



Adapting Plants to the Space Environment for Improved Crop Productivity and Safety

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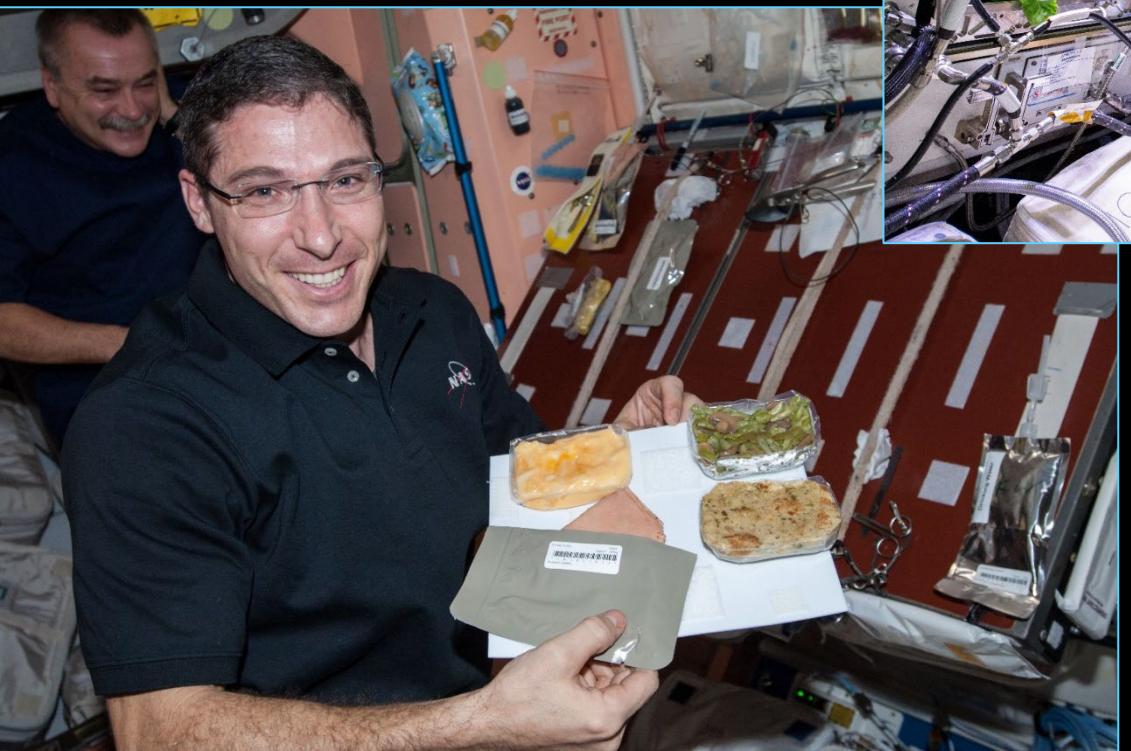
Exploration Research & Technology Programs

