Lessons learned from plant research in low Earth orbit

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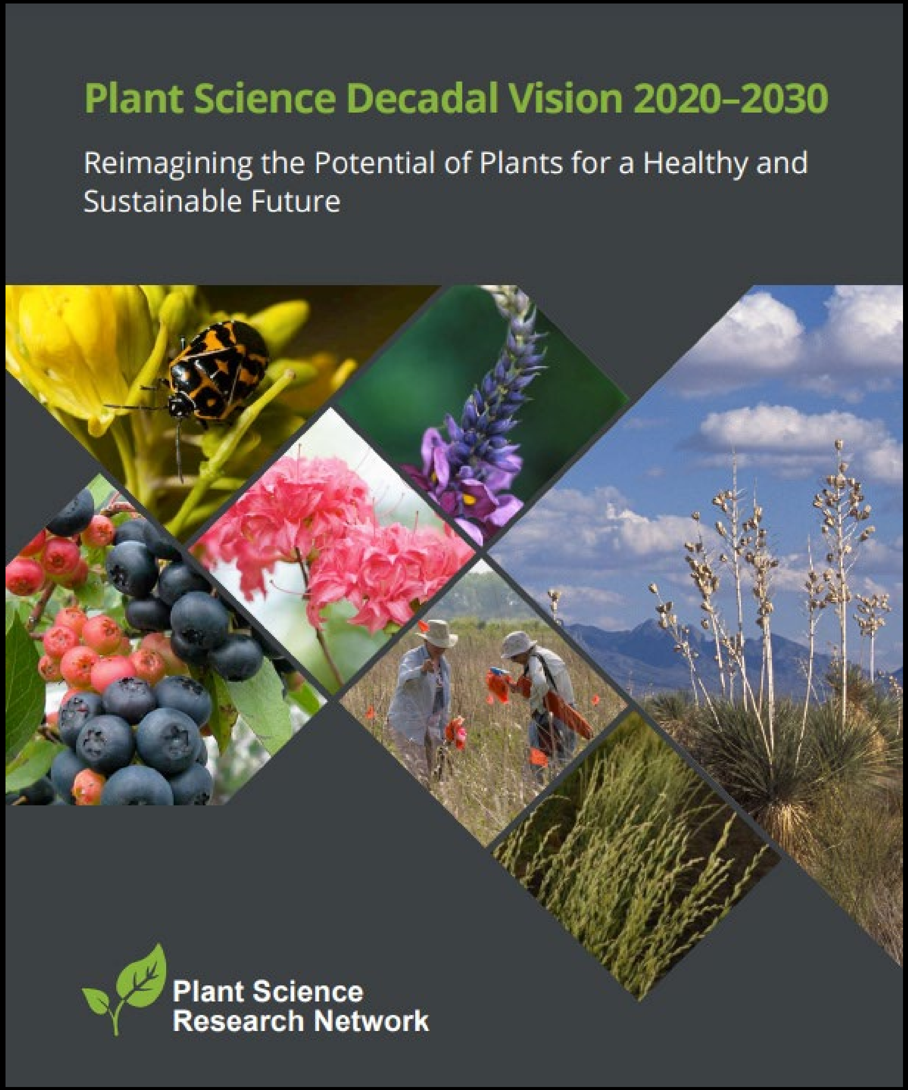
Vision about how plants are crucial for a sustainable future for humans and all life on Earth



