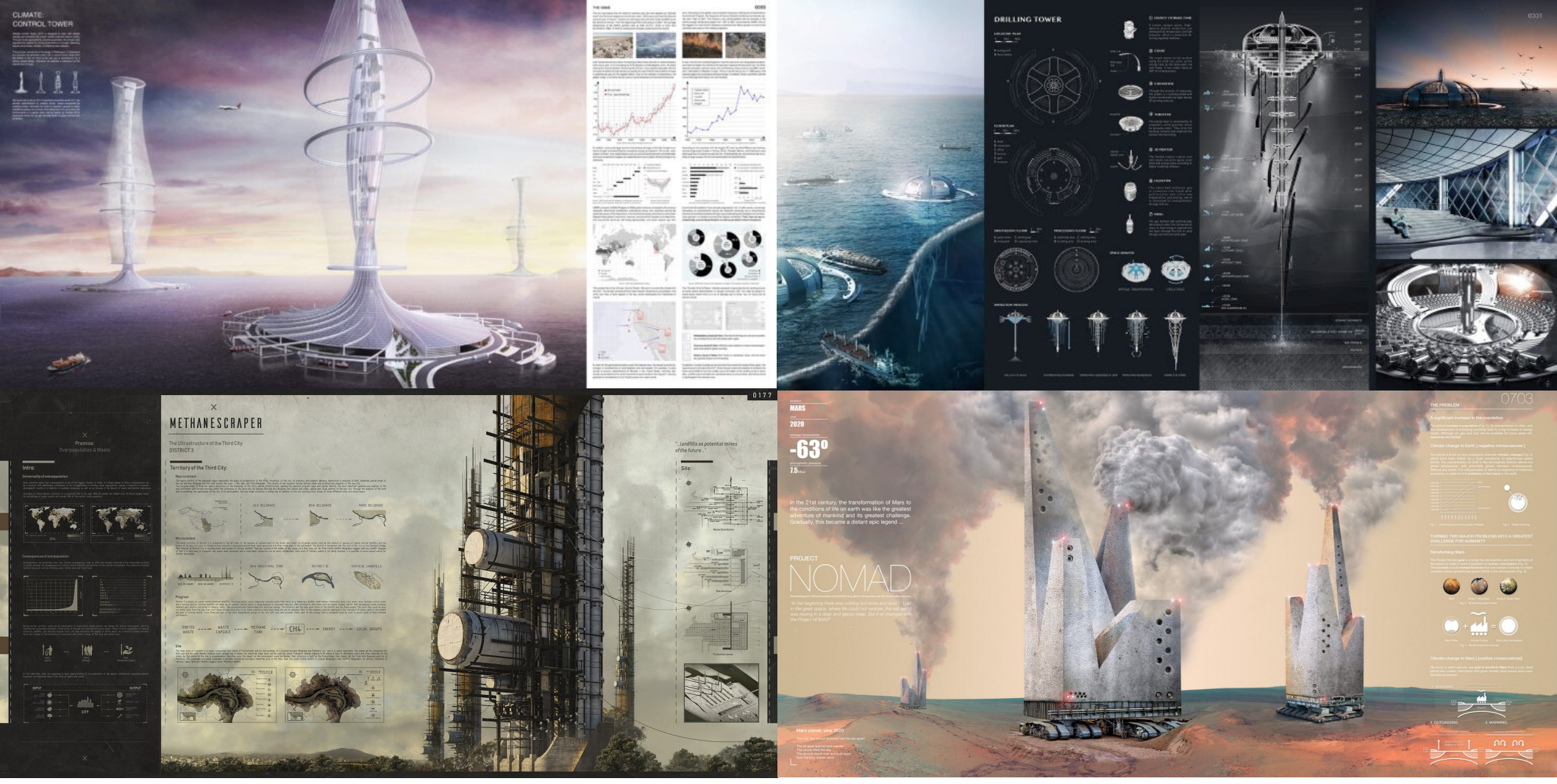
- Devise a terraforming plan using microbial metabolism as main tool (but not exclusive)

- Present it as a visual poster the terraforming plan



https://www.evolo.us/ eVolo Competition

CLIMATE:
CONTROL TOWER

Climate Control Tower [CCT] is designed to cope with climate change and overcome the current climate crisis the world is facing. Through clouds generated by absorbing seawater, the climate crisis regulates the weather by raising where there is a drought, absorbing clouds where heavy rainfalls, or reflecting solar radiation.

This process reminds me of the shape of Waterspout. A waterspout is a powerful low-pressure vortex with a narrow funnel shape from the bottom of the red cloud to the sea and is accompanied by a strong upward airflow. Therefore, we selected a waterspout as the overall form of mass.

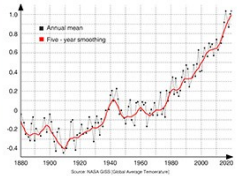
We would like to set up CCT in countries around the world. CCT can prevent desertification by creating clouds, create ecosystems by creating forests, eliminate the threat of disasters caused by heavy rainfalls by getting rid of clouds. We believe that CCT can protect the environments in a global scale, and by setting up multiple CCTs around the world, we can get one step closer to global environment protection.

