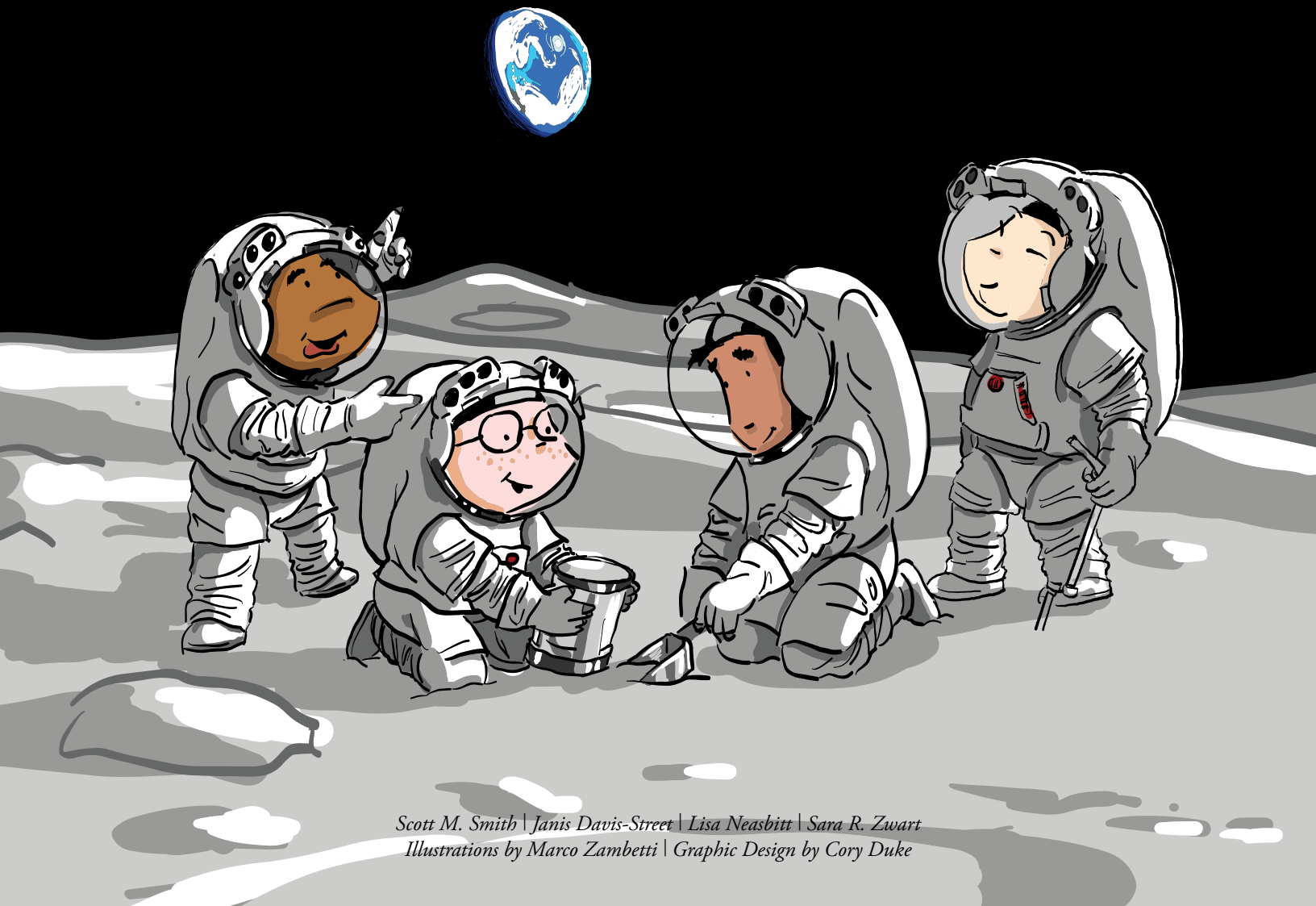
National Aeronautics and Space Administration

Space Nutrition

Second Edition



Scott M. Smith | Janis Davis-Street | Lisa Neasbitt | Sara R. Zwart
Illustrations by Marco Zambetti | Graphic Design by Cory Duke

Space Nutrition Second Edition

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Preface

Space Nutrition evolved from an "Adopt-a-Classroom" effort led by scientists in the Nutritional Biochemistry Laboratory at the NASA Johnson Space Center in Houston. Our goal was to bring students closer to space research while learning about the importance of nutrition for astronauts (and for kids, too).

Specifically, we were focused on finding a way to bring students along with us as we worked to develop an experiment being readied for flight on a Space Shuttle mission. Starting in the Fall of 2001, monthly newsletters would highlight different elements of the experiment, the scientific process, and the breadth of the team involved in enabling life sciences research to be conducted by astronauts while orbiting the Earth. The tragic loss of Columbia and her crew on February 1, 2003, was devastating for all involved, along with the nation. We dedicate this book to Columbia's STS-107 crew and all men and women who have given their lives in pursuit of space exploration. We celebrate here, the continued work of conducting science in space to provide myriad benefits for those watching from the Earth's surface.

The original monthly newsletters were reimagined into book form, and the first edition of *Space Nutrition* was published in 2012. We continue to learn more about human adaptation to flying in space, and the role nutrition plays in keeping crews healthy. With support from NASA's Human Research Program, this book—*Space Nutrition 2nd Edition* - was made possible.

We hope that this book will engage students, teachers, and parents about the work going on in our tiny corner of NASA, and inform readers of the implications of this work for those on and off the planet. We remain honored, awed, and humbled to have the opportunity to continue to work with America's space program. We hope this book provides readers the opportunity to share in our journey of scientific and space exploration, and inspires the Artemis generation to go even further.

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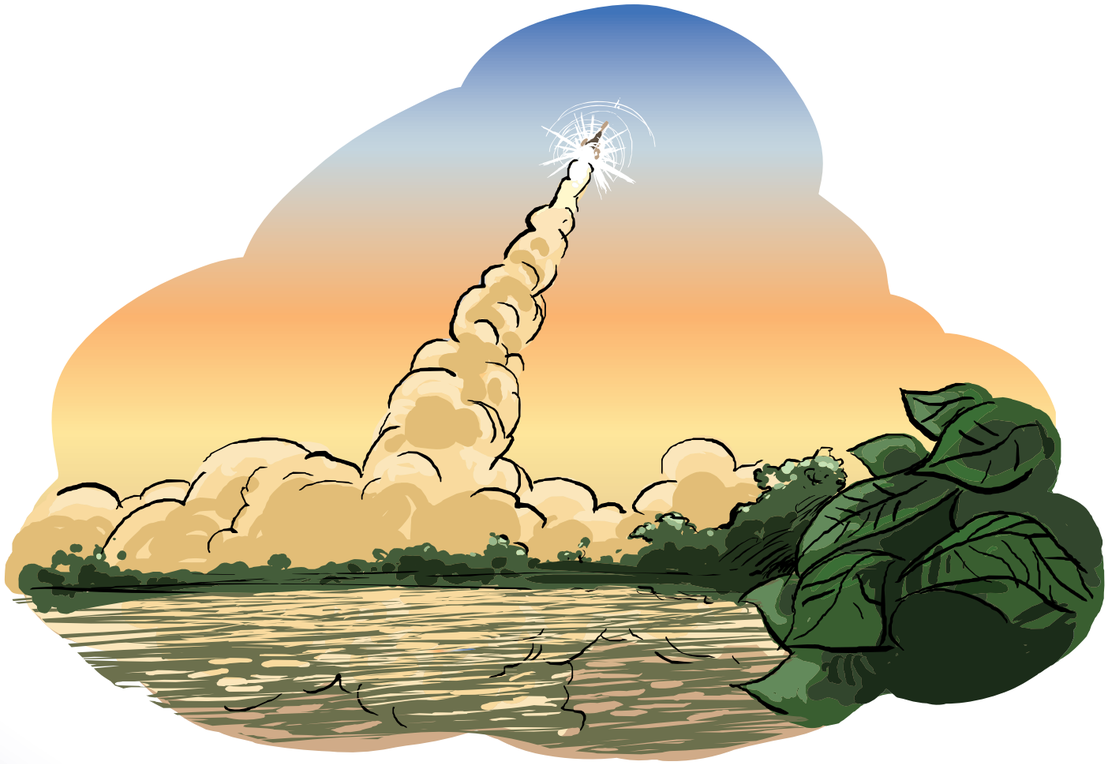
Section One

Human Space Flight



When flying in space, the human body feels that it is in an environment very different from the ground. You spend your whole life on the ground with gravity—and in space, all of a sudden that changes. The body does a great job of quickly realizing this, and it starts to change to get used to this new world—a process we call adaptation. Adaptation to space flight affects almost every part of the body in one way or another: heart, muscles, bones, stomach, blood, even your inner ear (the part that helps you keep your balance). This can make the first few days of space flight very rough, sort of like living on a roller coaster!

