The Need for Earth-Based Experiments to Inform Microbial Evolution on Planetary Surfaces

Science and Planetary Protection in Advance of Human Missions

Virtual Seminar

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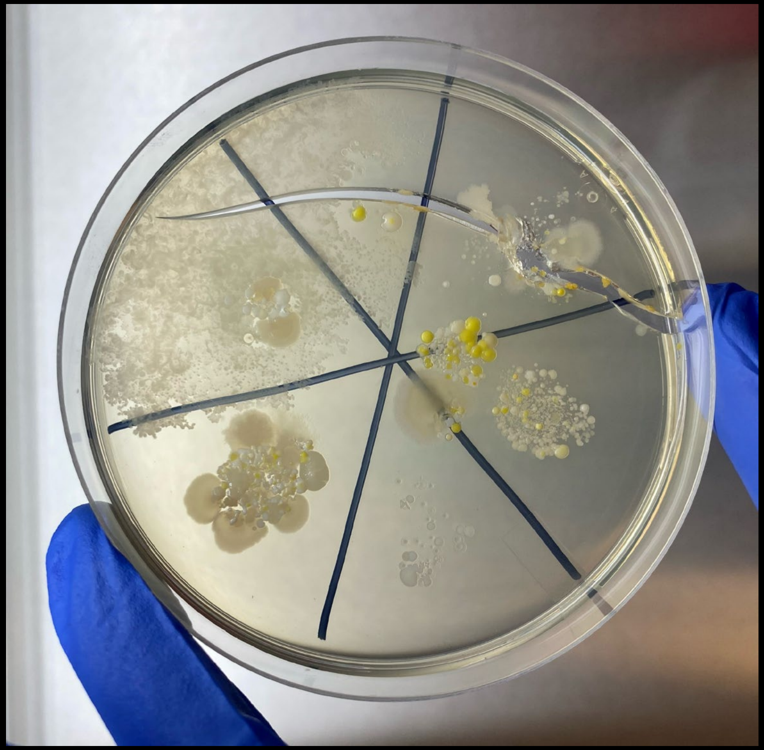
Introduction

- The goal of forward planetary protection at NASA is to mitigate the risk of contaminating sensitive target bodies with biological life
  - Typically microorganisms

When Humans Go…

- …microbes will too.

- Human skin harbors millions of bacteria, fungi, and viruses
  - Halotolerant and desiccation resistant
- Microbes aboard the International Space Station evolve and adapt to life in low earth orbit
- Possible harmful effects to crew and impacts to planetary or astrobiological science



Risks of Microbial Evolution

1. Microbes carried by humans will evolve to new environments even before landing on Mars, during the several month cruise phase.

2. Once landed, microbes will encounter different stressors within the crew habitats on Mars.

3. During extravehicular activities, venting, or other release events, microbes will find their way out onto the Martian surface.

4. The induced environments around crewed systems will create potentially-favorable conditions for microbes to continue evolving on Mars