https://plantae.org/education/psrn/

Plant Science Research Network
Plantae.org/PSRN

American Phytopathological Society

American Society for Horticultural Science

American Society of Plant Biologists

American Society of Agronomy

American Society of Plant Taxonomists

Association of Independent Plant Research Institutes

Botanical Society of America

Council on Undergraduate Research

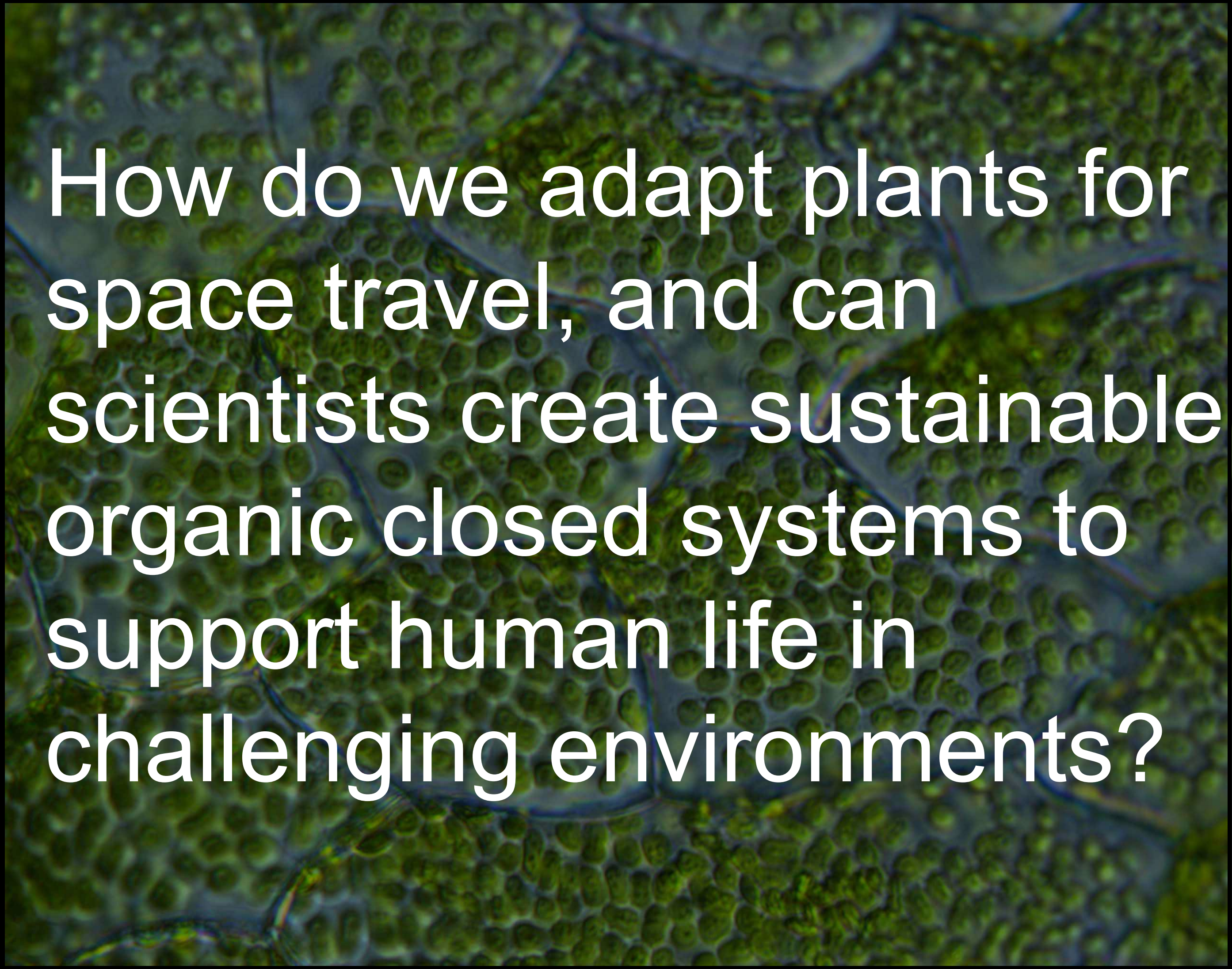
Crop Science Society of America

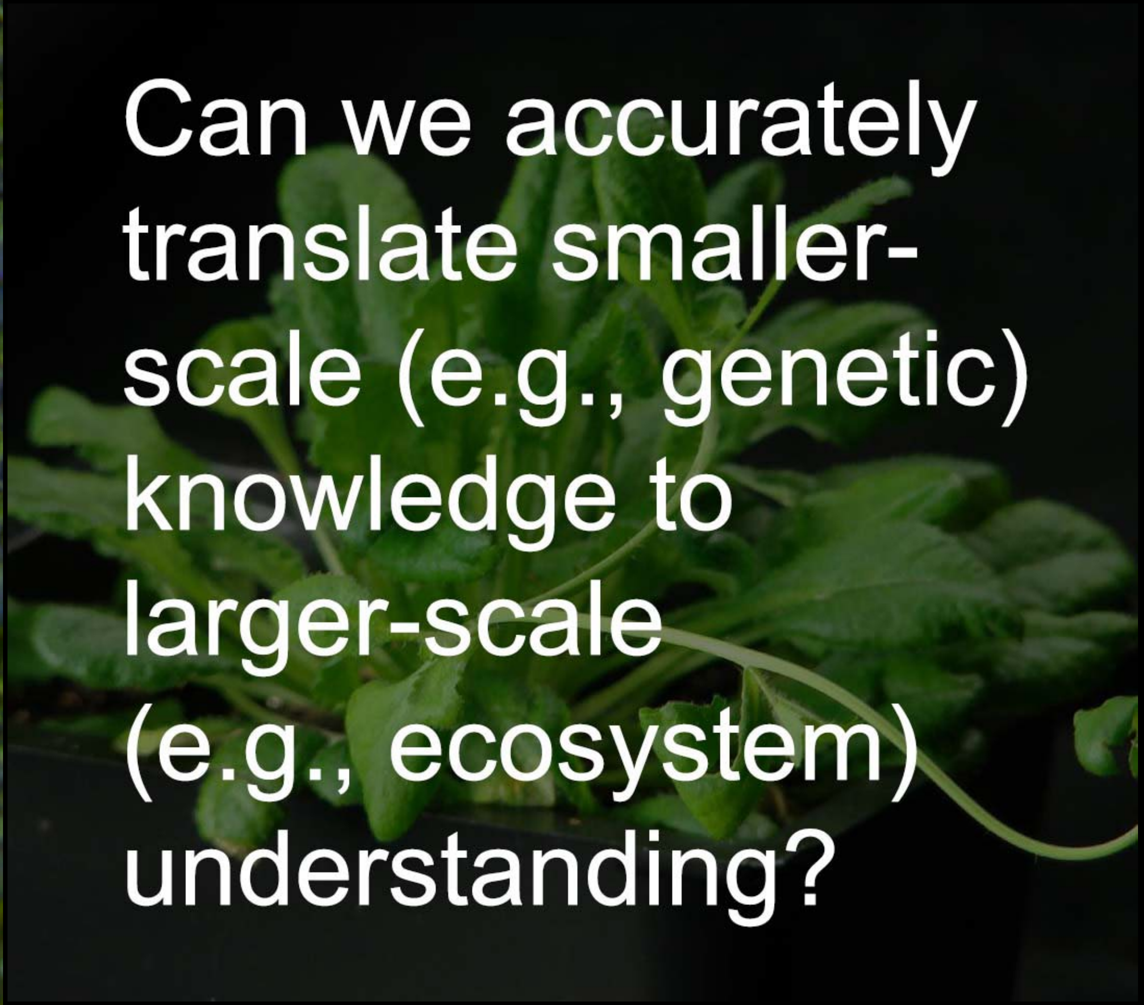
Ecological Society of America

Genetics Society o
America

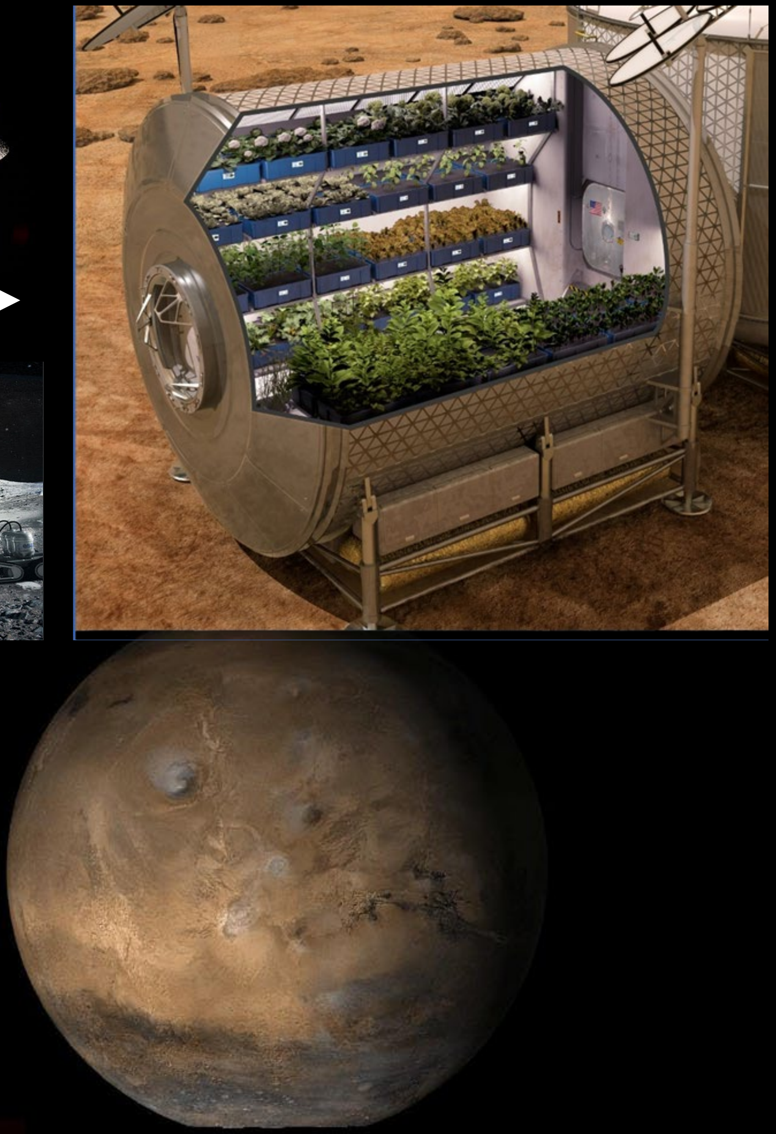