Most of these changes don't have a negative effect while you are in space, but some can have large effects when you land on Earth again. For example, your body needs less blood while you are weightless, probably because it is easier to get blood (and oxygen) to all parts of the body without gravity. This adaptation takes a week or two. During that time your body lowers the number of blood cells and the amount of fluid circulating in your blood vessels. Some of the fluid (that is, liquid) is shifted out of the blood vessels and into other areas of the body (like into cells) or out of the body (in urine). This works fine in space, but when you come back to Earth, your body won't have enough blood, so we need to be careful that the astronauts don't faint on their return to Earth's gravity! To help prevent problems, about 45 minutes before returning to Earth, the astronauts drink a liter of salty water to help them during and soon after landing.

...Human Space Flight

The muscles also weaken during space flight. This is called "muscle atrophy." We're still working to understand the details of why this happens, but it seems that because the body doesn't use muscles the same way in weightlessness as on Earth, the unused muscles will weaken. Although this doesn't matter while an astronaut is orbiting the Earth, it is very important for walking around after landing. The longer the flight, the weaker the muscles get. This is hard on crews on the International Space Station (ISS), who stay in space for months, and will be hard for astronauts on exploration missions lasting years. Because of this, astronauts exercise hard every day to try to avoid these changes.

Understanding and preventing the negative changes that occur during space flight is an important job. Scientists at the Nutritional Biochemistry Laboratory at NASA's Johnson Space Center in Houston spend a lot of time on this, because good nutrition may be one way to help keep astronauts healthy during space flight. Throughout this book, we will tell you all about the work going on in the Nutritional Biochemistry Laboratory, and also what good nutrition means to you!

What is "adaptation"?

Adaptation is the process of something becoming better suited to a new environment.

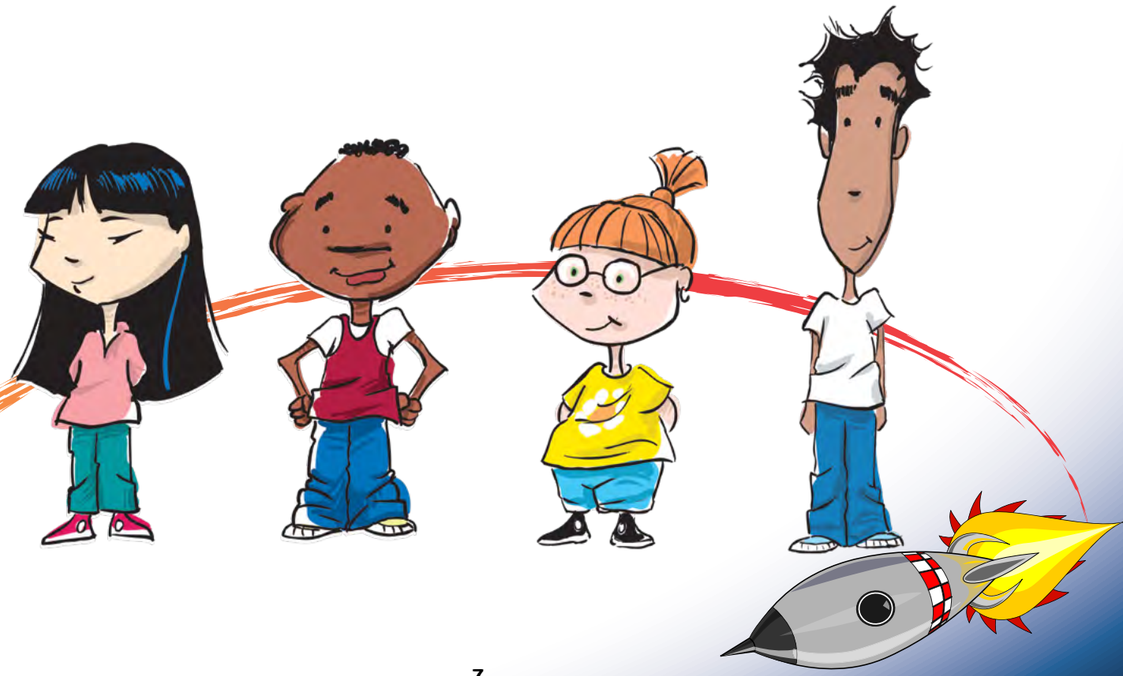
What does "orbit" mean?

An orbit is the path an object takes around another object. The International Space Station orbits around the Earth, and does this once every 90 minutes.

Space History (Past and Present)

The Space Nutrition Team—**Lin, Tim, Thea, and Diego**—are here to guide us through the history of human space flight, and through the many historical aspects of space nutrition.

The first humans to leave the planet did so way back in the early 1960s. NASA has had several projects and programs over the decades, each with unique goals. At the time, each was incredibly challenging, but building step by step, we have learned more and more about what it takes to fly in space, and we continue to work towards the next challenge.



...Space History (Past and Present)

Mercury (1961–1963)

Mercury was the United States' first space program that sent humans to space. Mercury astronauts were launched into space on either a Redstone or Atlas rocket, depending on how far they traveled.

Alan Shepard was the first American in space. He took his first trip to space less than 1 month after Yuri Gagarin's flight, and it lasted 15 minutes and 28 seconds. That first flight was a suborbital flight, meaning that it did not orbit the Earth.

The Mercury program ended with Astronaut Gordon Cooper completing 22 orbits around the Earth and staying in space for a whole day (a little over 34 hours).

Did you know?

Russian cosmonaut Yuri Gagarin was the first human in space. He launched from Russia on April 12, 1961. Although he was in space for only a short time (108 minutes, to be exact!), this was a big step that paved the way for the future space programs. Every year on April 12, there is a global celebration called "Yuri's Night" to celebrate this historic day (https://yurisnight.net/).

Did you know?

The first American orbital flight, part of Project Mercury, was flown by John Glenn. His spacecraft, named Friendship 7, was launched on an Atlas 6 rocket. He orbited the Earth 3 times for a total of almost 5 hours in space. John Glenn was also NASA's first astronaut to eat anything in space. Foods enjoyed by Mercury crew members included bite-sized cubes, freeze-dried powders, and semi-liquids in aluminum tubes that looked like toothpaste tubes.

Gemini (1964–1966)

The Gemini program, Project Gemini, was created to bring NASA one step closer to going to the Moon. It included the first 2-person missions, and the first American space walk by astronaut Ed White.

Foods used in Project Gemini were a little better than the original items developed for Project Mercury. They included foods like shrimp cocktail, chicken and vegetables, pudding, and applesauce.

Did you know?

Gemini is a Latin word that means "twins". Gemini is a constellation of stars, with the brightest stars being the twin stars Castor and Pollux.

Apollo (1961–1972)

In 1961, when U.S. astronauts had about 15 minutes of space flight experience, President Kennedy challenged us to get to the Moon by the end of the decade. With tremendous teamwork and an outstanding effort, in 1969 the Apollo 11 crew landed on the Moon. At 4:17 p.m. eastern daylight time on July 20, 1969, Neil Armstrong radioed the first words from the Moon: “Houston, Tranquility Base here. The Eagle has landed.” Just under 7 hours later, he took the first steps out of the lunar module and proclaimed “That’s one small step for man, one giant leap for mankind.”

The Apollo astronauts were the first to have hot water in space, so the variety of space foods increased even more. On Christmas Day, 1968, the Apollo 8 crew ate a package of turkey and gravy using spoons. The Apollo crews enjoyed bread slices with sandwich spreads and cheddar cheese spreads, and even frankfurters. Fruit juices were also added to the menu.

