BPS Advisory Committee Meeting
April 25-26, 2024

National Aeronautics and Space Administration

Space Biology Program Update

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BPS

Biological & **P**hysical **S**ciences

Agenda

1. Recent Spaceflight Missions
2. Recent Activities and Achievements
3. Accomplishments in Open Science
4. Space Biology Funding Opportunities
5. Science Highlights

Recent Missions

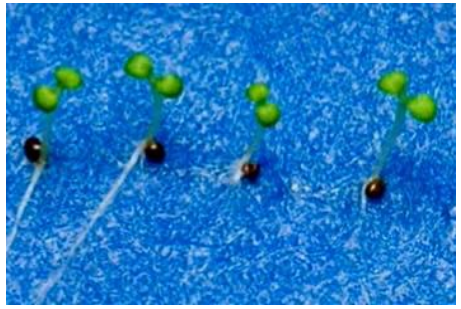
Biological Experiment 1 (Bio-Expt 1) carrying plant, fungi, and algae launched on Artemis I

- Experiments were launched on 11/16/2022 and returned on 12/11/2022
- Bio-Expt 1 seeks to uncover the genetic and biochemical pathways in model organisms that confer the best survival advantage under combined spaceflight stressors
- Won the NASA 2023 Agency Honor Award for Group Achievement !

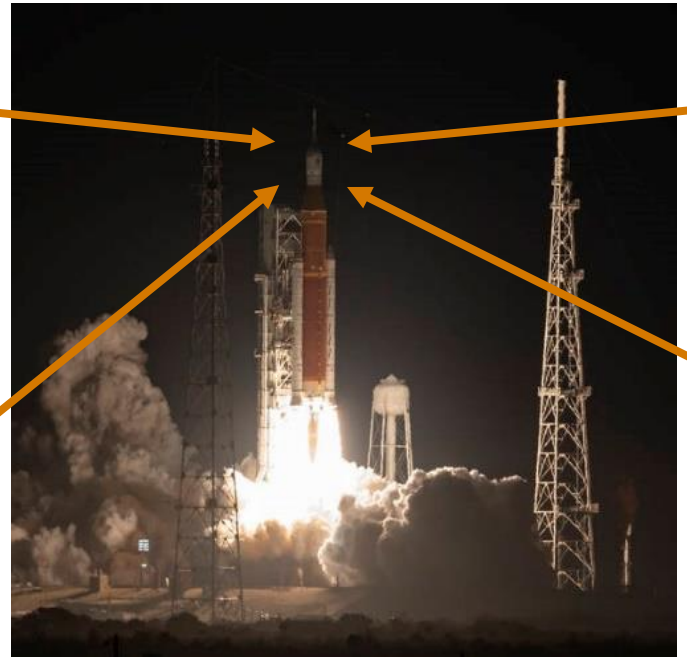
Timothy Hammond

Chlamydomonas reinhardtii

Frederica Brandizzi

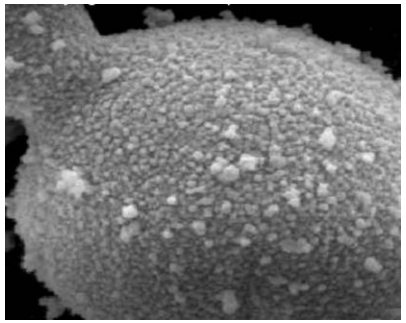


Arabidopsis thaliana

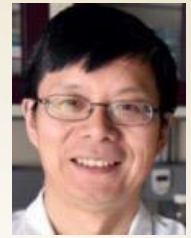


Bio-Expt 1 launch

Aspergillus niger



Saccharomyces cerevisiae



Zheng Wang

Luis Zea

Rodent Research-20

- This experiment was designed to study the effects of spaceflight on the fertility of adult female mice:
- Forty female mice were launched to the ISS on SpX-29 on Nov. 9th, 2023.
- After 60 days, tissues were preserved on the ISS from half the cohort for subsequent analysis.
- Remainder of the cohort returned to Earth alive on SpX-29 (12/22/23) and were mated with male mice.
- Mating was successful and F1 pups were born and delivered to the PI for further analysis (02/28/24).
- Multigenerational studies are ongoing with some potentially interesting epigenetic phenotypes.

Dr. Lane Christenson, KUMC

MVP-Cell-02A
Experimental Evolution of *Bacillus subtilis* Populations in Space: Mutation, Selection, and Population Dynamics



PI: Dr. Craig Everroad, NASA Ames Research Center

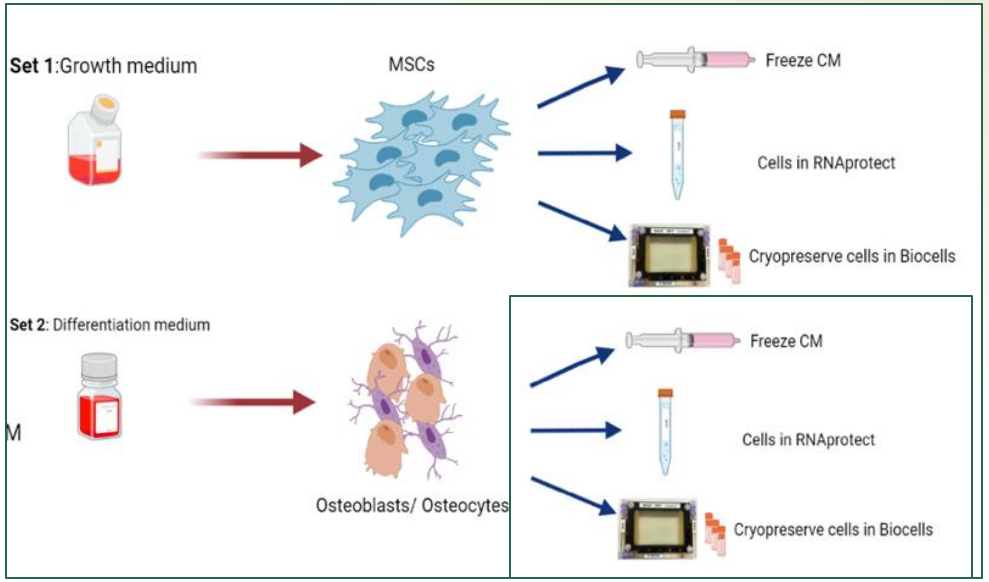
- MVP-Cell-02A launched on NG-19 in August 2023 and ran successfully on the ISS.
- Different strains of Bacillus subtilis were ‘raced’ along solid surfaces to allow continuous selection. Imaging captured adaptive changes in fitness.
- **Upon return on SpX-29, deep sequencing of winners will identify mutation rates, mechanisms, and targets of selection.**
- This investigation advances our understanding of the evolutionary processes and challenges facing biological systems during long-term space exploration and habitation.

MABL-A: Role of Mesenchymal Stem Cells in Microgravity Induced Bone Loss

PI: Abba Zubair, M.D., Ph.D.
Mayo Clinic, Jacksonville, FL

- **MABL-A assesses the effects of microgravity on bone marrow mesenchymal stem cells (MSCs), specifically their capacity to secrete bone forming and bone dissolving cytokines** (small secreted proteins that affect other cells).

- MABL-A launched on NG-20 on January 30th, and flight samples will return on SpX-30 in April 2024.
- *MCSs from 12 human bone marrow donors (6 males and 6 females, 3 young and 3 old in each group) were used.*
- MSCs produce bone-forming cells and are known to play a role in making and repairing skeletal tissues.
- Results aim to provide a better understanding of the basic molecular mechanisms of bone loss caused by spaceflight and normal aging on Earth.



Half of samples were differentiated into Osteoblasts/Osteocytes, while half were not.

Mouse Habitat Unit-8 (MHU-8) Mission

- The NASA-JAXA Joint Partial-gravity Rodent Research Mouse Habitat Unit-8 (JPG-RR MHU-8) mission is the first rodent mission to test partial gravity using centrifugation on ISS (0, 0.33, 0.66, 1 g).
- Multi-disciplinary study involving principal and co-investigators from Space Biology, HRP and JAXA.
- PI team will investigate multiple biological systems (bone, muscle, cardiovascular system, neuro-performance, circadian rhythms, and microbiome).

Vitaterna

Fuller

Space Biology

Bouxsein
HRP

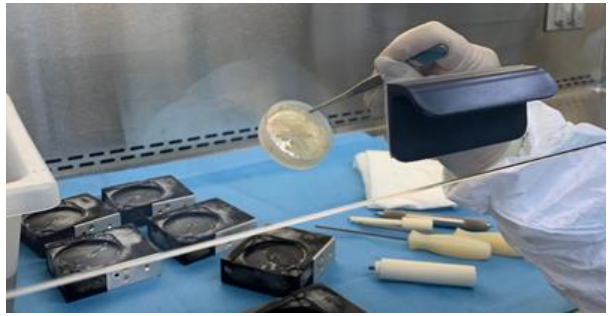
Takahashi
JAXA

Launch and Return of More Space Biology Experiments

- Several BPS-funded space biology flight experiments were launched and returned on SpaceX-26, 27, 28, 29, NG-18, and -20, CREW-5 and -7; and Axiom-3.
- The experiments supported included Plant Habitat (PH)-03A and B, PH-06, Veggie (VEG)-05, DynaMoS, APEX-10, BRIC-25, and BRIC-26.
- Principal Investigators supported were Drs. Paul (University of Florida), Massa (KSC), Jansson (PNNL), Gilroy (University of Wisconsin), Iyer-Pascuzzi (Purdue University), and Rice (University of Florida).
- Experiments asked a range of biological questions, encompassing plant-microbe interactions, plant epigenetics, crop production, bacterial quorum sensing, and microbiome dynamics.
- Organisms studied included Arabidopsis thaliana, Solanum lycopersicum (tomato), Bacillus subtilis, Staphylococcus aureus and a consortium of soil microbes.