https://www.newphytologist.org/100-important-plant-science-questions-revisited

20 panelists representing Africa, Asia &Oceania, North & South America, and Europe came up with 100 important plant science questions





Can we translate research on model plants and crops in Low Earth Orbit to food production systems on the Moon and Mars?

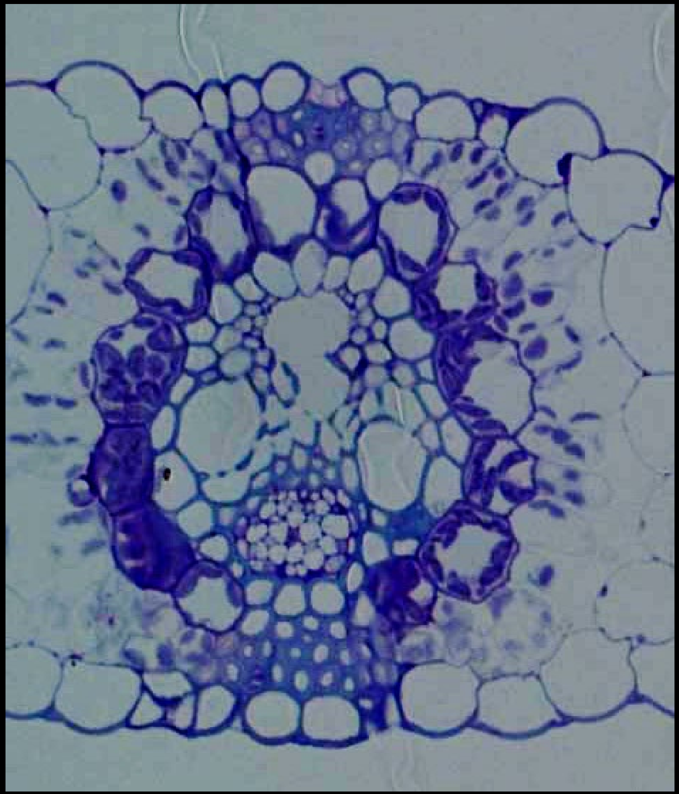


Plants began to colonize land about 450 million years ago

Several structural and physiological innovations enabled plants to thrive on land

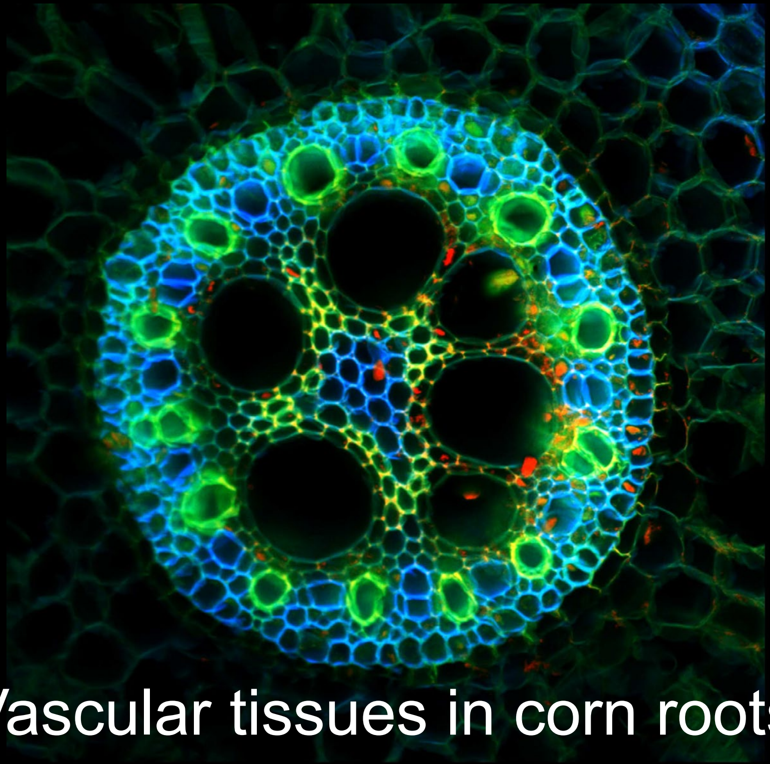
Preston et al.(2022) *Plant Physiol.* 190: 1- 4.

