ISS “Kibo” utilization research in Japan

The 11th Korea-Japan Joint Seminar
on Space Environment Utilization research
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Topics

- The Dawn of Japanese Space Environment Utilization Research
- The preparation of “Kibo” Utilization Research
- Beginning of “Kibo” Utilization Research
- “Kibo” Utilization Research
- “Kibo” Utilization Cooperation between Korea and Japan

The Dawn of Japanese Space Environment Utilization Research

- Japanese space environment utilization research activities started by the Space Shuttle/Spacelab mission launched in September of 1992.
  - 12 Life science experiments
  - 22 Material and Physical experiments
  - Duration: 7days

- In the same year, 1992, first announcement of opportunity for “Kibo” utilization research was released. And in 1993, 50 proposals were selected as the candidates research projects. This is the beginning of “Kibo” utilization research preparation.
  - 21 Life science experiments
  - 29 Material and Physical experiments

The Preparation of “Kibo” Utilization Research

- Until “Kibo” operations starts, many space experiments had been conducted by Space Shuttle or sounding rocket missions.
  - 9 sounding rocket flights
  - 9 Space Shuttle missions (including 3 Space Shuttle/Mir missions)

- Under these circumstance, this Korea-Japan Joint Seminar on Space Environment Utilization research has started in 2003.

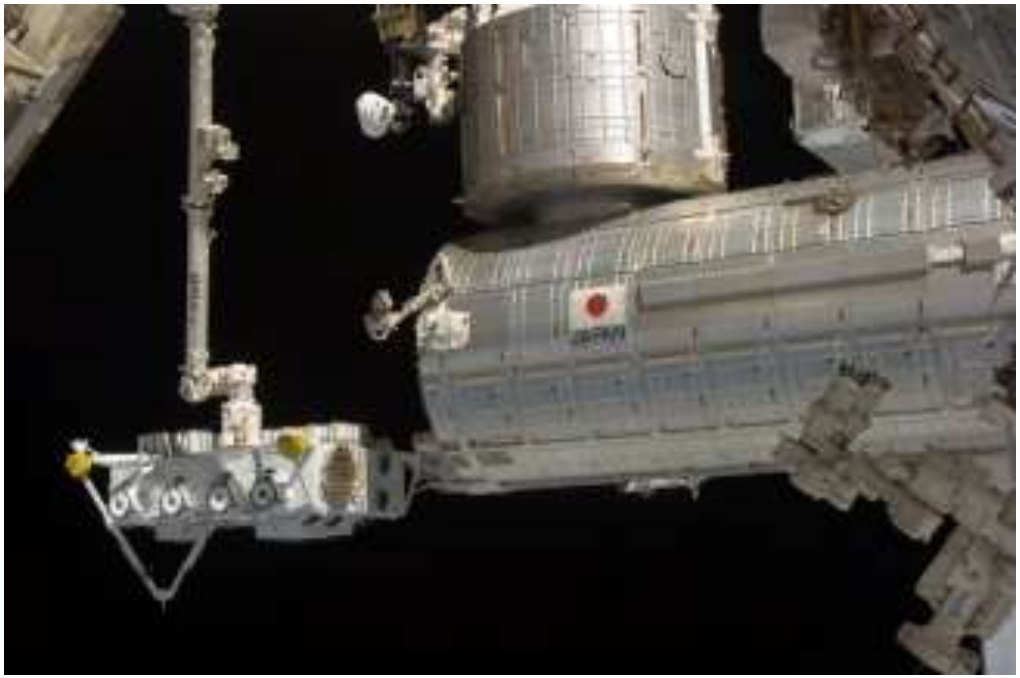
Japanese sounding rocket launch(TR-1A)

Plant experiment on Space Shuttle(STS-95)

Beginning of “Kibo” Operation

- The assembly of “Kibo” started with the launch of Pressurized Logistic Module on March 11th of 2008.