VEG-05

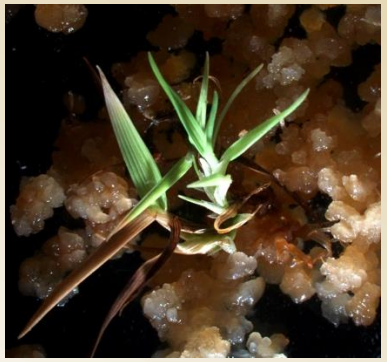
PH-03A

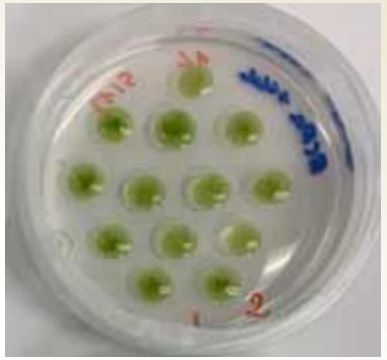


BRIC-25

PH-06

Plant Experiments Anticipated on NG-21 & SpX-31





- Plant Habitat (PH)-07: PI Dr Massa
  - Will investigate how controlled water stress affects plant health and the microbiome in 'Outredgeous' red romaine lettuce, grown under ISS conditions.
- Advanced Plant Experiments (APEX) in Space-09: PI: Dr. Handakumbura
  - Will investigate the impact of spaceflight on C3 and C4 metabolism using the model grasses, *Brachypodium distachyon* and *Setaria viridis*.
- VEG-06: PI: Dr. Lewis
  - Will determine how microgravity affects interaction between alfalfa plants and symbiotic Nitrogen-fixing (N-fixing) bacteria.
- ARTEMOSS: PI: Dr. Zupanska
  - Will determine how the combined effect of cosmic ionizing radiation and microgravity affects the biology of the Antarctic moss *Ceratodon purpureus.*
- Biological Research in Canisters (BRIC)-Light Emitting Diode (LED)-002: PI: Dr. Gilroy
  - Will investigate plant microbial pathogenicity during spaceflight using *Arabidopsis thaliana*.

Recent Activities & Achievements

NASA Senior Scientist and BPS-funded PI receive prestigious awards

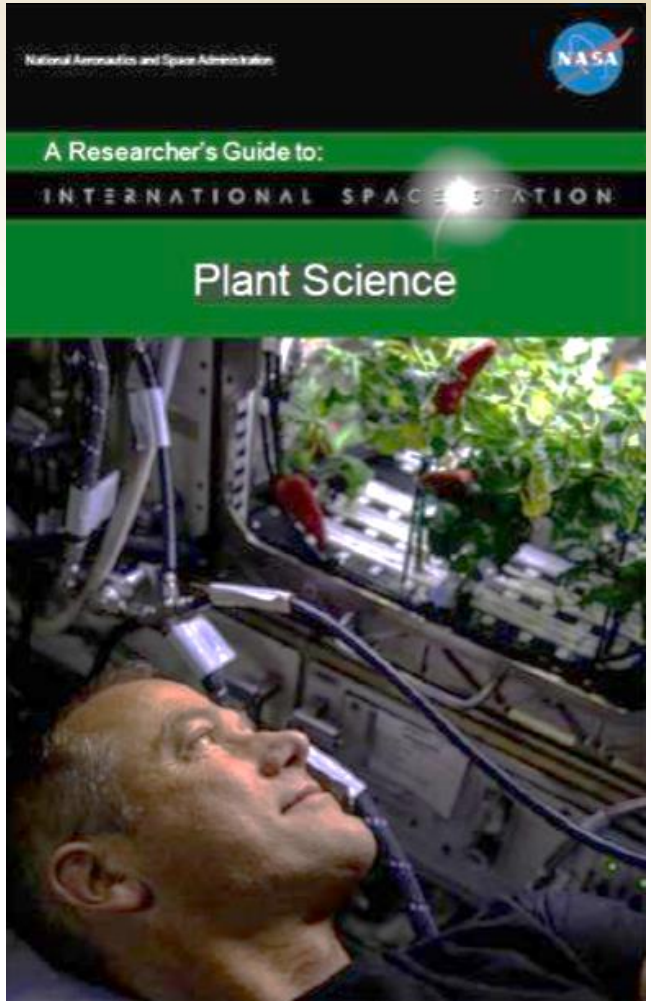
Dr. Raymond Wheeler was selected as a **Fellow of the American Society for Gravitational and Space Research** (ASGSR) in recognition of distinguished contributions to the advancement of gravitational and space research.

Dr. Anna-Lisa Paul, Director of the Interdisciplinary Center for Biotechnology Research (ICBR) at the University of Florida was honored as Lifetime **Fellow by the American Association for the Advancement of Science (AAAS).**

A Researcher's Guide to Plant Science (2023) is Published

The guide contains the following information:

- A broad overview of what has been learned from plant/crop research on the ISS.
- A description of plant growth hardware on the ISS and associated support facilities.
- What it takes to develop and launch plant experiments on the ISS.



www.nasa.gov/connect/ebooks/researchers_guide_plant_science_detail.html

NASA Space Life Sciences Library (NSLSL) is released for public use

- NSLSL database development initiated by the Microgravity Simulation Support Facility (MSSF) was completed on 07/25/2023.
- The NSLSL is a public-access database that houses peer-reviewed publications, dissertations, NASA technical publications, white papers, and patents related to space life sciences.
- The NSLSL will provide a valuable resource for the space life science community.

Homepage of the NSLSL

https://public.ksc.nasa.gov/nslsl/

NASA Kennedy Space Center establishes partnerships with an Australian Research Council (ARC) center that seeks to enable human deep space exploration through plant and food redesign.

PLANTS FOR SPACE
ARC CENTRE OF EXCELLENCE

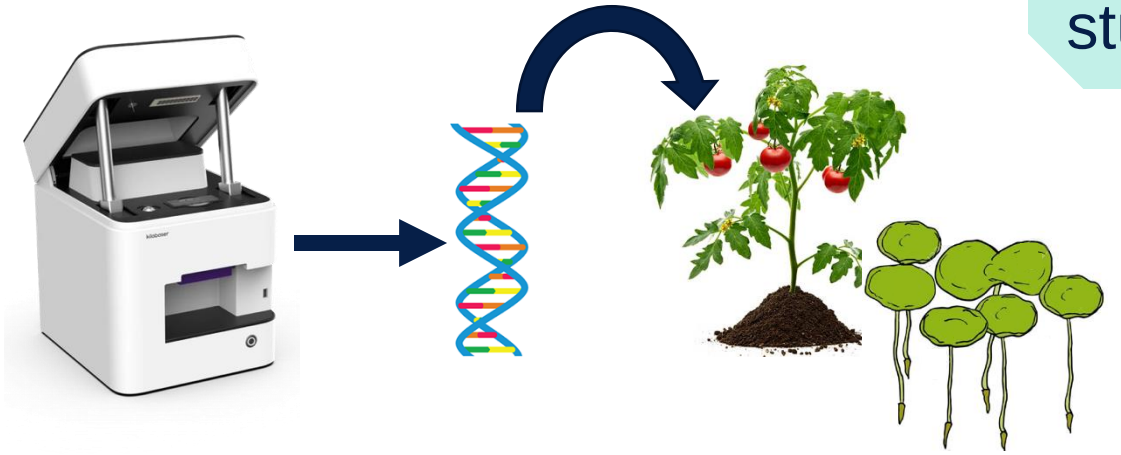
KENNEDY SPACE CENTER
LAUNCHING HUMANITY'S FUTURE

Plant-based food & health solutions

Biological solutions for space

Innovative public & student engagement

High-efficiency agriculture & biomanufacturing



New STEM research & industry capacity

https://plants4space.com/

Plant Space Biology takes center stage at the largest gathering of plant scientists in North America

- The American Society of Plant Biologists (ASPB) : 2023 annual meeting in Savannah, Georgia Aug 5-9.
- A plenary symposium titled, Thriving in Deep Space: Plant Biology for the Moon, Mars, and Beyond: more than 1000 attendees from 50 countries got to know about the field of plant space biology.

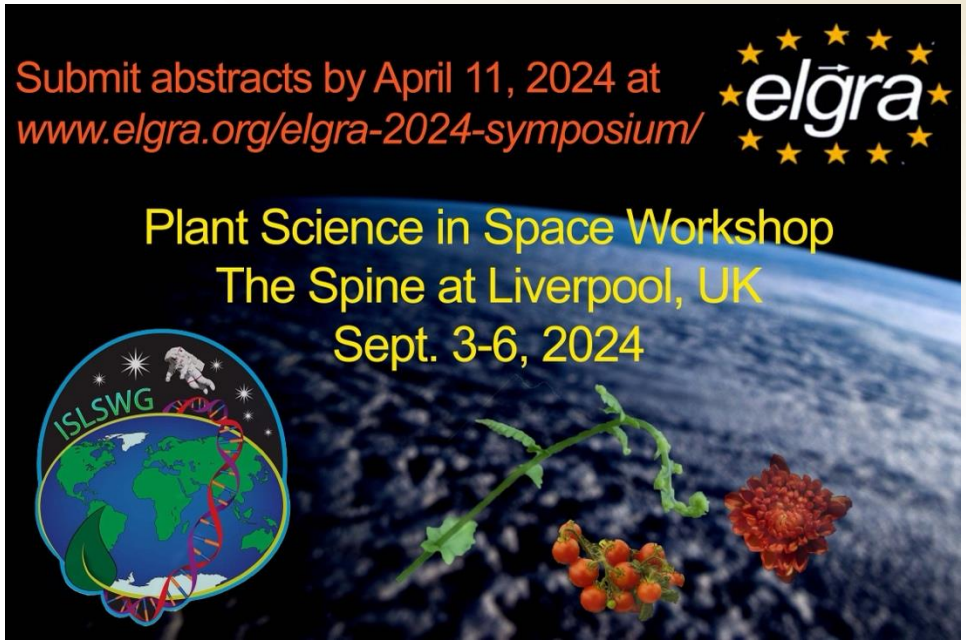
NASA Plant Space Biology exhibit booth at the Savannah Convention Center

Space Biology-funded PI Dr. Janet Jansson giving an ASPB plenary talk on microbial dynamics in space

Plants in Space educational booth at the Forsyth Farmer's Market

International Collaborative Workshop

- Space agencies from the International Life Sciences Working Group (ISLSWG) and the European Low Gravity Research Association (ELGRA) are organizing a workshop titled "Plant Science for Space Exploration and Earth Applications"
- The workshop will be held at the Spine in Liverpool, United Kingdom from September 3-6, 2024
- Four scientific sessions:
  - Plant Adaptation and Response to Space Environmental Stress
  - Plants for Environmental Control and Life Support Systems in Space
  - Advances in Plant Gravitational Biology and Space Genomics
  - Enabling Technologies for Crop Production in Space and Applications for Earth Agriculture



More Collaborations

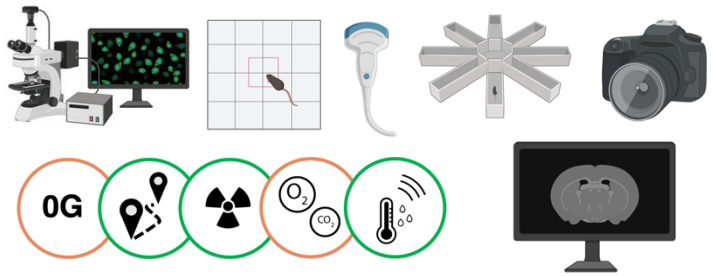
- **With ISSNL (ISS National Lab):**
  - Biospecimen sharing collaboration for RR-28 experiment (PI: Ramkumar).
  - "Preclinical Validation of a Modifier Gene Therapy to Prevent Spaceflight-Associated Oxidative Stress and Apoptosis in Microgravity Model of Dry Macular Degeneration".
  - Procured an OCT (Optical Coherence Tomography) machine to enable science analysis & tissues will be archived in Space Biology's open science sample repository *(NBISC: https://osdr.nasa.gov/bio/)*
- **With ESA & JAXA (The European and Japanese Space Agencies):**
  - Open science data collaboration for "omics" data between ESA and NASA for Genelab (in work).
  - JAXA and NASA have cross-referenced each other's open science databases to facilitate searches.
- **With Partners from the International Life Sciences Working Group (ISLSWG):**
  - Organizing an international Plant Workshop titled "Plant Science for Space Exploration and Earth Applications" at the ELGRA meeting in 2024 (POC: Elison Blancaflor)
- **With ARES (NASA's Astromaterials Research and Exploration Science) division:**
  - Partnered on Lunar Regolith ROSES solicitation *(highlighted in the last section of this talk)*
- **With HRP (Human Research Program):**
  - Partnered on HRP's Flagship Solicitation 2024 *(highlighted in the last section of this talk)*
  - "Space Tomatoes" collaboration with HRP to vet procedures for crew consumption with FDA, USDA, EPA etc.

