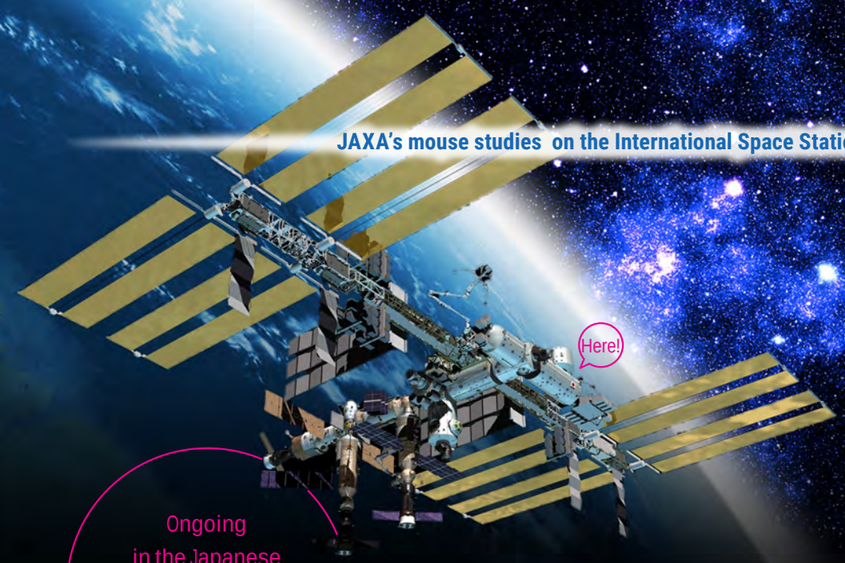
Space Mouse
A Key to the Secret of Life

JAXA's mouse studies on the International Space Station



Ongoing in the Japanese Experiment Module "Kibo"

National Research and Development Agency
Japan Aerospace Exploration Agency
Human Spaceflight Technology Directorate

Mouse Habitat Unit (MHU)
https://humans-in-space.jaxa.jp/en/biz-lab/experiment/facility/pm/mhu/

JAXA Explore to Realize

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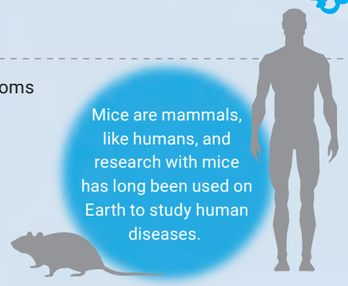
Standardized conditions, comparison, and tissue analysis impossible in humans

Living in space causes a variety of physiological changes, including weakened bones and muscles, lowered immune function, and a worsened sense of balance. Such symptoms are similar to those associated with aging, except that their progression is much faster in space. Mouse studies on the International Space Station (ISS) provide an accelerated platform for aging research, which can help us understand the mechanisms of aging-related symptoms and develop methods for preventing and treating them. Mouse research also gives us valuable information about how humans can operate in space over longer times and distances.

1 Physiological changes in space

After spending a long time in space, even healthy astronauts experience symptoms such as weakened bones and muscles, a worsened sense of balance, optic disc edema (swelling in the area where the optic nerve enters the eye, caused by increasing pressure on the brain and its periphery), and enlargement of the heart. Although we use exercise and other health management measures to address these health issues, we still do not fully understand the mechanisms behind them.



2 Mouse studies tells us about disease mechanisms

U.S. and Russian space studies using mice and other small animals have shown that these animals experience physiological changes similar to those in humans. We expect that mouse-based research will help us understand the mechanisms behind such changes at the genetic level.

Research into mice raised in space could reveal the mechanism of sarcopenia (loss of muscle mass) and the effect of bone and muscle loss, and also show how the stress of living in a space environment affects the immune system and the central nervous system. By performing mouse research in parallel with measuring the effects on astronauts, we can compare the effects in mice and humans. This will also show how humans can adapt better to the long-term effects of different gravitational environments, such as by investigating how changes in gene expression are passed on to future generations in space environments.

3 A platform for accelerated aging-like phenomena

The physiological changes seen during time spent in space are like an accelerated version of the changes seen in elderly people on Earth. In the absence of sufficient exercise in space, bone density loss occurs around 10-fold faster than in patients with osteoporosis on Earth, and a single day's calf muscle loss in space is equivalent to two days' loss in a bedridden patient, or around six month's loss in an elderly person.

