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April 14th, 2025

2024 Summary Report for the Mason Lab

In 2024, Dr. Christopher Mason and his laboratory significantly advanced the fields of genomics, space biomedicine, computational biology, and cancer research through various projects and publications. Below is a summary of some of the highlights of the year, spanning January-December 2024.

1) **Spaceflight Research and the Space Omics and Medical Atlas (SOMA)**
   Dr. Mason published the first set of data from the Space Omics and Medical Atlas (SOMA) project, a comprehensive international research initiative involving over 100 investigators from more than two dozen countries from 2021-2024[1-2]. This project analyzed the molecular and physiological impacts of space travel on astronauts, notably built upon data from the SpaceX Inspiration4 crew. The SOMA package of papers, published in a special collection in *Nature* and partner journals in June 2024, provides valuable insights for aerospace medicine and future space missions, with several key highlights (featured on the cover of *Nature*, Figure 1):
   a. A 10-fold increase in all available human spaceflight data.
   b. All raw and processed data acquired from the crew during and after their missions have been made available in Cornell's SOMA data repository as well as NASA's Open Science Data Repository (OSDR)[3], an expansion of NASA's GeneLab.
   c. Four new data portals[4] have been created for browsing results from the missions, examining changes in gene expression, protein production, metabolism, and microbiome composition across the whole cohort of papers[5-24].
   d. The SOMA created a first-ever private astronaut biobank (Cornell Aerospace Medicine Biobank, CAMBank), atlas, and a repository of nearly 15,000 biological samples to support ongoing and future research[25-26].

Figure 1: Nature cover featuring the Space Omics and Medical Atlas (SOMA). *Rapid advancements in space travel by new companies and space-related entities from various countries have ushered in a "Second Space Age." For the first time, this era allows collaboration among previously separated entities to apply modern tools and methods of molecular biology and precision medicine for the benefit of astronauts and crew. This collection brings together articles featuring the analysis of data collected from JAXA studies, Inspiration4 (I4) mission crew members, and NASA and ESA astronaut missions. Additionally, it integrates parallel studies, including cellular profiles, ground analogs, computational models, countermeasures, and extensive model organism data. The package showcases an incredible collaboration across more than 100 institutions, reporting changes at the cellular, tissue, organismal, and systemic levels as a consequence of spaceflight. his work also begins to map differences in how female and male individuals respond to spaceflight and links specific molecular countermeasures to each astronaut.*

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2) **Cancer Research and the SAMBAI Project**
Dr. Mason was part of an international team awarded up to $25 million by Cancer Grand Challenges to investigate cancer inequities[27]. The project, known as SAMBAI (Social, Ancestry, Molecular and Biological Analysis of Inequalities), includes researchers from institutions in the U.S., U.K., Ghana, and South Africa. The team's goal is to understand the societal, ancestral, molecular, and biological factors contributing to cancer disparities, aiming to inform strategies to reduce these inequities and disparate cancer outcomes.

3) **Public Engagement and STEM Advocacy**
Beyond his research, Dr. Mason engaged in public outreach to inspire interest in STEM fields. In December 2024, he presented at Sewickley Academy's STEM Speaker Series, discussing genetic and epigenetic responses to spaceflight and future plans for lunar and Martian missions. His talk aimed to motivate students to explore careers in science, technology, engineering, and mathematics[28].

4) **Methodological Advances in Spaceflight Research**
In the realm of space biology, Dr. Mason co-authored "Methodologies for Mitochondrial Omic Profiling During Spaceflight," a chapter in *Methods in Molecular Biology*[29]. This work detailed advanced techniques for analyzing mitochondrial changes during space missions, providing essential protocols for researchers studying the effects of spaceflight on cellular energy dynamics.

5) **Infectious Diseases: Diagnostics and Tracking**
   a. An expansion of the GeoSeeq Platform at Biotia, moving from just over 100,000 samples in 2023 to 294,039 samples and annotated microbial profiles by January 2025 (https://portal.geoseeq.com/)(Figure 2).