Accomplishments in Open Science

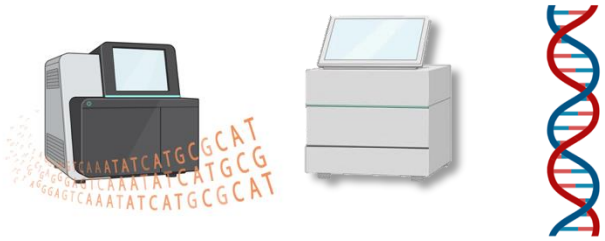
- Open Science Data Repository (OSDR)

Open Science Data Repository Released

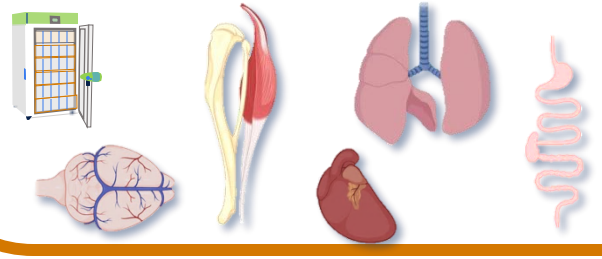
Physiological/Phenotypic/Imaging/ Environmental Telemetry Data



Molecular/Omics Data



Biospecimens



ALSDA

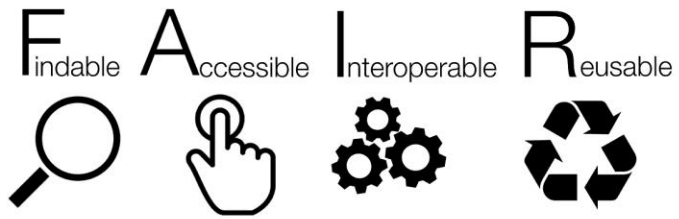
GeneLab

NBISC

NASA Open Science Data Repository (OSDR)

osdr.nasa.gov/bio

- **Single Submission Portal (BDME)**
- **User Interface/Website Tool for RDSAs (Research Data Submission Agreements)**
- **Maximally Open Access with Necessary Controls for Sensitive Data**
- **Data Maximally FAIR**



OSDR Database (GeneLab and ALSDA)

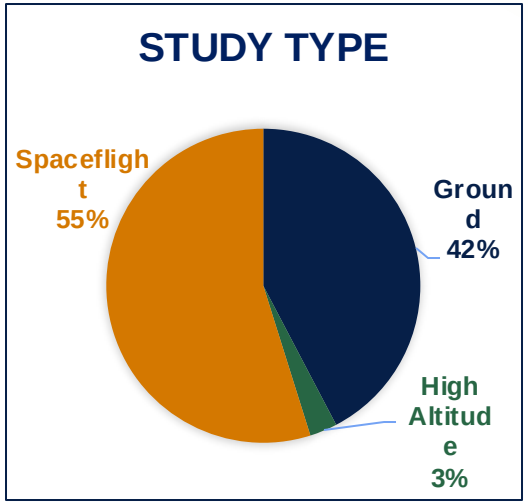
488 Studies

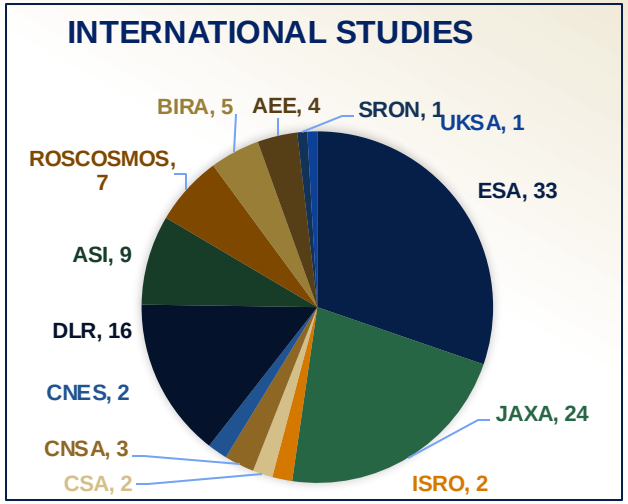
927 Datasets

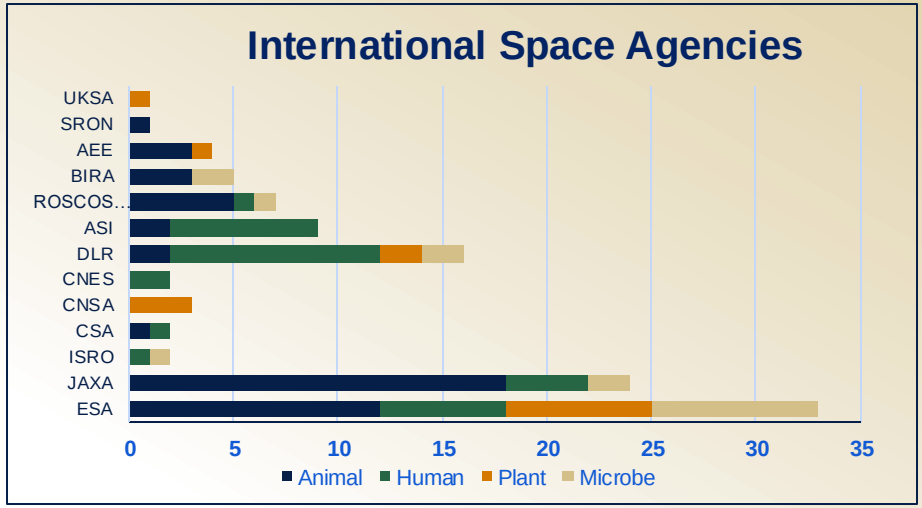
45 Species

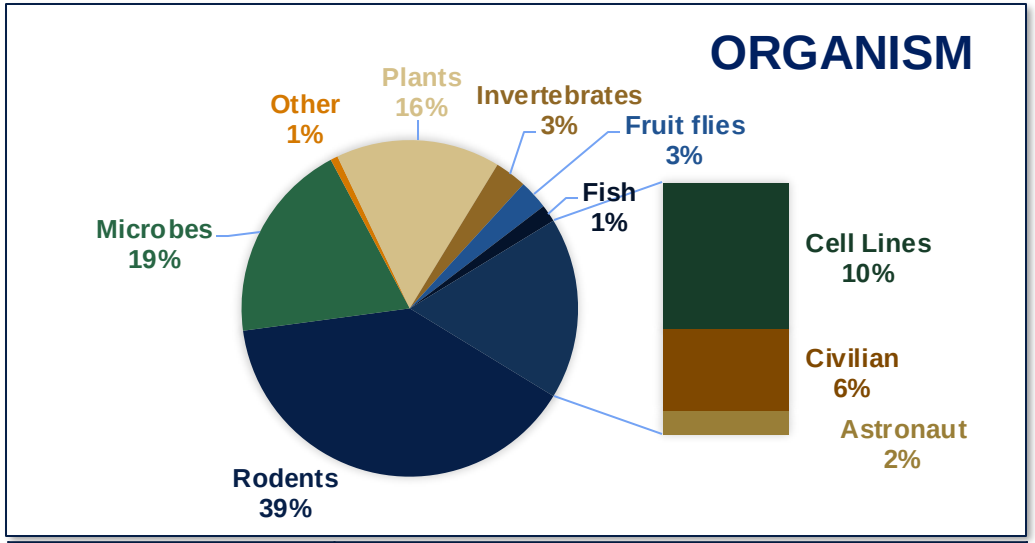
>80 Assays

>150TB Data

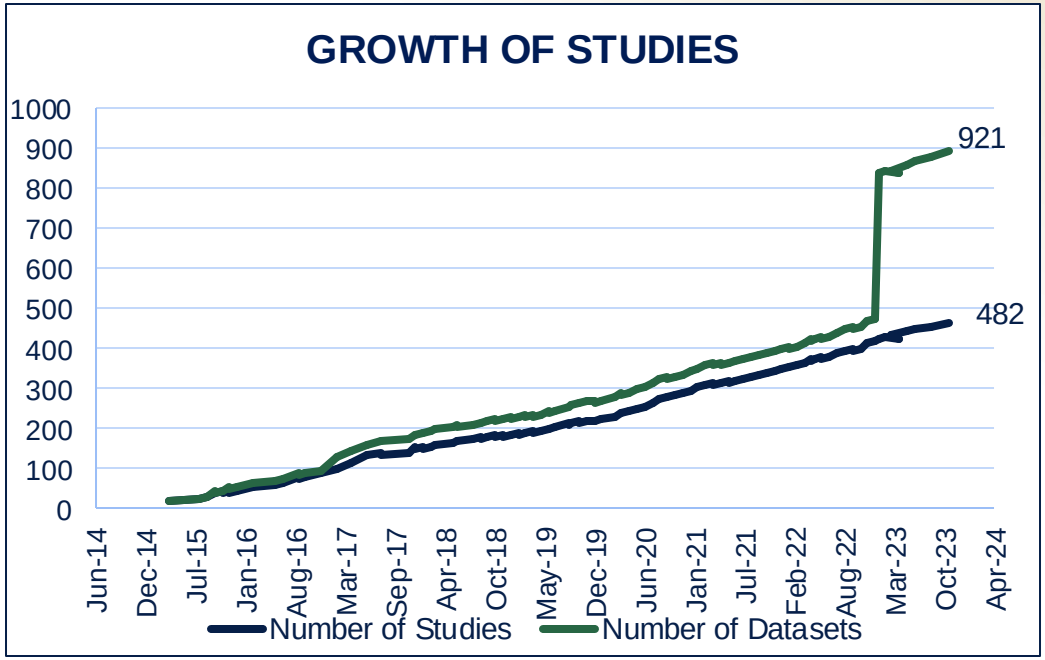








Civilian and Astronaut	Bed Rest, Spaceflight, Mars simulation
Cell Lines	Radiation (Ground), Simulated uG, Spaceflight, Parabolic Flight



