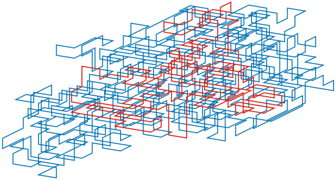
Human space travel: an astrobiologist's point of view

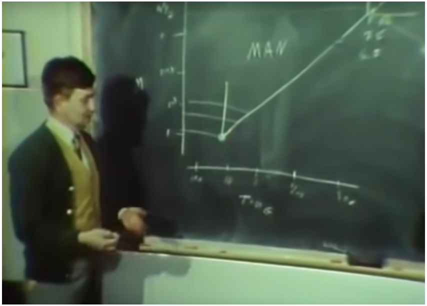
Franco Ferrari[1]

[1]CASA* and Institute of Physics, University of Szczecin, Szczecin, Poland



Galactic Nuclei in the Cosmological Context, June 3-6, 2024,
Szczecin, Poland

Mice equivalents of human societies



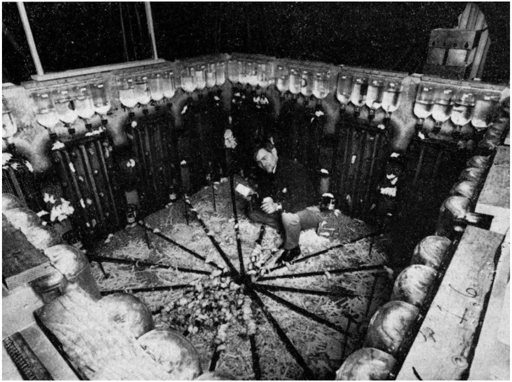
John B. Calhoun
(1917 - 1995)

Universe 25: Simulation of an hypertechnological society in which all problems of paucity have been solved apart from the lack of space.

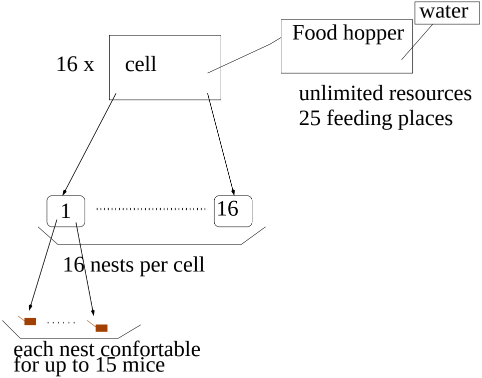
Universe 25

John B Calhoun, Proc. roy. Soc. Med. Volume 66, January 1973, 80

Universe 25 was characterized by excellent conditions for a population of up to 3840 mice. The only stress condition was the constrained space ($2.47 \times 2.47\text{m}^2$ and 1.37m height).



Optimal life condtions in Universe 25



16 x

cell

Food hopper

water

unlimited resources
25 feeding places

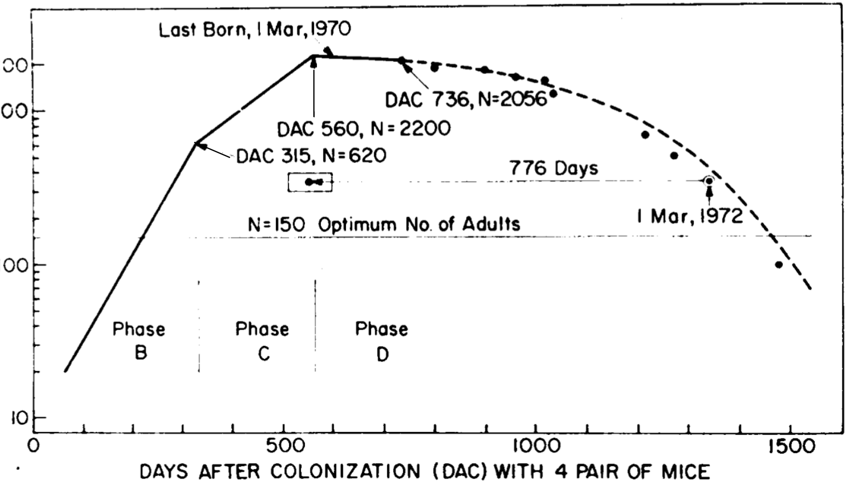
1 16

16 nests per cell

each nest confortable
for up to 15 mice

- Resouce supra-availability: shelter not a limiting factor until the population exceeded 3840, food availability for max. 9500 mice, water availability for max. 6144 mice, unlimited resources for building nests,
- Weather amelioration
- Disease control, lack of predators

Population trends



Social disruption I - behavioral sink

Usual social behavior of mice: grooms of about twelve specimens with most complex behaviors involving courtship, maternal care, territorial defence and hierarchical intragroup and intergroup social organization. Young mice failing to find a role in their initial groom emigrating and starting new grooms.