More efficient photosynthesis



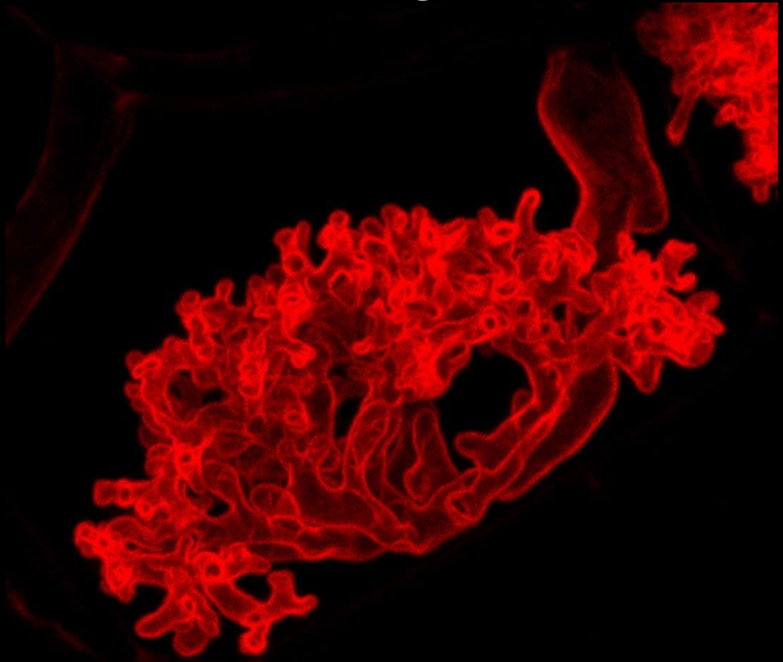
Kranz anatomy in switchgrass

Lignin-fortified vascular tissues



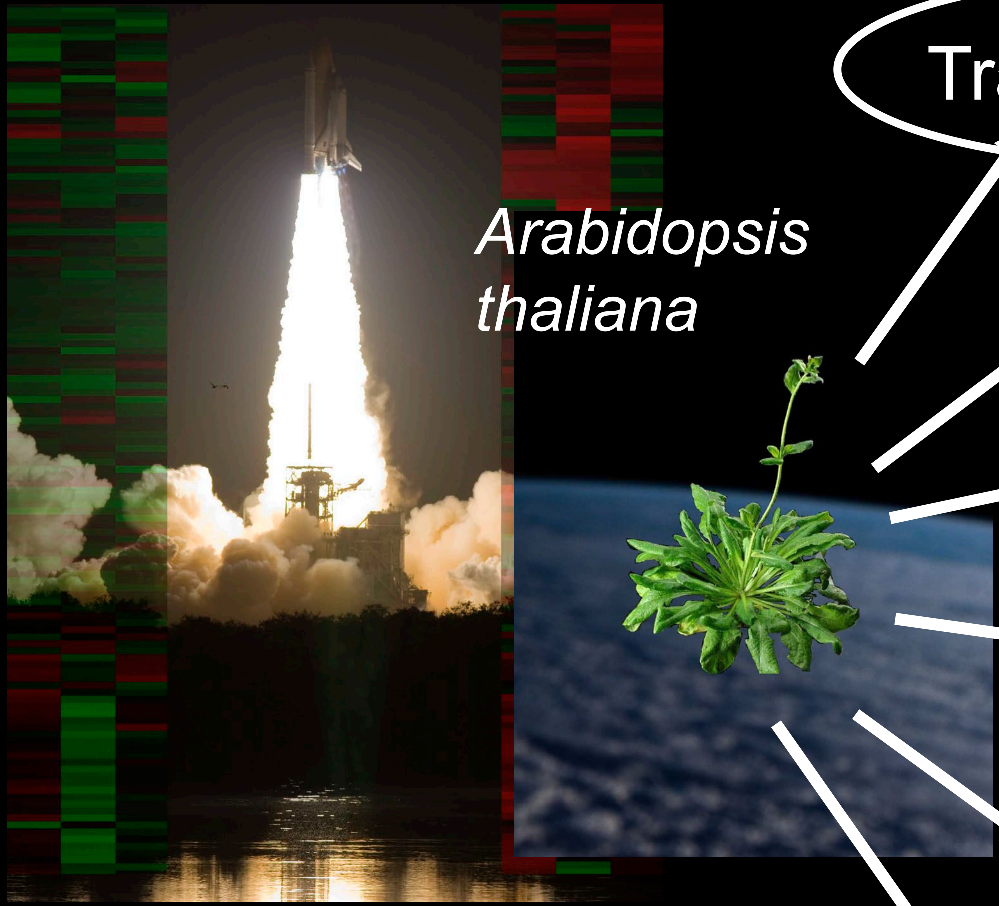
Vascular tissues in corn roots

Interaction with microorganisms



Arbuscular-mycorrhizal fungus in a legume root cell

The genomics age (2010 – present) ushered in the application of large-scale biology to plant research in space



