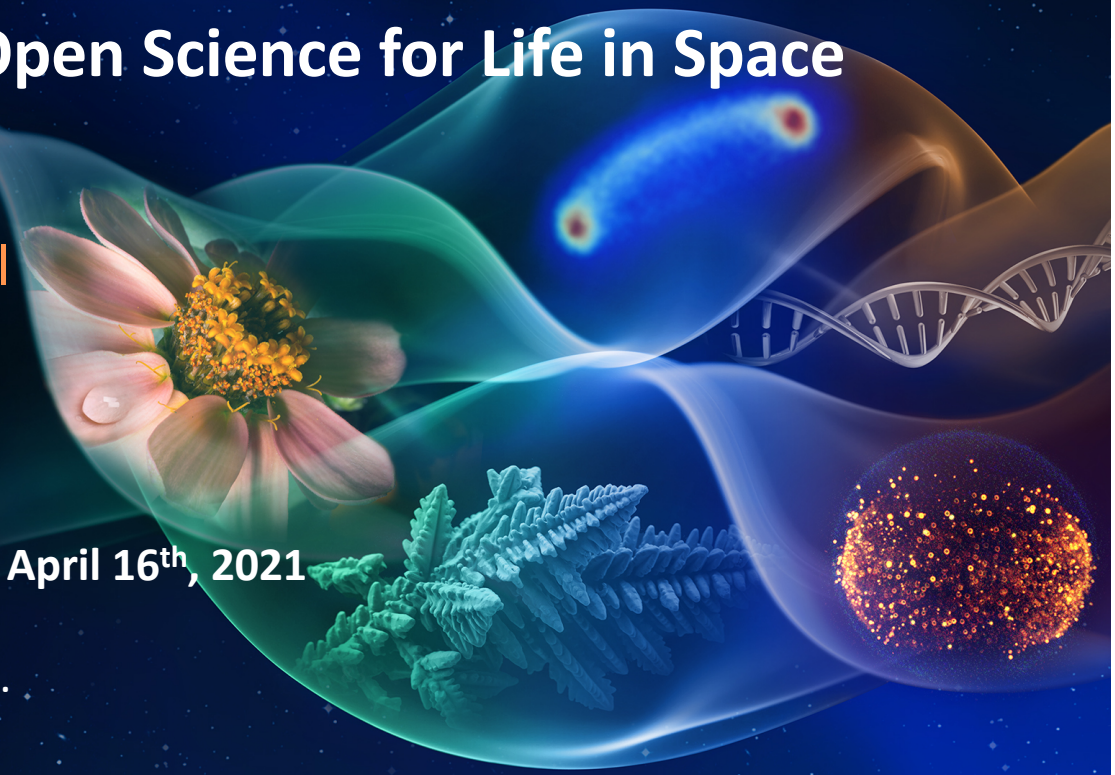
National Aeronautics and Space Administration

NASA GeneLab: Open Science for Life in Space

Biological and Physical Sciences



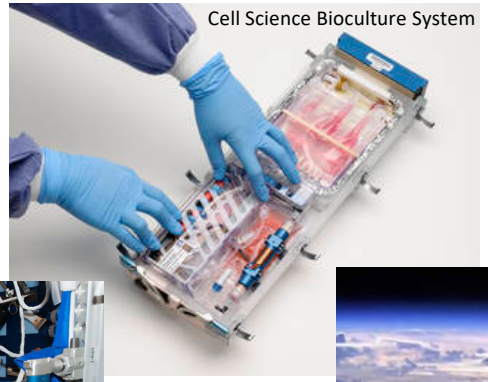
CA Space Grant Webinar Series April 16th, 2021

Amanda M. Saravia-Butler, Ph.D.
GeneLab Data Processing Lead
NASA Ames Research Center

NASA's Mission

Drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality and stewardship of Earth

https://www.nasa.gov/content/the-crawlers



Cell Science Bioculture System

NASA astronaut Christina Koch

https://www.nasa.gov/cygnss/overview

How does NASA achieve its Mission?

- **NASA HQ** – Provides overall guidance and direction to the Agency
- **NASA Centers and Facilities** – Where the day-to-day NASA work is performed in laboratories, airfields, wind tunnels, etc.
- NASA conducts its work though four main organizations called **Mission Directorates**:
  - Aeronautics Research (ARMD)

  - Human Exploration and Operations (HEOMD)

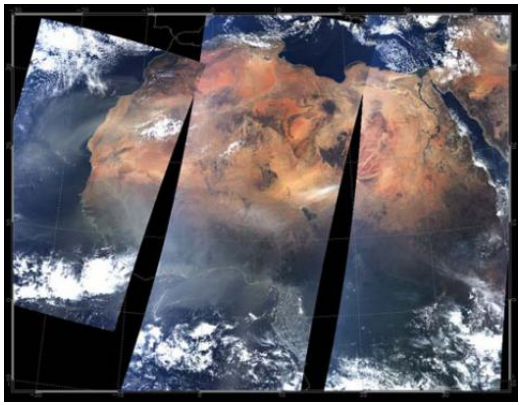
  - Science (SMD)

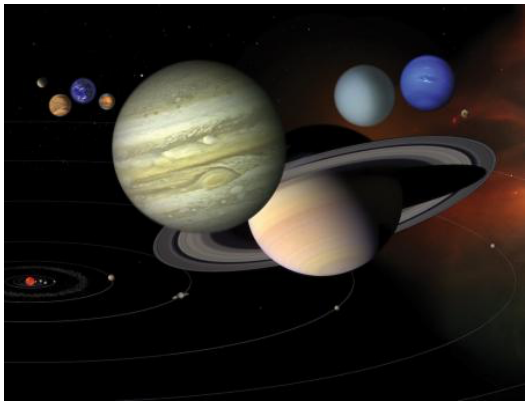
  - Space Technology (STMD)

https://www.nasa.gov/offices/olia/overview/index.html

NASA Science

Earth Science
The study of planet Earth

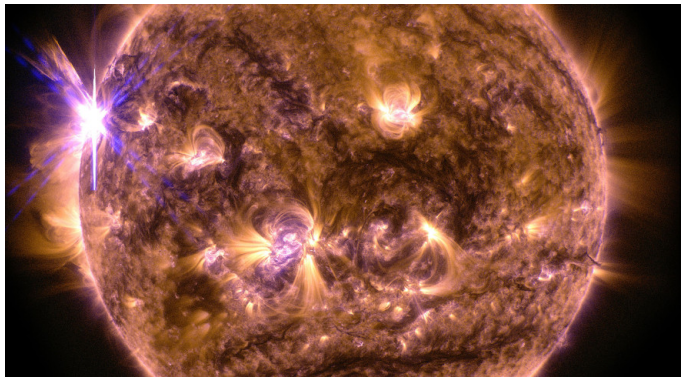




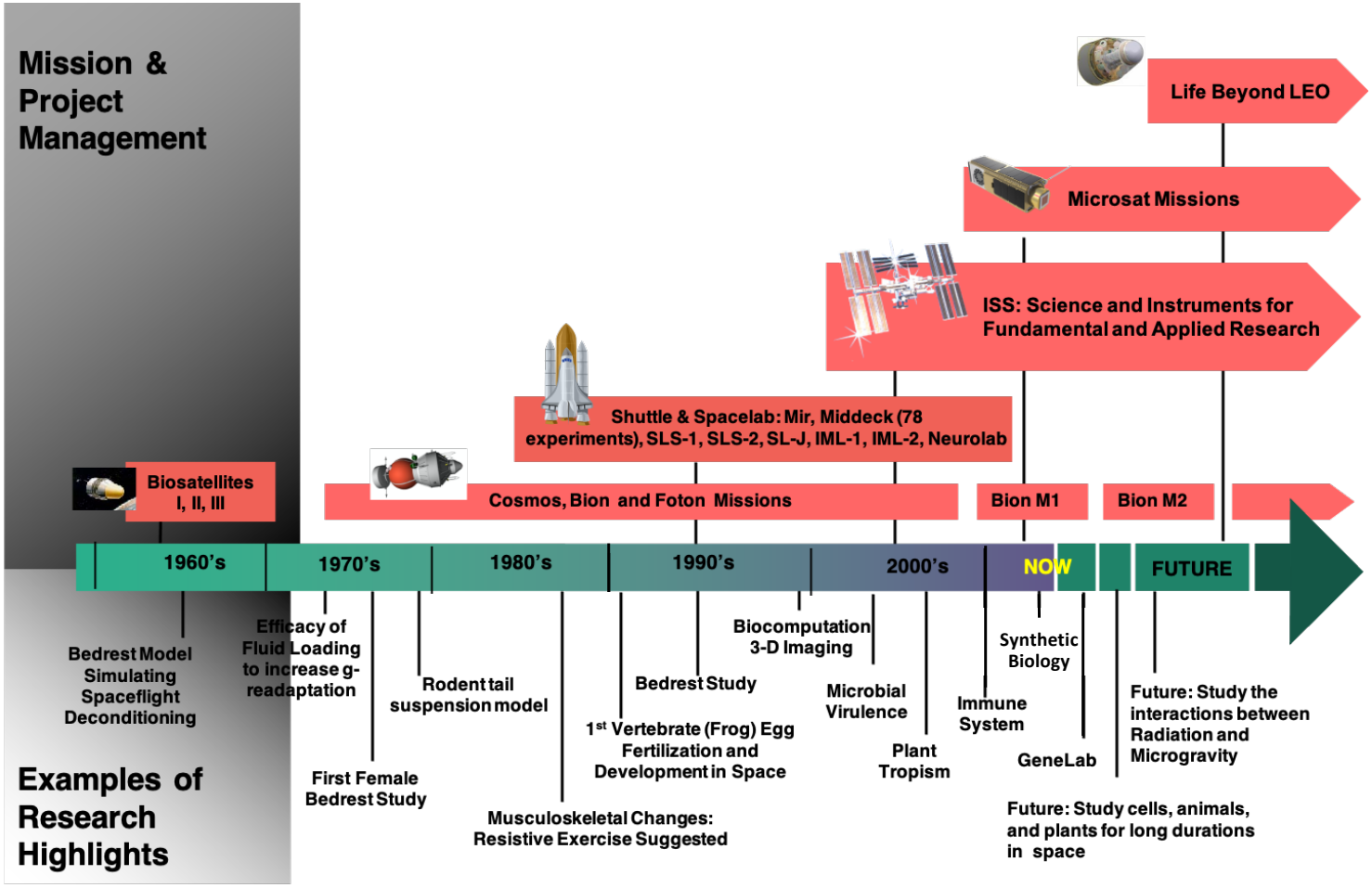
Planetary Science
the study of the origin and history of the solar system and the potential for extraterrestrial life

Astrophysics
The study of the origin, structure, evolution and destiny of the universe

Heliophysics
The study of the sun and its effects on the solar system



5+ Decades of NASA Life Sciences Research



Exposure to Spaceflight Changes our Physiological Systems

The Musculoskeletal System

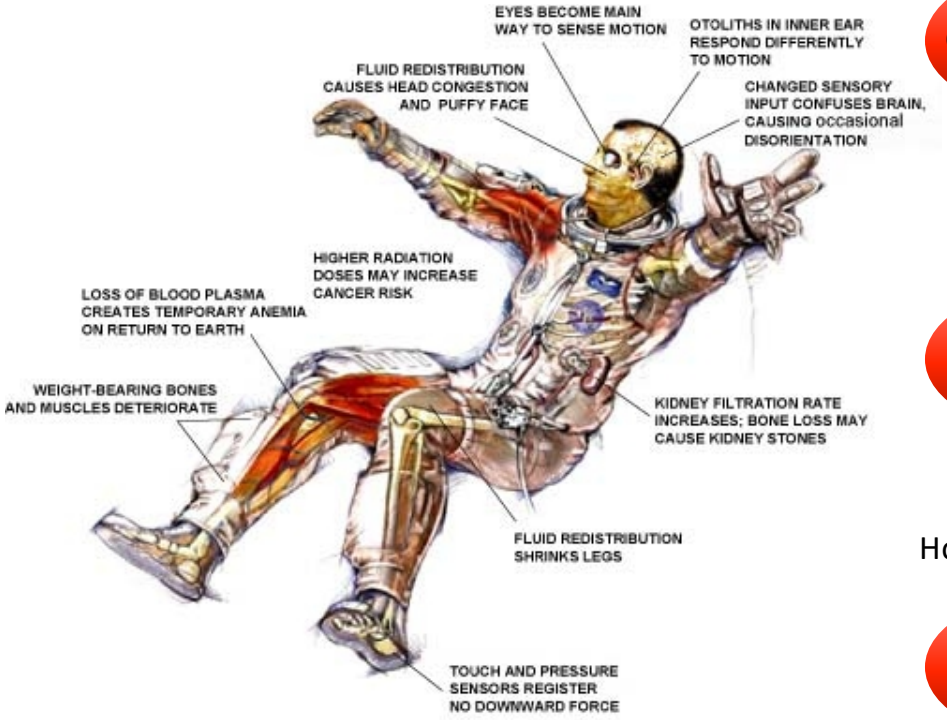
Osteoporosis
Osteoarthritis
Muscle atrophy

The Cardiovascular System

CVD
Atherosclerosis
Anemia

The Lymphatics

Lymphatic pump disorders



The Central Nervous System

Memory loss
Retinal edema

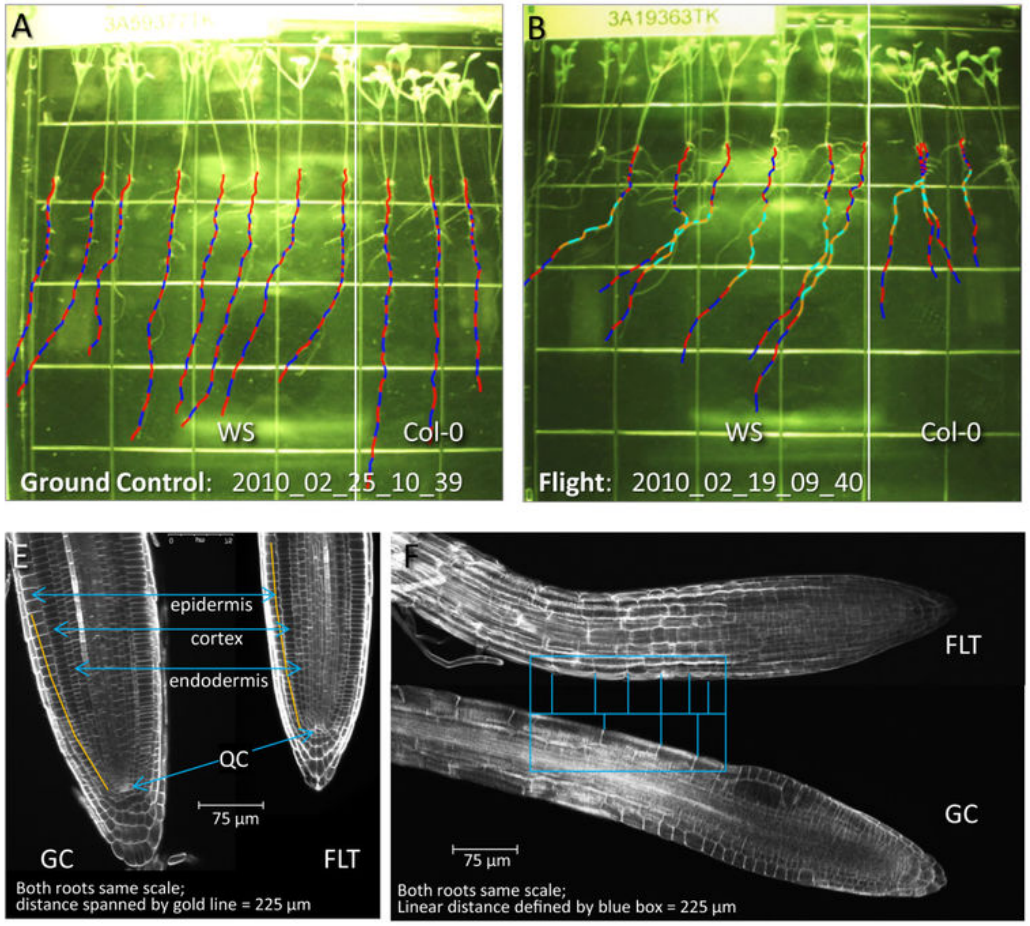
The Reproductive System

Sperm motility
Infertility
Hormonal imbalances

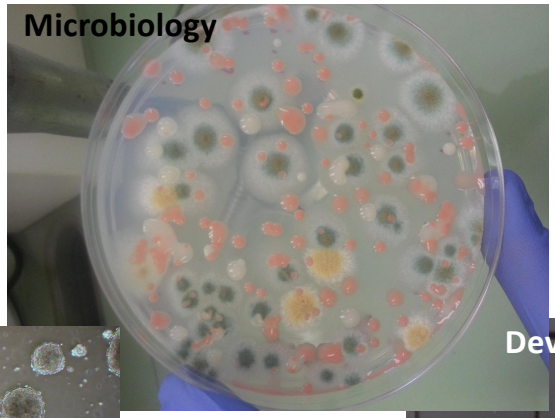
The Digestive System

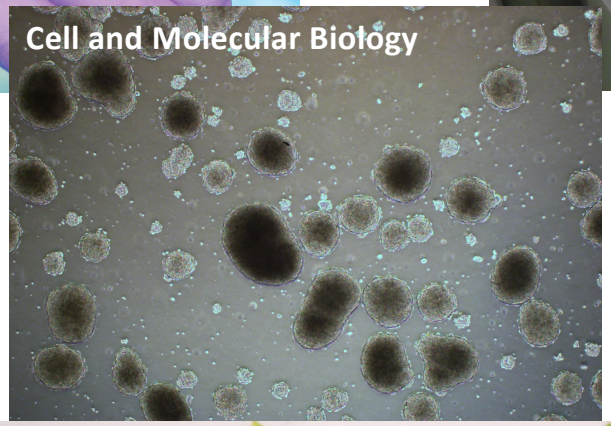
Liver fibrosis
NAFLD
IBS
Microbiome

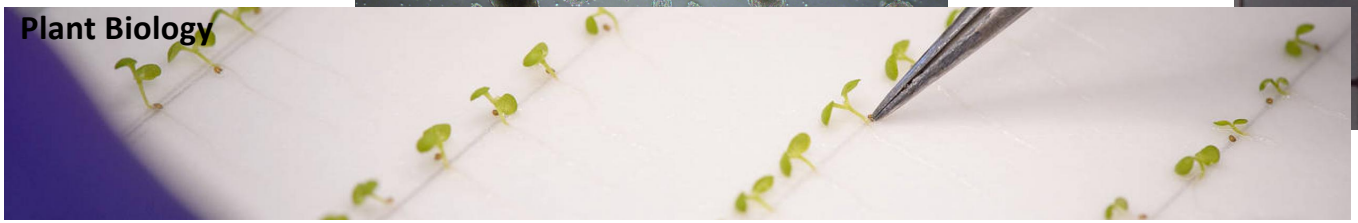
Exposure to Spaceflight Changes Plant Physiology Too