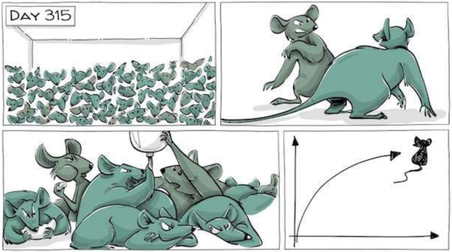
- Phase A (Days 0-104): initial insecurity of individuals followed by adaptation (formation of social bonds, territory demarcation, construction of nests).
- Phase B (Days 105-315): booming population (doubling every 55 days). Social structuring in 14 broods with females, dominant male, associated males and their juvenile/subadult progeny. Strong territorial division, overcrowding of territories with stronger dominant males.

Social disruption II

- Phase C (Days 316-560): decrease of growth and stagnation. Raise of aggressivity: young males and females losing their fight for their roles in the groom could not emigrate due to the lack of space. Males who failed to aggregate became very inactive. Males returning from eating and drinking caused excitement following aggressions. Territorial males gradually losing their hability to continue territorial defence due to the strong demand of rejecting maturing associates. Females taking over the territorial role of males to defend their youngs, but eventually attacking them or abandoning them.

  Strong decline of social activities, more females stopped conceiving and more males ceased to fight, being engaged only in eating, drinking, grooming and sleeping (dubbed the ”beautiful” ones).
- Phase D (Days 560 - 1780) After day 560, in which the maximum population of $N = 2200$ specimens was reached, the population started to decline. Last conception was on day 920.

Attempt to draw some conclusions



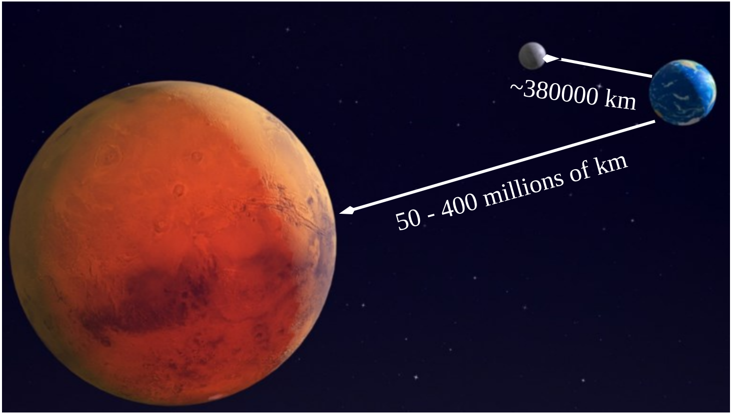
The experiment suggests that not the stress generated by the lack of physical space, but that due to too many social contacts caused the behavioral disruption observed in mice of Universe 25.

(Picture from sproutschools.com)

Making predictions on human society basing on the results of the experiments on mice is controversial.

Space exploration

A game of increasingly difficult levels



Near-Earth objects and space mining

The private sector has joined in

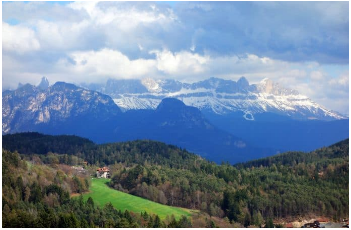
Robert Zubrin, engineer, space visionary

Elon Musk, Space X: stainless-steel rockets, retrievable vessels. Vision: colonize the massive bodies of the solar system (Moon, Mars)

Jeff Bezos, Blue Origin: aluminum rockets, retrievable vessels. Vision: Space stations in Low Earth Orbit (LEO)

Stumbling blocks on the path to space

- Psychological stress
- Ionizing radiation. Deterministic effects negligible, but stochastic effects pose a risk. We are adapted to some extent to low-LET radiation (e. g. photons and muons) which could have shaped our evolution (see F. F., E. Szuszkiewicz, (2009). Cosmic rays: a review for astrobiologists. Astrobiology, 9(4), 413-436), but certainly not to high-LET radiation (e. g. HZE particles).
- Microgravity: While ionizing radiation could be in principle screened, there is no way to mitigate the effects of microgravity.



