LESSON 3

Making Space People-Friendly

Quick Write

If you had the opportunity to spend a year in space as Scott Kelly did, would you do it? What would be the pros and cons of spending that much time in space?

Learn About

- how microgravity affects the human body
- threat of radiation to astronauts traveling in space
- space biomedicine

Imagine spending an entire year in space without being able to just sit down and eat a meal. Astronaut Scott Kelly has just completed his year in space and returns to a "Welcome Home" dinner with his family, — something he has been dreaming about for a long time. It's a normal occurrence for those of us on Earth, but for Scott it is a very different experience. It is the first meal in over a year that doesn't require him to use Velcro to hold down his utensils or duct tape to hold his plate in place.

There is another reality for Scott at his family dinner. He can feel gravity pressing him down into his chair. It has been 48 hours since his return from space, and he is struggling to make it through dinner. He's exhausted, and getting out of his chair is a struggle more like that of an 85-year-old man, not a healthy 51-year-old.

Now that he's out of his chair, he has to walk to his room. It's only 20 steps, but his body complains with each step. He hasn't walked in over a year and now his body has to get used to walking. Not only are his legs not cooperating, but his sense of gravity is off and the floor seems to tilt under him. As he stumbles into a planter, his twin brother, Mark Kelly, who is also an astronaut, congratulates him on doing so well. This is the first stumble that Mark has seen and he knows exactly what it's like for the body to return to Earth.

Scott's body hurts! His joints and muscles are not used to the pressure of gravity. Scott wakes in the middle of the night with his whole body in pain. As he struggles to get up from bed, he can feel the blood rush to his legs. This is a sensation he hasn't felt in a while. When he gets to the bathroom, he realizes his legs are very swollen. The blood has indeed rushed to his legs, and you can squeeze them and move the liquid around like a stress ball.

That's not all, though! Scott has a rash in every place that the sheets touched his body. His skin feels like it is burning, and he is covered with hives. Scott knew the risks when he went to space, and he knew the return would not be easy. He will be a science experiment for the rest of his life. NASA and scientists will study his body and the long-term effects that space has on the human body in order to reach the next step, Mars.

Expedition 43 NASA Astronaut Scott Kelly gives a thumbs as he has his Russian sokol suit pressure checked ahead of the mission's launch to the ISS.

Courtesy of NASA

Vocabulary

- osteoporosis
- muscle atrophy
- potassium perchlorate candle
- gene expression
- radiation sickness
- cataracts
- biomedicine
- in vitro fertilization (IVF)

How Microgravity Affects the Human Body

The United States met its goals of traveling to space and putting a man on the Moon. But what effects does space have on the human body? The environment in space and on the Moon is very different from Earth. Now that the goal is to return to the Moon and travel to Mars, it's essential we understand the effects of space on the human body to undertake these future missions.

NASA's Human Research Program (HRP) is responsible for discovering the best methods and technologies to support safe, productive human space travel. This may involve such diverse goals as making sure the astronauts have appetizing food to managing the risks of radiation.

Effects of Microgravity

The effects of microgravity on the human body include the following:

- Increased risk of neurodegenerative disease
- Eye abnormalities
- Puffy face
- Nasal congestion, loss of smell, and diminished taste
- Loss of muscle mass and bone density
- Lower red blood cell count
- Lower blood plasma volume and increased kidney output
- Greater risk of kidney stones
- Lower immune system
- 10 to 30% decrease in leg circumference

Microgravity and the Human Body

The effects of microgravity on the human body are immense. In a zero-gravity environment, the skeleton isn't required to hold up the body. As a result, the body loses bone density. In fact, astronauts lose 1 to 2% of bone density each month on the ISS. In a matter of six months, they will have a 10% loss of bone density, which is the equivalent of 10 years of aging on Earth.

In addition, bones begin to dissolve into the bloodstream from the bone loss. As bones dissolve, calcium levels increase in the blood, putting astronauts at a greater risk of kidney stones. Although kidney stones are easily treatable on Earth, astronauts are at a greater risk because surgery cannot occur in space.

Did You Know?