THE ISSUE

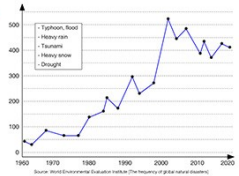
The two risk factors that will come to mankind over the next decade are "Climate crisis" and "failure to respond to the climate crisis". 2019 was confirmed "the Second warmest year in history". Experts are referring to the end of the Earth as 2050 due to the abnormal climate. From the beginning of the 21st century to 2021, the average temperature of the Earth's surface rose by 0.93 ±0.07℃, which is more than two-thirds of 1980. (A level of temperature increase varies around the world).

Land temperatures have been increasing at about twice the rate of ocean temperatures every year. (It is increasing by 0.13 degrees to 0.25 degrees every 10 years) Among the diverse factors influencing the climate, many experts speculate that the increase of carbon dioxide density caused by the use of fossil fuels and the increase in greenhouse gas are the biggest factors. Due to the increase in temperature, the global village is currently facing various natural disasters and environmental problems. According to the global natural disaster frequency table by the United Nations Environment Program, the frequency of natural disasters continues to increase rapidly from 1960 to 2021. This shows a very similar pattern with an increase in the world average temperature graph from 1951 to 2021 announced by NASA. One of the biggest and most known disasters is sea-level rise. Many people are aware that sea-level rise is due to the melting of glaciers.

In fact, not only the melting of glaciers rises the sea-level, but rising global temperature itself increases the volume of the sea and it leads to the sea-level rise. For other disaster examples, we have heavy rain and flooding. Heavy rains in July 2021 resulted in 190 deaths in Western Europe. This is a record heavy rain in 1,000 years, and experts judge it as a prelude to climate change. In addition, China, and India suffered a lot of damage from heavy rain and flooding.



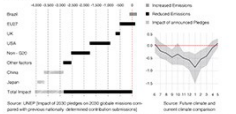
Source: NASA GISS Global Average Temperature[℃]



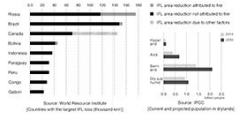
Source: World Environmental Evaluation Institute [The frequency of global natural disasters]

In addition, various damage, but the most serious damage of climate change to extreme drought and desertification caused by drying up long-term. Of course, reclamation of forest, man-made factors such as environmental pollution and deforestation have conspired to happen, but desertification due to global climate change is accelerating.

According to the 'countries with the largest IFL loss' by World Resources Institute, several large-scale forests in Russia, Brazil, Canada, Bolivia, and Indonesia were destroyed due to fractural causes like fire. A dramatically dry environment due to climate change caused the fire and accelerated the desertification.



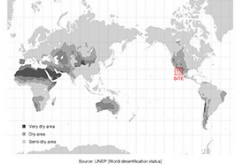
Source: UNEP [Impact of 2030 pledges on 2030 globale missions compared with previous nationally determined contribution submissions]



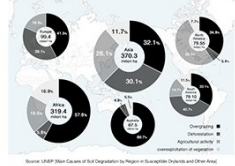
Source: World Resource Institute [Countries with the largest IFL loss (thousand km²)]

Source: IPCC [Current and projected population in drylands]

UNEP's [Impact of 2030 Pledges on 2030 global missions compared with previous nationally determined contribution submission] shows that countries around the world are aware of the importance of environmental issues and move to solve them Despite these global movements, however, environmental disasters and desertification around the world are still rising exponentially, and some experts say that environmental problems have already progressed a lot. In other words, awareness and policy on environmental issues are important nationally, but a movement to solve environmental problems through a groundbreaking technological and architectural approach is needed and should be applied worldwide. **Then, how can we architecturally prevent desertification as well as persistent natural disasters?**

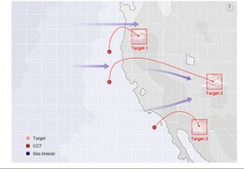


Source: UNEP [World desertification status]

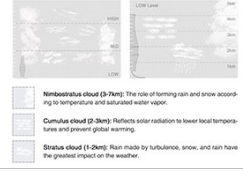


Source: UNEP [Main Causes of Soil Degradation by Region in Buzwpitzer Drylands and Other Area]

The answer lies in the 'Climate: Control Tower'. We want to control the climate with the CCT. The climate consists of three major factors: temperature, precipitation, and wind, and most of them appear in the sky, which emphasizes the importance of clouds.



The "Climate: Control Tower" absorbs seawater to generate clouds, sending clouds to areas where desertification or drought continues. CCT can also be placed on cloud routes where there is a lot of damage due to snow, rain, or heavy rain to absorb clouds.



Nimbostratus cloud (3-7km): The role of forming rain and snow according to temperature and saturated water vapor.

Cumulus cloud (2-3km): Reflects solar radiation to lower local temperatures and prevent global warming.

Stratus cloud (1-2km): Rain made by turbulence, snow, and rain have the greatest impact on the weather.

DRILLING TOWER

LOCATION PLAN

0 50m 100m

A. energy port
B. ferry station

FLOOR PLAN

0 50m 100m

A. hotel
B. restaurant
C. office
D. factory
E. gym
F. museum

SIGHTSEEING FLOOR

0 50m

A. guest room C. dinning bar
B. restaurant D. sighseeing trails

PROCESSING FLOOR

0 50m

A. collecting area C. melting area
B. crushing area D. drawing area

OPERATION PROCESS

COLLECT PLASTIC | 3D PRINGTING RUNNING | PRINGTING UNDERSEA FLOOR | PRINGTING BIOSENSOR | COMPLETE FORM

① ENERGY STORAGE TANK

A closed, opaque space. High-density plastic materials can withstand low temperature and high pressure, which is convenient for storing liquefied methane.