Space Biology Program



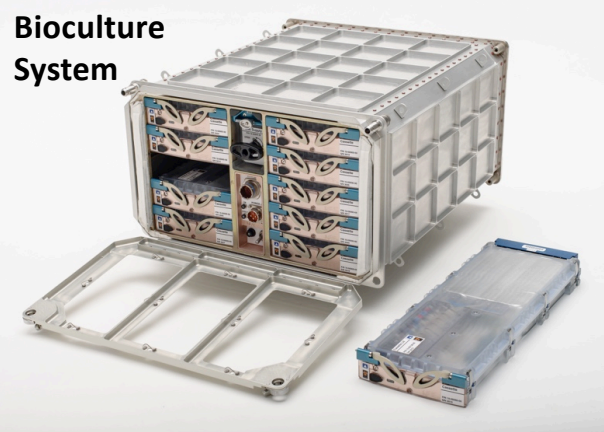




https://science.nasa.gov/biological-physical/programs/space-biology

Spaceflight Hardware: Cell Culture Systems

Bioculture System



CellCult

Spaceflight Hardware: Microbiology

Biological Research in Canisters (BRIC)

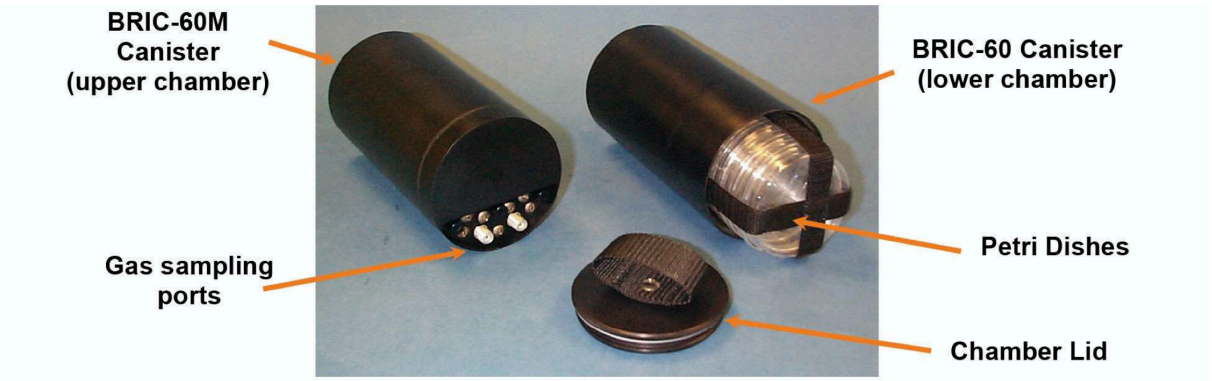


Fig. 1 BRIC-60 and BRIC-60M with petri dish configuration.

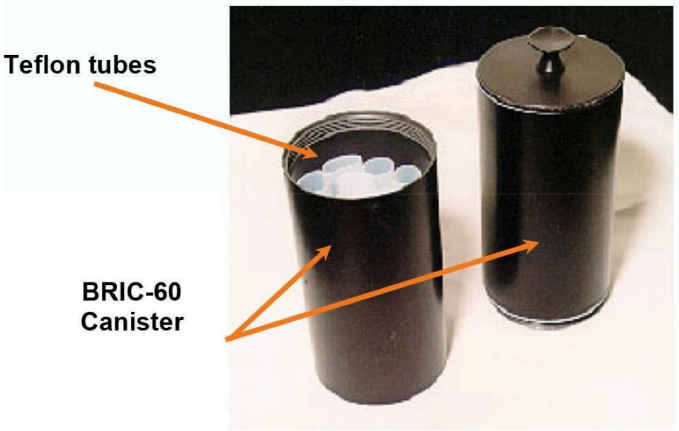
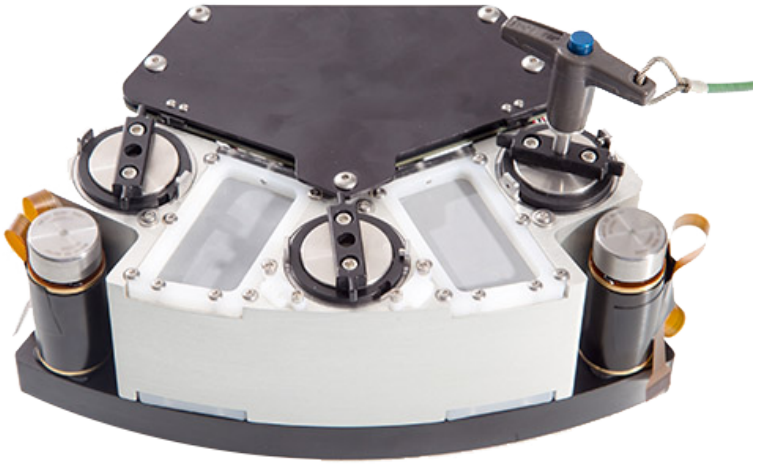


Fig. 2 BRIC-60 containing

Fig. 3 BRIC-60 Canisters as flown

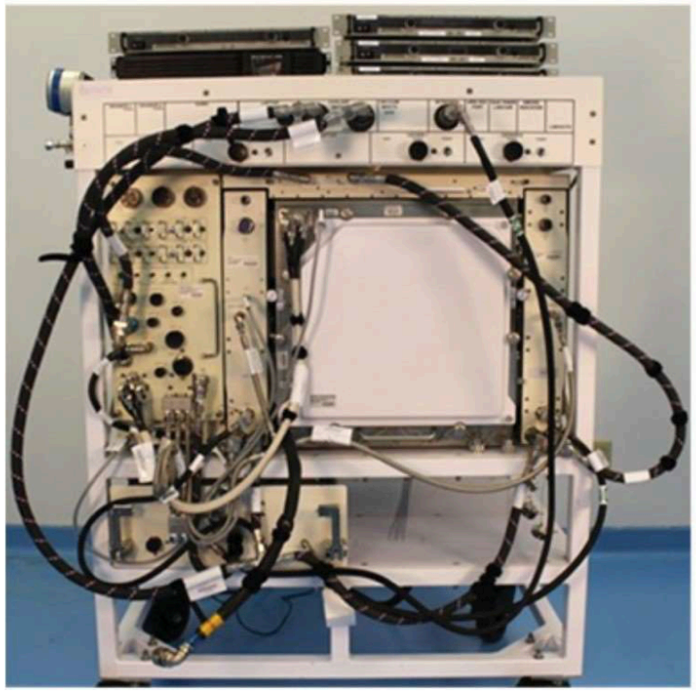
Spaceflight Hardware: Small Animals

Multi-use Variable gravity Platform (MVP)



Spaceflight Hardware: Plants

Advanced Plant Habitat



APH Flight Unit in Ground Support Equipment

Dwarf Wheat Growing in APH

Spaceflight Hardware: Plants

Veggie Habitat

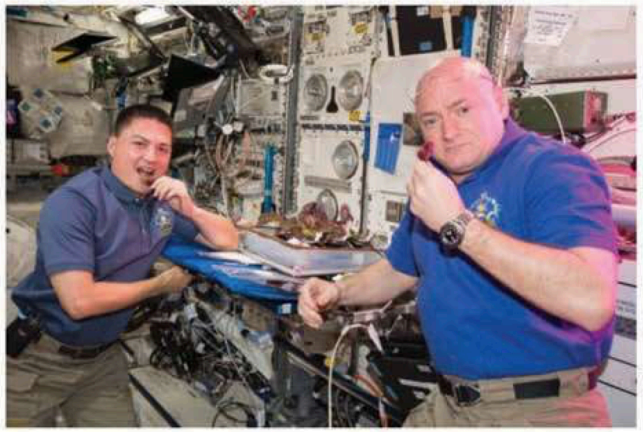
Veggie Configured for Growth of Lettuce

Veggie LED light bank.

Veggie plant pillow with quick disconnect fitting for adding water.

Veggie with 6 plant pillows contained within adjustable bellows.

Astronaut Steve Swanson harvesting lettuce grown on ISS.

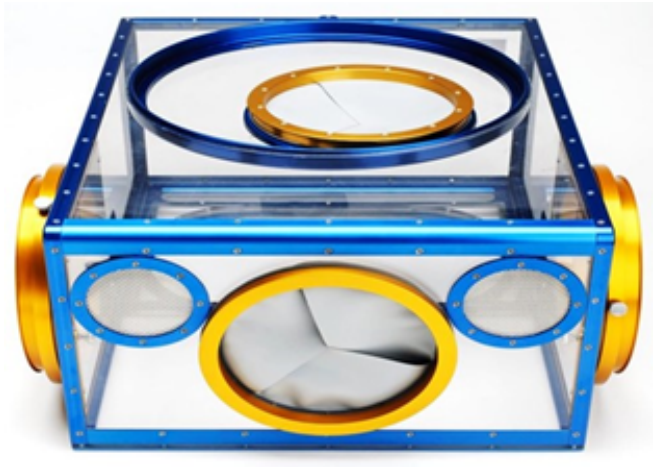


Astronauts Kjell Lindgren (left) and Scott Kelly (right) enjoying freshly harvested lettuce grown on ISS.

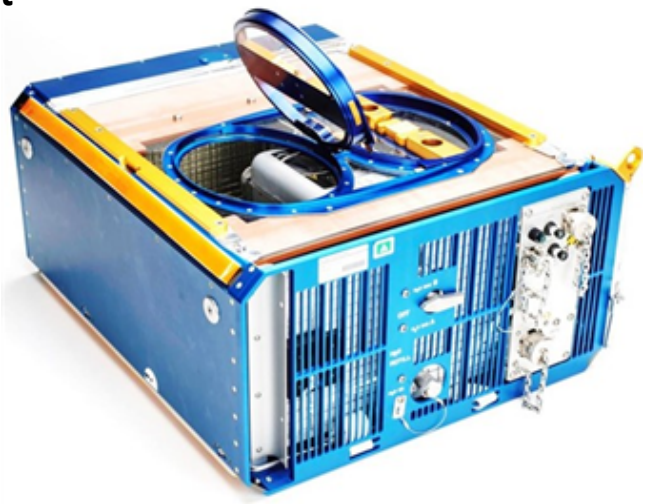
Astronaut Steve Swanson basking in the glow of Veggie.

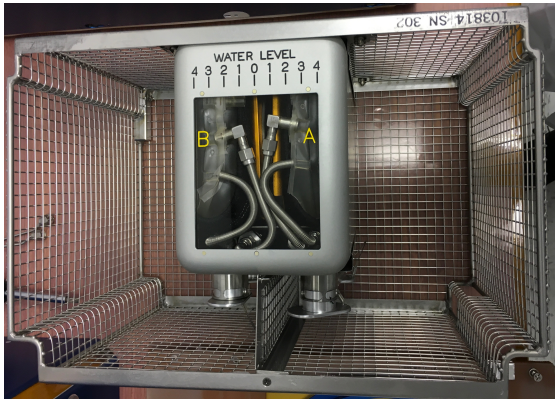
Spaceflight Hardware: Rodent Research

Animal Access Unit (AAU)