Astronauts are experimenting with the drug bisphosphonate during ISS missions. Bisphosphonate is an osteoporosis drug used to lower calcium levels in the blood. Osteoporosis is *a medical condition in which bones become brittle and fragile from loss of tissue*. The initial results of this experiment were positive, and NASA will continue to test the use of bisphosphonate, combined with exercise, to decrease the loss of bone density and lower the risk of kidney stones

Another skeletal concern for astronauts in space is the spine. Human spines are naturally curved, but without gravity the spine begins to straighten. Approximately 66% of all astronauts who have returned from space report back problems. And astronauts are four times more likely to have herniated disks--a condition in which the rubbery cushions (disks) between the bones (vertebrae) are damaged.

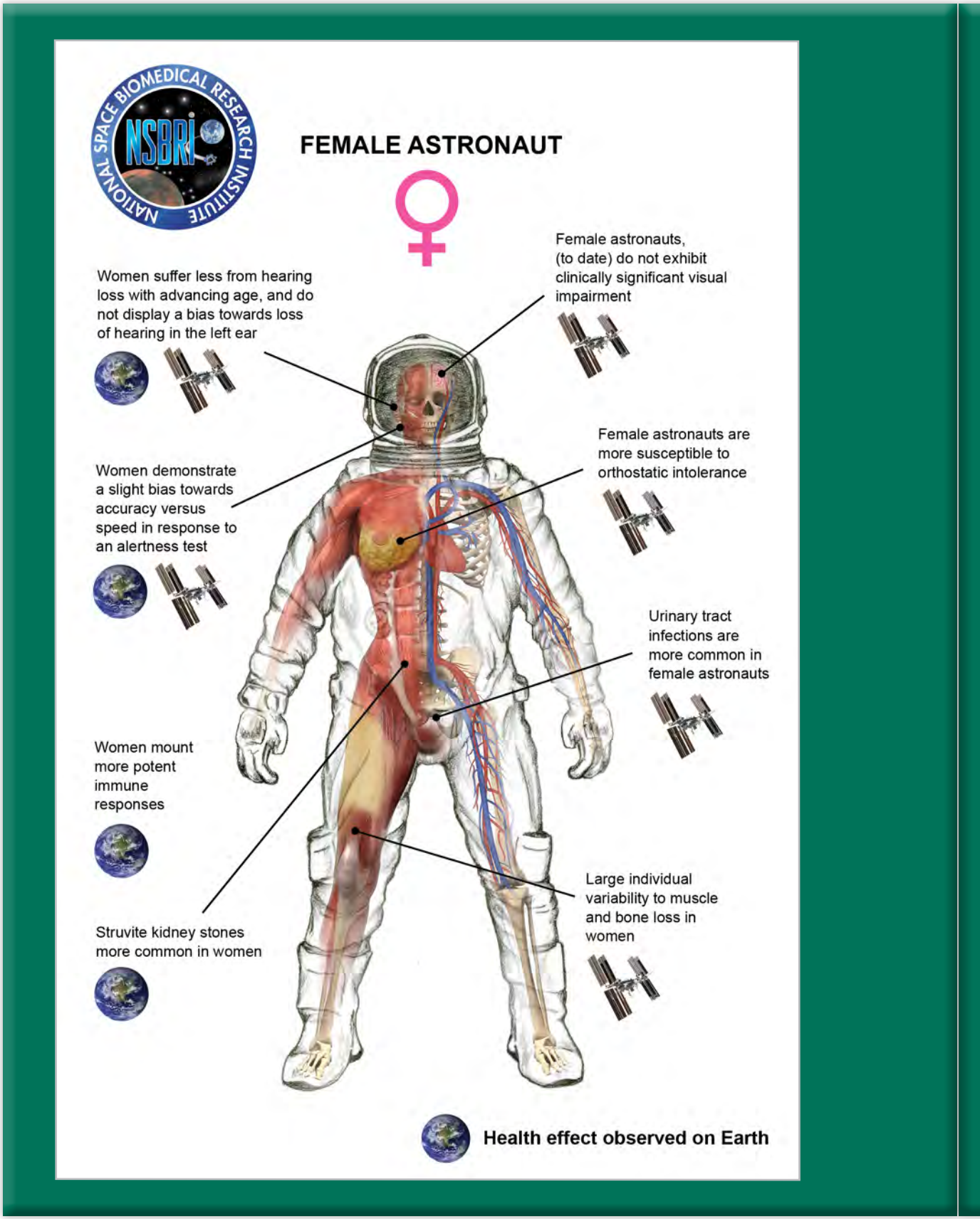
The muscular system can also take a hit from living in a zero-gravity environment. Muscle atrophy is *when muscles waste away from lack of use*. In space, an astronaut's muscle capacity for physical work can drop 40% in just 180 days. This is the equivalent of obtaining the body of an 80-year-old in a matter of six months.