② CRANE

The crane moves on the surface along the slide rail, picks up the energy tank by the telescopic rod and claws. It can rotate freely at 360° at a fixed position.

③ CONVERTER

Through the process of collecting, the plastic is crushed,melted and finally transformed into high-density 3D printing material.

④ THRUSTER

The energy tower is composed by 12 propellers, which generate thrust by spraying water. They drive the building forward and stabilize the position during mining.

⑤ 3D PRINTER

The flexible tubular robotic arm and nozzle can print spiral coral belts and energy tanks according to digital modeling software.

⑥ LIQUEFIER

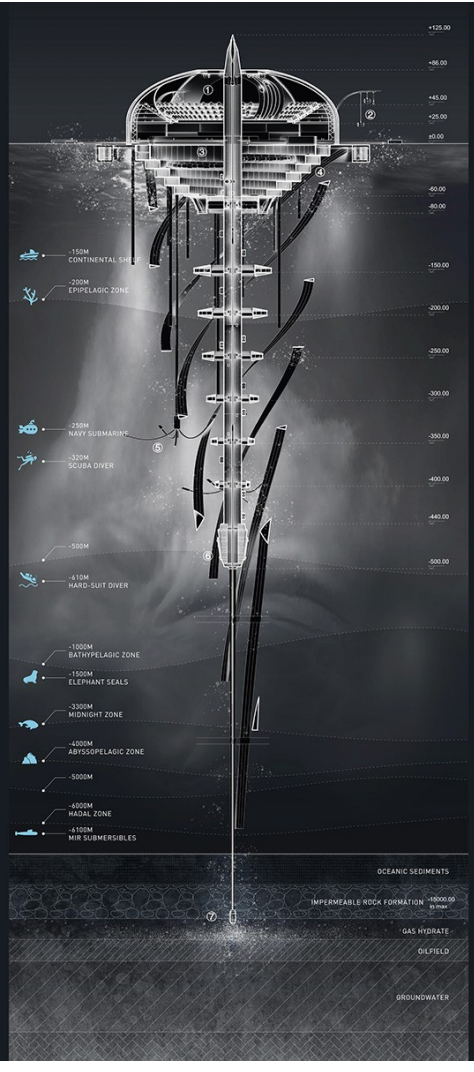
The absorbed methane gas is converted into liquid after purification and ultra-low temperature processing, which is convenient for transportation, storage and use.

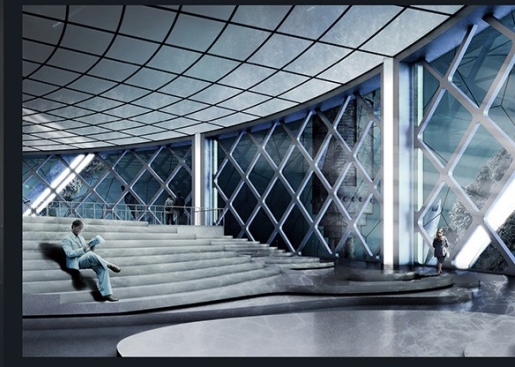
⑦ DRILL

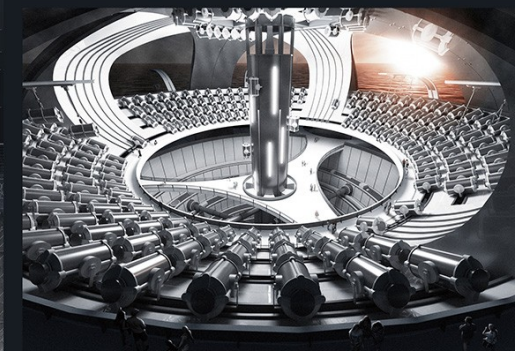
The gas hydrate will automatically decompose when the temperature rises, so heat energy is injected into the layer through the drill to send the gas out from the solid state.

SPACE ANALYSE

VERTICAL TRANSPORTATION | CIRCLE SPACE







METHANESCRAPER

The Ultrastructure of the Third City:
DISTRICT 3

Premise:
Overpopulation & Waste

Intro:

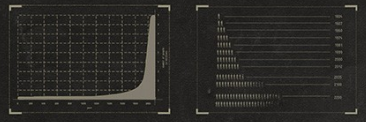
Universality of overpopulation

Many scientists agree that overpopulation is one of the biggest threats of today. In a large number of cities, overpopulation can be a catalyst that additionally contributes to the strengthening of existing social segregations, causes a reduction in economic development, results in a reduction in available resources, as well as an increase in the amount of waste and harmful substances.

According to United Nations statistics, it is predicted that in the year 2050 the planet will inhabit over 9.5 billion people, where the percentage of urban society will exceed 70% of the world's total population.

Consequences of overpopulation

Overpopulation can potentially have very serious consequences, some of which are already reflected in the indisputable problem of global warming, the disappearance of certain natural habitats and pollution of the natural environment, the reduction of limited natural resources such as drinking water, fertile land and fossil fuels.