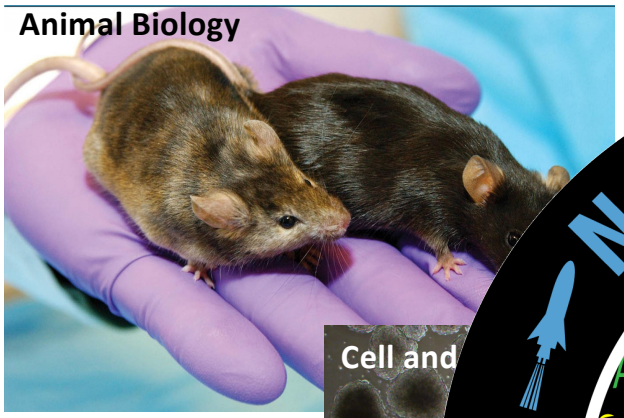


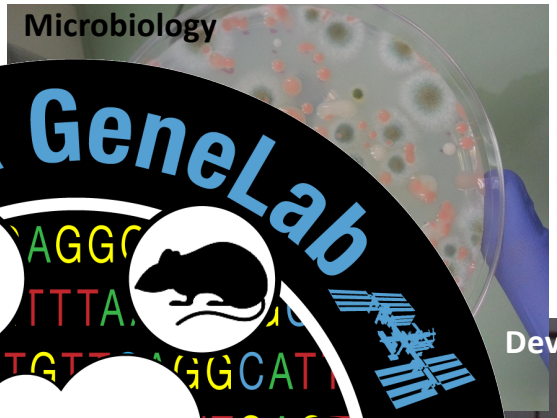
RR Habitat

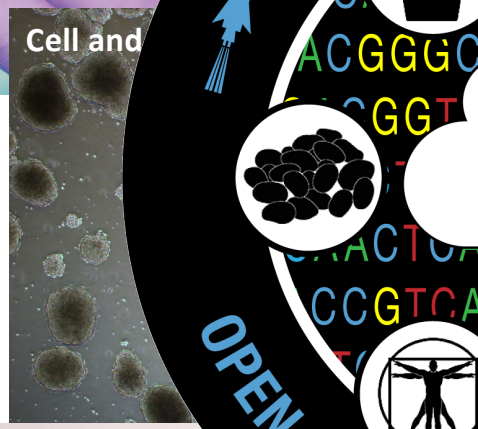




Space Biology Program

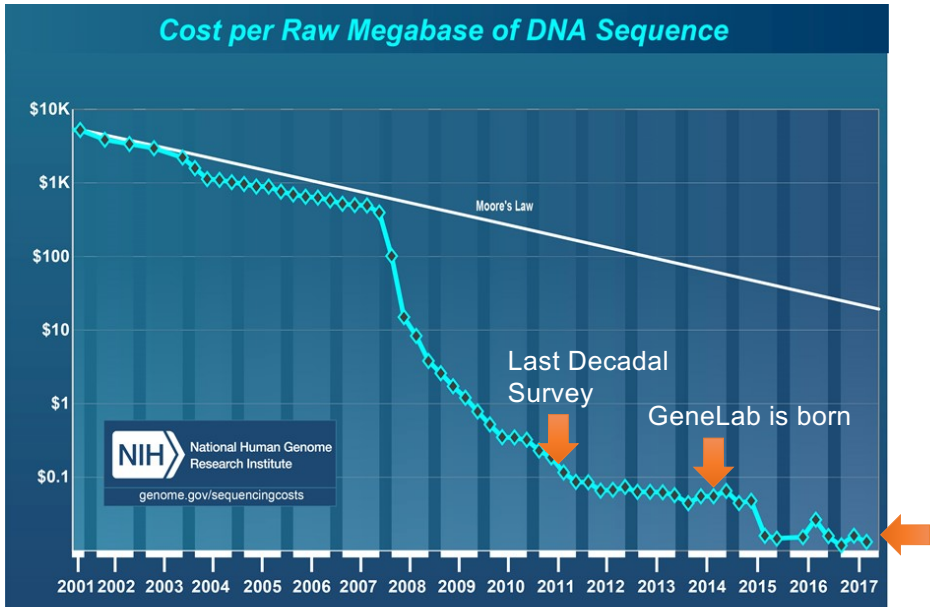


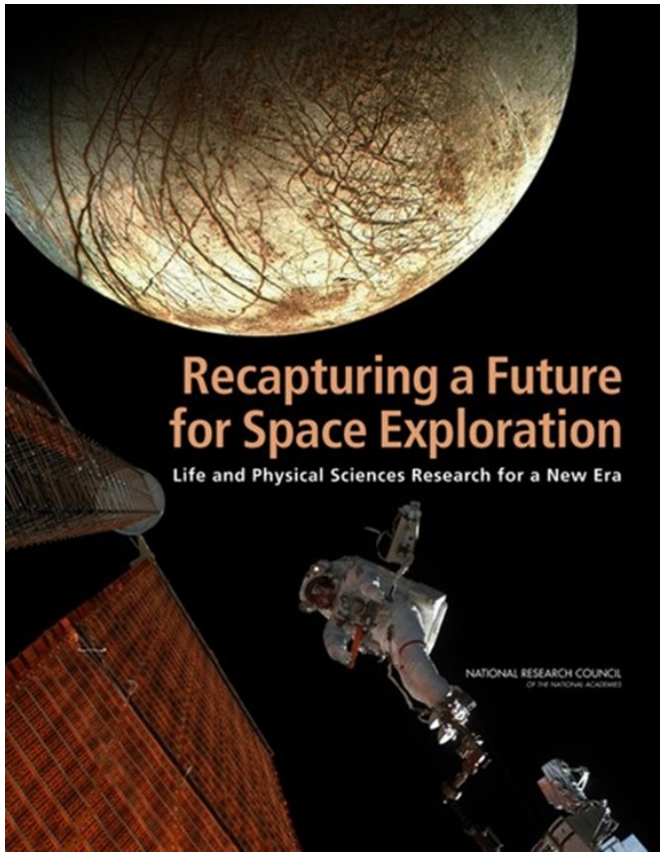




https://science.nasa.gov/biological-physical/programs/space-biology

2011 NRC Decadal Survey and the Sequencing Paradigm Shift

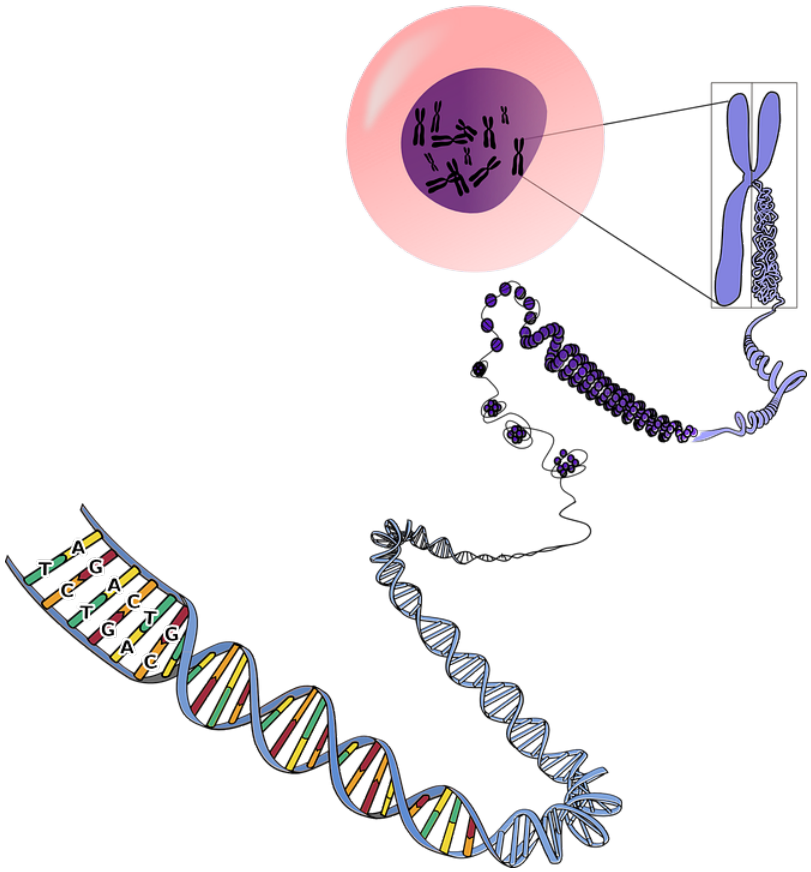


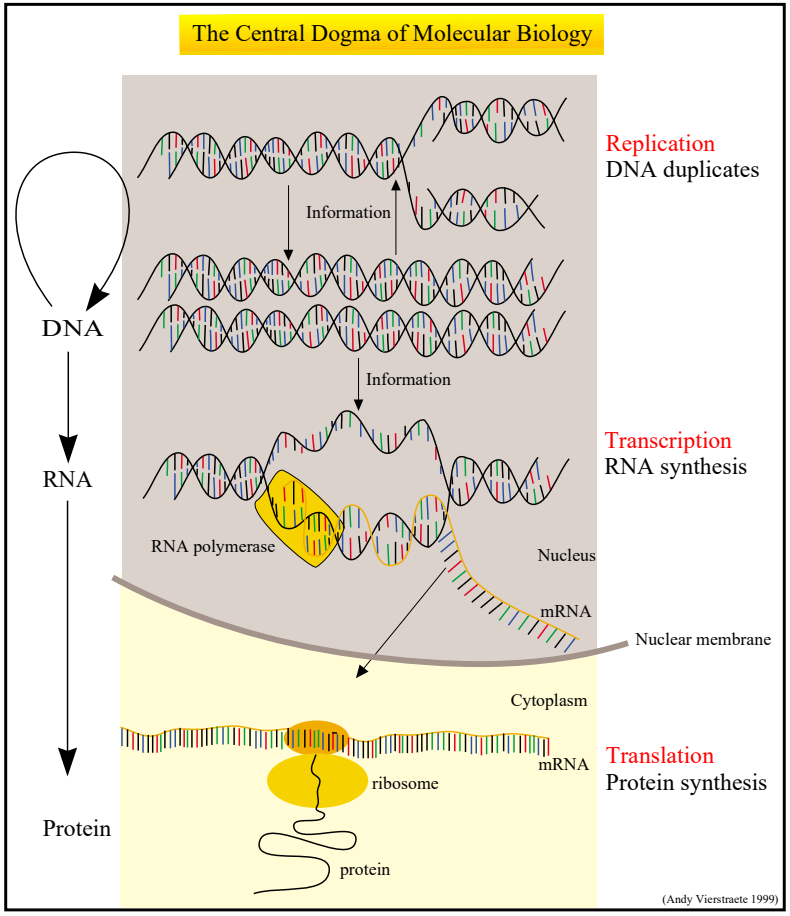


*"…**genomics, transcriptomics, proteomics, and metabolomics** offer an immense opportunity to understand the effects of spaceflight on biological systems…"*

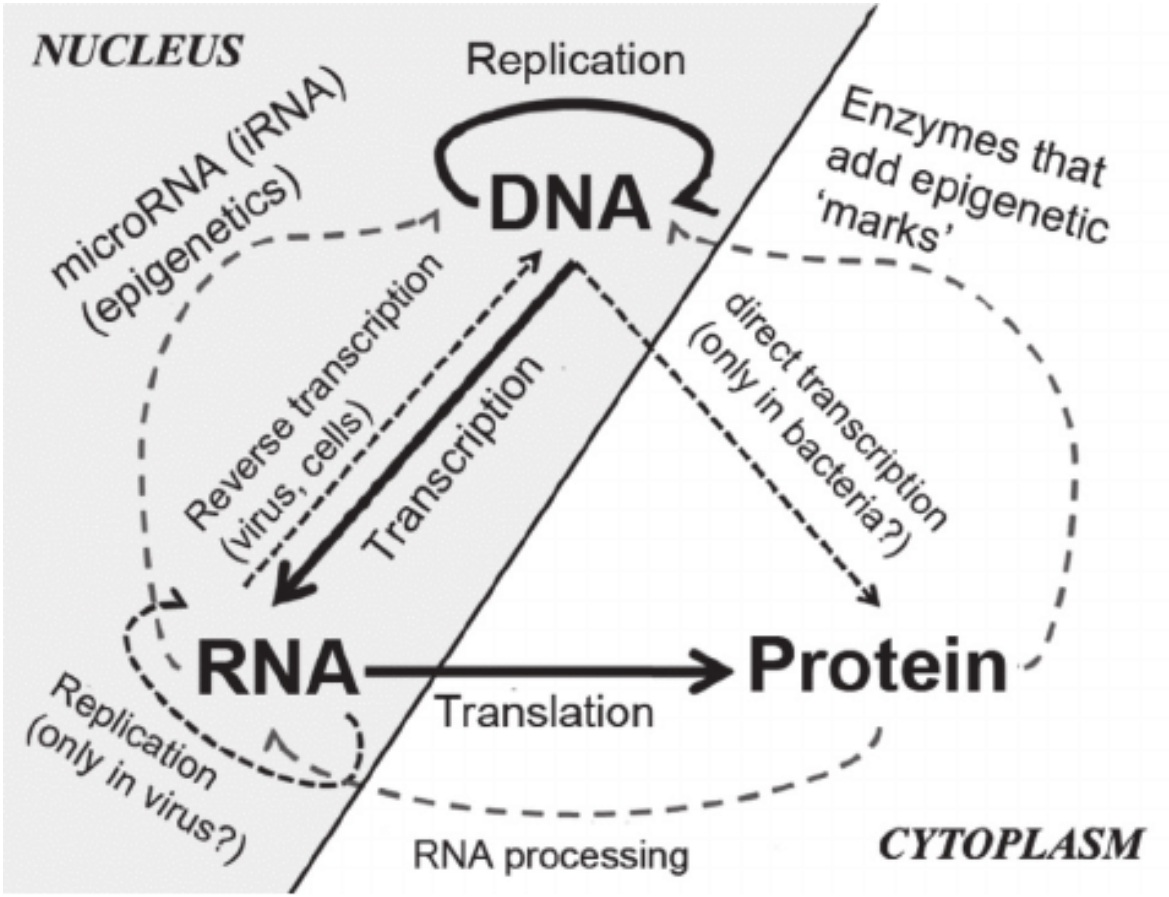
*"…Such techniques generate considerable amounts of **data that can be mined and analyzed** for information by multiple researchers…"*

What are ‘omics?



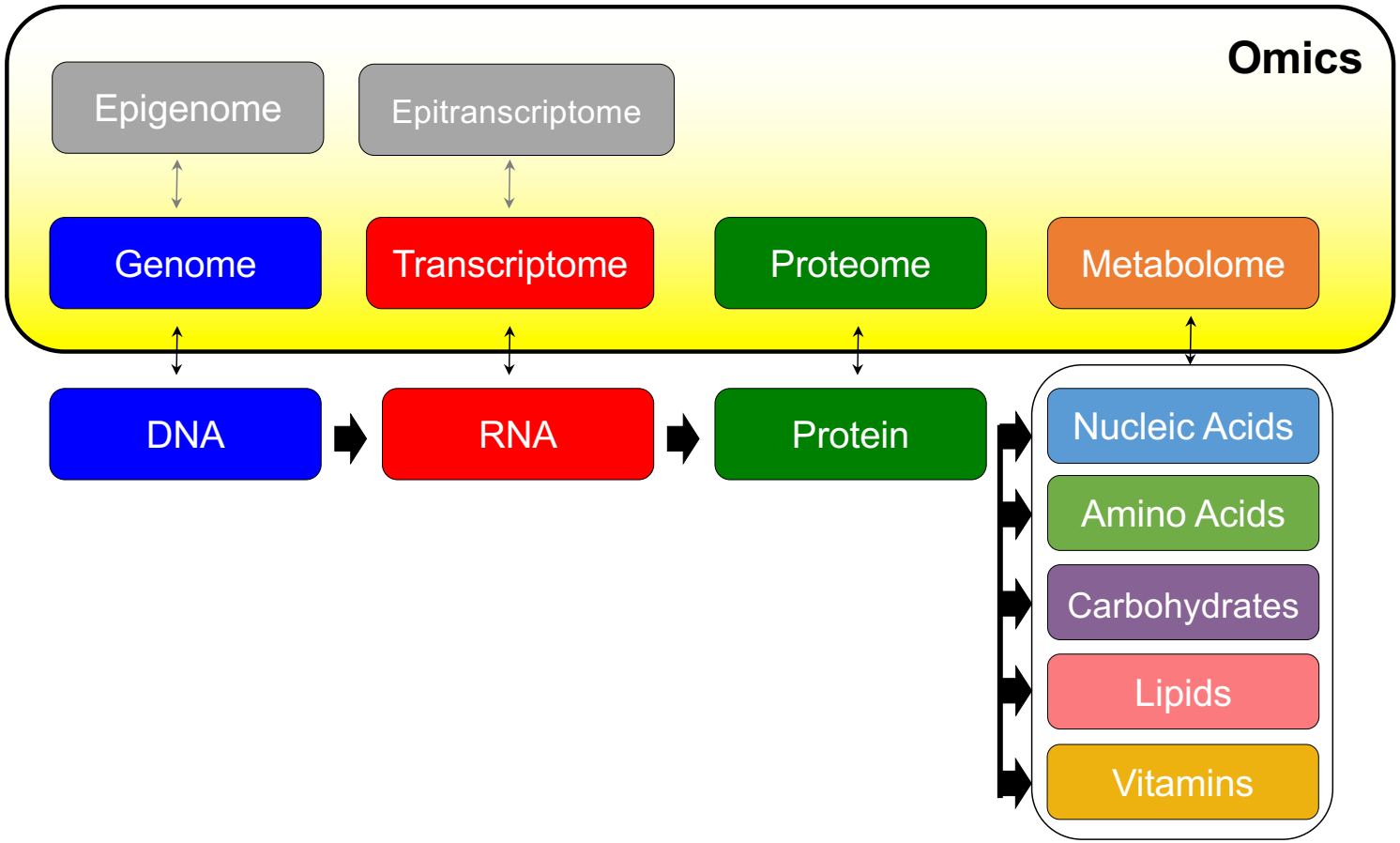


Beyond the Central Dogma



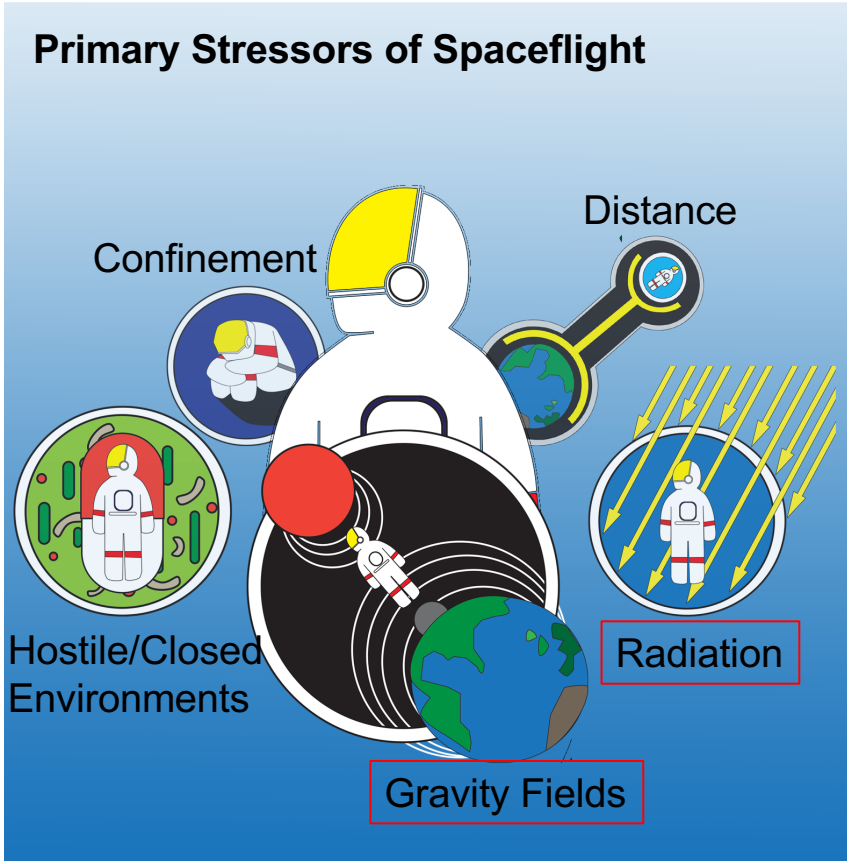
Gonzalez-Pardo and Alvarez, 2013

What are ‘omics?



Why is studying omics important for spaceflight?