- “Kibo” was assembled by three Space Shuttle launches. The assembly was completed by the Exposed facility attachment on July 19th of 2009.



Assembly of Japanese Exposed facility

Beginning of “Kibo” Utilization Research

- “Kibo” Utilization research has been conducted with phased approach.

- The first pahase is from 2008 until around 2010 and its aim is;
  - To conduct various themes to explore space environment utilization

- The the second is from around 2010 until now and the third phase is until around 2014. The aim of those phases are;
  - Implement leading scientific researches
  - Foster utilization to meet society need and citizen’s expectation

- Around 80 Experiment projects have been conducted in “Kibo” since its Utilization start.

Life science experiments in Kibo

Present

Life science experiments on Kibo began (in Feb. 2009).

Year	2009	2010	2011	2012	2013	2014 later
Cell & Life (CBEF)	Frog kidney cell (dome formation) [Asashima] Nematode (RNA interference) [Higashitani]	Muscle atrophy (ubiquitin) [Nikawa] Goldfish scale (bone metabolism) [Suzuki]		Medaka bone metabolism [Kudo]	Medaka 2[Kudo]	Cells: gravity response、muscle atrophy, bone marrow cell: osteogenesis Nematodes: gene effects through aging and alternation of generations in space Aquatic organisms: effects across generations (breeding across 3 generations), muscle atrophy, reproductive function, and stress evaluation
Technology for measuring the effects of radiation	Human cell p53 influence [Ohnishi] Silkworm egg [Furusawa] Mutant human cell [Yatagai]	Nerve cell (Mitochondria apoptosis) [Majima]			Frozen ES cells [Morita] Mouse's frozen and dried sperm [Wakayama]	Effects on life by long-term radiation exposure (max. 3 years), evaluation of effects on reproduction, growth and multiple generations Development of real-time radiation measuring technology
Plants (CBEF)	Arabidopsis thaliana cultivated (long term till 60th day) [Kamisaka]	Oryza sativa cell wall (ferulic acid) [Wakabayashi] Root hydro-tropism (auxin) [Takahashi]	Auxin dynamics [Takahashi]	Plant's gravity response system [Hoson]	the structure of "cortical microtubules [Soga]	Systems of graviperception and posture control Effective plant production, utilization technology, and life support
Microorganism	Experiment 1	Monitoring microorganism in the Kibo module [Makimura & Nasu]	Experiment 2	Experiment 3		In-orbit analysis and adaptation to monitoring and environment

Material and Fluid science experiments in Kibo

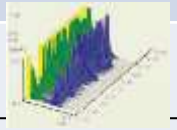
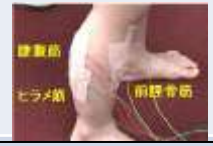
Start of materials science experiments on KIBO（Aug. 2008）

Present

Year	2008	2009	2010	2011	2012	2013	2014
Fluid (FPEF)	1st series	2nd series	1st series / 2nd series / 3rd series	4th series	5th series	Liquid Marangoni Convection Exp. Dynamic Surf[Kamotani]	Atomization Theory verification Exp. [Umemura]
Com-bustion (CCE)							Gaseous Combustion Exp. [Mikami]
Crystal Growth (SCOF) (Kobairo)	Ice Exp.[Furukawa]		Solidification/Crystallization Exp.. [Inatomi]		Single Crystal Semiconductor Exp. [Kinoshita] / Protein Crystal Observation Exp. [Tsukamoto]		Antifreeze Protein Crystal Observation Exp. (ICE2) [Furukawa]
Soft matter	Protein Crystallization Exp.	Nano-skelton Exp.[Abe]		200nm Nano-template Exp.[Kinoshita]			Semiconductor Growth Exp.[Inatomi]
Funda-mental physics	Plasma Exp. in collaboration with DLR (Germany)						

Space Medicine in Kibo

Start of Space Medicine experiments on KIBO(2008)