Did You Know?

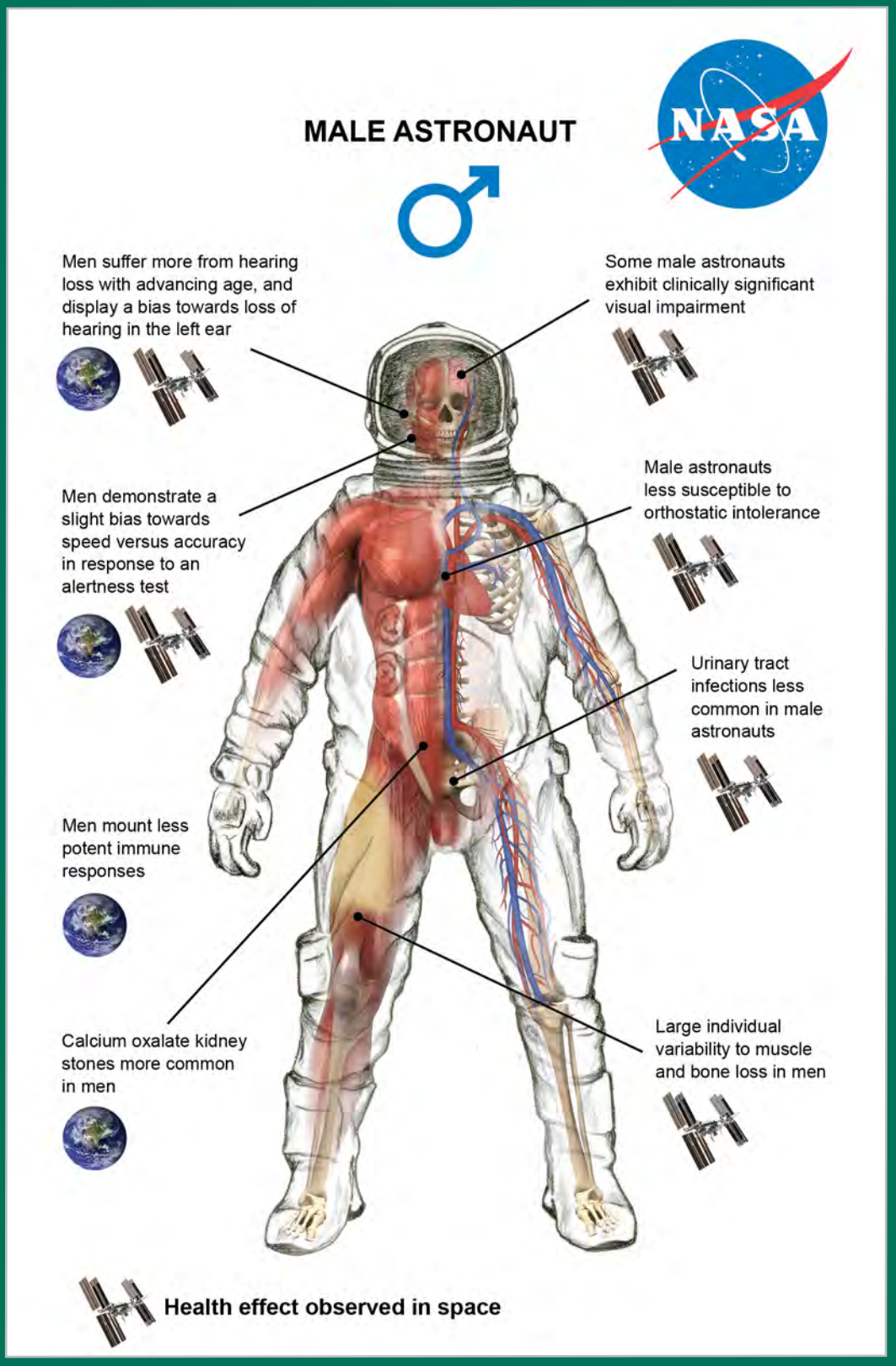
NASA experiments have shown that astronauts can lose up to 20% of their muscle mass on spaceflights lasting just five to 11 days.