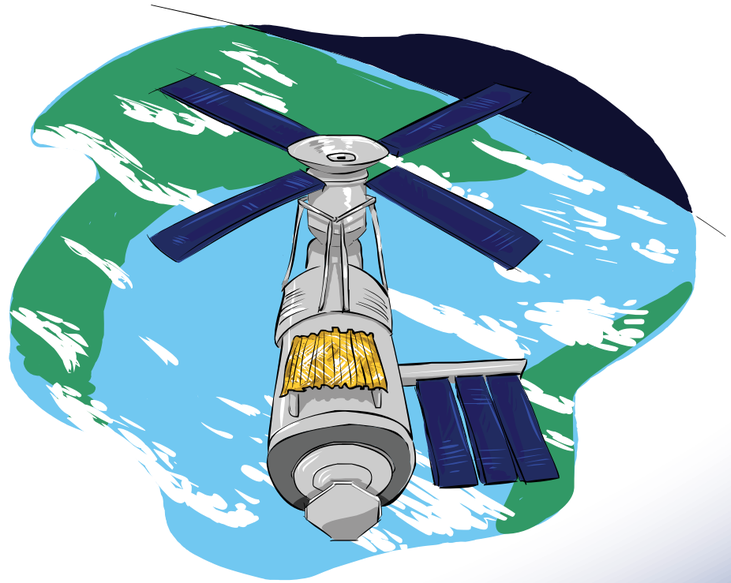
Did you know?

This figure depicts a very famous photograph. Neil Armstrong was not only the first person to step onto the Moon, he was also the first lunar photographer, taking this picture of Buzz Aldrin, the second person to step onto the Moon.

Skylab (1973–1974)

The first space station built by the U.S. was Skylab, depicted in the figure below. The goals of the Skylab program were to prove that humans could live in space for long periods of time, and to perform scientific experiments. Astronauts on Skylab used specially made equipment to keep an eye on, and better understand, what happens to the body when it is exposed to weightlessness for a long time. They also measured radiation from the sun and observed the Earth from space.

Skylab had one of the best space food systems. One part of the station had a dining area and table. A refrigerator and freezer were also available for storing food, and therefore the menu could be more extensive. The Skylab astronauts could choose from 72 different food items, including steak and vanilla ice cream.

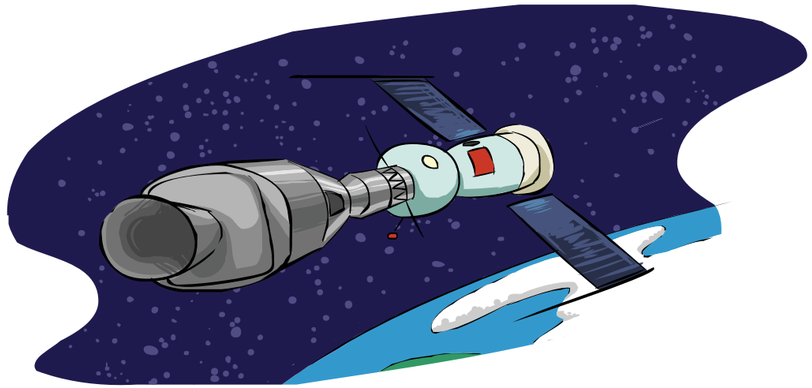


Apollo-Soyuz Test Project (1975)

The Apollo-Soyuz program was the first joint space program of the U.S. and Russia, which resulted in one mission. The mission lasted 9 days (July 15-24, 1975), but a great deal of planning went into those 9 days.

During the Apollo-Soyuz mission, a U.S. Apollo spacecraft launched from the U.S. and docked (that is, connected) with a Russian Soyuz spacecraft that had launched from Russia. Engineers had to design a special docking module that would fit onto both spacecrafts. The figure below depicts this mission, with the Apollo capsule on the left and the Soyuz capsule on the right. Photos of this event are unavailable, because there was no third spaceship to take the picture from!

The Apollo and Soyuz crews shared meals and performed experiments together. Overall, this program was a big success and paved the way for the future when these nations would work together again in space.



Space Shuttle (1981–2011)

The Space Shuttle was the world's first reusable spacecraft. Shuttle missions were 5- to 16-days long, and while most had 5-6 crewmembers, a few had as many as 8 crew members. The Space Shuttle had wings and was called the "orbiter." For launch, the orbiter was mounted on a huge fuel tank, with 2 solid rocket boosters also attached to the fuel tank. Inside the orbiter was the crew compartment (that is, the place where the crew members worked, ate, and slept). The crew compartment had 2 levels: the flight deck and the mid-deck (or middle deck). The flight deck was "upstairs," and was where the commander and pilot (and 2 other astronauts) sat and controlled the flight while they could see out the windows. The mid-deck was "downstairs," and was where most experiments were conducted, where the "kitchen" was, and where the bathroom was.

Shuttle astronauts prepared their food in the galley on the orbiter's mid-deck. The galley was a kitchen area, that had a water dispenser that could deliver warm or cool water. It also had a convection oven to warm foods. This oven was hot enough to warm foods, but it wasn't hot enough to bake foods—like cookies!

Did you know?

This is what some of the foods that we currently use look like. Many of the foods are packaged in a special container that can be used as a bowl after water is added to rehydrate the food. All of the foods are wrapped in special materials to make the foods last longer. Also, notice that the straws have a special one-way valve to prevent liquid from escaping when they are not in use.

The first Space Shuttle mission, STS-1 (Space Transportation System-1), launched April 12, 1981. The longest Space Shuttle mission ever was 17 and a half days on STS-80 in 1996. After an incredible 30-year run, the Space Shuttle Program, and it's remaining 3 Space Shuttles, was retired in 2011. STS-135 was the last mission.

NASA-Mir Program (1994–1998)

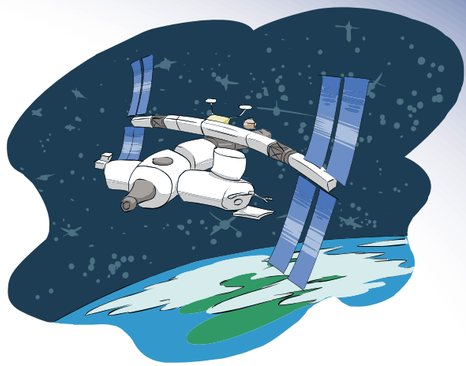
The NASA-Mir Program was a series of space missions that included 11 Space Shuttle flights to the Russian space station Mir. Cosmonauts flew on Space Shuttle missions, and 7 Astronauts participated in missions on Mir that lasted 3-4 months. The goals of this program were to learn how to work with international partners, gain experience in successfully living in space for many months, and conduct scientific experiments related to biology, weightlessness (also called "microgravity"), and Earth's environment.

The crew members on board Mir had their choice of American or Russian food. Astronaut Andy Thomas described the food this way: "The Russian foods were really good. The Russian soups were just outstanding." He went on to say "It was really a good selection of food, actually. The food is largely canned food and rehydratable foods, much like you might use on a camping trip or something like that, and I had more than enough to eat."

Did you know?

Sergei Krikalev (depicted here) was the first Russian cosmonaut to fly on the Space Shuttle, in 1994. This mission was called STS-60, and the Commander for this flight was Charlie Bolden. Commander Bolden participated in experiments to study fluid balance in the body during flight. He went on to be appointed by President Obama to become the NASA Administrator in 2009!

International Space Station (ISS) (2000–present)



The International Space Station (ISS) is a giant environment for living and working in space. The ISS was built in sections called "modules" that were taken to space either in the Space Shuttles or on Russian launch vehicles. The first module was launched in 1998, the first crew took up residence in 2000, and construction of the ISS was completed in 2011. Even though the ISS is traveling almost 200 miles above the Earth at 17,500 miles per hour, on a good night you can see it with just your eyes! Check out NASA's Web sites for when the ISS might pass over your head (https://spotthestation.nasa.gov/)!

Exploring space is a huge challenge. It requires teamwork from countries around the world. Just as the United States has the National Aeronautics and Space Administration (NASA), other countries have their own space organizations. The ISS organizations represent 26 countries, called the international partners. For the ISS, the international partners are the Canadian Space Agency, the European Space Agency (which represents 22 member countries), the Japanese Aerospace Exploration Agency, the United States' space agency—NASA, and the Russian Federal Space Agency. All of the partners work together to accomplish one task: learning more about space.

The ISS crews are international as well: six or seven crew members live on the ISS at one time, and they come from all around the world. The U.S. and its international partners make new foods to try to increase the variety of foods available to crew members.