- What, when, and where genes are expressed allow for cell type diversity and enable living organisms to respond and adapt to surroundings
- Gene expression is primarily regulated by environmental factors both micro (cell's micro-environment) and macro (organism's external stimuli or stressors)
- Spaceflight alters the transcriptional patterns and molecular signaling networks within our cells, which in turn causes physiological changes
- Understanding such changes will enable development of mitigation strategies to better withstand the rigors of long-duration spaceflight

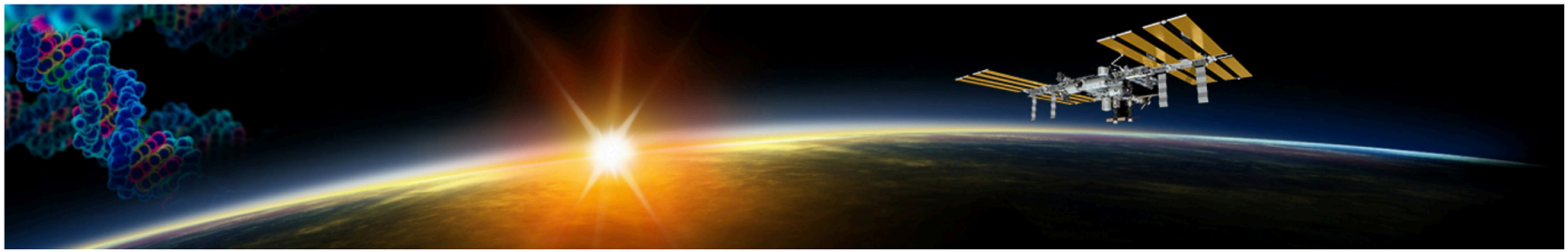


GeneLab: Open Science for Life in Space (https://genelab.nasa.gov)

Open Science for Life in Space

Home | About | Data & Tools | Research & Resources | Working Groups | Help

Keywords



Welcome to NASA GeneLab - the first comprehensive space-related omics database; users can upload, download, share, store, and analyze spaceflight and spaceflight-relevant data from experiments using model organisms.

Data Repository
Search and upload spaceflight datasets

Analyze Data
Perform large-scale analysis of biological omics data

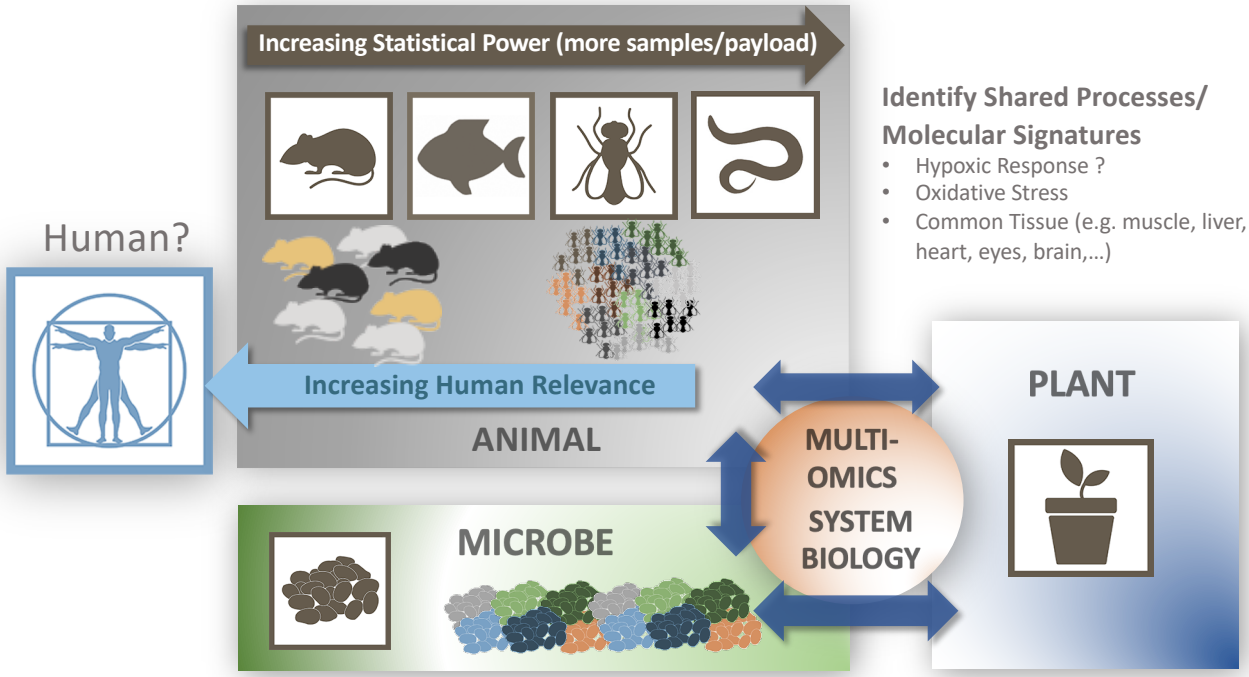
Environmental Data
Radiation data collected during experiments conducted in space

Collaborative Workspace
Share, organize and store files

Submit Data
Have space-relevant data to submit to GeneLab?

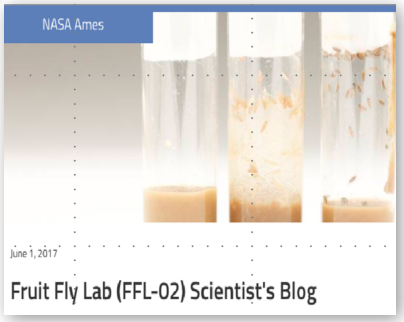
Visualize Data
Interact with GeneLab processed data

GeneLab ecosystem: Maximizing knowledge by bringing experiments together



Identify Shared Processes/ Molecular Signatures

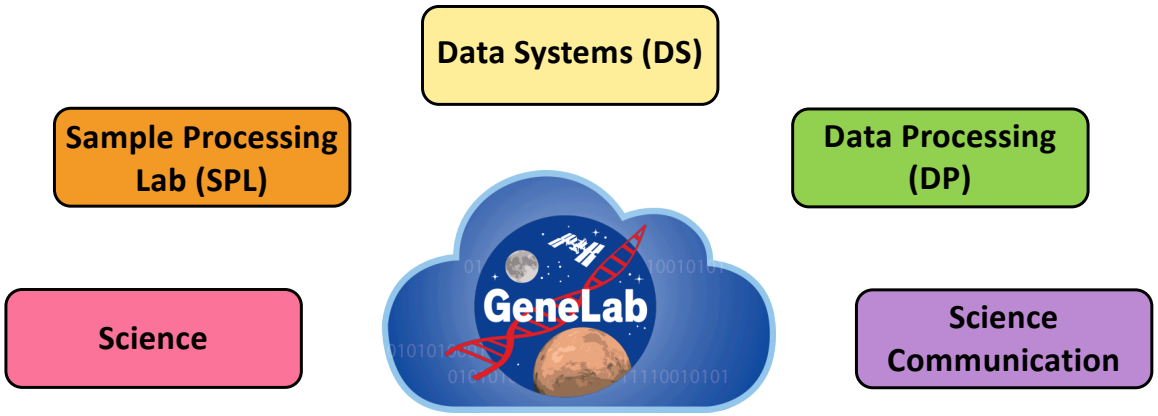
- Hypoxic Response ?
- Oxidative Stress
- Common Tissue (e.g. muscle, liver, heart, eyes, brain,…)

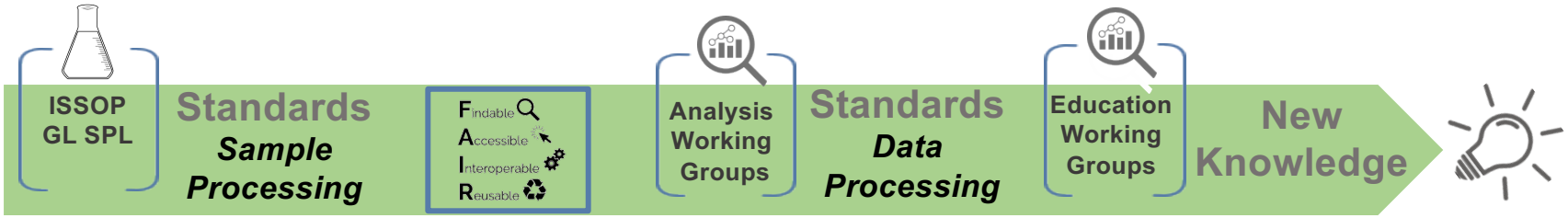


For Spaceflight

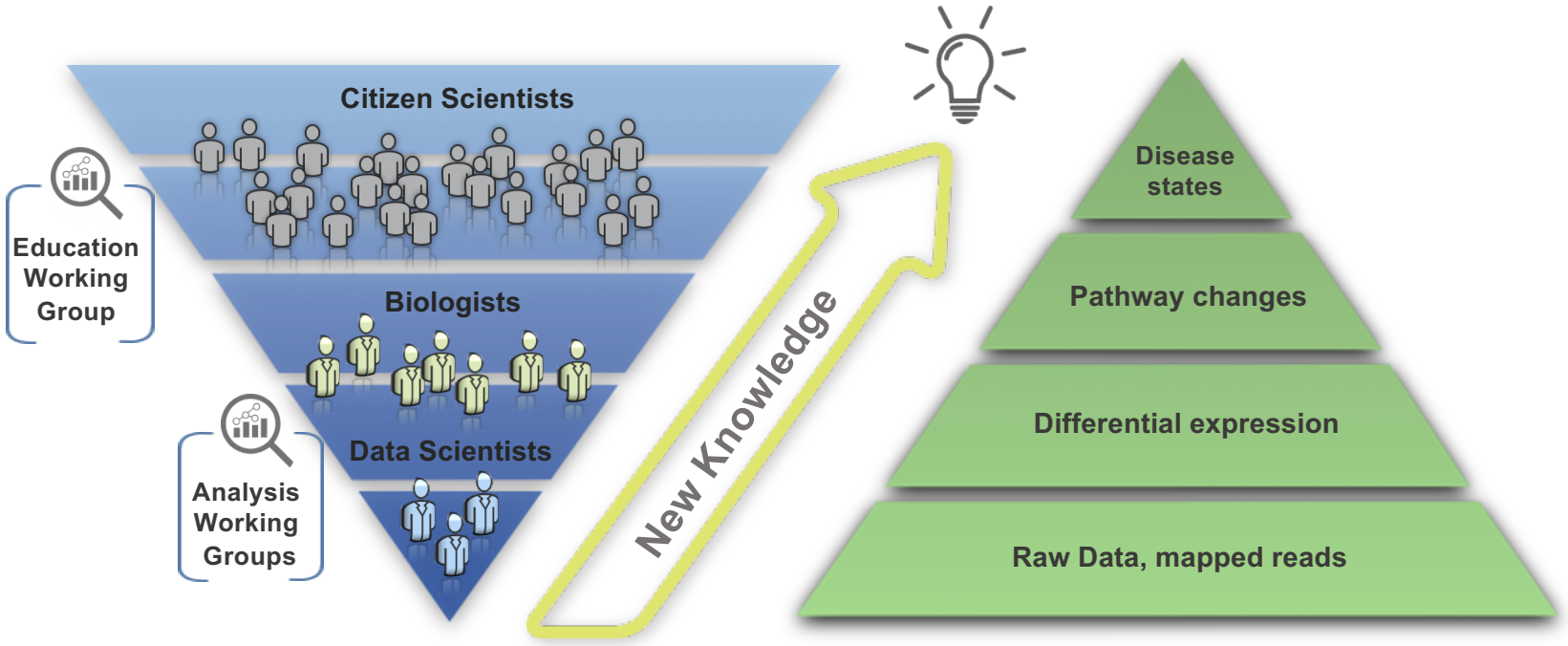
- High "n" number – statistically significant data
- Genetically identical animals
- Low resource requirements
- Short life cycle - multiple generations
- Measure response of a whole multicellular animal
- **Flies used as a model for humans for innate immunity, circadian rhythm, oxidative stress, neurobehavior, development, genetics, GWAS, "omics" studies etc**

GeneLab Teams

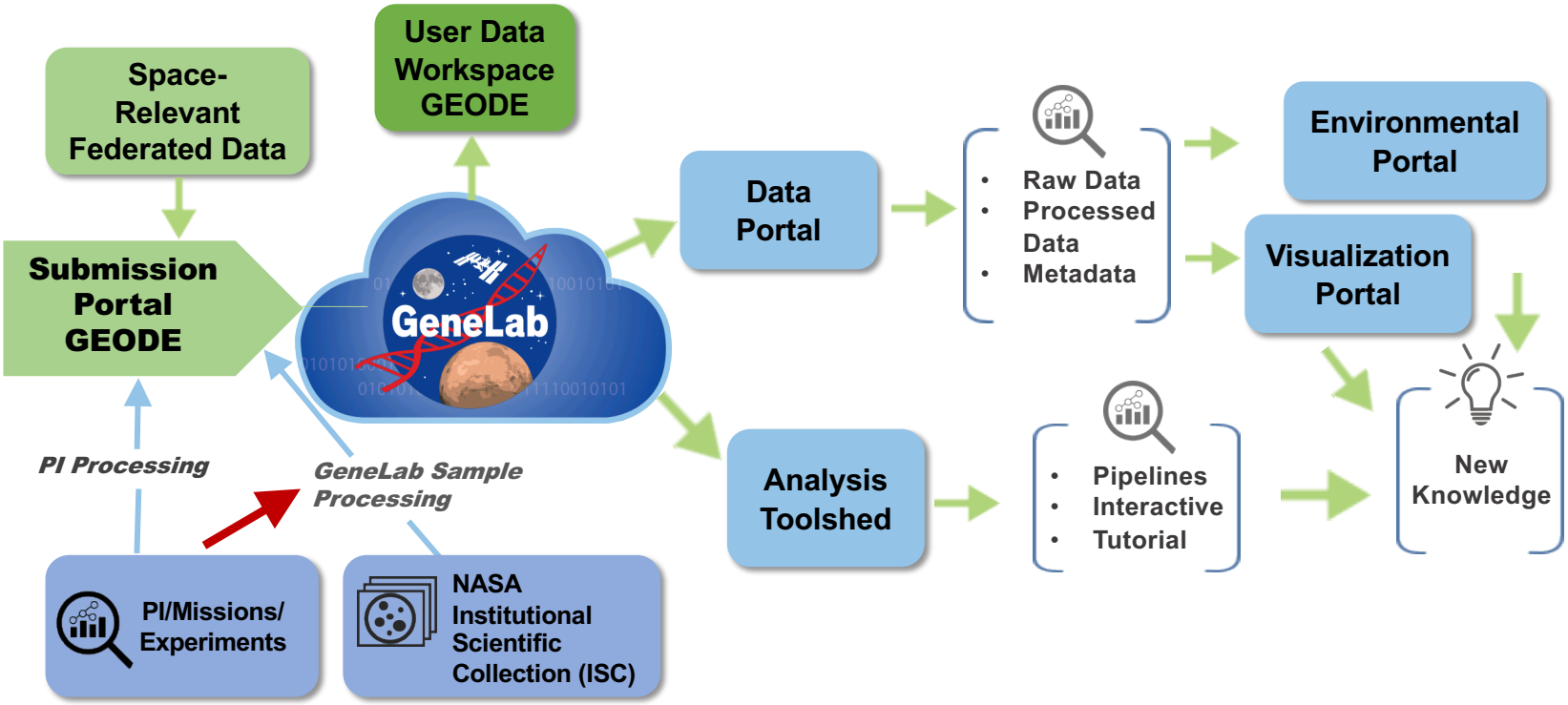




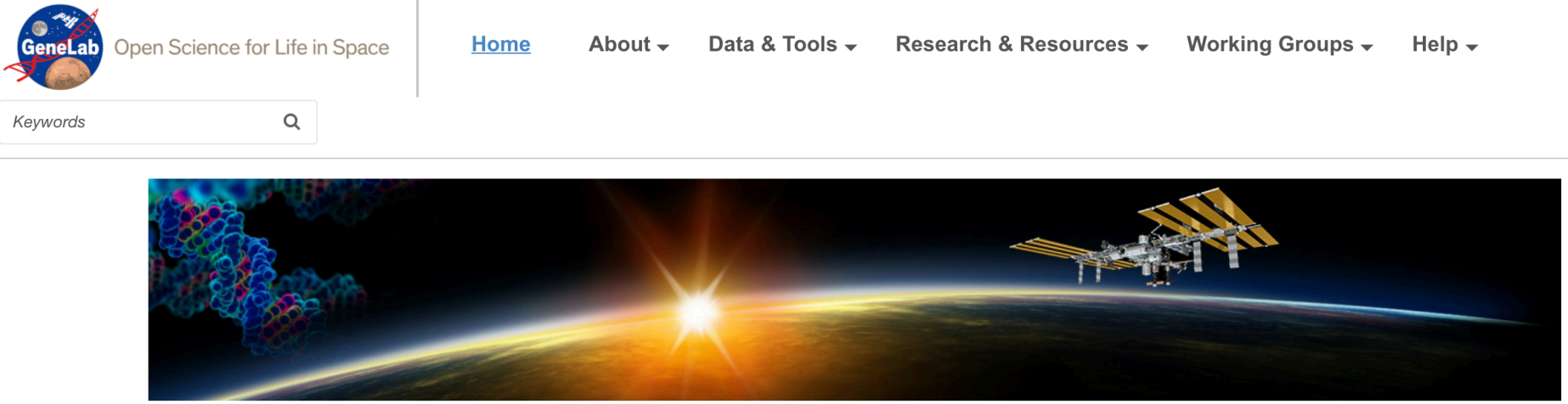
GeneLab Data Democratization



GeneLab Data System



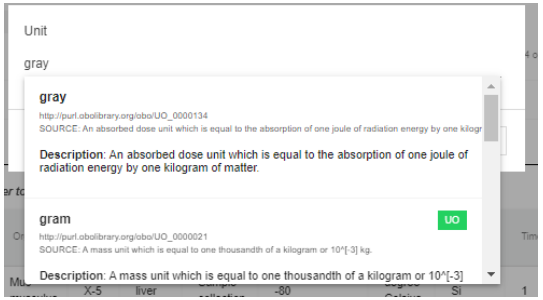
GeneLab: Submission Portal – GEODE (https://genelab.nasa.gov)



GeneLab Environment for Online Data Entry (GEODE)

Sample Name	Organism	Strain	Material Type	Protocol REF	Parameter Value - Storage Temperature Setting	Unit	Ionizing Radiation	Time	Unit	Dose	Unit
Sample1	Mus musculus	X-5	liver	Sample collection	-80	degree Celsius	Silicon	1	hour	1	gray
Sample2	Mus musculus	X-5	liver	Sample collection	-80	degree Celsius	Sham-irradiated	0	hour	0	gray
Sample3	Mus musculus	X-5	liver	Sample collection	-80	degree Celsius	Iron-56 Ion Irradiation	24	hour	2	gray
Sample4	Mus musculus	X-5	liver	Sample collection	-80	degree Celsius	Silicon	12	hour	3	gray
Sample5	Mus musculus	X-5	liver	Sample collection	-80	degree Celsius	Sham-irradiated	0	hour	0	gray
Sample6	Mus musculus	X-5	liver	Sample collection	-80	degree Celsius	Iron-56 Ion Irradiation	12	hour	2	gray

Sample level data

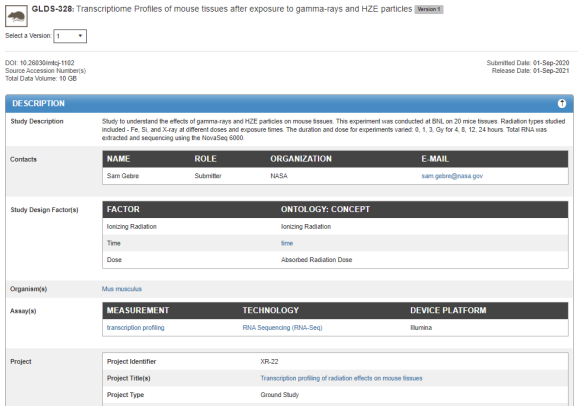


Terms are connected to a controlled ontology

- Space Biology PIs can now submit data through GEODE.
- Allows efficient input of sample and assay level metadata alongside data files.
- Tailored to specialized needs of spaceflight samples.
- Now exploring extending this portal for use on ALSDA submissions.

