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Microgravity Experiment Case Studies
For the Student Spaceflight Experiments Program

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Described below are case studies of different microgravity experiments suitable for the MDA min-lab, and organized by science category.

1. Case Studies: Bacteria

Growth of Bacteria and Biofilms in Microgravity

There are many possible ways to study the growth of bacteria in microgravity:

- investigating how microgravity affects the growth of different kinds of bacteria cultures compared with a control culture on Earth;

- investigating how microgravity affects the formation of biofilms of bacteria such as Bifidobacterium on different kinds of surfaces (which have been sterilized before exposure to the bacteria during the experiment) compared with a control system on Earth. *E.g.,* are the biofilms thicker in one case, or are the bacteria distributed differently on the surfaces?

- exposing endospores (dormant forms of bacteria) of organisms such as Bacillus subtilis to microgravity, and then comparing the growth of the bacteria from reactivated endospores once they are brought back to Earth, with the growth of bacteria from endospores that were not exposed to microgravity.

These experiments could address many areas of science, from assessing whether organisms such as bacteria could be transported across space on the surfaces of meteoroids, to providing information on the survival and growth of bacteria inside spacecraft.

Bacterial and biofilm growth experiments flown on previous Shuttle flights using the MDA include *Growth of Bacterial Biofilm on Surfaces During Spaceflight (GOBBSS) (STS-107)*

Antibiotic Resistance of Bacteria in Microgravity

Previous studies have suggested that antibiotics may not work as well in microgravity for preventing bacterial growth. By placing a bacterial culture and an antibiotic substance in the two separate wells of the MDA, and exposing the bacteria to the antibiotic in orbit, and comparing the bacterial growth with a control experiment conducted on Earth, the possibility of enhanced resistance of bacteria to antibiotics in microgravity can be investigated. These studies may lead to better antiobiotic and antibacterial materials and disinfectants for use in space, as well as on Earth.

Antibiotic resistance experiments flown on previous Shuttle flights using the MDA include *Bacteria with Expression of Antibiotic Resistance (STS-107)*

2. Case Studies: Cell Biology

Cell Growth in Microgravity

Comparing the growth and behavior of cells of various types when exposed to microgravity with a control experiment on Earth will make it possible to determine how different cells respond to microgravity. For example, studying the growth of collagen in a growth medium can provide important information on how bone cells produce collagen in microgravity, which may aid in developing strategies for the treatment of osteoporosis, among other possible applications. By comparing the rate of cell growth in microgravity and on Earth, one can investigate whether cell growth is slower in microgravity, as previous studies have suggested.

Cell growth experiments flown on previous Shuttle flights using the MDA include *Bone Cell Differentiation* (STS-56), *Heart Cells in Culture* (STS-56), *Human Red Blood Cell Morphology* (STS-56), *Immune Cell Response* (STS-56), *Mouse Bone Marrow Cells* (STS-56), *Nerve/Muscle Cell Interactions* (STS-56), *Osteoblast/Osteoclast Osteoporosis Experiments* (STS-107), *Regeneration of Nerve Cell Growth Factor* (STS-107)

Cell Response to Chemical or Biological Agents in Microgravity

In this modification of the cell growth experiment in microgravity, a solution containing chemical or biological agents is placed in the second well of the MDA. When the two wells are brought into contact in orbit, the response of the cells to the chemical or biological agents under microgravity conditions can be compared with a control experiment conducted on Earth. For example, studying the response of cells to exposure to bacteria through phagocytosis (a process where infection-fighting cells engulf and destroy foreign materials) in microgravity can not only help evaluate the capability of these cells to fight infections during spaceflight, but also provide a better understanding of their behavior in general. By exposing cell cultures to various chemical agents it may be possible to determine ways to promote or inhibit cell growth in microgravity conditions through exposure to different environmental agents.

