Fiscal Year:	FY 2016	**Task Last Updated:**	FY 03/02/2016
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Project Title:	An Integrated Omics Guided Approach to Lignification and Gravitational Responses: The Final Frontier		
Division Name:	Space Biology		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	SPACE BIOLOGY--Developmental biology		
Joint Agency Name:		**TechPort:**	No
Human Research Program Elements:	None		
Human Research Program Risks:	None		
Space Biology Element:	(1) Plant Biology		
Space Biology Cross-Element Discipline:	(1) Reproductive Biology		
Space Biology Special Category:	(1) Bioregenerative Life Support		
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Comments:			
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No. of Bachelor's Candidates:		**Monitoring Center:**	NASA KSC
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We propose a multi-omics study using the model plant Arabidopsis under both 1g and in microgravity conditions (spaceflight). Our approach spans comprehensive phenomics, metabolomics, transcriptomics, and proteomics strategies, and is incisively and uniquely melded via deployment of an integrated computational biology (ICB) approach we are pioneering. Our plant lines include wild type, various mutants we have generated with different lignin amounts through manipulation of the multigene family encoding arogenate dehydratases, and other lines enhanced in carbon assimilation capacity, and combinations thereof. We consider this places us in an unprecedented position to investigate how plants function in altered gravity environments.
We are very well positioned for incisive spaceflight and definition stage (1g) studies to investigate gene/metabolic network relationships and adaptations resulting from varying lignin and carbon assimilation levels, e.g., on photosynthesis, C allocation; water use efficiency (WUE), vascular plant growth/development; vasculature performance; auxin transport, and gravitational adaptations. Our overarching hypothesis is that a comprehensive interrogation (an integrative omics study) of our Arabidopsis lines with varying lignin levels and/or modulated carbon concentrating mechanisms (CCMs) or combination thereof will identify gene/metabolic networks, mechanisms and/or pathways that are differentially modulated at 1g and on exposure to microgravity, i.e., various omics (phenomics, transcriptomics, genomics, proteomics, metabolomics, and ICB) will allow us to study these in a truly unprecedented way.

Overall objectives:

Task Description:

1. Establish multi 'omics' effects of modulating lignin and CCM levels i) at 1g and ii) in spaceflight.

2. Compare/contrast data, using an ICB approach, to better define and understand gravity sensing and responses, and if threshold/induction parameters are modified or changed, when lignin and CCM levels are varied.

More specifically, we address distinct hypotheses for our various teams, and integrate, dissect, and incisively analyze them holistically in a manner hitherto not possible. These 5 hypotheses include that: modulating lignin and CCM levels differentially affect carbon assimilation/re-allocation, photosynthesis, and WUE (Team 1); modulating lignin and CCM levels differentially affect secondary and primary metabolite levels (metabolomics) (Team 2); system-wide modification in the transcriptome occurs through a common transcriptional regulatory mechanism, and transcriptome/proteome 'discrepancies' result from over simplification of transcript analyses (Team 3); differential alterations in lignin and CCM levels can often be attributed to overall distinct changes in protein expression and phosphorylation patterns in a defined set of proteins (Team 4); an integrated omics analysis will provide urgently needed new insights into global effects on plant biological processes at both 1g and in microgravity (Teams 1-4). Each hypothesis draws upon the most advanced technologies available for study. We consider that our ICB approach will transform omics analysis through our advanced instrumentation and analytical tools. We will utilize (or design) computational tools/mathematical algorithms for integration and correlation of high resolution phenotype measurements (phenomics) with 'low' resolution global subcellular system measurements (transcriptomics, etc.) through 'nth' dimensional analysis.

Our study aligns with Research Emphasis 1 and 3, and decadal survey elements in Cell, Microbial, and Molecular Biology (CMM-3, CMM-5), Organismal and Comparative Biology (OCB 2-5), Developmental Biology (DEV-4), and Plant and Microbial Biology, chapter 4 (P2). Our data generation will also be seamlessly integrated with various web-based platforms to handle, disseminate, and inter-actively utilize through iPlant and OpenMSI, and thus are made available to NASA as well as being a community resource.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits:

1). This research will provide NASA and science in general with the first big 'omics' data analysis, integration, and assessment - at the gene, protein, and metabolic outcome levels - as to how microgravity alters the basic responses of plants when the influence of gravity is removed/minimized. This will serve as the foundation 'omics' analyses in subsequent spaceflight and colonization experiments in space, as well as shedding new insights into the manifold effects of gravity during plant growth and development.
2). We are partnering with Kathy Lucchesi (K-8 teacher), at Lake Canyon Middle School (collectively Lake Canyon) in Sacramento, California, as well as other teachers there, and their students on a program where elementary students can follow and repeat certain very safe plant growth experiments developed for the International Space Station (ISS) experiments, i.e., where we will assist on a 'hands on' experience at Lake Canyon for the students, and their participation with the progress of our ISS multi-omics studies. This allows for the students to grow plants under similar conditions and to obtain information and insights on how the research impacts or benefits life on Earth. Our participation here includes offering instructions through Skype and written materials on the experiments at hand, and helping teach the young students about the joys and fun of the scientific method in experimental plant biology. Periodically, we will have Lake Canyon students present results over Skype to our team meetings where such work is routinely evaluated.

Task Progress:

Major emphasis (definition phase validation) upon initiation of the project has been to define the conditions required to obtain dependable, invariable, and reliable controlled growth of Arabidopsis plants using the given parameters and restrictions of the Advanced Plant Habitat (APH) prototype unit. Approaches to the experimental design and implementation have thus focused on confirming the ability to successfully germinate and grow Arabidopsis for up to a 6-week harvest point in a reliable manner as previously done (1). This is required as a precedent to successfully growing and harvesting the plants for experimental analysis in the APH on the International Space Station (ISS) for the multi-omics (phenomics, transcriptomic, proteomics, and metabolomics) study and analyses. This work is being done in close co-operation with Kennedy Space Center (KSC) and Orbitec personnel, and building on somewhat related studies (2). Currently, an APH LED assembly and RM-2 unit for porous tube delivery of water throughout the substrate facilitating plant growth are being tested and conditions optimized. We have compared numerous growing substrates to test the ability to deliver water to the plants by wicking action and to retain water, while providing for adequate oxygenation for roots, nutrients, and confinement of particles.

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2. Massa, G., Newsham, G., Hummerick, M.E., Caro, J.L., Stutte, G.W., Morrow, R.C., and Wheeler, R.M. (2013) Preliminary species and media selection for the veggie space hardware. Gravitational and Space Research 1: 95-106. http://gravitationalandspacebiology.org/

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