Arabidopsis thaliana

Transcriptomics

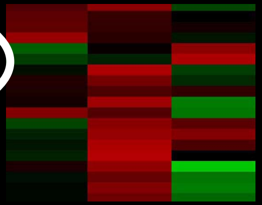
Proteomics

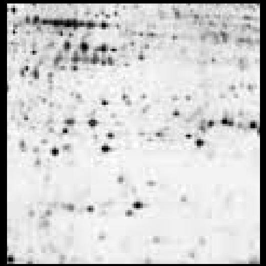
Methylomics

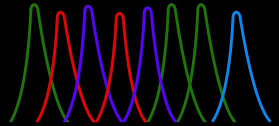
Metabolomics

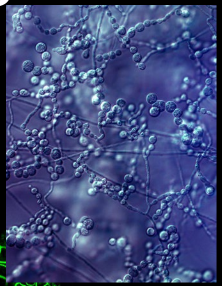
Metagenomics

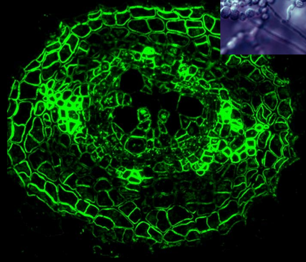
Glycomics











Oxidative stress

Response to pathogens

GeneLab

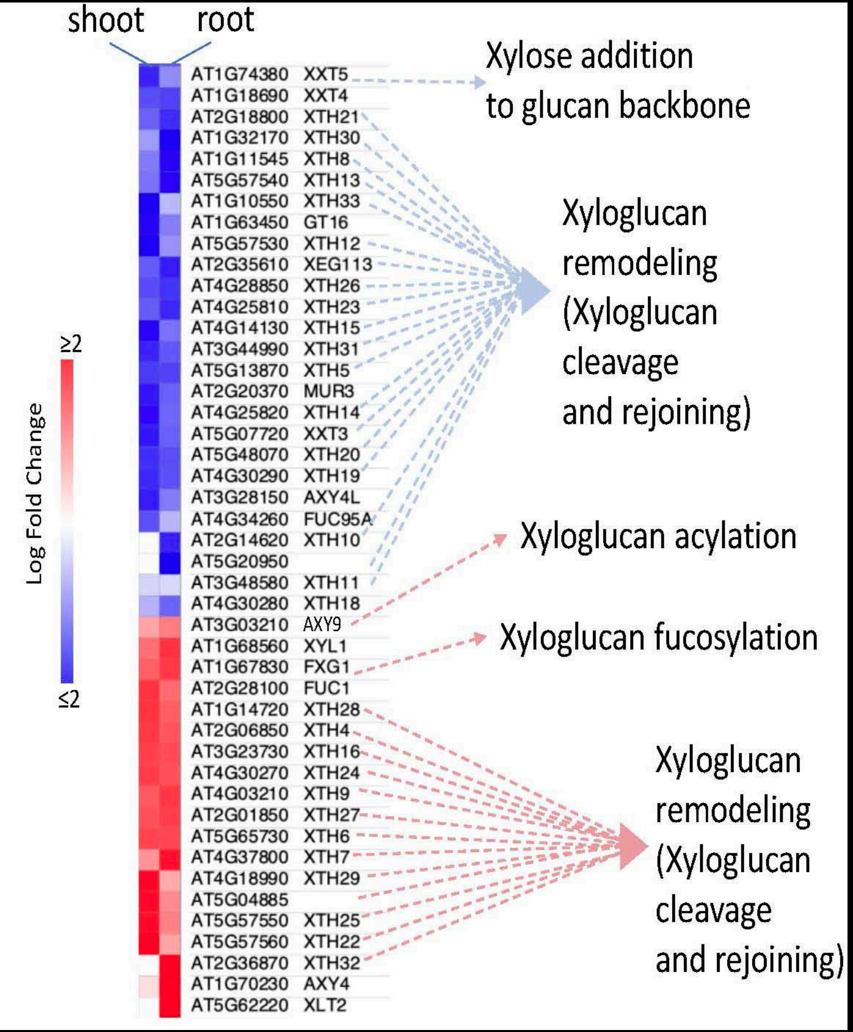
Photosynthesis

Cell wall remodeling

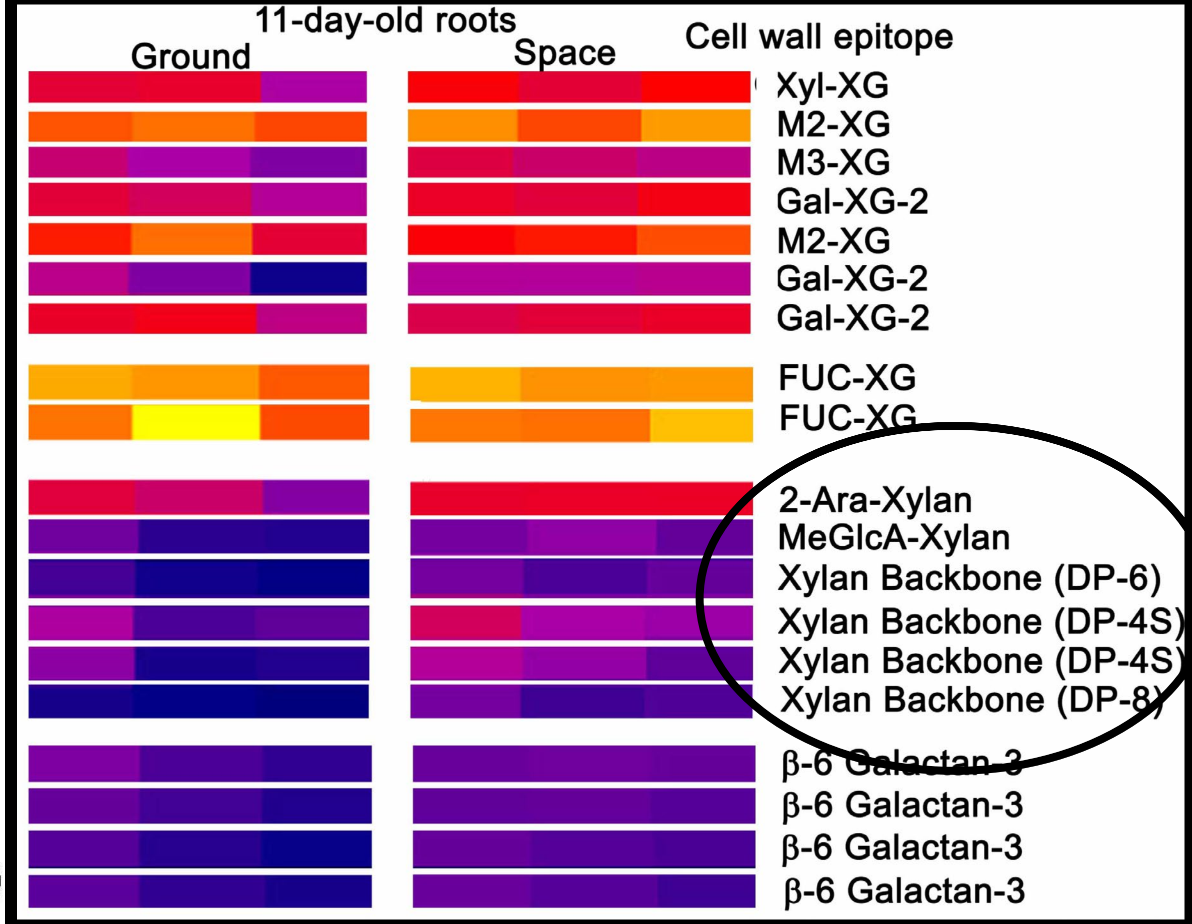
hypoxia

Meyers and Wyatt (2022) Annual Plant Reviews 5 (2) doi.org/10.1002/9781119312994.apr784

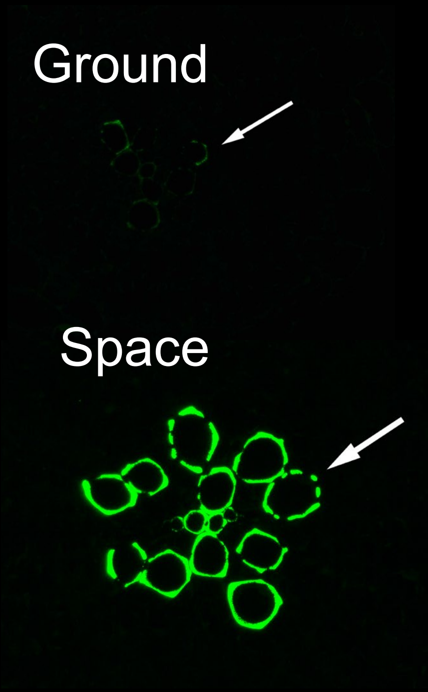
Xylan and xyloglucan (i.e., hemicellulose) components of the cell wall are modified by spaceflight