NASA, Kennedy Space Center

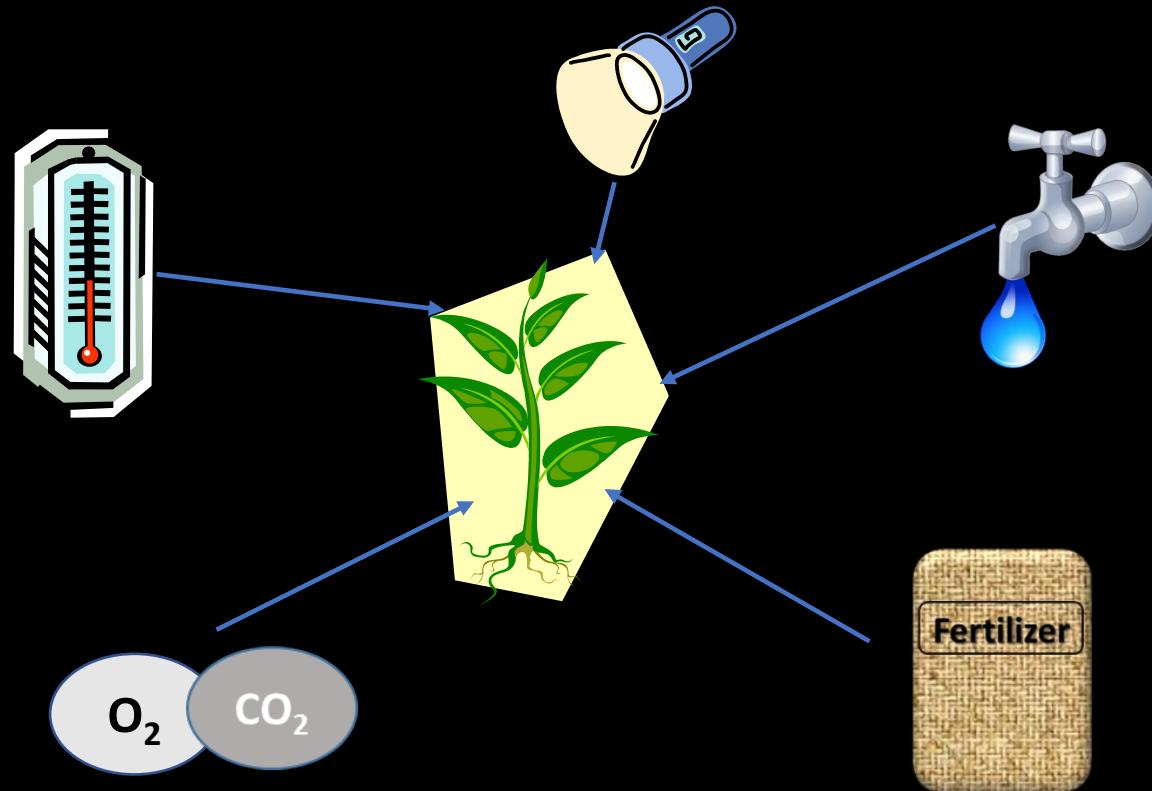
*Committee on Biological and Physical Sciences in Space
Adapting to Space*

Why grow plants in space?

- Food
- Psychological well being
- Atmosphere
- Water



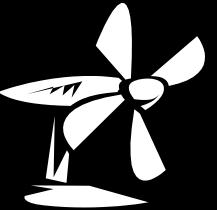
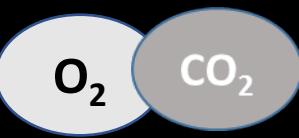
Cardinal Factors to Consider for Plants to Thrive in Space



How these work in the Space Environment



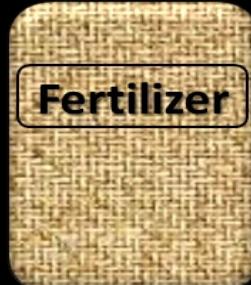
No natural convection without gravity so need to mix the air



Key plant characteristics may be modified with novel light recipes



Water forms a ball, and water and air don't mix well, and roots need both



Fertilizer is heavy to launch so we need to learn how to recycle plant (and other) wastes