On Earth, gravity pulls the blood in your body away from the heart and to your lower extremities. The heart then pumps the blood in your body and pulls it back to the heart. In space, there is no gravity to pull blood to the lower regions of the body. This results in a buildup of blood in the upper body, which astronauts commonly refer to as "puffy face," and a lack of blood in the lower body, which astronauts refer to as "chicken legs." While the nicknames given to these conditions can be humorous, the effects are quite serious. "Puffy face" can cause astronauts to feel as though they have a stuffy head or blocked sinuses. In addition, their vision, sense of smell, and sense of taste can be affected. Astronauts suffering from "puffy face" and "chicken legs" find that their heart weakens over time and their blood pressure drops because there is no need to pump the blood back to the upper body. In addition, tests have revealed that the shape of astronauts' hearts change in space and become more spherical.

Expedition 10 commander Leroy Chiao on the ISS displays the effects of "puffy face."
Courtesy of NASA/JSC



The male and female body are affected in different ways by living in a microgravity environment.



Courtesy of NASA/Human Research Program

NASA astronaut, Dan Burbank, exercising on the ISS.
Courtesy of NASA/JSC

European Space Agency (ESA) astronaut Alexander Gerst conducts a vision test while in space.
Courtesy of NASA/HRP

To combat the muscular and skeletal decay in the human body, astronauts must adhere to a strict exercise program in space. They must spend at least 15 hours a week exercising while on the ISS. In addition, scientists are working on a method to expel kidney stones with ultrasound while in space. Once back on Earth, astronauts can recover from the loss of bone density. It will take 3 to 4 years for the skeleton to fully recover.

Did You Know?

Just as you might get sea sick traveling on a boat, astronauts can get space sickness. After about two weeks, astronauts develop their "space legs" and recover from their space sickness. Unfortunately, when they return to Earth, they typically need to work hard to get their "Earth legs" back.

Astronauts also suffer from eye problems in space. On the ISS, particles are floating about due to the lack of gravity. These particles can get into the eye and cause abrasions to the eye itself. In addition, "puffy face" leads to a buildup of fluids in the face and head. This additional fluid pushes up against the back of the eye and causes permanent changes to the shape of the eye. While in space, astronauts typically require the use of eyeglasses to assist with their vision, due to "puffy face." When they return to Earth, their vision does not necessarily return to normal. Most astronauts deal with permanent vision deterioration.

The Right Stuff

Breathing in Space

Breathing oxygen is a requirement for human life. In a zero-gravity environment, such as space, there is no oxygen. If a human were to enter space without the protection of a spacesuit, the results would be devastating. Human lungs can hold about 15 seconds of oxygen when a person is holding his or her breath. But this would not help astronauts if they decided to hop out of a spacecraft and hold their breath. Space has no pressure, so the air in the lungs would expand, causing the lungs to rupture. Bubbles would form in the blood; the body would be in excruciating pain as it swelled to twice its normal size. Death would shortly follow. This is why astronauts must use protective spacesuits that supply oxygen and provide protection from the harsh environment in space.

On the International Space Station (ISS), it is not feasible to send oxygen tanks into space, so the ISS creates its own oxygen from electrolysis. This process involves passing electricity through wastewater (H2O) on the ISS. The H2 and O atoms are pulled apart during the process. The oxygen (O) is then pumped into the ISS for astronauts to breathe. Using the electrolysis system, the ISS requires six gallons of water per day to produce the 12 pounds of oxygen that would sustain four astronauts. Of course, with any vital system, you need a backup. What if a problem occurs with the electrolysis system in space? The ISS astronauts would use potassium perchlorate candles. A potassium perchlorate candle is *a chemical candle that contains sodium chlorate and iron, which when burned produces oxygen*. These chemical candles produce six and a half hours of oxygen each and take five to 20 minutes to completely burn.

