Drosophila Habitat Developed to Support Research on the International Space Station

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Abstract
The Fruit Fly Lab is a hardware suite being designed to support research on the International Space Station (ISS) for use by the entire Drosophila research community. A validation mission will launch and return on SpaceX-5 in late 2014, followed by Principal Investigator-lead science flights thereafter. Space flight experiments are selected via peer-reviewed proposals open to the Drosophila community. The cassettes (containers) that will house the Drosophila cultures were successfully used to conduct an immunity study on the Space Shuttle. Results showed that the innate immune system of Drosophila melanogaster was affected by space flight with a reduction in phagocytosis function of plasmatocytes, changes in antimicrobial peptides and other gene expression levels, as well as changes in development of the animals.

Current and early phase capabilities
• On-board 1g control by utilizing NanoRacks/Astrium BioRack centrifuge.
• Fractional-g setting for Mars and moon studies.
• Ability to perform on-orbit microbial challenges for infection studies.
• Ability capture video data in flight.
• Ability to supply proper day/night light cycles for maintenance of circadian rhythm.
• Freezing of samples for post-flight analysis.
• In-flight fixation of food trays containing embryos and young larvae.
• Environmental data collected throughout flight and used to program chamber to conduct ground control experiment.
• Temperature and humidity passively controlled to ISS levels.

Future phase capabilities
• Full environmental control, including temperature, humidity, CO2, and O2.
• In-flight fixation of all life stages.
• Increased living space volume and available food to further reduce required crew time.

Why Drosophila in Space?
Drosophila melanogaster (fruit fly) is a classic genetic and developmental model organism that has been extensively studied. Its genome contains only 4 chromosomes and has been completely sequenced. Despite its apparent simplicity, the vast majority of human genetic disease is homologous to fruit flies. The Drosophila immune system is also well conserved and is a classic model of human innate immunity. The fruit fly is also well suited for space flight studies. Its small size (~3mm) and rapid reproduction—a female can lay 100 eggs per day—allows studies with high "n" values to be conducted in small volume areas. The fruit fly also has a very short, 10-day life cycle from egg to adult, which make it ideal for development and multi-generational growth studies in space.

Characteristics that make Drosophila an ideal model organism for Space Research
• High "n" number studies.
• Isogenic animals allow for genetic studies.
• Low volume and crew time requirements.
• Short life cycle allows for multiple generations reared in space.
• Simple research of a multicellular organism.
• Homologous systems with other mammals.
• Demonstrated immunity model using human pathogens.

Table 1. Summary of FFL current and future capabilities.

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Figure 1. A. Fly Cassette with partially inserted food tray. B. Cassette restraint device showing the way the flies are confined. C. Fresh food placed in the cassette. D. Food tray being inserted into the cassette.

Hardware
Aluminum cassettes (Figure 1A) house Drosophila cultures and allow sufficient area for mating and development. Each cassette has a removable food tray that can be replaced to sustain the growth of the culture, or can be transferred to another cassette, along with embryos and burrowed larvae, enabling multi-generational studies. The cassette can be frozen in the Minus Eighty Laboratory Freezer for ISS (MELFI) to preserve samples until post-flight analysis, expanding the applications of the hardware and overcoming the loss of rapid sample turnover that resulted when Shuttle was retired. A food tray change-out platform (Figure 1B) is used to maintain containment during food maintenance operations, and allows ISS crew to perform operations quickly and safely without the need for a glove box. The food tray change-out platform can be preloaded with food trays containing microbial challenge organisms, which allows for easy administration of treatments on-orbit to support immune response studies, a capability that will be demonstrated on the initial validation flight. The cassettes slide into standard Type-I containers (ESA), and are compatible with the BioRack centrifuge (Astrium/NanoRacks) currently on-board ISS. Utilization of this centrifuge allows for on-orbit 1g controls for microgravity experiments, as well as variable g-levels for lunar or Mars environment studies. The standard form factor also allows for implementation of modular upgrades. An observation and circadian rhythm lighting system is currently being developed by Astrium to allow for capture of video data in-flight and to supply proper day/night light cycling. Data captured with prototype system (Figure 2) show entire cassettes and can be utilized to conduct behavior and development studies, as well as track health and viability of samples.

Figure 2. A. Fly Cassette with partially inserted food tray. B. Cassette restraint device showing the way the flies are confined. C. Fresh food placed in the cassette. D. Food tray being inserted into the cassette.

Research Potential
Several areas of space flight research can be conducted using fruit flies and the FFL hardware suite. A whole-genome microarray study conducted during the precursor shuttle mission showed an altered immune response after flight compared to ground control (Figure 3). FFL-01 will demonstrate on-orbit microbial challenge, allowing for future further developed immunity studies. Also, since FFL is well suited for multi-generational studies, research into the transmission of space-flight affects across generations may be conducted. A PI-led cardiovascular study is slated to be conducted on the second FFL flight. Development and behavior studies can also be easily conducted by utilizing the observation system. These areas of research are all called out by the decadal survey and NASA’s Fundamental Space Biology Plan as being crucial for space research (Table 3).

Table 2. Summary of characteristics of Drosophila that make it ideal for space research.

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Table 3. NASA’s Fundamental Space Biology Plan 2010-2020 Items Addressed

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<td>AH14 &amp; AH15 Both to address the mechanisms of the changes in the immune system and to develop measures to limit the changes, data from multiple organ/system-based studies need to be integrated.</td>
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<td>AH16 Study the transmission of structural and functional changes induced by exposure to space across multiple generations.</td>
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<td>CC8 Expand the use of animal studies to assess space radiation risks to humans from cancer, cardiovascular disease, neurologic dysfunction, degenerative disease.</td>
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References

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