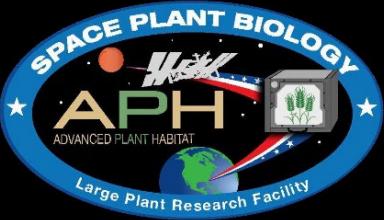
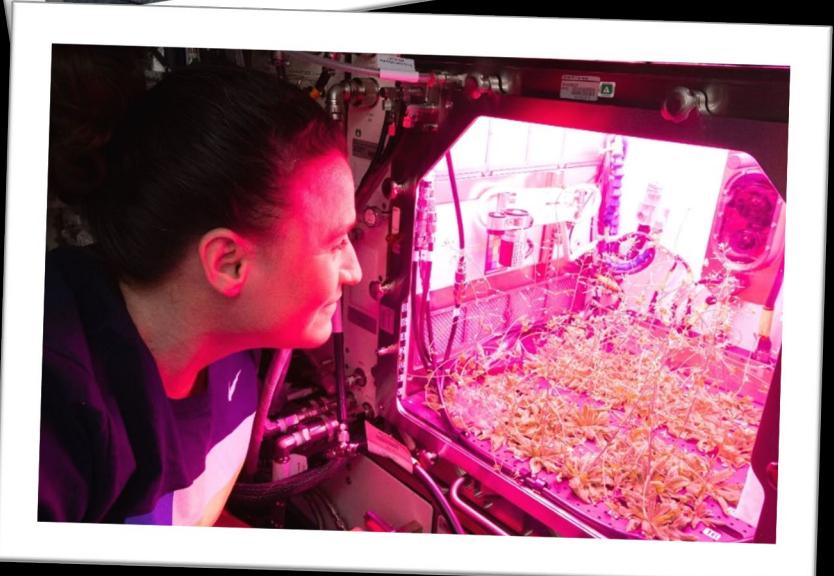
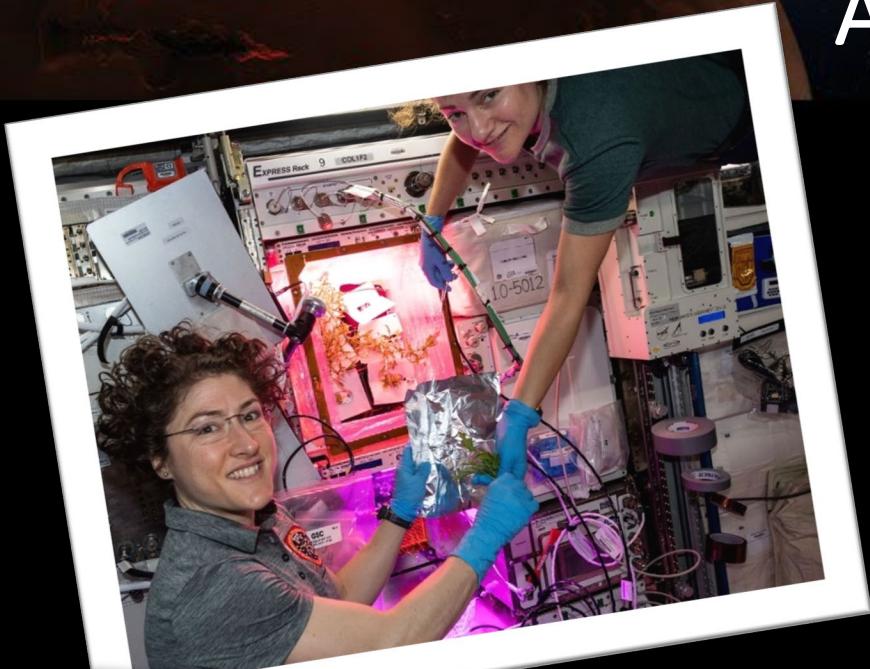