Glycome profiling



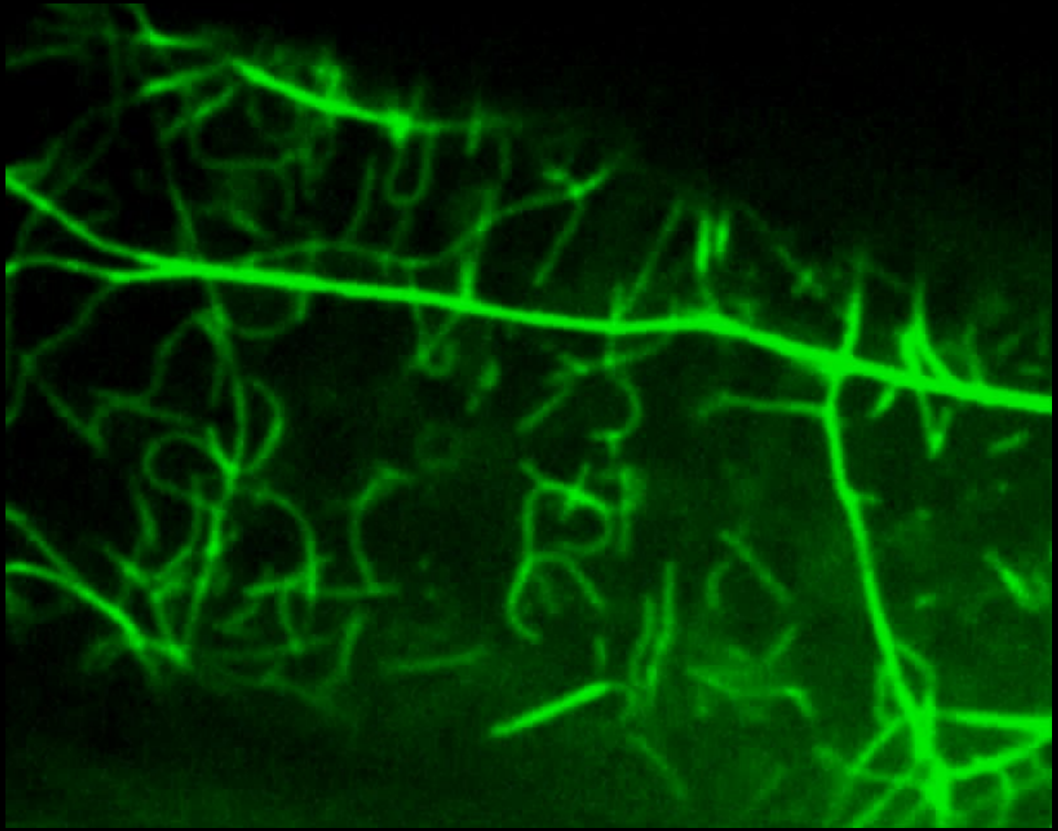
Xylan Labeling in *A. thaliana* roots

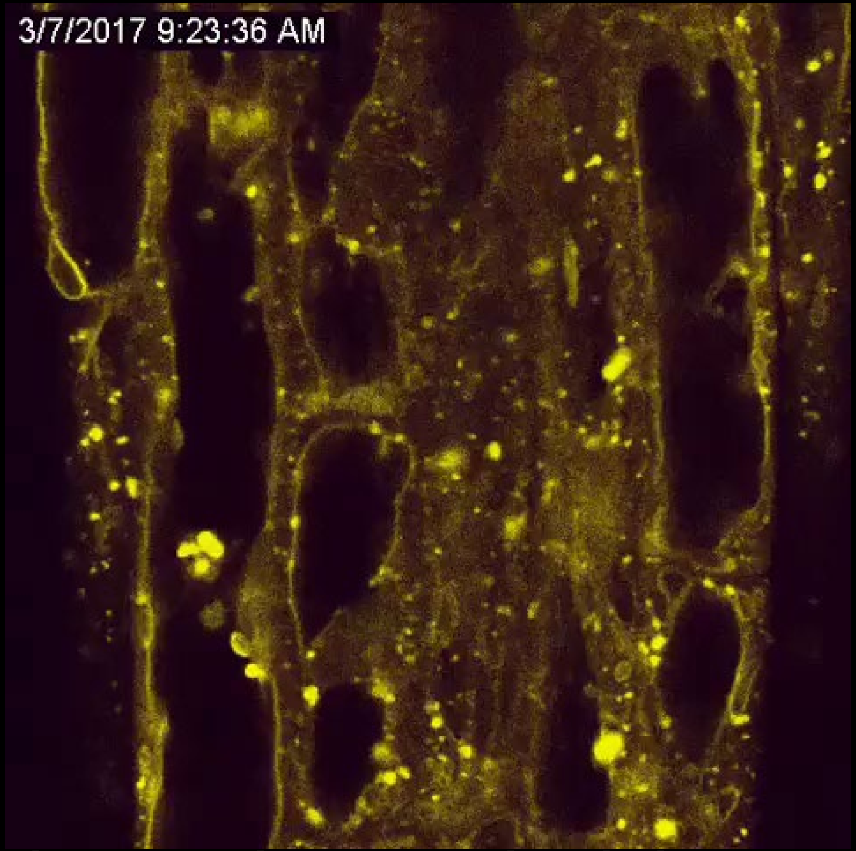


Cell biology

Transcriptomics (Barker et al. 2020 Front Plant Sci. 11:147; Zhou et. al 2019 BMC Genomics 20:205)

Genetically-encoded biosensors on Earth enable studies of plant gravitational phenomena and upstream events that affect cell wall remodeling