Mental Health in Space

Can you imagine being cramped in a small space for over 100 days? It is bound to affect an astronaut's mental health. Many countries have conducted tests on astronauts to see how they would handle being confined to a small space by having them live in isolation chambers for extended periods of time. NASA kept volunteers in their closed environmental chambers for 91 days as part of their Lunar-Mars Life Support Test Project. The longest experiment of this type was the Mars500 experiment conducted by the European, Russian, and Chinese space agencies, in which a crew of six was confined for 520 days. This is the time it would take to reach Mars and back.

A view of astronauts in the Lunar Module Simulator at the Kennedy Space Center.

Courtesy of NASA

The results have shown that astronauts suffer from sleep disorders, alterations of time sense, homesickness, anxiety, depression, psychosis, and more. Another result that was seen was the buildup of tension. The tension can then be taken out on other crew members, causing behavioral issues in space.

Mental health during space missions is an area that is still quite unknown. With our sights set on Mars, it is important to explore the mental effects of space. Imagine floating in a small confined space for an extended period of time, with only darkness outside. Researchers are examining the use of meditation, positive impact pictures, and even virtual reality.

Did You Know?

In 2007, Lisa Nowak brought a knife, mallet, rubber tubing, and a BB gun to the Orlando airport…900 miles away from her home. Once at the airport, she disguised herself and followed Air Force Captain Colleen Shipman to the parking lot. Nowak tried to lure Shipman into giving her a ride and eventually tried to pepper spray her. According to the arrest record, Nowak was intending to harm Shipman over a love triangle. Months earlier, Nowak was controlling robotic instruments during spacewalks aboard ISS as part of the shuttle Discovery mission. Lisa Nowak was a NASA astronaut who was now diagnosed with a psychotic disorder and depression.

NASA conducted medical research on astronauts between 1981 and 1998 to determine possible mental health issues that may arise due to extended periods of time in space. Over the course of 89 missions, there were 1,800 medical events and only 2% of them related to behavior. The majority of the behavior episodes were related to anxiety. However, there is evidence that some missions may have ended early due to behavioral issues.

The evidence isn't all bad! Researchers also found that space travel can create joy and happiness, which leads to happy astronauts. After all, astronauts are getting a once-in-a-lifetime opportunity to travel to space and view Earth from the outside. It is an awe-inspiring view! Most astronauts who visit the ISS come back with a change in perspective: viewing life as a small part of the universe.

NASA focuses mainly on prevention of mental health issues. Candidates complete hours of psychiatric screening. Once selected for a mission, NASA has psychologists and psychiatrists to support astronauts on their missions. On the ISS, astronauts must complete a psychological conference with medical staff every two weeks.

Did You Know?

The ISS has antipsychotics, antidepressants, and anxiolytic drugs on board to administer to any astronaut who may require them based on mental health issues that arise. In addition, they have a "restraint system" that can be used if necessary.

Kelly Brothers Experiment

Scott and Mark Kelly are identical twins born on February 21, 1964. NASA had a unique opportunity when both Scott and Mark applied for the 1996 astronaut class. They were both test pilots at the time and were both accepted as astronauts into the program. In 2015, NASA began the Twins Study. Scott would spend a year on the ISS, while Mark remained on Earth (but still assigned to duty as an astronaut). Samples would be taken from both men before, during, and after the mission.