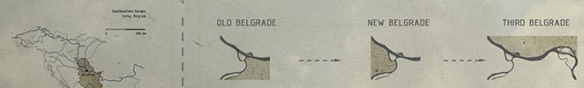
During certain activities, which can be urbanization or exploitation, human actions can change the natural environment, often by violating the sustainable principles. Construction of thermal and hydroelectric power plants, Amazon forests, exploitation of mineral resources, landfills, gas emission, nuclear tests, etc. man influences the change of entire areas. As a result of human activities there are changes or disturbances of ecosystems and climate change at the local and global level.

At the same time, cities are beginning to have characteristics of true parasites of the planet, continuously consuming natural resources and disposing them in the form of waste and smoke.

Territory of the Third City:

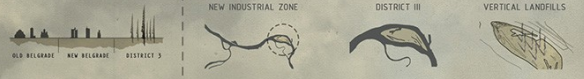
Macrocontext

The macro-context of the analysed region represents the place of juxtaposition of the three 'situations' of the city, its presence and complete absence, manifested in relations of built, inhabited coastal areas of the old and New Belgrade and the 'void' across the river – "Old, New, and Third Belgrade". The results of the research include defined urban and architectural elements of the new city.
Two occupied areas of Belgrade upon a discussion of the character of the city's spatial infrastructure, opening the question program types and spatial identity. The most important qualities are relation of the new settlement with formed matrices within the confluence of the Sava into the Danube (Old and Novi Belgrad with Zemun) and urban, spatial and visual identity of the new city. Through the analysis of the form and re-examining the significance of the city in its development, the new urban structure is acting like an addition to the two existing cities. Areas of three different cities are shown below.



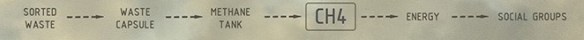
Microcontext

The initial structure of District 3 is connected to the left bank of the Danube, on wetland east of the Great war Island. Six strategic points, such as the centers of genesis of typical vertical landfills, are the pillars of the new city core. An infrastructure network is developed around them, which generates a further urban plan of the settlement. The district is connected with the rest of the city by the Pancheu Bridge. Main function of District 3 is a recycling plant and system of vertical landfills. They are located in the middle of the island, on a free zone not far from Vinchа landfill, Belgrade's biggest and only landfill. Because of that it is very easy to transport any waste when necessary and a road/water connection can be easily established. Since most of Vinchа's waste is not being recycled, it is possible to move unused waste for further processing.



Program

District 3 contains six waste towers (vertical landfills), recycling center, seven temporary concrete pools that serve as a temporary landfill, small harbor, incinerator area, toxic waste area, multiple control routes and a sorting facility. Vertical landfills are made up of modules; sorted waste is being disposed in vacuumed capsules, then attached to the tower core by cranes. Organic matter that decomposes inside produces methane gas, which is extracted to hanging tanks, then processed and transformed into electrical energy. The initiators and the main work force of the District are the Roma people. The work they could do does not differ much from the jobs that most Roma already know how to do, Roma collectors have been doing the job for decades. Part of the company could be employed in the transport of waste, part of the landfill and part in sorting facility. Since Roma are one of the most marginalized groups in the city with very bad economic state, part of the energy that is produced could be used to power some of their informal settlements.

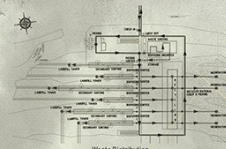


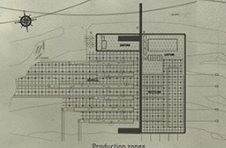
Site

The inner area of research is a region concerning river island of Furkuntunac and its surroundings. It is located between Belgrade and Pancheu city, and it is easily accessible. The island can be connected with both wat and dry path. Nearby chemical plant already has a harbor for industrial ships which can be used for easier transport. Nearby highway E-70 makes it easy to distribute waste and other materials to the island. As the center of the site is predominately free-free zone, the impact on the environment would be minimal. Main structure is built on the Furkuntunac river island, not far from both Belgrade and city of Pancheu. This seemingly untouched landscape is actually considered secondary industrial zone in the area. Near the island Vinchа landfill is located (Belgrade's main landfill), Belgrade's oil refinery, Pancheu oil refinery, many factories, Serbia's biggest plant, Pancheu landfill.

"...landfills as potential mines of the future..."

Site:





location
MARS

year
2020

average temperature
-63º

atmospheric pressure
7.5 Mbar

In the 21st century, the transformation of Mars to the conditions of life on earth was like the greatest adventure of mankind and its greatest challenge. Gradually, this became a distant epic legend ...

PROJECT
NOMAD

@eVoloMagazine #OverPopulation #GlobalWarming #Mars #ProjectNomad #Factories #Terraforming

"In the beginning there was nothing but rocks and dust ... Lost in the great space, where life could not venture, the red world was resting in a deep and glacial sleep. But it all changed with the Project NOMAD"

...

Mars planet, year 2020

One day, the nomad factories tore the sky apart!

The air grew warmer and warmer
The clouds filled the sky
The ground shook over and over again
then the blue waters came

THE PROBLEM

A significant increase in the population

The global **increase in population** (Fig. 1), its concentration in cities, and the development of emerging countries lead to a big increase in energy needs. Although oil, gas and coal will be available for many years still, **resources are limited**.

Climate change in Earth [negative consecuences]

The planet is know to have undergone dramatic **climatic changes** (Fig. 2) which have been linked, by a large consensus, to greenhouse gases (GHG). The concentration of GHG in the atmosphere directly affects the global temperature, with potentially global, dramatic consequences. Without any doubt, it is indispensable to define an objective of maximum emissions, in order to limit **problems in the future** in the earth.