Reuse of Data and Enabling New Discoveries

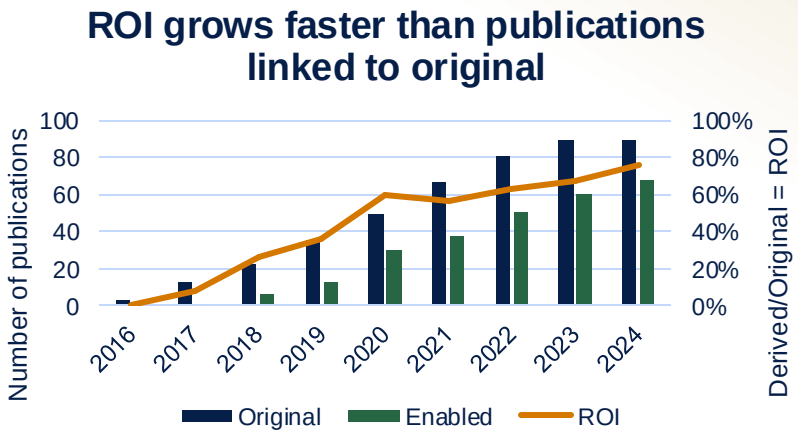
Return on Investment

89
Original Publication linked to OSDR

68
Enabled Publication linked to OSDR

80+
Presentations linked to OSDR

150+
Datasets used in enabled publications



Analysis Working Groups

131
New AWG Members in FY24 so far! (301 new members in past two years)

Upcoming

The **Space Omics and Medical Atlas (SOMA) across orbits** package of manuscripts to be published in **Nature Portfolio.**

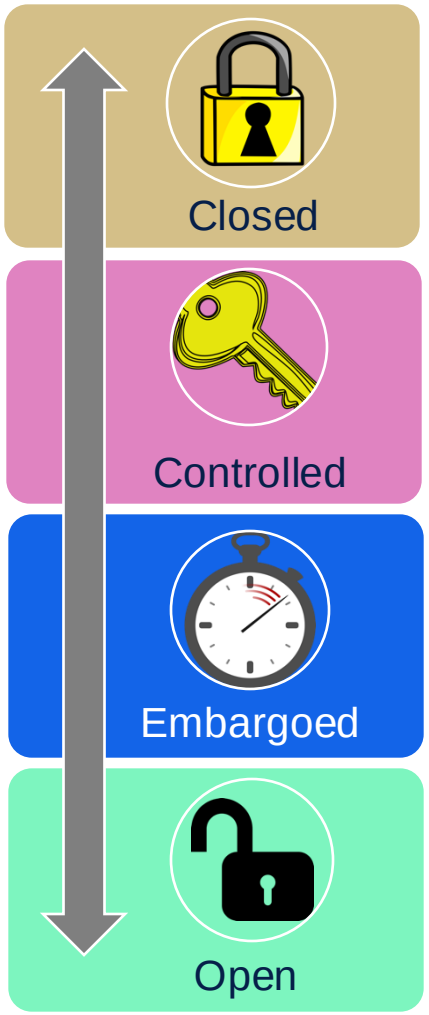
International collaboration of papers related to space biology and aerospace medicine featuring data from the first **all-civilian crewed mission, *Inspiration4 (I4).***

- Over 100 institutions from more than 25 countries
- Featuring collaborative meta-analysis manuscripts from the AWGs
- Data submitted to OSDR
- Led by Christopher Mason and Afshin Beheshti

To be published in April/May 2024

Expanded OSDR: Controlled Access Data

The Continuum



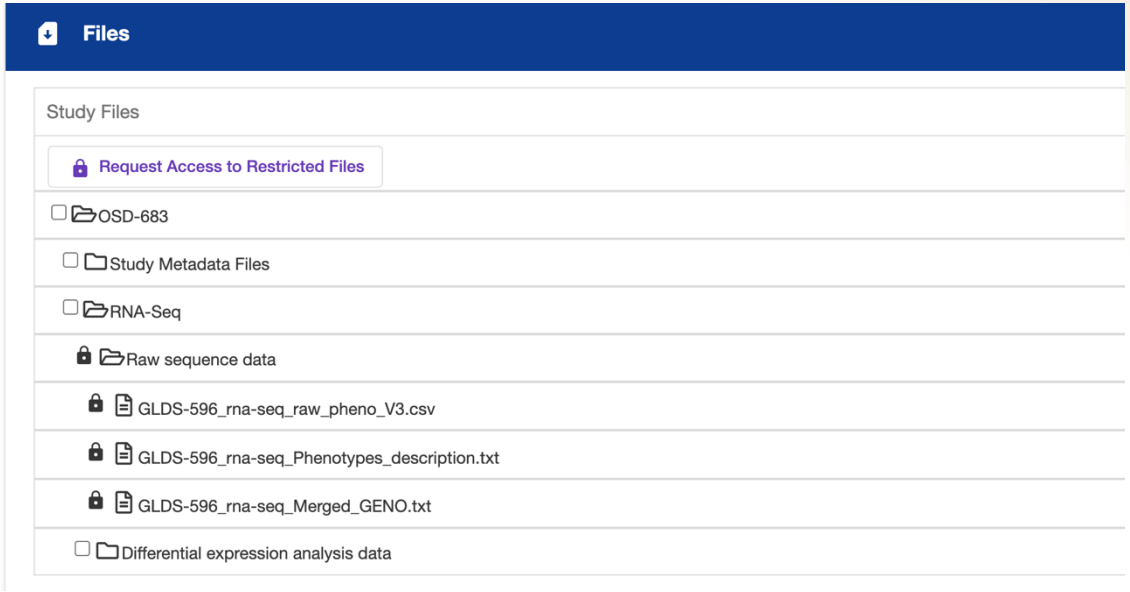
1	2	3	4	5	6	7
Pre-Submission	Investigator Submits	Signing Official Reviews	Data Access Committee Reviews	Access Data	Renew Project (Optional)	Close Out Project
Request Button clicked in OSD dataset	OSDR Data Request Package sent w/ Data Use Agreement	OSDR Follows Up with your institution	Review Board with Specific Stakeholders (OSDR, PIs, etc)	Approved /Denied Secure Transfer	Approved /Denied	Access removed at end of IRB, or upon participant request, or if conditions of Data Use Agreement are violated

Process inspired by NIH's Database of Genotypes and Phenotypes (dbGaP)

Example of Controlled Dataset Request

Data should be as open as possible, as closed as necessary.

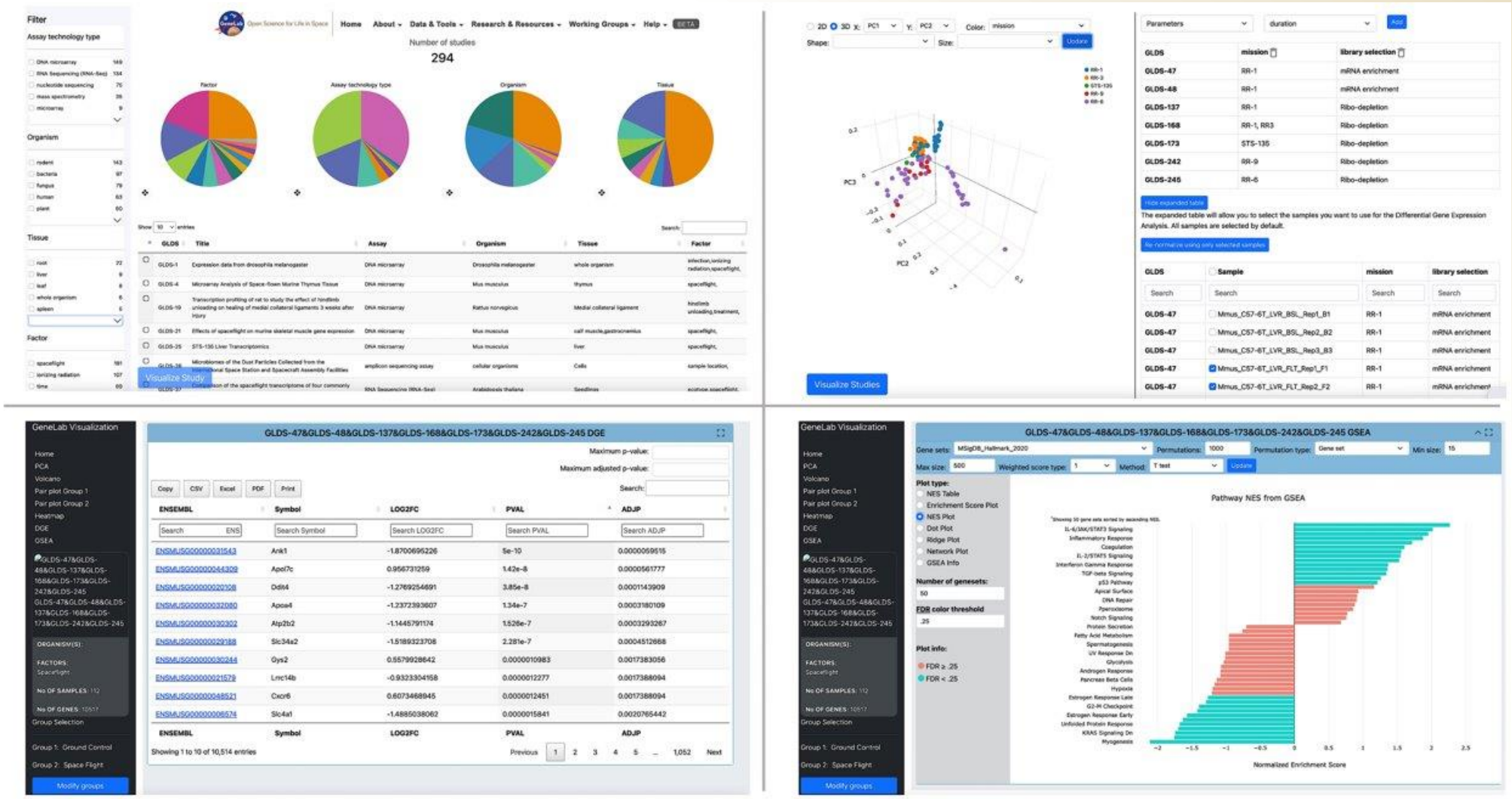
Metadata can almost always be open.