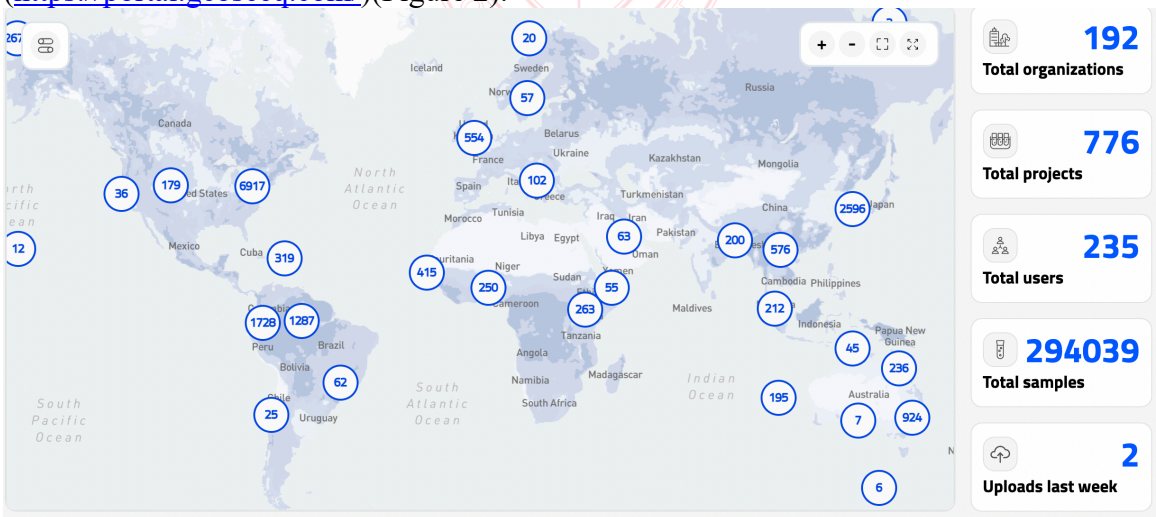

Figure 2: GeoSeeq data portal. *A global metagenomic map of urban microbiomes and antimicrobial resistance, including a partnership with the Pasteur Institut of France.*

   b. Dr. Mason contributed to a study on public health and infectious diseases, with. The research, titled "Detection and genetic characterization of multidrug-resistant staphylococci isolated from public areas in an international airport," was published in *Scientific Reports* in 2024. This study

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identified and genetically characterized multidrug-resistant *Staphylococcus* strains found in public areas of an international airport, underscoring the importance of monitoring antimicrobial resistance in public spaces to inform infection control strategies[30].

c. New York State (NYS) Department of Health (DOH) approval for a new clinical diagnostic test, Biotia-ID, which is the first genomics-based urine assay leveraging AI to be approved by the NYSDOH[31].
d. Awarded a $4.4M grant from the National Institutes of Health to study the emergence of new viruses, as part of the Human Virome Project, in a project called VAST (Viromes Across Space and Time)[32].
e. Discovered novel phages that can be used for new therapeutics, using computational mining methods from the MetaSUB data sets[33].

6) Neuro-genetics and other Genomics Research

a. Alzheimer's Disease-Associated CD83(+) Microglia Are Linked with Increased Immunoglobulin G4 and Human Cytomegalovirus in the Gut, Vagal Nerve, and Brain, *Alzheimer's & Dementia*, 2024. This study explored the association between CD83(+) microglia, elevated Immunoglobulin G4 levels, and human cytomegalovirus presence across various tissues in Alzheimer's disease patients[34].
b. A Robust Benchmark for Detecting Low-Frequency Variants in the HG002 Genome In A Bottle NIST Reference Material. 2024. This publication presents a benchmark for identifying low-frequency genetic variants, enhancing the accuracy of genomic analyses[35].
c. Wrote about the expanding genomics research empowered by the Polaris Dawn mission in Genetic Engineering News (GEN)[36].