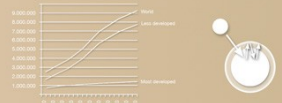


Fig. 1 World Population (Thousands of People)

Fig. 2 Global Warming

TURNING TWO MAJOR PROBLEMS INTO A GREATEST CHALLENGE FOR HUMANITY

Terraforming Mars

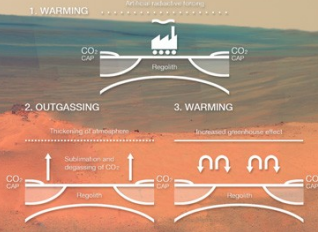
The Project Nomad **goal** is change the atmospheric and soil chemistry of the planet to make it more hospitable for **human colonization** (Fig. 3). The **concept** is build **nomad factories** that use martian minerals to create complex carbon greenhouse gases (GHG) in the atmosphere (Fig. 4).

Fig. 3 Terraforming Mars Phases

Fig. 4 Terraforming Mars Concept

Climate change in Mars [positive consecuences]

We know to warm planets, **our goal is terraform Mars** from a cold, dead planet into a warm, vital planet with green forests, blue oceans and a sustainable ecosystem.



EXAM AND FINAL PRIZE

The final exam will consist of the discussion and defense of your terraforming project

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There will be an international jury responsible for ranking the poster (NASA, ASI, NMNH, ELSI)

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EXAM AND FINAL PRIZE

The final exam will consist of the discussion and defense of your terraforming project

There will be an international jury responsible for ranking the poster (NASA, ASI, NMNH, ELSI)