Did you know?

Since November 2000, astronauts have been living off the planet on the ISS. Most spend about 6 months on ISS before the next crew arrives for their turn. That really is quite amazing!

The parts of the ISS were built in different countries. For example, the Canadian Space Agency built a robotic arm; the European Space Agency built the Columbus Laboratory module; the Japanese Aerospace Exploration Agency built an experiment module known as Kibo, which means "hope" in Japanese. The Russian Federal Space Agency built the Functional Cargo Block, FGB for short, known as Zarya (the Russian word for sunrise), and NASA built the lab module called Destiny. These huge pieces were never near each other until they were attached in orbit!

Commercial Space Companies

When the Space Shuttle retired, and NASA focused on building rockets to get to the Moon, several companies stepped up to launch people into what we call low-Earth orbit. SpaceX, Boeing, Sierra Nevada Corporation, and Blue Origin are just a few of these companies. NASA has agreements with some of these companies to launch astronauts to ISS, and with many more companies to develop parts of the Artemis program, including the Human Lander System or lunar rovers!

Did you know?

The term "low-Earth orbit" refers to an orbit around the Earth that is less than 1,200 miles (1931 km) from Earth's surface. It's in the zone that is considered close enough to Earth for convenient transportation, observation, satellite communication, and resupply vehicles. This is the zone where the ISS currently orbits the Earth.

Artemis (2022–present)

Artemis missions are planned to bring the first woman and first person of color to the surface of the Moon. This program consists of several parts: 1) the Space Launch System, a rocket that will launch with 2) an Orion capsule, which will bring crews to the Moon's orbit to dock with 3) Gateway, a mini-space station that will orbit the Moon, and 4) a Human Lander System, which will take astronauts from Gateway down to the surface of the Moon, and then launch to return them to Gateway after their mission is complete.

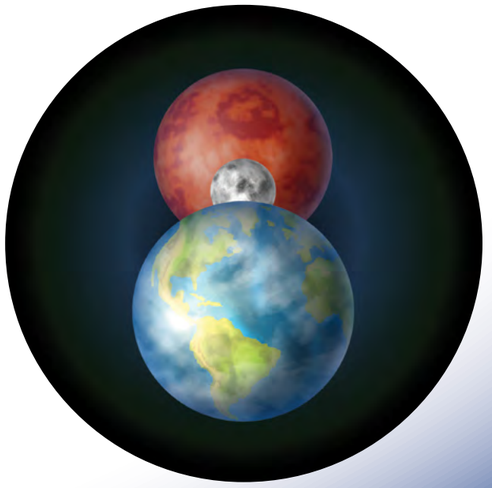
The Artemis 2 crew is training for their mission to fly in an Orion capsule around the Moon for a few weeks. The Artemis 3 crew will be the first people to land on the surface of the Moon since 1972! These are very exciting missions and a great next step for space exploration!

Did you know?

Artemis is the name for an ancient Greek goddess of the Moon who happens to be the twin sister of Apollo. Apollo is a name for the Greek and Roman god of sunlight, prophecy, music, and poetry. Apollo was selected as the name of the space program that first took NASA astronauts to the Moon. The Artemis program will bring astronauts back to the Moon!

Did you know?

"Astronaut" is from Greek words meaning "star sailor". You can apply to be an astronaut one day too! In addition to educational and medical requirements, astronaut candidates must also have skills in leadership, teamwork, and communications.



Space Food

Space food has come a long way from the food mashed into tubes as they were on early flights, such as Mercury and Gemini missions.

Space foods on the ISS are either rehydratable, thermostabilized, or in natural form. A rehydratable food is one that is dehydrated, meaning all the water has been taken out. You might be familiar with some of these, such as packets of hot cocoa mix or dried noodle soups. To eat one of these items, you must rehydrate it, meaning you must add the water back. Thermostabilized foods are heated to high temperatures and packaged in cans or closed pouches. Examples of thermostabilized foods are canned ravioli and soups. We also use some foods in their natural form, that is, just like they are in nature (or at the grocery store). A food in its natural form is in a vacuum-sealed package, meaning all the air has been removed so that it stays fresh longer. These foods include nuts and dried fruit.

The ISS crew members enjoy a diverse menu that reflects their global origins. Their meals include a variety of international foods, including Canadian, European, Japanese, and Russian food items. The astronauts and cosmonauts have more than 300 food items to choose from.

Did you know?

- "Dehydrated" means that the water has been removed and the solid matter has been left behind.
- "Thermostabilized" means that foods have been heated a certain way to destroy bacteria in the food that could make it spoil.

Did you know?

- In order to keep food nearby or on a tabletop during a meal, crew on the ISS use a variety of fasteners, including tape, tethers, and Velcro patches on packages.

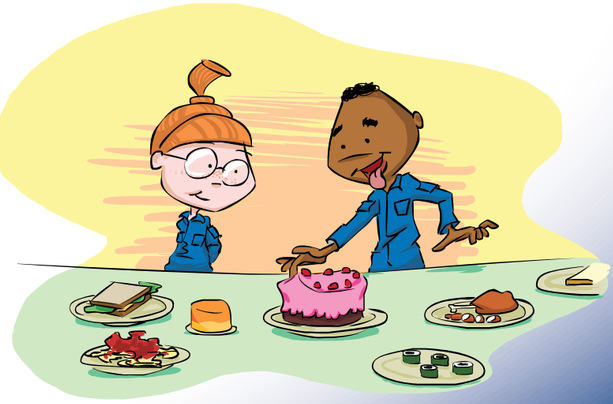
Preparing food that can be eaten in weightlessness is a challenge. Crumbs are not allowed because they can float around the cabin and could float into someone's eye (or nose), into instruments, or clog air vents. Also, the food must not float away while an astronaut is trying to eat it, so packages and foods are designed to make this less of a problem in space. Another challenge for food system developers is trash. Wrappers and empty packages must be compressible to minimize the amount of trash on the spacecraft. The garbage truck doesn't stop by the ISS, and there are very few opportunities to get trash off the vehicle. In fact, trash is disposed of only when space vehicles such as Soyuz capsules, and other cargo vehicles visit the ISS and then depart. This happens about once a month, and even these vehicles have limited amounts of space available, so trash must be as compact as possible. These are just a few of the challenges of developing space foods. The NASA Space Food Team does a great job of meeting these challenges, and of developing foods that the astronauts will like during their space missions.

Food storage is a big issue for space travelers. The ISS had no freezers or refrigerators for food, so the food has had to be "shelf stable" and not likely to spoil for at least 6 to 12 months. Food for a Mars mission will need to be stable for up to 5 years. A small refrigerator-freezer known as MERLIN (Microgravity Experiment Research Locker/Incubator) is now available on the ISS. It can be used to store a small amount of fresh food and drinks. This is especially helpful for cooling drinks - nothing beats a cold drink, especially after a hard workout!

Did you know?

When you see an expiration date on a food purchased at the grocery store, it means that after that date, the nutrient content or the flavor or smell of the food is likely not good anymore.

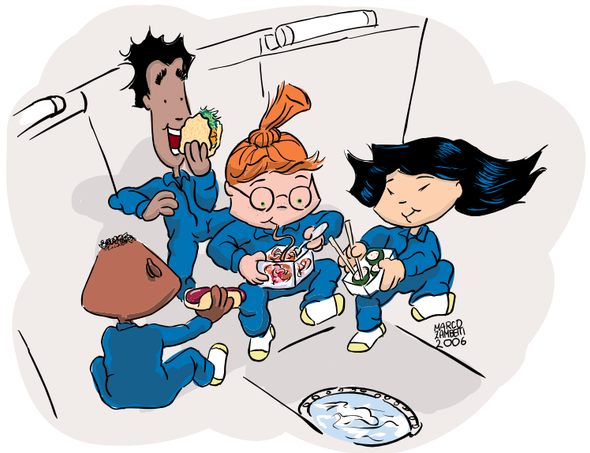
Eating food that is past the expiration date (or older than its suggested shelf life) could even make you sick, depending on the food item.



...Space Food

Taste and texture—how the food feels in your mouth—are very important for space travelers. When new foods are developed for astronauts, taste tests are conducted on Earth. Some astronauts have reported that their tastes changed during space flight, and that in space they tended to like spicier foods. One of the reasons for this is related to congestion that astronauts sometimes have, similar to when you have a cold and your nose is stuffy. Most ISS astronauts say that this is troublesome only in the early days of flight, and that after a week or two, foods taste great.