Mark and Scott Kelly.
Courtesy of NASA

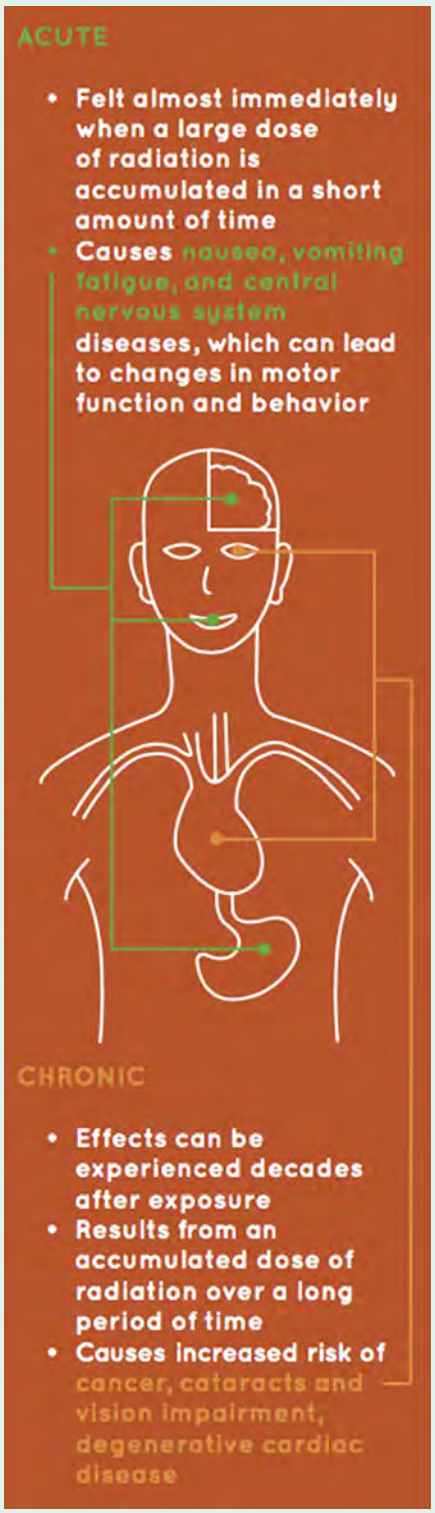
Scott ended up spending 340 consecutive days in space. Combining that with his previous missions, Scott Kelly has accumulated 520 days in space. He returned to Earth on March 2, 2016.

So, what happened? NASA discovered that Scott's DNA did not fundamentally change and the brothers remained identical twins. However, they found changes in gene expression, which is *how your body reacts to your environment*. Scott had approximately a 7% change in gene expression after being back on Earth for six months. The 7% of gene changes relate to his immune system, DNA repair, bone formation networks, hypoxia, and hypercapnia.

Scott Kelly on the ISS looking toward Earth.
Courtesy of NASA

Most of the effects of space travel, such as "puffy face" and reduced bone density and muscle mass, returned to normal upon Scott's return to Earth. Some changes reverted within days, while others took up to six months to reverse. The twins will continue to be studied as they age to determine how their bodies react to space travel on a long-term basis.

Radiation Effects on Humans



Courtesy of NASA

Threat of Radiation to Astronauts Traveling in Space

In Chapter 3 Lesson 3, we talked about radiation in space and how it affected the spacecraft. But how does this radiation affect humans traveling in space? Remember, radiation is all around us on Earth, but our atmosphere protects us from the harsh radiation that exists in space.

The ISS orbits just within the Earth's magnetic field so that astronauts have some of the protection of Earth's atmosphere. However, on the ISS, astronauts are exposed to more than 10 times the radiation they would receive on Earth. This level of radiation increases the risk of cancer, central nervous system effects, and degenerative diseases for astronauts. In addition, astronauts may suffer from radiation sickness. Radiation sickness is *the damage to the body caused by a large amount of radiation over a short amount of time*. Symptoms of radiation sickness include nausea, vomiting, diarrhea, headache, fever, dizziness, weakness, and fatigue.

There are three factors that affect the amount of radiation astronauts receive in space:

1. Altitude – The farther the astronauts travel from Earth's protective atmosphere, the greater the risk of radiation.

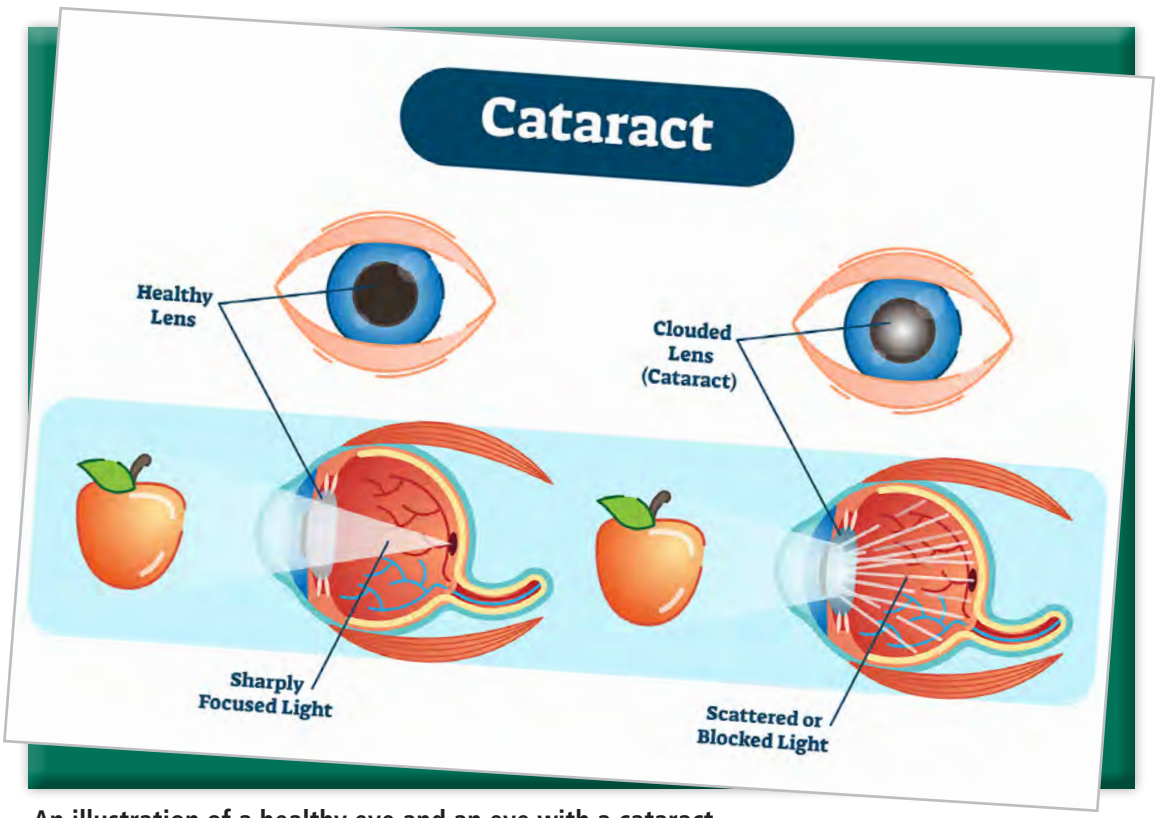
2. Solar cycle – The Sun has an 11-year cycle, and toward the end of the cycle there is a large increase in the number and intensity of solar flares, which produces increased levels of radiation.

3. Susceptibility – Each person is unique, and an individual astronaut may be more susceptible to the effects of space radiation. This is an area that NASA is actively investigating.

Radiation and Cataracts

Astronauts develop an increased risk of cataracts from the radiation they endure in space. Apollo astronauts first described the phenomenon of flashes of light in their eyeballs. What they experienced was space radiation flying through their eyes. When the space radiation hits the retina, it triggers a signal that the brain sees as a flash of light. Obviously, this phenomenon is not good for your eyes.

Many former astronauts have developed cataracts after traveling into space. Cataracts *occur when the lens over the eye becomes cloudy*. Someone with cataracts has blurry or hazy vision. Some astronauts develop cataracts four to five years after returning to Earth. For others, it may take up to 10 years to develop cataracts. Cloudy lenses occur on Earth as a natural progression of aging. Over 50% of people over 65 will develop cataracts. Scientists know that radiation plays a role in cataracts, but they are not yet sure how it makes the eye develop cataracts. If researchers are able to figure out how radiation effects the lens, then they may also be able to prevent cataracts here on Earth.



An illustration of a healthy eye and an eye with a cataract.

Courtesy of VectorMine/Shutterstock

Reproduction Risks with Space Radiation

Another concern for astronauts traveling in space is the risk of radiation on reproduction. The particles in space do direct damage to a human's DNA, so how does that affect an astronaut's ability to reproduce? Researchers suspect that astronauts who return to Earth will have no greater chance for infertility based on a short-term spaceflight. This has been proven by several astronauts who returned to Earth and had children.

However, what are the long-term effects of space radiation on reproduction? In order to establish a new colony on the Moon, or even Mars, reproduction must be researched. The only method of sustaining a new colony is for humans to reproduce on that colony. The ISS conducts many experiments to determine the effects on reproduction in space for plants and other animals. Testing has not yet been completed for human reproduction.