Recently, locomotive syndrome, which involves weakening of bones, muscles, and other organs related to movement, has become an area of increasing interest. Through mouse experiments on Kibo, we plan to identify factors for the early diagnosis of such age-related diseases and to perform pre-clinical studies to investigate the efficacy and safety of prophylactic and therapeutic drug candidates. By helping to prevent and treat locomotive syndrome, these studies are expected to extend health during the lifespan.

4 Standardized conditions, comparison, and tissue analysis impossible in humans

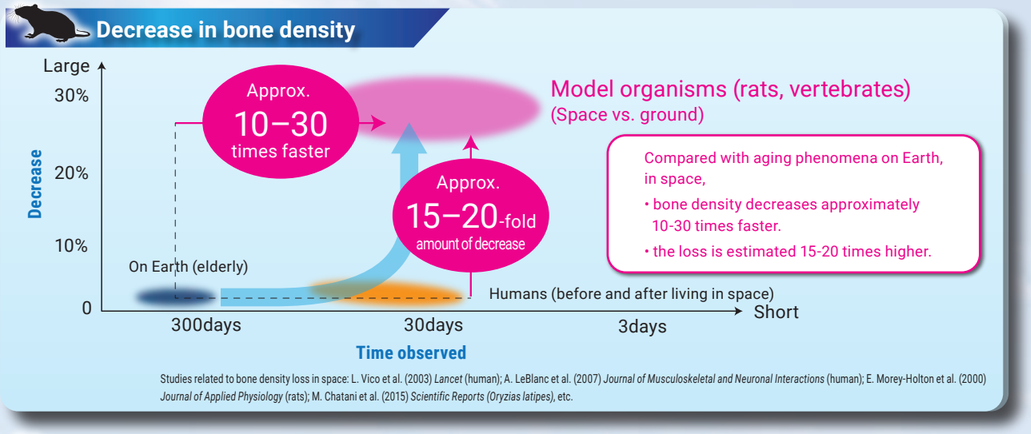
There are many aspects of research that cannot be applied to astronauts, such as standardized experimental conditions for genetics and living environment, strict comparison of gravity effects by creating artificial gravity in space, and detailed analysis of tissues and organs. Better results can be obtained for human healthcare on Earth by complementing the data from studies on astronauts with what we learn from mice.

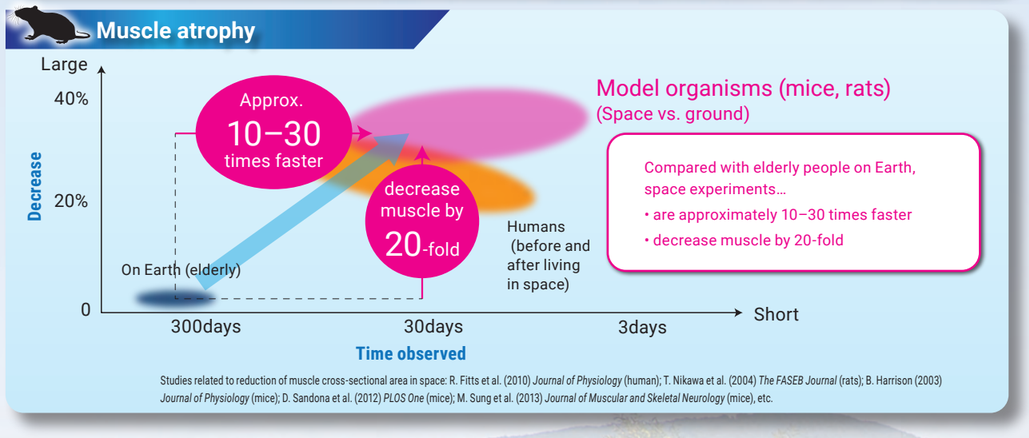
5 Data that cannot be obtained on the ground

The following are some characteristics of space studies using mice:

1. Aging-like phenomena occur 10 to 30 times faster in space than on Earth. In comparison with astronauts, who must exercise every day for health maintenance, the model organism allow for observations of bone density and muscle area losses that are fifteen- to twenty-fold the severity.
2. Changes can be measured over time in response to only gravitational changes within individual mice. After returning those mice to Earth, it is also possible to observe recovery from symptoms similar to aging.
3. Whole-body effects can be observed without artificial conditions such as altered genetics or partial paralysis.

