

## **Moon to Mars Biomedical Life Sciences: Six Discovery Areas Contributed Through NASA's Open Science Data Repository**

Ryan T. Scott<sup>1</sup>, Amanda Saravia-Butler<sup>1</sup>, Danielle K. Lopez<sup>1</sup>, Samrawit G. Gebre<sup>2</sup>, Jonathan M. Galazka<sup>2</sup>  
<sup>1</sup>Amentum, Moffett Field, CA; <sup>2</sup>Space Biosciences Division, NASA Ames Research Center, Moffett Field, CA

The re-use of biomedical life sciences data is essential for fundamental science, applied science, clinical support, and operational research and development to meet NASA's goals for the exploration of the Moon and Mars. The NASA Open Science Data Repository (OSDR; an extension of NASA GeneLab), houses >500 studies, >1000 datasets, and is critical to the space biomedical life sciences field. OSDR has served as the foundation for ~150 peer reviewed publications, pre-prints, and student theses. This includes 19 of the 34 artificial intelligence and machine learning (AI/ML) papers worldwide in the field.

Meta-analyses, data mining, and usage of AI/ML on OSDR data has led to six main areas of discoveries and advancements: Countermeasure development, AI/ML models, radiation biology, mitochondrial impacts, environment and organism microbiomes, and plant-crops. Countermeasure research identified microRNA-targeted therapies for radiation damage, drug repurposing strategies for muscle atrophy, and an enhanced focus on CO<sub>2</sub> accumulation mitigation. AI/ML advances include federated learning deployed between Earth and the International Space Station, and explainable algorithms for a deeper understanding of muscle health deconditioning. Radiation studies revealed tissue-specific vulnerabilities, particularly cardiovascular FYN kinase activation and disrupted epigenetic clocks. Mitochondrial dysfunction emerged as a central hub affecting liver, muscle, and kidney tissues. Microbiome analyses documented reproducible gut community shifts and enhanced antimicrobial resistance aboard spacecraft. Plant research identified adaptive mechanisms in root development and photomorphogenesis critical for space agriculture, as well as nutritional pharmacogenomics for precision nutrition.

These discoveries were made possible by OSDR's high quality datasets, analysis-visualization tools, and the ecosystem of over 1000 volunteer Analysis Working Group members who provide feedback on OSDR's scientific data-metadata standards and collaborate on data mining projects. This community-driven approach has contributed to the biomedical life science knowledge base essential for protecting astronaut health and enabling sustainable human exploration to the Moon and Mars.

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