

Slide 1 - Men and women have always been interested in space travel. They have desired to learn about the environment of space and its effects on humans and other living organisms. Unlike on Earth where we experience a strong gravitational force, in space the gravitational force is greatly reduced, and we refer to it as microgravity - Unknown

Slide 2 - Scientists have been interested in how organisms are affected by microgravity. Therefore, scientists have studied organisms in microgravity environments at one of the smallest levels, the cellular level. The cell is considered to be the basic unit of life. It is hoped that if we can gain insight into how cells are affected by gravity, we might be able to understand how an entire human being may be affected. -

Slide 3 - Therefore, the Space/Gravitational Biology Program was created to study the effects of space travel on living organisms. The goals of the cell biology program have been to: listed on slide. - Unknown

Slide 4 - Studying the effects of gravity on cells has been a great challenge. NASA has utilized a surprising array of organisms to meet this goal.

For example, who would have ever thought that tiny jellyfish would be used to study developmental biology in space? - D. Spangenberg

Slide 5 Or how about frogs? - Unknown

To be able to study these organisms as well as different cell types during space travel, the people at NASA have had to develop special equipment.

Slide 6 - This is a device for changing the medium of cells. Medium is a type of liquid food for cells. Because in space there is less gravity, fresh liquid cannot simply be added to a container of cells. The liquid would float upwards into the spacecraft. Therefore people had to design these containers. - Unknown

Slide 7 - Other devices used for filling the containers are shown here. - Unknown

Slide 8 - Special machines have also been built. This one is for keeping the various specimens during a space flight. - Unknown

Slide 9 - The study of cell biology has aided men and women's understanding of the effects of space travel in a number of ways. Space Adaptation Syndrome, otherwise known as Space Motion Sickness, is a common problem in space flight. Approximately 60% of the astronauts are sick during the first few days of space flight. Scientists believe that the problem has something to do with the vestibular system. This system is located in the inner ear and helps to detect head movement. This slide shows a basic outline of the vestibular system. - Unknown

Slide 10 - Inside the vestibular system are otoconia which are a type of gravity receptor. These receptors are used to sense the position of the head with respect to gravity, so that the head is maintained in an upright position. - Unknown

Slide 11 - Scientists have studied the otoconia, or gravity receptors, in rats. As you can observe, the number of gravity receptors is greatly reduced in rats exposed to space flight as compared with ground controls. Ground controls are those rats which have not been exposed to spaceflight or a microgravity environment. It may be this reduction in gravity receptors which result in the feelings of motion sickness experienced by some astronauts. - Unknown

Slide 12 - The vestibular system is only one system which appears to be altered by space flight. Changes in bone metabolism have also been detected. Bone is created by cells called osteoblasts. If the number of osteoblast cells is reduced, bone development can be decreased. The progression of a cell to an osteoblast is represented on this slide. A precursor cell is first formed, labeled as "A". This cell is not an osteoblast yet. It is not destined to become an osteoblast until it reaches the committed stage, labeled "A prime" or committed osteoprogenitor. With an added stimulus of stress or strain, this cell becomes a G1 and then a G2 preosteoblast cell (C and D). The "D" cell or G2 preosteoblast eventually becomes a full-fledged osteoblast, which is then able to create bone. - L. Garetto and Roberts

Slide 13 - This slide is a different perspective of what was just discussed. You can see the progression of the different cell types. Again type A is the first cell, and it becomes committed to form an osteoblast. It then progresses through three more stages of development on its way to becoming an osteoblast, which can form bone. - Garetto and Roberts

Slide 14- This slide is similar to the first slide shown about osteoblasts. However, you will note one difference. On the pathway from A prime to C, in a red box is written the word "microgravity". It is at this point that scientists believe the reduced gravity in space may affect the development of bone cells. Normally, bone cells are under a certain amount of stress, also indicated on the diagram. This stress is needed for the cell to progress from a committed osteoprogenitor (A prime) to a G1 preosteoblast. On Earth this stress is usually present as gravity exerts a downward force on our bodies, and hence our bones. In space, because the gravitational force is greatly reduced, this does not occur and the stimulus to form a G1 preosteoblast (labeled "C" on the diagram) is lacking. Since the transition from A prime to C is reduced in microgravity environments, fewer osteoblasts are made. This in turn may reduce bone formation. Spaceflight experiments aboard Cosmos 1129 and Space Lab 3 missions have suggested the microgravity associated with these flights may inhibit A prime to C conversion and could account for the observed decreased bone formation. Garetto and Roberts

