Animal Invertebrate Models in Space Biology Research

Jacob Cohen, Ph.D.
Chief Scientist, Ames ISS Utilization Office
Deputy Chief (Acting), Mission Design Division
Director, Ames Biology Office, Engineering Directorate
NASA Ames Research Center
Jacob.cohen-1@nasa.gov
(650) 604-3261

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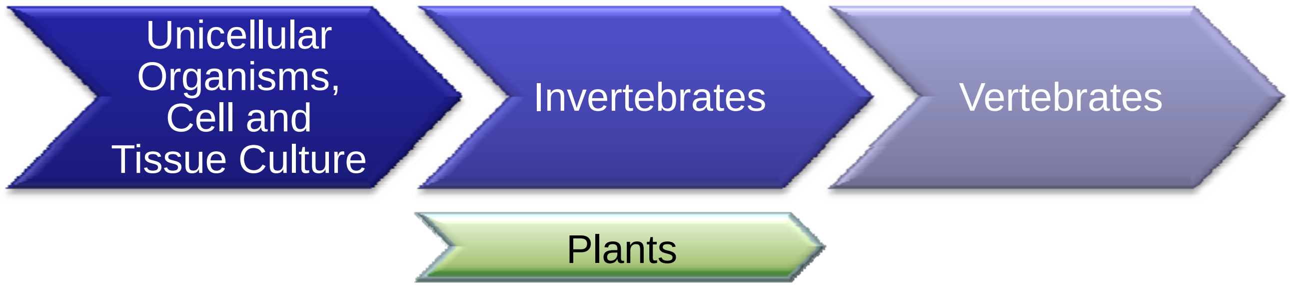
Why Use Invertebrates?



- Small size
- Replication rate / short generation time
- Ease of maintenance / hardy
- Similar / homologous pathways
- Well established systems with many analysis tools
  - Multi strains/mutants
- Large *n* (sample size)
- Least complex model to study hypothesis
  - No IACUC regulations on the use of invertebrates

Space Biology Areas of Study

Pull-Push Relationship

Knowledge Leads to Application
Application Leads to Knowledge

Knowledge	Application

• Sensing - Response
  • Signal Transduction
  • Direct or in-direct
• Effects
  • Physiology
    • Neurology
    • Muscle
    • Circulation
    • Immunology
  • Developmental Biology
  • Aging / life span
  • Behavior
  • Systems Biology
• Adaptation
  • Short Term
  • Long Term
	• Virulence
	• Regenerative Medicine
	• Drug Development
	• Life Support
	• Space Exploration *vs.* Earth

Examples of Invertebrate Animals Flown in Space

Most Common Invertebrate Animal Models

Fruit fly (*Drosophila melanogaster*)

Nematode (*Caenorhabditis elegans*)

Other Invertebrate Animal Models

Snail (*Biomphalaria glabrata*)

Monarch butterfly (*Danaus plexippus*)

Gypsy moth (*Pothetria dispar*)

Beetle (*Tribolium confusum, Trigonoscelis gigas*)

Tobacco hornworm (*Manduca sexta*)

Wasp (*Habrobracon juglandis*)

Spider (*Araneus diadematus*)

Cricket (*Acheta domesticus*)

Silkworm (*Bombyx mori*)

Planaria

Note: This is not an exhaustive list of all flown invertebrates.

Drosophila Spaced Based Results

Space environment effects on Drosophila shown by various studies

- Increases oocyte production and size.
- Enhances the number of growing embryos laid by the flies.
- Interferes with the distribution of maternal components involved in the anterioposterior axis of the embryo.
- Alters the deposition of yolk.
- Significantly decreases the number of larvae hatched.
- Reduced/delayed post flight development of recovered embryos to adults.
- Reduces the life span of adult males emerged from recovered embryos.
- Significantly decreases mating.
- Reduces negative geotaxis response.
- Increases locomotor activity.
- Increases the frequency of sex-linked recessive lethal mutations by 2 and 3 folds.
- Does not increase the frequency of somatic mutations.
- Does not significantly increase the accumulation of lethal mutations as measured through the male to female ratio in the descendant generation.

Note: This is not an exhaustive list of all results or studies.