Sample Name	Protocol REF	Parameter Value - QA Instrument	Parameter Value - QA Assay	Parameter Value - QA Score	Unit	Extract Name	Protocol REF
Sample1	Nucleic Acid Extraction	BioAnalyzer	NanoChip	8	RIN	Extract 1	Library Construction
Sample2	Nucleic Acid Extraction	BioAnalyzer	NanoChip	9	RIN	Extract 2	Library Construction
Sample3	Nucleic Acid Extraction	BioAnalyzer	NanoChip	9.1	RIN	Extract 3	Library Construction

Assay level data with fields specific to that assay



PIs are presented with a study preview and a private link for sharing with reviewers and collaborators.

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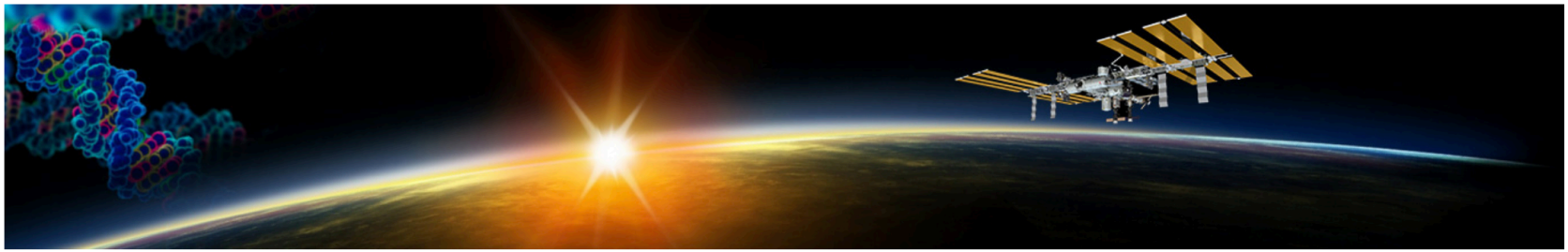
Keywords



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NASA

Search Data

All | GeneLab | NIH GEO | EBI PRIDE | ANL MG-RAST

Search Filters (GeneLab Only)

Project Type | Factors | Organisms | Assay Type | Clear

Show Only:

Studies With Visualizations

Page 1 of 12 (Total Studies: 278) Next >

Studies Per Page: 25

GLDS-322

Comparative RNA-Seq transcriptome analyses reveal dynamic time dependent effects of 56Fe, 16O, and 28Si irradiation on the induction of murine hepatocellular carcinoma

Organisms	Factors	Assay Types	Release Date	Description
Mus musculus	Ionizing Radiation Time	transcription profiling	27-Aug-2020	One of the health risks posed to astronauts during deep space flights is exposure to high charge, high-energy (HZE) ions (Z>13) which can lead to induction of hepatocellular carcinoma (HCC). We perfor...

GLDS-320

Gamma radiation and HZE treatment of seedlings in Arabidopsis

Organisms	Factors	Assay Types	Release Date	Description
Arabidopsis thaliana	Genotype Time of sample collection after treatment Ionizing Radiation	transcription profiling	18-Sep-2014	Plants exhibit a robust transcriptional response to gamma radiation which includes the induction of transcripts required for homologous recombination and the suppression of transcripts that promote ce...

GeneLab: Data Repository

GLDS-137

Version 4

- DESCRIPTION
- PROTOCOLS
- SAMPLES
- ASSAYS
- PUBLICATIONS
- STUDY FILES
- VISUALIZATION

Search Data

GLDS-137: Rodent Research-3-CASIS: Mouse liver transcriptomic, proteomic, and epigenomic data Version 4

Select a Version: 4

DOI: 10.26030/9k6w-4c28
Source Accession Number
Total Data Volume: 2.5 TB

Submitted Date: 04-Aug-2017
Release Date: 28-Aug-2017

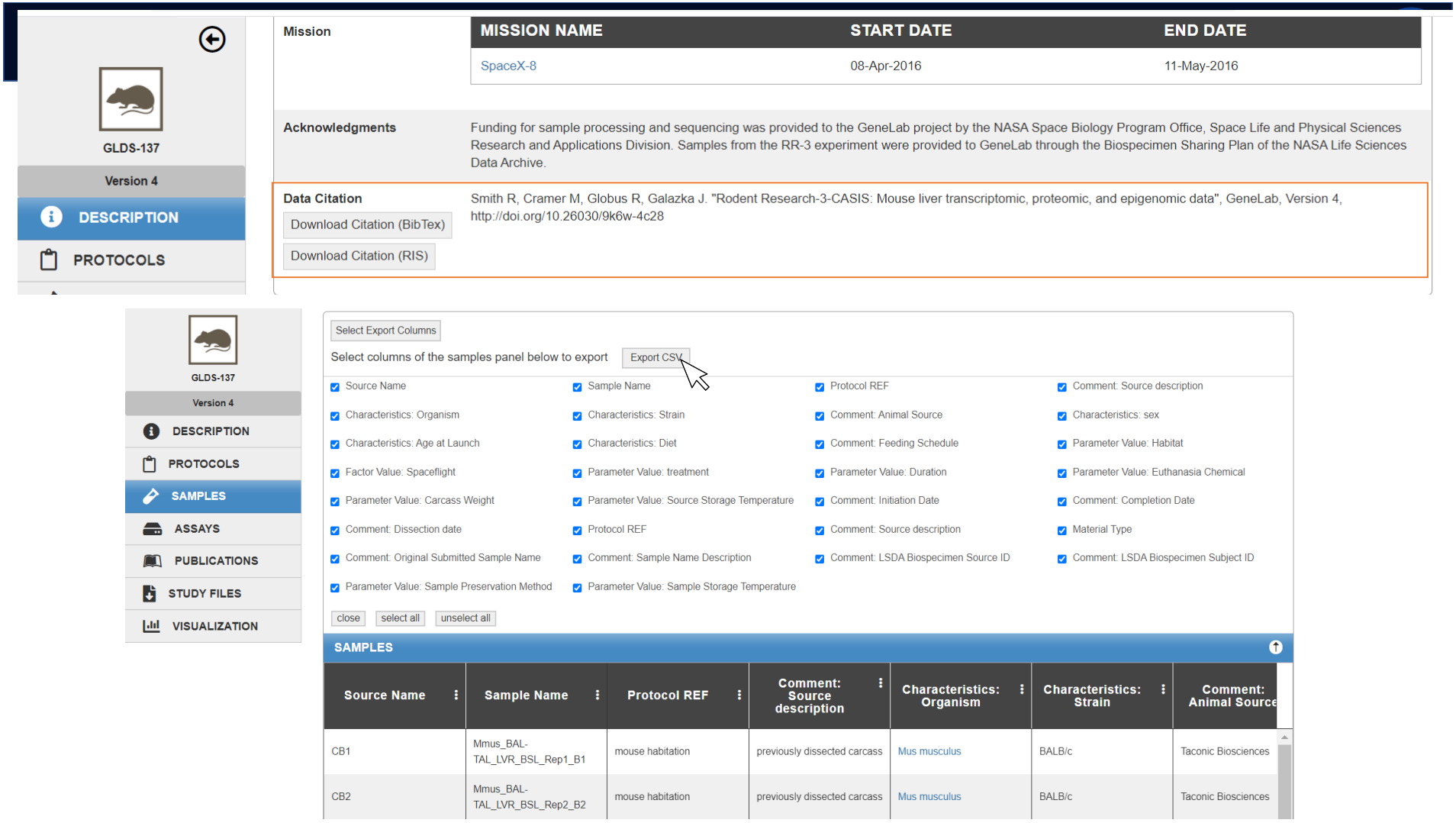
DESCRIPTION

Study Description

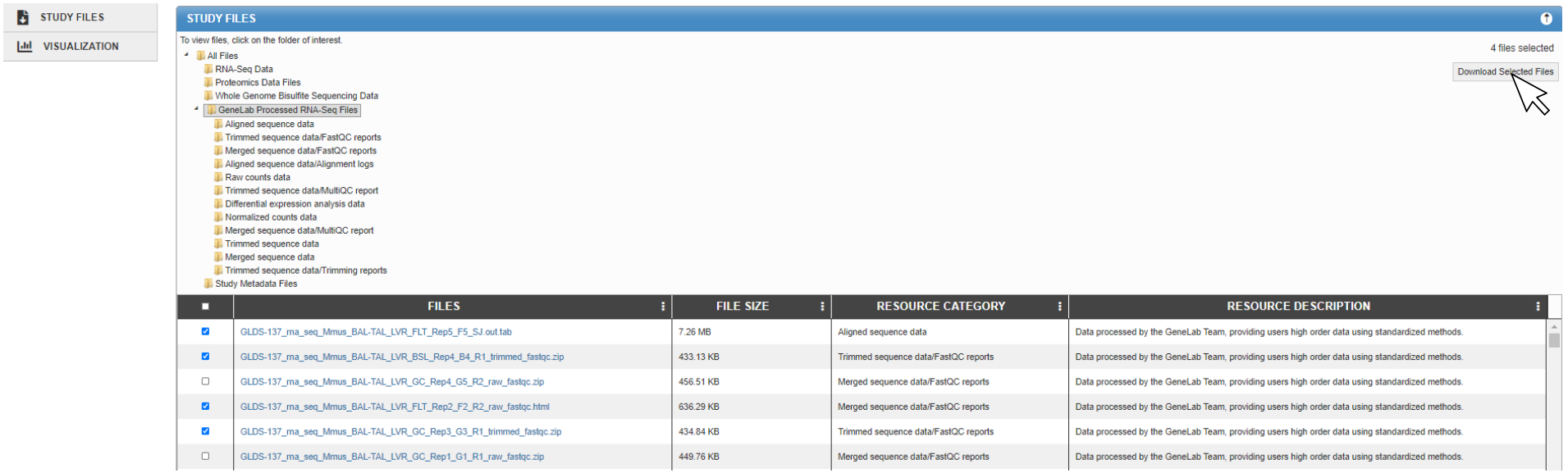
The Rodent Research-3 (RR-3) mission was sponsored by the pharmaceutical company Eli Lilly and Co. and the Center for the Advancement of Science in Space to study the effectiveness of a potential countermeasure for the loss of muscle and bone mass that occurs during spaceflight. Twenty BALB/c, 18-weeks old female mice (ten controls and ten treated) were flown to the ISS and housed in the Rodent Habitat for 39-42 days. Twenty mice of similar age, sex and strain were used for ground controls housed in identical hardware and matching ISS environmental conditions. Basal controls were housed in standard vivarium cages. Spaceflight, ground controls and basal groups had blood collected, then were euthanized, had one hind limb removed, and finally whole carcasses were stored at -80 C until dissection. All mice in this data set received only the control/sham injection.

Contacts

NAME	ROLE	ORGANIZATION	E-MAIL
Ruth Globus	Project Scientist	NASA Ames Research Center	ruth.k.globus@nasa.gov
Jonathan Galazka	Project Scientist	NASA GeneLab	jonathan.m.galazka@nasa.gov
Rosamund Smith	Principal Investigator	Eli Lilly and Company	

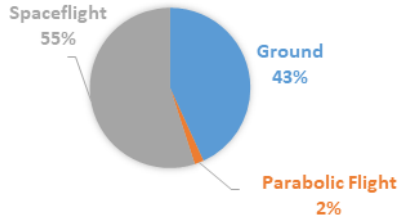

GLDS-137
Version 4
DESCRIPTION
PROTOCOLS
Mission
MISSION NAME
START DATE
END DATE
SpaceX-8
08-Apr-2016
11-May-2016
Acknowledgments
Funding for sample processing and sequencing was provided to the GeneLab project by the NASA Space Biology Program Office, Space Life and Physical Sciences Research and Applications Division. Samples from the RR-3 experiment were provided to GeneLab through the Biospecimen Sharing Plan of the NASA Life Sciences Data Archive.
Data Citation
Download Citation (BibTex)
Download Citation (RIS)
Smith R, Cramer M, Globus R, Galazka J. "Rodent Research-3-CASIS: Mouse liver transcriptomic, proteomic, and epigenomic data", GeneLab, Version 4, http://doi.org/10.26030/9k6w-4c28
GLDS-137
Version 4
DESCRIPTION
PROTOCOLS
SAMPLES
ASSAYS
PUBLICATIONS
STUDY FILES
VISUALIZATION
Select Export Columns
Select columns of the samples panel below to export
Export CSV
Source Name
Sample Name
Protocol REF
Comment: Source description
Characteristics: Organism
Characteristics: Strain
Comment: Animal Source
Characteristics: sex
Characteristics: Age at Launch
Characteristics: Diet
Comment: Feeding Schedule
Parameter Value: Habitat
Factor Value: Spaceflight
Parameter Value: treatment
Parameter Value: Duration
Parameter Value: Euthanasia Chemical
Parameter Value: Carcass Weight
Parameter Value: Source Storage Temperature
Comment: Initiation Date
Comment: Completion Date
Comment: Dissection date
Protocol REF
Comment: Source description
Material Type
Comment: Original Submitted Sample Name
Comment: Sample Name Description
Comment: LSDA Biospecimen Source ID
Comment: LSDA Biospecimen Subject ID
Parameter Value: Sample Preservation Method
Parameter Value: Sample Storage Temperature
close
select all
unselect all
SAMPLES
Source Name
Sample Name
Protocol REF
Comment: Source description
Characteristics: Organism
Characteristics: Strain
Comment: Animal Source
CB1
Mmus_BAL-TAL_LVR_BSL_Rep1_B1
mouse habitation
previously dissected carcass
Mus musculus
BALB/c
Taconic Biosciences
CB2
Mmus_BAL-TAL_LVR_BSL_Rep2_B2
mouse habitation
previously dissected carcass
Mus musculus
BALB/c
Taconic Biosciences