Cell response experiments flown on previous Shuttle flights using the MDA include *Live Cell Investigations* (STS-56), *Phagocytosis* (STS-56)

3. Case Studies: Fish and Other Aquatic Life

Development of Organisms in Microgravity

By allowing fish (or other aquatic life) eggs to hatch and embryos to develop under microgravity, and comparing the results with a control experiment conducted on Earth, it is possible to determine how the lack of gravity affects the development of these animals. The experiment can be done by just using one well of the MDA and exposing the contents to microgravity for several days, or by activating the development of the eggs and embryos by placing them in one well of the apparatus, suitable growth medium in the other, and mixing the two in orbit.

Growth of Aquatic Life in Microgravity
To determine if fish and other aquatic life such as shrimp might be a good food source during long-duration space flight, it is important to see how well they grow in microgravity. This could be done by allowing eggs to hatch or larvae to develop in microgravity and then seeing how much food they consume, when compared with a control experiment conducted on Earth, or by comparing the size of the specimens grown in microgravity and on Earth. For example, the protein-rich muscles of shrimp develop when they work against gravity while swimming. When in microgravity, the shrimp need to swim less, which could lead to smaller appetite, smaller muscle growth, making the shrimp grown in microgravity a less valuable protein-rich food source.

Regeneration of Planaria Worm in Microgravity
The experiment to see how the regeneration of the body parts of the Planaria worm may differ in microgravity from the process on the surface of Earth can be achieved by placing worms with missing segments in water, and comparing how the regeneration of lost body parts in microgravity may differ from a control experiment performed on Earth. Typically, a planaria worm split lengthwise will regenerate into two individual worms; does this occur in the same way in microgravity?

Fish and other aquatic life experiments flown on previous Shuttle flights using the MDA include *Brine Shrimp and Seeds in Space* (STS-67), *Fish Egg Hatching* (STS-56), *Killifish Embryos* (STS-80), *Larval Development of Artemia Salina* (a species of brine shrimp) (STS-80), *Larval Development of Brine Shrimp* (STS-52)

4. Case Studies: Fluid Diffusion
A simple way to investigate fluid diffusion in microgravity would be to place two fluids with a large difference in densities in the two wells of the MDA and bring them into contact in orbit. By comparing the level of mixing between the two fluids in the experiment aboard the Shuttle and one that remains on Earth can provide information of the effectiveness of fluid diffusion in microgravity. In a variation, particles could be contained in one of the fluids to see how they affect the mixing of the two fluids, and how the particles become distributed through the combined volume of the MDA wells. But to do this experiment requires the experiment to be 'turned off' before the Shuttle de-orbits, by separating the two MDA wells. If not, the introduction of gravity will then cause large-scale mixing and there will be no means of determining the effects of fluid diffusion. On STS-134 the wells cannot be separated before de-orbit because of the required MDA slide protocol on STS-134.

Fluid diffusion experiments flown on previous Shuttle flights using the MDA include *Gas Diffusion* (STS-80)

5. Case Studies: Food Products

Nutritional Value of Food Products Containing Probiotics in Microgravity

By placing a food product containing probiotics in the well of the MDA, it is possible to determine how well the micro-organisms beneficial to humans survive in microgravity. After landing, samples of the food product containing probiotics can be cultured, and the level of growth of the bacteria compared with the growth of bacteria taken from samples of a control food product that remained on Earth.

Food Storage and Spoilage of Foods in Microgravity

The effectiveness of various food storage materials could be assessed by encasing foods in storage material in the well of the MDA, and comparing the product after exposure to the microgravity environment with a control product that remained on Earth. Alternatively, one could place a chemical or a harmful bacteria solution in the second well of the MDA, and bring it to contact with the food product in orbit. The level of spoilage of the food product during the mission can then be compared with a control experiment conducted on Earth. These experiments address how effective food storage methods might be developed for human spaceflight missions.

Food product experiments flown on previous Shuttle flights using the MDA include *Food Products in Space* (STS-107).