C. elegans Spaced Based Results

Space environment effects on *C. elegans* shown by various studies

- Does not affect gross morphology, growth, development and behavior.
- Increases rate of mutation, with radiation, not microgravity, being the key cause.
- No surface tension issues (liquid *vs.* solid media growth).
- Normal occurrence of apoptosis.
- Alters muscle development.
- Total muscle protein increased in muscle mutants.
- Up-regulates genes related to embryonic and larval development, gametogenesis, and reproduction, and down-regulates genes related to locomotor, behavior, G-protein coupled receptor protein, and ion transport.
- Exhibit slower protein aggregation rate.

- Cultured in the space environment for up to ten generations.
- Grown on NGM, M9 and CeMM Media.
- STS-107 flight worms survived Columbia accident.

Note: This is not an exhaustive list of all results or studies.

Space Environment Variables and Controls

Disruptive
- Gravity
- Radiation

Process
- Transportation
- Vehicle
- Equipment
- Sample Preservation

Controls
- On-Orbit & Ground
- Synchronous & Asynchronous

ISS Hardware/Platforms for Space Biology Research

BSTC (Biotechnology Specimen Temperature Controller)
- Incubator: +4°C to 50°C for up to 32 stationary tissue culture modules (TCMs)

CGBA (Commercial Generic Bioprocessing Apparatus)
- Refrigerator/Incubator from +4°C to 37°C

EMCS (European Modular Cultivation System)
- Centrifuges: two centrifuges for 0-2x gravity experiments in a controlled environment

BioLab (Biological Experiment Laboratory in Columbus)
- Bioglovebox providing two levels of containment and ozone sterilization
- Centrifuges: two centrifuges from 0.001 to 2 x gravity
- Incubator: 18°C to 40°C
- Microscope: bright field, phase contrast and dark field
- Spectrophotometer: 220-900 nm
- Refrigerator/Freezer: -20°C to +10°C

ABS (Autonomous Biological System)
- Acquatic habitat

ADF (Avian Development Facility)
- Centrifuge: 0 to 5 x gravity

ADSEP (Advanced Space Experiment Processor)
- Thermally controlled incubator

ABRS (Advanced Biological Research System)
- Incubator for biological specimens

BCA (BioServe Culture Apparatus)
- Cell culture chambers

GAP-FPA (Group Activation Pack - Fluid Processing Apparatus)
- Microgravity test tube and serial transfer investigations

MOBIAS (Multiple Orbital Bioreactor with Instrumentation and Automated Sampling)
- Incubator: 10°C to 25°C

Food	Temperature	Humidity
Gas	Waste	Passaging
Gravity	Lighting	Imaging/Data

http://www.nasa.gov/mission_pages/station/science/index.html

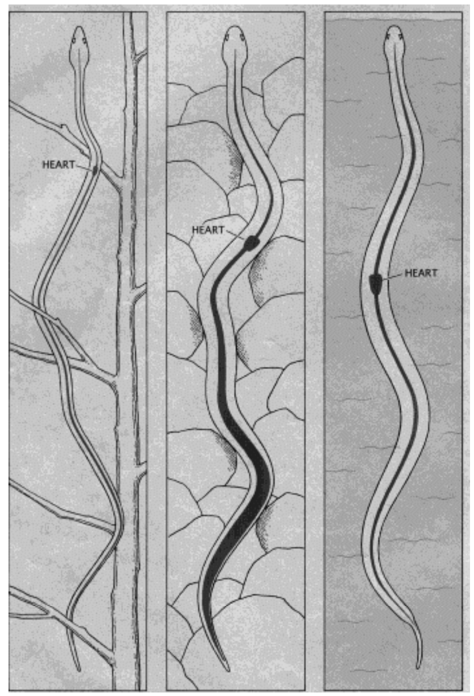
Note: This is not an exhaustive list of all available hardware.

Does Gravity Play a Role in Evolution?

SNAKES

Response to Gravity

Tree Snake>Land Snake>Aquatic Snake



Tree **Land** **Sea**

- Lillywhite, H.B. Snakes, blood circulation and gravity. Scientific American. 256:92-98, 1988.
- Lillywhite, H.B., R.E. Ballard, A.R. Hargens, and H.I. Rosenberg. Cardiovascular responses of snakes to hypergravity. Gravitational Space Bio. Bull. 10 (2):145-152, 1997.

Model organisms, and in particular small invertebrates, offer a method by which we can gain insight into novel pathways and processes affected by gravity and the space environment, and provide a test-bed for various novel applications for use in space and on Earth.