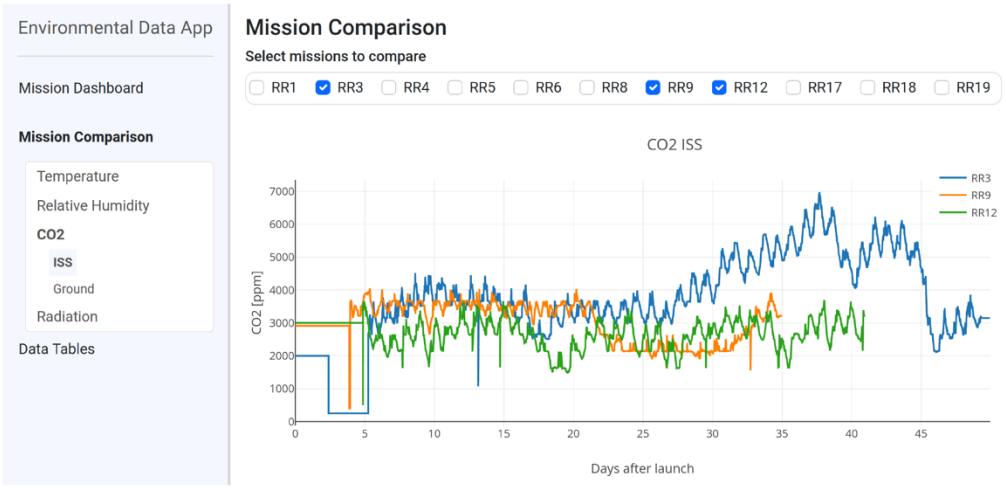
(Credit for slide design/content, Kristen Peach, GeneLab Curator)

New app: Multi-Study Viz

Expanding GeneLab visualization app to now compare data across RNA-seq studies. Users can now discover how gene expression changes within one study or across multiple studies. https://visualization.genelab.nasa.gov/data/



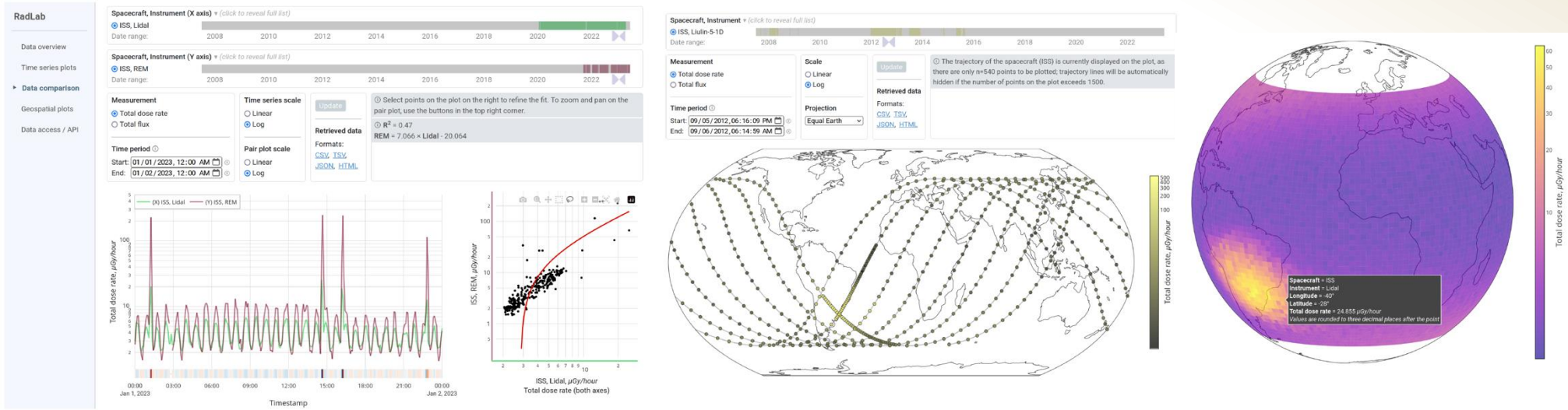
Environmental Data App and RadLab



The Environmental Data App (EDA) is a portal where users can visualize and compare ISS (International Space Station) cabin environmental telemetry data and radiation data gathered from spaceflight missions.

https://visualization.osdr.nasa.gov/eda

RadLab is a portal that aims to provide a single point of access to radiation telemetry data from multiple databases maintained by multiple space agencies.

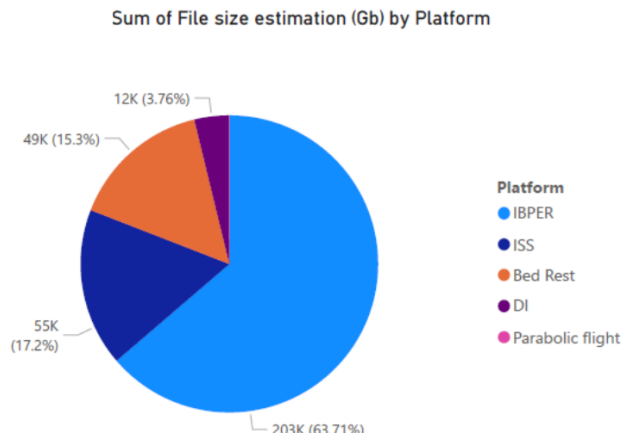


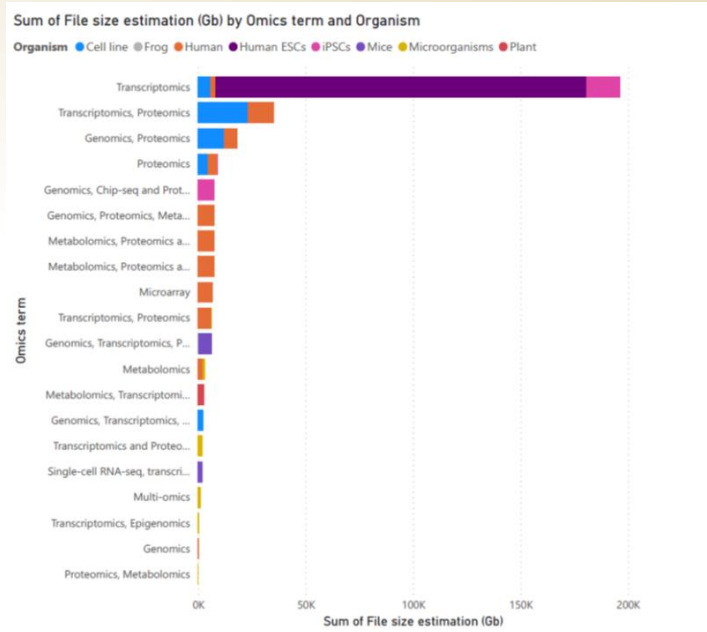
https://visualization.osdr.nasa.gov/radlab

ESA Omics Data

In the next 5 years, ESA estimates they will collect 300 TB of omics data.

- Majority of the omics projects are transcriptomics across several platforms using various organisms.
- To utilize the current infrastructure, ESA SciSpacE team has requested all omics data be submitted and hosted on GeneLab (via OSDR).
- Formal agreement for collaboration is currently in progress.



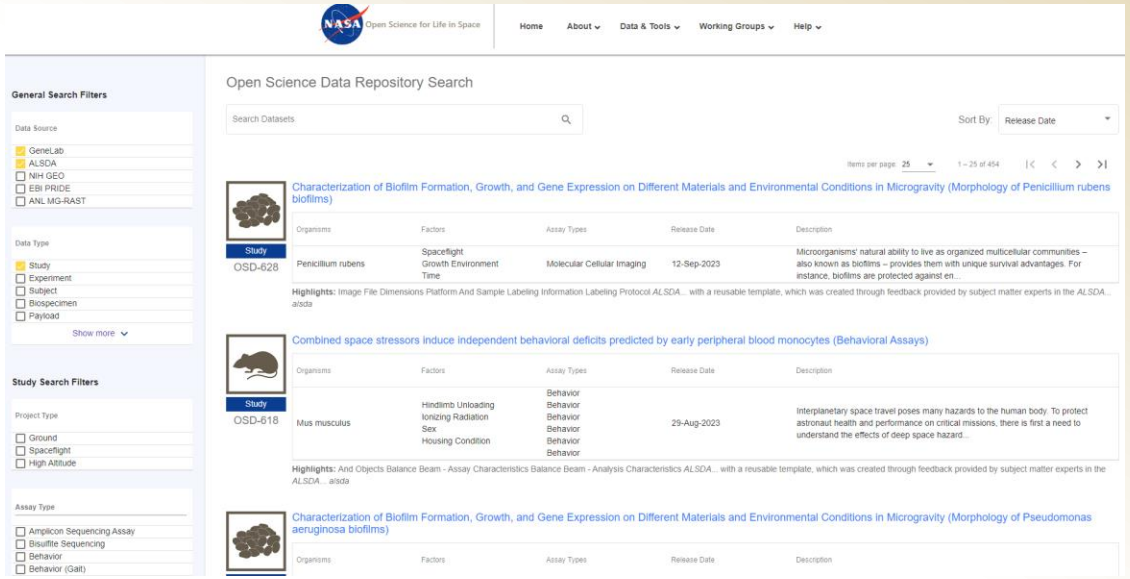


This initiative aims to centralize space omics data for the scientific community, facilitating cross-analysis and interoperability (FAIR), and leading to cost savings by avoiding infrastructure duplication.