6. Case Studies: Inorganic Crystal Growth

Growing Inorganic Crystals in Microgravity

A simple way to produce inorganic crystals in orbit is to create a crystallization solution (for example by mixing hot water into the inorganic crystal chemicals, such as potassium aluminum sulfate or potassium chloride sulfate, and letting the solution cool to room temperature), then placing the solution in one well of the MDA, and leaving the other well empty, so that it contains just air. Bringing the two wells together in orbit starts the evaporation of the solution and activates the growth of the crystals. The crystals grown in microgravity can be compared with control crystals grown on Earth to see whether the crystals grown in microgravity are larger and purer, as previous studies have suggested.

Inorganic crystal growth experiments flown on previous Shuttle flights using the MDA include *Tin Crystal Production* (STS-80), *Inorganic Crystal Growth in Microgravity* (STS-107), and *Tin Crystal Formation* (STS-107).

7. Case Studies: Microencapsulation

Creating Microcapsules in Microgravity

In a microencapsulation experiment, two immiscible fluids can be placed in the two wells of the MDA. In one fluid, the planned contents of the microcapsule, such as the drug ciprofloxacin, are mixed in, while the other includes the planned coating, such as polyvinyl pyrollidone. The two fluids are brought together in microgravity, the solution is allowed to mix and evaporate, and the resulting microcapsules are analyzed with a microscope to determine their shape and size. The results can be compared with those from a control experiment performed on Earth.

Microencapsulation experiments flown on previous Shuttle flights using the MDA include experiments flown on STS-95 and STS-107 (*Microencapsulation of Drugs*).

8. Case Studies: Protein Crystal Growth

Growing Protein Crystals in Microgravity

One way to create protein crystals in microgravity using the MDA is to dissolve the protein into a medium such as a sodium acetate buffer, or a solution made of Tris HCl buffer and ammonium sulfate. The protein solution is placed in one well of the apparatus, and a salt solution (as just one example: made with sodium chloride and water) in the second. In orbit, the two wells come into contact, and protein crystals start forming from the solution; this technique for protein crystal production is called "interfacial diffusion." In past MDA experiments, one research focus has been on the protein urokinase, which has been identified as a key enzyme in the metastasis of brain, lung, colon, prostate, and breast cancers, but many different protein crystals can be grown in microgravity and then compared with control crystals grown on Earth to see whether the crystals grown in microgravity are larger and purer, as previous studies have suggested.

It is interesting to note that of the human body's estimated two million proteins, perhaps 70,000 are playing essential roles in maintaining stable healthy life and only a small fraction of those have been crystallized—which is one reason why this space research is so important.

Protein crystal growth experiments flown on previous Shuttle flights using the MDA include a urokinase protein crystal growth experiment aboard STS-95, and *Urokinase Cancer Research (*STS-107).

9. Case Studies: Seeds & Plant Studies

Seed Germination and Plant Growth in Microgravity

There are numerous experiments that can be conducted with plants and seeds to determine how plants grow, and whether seeds and spores can germinate and develop properly in microgravity.

Different seeds can be placed in different kinds of soil in the well of the MDA, and the germination of the seeds and the growth of the seedlings after exposure to several days of microgravity can be compared with a control experiment conducted on Earth. In variations of this experiment, germination could be activated in orbit by placing water in the second well of the MDA, and bringing the two wells into contact in orbit, or seeing how effectively a chemical promoting plant growth works in microgravity when compared with a control experiment conducted on Earth.

Seed and plant study experiments flown on previous Shuttle flights using the MDA include *Brassica Rapa (Mustard Seed Variety) Reproduction* (STS-52), *Brassica Rapa Production* (STS-56), *Diatoms* (STS-56), *California Poppy Seeds* (STS-80), *Coreopsis Seed Germination* (STS-52), *Columbine Seed Germination* (STS-52), *Mushroom Mycelial Growth* (STS-56), *Mustard-Spinach Seed Germination* (STS-52), *Seeds in Space* (STS-67), *Vegetable Seeds* (STS-69), *Zoology and Botany Experiments* (STS-56)