The ”Yeast TardigradeGene” Experiment

Before going to Mars: Can tardigrades help in protecting other organisms in space?

Goals of the experiment:

1. Enhance the adaptability of yeast (*S. Cerevisiae*) to microgravity conditions in space by editing the yeast’s genome using CRISPR-Cas9
2. Evaluation of the influence of microgravity on the functionality of mitochondira and on vitality of microorganism
3. Biotechnological applications of yeast in space

The „Before going to Mars” Team (Yeast TardiGradeGene)

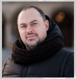
University of Szczecin

Ewa Szuskiewicz (coordinator)

Franco Ferrari

Adam Mickiewicz University

Hanna Kmita



Andonis Karachitos

Nina Antos-Krzemińska

Łukasz Kaczmarek

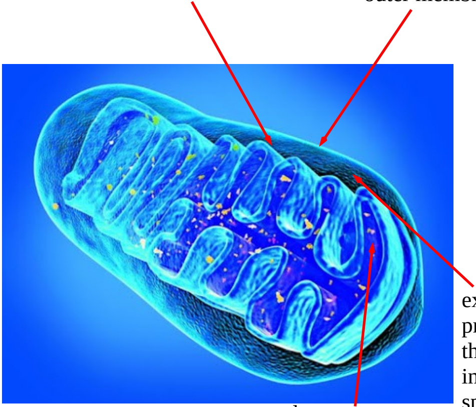
University of Silesia

esa

POLSA
Polish Space
Agency

The mitochondrion

Organelles that power the cell



inner membrane

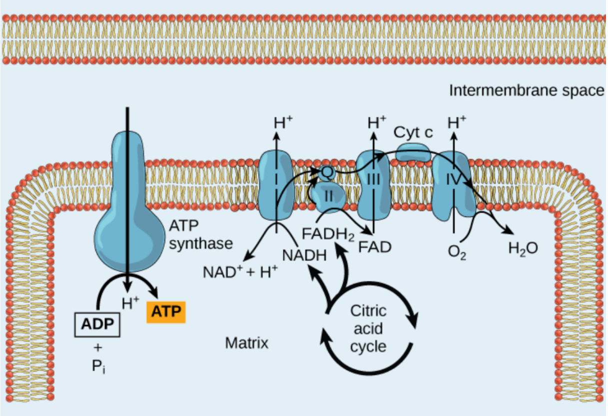
outer membrane

excess of protons in the intermembrane space

low proton concentration

Electron transport chain

How cells are breathing



In stress conditions the production of Reactive Oxygen Species (ROS) can grow considerably

The ”Yeast TardigradiGene” experiment

Tardigrades - extremotolerant organisms

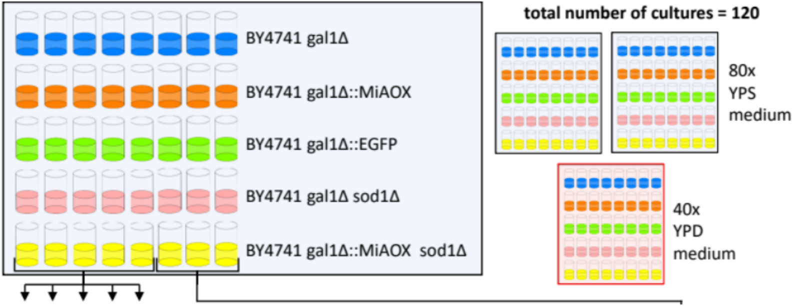
Tardigrades are extremely resilient

1. Can live for several years
2. Can almost completely dehydrate and stop metabolism (cryptobiosis) allowing them to survive in harsh conditions

The tardigrade mitochondrial alternative oxydase (AOX) enables mitochondrial reduction-oxidation reactions important for cell metabolic plasticity involved in adaptation to variable biotic and abiotic stress factor.

The "Yeast TardigradiGene" experiment

The yeast's strains that will be sent to space



The experiment has been already simulated on Earth with all space conditions reproduced but microgravity and shows the protective role of the tardigrade AOX.

Thank you!

The „Before going to Mars” Team
(Yeast TardiGradeGene)

University of Szczecin

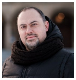
Ewa Szuskiewicz (coordinator)

Adam Mickiewicz University

Hanna Kmita

University of Silesia

Franco Ferrari



Andonis Karachitos

Nina Antos-Krzemińska

Łukasz Kaczmarek

esa

POLSA
Polish Space
Agency