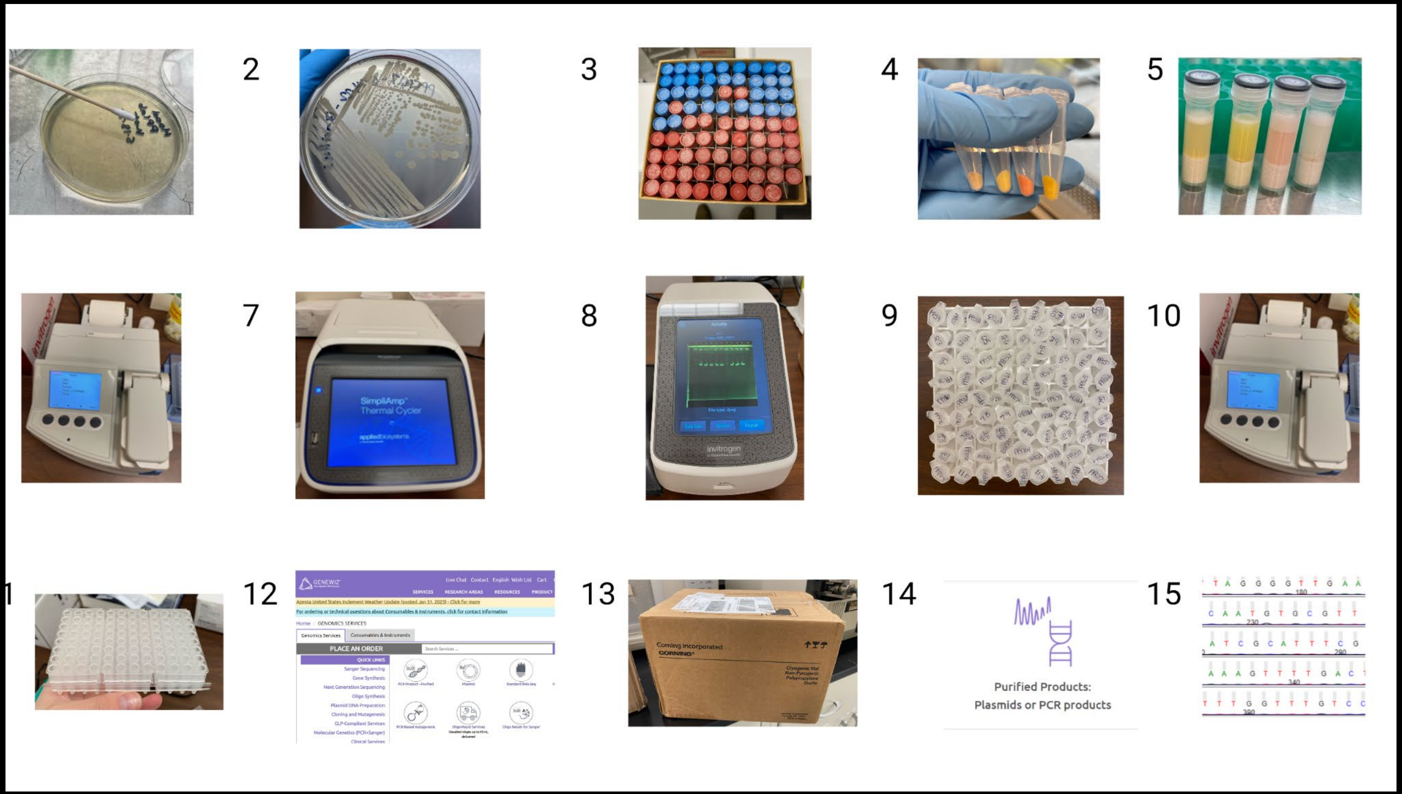
5. Eventually, microbes may find their way beyond the close confines of the crewed area and continue evolving so as to fill new or distant niches on the Martian surface.

Examples of Evolution on Earth

- Serial passaging by Richard Lenski shows dramatic changes *E. coli* undergoes within a laboratory setting
- Michael Baym demonstrated the power of single mutations in microbial development of antibiotic resistance
- Could we do similar experiments for space-like stressors? Space environments?
- What experiments can we have the crew do during cruise phase to Mars?