Slide 15 - This is another way of depicting the reduction in the transition between A and A prime cells and C and D cells. This is bone cell data obtained during postflight recovery. As you can see immediately after landing, there was a decrease in C and D cells, which are the committed osteoblast cells which could form bone. There was an increase in the A and A prime cells which are not committed to form osteoblasts. With time, these values begin to return to normal with C and D cells eventually surpassing A and A prime cells in number. Therefore, it seems that the return to the gravity of Earth following space flight results in a mechanical stimulatory response, which increases those cells able to form bone. This may be to compensate for a decrease in bone cell mass which is usually observed with spaceflight. - Garetto and Roberts

Slide 16 - The reason bone cell formation is so crucial is because bone is constantly being broken down by cells called osteoclasts. How the osteoclasts break down bone is shown in this figure. The breaking down of bone is a normal process that occurs in each of us throughout our lives. The bone which is broken down by osteoclasts is normally replaced by healthy bone by osteoblasts. Problems arise however if osteoblast cell number is decreased with space flight. Bone formation may not keep up with bone break down by the osteoclasts. Therefore, maintenance of a healthy number of osteoblasts is crucial for maintaining bone mass and strength. - Unknown

Slide 17 - Along with bone cells, other structures may become altered during spaceflight. For example, a major substance found in bone and other connective tissues is collagen. Collagen is normally present in the form of bundles of fibers, which add strength to the tissues. With spaceflight, the arrangement of collagen fibers can become disordered. The pictures on the left show the organization of collagen fibrils, indicated by the arrows, from cells that did not experience microgravity. The collagen is parallel to the long axis in order to provide the greatest strength to the structure. However, you can see in cells exposed to microgravity (those on the right), the collagen organization is disrupted. - Unknown

Slide 18 - This is another picture of the arrangement of collagen fibers in a rat after a space flight. As you can see on the right side, after spaceflight, the fibers are no longer in parallel rows, but rather take on a more random arrangement. This type of arrangement does not provide as much strength to the structure. - Unknown

Slide 19 - It is not always possible to have cells on a space flight. Also it becomes a problem to determine if what happens to individual cells is actually what is occurring in an intact body. Scientists have tried to develop other models in order to determine how the body functions. One model that has tried to solve this problem is called hind limb suspension. In this case, the hind legs of rats are placed in a device which raises them off of the ground, so that the hind legs are suspended in the air. The rats are not harmed and are able to walk around on their front legs. Essentially, it would be like a person walking on his or her hands for a certain amount of time. It has been found that for the hind limbs this model is often accurate in modeling what occurs in the microgravity environment, as reduced stress is placed on the hind limbs. This table shows how hind limb suspension results in similar physiological responses compared with spaceflight. Thus, hind limb suspension is considered to be a good model to simulate weightlessness. Also shown on the table are the physiological responses to prolonged bed rest in humans. When humans are resting in bed, there is reduced stress placed on the body, as they are not walking upright or completing normal daily movements. This reduction in physical stress results in comparable changes as to what occurs in spaceflight. Thus, human bed rest could also be considered to be a suitable model for spaceflight. - Bikle

Slide 20- This shows some of the results from an experiment using hind limb suspension in rats. Each of these graphs show development of bone relative to rats who did not undergo hind limb suspension. The two bones you want to look at are the tibia and L1 vertebrae, as these are unstressed during hindlimb suspension. The tibia is a lower leg bone and is represented by open circles on the graphs. The L1 vertebrae is a bone in the lower back and is represented by open triangles. Normally, when the rat walks around, stress is placed on the bones. The bones

respond to this stress by increasing bone mass. However, when the lower legs are suspended, no stress is placed on the bones and they may decrease in mass. You can see on the graphs, how the values for bone mass are reduced for the tibia and L1 vertebrae bones in animals whose hind limbs were suspended compared to control animals who were allowed to walk normally. In space, astronauts often lose bone mass as well. - Bikle