Other challenges in developing space foods are making sure that they are tasty, have good nutrient content, and can be easily prepared. Some foods must be stored for a long time during space flights, so "shelf life" must be extended, which is a concern as well. On the ISS, the foods have to sit on the shelf (a shelf in the pantry, not in the refrigerator or freezer) for at least 9 months and still be tasty. During a Mars mission food will have to be stored even longer than that. Can you imagine going to the grocery store, filling your pantry with food—and not going back to the store for a year, or 2 or 5? That's a lot of food and a long time!



Did you know?

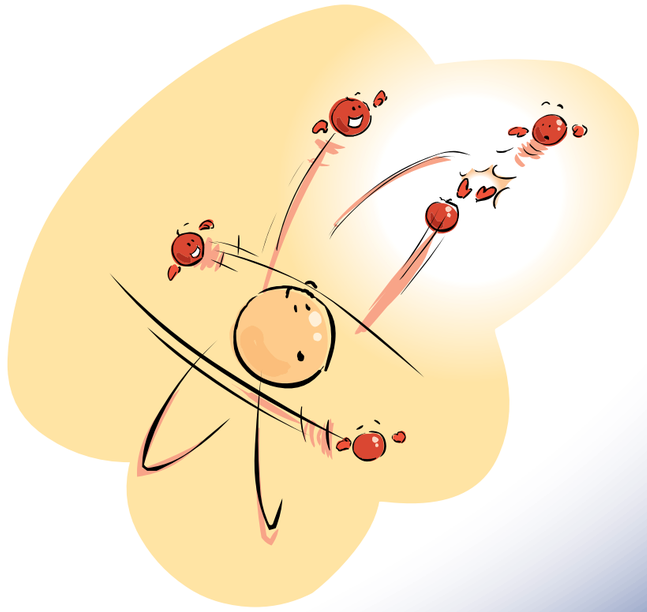
Many astronauts say that the most popular space food is shrimp cocktail, in part because of the spicy sauce!

Food scientists in the Space Food Systems Laboratory at the Johnson Space Center have created another success story. They have developed special tortillas that still taste good after almost a year. Tortillas are great for making sandwich roll-ups in space (a regular sandwich with two slices of bread would take three hands to make—otherwise one slice will float away!). The scientists keep these tortillas fresh with special packaging that includes an oxygen scavenger. An oxygen scavenger is a chemical that traps oxygen, and the lack of oxygen in the packaging prevents mold from growing.

Did you know?

Some space foods are irradiated. These foods are packaged and then exposed to a source of radiation that kills any mold or bacteria on the food, allowing it to be safe to eat for a long time. No radiation stays on the food. This is like when you go to the doctor to get an X-ray, once the X-ray is taken, there is no radiation on you.

"Irradiated" means to expose to radiation.

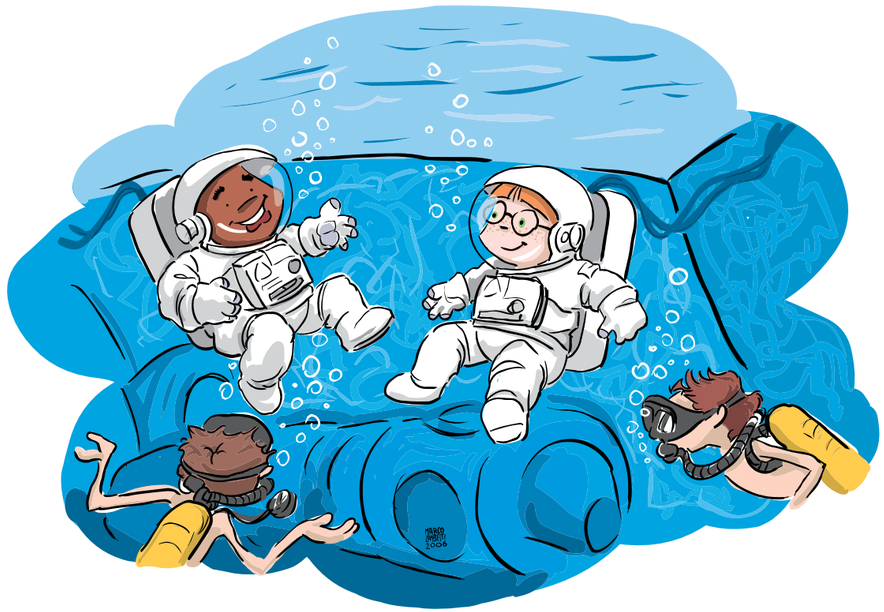


Space Walks

Space Walks and The Smallest Spacecraft

Space walks, or what NASA calls “extravehicular activity” (EVA), are a very important part of many space missions.

When astronauts need to go outside the International Space Station, they have to put on a special suit that acts like a personal spacecraft. The EVA suit provides oxygen for the astronauts to breathe, and is cooled with a special suit underneath that can have cool water circulating throughout it. During an EVA, astronauts can be in these suits for up to 10 hours.



To train for doing EVAs in space, astronauts need a place that is similar to the space environment where they can wear their EVA suits. The Neutral Buoyancy (bo-yun-see) Lab is a giant swimming pool that allows astronauts to train for space missions involving space walks. There is a full-scale model of several parts of the ISS at the bottom of the 40 foot pool, and there is even a mission control center that directs the activities of the dives. When something is buoyant, it has a tendency to float or rise when submerged in water. What does it mean to be neutrally buoyant? It means to have an equal tendency to float and to sink. When an item is neutrally buoyant, it is very easy to move the item while it is under water—much like moving an object in space.

When astronauts train in the Neutral Buoyancy Lab, they wear space suits similar to those used during space flight EVAs, and they breathe high levels of oxygen as they would on EVAs. Although we need oxygen to survive, too much oxygen can cause damage to cells in the body. We can measure the amount of damage by looking at chemicals in the blood and urine to see how much damage was done by the excess oxygen. Antioxidants are chemicals found in foods, such as vitamin C or vitamin E, that can reduce damage from oxygen. Colorful fruits and vegetables such as melons, grapes, peppers, tomatoes, and berries are rich in antioxidants. Astronauts are encouraged to consume fruits and vegetables during their missions because they contain large amounts of these important nutrients.

Did you know?

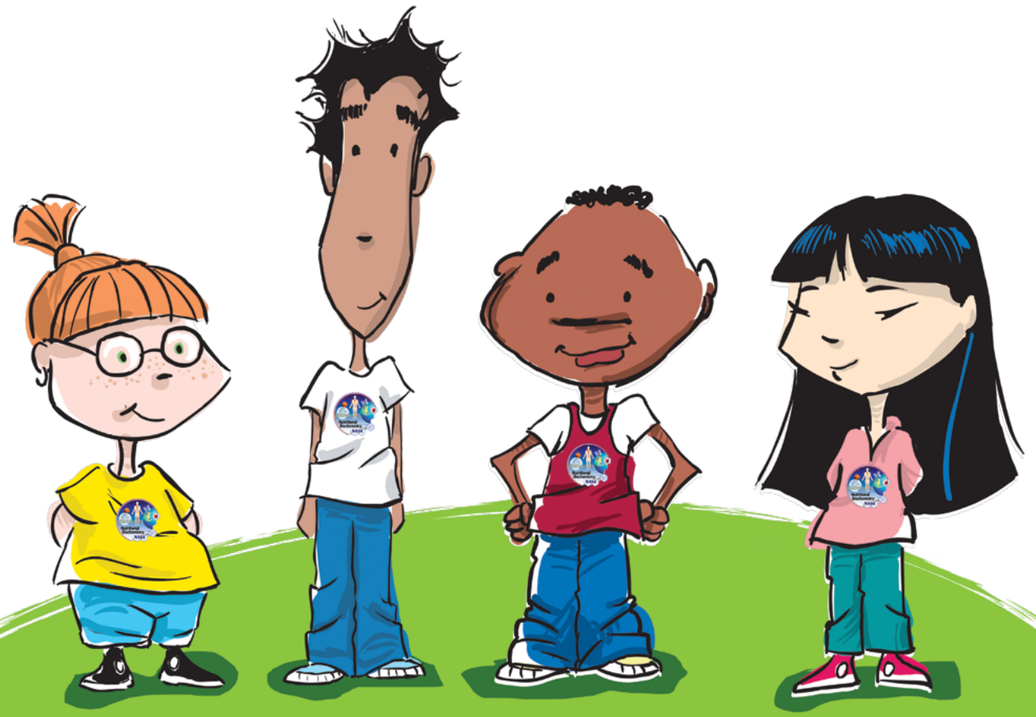
There are more than 326 million trillion gallons (1 gallon = 3.79 liters) of water on Earth!