Did You Know?

Mouse seminal fluid has been freeze-dried and sent to the ISS so that it could spend 288 days on the ISS and then come back to Earth so that the sample could be compared with the mouse seminal fluid kept on Earth. The results showed that the space seminal fluid had higher amounts of fragmented DNA, which is a cause of male infertility. Scientists then used the space seminal fluid to fertilize an egg. The result was the same number of healthy embryos and they produced healthy baby mice.

NASA astronaut Dan Burbank using the Integrated Cardiovascular Resting Echo Scan on the ISS to conduct research experiments.

Courtesy of NASA

Space Biomedicine

Biomedicine is *the medical study of principles of the natural sciences, especially biology and biochemistry*. It is often seen as a branch of medicine that studies the capacity of humans to survive and function in stressful environments. Space biomedicine is an essential component of the ISS. During a routine trip to the ISS, an astronaut may perform over 50 medical research experiments.

As we discussed earlier, one of the studies that scientists have been exploring is reproduction in space. For a species to survive on a newly colonized planet, it must reproduce. On the ISS, experiments have been conducted on certain animals, such as fruit flies and fish. Scientists

have used in vitro fertilization (IVF) where *scientists inject the seminal fluid of the animal into the egg to create an embryo*. The initial studies show that while pregnancies can occur in space, the embryo's development may be slowed down based on lower gravity. Embryos and pregnant animals have been sent to space, but the entire cycle from an animal getting pregnant, the fetus developing, and a healthy baby being born has not been successful in space yet.

The microgravity studies on pregnant rats, geckos, and sea urchins in space have shown that unusual abnormalities appear during fetal development, which is most likely from the exposure to increased radiation. NASA has a strict policy that forbids human pregnancy in space, but as more testing is completed and the goal of colonizing another planet is reached, pregnancy in space may become a reality.

Another biomedical study completed on the ISS looked at the effect of space travel on the human brain. Dr. Donna R. Roberts and Dr. Michael U. Antonucci from the Medical University of South Carolina in Charleston set about studying the MRI scans of astronauts before and after space missions. The study involved 18 astronauts on long-term missions to the ISS. The average stay on the ISS was 164 days. The study also included 16 astronauts who went on short-term space shuttle flights that averaged 13 days. The findings were remarkable. Ninety-four percent of the astronauts on long-term missions experienced narrowing of the central sulcus, which is a groove at the top of the brain. Only 19% of the short-term space shuttle travelers experienced this same condition. In addition, the brain scans of the long-term space travelers showed that all of them suffered from their brains shifting upward in the skull. These studies provide a starting point for researchers. Now that they know what can occur to the human brain in space, they can develop ways to counteract these effects to the human brain and ensure the safety of astronauts on long-term missions.

The study of space biomedicine directly impacts medical research and development on Earth. Some projects that will have direct effects on Earth include the following:

- No-drill dental care
- Noninvasive treatment for skin disorders
- Emergency wound closure
- Biofilm eradication
- Surface and water decontamination
- Waterless cleansing of garments

This lesson may have made space seem like a scary place to visit, but there is good news: NASA has been working on solutions for the health problems associated with space travel for years so that when it is time to travel to Mars, they can ensure the safe return of our astronauts.

CHECKPOINTS

Lesson 3 Review

Using complete sentences, answer the following questions on a sheet of paper.

1. What is NASA's Human Research Program (HRP) responsible for?
2. Why do astronauts have an increased risk of kidney stones?
3. What is the cause of "puffy face" and "chicken legs" in astronauts?
4. How long does it take the skeletal system to fully recover from its time in space?
5. What were the results of the confinement studies conducted by NASA and other space programs?
6. What does NASA focus on with regard to astronauts' mental health?
7. What was the initial result of the Twins Study?
8. What are the three factors that affect the amount of radiation an astronaut receives in space?
9. What causes the phenomenon of flashing lights that astronauts see in their eyes?
10. Why is reproduction an experiment on ISS?
11. What were the results of the ISS study on the human brain in space?
12. What are some of the space projects that will have a direct effect on Earth?

APPLYING YOUR LEARNING

13. What do you think would be the biggest drawback to space travel as far as the effects on the human body? Would this deter you from volunteering for future space missions?