Poster will contribute to 70% of final grade, presentation 30%

The winning poster will be presented at an international conference

International Geochemical Society

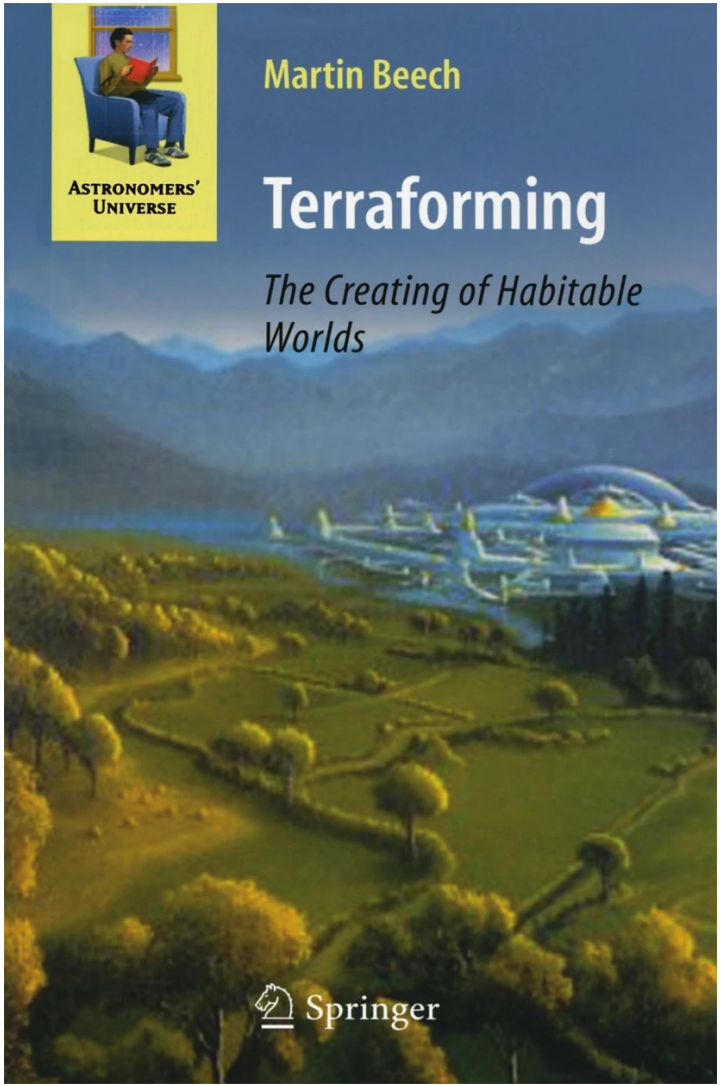
Goldschmidt 2023 - Lyons

GOLDSCHMIDT® LYON 2023 9–14 JULY

Astrobiology Science Conference

AbSciCon 2024

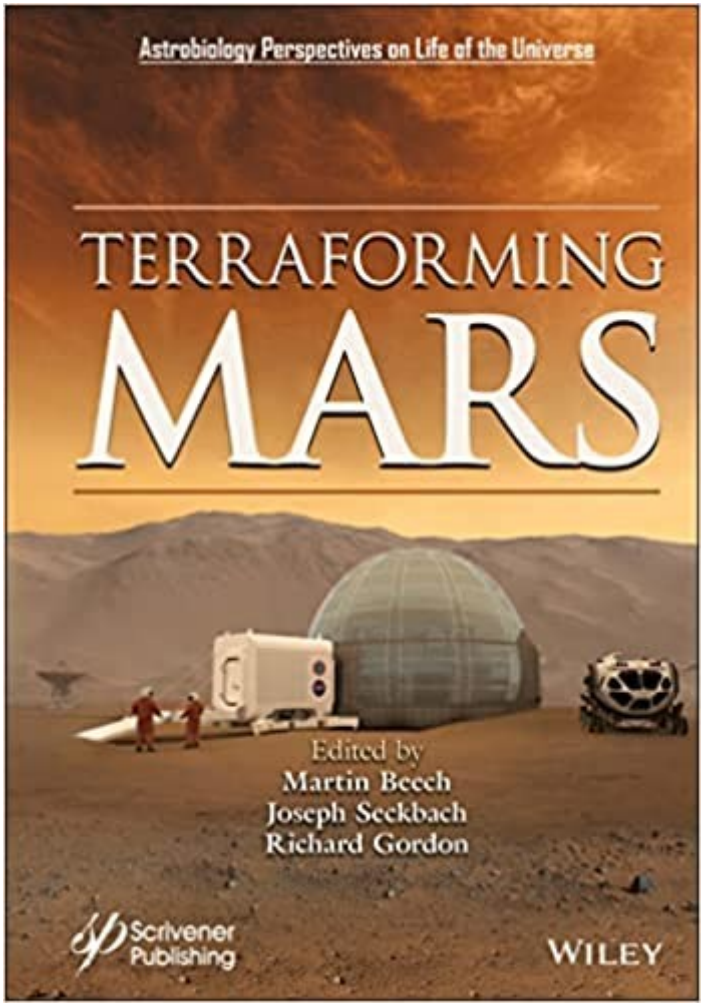
COURSE MATERIAL AND IN-DEPTH READINGS



Terraforming
The Creating of Habitable Worlds

Beech

2009 Springer



Terraforming Mars

Beech, Seckbach, Gordon

2022 Wiley Edition

MICROBIAL METABOLISM AND PLANETARY HABITABILITY

Life or life

Write a definition of Life

Life or life

"It is commonly said," the scientists Frances Westall and André Brack wrote in 2018, "that there are as many definitions of life as there are people trying to define it."

- Empirical definitions of Life

- Physical definitions of Life

- Life as Information

- Darwinian definition fo Life

- Life as a Process

Astrobiology > Vol. 10, No. 10 > Special Collection of Essays: What is Life? Full Access

The Definition of Life: A Brief History of an Elusive Scientific Endeavor

Stephane Tirard, Michel Morange, and Antonio Lazcano

Published Online: 16 Dec 2010 | https://doi.org/10.1089/ast.2010.0535

Springer Link

Published: 29 January 2011

Why I stopped worrying about the definition of life... and why you should as well

Edouard Machery

Synthese **185**, 145–164 (2012) | Cite this article

Springer Link

Published: June 2004

A Universal Definition of Life: Autonomy and Open-Ended Evolution

Kepa Ruiz-Mirazo, Juli Peretó & Alvaro Moreno

Origins of life and evolution of the biosphere **34**, 323–346 (2004) | Cite this article

Perspectives in Biology and Medicine
Volume 53, Number 3, Summer 2010
Johns Hopkins University Press
Article

Towards a Definition of Life

Peter T. Macklem and Andrew Seely

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What is life?

Jaime Gómez-Márquez

HYPOTHESIS AND THEORY article

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Sec. Astrobiology
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This article is part of the Research Topic
Presentations at the 4th Workshop of the German Astrobiological Society (DAbG) on Astrobiology, 26–27 September 2019, Vienna, Austria
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What is Life?

Guenther Witzany*

Life or life

Instance vs Phenomenon

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***Life**: is the universal phenomenon*

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Habitable vs Inhabited

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Homo sapiens

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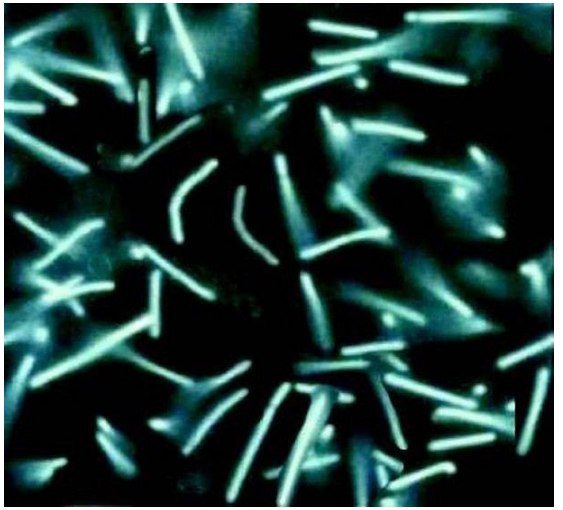

Methanopyrus kandleri

Microbial habitability and have a very broad (or narrow) set of conditions under which can thrive

DIFFERENT HABITABILITIES

Natural Habitability

An environment or ecosystem that meets the habitability requirement for a given species/community without the need for technological sustaining