These features that are impossible to reproduce on Earth can be used to discover new phenomena. The results may identify genes related to diseases in which aging and environment are factors.

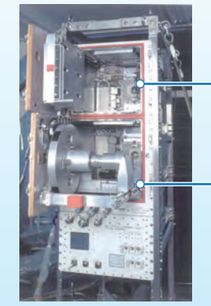




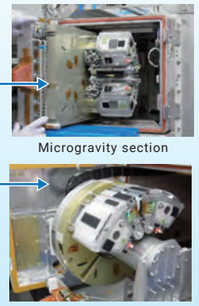
Experiment Facility

Biological experiment facilities in Kibo

JAXA's Cell Biology Experiment Facility (CBEF) has a centrifuge section and a microgravity section to compare gravitational effects on mice. Each section accommodates six mouse cage units. Using the Cell Biology Experiment Facility-Left (CBEF-L) provides additional research opportunities in operation with more habitat cages attached.

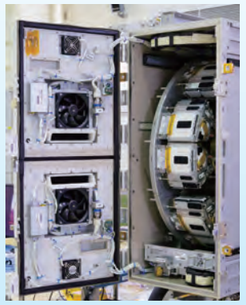


Cell Biology Experiment Facility (CBEF)

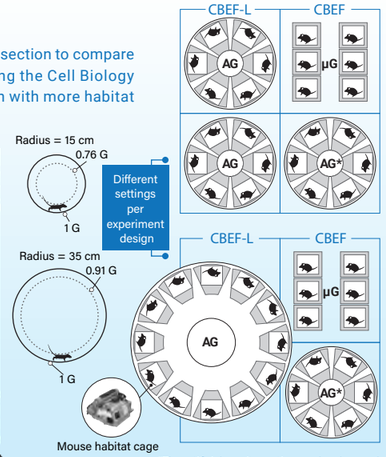


Microgravity section

Artificial gravity section



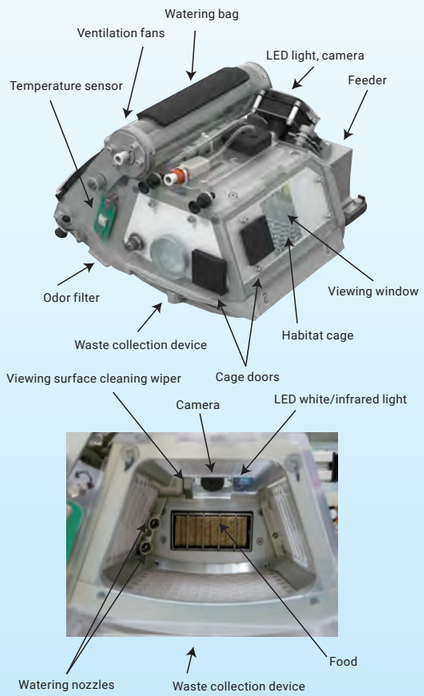
Cell Biology Experiment Facility-Left (CBEF-L)



*The artificial gravity section can be also used for microgravity experiments.

Mouse habitat Cages

The JAXA's habitat cage provides individual housing per mouse for a 30-day flight experiment. Each cage has a feeder, watering system, LED light, waste collection device, odor filter, ventilation fans, temperature sensor and infrared video camera with a lens wiper equipped. Optionally, a habitat cage can be exchanged after a month of use to expand the duration of a flight experiment.



Tele-Luminescence Analysis System (TELLAS)
- Non-invasive In Vivo Bioluminescence Imaging System -

In 2024, JAXA has introduced biology imaging hardware, TELLAS to Kibo to detect genetic changes in living organisms during space flight. In Vivo imaging technologies enables observation of longitudinal changes that occur on mice during a flight experiment, but the changes cannot be observed after live return to the Earth.

First-ever In Vivo Imaging Analysis in Space!