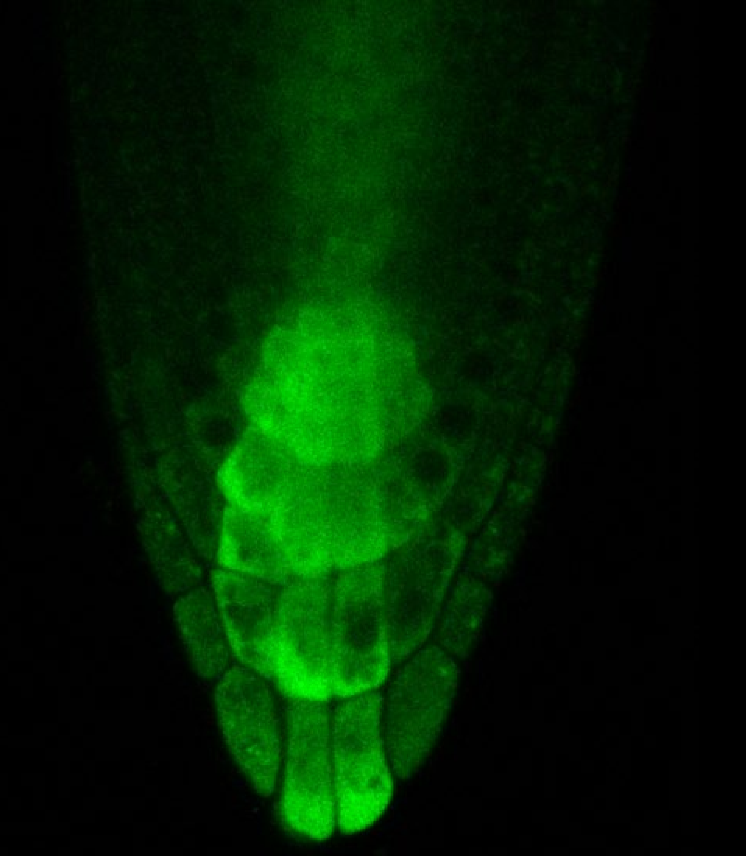
The actin cytoskeleton and endomembranes in living *Arabidopsis thaliana* roots

Sparks et al. (2016) *Plant Cell* 28:746; Chin et al (2021) *Plant Cell* 33: 2131

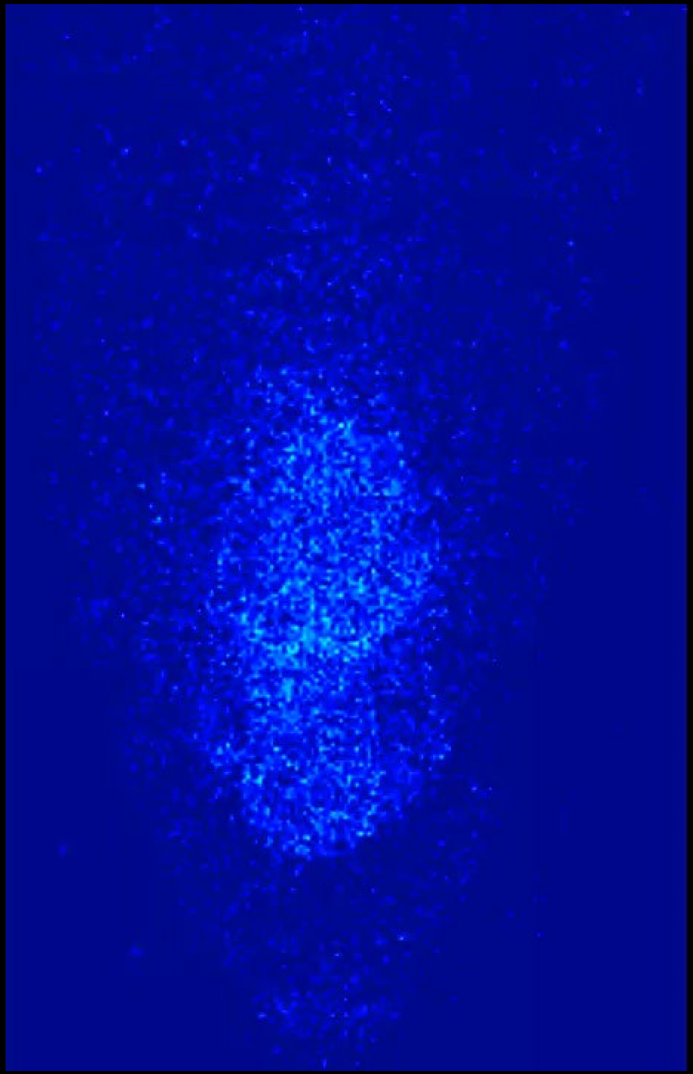
Targeting biosensors to relevant cell/tissue types along with hardware/technology for their accurate detection in space could uncover true effects of microgravity on plants