Space Crop Production Challenges

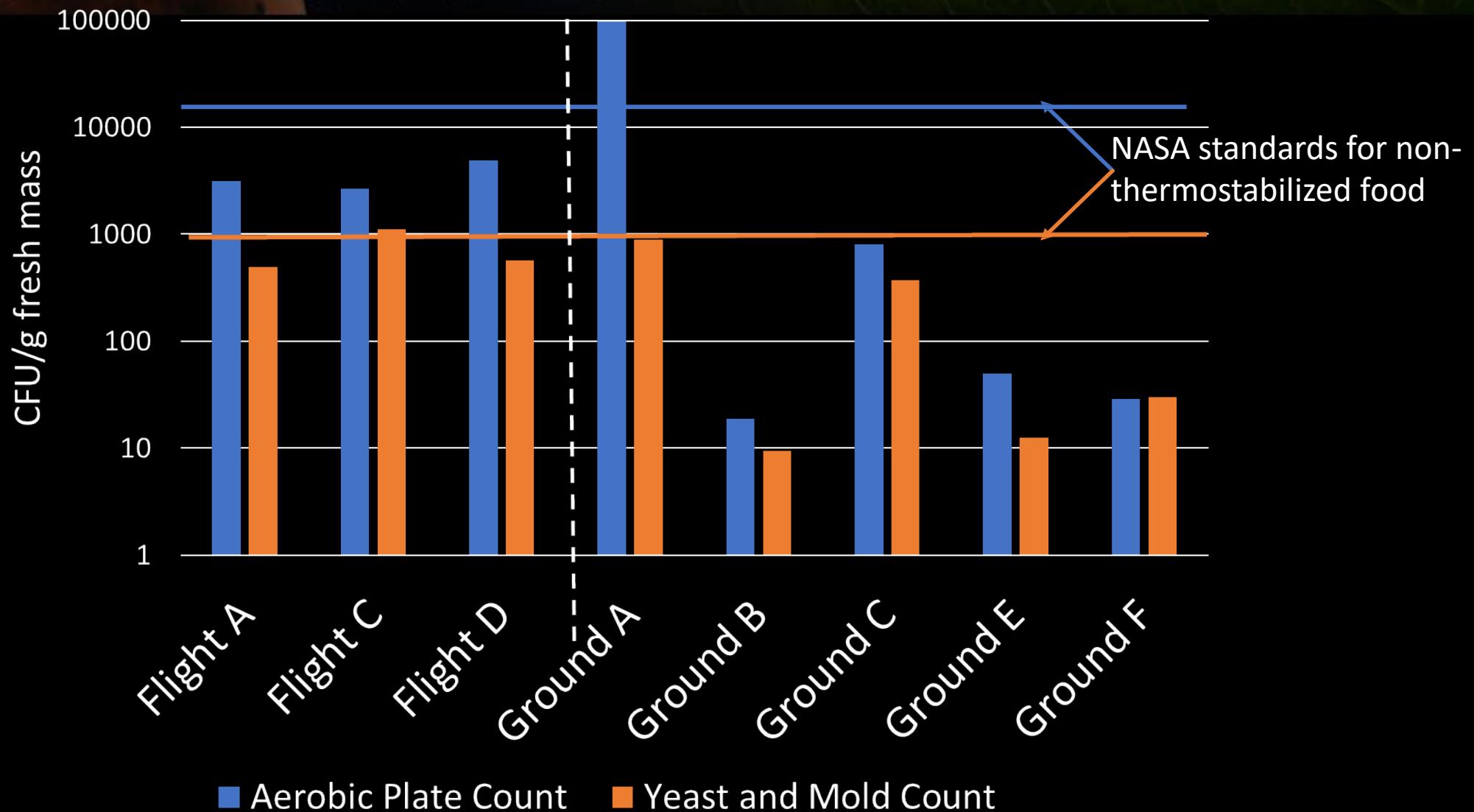


*Solving space crop production challenges requires a basic understanding of **BIOLOGICAL** and **PHYSICAL** processes*