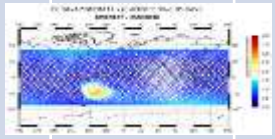
Year	2008	2009	2010	2011	2012	2013	2014 or later
Space Medicine		  Hair: Biomedical Analyses of Human Hair					
		Biological Rhythms 24hrs			48hrs: cardiac autonomic function	  	
		   **Myco:** Mycological Evaluation			 V-C Reflex: Plastic alteration of vestibulo-cardiovascular reflex and its countermeasure		
							 Synergy: The elucidation of the re-adaptation on the attitude control
							IPVI: Non-invasive assessment of intracranial pressure for space flight and related visual impairment

Exposed experiments in Kibo

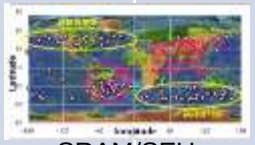
Start of exposed experiments on KIBO（Aug. 2009）

Present

Year	2008	2009	2010	2011	2012	2013	2014 or later
SEDA-AP (2009~)	Space Environment Data Acquisition Equipment						
MAXI (2009~)	Monitor of All-sky X-ray Image						
SMILES (2009~)	Superconducting Submillimeter-Wave Limb-Emission Sounder						
MCE (2012~)	Multi-mission Consolidated Equipment ・IMAP (Ionosphere,Mesosphere,upper Atomosphere, and Plasmasphere mapping) ・GLIMS (Global Lightning and sprIte Measurements) ・SIMPLE (Space Inflatable Membranes) ・REXJ (Robot Experiment) ・COTS-HDTV (COTS HTDV Verification)						
ExHAM (2014~)	Exposed Handrail Attach Mechanism						
CALET	CALorimetric Electron Telescope						

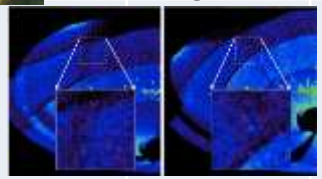


SAA



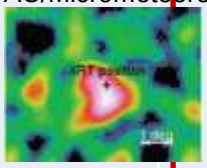
SRAM/SEU

MPAC/Micrometeoroid

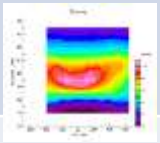


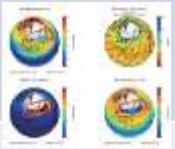
a massive black hole swallowed a star

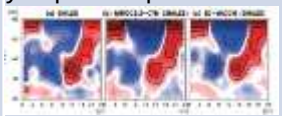
the huge luminosity emitted by a “fireball” dwarf,
an early explosion phase of a massive white dwarf



a gigantic gamma-ray burst



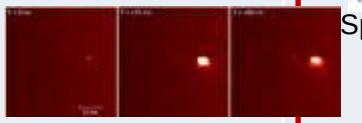




Ozone Distribution

Space Inflatable Membranes

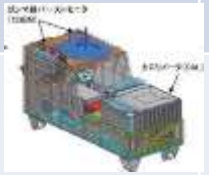
Robotics Ops

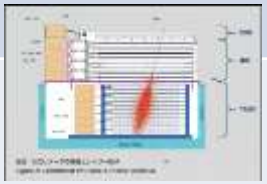


upper-atmospheric lightning

Tohoku/Japan

Typhoon





Techinical Development and Education Activities

CY	2008	2009	2010	2011	2012	2013 later
Technical Demonstration	Holter HDTV/MPC Area PADLES			SSHDTV Onboard Diagnostic Kit	i-Ball Small Satellite Deploy	4K HDTV FROST Hybrid Training System
Education		1st series	moon score Aqua sphere Ink Ball Clay neuron message in the bottle Spiral Top Green Tea Ink Ball	Asian Mission 2nd series Space SAKURA Space Music Space Sound	Blue Earth Gazing Asian Seed 2013	

“Kibo” Utilization Cooperation between Korea and Japan

- **This Korea-Japan joint seminar reached 11 times.**
  Furthermore, a Korea-Japan researcher raises a study level each other and promotes the Korea-Japan space environment utilization and raises the science technology of the two countries, and a thing becomes important.