Slide 21 - The bone does demonstrate an ability to return to normal once it is placed under stress again. These graphs show the recovery of bone once the rat is allowed to walk around normally. If you look at the tibia and L1 vertebrae, you can see the bone recovery is high. Upon the return to Earth, astronauts also demonstrate an ability to recover bone mass that was lost due to space travel. - Bikle

Slide 22 - Scientists have wondered how cells are deformed by stress such as gravity, and how the cell responds once the force of gravity is removed. How does the cell maintain its shape and how is this shape affected by the microgravity environment? One idea that has been developed is “Tensegrity”. Tensegrity is a word formed by combining “tensional” and “integrity”. Tensional refers to straining and stretch, and integrity refers to firmness and strength. Tensegrity structures are composed of strong, rigid struts connected by a continuous series of tensional elements. It might be best to think of this in terms of drinking straws and elastic string. The straws would represent the rigid support, while the string would connect the straws in the form of a structure. - Ingber

Slide 23 - This can be seen more simply in this picture. Here wooden rods, rather than straws, serve as the rigid support while the string serves as a tensional unit, pulling the rods up and out. On a more complex level, scientists believe such a structure may be what gives our cells shape. - Ingber

Slide 24 - Here is a drawing of how these tensional structures may appear in interconnected cells. You can see how this gives the cells shape. - Ingber

Slide 25 - Scientists are interested in the response to stress by these tensional structures as a possible model for what occurs in the body. For example, this is a set of pictures of a tensional structure. When a weight is hung from this structure, it changes form. In these pictures increasing weights were added in each picture from left to right. With the addition of increased weight, the structure has an increased change in form. What is interesting about these tensional structures is that the entire structure changes form in response to the stress of the weight hanging from it. It is not only the part of the structure specifically attached to the weight that changes form, but rather the entire structure itself. This model may represent how cells respond to increase stress placed upon them. - Ingber

Slide 26- Here is another view of changes in a tensional structure made to model a cell. The tiny circular structure inside the larger structure represents a nucleus inside a cell. This shows that when stress is placed on the cell, the structure of the nucleus is also changed. It is thought that this may play a role in how the cell responds to stress. Scientists continue to be interested in this model for spaceflight, since in space a very large stress, gravity, is removed. Scientists are

trying to determine, with the aid of the tensegrity model how this changes cell structure and function. - Ingber

Slide 27 - A more real life example of cells responding to the stress of gravity might be the jellyfish. Jellyfish have been used to determine how organisms respond to a microgravity environment. This figure shows the developmental cycle of a jellyfish. Because of these stages, scientists are able to see how jellyfish respond to microgravity during each stage of development. - Spangenberg

Slide 28 - Jellyfish contain tiny crystals called statoliths which perceive the direction of gravity, similar to the otoconia in the vestibular system. Thus, the jellyfish are a good specimen to study gravitational effects. In fact on a NASA flight in 1991 over 2478 jellyfish were sent into space!! This is a picture of a ephyrae, a larvae form of jellyfish. The jellyfish were able to live, develop and multiply in the reduced gravity environment of space. However, there were some behavioral changes noted and some lost statoliths in their gravity receptors. - Spangenberg

Slide 29 - Here is a close up view of an arm of an ephyrae. From the work on jellyfish, it appears that detectable behavior changes begin to occur somewhere in the range of .240 to .388 g. This means that when gravity levels are equal to 24 to 38% of the Earth's gravity level behavioral changes were detected in the jellyfish. This information may help us better understand how humans are affected by various levels of gravity. - Spangenberg

Slide 30 - Hopefully, the knowledge we have gained about spaceflight and the effects of microgravity on various organisms, especially at the cellular level, can help us better understand the effects on human beings. With the knowledge we will continue to gain, even more successful missions can be ensured.