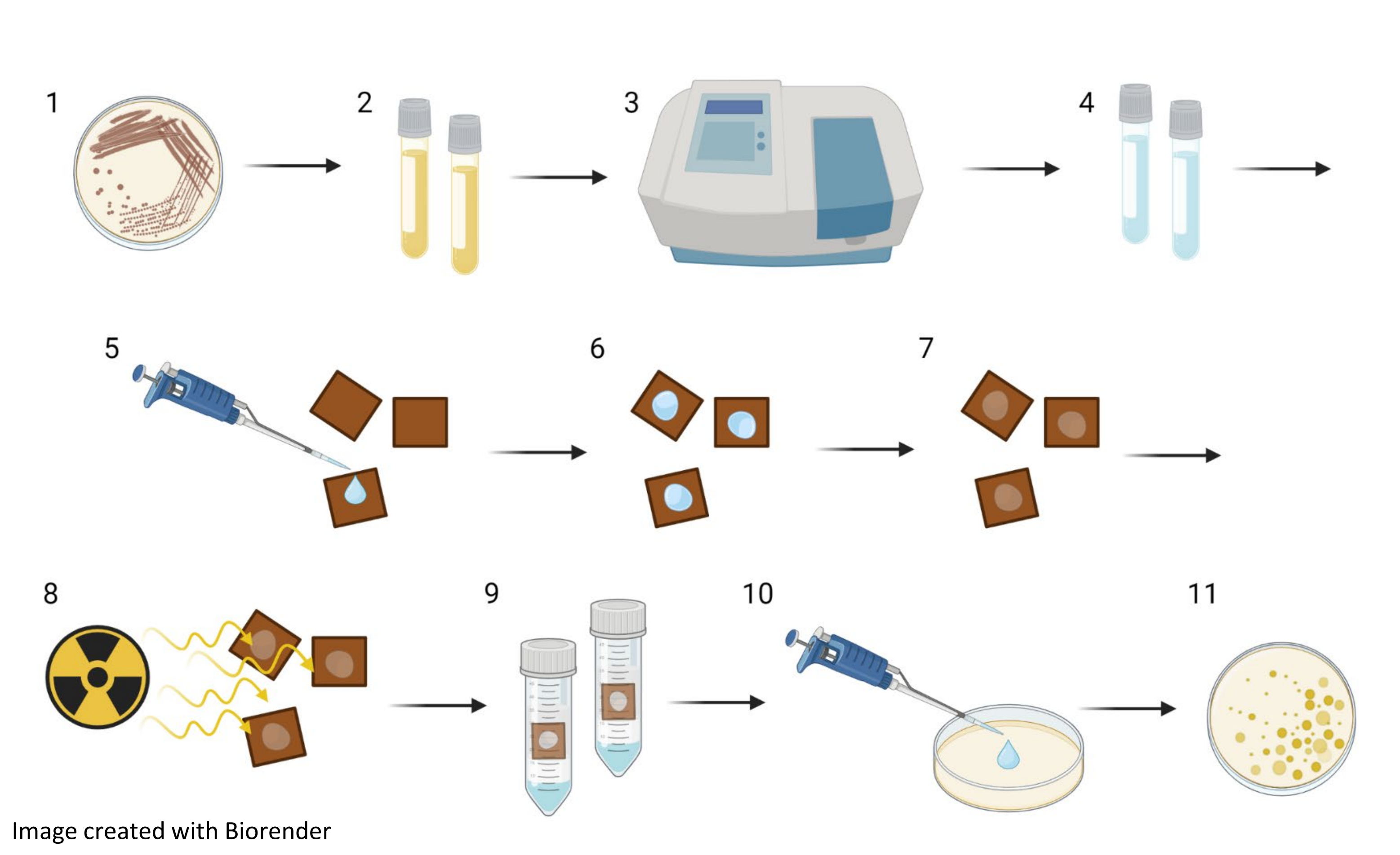
MSFC Cleanroom Microbial Library

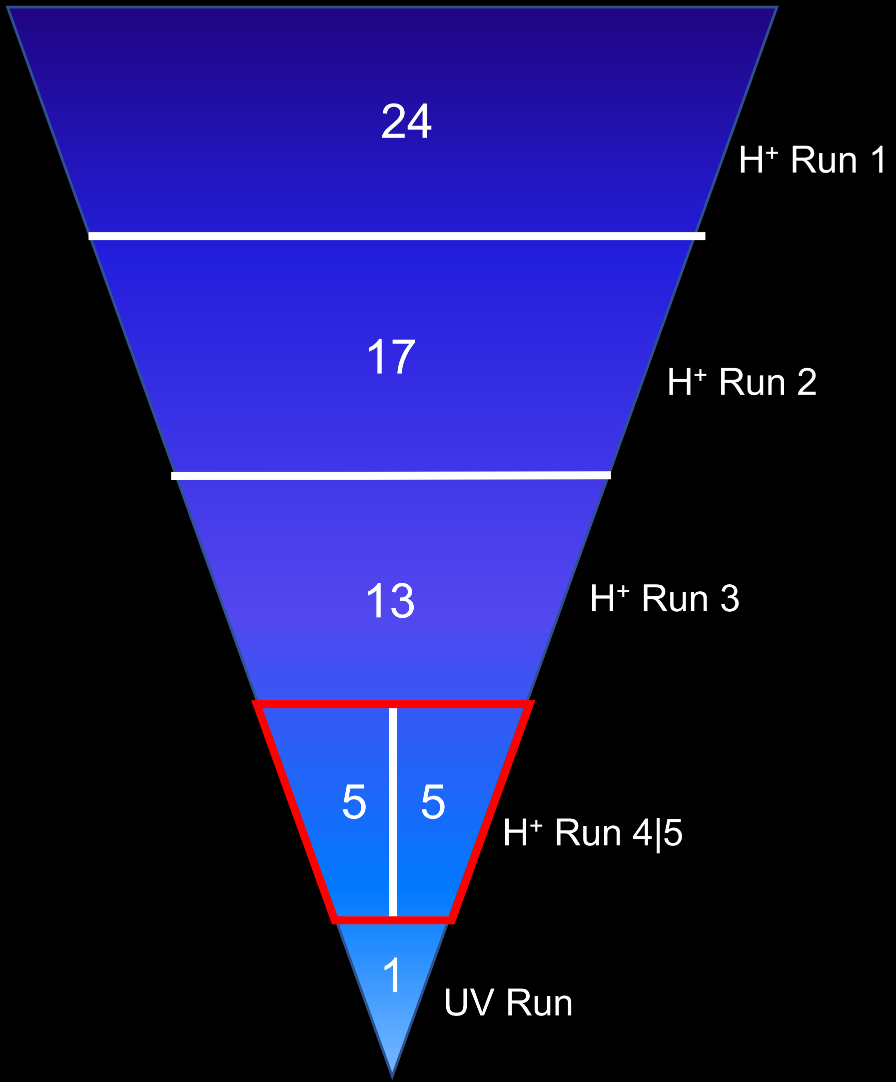
- Collected 95 microbial isolates from cleanroom environments at MSFC
- Identified them using 16S or ITS commercial sequencing