- **Therefore, it is important that the academic cooperation by the Korea-Japan researcher continues evolving more.**

Highlights of Kibo Utilization Overview
~ Life Science ~

High-quality Protein Crystal Growth(PCG) Experiment

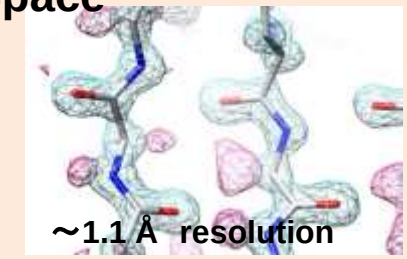
■The purpose of the experiments

- To obtain high-quality protein crystals under microgravity and to achieve more precise 3-D protein structures.
- Developing industrial applications as functional protein and drug designs based on protein structures.
- Contributing to structural biology by clarifying protein structures and functions.

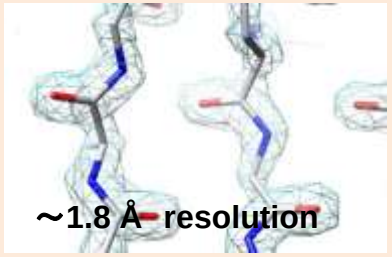
■Examples of Results

Nylon Oligomer Hydrolase (University of Hyogo)

Space

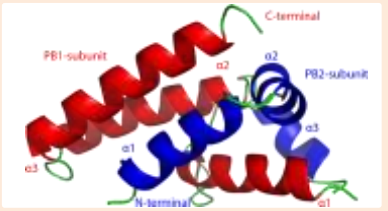


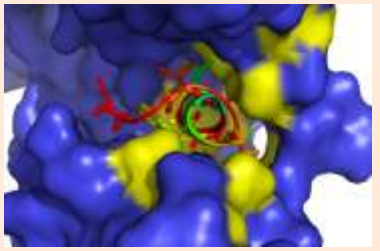
Ground



Create new enzymes and catalyze the synthesis of nylon-6 (reverse reaction) or other potential products.

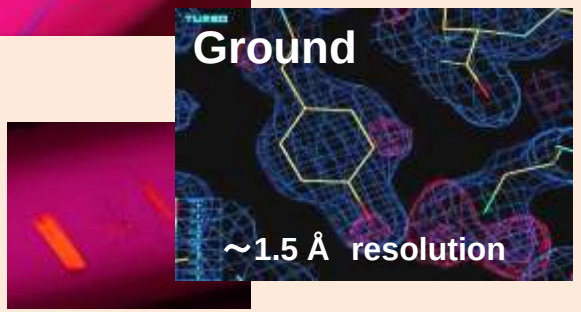
Influenza virus RNA polymerase (Yokohama City University)





Structural insight into the RNA polymerase lead to the development of new medicine regardless of influenza viruses type.

Prostaglandin D Synthase (Osaka Bioscience Institute)



A drug for muscle diseases was designed by pharmacists and its effect was confirmed with animal experiments.

High-quality Protein Crystal Growth Experiment

Soyuz/Progress

Launch

Crystallization in Kibo

Return

Soyuz

Concept of JAXA PCG

- User-friendly support system
- Application of accumulated know-how to maximize space crystallization

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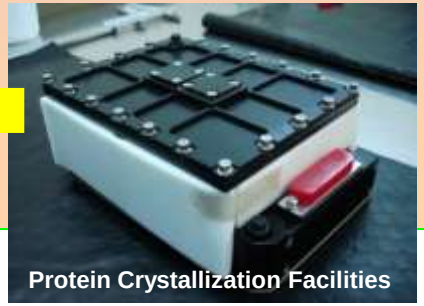