The Neutral Buoyancy Lab is 202 feet (62 meters) long, 102 feet (31 meters) wide, and 40 feet (12 meters) deep. It holds 6.2 million gallons (230 million liters) of water, and the water in the NBL is recycled every 196 hours. The water is kept at a temperature from 84-86 degrees Fahrenheit (28.9-30°C).

Section Two

Space Nutrition

In this Section, ***Lin, Tim, Thea, and Diego****—the Space Nutrition Team—help us understand more about the world of space nutrition, and how the Nutritional Biochemistry Lab works to keep astronauts healthy!*



Nutrition is a field of science that studies the relationship between what you eat and how your body works. Nutrients are chemicals in food that your body needs in order to function. Some nutrients–including carbohydrates, fats, and protein – provide the body with energy. Vitamins and minerals can help support chemical reactions, and others provide structural components (like calcium in your bones).

Biochemistry is a fancy word for studying how living organisms work—all the way down to the chemicals in the cells that make up the body. Nutritional biochemistry is the study of how nutrients in food affect how our bodies work. Every cell in your body requires many nutrients – including vitamins and minerals and energy – to keep you alive and healthy.

The Nutritional Biochemistry Laboratory team works to keep astronauts healthy from a nutrition point of view. One element of this is to figure out how much of each nutrient the body needs during space flight—in other words, defining the nutrient requirements for space flight. Just like on Earth, there are defined nutrient requirements for space, and as research reveals new information, these requirements are updated. As new information is gained and requirements are updated, the Food Scientists in NASA's Space Food Systems Laboratory work to develop foods and menus that will not only meet the nutrition requirements, but also obey the many other special rules that are made for space foods. (see Space Food section).

Having space nutritional requirements is great, but we also need to know whether astronauts are eating right to meet those requirements, and whether astronauts are getting enough, or too much or too little, of each nutrient. How do we know if the body is getting the right nutrients? Keeping track of what astronauts eat tells us what we need to know. We do this with an iPad App that the astronauts use at mealtimes to record the food they have eaten.

...Space Nutrition

Another part of keeping astronauts healthy is checking their nutritional status. One way we do this is by collecting blood and urine samples from the astronauts before and after they fly into space, and when we measure the biochemicals in these samples it tells us how well the astronauts are processing each nutrient. The concentration of vitamins, minerals, and other biochemicals in the samples can tell us about muscle, bone, kidneys, and more! By putting together these two parts of our knowledge (food records and nutritional status), we can look at the relationship between what the astronauts ate and how well their bodies used each nutrient. Then we can estimate whether they are getting enough, too little, or too much of each nutrient. We also keep track of each astronaut's weight, and we use a special whole body X-ray machine (called a DXA, dual energy X-ray absorptiomer) to evaluate their bones and muscles.

What astronauts eat and how well they meet their nutrient requirements can affect how much (or how little) bone and muscle they lose during a mission, how well they can exercise, how well they can concentrate on important activities, and even how well they sleep. It's easy to see why nutrition is as important to you as it is to the astronauts!

Did you know?

Lin is using an iPad App to record her food intake. We now know that she likes salmon because she ate it three times this week! Salmon contains a lot of vitamin D and important omega-3 fatty acids that will help protect her muscles and bones during space flight.

Nutrients

Our bodies need several types of nutrients, these are grouped into categories. Macronutrients are ones that we need a lot of, like fat, protein, and carbohydrate. Vitamins and minerals are micronutrients. We don't need a lot of each one, but they are vital for our good health.

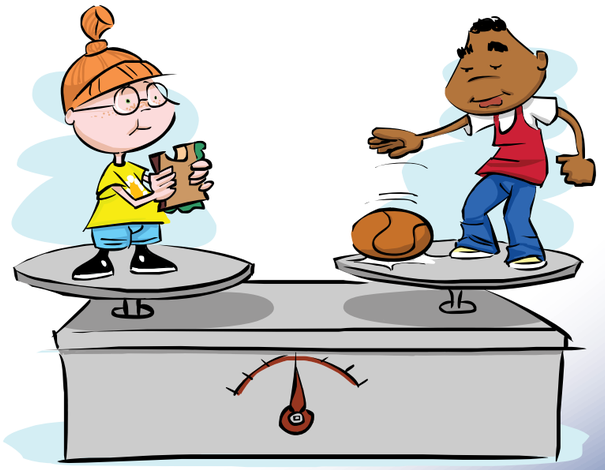
Macronutrients

Fat, protein, and carbohydrate provide the energy we need to grow and do things.

Energy (Calories)

Energy is what keeps us going. Every cell in your body needs energy to function properly. The food you eat provides energy, which is measured in calories. Balancing the energy you take in from foods with the energy your body uses each day is important for good nutrition. Eating enough calories helps make you alert and able to do your schoolwork. Without enough calories, you will be tired and your muscles will not work well. However, too many calories can also be bad for your overall health. Balancing exercise and good nutrition is key to your overall health.

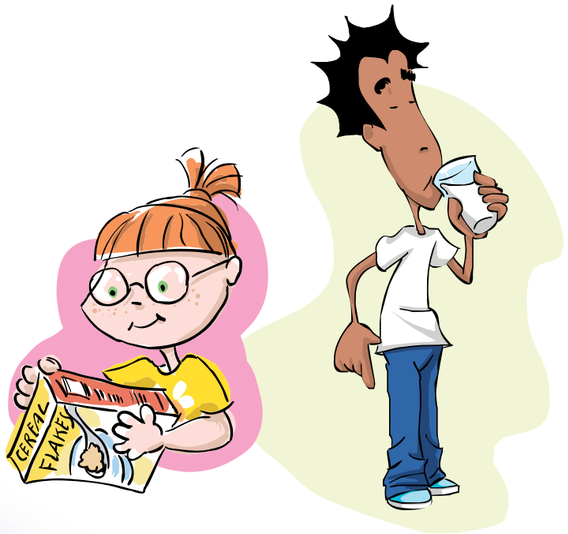
>> Thea and Tim know that eating too many calories can lead to gaining weight, and that playing basketball can burn calories that are not burned while sitting on the couch and watching television.



...Nutrients

At every stage of life, proper nutrition is important for staying healthy and reaching your full potential. 60–80% of the difference in height between people is determined by their genetics, and the other 20–40% is determined by environmental effects, especially nutrition. In general, for a healthy diet, calories should come from the following sources: roughly one half of calories should come from carbohydrate, about a third of calories from fat, and the rest of calories should come from protein. Carbohydrates are found in a variety of foods such as grains, vegetables, and fruits; fat is found in oils, nuts, seeds, fatty fish, meats, dairy products, and certain fruits such as avocado or olives; and protein is found in foods such as dairy products, nuts, seeds, beans, and meat.

Food labels are a great place to learn about your favorite packaged food. First, check the serving size and how many servings are in that package. Next, look at how many calories are in each serving, and what percentage of the calories come from fat, carbohydrate, and protein. For more information about the number of servings of foods you need each day, check out the guidelines for healthy eating established by the U.S. Department of Agriculture at http://www.choosemyplate.gov/.



Did you know?

Fat has more than twice as many calories, per unit weight, as carbohydrate and protein.

Thea and Diego know that maintaining a healthy diet with a variety of fruits and vegetables can help them perform better in school, give them energy to play with their friends, and maintain a healthy body.

Vitamins

Vitamins are chemicals found in foods and are important for your body to function. Vitamins sometimes have complicated names, like thiamin, riboflavin, niacin, folate, biotin, and pantothenic acid—or sometimes they may simply be letters, like vitamins A, B6, B12, C, and E. Either way, these are critical elements of what you eat, and missing one single vitamin in your diet over time could be catastrophic to your health.