Pelletron at MSFC

Exposure of Cleanroom Microbes to Simulated Space Environments





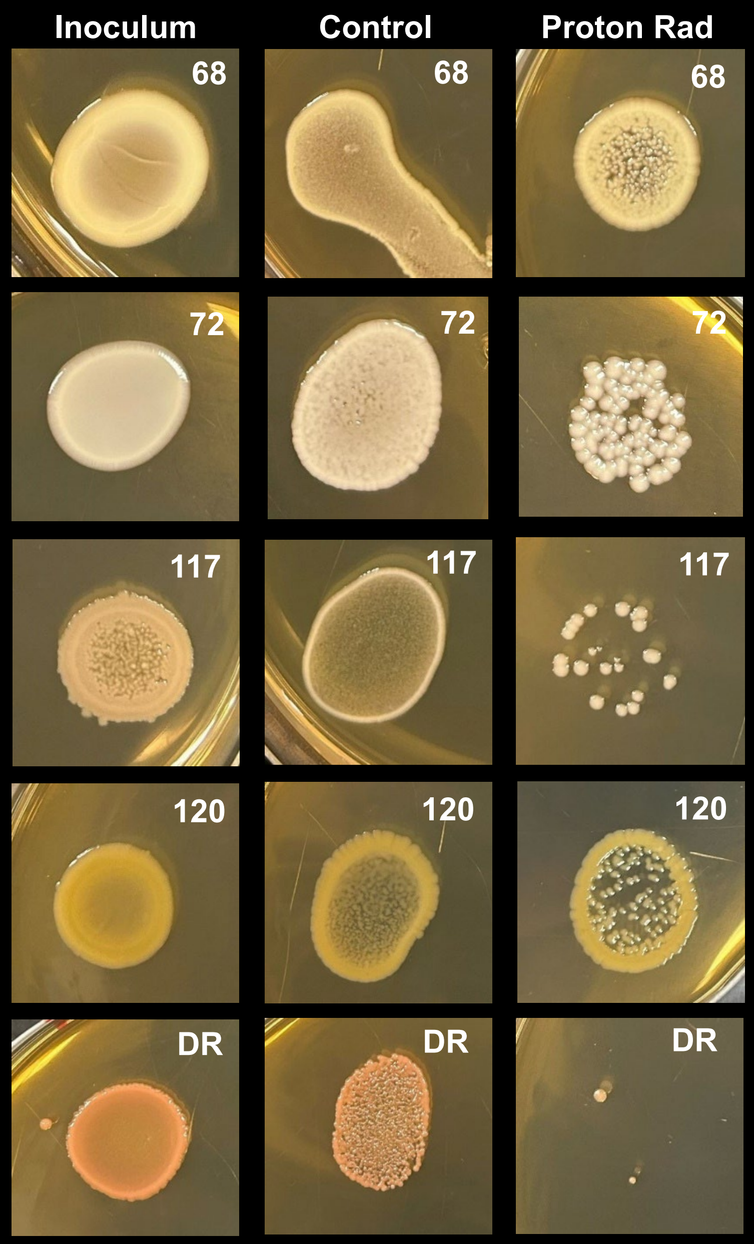
Four Isolates with Increased Ionizing Radiation Resistance