GeneLab: Data Repository

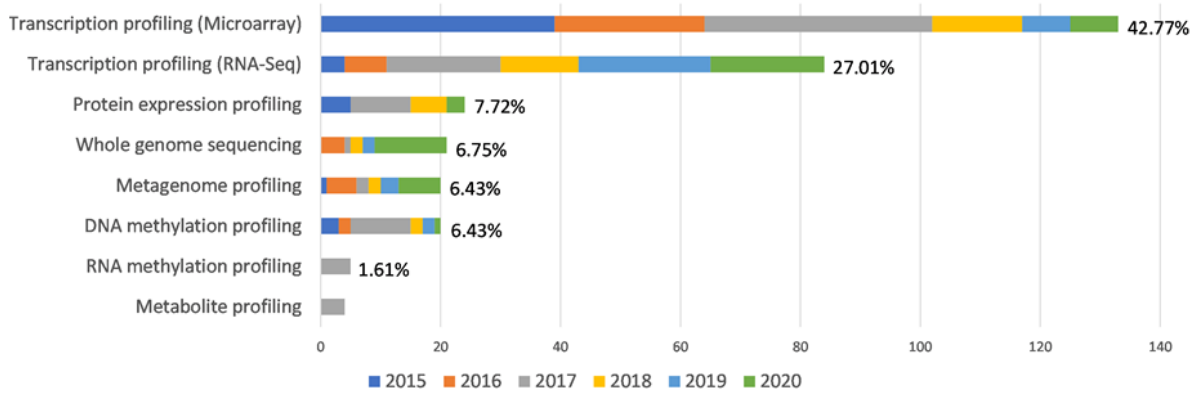


GeneLab: Data Repository

Experiment environment



Assay type



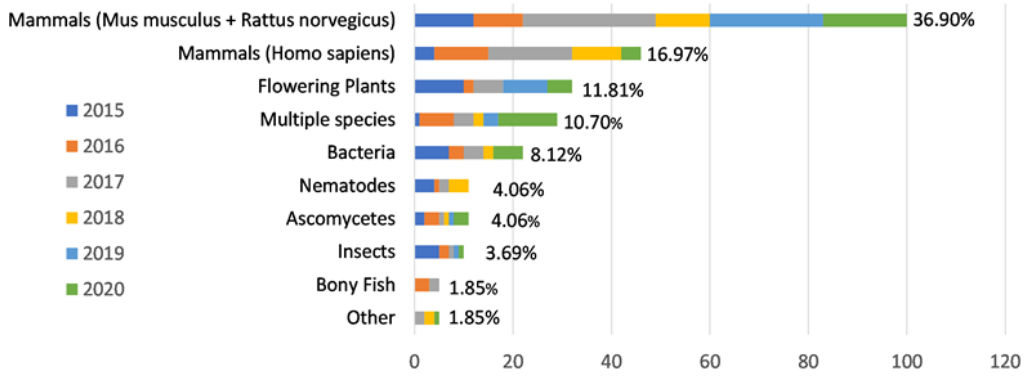
302 Studies

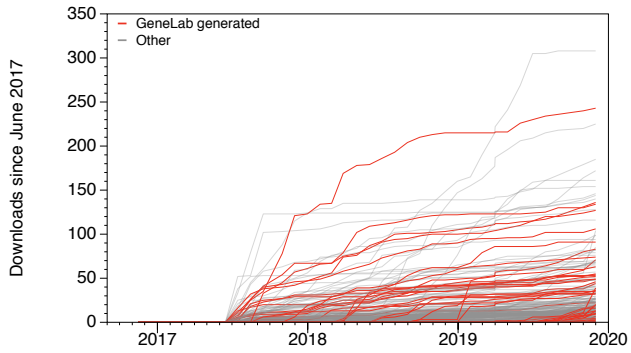
45 Species

>10 Assays

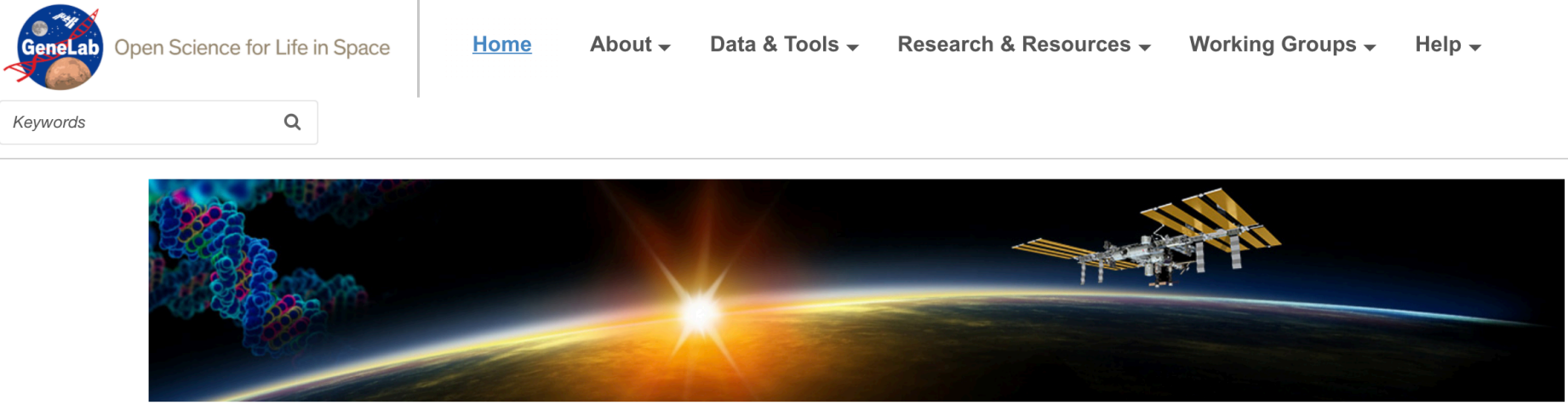
>130TB Data

Organism





GeneLab: Environmental Data (https://genelab.nasa.gov)

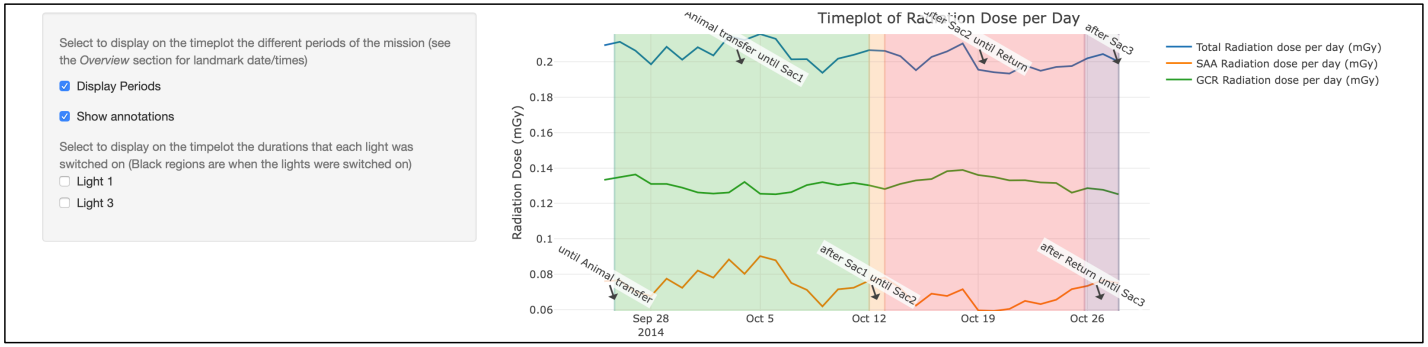


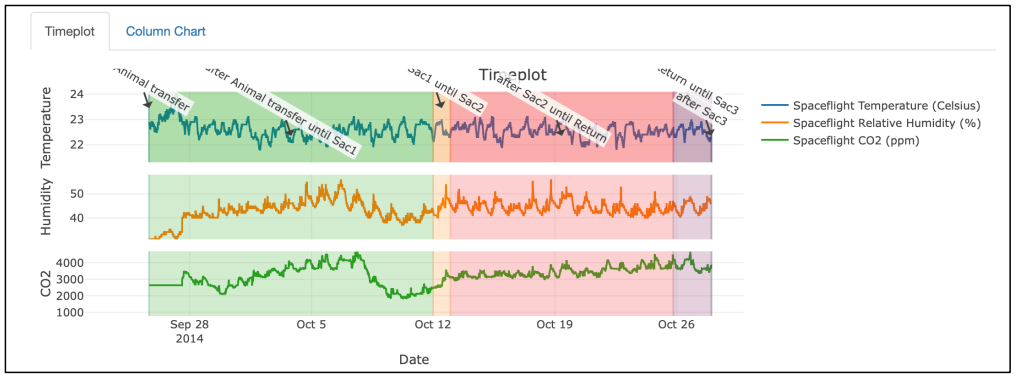
GeneLab: Environmental Data

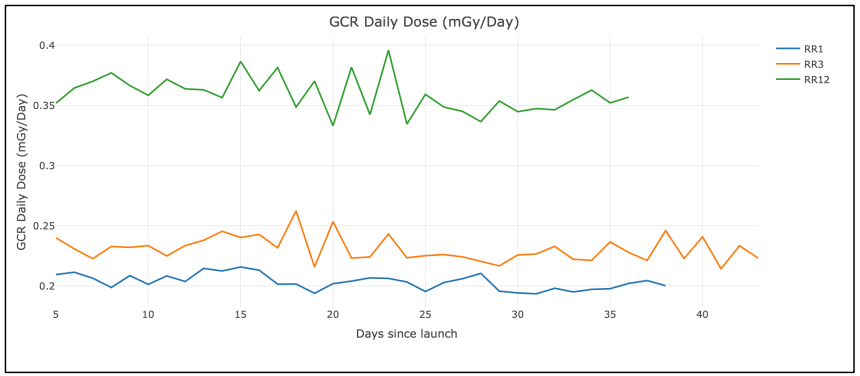
Users can view environmental data relevant to a dataset.

This includes temperature, relative humidity, CO2, radiation exposure.

Users can compare conditions of different datasets.





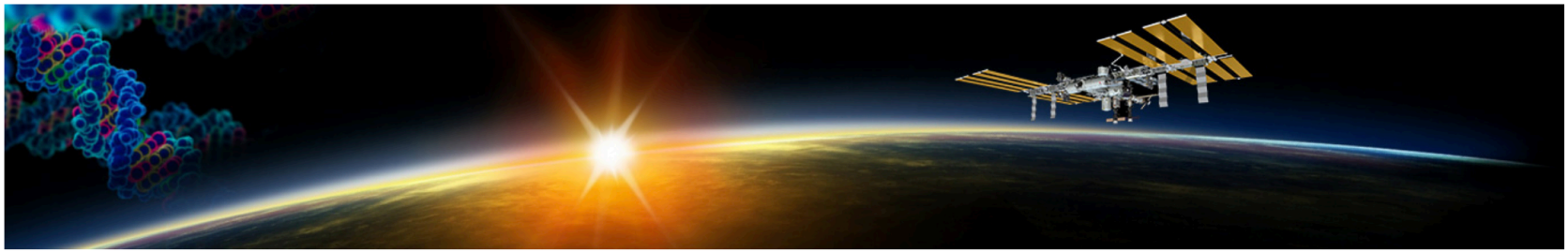


GeneLab: Data Visualization Portal (https://genelab.nasa.gov)

Open Science for Life in Space

Home | About | Data & Tools | Research & Resources | Working Groups | Help

Keywords



Welcome to NASA GeneLab - the first comprehensive space-related omics database; users can upload, download, share, store, and analyze spaceflight and spaceflight-relevant data from experiments using model organisms.

Data Repository
Search and upload spaceflight datasets

Analyze Data
Perform large-scale analysis of biological omics data

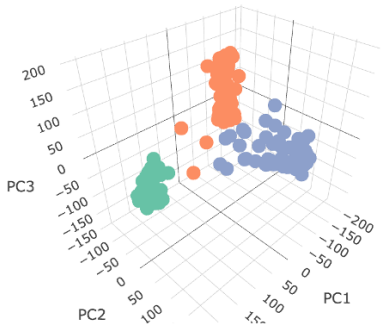
Environmental Data
Radiation data collected during experiments conducted in space

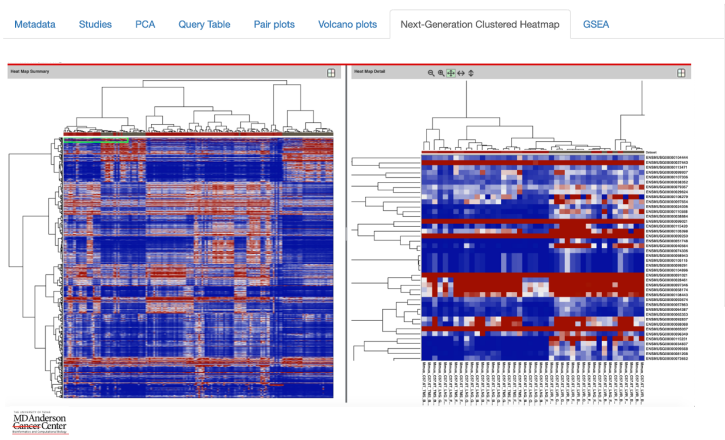
Collaborative Workspace
Share, organize and store files

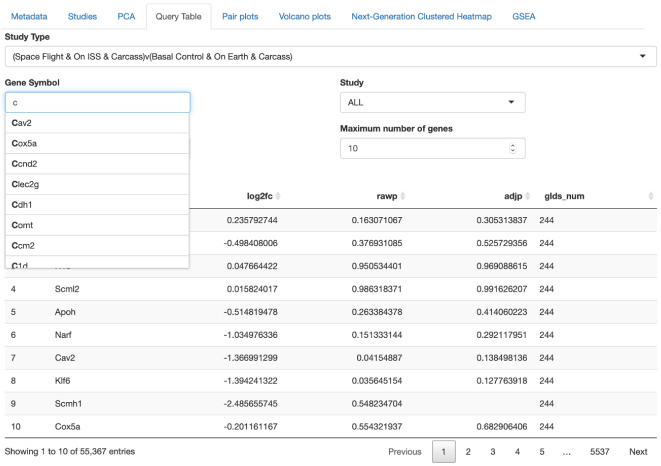
Submit Data
Have space-relevant data to submit to GeneLab?

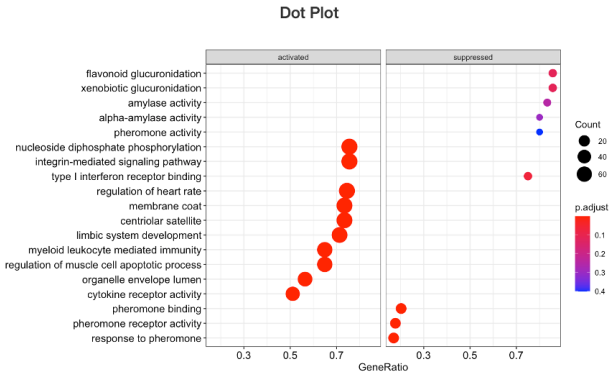
Visualize Data
Interact with GeneLab processed data

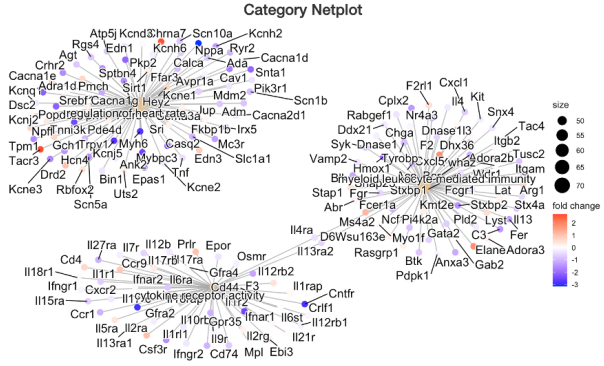
GeneLab: Data Visualization Portal



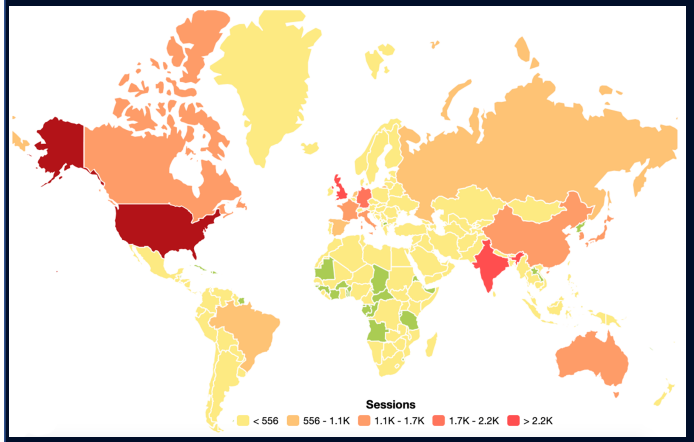








GeneLab User Growth



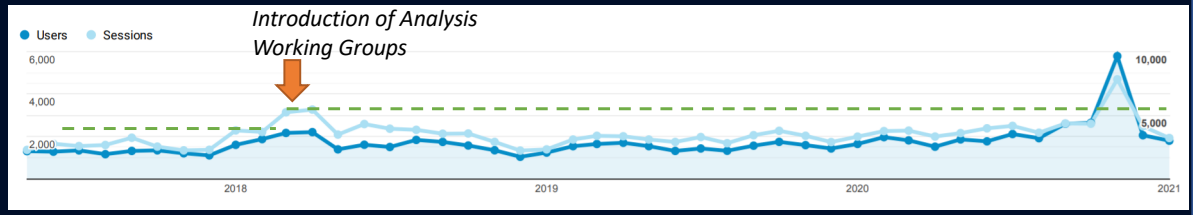
Top 10 Countries – Sessions

1. United States
2. India
3. United Kingdom
4. Germany
5. Canada
6. France
7. South Korea
8. Japan
9. China
10. Australia