Cross linking HREDA and OSDR

HREDA - Human and Robotic Exploration Data Archive (ESA)

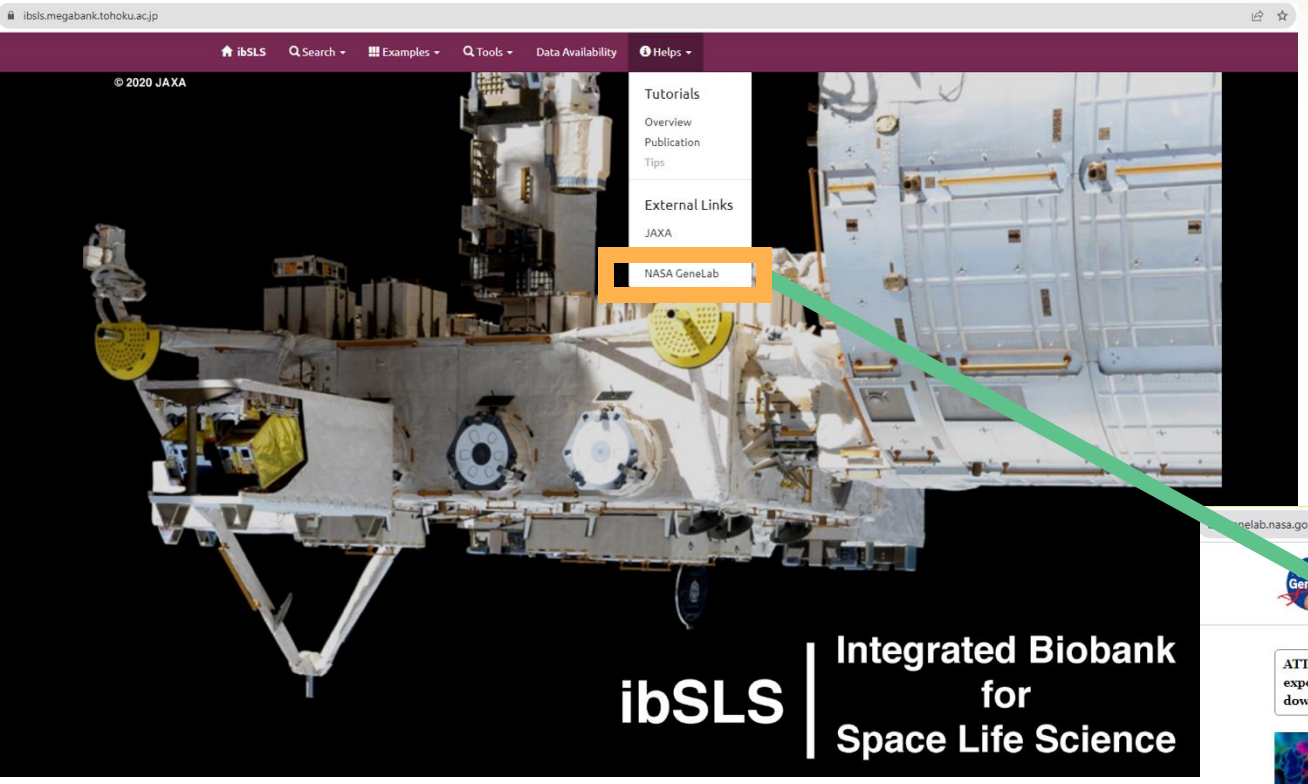
OSDR – Open Science Data Repository (NASA)

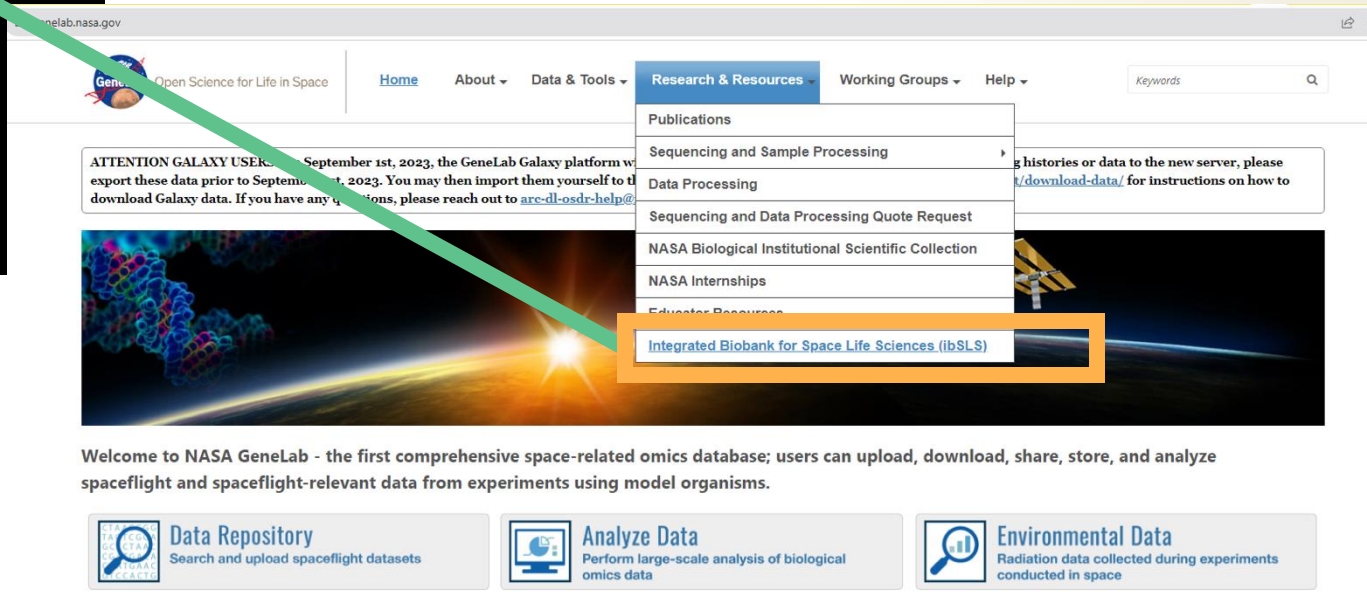


To enhance discoverability, HREDA and OSDR will cross link experiment pages and data from common missions.

Formal agreement with ESA for collaboration is currently in progress

Cross linking with JAXA ibSLS





Recent & Anticipated Future Funding Opportunities

Space Biology Solicitation for Lunar Regolith (Simulant) Studies

Research Studies Released as ROSES Program Element E.9:

- Selections Announced: Jan 2024
  - Released in collaboration with NASA's Astromaterials Research and Exploration Science (ARES) Division
  - ARES will supply lunar regolith simulant that is formulated to resemble regolith present within the Lunar Highlands of the lunar south pole, (near the candidate landing sites proposed for the Artemis III Mission).
  - The curation office will supply lunar regolith collected from Apollo missions to a subset of awardees with demonstrated progress with simulant to conduct a final set of validation studies using genuine material.
  - 11 grants selected for a total of $ 2.3 million over 3 years.

Space Biology Solicitation to Study How Organisms can Thrive in Space

ROSES-2022 Program Element E.11: “Research Pathfinder for Beyond Low Earth Orbit Space Biology Investigations”:

- Selections Announced: ~Sept 2023
  - Initially intended for launch on Artemis II but could not be accommodated on that mission.
  - Selected 1 proposal for flight on ISS and 1 as a ground study.
  - 2 grants selected for a total of 1.5M over 3 years

HRP's Recent Call in Collaboration with Space Biology

2024 HERO Appendix A, Topic 2: NASA Human Research Program Flagship Opportunity:

- Released: Oct 2, 2023;
- Step-1 Proposals (mandatory) Due: Nov 1, 2023
- Final Step-2 Proposals Due: Jan 30, 2024
  - The NASA Human Factors and Behavioral Performance (HFBP) Element within HRP
  - Appendix A, Topic 2, "Biomarker exploration system for measuring operationally meaningful performance in future exploration missions".
  - Animal ground studies with radiation in conjunction with other relevant stressors such as sleep loss, circadian misalignment etc.
  - Funding over 3 years for a total of $1.2M (inclusive of directs and indirects).

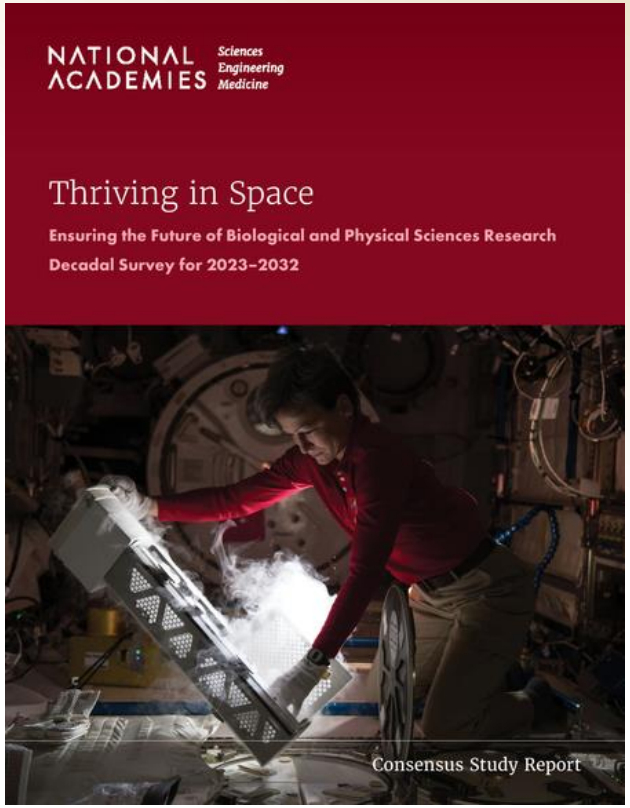
Consortium in Biological Sciences:

Space Biology will release a solicitation for space-relevant research investigations in response to the Commerce, Justice, Science, and Related Agencies Fiscal Year 2024 Appropriations Bill.

- This program element is established in response to the Explanatory Statement (page 67) of the Commerce, Justice, Science, and Related Agencies Fiscal Year 2024 Appropriations Bill. That language directs that NASA shall "establish a consortium including academic institutions with demonstrated expertise within the human health, animal, and plant sciences."
  - $2.5M total for up to 5 years period of performance.
  - To be Released under ROSES-2024:
  - Anticipated Release: ~Summer 2024

Space Biology's Upcoming Annual ROSES Solicitation:

- The plan is for Space Biology to release solicitations for animal, cellular, and plant biology that is responsive to the National Academies' Decadal Recommendations as part of the ROSES 2024 announcements.



Science Highlights

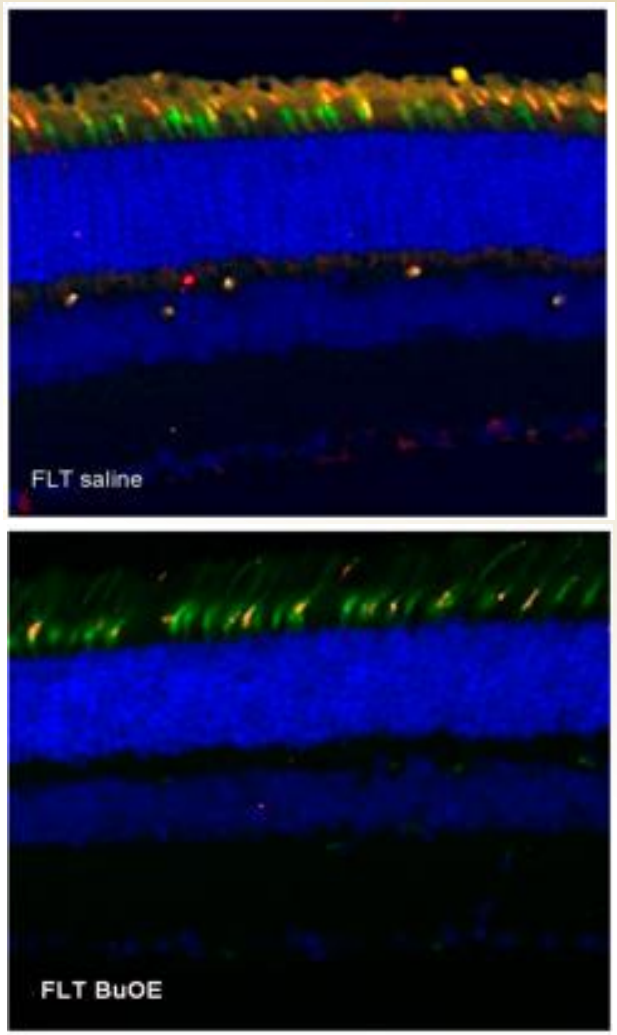
(Can only cover a small number of items from a much larger number.)