Imaging acquisition of luminescent cells and tissues with TELLAS

- The space-model – TELLAS, designed lighter in weight than the ground model to be flown to and used in a limited space environment
- Longitudinal image data acquisition of living mice
- Real time data downlink from the Kibo to the ground
- Non-invasive measurement, without disturbing regular animal cares

Tele-Luminescence Analysis System (TELLAS)

Data analysis by researches on the ground

- Image acquisition in the Kibo can be made by a ground operator.
- The resulting images are real time downlinked from the Kibo to observe by researchers on the ground.
- In the future, it is expected to use TELLAS in a wide range of research fields such as gene expression, tumors, regenerative medicine, and drug development.

Single-CTB Mouse Automated Rearing Transporter (SMART)

Innovative mouse transporter and habitat system is under development!
Long-term maintenance capability of basic animal care (food, water, cage cleaning etc.)

The new type of JAXA's mouse habitat system, SMART is designed maintenance free for a month to keep mouse habitat cages healthy and clean. Which minimizes crew's intervention to reduce costly crew time onboard. The SMART will be equipped with the capability of real time data acquisition from the ISS.

Project Flow

Solicitation (Public use)

Announcements of opportunity for space experiments
Proposals for experiments are solicited from universities, research organizations, and companies.

Experiment selection
Experiments are selected based on their proposals and expected outcomes.

On-demand (Commercial use)

Request and consultation
A service user requests and consults with JAXA to conduct a space experiment, including technical feasibility, schedule and costs.

Conclusion of a contract
The user makes an agreement with JAXA to initiate pre-flight activities.

Study of experimental conditions
The details of experimental conditions, such as number of samples, scheduling on Earth and in space, and equipment, are studied collaboratively by JAXA and the researchers.

Preparatory experiments
Gravitational effects can be evaluated before space experiments by using a centrifugal habitat that produces a hyper-gravity environment on the ground.

Committees
All experimental plans, including preparatory experiments, are subject to approval by institutional animal care and use committees and ethics review boards in related organizations in Japan and overseas.

Launching to the ISS
Mice are transported to the ISS.

Performing experiments on Kibo
Experiments are conducted on Kibo.

Transport to Earth and handover to researchers
Flight mice are transported to Earth are transported to Earth and returned to their respective researchers.

Kibo is a laboratory that allows for unique experiments in space.

JAXA has accumulated technology and know-how to support new ideas for R&D using the space environment.

Research results of the first Mouse Habitat Unit (MHU-1) mission

The MHU-1 mission was successfully conducted in Kibo with 12 mice in July-August 2016. All mice were returned alive to the Earth after the 35-day flight experiment.

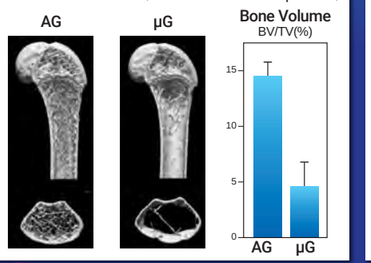
Microgravity (μG)

Artificial gravity (AG: 1G in space)

Fifth day of on-board rearing (July 25, 2016)
http://iss.jaxa.jp/kiboexp/news/20161013_mouse.html

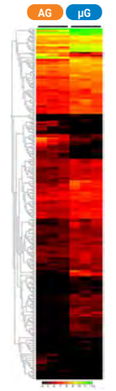
Changes in bones

It was found that cancellous bones in the femur of the returned mice had dramatically decreased among mice reared in the μG section compared with those reared in the AG section. Symptom similar to severe osteoporosis was observed by rearing in space for only 35 days.
(Shiba D et al. Sci Rep. 2017)



Changes in muscles

Muscle weight of the soleus, one of the antigravity muscle, of mice reared in the μG section was reduced by 10% compared with the mice reared in the AG section. Gene expression was also altered in 300 genes. Further precise analysis with less dispersion of data was anticipated.
(Okada R et al. Sci Rep. 2021)



Data of 3 mice /group

Check! Mouse studies in Kibo can contribute to research on age-related symptoms such as osteoporosis and sarcopenia.

Future Research Using the Mouse Habitat Unit

Strategic domains

A platform for supporting research into aging

In space

An accelerated model for aging-like phenomena (bone and muscle loss, lowered immunity)

- Analysis of epigenomic changes characteristic of space environments
- Correlation with age-related disease on Earth
- Drug target Identification for drug discovery

In space

Non-clinical testing new drug candidates

- Verification of the effects of preventative and ther apeutic drug candidates in mice reared in microgravity.