Usage: May 2017- Jan 24, 2021

3494 Avg Monthly Sessions

1718 Avg Monthly Users

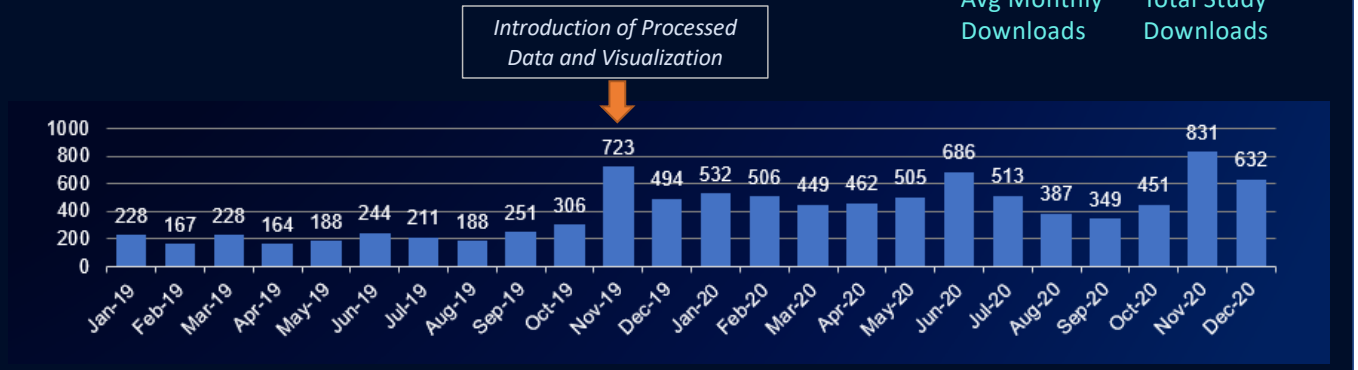


Downloads: Jan 2019 - Dec 2020

**represents downloads per GLDS Study, not per file*

405 Avg Monthly Downloads

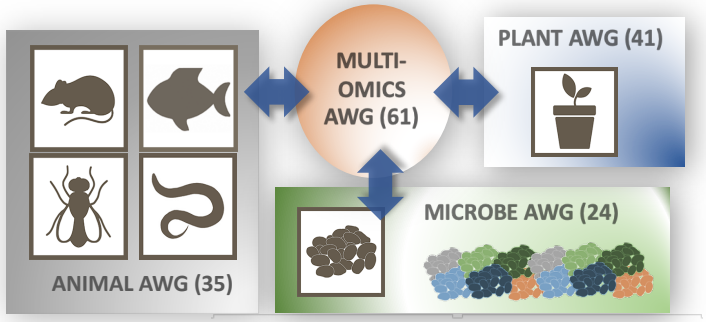
10146 Total Study Downloads



GeneLab Power Users

GeneLab Analysis Working Groups (AWGs) *consist of* ***130+ scientists*** *from multiple space agencies, international institutions, and industry. Scientists meet monthly with each group to analyze data in the GeneLab repository. Majority of members are non-NASA PI's – many have applied for NASA funding following AWG interactions.*

https://genelab.nasa.gov/awg/join



AWG Members represent:

- 48 US Universities
- 4 NASA Centers
- 4 Other Government-funded Organizations
- 3 Institutes or Private Industry
- 3 International Universities

Educational Working Group (EWG) *consists of educators and scientists spanning across high school and college, focusing on developing content to learn about spaceflight OMICS, promoting the use of GeneLab's database via the repository, and the visualization and analytical portals.*

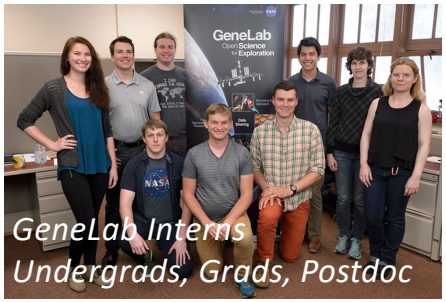
GeneLab for High Schools (GL4HS)

GeneLab for College/University (GL4U – Pilot with SJSU)

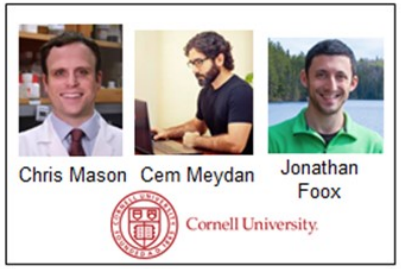
SJSU SAN JOSÉ STATE UNIVERSITY

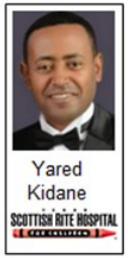
GeneLab included in Bioinformatics curriculum of degree granting university

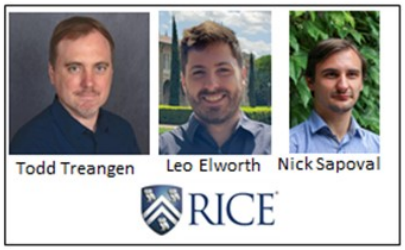
GL4HS (Tutorial + Tools)



Analysis Working Groups (AWGs) are Driving Data Reuse







Publications Using GeneLab Data

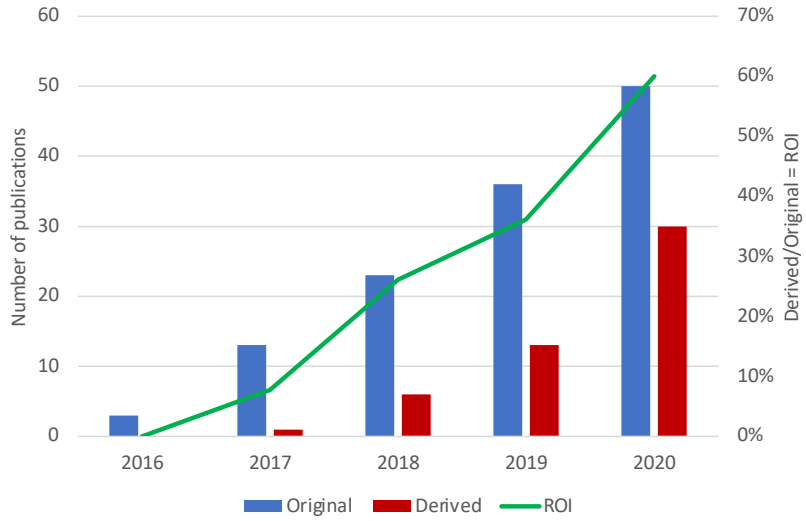
Publication Metrics

50
Original Publication linked to GeneLab

30
Derived Publication linked to GeneLab

60+
Presentations linked to GeneLab

92
Datasets used in derived publications



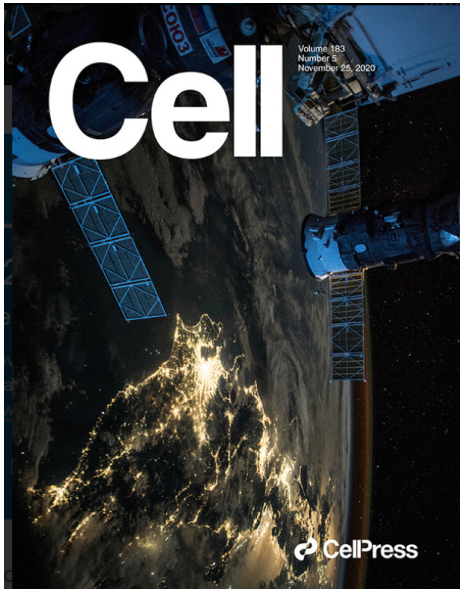
ROI grows faster than publications linked to original

Original – Publications with original dataset submitted to GeneLab
Derived – Publications using data submitted to GeneLab repository

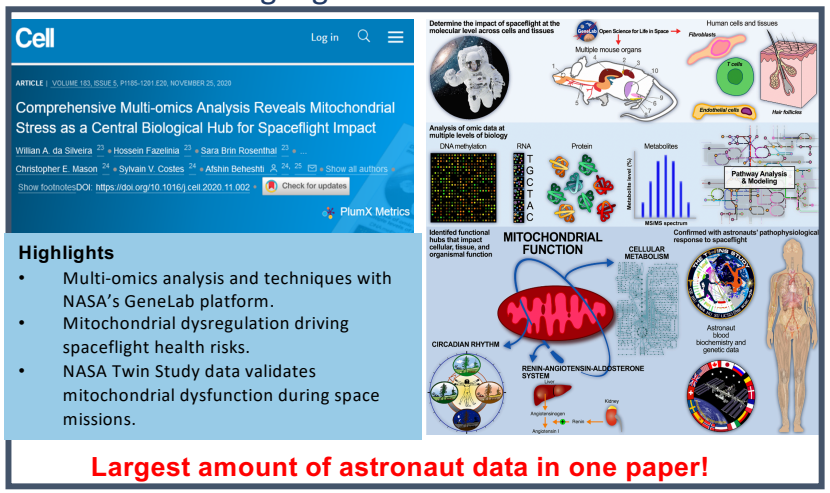
Most Recent Publications

A special collection on **the biology of spaceflight**, published on November 25th, 2020 in *Cell* and other Cell Press journals, done in collaboration between NASA and other space agencies around the world, uncovers the impact of known hazards of spaceflight, such as radiation and microgravity, and discusses the standards for multi-omics from space and the preparations needed for Mars and other missions in the next two decades.

- 29 scientific papers, 200+ authors
- **9 papers utilize data in GeneLab or GeneLab resources**
- 2 AWG papers
- *Covered by 200 News Articles worldwide with 43 articles mentioning GeneLab*



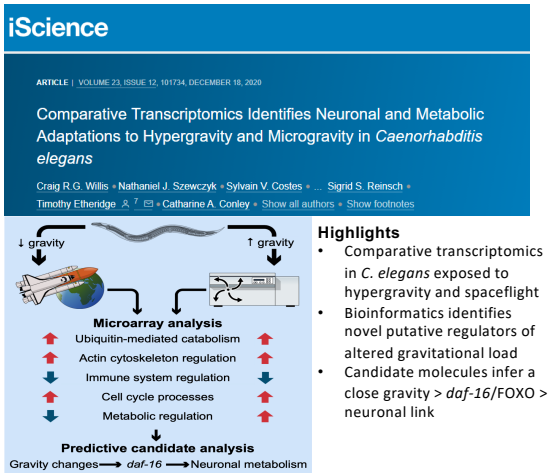
Cell Bundle - Highlights



Highlights

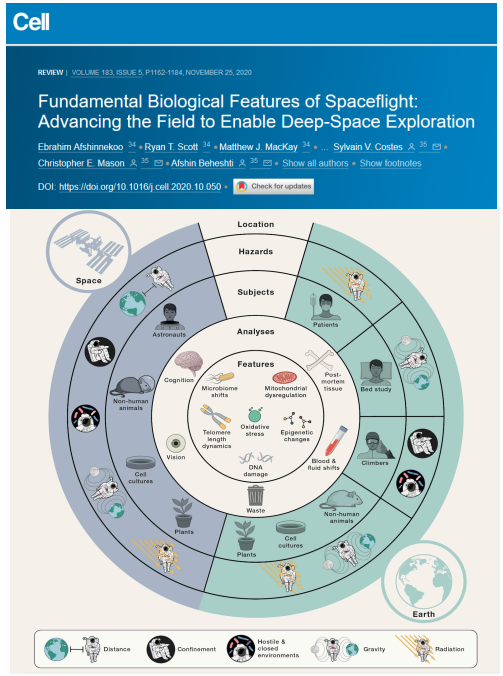
- Multi-omics analysis and techniques with NASA's GeneLab platform.
- Mitochondrial dysregulation driving spaceflight health risks.
- NASA Twin Study data validates mitochondrial dysfunction during space missions.

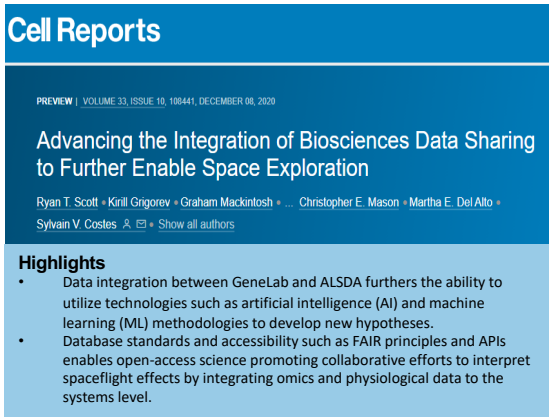
Largest amount of astronaut data in one paper!



Highlights

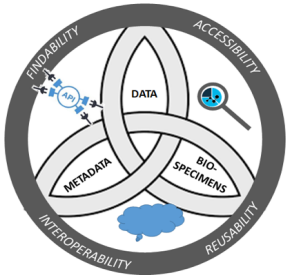
- Comparative transcriptomics in *C. elegans* exposed to hypergravity and spaceflight
- Bioinformatics identifies novel putative regulators of altered gravitational load
- Candidate molecules infer a close gravity > *daf-16*/FOXO > neuronal link

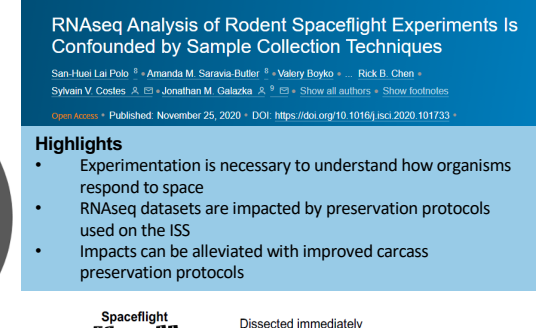




Highlights

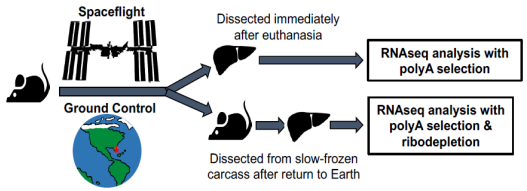
- Data integration between GeneLab and ALSDA furthers the ability to utilize technologies such as artificial intelligence (AI) and machine learning (ML) methodologies to develop new hypotheses.
- Database standards and accessibility such as FAIR principles and APIs enables open-access science promoting collaborative efforts to interpret spaceflight effects by integrating omics and physiological data to the systems level.

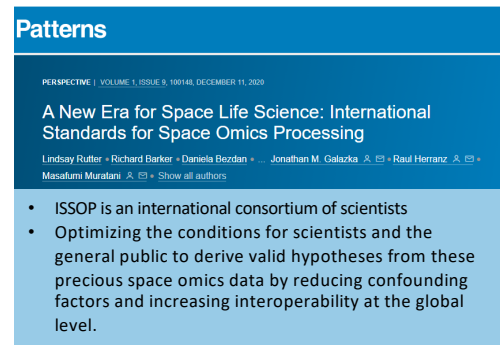




Highlights

- Experimentation is necessary to understand how organisms respond to space
- RNAseq datasets are impacted by preservation protocols used on the ISS
- Impacts can be alleviated with improved carcass preservation protocols





- ISSOP is an international consortium of scientists
- Optimizing the conditions for scientists and the general public to derive valid hypotheses from these precious space omics data by reducing confounding factors and increasing interoperability at the global level.

https://www.cell.com/c/the-biology-of-spaceflight

NASA Opportunities

Outreach / NASA Internship Opportunities - HS

GeneLab for High Schools (GL4HS): A four-week intensive training summer program for rising high school juniors and seniors sponsored by NASA Ames Research Center

During the training program, students learn and obtain training in:

- NASA space biology research
- Bioinformatics and computational biology methods and techniques to analyze omics data
- Designing an experimental proposal based on analyzed GeneLab data
- Formal oral presentation skills
- Networking opportunities

Eligibility for Class of 2022 (Applications open early 2022):

- US citizen or US Green Card holder
- Age 16 or older as of 12/31/2022
- Entering junior or senior year in Fall 2022
- Have a GPA or equivalent of 3.0 or higher

Learn more and apply at: https://www.nasa.gov/ames/genelab-for-high-schools

Caption: Gene Lab for High Schools 2020 Virtual Cohort

Students in grades 7 through 12: Design DNA experiments that address a challenge in space exploration

The 2021 Contest is Currently Open – proposals are due on April 12th, 2021

Learn more and submit a proposal at :
https://www.genesinspace.org/

Ames ECN
Early Career Network

Outreach Committee will be hosting virtual Q&A sessions with NASA Scientists and Engineers at K-12 schools
Interested Educators can e-mail me:
Amanda.m.saravia-butler@nasa.edu

Outreach / NASA Internship Opportunities – College+

Young Scientist Program

Blue Marble Space Institute of Science

- Opportunities for students and eligible early career scientists to participate in basic research, learn about effective science communication, and develop critical thinking skills in ethics, policy, and more
- **The NASA/BMSIS Young Scientist Program in Space Biosciences:** For post-bachelors and pre-doctoral students (at Mountain View, CA)
- **The BMSIS Young Scientist Program:** For undergraduate students and those who have completed undergraduate studies but have not yet enrolled in graduate school (primarily virtual)
- **Learn more and apply at:** https://www.bmsis.org/ysp/

Learn more and apply at: https://www.nasa.gov/ames/research/space-life-sciences-training-program