Root gravity sensing cells (columella cells)

Krogman et al (2020) *Int. J. Mol. Sci.* 21:3685



Calcium biosensor expressed in the columella



Plants tolerate the spaceflight environment well

Wheeler RM (2017) *Open Agriculture* 2: 14-31; Kordyum and Hasenstein (2021) *Life Sciences Research in Space* 29:1-7; Vandenbrink et al. (2016) *Planta* 244: 1201; Morohashi et al (2017) *New Phytol*. 215: 1476; Hasenstein et al., (2022) *Sci. Rep.* 12:18256

- They photosynthesize efficiently
- They can complete an entire life cycle in space (seed to seed experiments)
- Microgravity affects starch metabolism and size of amyloplasts
- They exhibit altered growth (reduced circumnutation, epinasty, and root skewing)
- Other tropisms (e.g., phototropism, hydrotropism) are enhanced in microgravity

Reduced convection in microgravity presents challenges for water provision and nutrient delivery

Poulet et al (2021) *Front. Astron Space Sci.* 8: 733944

- Insufficient water in the root zone
- Excess water in the root zone (low oxygen)
- Water condensation and high humidity result in pathogen proliferation

NASA's Moon to Mars Science Objectives highlight both fundamental plant biology and applied crop production

Human and Biological Science (HBS) goal

HBS-1 Understand the effects of short- and long-duration exposure to the environments on biological systems and health, using humans, model organisms systems of human physiology and *plants*

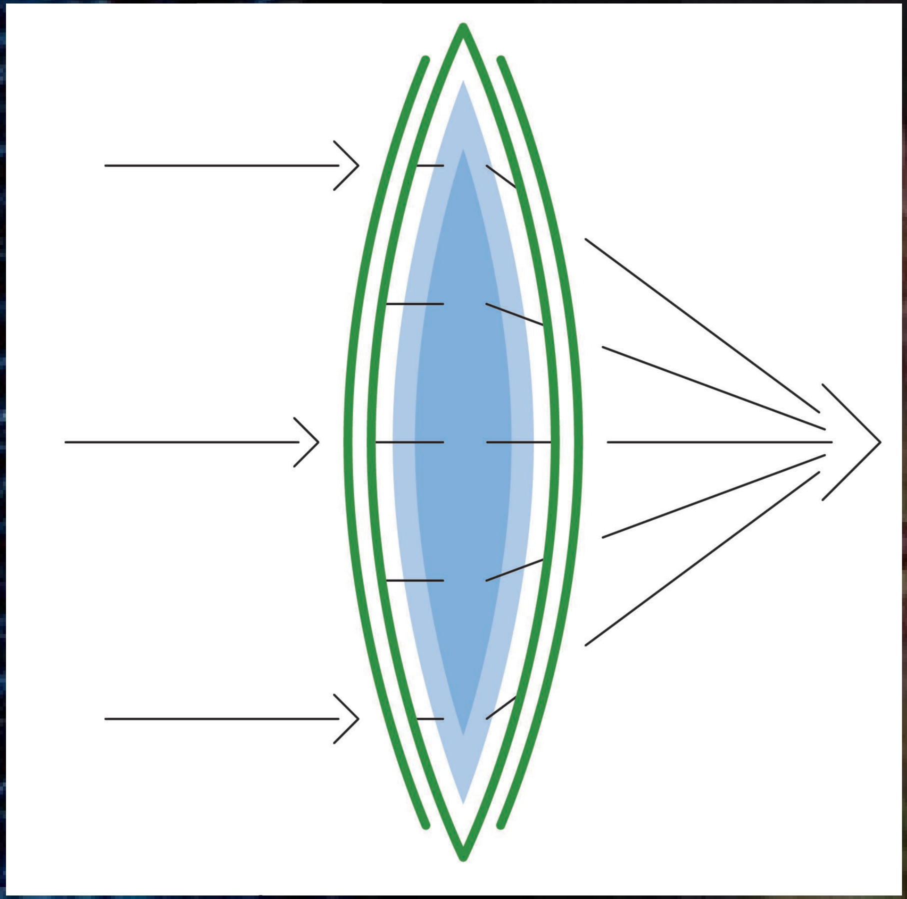
Science-Enabling Applied (AS) Goal

AS-5 Define *crop plant* species, including methods for their productive growth, capable of providing sustainable and nutritious food sources for Lunar, Deep Space transit, and Mars habitation

How can we leverage knowledge about plant biology to space crop production?

HBS-1: Basic plant science

- Cell wall and metabolic engineering
- Sensors of plant biological processes
- Plant growth on regolith



AS-5: Space crop production systems

Space crop ideotypes

- Compact size
- Increased seed viability
- High nutrient and vitamin content

Crop health monitoring

In situ resource utilization

Questions to consider as we take plant research Beyond Low Earth Orbit

- What instruments do we need to make better use of biological tools to get the most impactful science?
- What crop ideotypes can best tolerate water, nutrient deficiency, and pathogen stress?
- Can knowledge from basic plant biology guide engineering solutions for optimal crop growth in space?
- How can we harness the microbiome to enhance space crop production?

Plant Biology
2023 | SAVANNAH, GEORGIA
AUGUST 5 - 9

Plenary Symposium

Thriving in Deep Space: Plant Biology for the Moon, Mars, and Beyond

Dr. Anjali Iyer-Pascuzzi
Purdue University

Dr. Lauren Azevedo-Schmidt
Climate Change Institute
University of Maine

Dr. Janet Janssen
Pacific Northwest
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Dr. Robert Jinkerson
University of California
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