Evidence of Spaceflight-Induced Adverse Effects on Photoreceptors and Retinal Function in the Mouse Eye.

Citation: Mao, X.; Stanbouly, S.;Holley, J.; Pecaut, M.; Crapo, J. Int. J. Mol. Sci. 2023, 24, 7362.

- Spaceflight induces neuro-ocular changes in astronauts during and after space flight.
- The RR-18 mission (PI Dr. Vivien Mao, Loma Linda U.) characterized acute oxidative damage in ocular structure and retinal function of mice and evaluated the efficacy of an antioxidant in reducing spaceflight-induced changes in the retina.
- **Postflight evaluations showed increases in retinal oxidative stress and apoptotic cell death after spaceflight** and decreases in the amplitudes of alpha and beta waves.
- **Treatment with the antioxidant, BuOE (superoxide dismutase mimic), significantly reduced levels of oxidative stress**, but levels of apoptotic cell death, and ERG metrics remained unchanged.

Peggy Whitson performing an eye check aboard the International Space Station. Credit NASA.

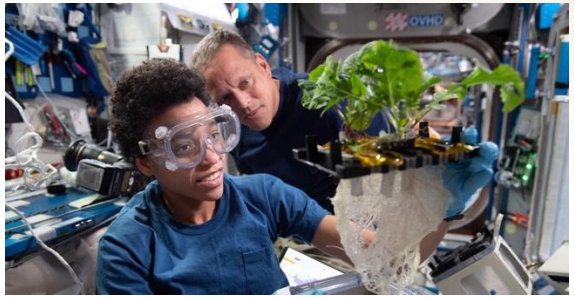


Flight induced oxidative stress in cones (yellow signal) which was mitigated by treatment with the antioxidant, BuOE.s

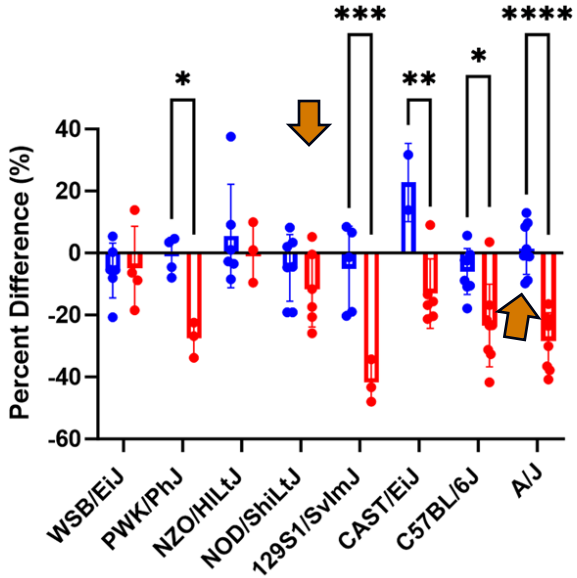
Genetic diversity modulates the physical and transcriptomic response of skeletal muscle to simulated microgravity in male mice

Citation: Zeineddine, Y., Friedman, M.A., Buettmann, E.G. et al. npj Microgravity 9, 86 (2023)..

- Astronaut data shows considerable variation in muscle loss in response to microgravity1.
- Strength losses vary from 0–55% for missions between 30-380 days2,3,4.
- Study compared response of muscle in **8 mouse strains to 3 weeks of hind limb unloading**.
- **Saw substantial differences in muscle loss between strains.**
- Differences are reflected in the magnitude and pattern of changes within muscles from each strain.

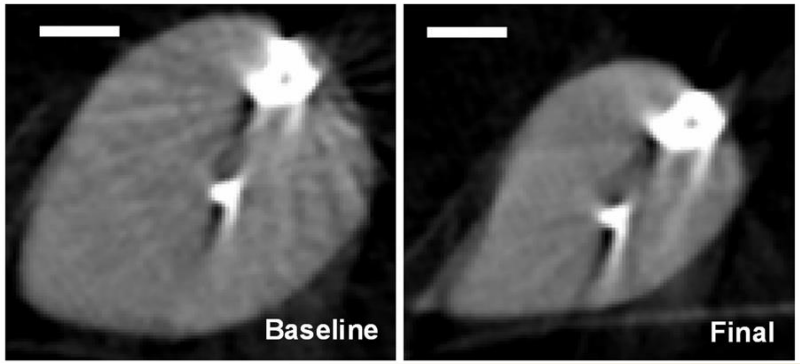


Astronauts aboard the ISS. Credit NASA.

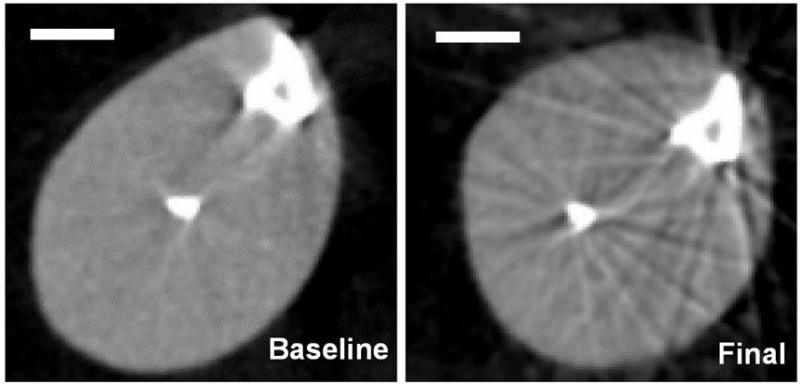


Red is unloaded. Blue is control. Adapted from Figure 3 of Zeineddine et al. 2023.

A/J mouse



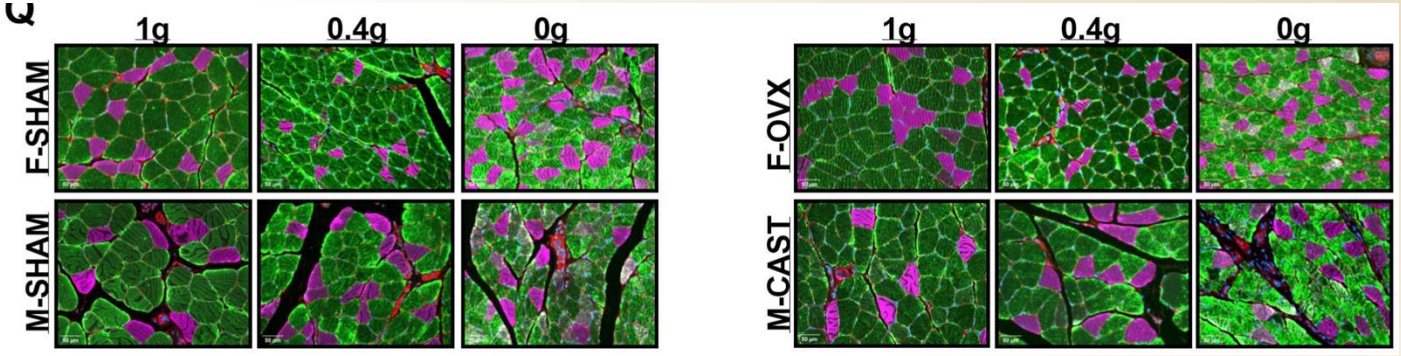
NOD/ShiLtJ mouse



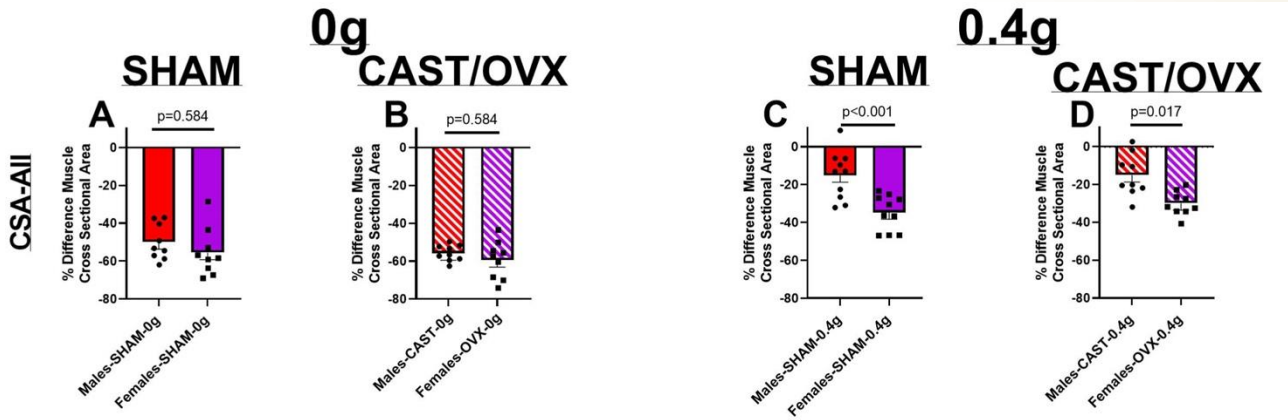
Sex Differences in Muscle Health in Simulated Micro- and Partial-gravity Environments in Rats.

Rosa-Caldwell ME, Mortreux M, Wadhwa A, Kaiser UB, Sung DM, Bouxsein ML, Rutkove SB. Sports Med Health Sci. 2023 Sep 12;5(4):319-328. doi: 10.1016/j.smhs.2023.0

- Male and female Fisher rats underwent either castration/ovariectomy (CAST/OVX) or sham surgeries.
- After recovery, animals were exposed to either simulated microgravity (0g), partial-gravity (40% of weight bearing, 0.4g), or full weight bearing (1g) interventions for 28 days.
- Measurements of muscle size and strength were evaluated prior to and after interventions.
- **Females had greater musculoskeletal aberrations during exposure to both microgravity and partial-gravity environments; these differences are not dependent on the presence of sex steroid hormones**.



Histology of soleus muscles. Purple shows type 2 fibers, green type 1.