Protein Crystallization Facilities

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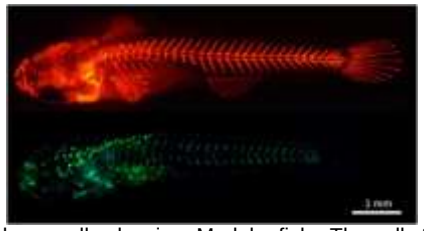
Visual inspection and X-ray diffraction

Medaka Osteoclast - 2

Effect of Microgravity on Osteoclasts and the Analysis of the Gravity Sensing System in Medaka

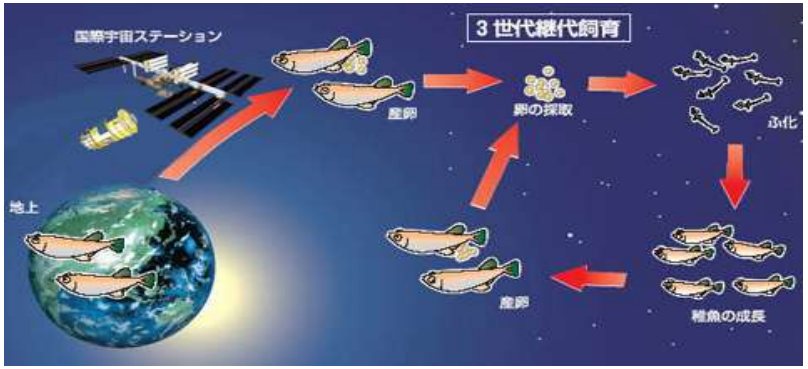
PI: Professor Akira Kudo, Tokyo Institute of Technology, et al. Sponsoring Space Agency: JAXA



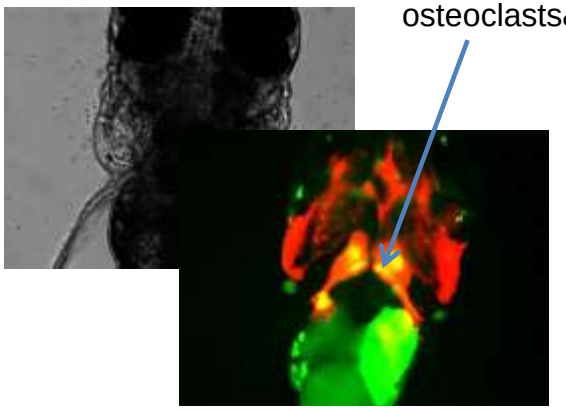
Visible fluorescent bone cells glow in a Medaka fish. The cells that create bone are red, while those that break it down are green

Research Objectives

During space flight, bone mineral density is decreased by the influence of osteoclast activation. The molecular mechanism of this phenomenon is investigated in this study. In order to examine the effect of microgravity on osteoclast activation in space, this experiment performs *in vivo* imaging analyses of gene expression and cell mobility with embryonic and juvenile Medaka from osteoclast-specific transgenic lines. In combination with the long-term growth experiment (Medaka Osteoclast), the alteration of osteoclast activity in microgravity is studied microscopically and by means of gene expression analysis.



Multigenerational research of model fish onboard the ISS. [JAXA]



Fluorescence imaging of Medaka osteoclasts. [JAXA]

Medaka (*Oryzias latipes*) in the Aquatic Habitat (AQH).

Using Medaka as a "model specimen", the effects of space flight on individual systems can be investigated:

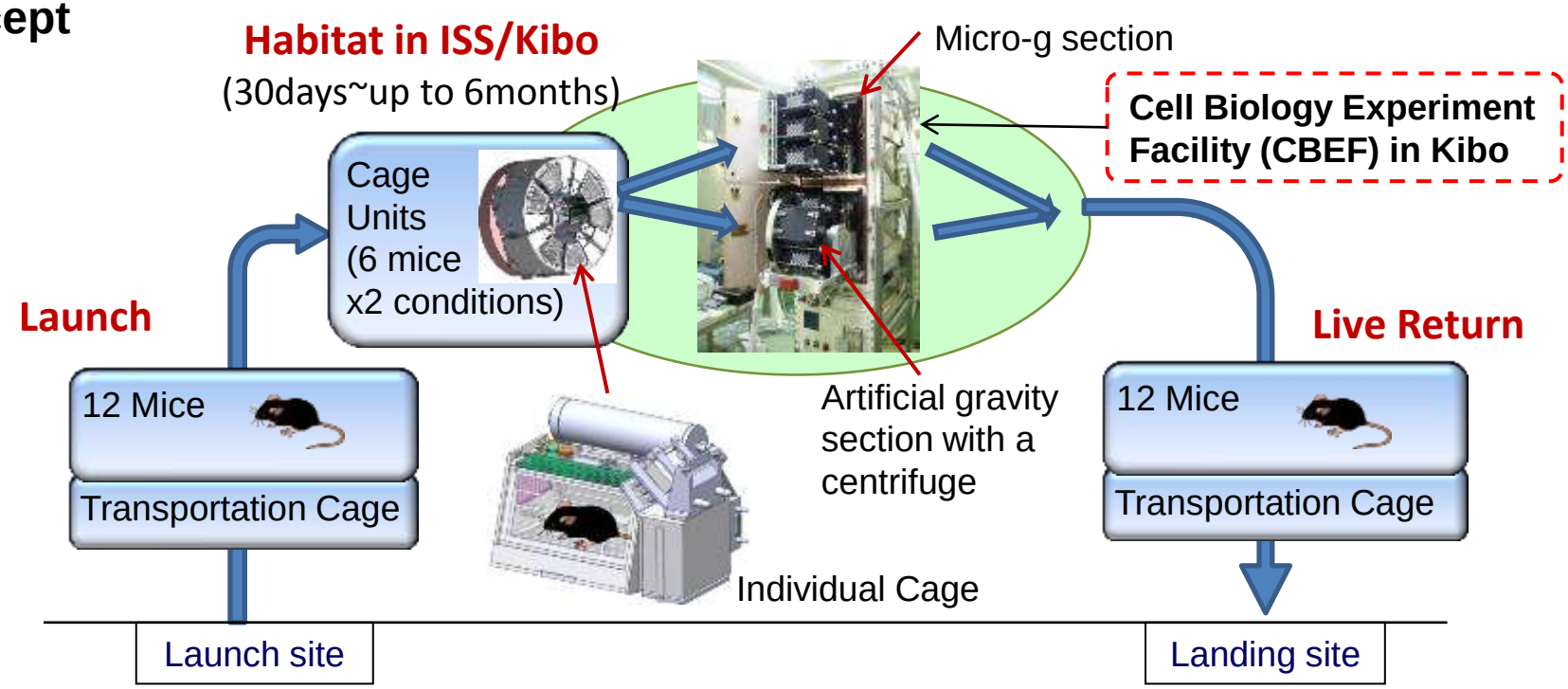
- Bone degradation
- Muscle atrophy
- Radiation effects
- Early development

Space Applications: Elucidation of the molecular mechanism of bone mineral density decrease in space flight.

Earth Applications: Development of pharmaceuticals to treat senescent osteoporosis.

Japan's Mouse Habitat Experiment in ISS/Kibo

Concept

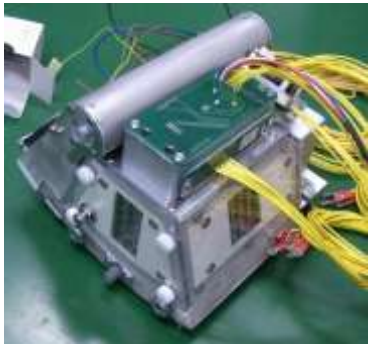


Advantages of Japanese experiment to the other mice experiments in space

1. **Comparison between micro-G and artificial-G (1G) conditions in space:** Provide the world's first, long-term artificial gravity environment for mammal in space
2. **Individual Habitat (1 mouse per cage**): Able to accommodate male mice which may fight each other in a group habitat condition; Able to monitor behavior of individual mouse
3. **Return mice to the ground in living condition**: Skilled researchers can dissect mice for their detailed analysis with cutting-edge techniques