Run 3

Isolate #	Identity	Inoculum	Control	Proton Rad
PPS55	*Alkalihalobacillus gibsonii*	+	-	-
PPS67	*Brevundimonas vesicularis/nasdae*	+	-	-
PPS68	***Arthrobacter koreensis***	**+**	**+**	**+**
PPS69	*Acinetobacter lwoffii or Prolinoborus fasciculus*	+	+	minor
PPS72	***Paenarthrobacter nitroguajacolicus***	**+**	**+**	**+**
PPS73	*Staphylococcus hominis*	+	+	-
PPS74	*Brevundimonas* sp.	+	minor	-
PPS77	*Janibacter hoylei*	+	+	-
PPS111	*Bacillus licheniformis*	+	minor	-
PPS114	*Bacillus atrophaeus*	+	+	-
PPS117	***Mycetocola manganoxydans***	**+**	**+**	**+**
PPS120	***Erwinia* sp.**	**+**	**+**	**+**
PPS125	*Neocylindroseptoria* sp.	+	+	-
ATCC 13939	*Deinococcus radiodurans*	+	+	minor
Negative	Water	-	-	-

Control: ambient drying

Radiation: 100 keV protons at a fluence of $2 \times 10^{15}/cm^2$ at ~10^{-6} Torr

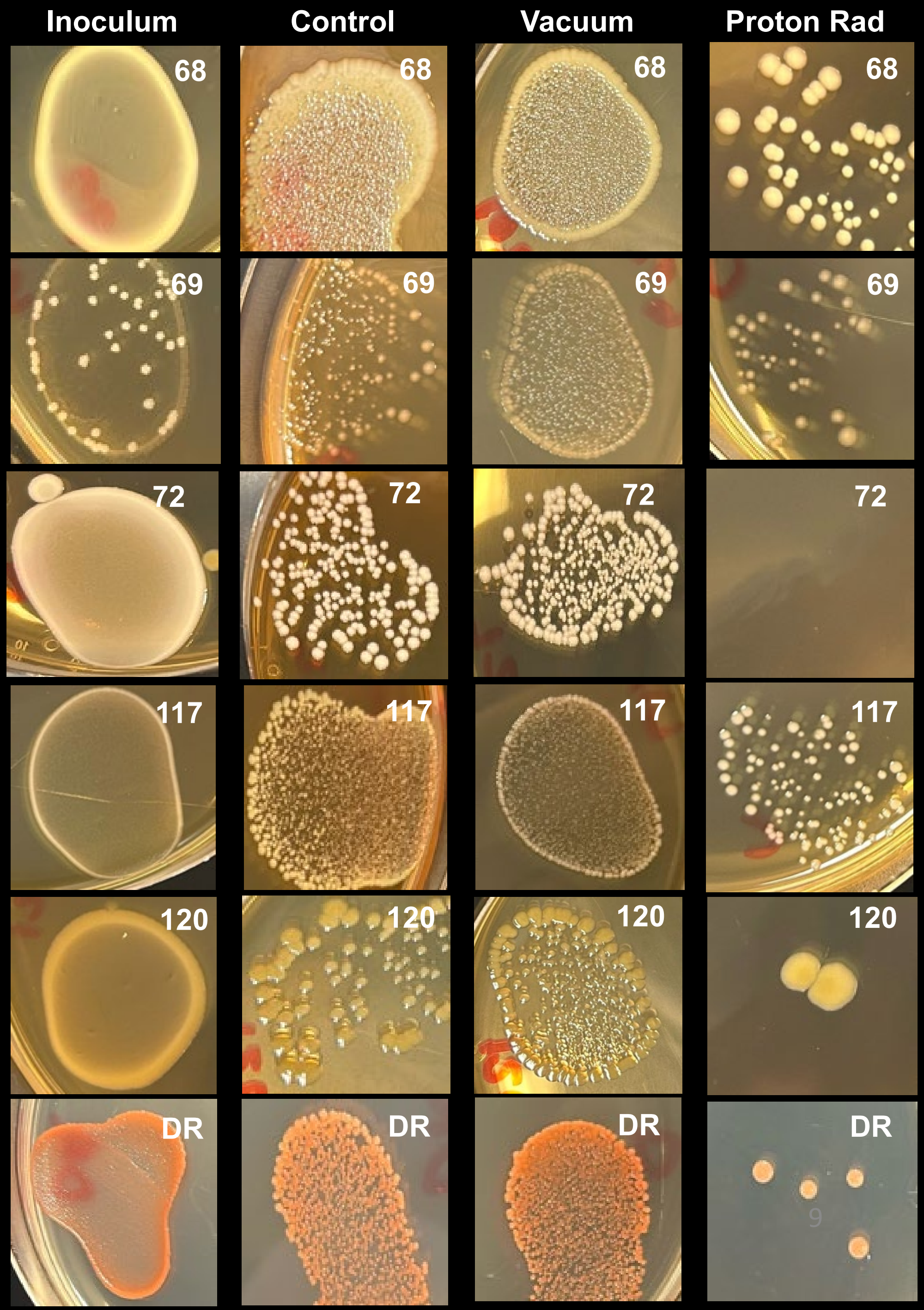


Four Isolates with Increased Ionizing Radiation Resistance

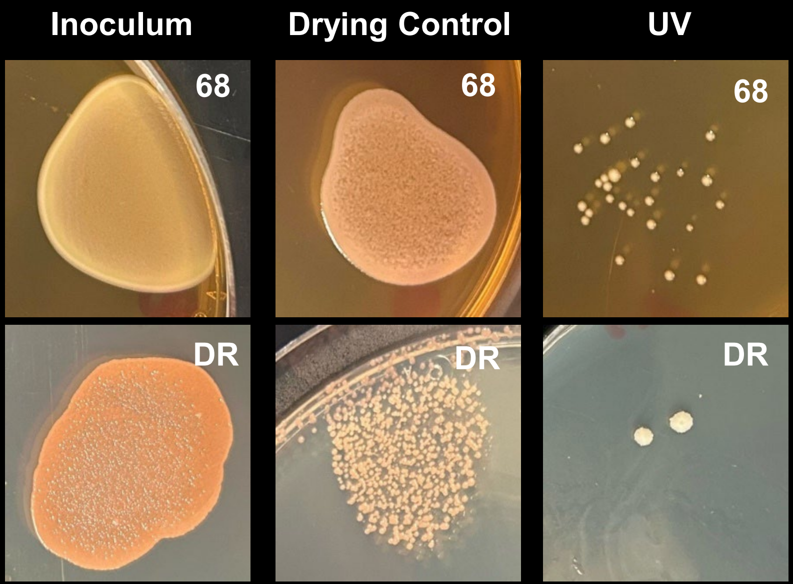
Run 5

Isolate #	Identity	Inoculum	Control	Vacuum	Proton Rad
PPS68	*Arthrobacter koreensis*	+	+	+	+
PPS69	*Acinetobacter lwoffii* or *Prolinoborus fasciculus*	+	+	+	+
PPS72	*Paenarthrobacter nitroguajacolicus*	+	+	+	-
PPS117	*Mycetocola manganoxydans*	+	+	+	+
PPS120	*Erwinia* sp.	+	+	+	minor
ATCC 9372	*Bacillus atrophaeus* spores	+	+	+	+
ATCC 13939	*Deinococcus radiodurans*	+	+	+	minor
Negative	Water	-	-	-	-