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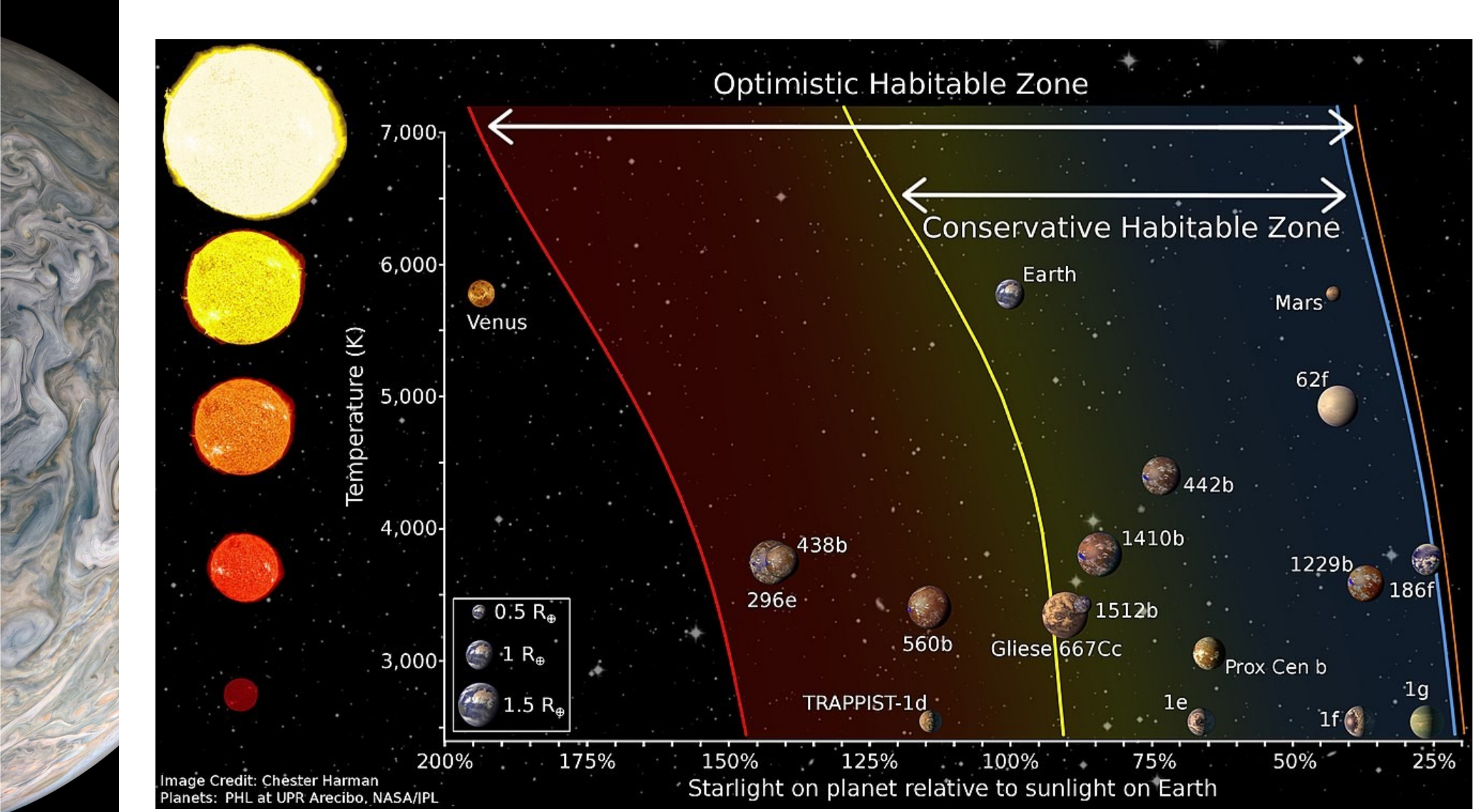
Technological Habitability

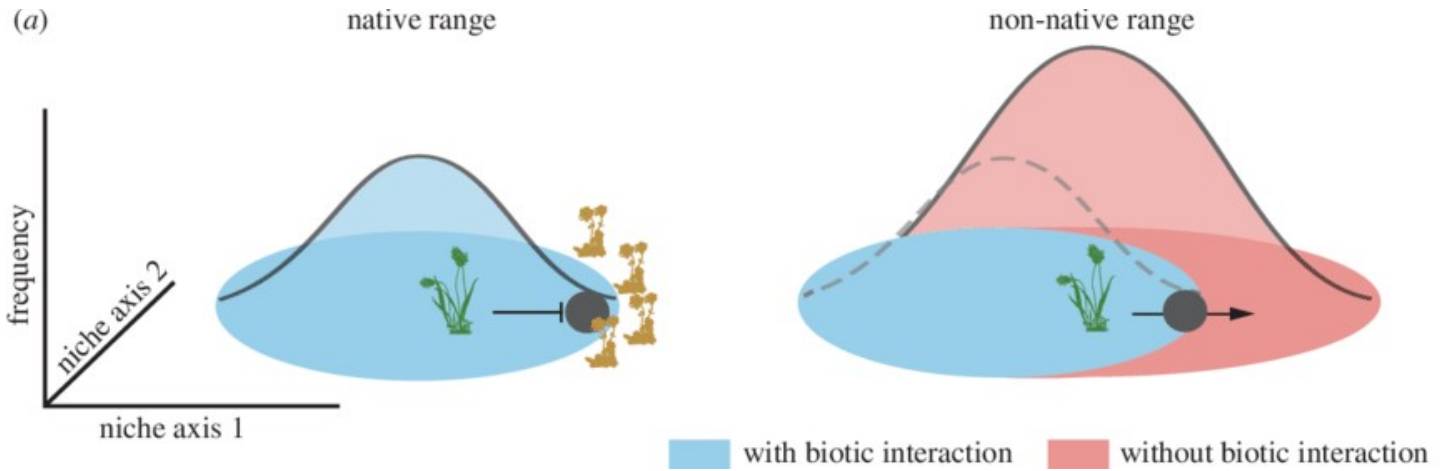
The use of technology (life-support systems) to overcame limitations in the conditions naturally found in an environment/ecosystem