Preparation Status of JAXA Mouse Habitat Experiment

1. Development of experiment system (Mouse Habitat Unit)
   1) Animal compatibility tests using mice with test models of hardware completed.
      - 30-days for onboard cage unit
      - 10-days for transportation cage unit
   2) Critical design of the flight model on going.
   3) Target timeframe of the first experiment is early 2016.
2. Researches using the Mouse Habitat Unit
   1) A research focusing on epigenetic alterations is planned as the first experiment using the Mouse Habitat Unit in early 2016.
   2) Post landing dissection procedure has been developed and verified.
3. Ground-based experiment
   1) Preliminary centrifugation experiments showed a short-arm centrifuge (R=15cm; same as onboard CBEF) is usable for mice.
   2) Various mice experiments using elements of the Mouse Habitat Unit have been conducted and fundamental data have been accumulated.



Cage unit used in CBEF (test model)

Transportation cage unit (test model)

Short-arm centrifuge for mice (R=15cm)

Stem Cell

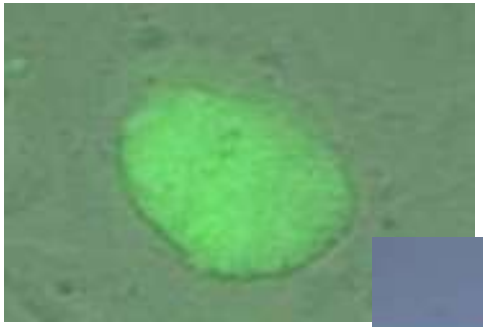
Study on the Effect of Space Environment to Embryonic Stem Cells to Their Development

PI: Professor Takashi Morita, Osaka City University, Osaka, et al.

Sponsoring Space Agency: JAXA

Research Objectives:

Stem Cells is an investigation that uses embryonic mouse stem cells to study the effects of the space environment on their DNAs, chromosomes, and on their development into adult mice after return to Earth. Frozen stem cells are placed in the Kibo module for periods ranging from 6 to 36 months, and then returned to Earth where scientists will microinject them into 8-cell mouse embryos that will be implanted in female mice. Investigators will also look for double-strand DNA breaks and chromosome aberrations caused by space radiation



Mouse ES Cell

Cryo tubes in the Case

Stem Cells Sample Case

A “Stem Cells Sample Case” in a mock up of MELFI 1/2 box module

MELFI

Space Pup

Effect of space environment on mammalian reproduction

PI: Professor Teruhiko Wakayama,
Yamanashi University, et al.
Sponsoring Space Agency: JAXA

linjecting male germ cells directly into an oocyte using microscope

Research Objectives: Space Pup represents the first step towards studying the effects of space radiation on mammalian reproduction, which must be understood to sustain life beyond Earth. This starts by holding freeze-dried mouse sperm aboard the International Space Station for one, 12, and 24 months, and then fertilizing mouse eggs on Earth to produce mouse pups to study the effects of space radiation.

Ampoule (in the case)

Space Pup Sample Case

A “Space Pup Sample Case” in a mock up of MELFI

Space Applications:Sustaining life beyond Earth either on space stations or other planets requires a clear understanding of how the space environment affects key phases of mammalian reproduction. So far only non-mammals have been used in reproductive studies in space. Studies using simulated microgravity on Earth showed birth rates due to poor placental development, indicating that microgravity has an adverse but unknown role in fertilization and gestation. Space Pup will help isolate radiation as a factor in long-term studies.
Earth Applications: The gestational period is highly sensitive to environmental factors, including radiation and potentially the effects of gravity. Results from this experiment should provide valuable information for the collection and preservation of mammalian reproductive tissue for a range of uses.