SLSTP: Provides undergraduate students entering their junior or senior years, and entering graduate students, with professional experience in space life science disciplines including:

- The effects of spaceflight on living systems
- The development and operation of specialized research facilities to support investigations in microgravity, partial gravity, and hypergravity
- Research and development of advanced biotechnologies that enable NASA's exploration of distant destinations

NASA STEM Engagement

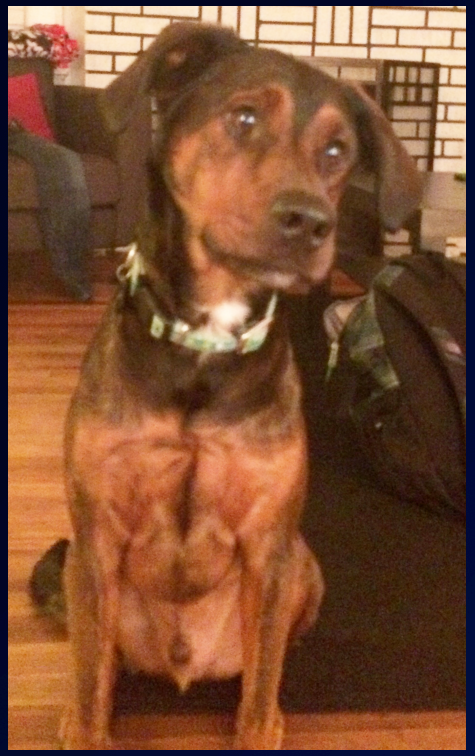
Discover more NASA Internship opportunities and apply at: https://intern.nasa.gov/

Coming Soon: GeneLab for College/Universities (GL4U):

- For educators to learn how to teach omics data analysis using GeneLab standard pipelines and space-relevant data

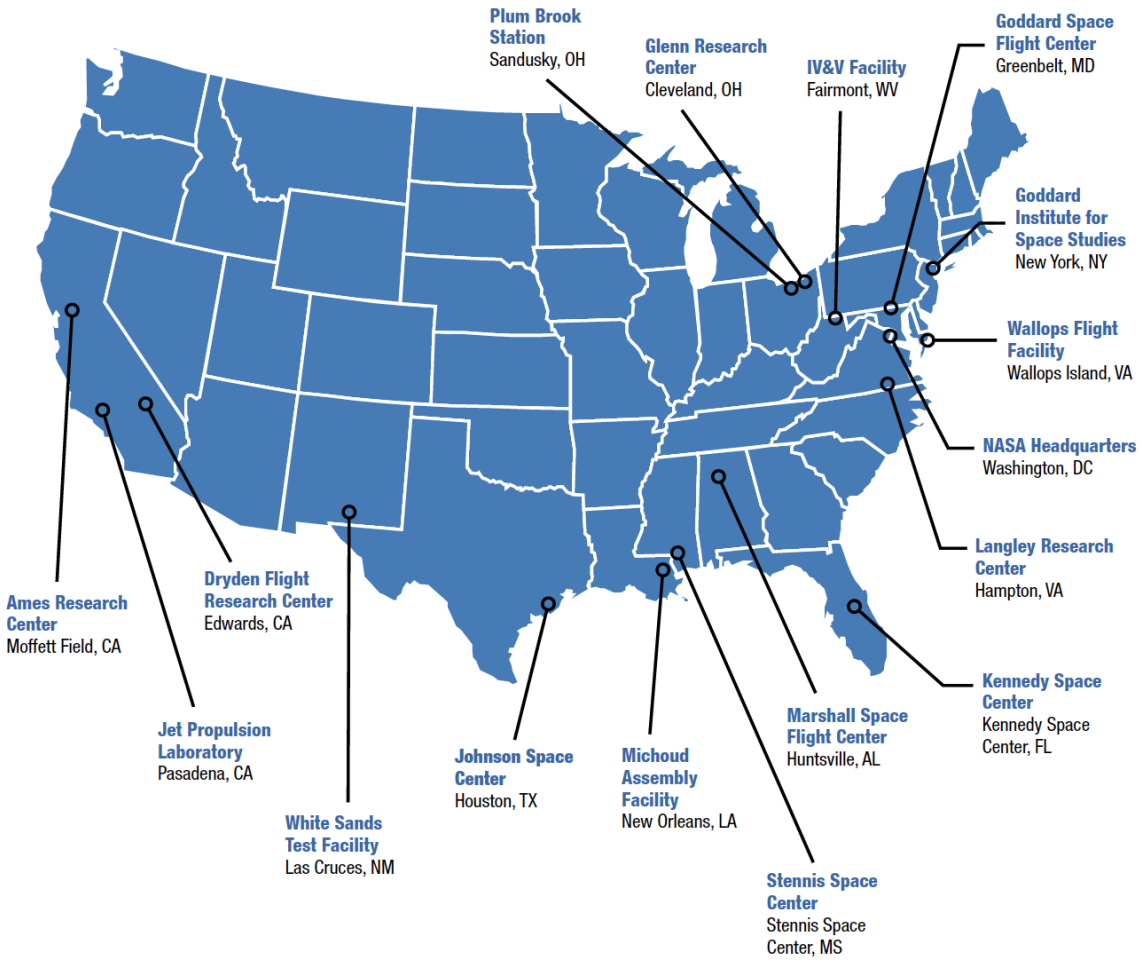
NASA GeneLab — OPEN SCIENCE FOR LIFE IN SPACE

Questions?



Extra Slides

NASA Centers and Facilities



NASA Centers and Facilities

NASA HQ

Ames Research Center

Armstrong Flight Research Center

Glenn Research Center

Goddard Space Flight Center

Jet Propulsion Lab

Johnson Space Center

Kennedy Space Center

Langley Research Center

Marshall Space Flight Center

Stennis Space Center

White Sands Test Facility

https://history.nasa.gov/

What has NASA done for us?

A Workforce Innovating To Go Farther

Space Launch System/Multi-Purpose Crew Vehicle

NASA is innovating to continue American leadership in an ambitious space program that takes us farther than ever before. The Agency is supporting technology innovation and commercial partnerships that fuel the American economy. With the development of the newest generation of space transportation, the Space Launch System (SLS) and the Orion Multi-Purpose Crew Vehicle, NASA is developing capabilities to access deep space destinations like the Moon, an asteroid, and Mars.

This capability is being built right here in the United States. Thousands of workers in over 30 states are currently building our Nation's next generation of space travel.

An exploration flight test of Orion will take place in 2014 with a follow-on Integrated Orion/SLS uncrewed flight in 2017.

A crewed flight of the integrated deep space system will occur as early as 2021.

Game-Changing Innovation

International Space Station—A Laboratory for Life Improvement Today

The United States has an active astronaut program. In fact, American human space flight occurs daily on board the International Space Station (ISS).

NASA is committed to maintaining American excellence in science, technology, engineering, and mathematics (STEM) while sustaining a long-term human presence in space. The ISS provides important technology and innovation development, not only for future long-term human space missions, but to enhance life on Earth today.

Outstanding advances in microbial vaccine development, unprecedented cancer research involving treatment delivery, and improved water purification technologies are just some of the technological advances that research on board the ISS has provided to life here on Earth.

Science

NASA is committed to groundbreaking science missions today and in the future. Our missions focus on providing critical data about our home planet, unraveling the mysteries of our universe, understanding solar variability and the impacts of space weather, and exploring the diverse planetary bodies of our solar system.

Aeronautics

Aeronautics research is leading the Nation to less congested airways and a more environmentally friendly aviation industry.

Investment in American Technology

By pushing the boundaries of technology, NASA's programs keep American business and workers on the cutting edge. Investing in technology development today enables future missions of NASA while growing the economy by creating new industries, jobs, products, and services. To ensure access to the most innovative tech development, NASA partners with American companies throughout the Nation in all 50 states.

$12.5 Billion in FY 2011 Obligated to American Industry

Inspiring the Next Generation

Over the past year, NASA's K–12 education projects reached more than 1 million students through STEM programs and initiatives. The Summer of Innovation Program engaged over 45,000 students and over 5,500 educators through camps and activities in 46 states, the District of Columbia, and Puerto Rico.

$941 Million in FY 2011 Obligated to Educational Institutions Throughout the Country

Investing in a New Aerospace Economy

Commercial Partners

NASA is committed to developing a new aerospace economy. The Agency is currently partnering with American industry to achieve safe and reliable access to low-Earth orbit and the ISS.

In fact, private industry began test flights in 2010, and these will continue through 2012. This progress will culminate with human access to the ISS by 2017.

Building a strong commercial space industry enables the development of a capability that will assure the Nation's future in space. Doing so will increase national revenue while positioning American companies as competitors in the global marketplace in the space economy.

NASA Technologies Americans Use Daily

TV Satellite Dish

NASA developed ways to correct errors in the signals coming from spacecraft. This technology is used to reduce noise in TV signals coming from satellites.

Medical Imaging

NASA developed ways to process signals from spacecraft to produce clearer images. This technology also makes photolike images of the insides of our bodies possible.

Vision Screening System

This technology uses techniques developed for processing space images to examine the eyes of children and find out quickly if they have any vision problems. The child doesn't have to say a word!

Ear Thermometer

Instead of measuring temperature using a column of mercury (which expands as it heats up), this thermometer has a lens like a camera and detects infrared energy, which we feel as heat. The warmer something is (like your body), the more infrared energy it puts out. This technology was originally developed to detect the birth of stars.

Firefighter Equipment

Firefighters wear suits made of fire-resistant fabric developed for use in spacesuits.

Smoke Detector

These devices were first used in the Earth-orbiting space station called Skylab (launched back in 1973) to help detect toxic vapors. Now they are used in most homes and other buildings to warn people of fire.

Automobile Design Tools

A computer program developed by NASA to analyze a spacecraft or airplane design and predict how parts will perform is now used to help design automobiles.

Thermal Gloves and Boots

Thermal gloves and boots have heating elements that run on rechargeable batteries worn on the inside wrist of the glove or embedded in the sole of the ski boot. This technology was adapted from a spacesuit design for the Apollo astronauts.

Advanced Plastics

Spacecraft and other electronics need very special, low-cost materials as the base for printed circuits (like those inside your computer). Some of these "liquid crystal polymers" have turned out to be very good, low-cost materials for making containers for food and beverages.

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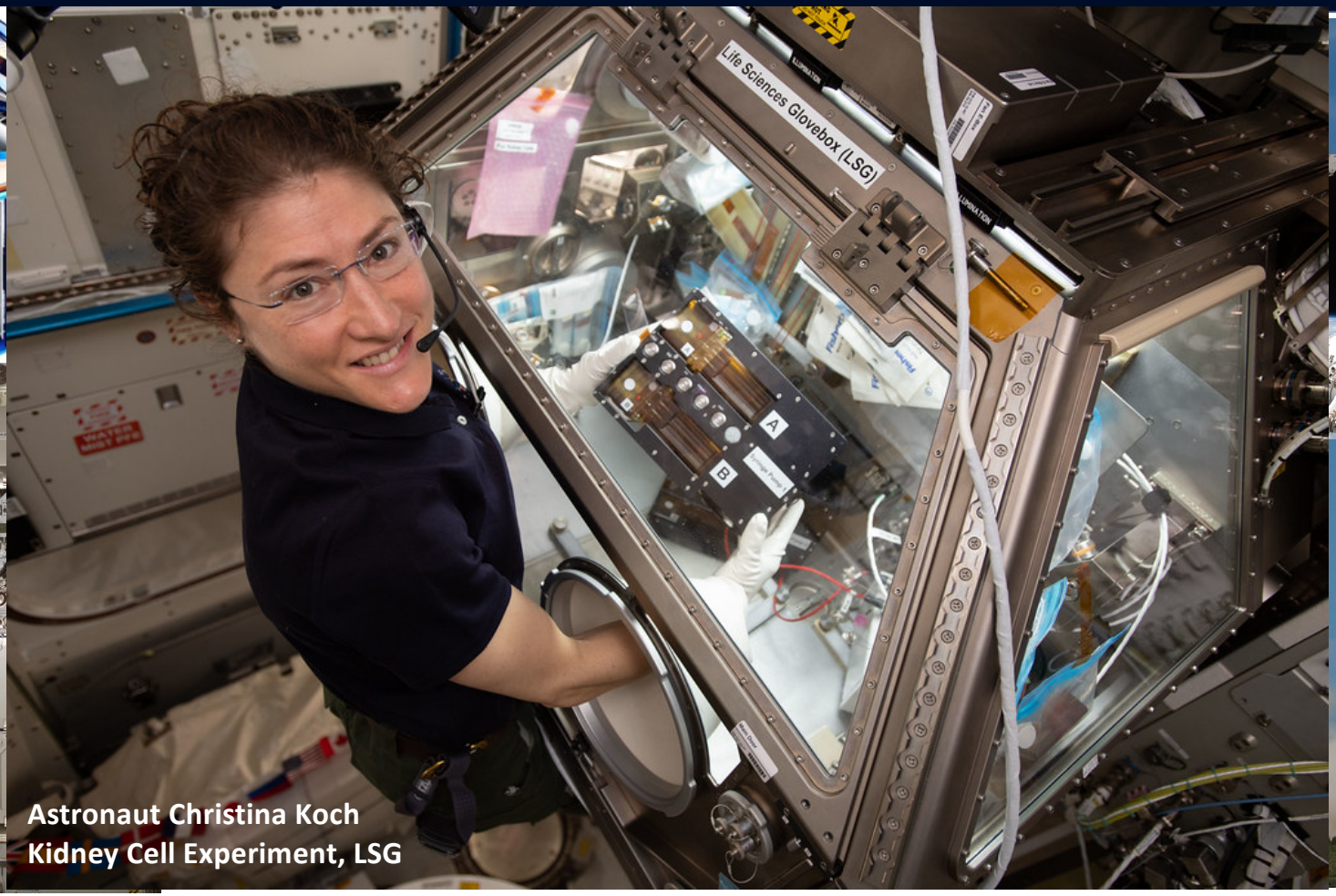
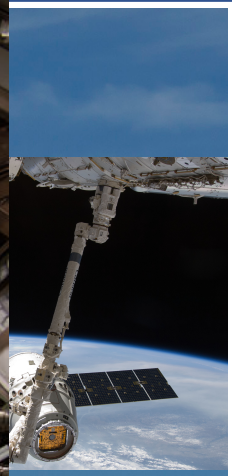
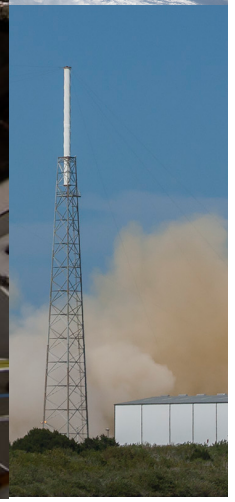
Mission Scientist: Rodent Research (RR) Project



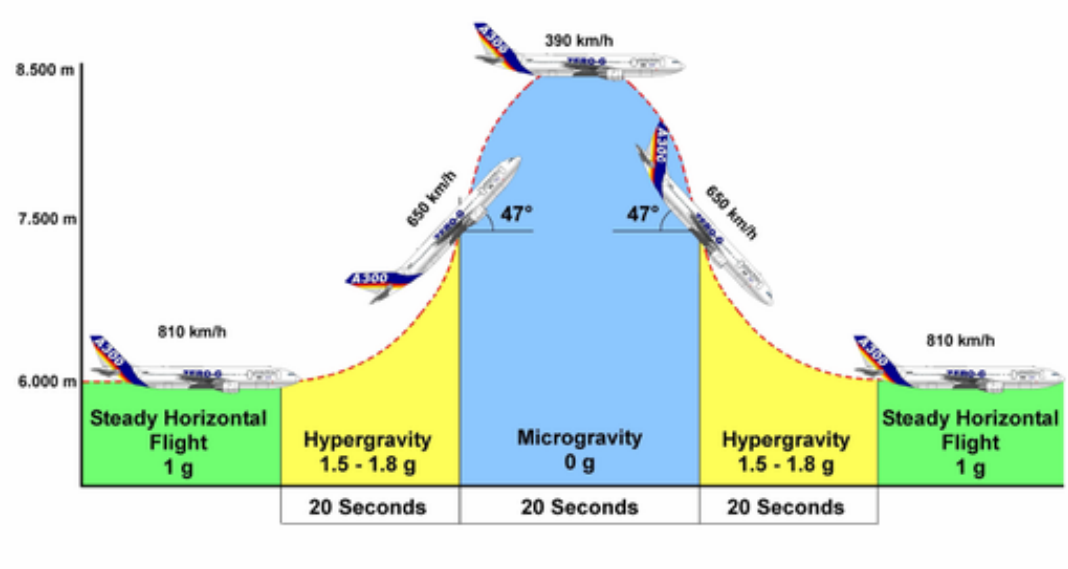
Astronaut Christina Koch
Kidney Cell Experiment, LSG





Space is Hard!

Parabolic Flight aka the Vomit Comet



Space is Hard!

Dr. Andrew Feinberg

Mice in Space…

Ronca, A.E., Moyer, E.L., Talyansky
Rep **9,** 4717 (2019). https://doi.org/

NASA's Vision

We reach for new heights and reveal the unknown for the benefit of humankind