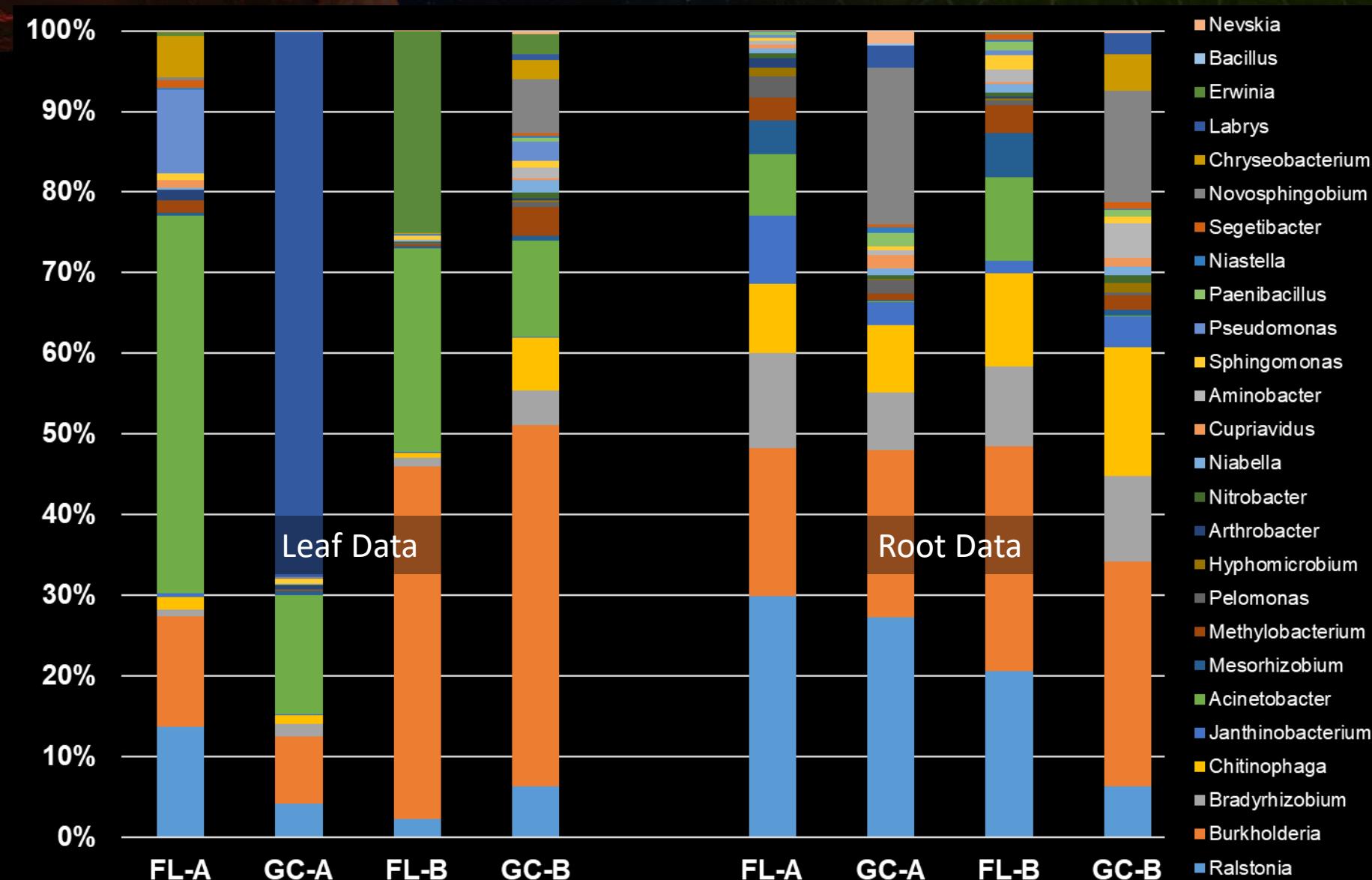
Hardware on ISS that Enables a Basic Understanding of Crop Adaptation to Space