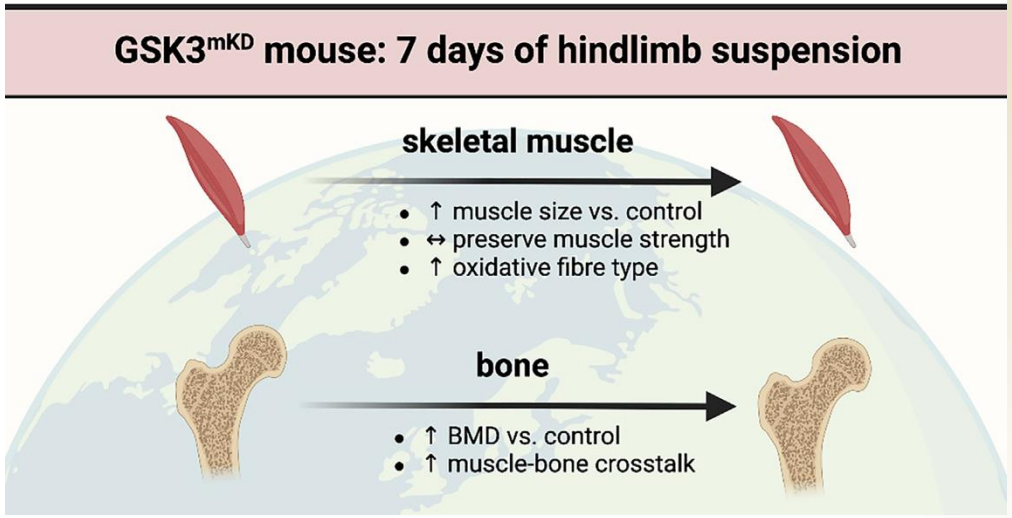
SHAM = sham surgery animals with intact gonads, CAST = castrated males, OVX = ovariectomized females.

Space Biology grants 80NSSC21K0311 and 80NSSC19K1598 to Dr. Megan Rosa-Caldwell and Dr. Seward Rutkove, respectively.

Open Science Enabled. Toward countering muscle and bone loss with spaceflight: GSK3 as a potential target.

Baranowski RW, Braun JL, Hockey BL, Yumol JL, Geromella MS, Watson CJF, Kurgan N, Messner HN, Whitley KC, MacNeil AJ, Gauquelin-Koch G, Bertile F, Gittings W, Vandenboom R, Ward WE, Fajardo VA. iScience. 2023 Jul 21;26(7):107047. https://pubmed.ncbi.nlm.nih.gov/37360691

- In the musculoskeletal system, **GSK3 is a negative regulator of muscle and bone mass. Possible target to mitigate spaceflight impacts.**
- Study measured the level of GSK3 muscles from mice flown on BION-M1, RR-1, RR-9, and RR-18 obtained from BSP and NBISC.
- **Reduced GSK3β in soleus muscles from all missions,** correlated with a change from slow to fast twitch muscle fiber types.
- **GSK3 knock-down mice showed increased soleus muscle mass, myogenic signaling, and preserved muscle strength after 7 days of hindlimb suspension**.
- These results point to **GSK3 inhibitors like lithium and tideglusib as being interesting candidates for future investigations**.

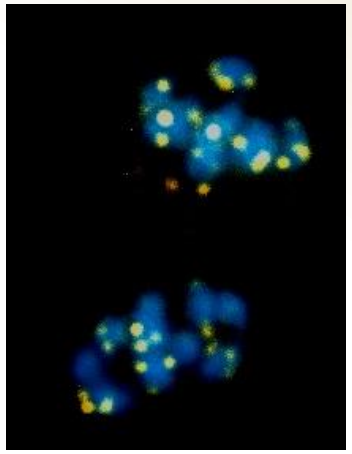


The authors used **tissue from NBISC and BSP** to show that **GSK3β content was reduced (−36%) in murine soleus muscles after ~30 days of spaceflight.** *Gsk3* muscle knockdown (GSK3^{mKD}) preserved muscle strength after hindlimb suspension. Spaceflight reduced bone mineral density in mice. GSK3^{mKD} increased FNDC5 expression and tibia bone mineral density.

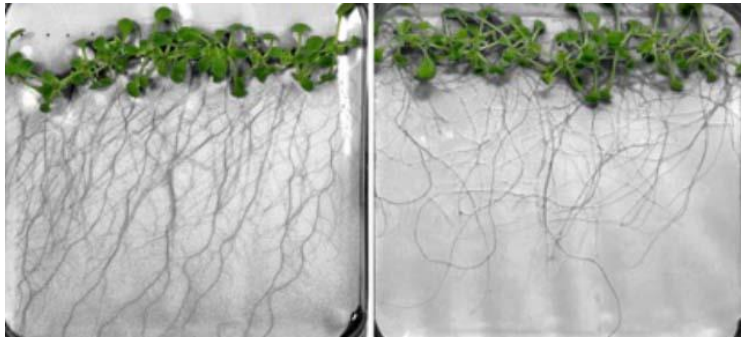
Spaceflight reveals new insights into telomere function that may help plants survive harsh environments

Barcenilla BB, Meyers AD, Castillo-González C, Young P, Min JH, Song J, Phadke C, Land E, Canaday E, Perera IY, Bailey SM, Aquilano R, Wyatt SE, Shippen DE (2023) *Nature Communications*. 14(1):7854. doi: 10.1038/s41467-023-41510-4.

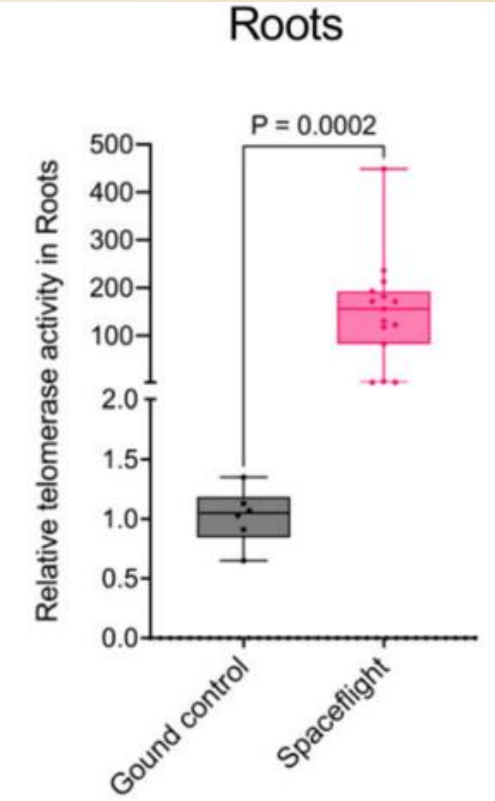
- Repetitive DNA sequences called telomeres are protective structures at the end of chromosomes that serve as biomarkers of the health of an organism.
- An enzyme called telomerase maintains the length of telomeres.
- Telomere length in roots of *Arabidopsis thaliana* plants grown on the ISS remained unchanged despite exhibiting enhanced telomerase activity.
- Results indicate a novel protective function of telomerase in plants that is independent of telomere length.



Telomeres (yellow) in Arabidopsis chromosomes (blue)



Ground Control Spaceflight

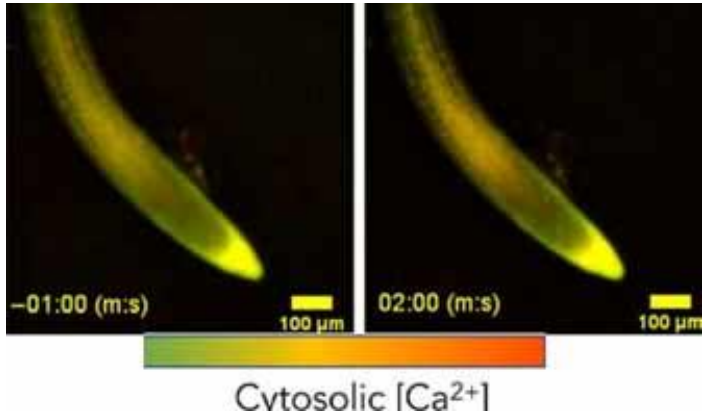


Plant telomerase activity is higher in spaceflight than that on Earth

Plant response to flooding is facilitated through cytosolic calcium signaling

Bakshi A, Choi WG, Kim SH, Gilroy S (2023) *New Phytologist* 240(5):1830-1847. doi: 10.1111/nph.19274

- Excess water (flooding) is harmful to some plant species because it depletes oxygen in the root zone.
- The manner, by which water behaves in microgravity could cause excessive water accumulation in crop roots.
- Calcium functions as signaling molecules in cells of living organisms.
- This paper **shows that signaling pathways that dictate how plants respond to flooding is mediated by calcium through a protein called Cation Exchanger 2 (CAX2).**
- **CAX2 could present a genetic target to increase plant survival under flooding stress.**



Flooding triggers a rise in cytosolic calcium in roots.

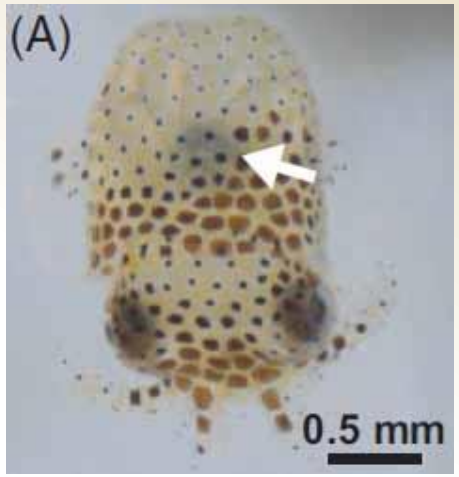
4 weeks flooding

Arabidopsis thaliana mutants lacking the CAX2 protein tolerate excess water.

Modeled microgravity affects innate immunity in a beneficial animal-microbe symbiosis that has implications for astronaut health in space

Duscher AA, Vroom MM, Foster JS (2024) *Scientific Reports* 14(1):2912 doi: 10.1038/s41598-024-53477-3

- The innate immune system is the animal's first line of defense against invading microbes and toxins.
- Microgravity could lead to a dysregulation of innate immunity and pose a health issue for astronauts.
- **The Hawaiian bobtail squid *Euprymna scolopes* and the beneficial bacterium *Vibrio fischeri* was used as a model to study how simulated microgravity affect the NFκB signaling pathway, a component of the innate immune response pathway**.
- Results showed that low-sheared modeled microgravity (LSMMG) accelerated the expression of genes associated with the NFκB pathway, reinforcing previous findings that spaceflight could negatively impact innate immunity.



Hatchling of bobtail squid with the location of the symbiotic light organ depicted (white arrow).

Example of a high aspect-ratio vessel used to simulate LSMMG.

Plenty of Exciting Results and Interesting Trends,

- Study of mitochondrial dysregulation and metabolism changes from space (from model organisms to Twin Study).
- Epigenetics - animals, plants, and microbes.
- Understanding the effects of genetic diversity, sex-specific changes, multigenerational effects.
- Crops for the future; fundamental research of plant physiology, omics, cellular, and metabolic responses.
- Look to the future with research on CLDs (commercial LEO platforms) and Beyond LEO (Artemis, CLPS, Orion, and Gateway) –
  - Tissue chips & organoids
  - Model organisms
  - Plants
- Will continue to look at decadal recommended science and more ahead!

but….

➢ CHALLENGE: making things fit in a flat or declining budget environment!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Thank You!
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