Millions of sailors died in the 18th century from a disease called scurvy, which developed because these explorers were missing vitamin C in their diet. After it was realized that diet could protect sailors, many ships carried lemons, limes, and oranges to protect sailors from getting scurvy. Today, many of the foods you eat are fortified with vitamin C, and fresh fruits that supply vitamin C are readily available, but scurvy could still occur if you don't eat these types of foods. We learned an important lesson from those early sailors.

Vitamin D

Vitamin D is unique because it can be considered a vitamin or a hormone. A hormone is a biochemical that is made in one part of your body and acts on another part. Vitamin D can be synthesized (made) in your skin when you are exposed to sunlight.

If you don't get enough sun exposure, you need to get vitamin D from the foods you eat. Vitamin D is found naturally in fish, milk and cereals; and some orange juices are fortified with vitamin D. A fortified food is one that has had nutrients added to it. Reading food nutrition labels will help you find out if the food you eat has any added vitamin D.

Vitamin D is very important for your bones because vitamin D helps your body use the calcium in your diet. If you don't get enough vitamin D, your body will be "deficient" in that vitamin and won't be able to use calcium from food. This can cause your bones to become weak.

Knowing that vitamin D is synthesized in your skin after exposure to sunlight, you can imagine that getting enough vitamin D from the sun would also depend on the time of year and where you live. Do you think living in Texas or in Alaska would be better for skin production of vitamin D?

...Vitamins

Vitamin D is like many nutrients: although getting too little of it is bad for your health, getting too much can also be bad for you. This usually happens only if you supplement your diet with high doses of vitamins. Luckily, the body won't get too much vitamin D just from sun exposure. However, too much sun can cause health problems like sunburn, or even skin cancer.

Astronauts cannot make vitamin D from sunlight exposure during space flight because the windows of the space vehicle block the specific types of rays that help make vitamin D. The foods on board a spacecraft do not contain enough vitamin D to make up for the lack of sunlight, so we provide astronauts with vitamin D supplements to ensure they get enough vitamin D.

Vitamin D deficiency, long thought to be rare, is being identified in kids in America. Be sure to get enough vitamin D in your diet or to get out in the sun for short periods!

The Space Nutrition crew is enjoying a quick game of volleyball in the sunshine, and all the time their skin is making vitamin D for strong bones. They also know not to spend more time than 5-10 min in the sun without sunscreen because of the risks for skin cancer.

Did you know?

A fortified food is one that has had nutrients added. If you look at a Food Nutrition Label on a packaged food and see vitamins and minerals in the ingredients list, this means they have been added to the recipe.

Milk and orange juice may be fortified with vitamin D, meaning that vitamin D is added to them. This makes them good dietary sources of vitamin D.

Vitamin K

When you get a cut, the blood eventually stops flowing because a blood clot forms. This process is known as "coagulation" (pronounced ko-ag-you-lay-shun). Vitamin K is very important in this process. Vitamin K represents just how exciting the field of nutrition can be. We are still learning more about what vitamin K does in the body, and how important it is for all of us—even astronauts.

In addition to its role in blood clotting, vitamin K is very important for bone health. Vitamin K helps bones make proteins that hold calcium in place, which makes this a really important vitamin for astronauts.

The story of vitamin K has an unusual cast of characters.

Bacteria...they are a normal part of your digestive tract. Although having bacteria in your intestines may sound gross, it is very important, especially when it comes to vitamin K. The bacteria in your large intestine actually make vitamin K, some of which can be absorbed and used by your body!

Rats....dead ones to be exact…and you thought the bacteria part was gross! What do dead rats have to do with vitamin K? They provide a good example of why vitamin K is important. Some types of rat poison are made from a chemical called warfarin that blocks the action of vitamin K in the body. Rat poison works because the rats eat the poison and end up not having enough vitamin K for their blood to clot normally. They die from internal bleeding. This helps show you just how important each vitamin is!

As with most vitamins, the best food sources of vitamin K are vegetables. Vitamin K-rich foods are the dark green and leafy kinds—like spinach, kale, and broccoli. Just a few bites of spinach have all of the vitamin K you need in a day (and a lot of other vitamins as well). Vegetables are an important part of an astronaut's diet, and of yours. You can eat spinach as the green part of your salad, instead of lettuce. Give it a try...it worked for Popeye!

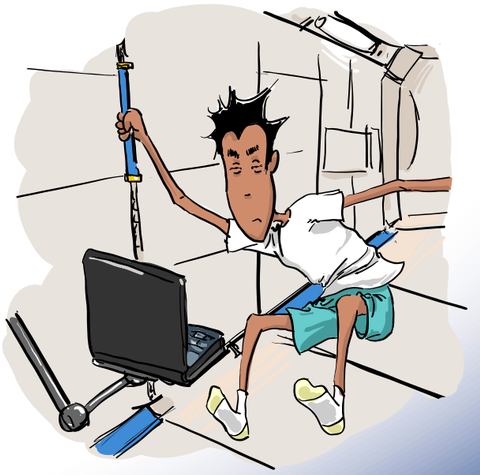
Did you know?

Vitamin K is essential for blood clotting. Scientists in Copenhagen, Denmark, discovered this and named the vitamin for its role in "koagulation."

Vitamins, Genetics, and Astronaut's Eyes

With more and more astronauts living on the ISS, it was realized that some of them were developing eye problems. The changes in the eyes of these astronauts have been named "spaceflight associated neuro-ocular syndrome," or SANS for short. Some astronauts launched into space with perfect vision, but they needed glasses after they got back. For some, there were changes in the back of their eyes that could only be seen with a special camera. The Nutritional Biochemistry Team's research found out that the blood biochemistry of the astronauts who developed eye issues was different from the blood chemistry of astronauts who did not develop these issues. This started a long and complex line of research and discovery.

Astronauts who developed SANS had higher concentrations of certain chemicals in their blood. These chemicals are part of an important biochemical pathway called "One Carbon Metabolism." This pathway is how the body moves carbon atoms, one at a time, to modify the chemical structures of two different compounds. Essentially, one compound gains a carbon atom, while another loses a carbon atom, which results in two different compounds. This is a very important (and very complex) biochemical pathway. Several B vitamins are essential for this pathway to function efficiently. These vitamins are: folate (also called vitamin B9), vitamin B12, vitamin B6, and riboflavin.

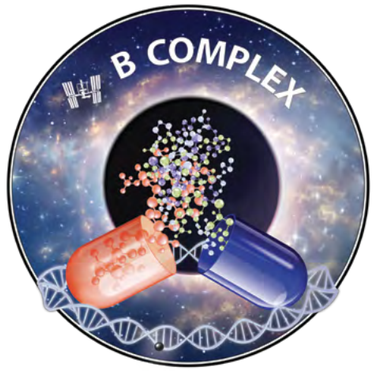


...Vitamins

Vitamins often function to help enzymes work more efficiently. Enzymes are proteins, which help catalyze, or speed up, chemical reactions. Without enough of a given vitamin, the enzyme it helps will not work as well, which can lead to diseases (like scurvy, as mentioned previously). Enzymes can also be affected by a person's genetics, or DNA. There are differences in the genetics in groups of people. These differences can affect the structure and function of specific enzymes. If a person's one carbon metabolism pathway enzymes are affected, they can develop symptoms similar to vitamin deficiency.

The Nutritional Biochemistry Team identified that the astronauts who develop SANS had genetics that cause the One Carbon Metabolism Pathway to be less efficient. That explains why they had different blood biochemistry. Although we don't know how this might cause these astronauts to develop SANS (and nobody knows what causes SANS yet), we are continuing to research how these factors (genetics, vitamins, and eyes) are interrelated.

Because we found out that astronauts who develop SANS have specific genetic patterns in their One Carbon Metabolism pathway, we hypothesized that giving the astronauts B-vitamin supplements might help to override the genetic effect and make the pathway function better. In other words, we think that providing extra B vitamins might overcome the genetic effect that slows the pathway down, and that might lessen or eliminate the problem. We are testing this in astronauts on ISS missions in an experiment called B Complex. The findings from this research might not only help prevent SANS in astronauts, they might also help doctors better understand the relationships between genetics, vitamins, and eye health in people on Earth!