Assessing Crop Microbial Food Safety for Humans



Space and Ground Crop Microbiomes Differ with Time, Tissue Type, and Stress



Ventilation and Water Issues & Consequences in Zinnia



Guttation and Leaf Curling



Fungal Development & Abnormal Growth

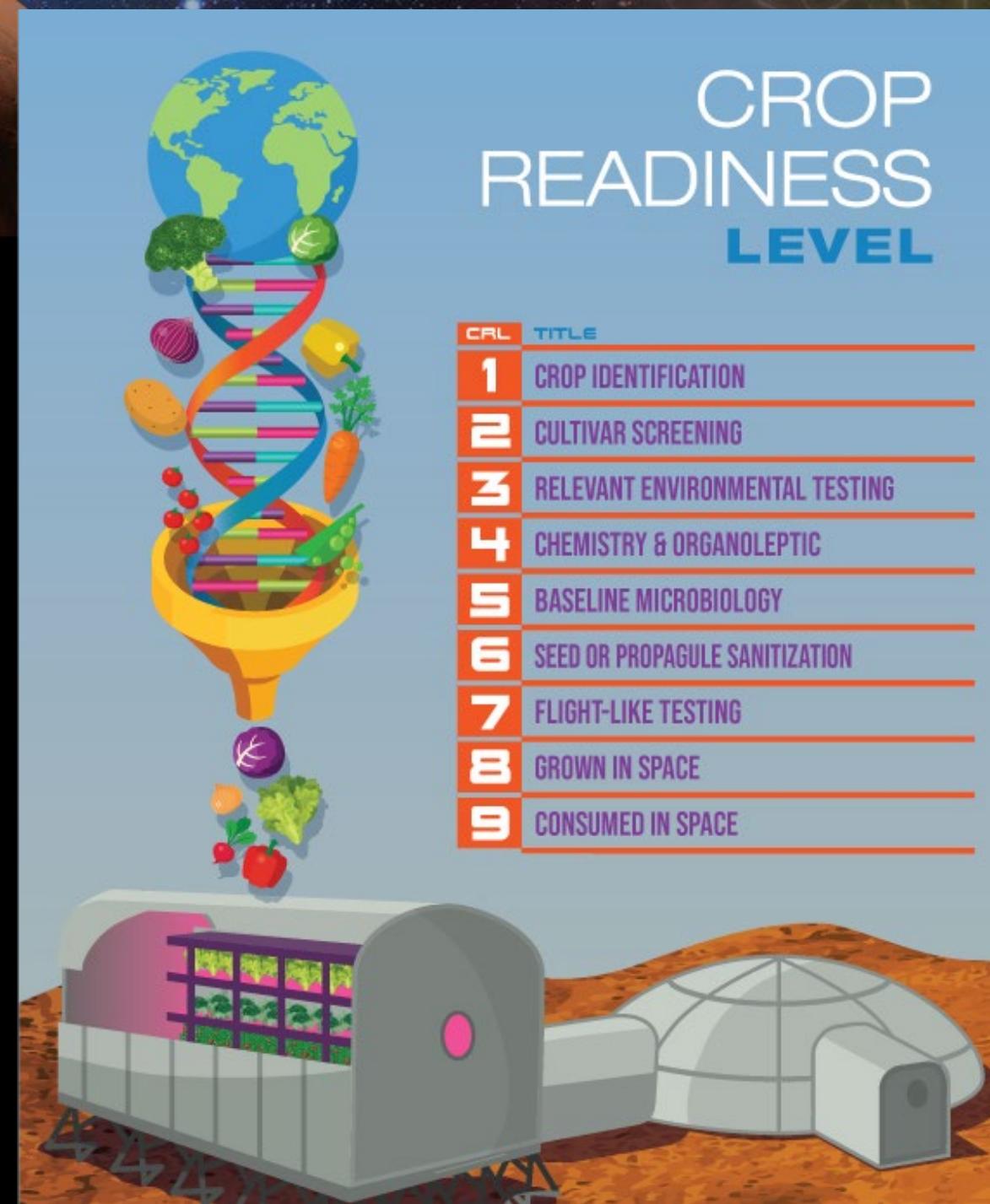
Key Crop Plant Takeaways

- Data indicate astronauts enjoy growing and eating plants in spaceflight
- Crop yield is similar between ground and flight when plants are not stressed¹
- Some differences between ground and flight plant nutrient content, but these are not consistent between species or experiments ^{1, 2}
 - Influenced by crop type, harvest scenario, other environmental conditions (e.g., light, stress)
- Microbial counts and compositions vary between flight and ground-grown plants^{1, 2}
 - Microbes typical of the space station environment are often associated with ISS-grown plants
 - Human pathogens are rarely identified on space-grown plants and only below levels of concern to human health
- Microbial communities vary between shoot and root tissues and but not as much between flight and ground ²
- Plants adapt well to the space environment, and to date, space-grown crops are safe to eat, nutritious, and highly acceptable to astronauts ^{1,2}

1. Buncek et al., 2024, Pick-and-eat space crop production flight testing on the International Space Station, *J. Plant Interact.*

2. Khodadad et al., 2020, Microbiological and Nutritional Analysis of Lettuce Crops Grown on the International Space Station, *Front. Plant Sci.*

*Key Science
Questions
under the
“Adapting to
Space” Theme
help guide
Crop Readiness
Levels*



*Modified from Romeyn et al., 2019,
Crop Readiness Level (CRL): A Scale to
Track Progression of Crop Testing for
Space*

Examples of Knowledge Gaps for Space Crop Production

- The library of crops tested is limited – we need to test a wider diversity of different crops and crop types for exploration
 - One plant family should not make up $>1/3$ of the entire crop library
- Plant Microbiome - Food Safety/Plant Health
 - Crops will be grown hydroponically in space habitats near to mid-term. There are many unknowns on hydroponic water and nutrient delivery, and few data on the hydroponic microbiome.
 - Plant performance in exploration atmospheres (reduced pressure) is largely unstudied, including plant-microbial interactions, responses to pathogens, etc.
- Deep-space radiation impacts on seeds and plants remain unknown



Thank you!

- Veggie, APH, and Space Crop Production teams
- NASA's astronauts
- NASA's Biological and Physical Sciences Division, ISS Program, Human Research Program, Mars Campaign Office