Optimistic Habitable Zone
Conservative Habitable Zone
Temperature (K)
7,000
6,000
5,000
4,000
3,000
Venus
Earth
Mars
62f
442b
1410b
438b
296e
1229b
186f
1512b
560b
Gliese 667Cc
Prox Cen b
1g
TRAPPIST-1d
1e
1f
0.5 R⊕
1 R⊕
1.5 R⊕
200%
175%
150%
125%
100%
75%
50%
25%
Starlight on planet relative to sunlight on Earth
Image Credit: Chester Harman
Planets: PHL at UPR Arecibo, NASA/IPL

ECOLOGICAL NICHE

In ecology, a niche is the match of a species to a specific environmental condition. It describes how an organism or population responds to the distribution of resources and competitors.

The type and number of variables comprising the dimensions of an environmental niche vary from one species to another and the relative importance may vary according to the geographic and biotic contexts.



NICHE CONSTRUCTION

Niche construction is the process by which an organism alters its own (or another species') local environment. Alterations are generally physical change to the environment. Alterations are often beneficial to the constructor, but not always.

For niche construction to affect evolution it must satisfy three criteria:

1) The organism must significantly modify environmental conditions

2) The modifications must influence one or more selection pressures

3) There must be an evolutionary response caused by the environmental modification

EXTENDED PHENOTYPE

The set of environmental modifications produced by organisms related to the extended phenotype concept that may persist for longer than the individual constructors, and may continue to modulate the impact of these effects on subsequent generations of the same or other populations, even driving macroevolution over geological timescales. (1982 Richard Dawkins)

HABITABLE PLANET CLASSIFICATION

Class I *planetary bodies with liquid water available at the surface, along with sunlight, so that complex multicellular organisms may originate*

Class II *planetary bodies that lost their ability to sustain liquid water on their surface over time and never developed complex life*

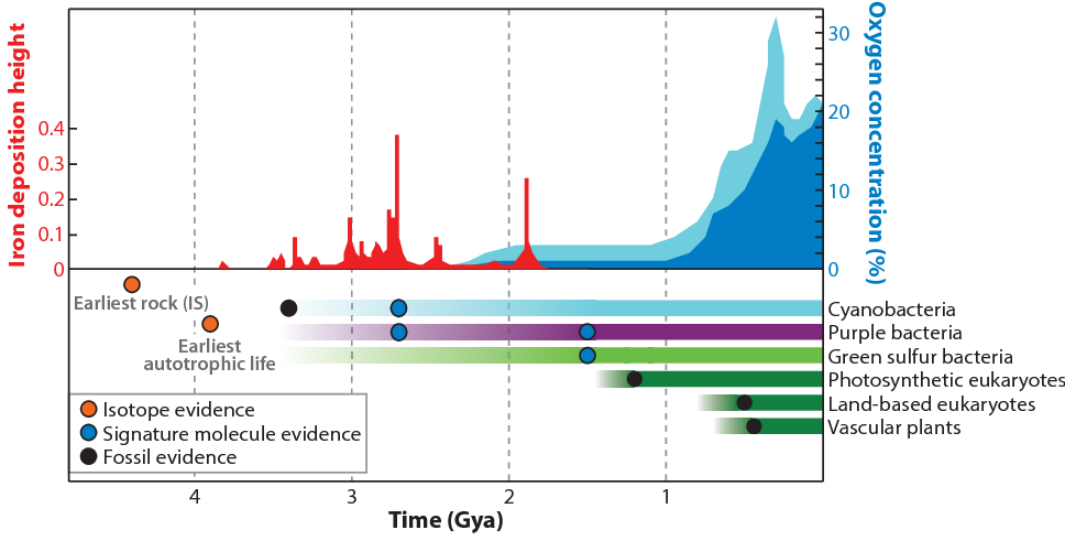
Class III *planetary bodies where liquid water oceans exist below the surface, where they can interact directly with silicate-rich rocks*

Class IV *planetary bodies where a liquid water layers is between two ice layers, or liquids above ice, so that water cannot interact with silicate-rich rocks*

Lammer et al. 2009 Astronomy and Astrophysics Review

ECOLOGICAL INHERITANCE

Ecological inheritance is the passing on to descendants of inherited resources and conditions, and associated modified selection pressures, through niche construction. Ecological inheritance has significant implications for macroevolution.



Water	*Inventory of water in different phases* *Activity of liquid water* *Past or future liquid and ice inventories* *Salinity, pH, and Eh of available water*
Chemical Environment	*C, H, N, O, P, S and building blocks* *Essential metals and micronutrients* *Availability/mineralogy* *Toxic substances* *Active recycling of elements and volatiles*
Energy for metabolism	*Solar energy (surface and near-surface only)* *Geochemical/Geothermal (near-surface and subsurface)* *Availability of oxidants and reductants* *Redox gradients and redox recycling*
Physical conditions	*Temperature fluctuation (daily, seasons)* *Low pressures* *Ultraviolet and cosmic radiation shielding* *Climate stability (short term and long term)* *Transport (aeolian, atmosphere, hydrology, erosion rock cycling)*