On Earth (universities, laboratories, etc.)

Building database of space life sciences and correlation analysis with space

- Identifying biomarkers* for age-related disease

*Indices for evaluating illness and physical condition

On Earth (pharmaceuticals manufacturers, laboratories, etc.)

Drug discovery for age-related diseases

- Designing suitable compounds for regulating the activity of targets of underlying disease

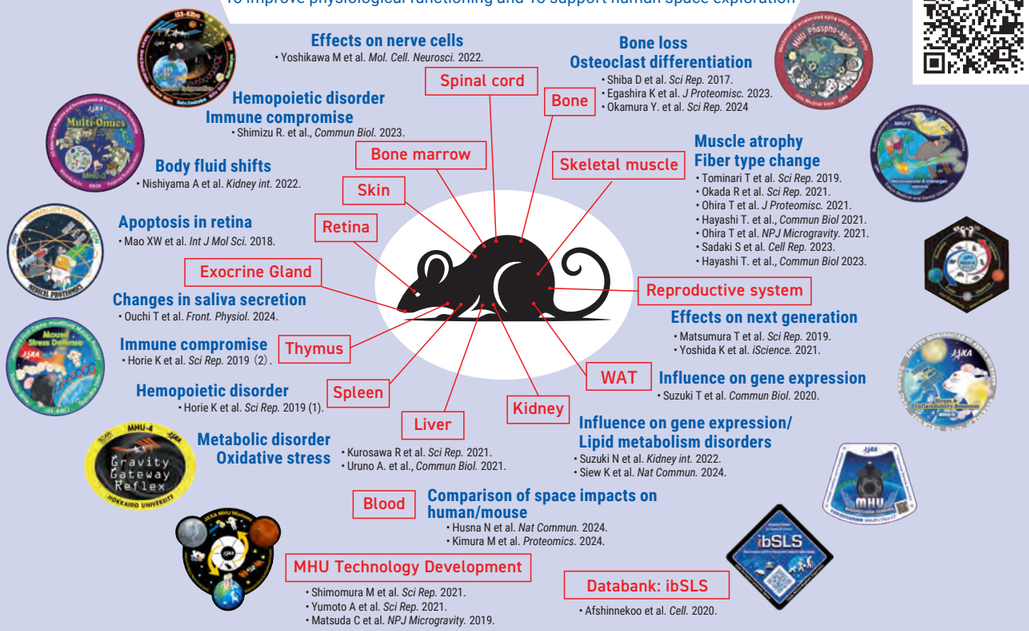
Technologies for early disease detection/ Innovative preventive and therapeutic drugs

Note: Research based on new ideas is possible

Knowledge discovery by MHU missions

To improve physiological functioning and To support human space exploration

Latest information (In Japanese) >>



Q Can rats or other animals besides mice be used?

A Currently, we can only accommodate experiments using mice. There is the other equipment aboard Kibo available for use as a habitat for *Oryzias latipes* (Medaka fish) or other small freshwater fish.

Q Can transgenic mice be used?

A Yes. However, experiments requiring transport of mice to the U.S. require time for applications and reproduction, so the feasibility of such studies will require consideration based on experimental requirements.

Q Are there limits on the age of mice at the time of launch?

A There are some. Mice in the cages in space are assumed to be capable of using a water nozzle and eating solid food, and so will require being raised on Earth to some extent. The launch of very young mice may require special handling.

Q Is group rearing possible?

A The current equipment does not allow this.

Q Are experiments on mice (blood and other samples, data acquisition, observation) in orbit possible?

A Yes, these are possible, as long as the astronauts can perform them in a glove box. The feasibility will be considered based on the experimental requirements.

Q Are experiments by private organizations allowed?

A Yes, they are. Please contact us for details.

Integrated Biobank for Space Life Science (ibSLS)

Database to link mouse studies in space to human studies

From Space Mouse to Human on Earth

JAXA with Tohoku Medical Megabank Organization (ToMMo) have been promoting public database of multi-omics data obtained from JAXA MHU missions and sample sharing programs related to space biology. Researchers who are not involved in space missions can investigate physiological changes in space regarding their targeting factors. Using the ibSLS, multi-omics data in space mice can be comparable with those in ToMMo's Japanese Multi Omics Reference Panel (jMorp) datasets.