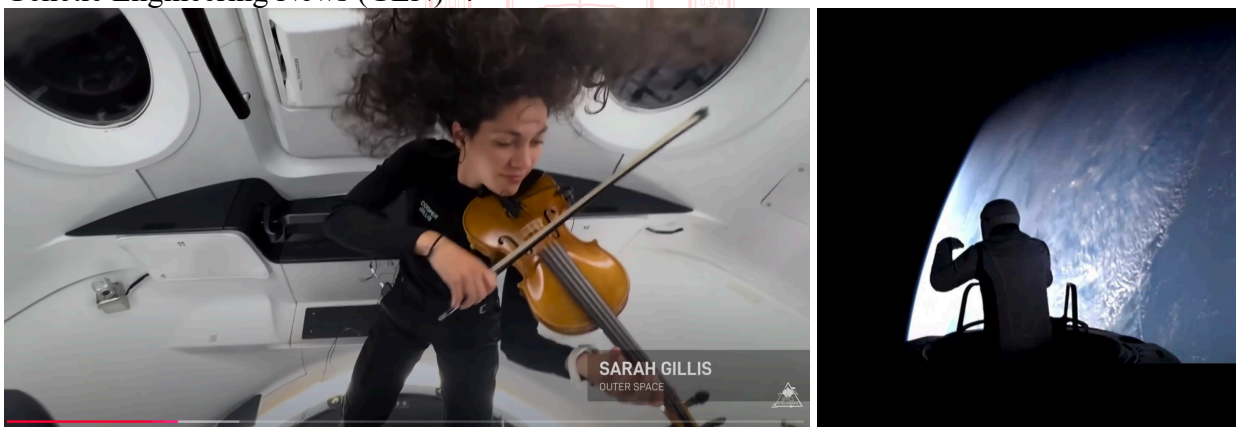

Figure 3: Polaris Dawn Art and Spacewalking. *The SpaceX 2024 mission of the Polaris Dawn crew featured the first violin played in the Dragon capsule by Sarah Gillis (left) and the first private spacewalk with Jared Isaacman (right). Their samples are now part of the SOMA data portals and CAMBank.*

7) Pedagogy and Training

- Started a new partnership with Sage Commons and the sharing of clinical and genomics data from the SAHA project, with plans to expand to SOMA.
- Expanded our new non-profit (501c3), BioAstra (https://www.bioastra.org/), to help democratize access to the spaceflight protocols and methods (like the SOMA protocols, and others), for industry, academic, and NGO groups.

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- Recruited 4 new staff, scientists, and students, including Paul Collier (Roche), Kevin Walsh (Tempus), Theodore Maximilian Nelson (Cambridge, now in the Tri-I MD/PhD program), and Akua Agyemang (Yale).
- Graduated: one post-doc, Braden Tierney, who Founded and leads the Two Frontiers Project (2FP), one new post-bac student (Ashley Kleinman), who is now in a Ph.D. program at Harvard University, one staff, Krista Ryon, left to be the Founder and Director of operations for the Two Frontiers Project (2FP).
- Lucy Innes, a Ph.D. student in the laboratory, presented an updated summary of uveal melanoma at the "A Cure in Sight" melanoma foundation.
- For the 3rd consecutive year, we hosted the 7th and 8th grade students from the International School of Brooklyn (ISB) in our laboratory, where we taught them about genetics, data models, and cell engineering (**Figure 3**).

Figure 3: Laboratory visit by 7th and 8th grade students to Weill Cornell Medicine. *Students learned about the latest technologies, opportunities, technologies, and applications in genetics and met Mason lab members and scientists. Dr. JangKeun Kim, Director of Spaceflight and leader of several missions.*

- Partnered with the Metropolitan Art Museum (MET) and Colossal Biosciences for new projects on DNA preservation and de-extinction; sequenced the embryo of the first de-extinct species.
- Launched the Microbe Mineral Atlas (MMA) with investigators at Cornell University. An international research team led by Cornell is addressing the problem of rare minerals, with financial support from the National Science Foundation (NSF)[37]. A three-year, $2 million NSF grant will fund a project aimed at creating a "microbe-mineral atlas" – a catalog of microorganisms and genes and how they interact with minerals, an important step toward using

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synthetic biology to build genetically engineered microorganisms useful for mining critical and rare Earth metals.

In 2024, our lab published a total of 37 scientific papers (including three featured on journal covers), one updated book (The Next 500 Years, second edition, now translated into Mandarin, Arabic and Russian). Members from the lab gave >60 talks and presented at over 20 meetings around the world, Including MIT's Beyond the Cradle. Work from the lab also led to submission of three new patents, expansion of one new company for newborn genome sequencing and diagnostics (Nurture Genomics, https://nurturegenomics.com), and expanded work from 2 non-profits (http://twofrontiers.org & http://bioastra.org), the expansion of a new pandemic prediction platform (GeoSeeq, above), and the submission of a patent on a new method to recycle water from spacesuits[37].

This work would not have been possible without the extraordinary support of the WorldQuant team, and the WorldQuant Initiative for Quantitative Prediction. Our team is immensely grateful for your support and generosity.

Thank you!

Sincerely,

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3) OSDR page for NASA. Open Science Data Repository.
4) SOMA Data Portal Hub: https://soma.weill.cornell.edu/apps/SOMA_Browser/

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