Control: ambient drying
Vacuum: ~10^{-6} Torr
Radiation: 100 keV protons at a fluence of $4x10^{15}/cm^2$ at ~10^{-6} Torr

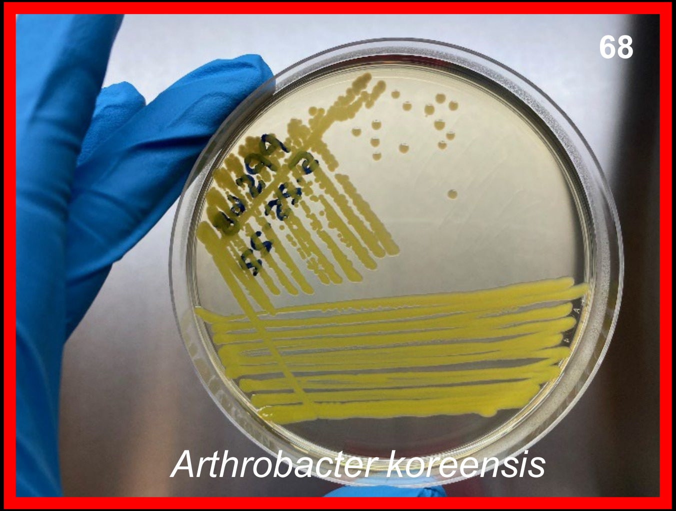


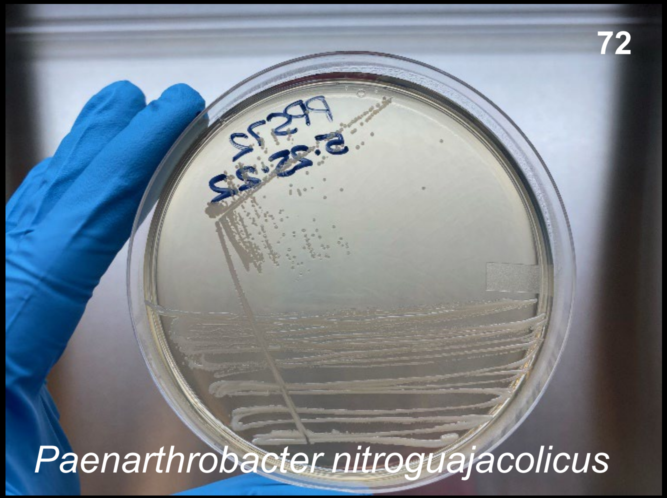
A. koreensis Demonstrates Resistance to UV

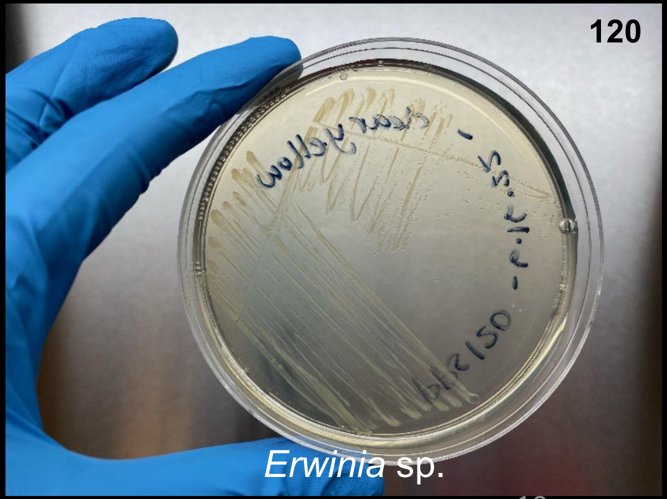


UV: 254 nm wavelength light at an intensity of 80 W/m^2 at ~18 cm for 10 minutes

Four isolates sent for whole genome sequencing







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Community Discussion

- Short duration exposures are not enough
- Larger and more gradual studies to replicate 1) cruise, 2) to surface habitats, 3) to induced surface environments, and finally true 4) Martian environments
- No Earth-based experiment can perfectly replicate the Martian environment
- We cannot test every possible microbe in simulation experimental regimes
- Examine the evolutionary potential of the "usual suspects" on ISS or in other crewed environments
- What else?