Minerals

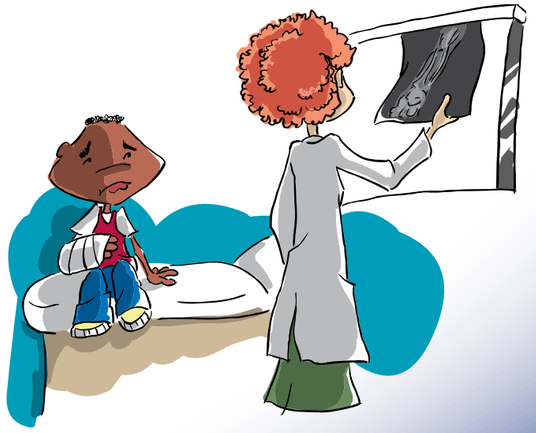
Minerals are natural substances that have important functions in the body. Whereas vitamins tend to be large chemicals made of elements like carbon, and hydrogen, and oxygen, minerals are single elements. Some examples of minerals are calcium, iron, zinc, sodium, and potassium.

Calcium (and Bones!)

Calcium (kal-see-um) is a mineral our bones need to grow and be strong. Calcium is found in many of the foods and beverages we eat and drink. Did you know that milk, broccoli with cheese, and pizza are loaded with calcium? If we don't eat enough calcium, our bones become weak. Healthy bones have millions of tiny holes in them that are part of the bones' framework or structure that helps make them strong and keep our bodies standing up. The part of the bone that has these holes is called "cortical bone." Without calcium, the tiny holes start to become larger. This can cause the bone to become very brittle, and can lead to a disease called "osteoporosis" (os-tee-oh-por-oh-sis). Although osteoporosis usually occurs in older people, not getting enough calcium can be bad for anyone! Calcium is needed for other things besides bones. We need calcium for strong muscles, healthy blood, and healthy teeth and gums. How much calcium do we need? People 9 to 13 years old need to eat 1,300 milligrams (mg) of calcium each day.

Did you know?

Tim may need to include more foods with calcium in his diet. What else can he do to develop strong bones? One way astronauts keep strong bones during space flight is to do "resistive" exercise, such as using a muscle or a machine or device to resist the force of another muscle. Participating in activities like playing hopscotch and jumping rope can help make your bones strong.



Reduced gravity (microgravity) in space produces less pressure on your bones because you are not using them to hold your body up against the gravitational force of Earth. This causes them to not be as strong as they are on Earth. Astronauts lose bone during space flight. Simply eating more calcium is not going to help their bone loss because their body's ability to absorb calcium is decreased during space flight, so they need to exercise, too!

Did you know?

A milligram (mil-li-gram) is a measurement of weight. 1000 milligrams is equal to 1 gram. If you look for calcium on a food nutrition label you will typically not see it listed in milligrams. Instead, you will see it listed as the percent of daily value (% DV). The % DV listed on a food label is the one for adults. For young people 9-13 years old, your % DV numbers for all the foods you eat in a day should add up to at least 130% DV each day for calcium.

Almost 99% of the calcium in our bodies is found in our bones.

Vitamin D helps the body absorb calcium from the diet.

Women have to really watch their calcium intake because they are more likely to develop osteoporosis later in life than men.

Iron (and Blood!)

Iron is a very important mineral that has many functions in your body. Iron works with proteins in your body to produce energy from the fat and carbohydrate in your diet. In fact, if you don't eat enough iron, you will get tired more easily and you may not be as alert during school.

Iron is also important for transporting oxygen in blood to all your tissues and organs. Iron is found in erythrocytes (uh-rith-row-sites), also known as red blood cells. About two-thirds of the iron in the body is stored in erythrocytes. The rest circulates through the blood while it is bound to another protein, called transferrin, and some iron is stored in tissues. Many cellular proteins use iron for important processes.

Erythrocytes act like a delivery truck full of oxygen that delivers oxygen to the areas in the body that need it. Iron deficiency can happen if you have too little iron in your diet, or if you bleed too much. If you have a severe iron deficiency you develop a disease called anemia.

Iron-deficiency anemia impairs brain development in infants and children. Although iron deficiency can be reversed by adding more iron to the diet, scientists are not sure whether the effects on the brain can be reversed, so... it's important to include iron-rich foods in your diet, such as meat, eggs, dried fruits, pumpkin, and fish.

Did you know?

Can you tell the difference between Lin and Diego? Which student had iron-fortified cereal for breakfast? What types of foods do you eat that contain iron? Iron is found in meat, eggs, dried fruits, pumpkin, fish, and iron-fortified cereals. If you read the food nutrition label, you will find the iron content of the foods you are eating.

Where are these oxygen molecules headed? What does the truck represent? What mineral helps get oxygen to the areas in your body that need it?

...Minerals

Space flight has many effects on the body, and changes to iron and blood are some of the most unique. Astronauts have fewer blood cells during space flight, but this does not seem to be related to not getting enough iron in their diets. In fact, we are concerned that astronauts might get too much iron during space flight. This is the opposite of concerns for people on Earth, where too often people don't get enough iron in their diets. This is very important, especially for you, because you are growing.

Did you know?

The iron in red blood cells is what gives blood its red color.

Vitamin C increases your body's ability to absorb iron from the diet. So...next time you eat some oatmeal or cereal, put some strawberry slices on top to increase your absorption of iron!

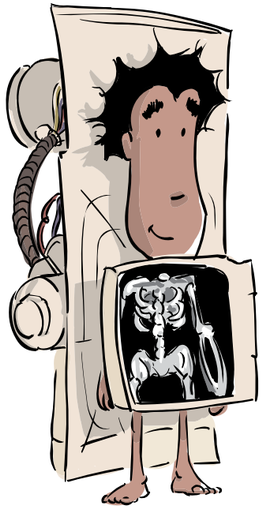
Tim is pumping iron. Is this the same kind of iron that is found in the foods you eat to maintain your good health?

Antioxidants, Radiation, and Oxygen

Radiation

Everything around us is made up of very small particles called atoms, which are constantly moving. The atoms in an object can be packed very close together or be relatively far away from each other. This packing determines which state the "matter" of an object is in—solid, liquid, or gas. Solids have atoms that are very close together; an example is a rock. Liquids have atoms that are also close together, so they are also hard to compress. Gases have atoms that move freely, and in fact the atoms try to spread themselves out. Some atoms in solids, liquids, or gases aren't as "calm" as others. These "nervous" atoms are unstable, and when moving around, they give off energy. We call this energy "radiation." As they move, the atoms try to become calm again, or become stable.

Believe it or not, we are surrounded by radiation all the time. Radiation comes from outer space, the sun, the Earth, and even from our own bodies! Radiation can also come from cellular phones, televisions, microwaves, glow-in-the-dark watches, high-voltage power lines (these are lines that distribute electricity to your home), and many other items. Radiation can be very helpful to us—it can be used to fuel power plants, to produce medical X-rays, or to treat cancer. Ultraviolet (UV) radiation from the sun even helps your body make vitamin D!



Did you know?

Just as length is measured in a unit called a meter, radiation is measured in a unit called a rem. One-thousandth of a rem is called a millirem (similar to how one- thousandth of a meter is called a millimeter).

Most Americans are exposed to about 360 millirem of radiation per year. Check out https://www.epa.gov/radtown to learn about your exposure to radiation.

UV radiation from the sun can be beneficial, as when sunlight makes plants grow, or harmful, as when overexposure to the sun's rays causes sunburn.

...Antioxidants, Radiation, and Oxygen

Too much radiation exposure can be bad for our health and for the environment. The radiation given off by the sun can be quite dangerous to humans on Earth when they are exposed to too much sun. In space, the astronauts are outside the protection of the Earth's atmosphere, so they are exposed to more radiation than we are here on Earth. The ISS and other space exploration vehicles help shield astronauts from harmful space radiation. Astronauts wear spacesuits that protect them from many dangers in space, one being radiation. During space walks, astronauts wear spacesuits that protect them from many dangers, including radiation exposure. The face shields in the helmets of their spacesuits protect the astronauts from the high levels of UV radiation. UV radiation can cause damage to the skin, commonly known as sunburn and increase the risk of skin cancer. On Earth, the ozone layer and lower atmosphere help to protect us from some of the UV radiation given off by the sun. Although, some of the UV light filters through the atmosphere and still reaches us here on Earth, which is why we protect ourselves with sunglasses and sunscreen with sun protection factor (SPF) 15 or higher.

Did you know?

Energy produced by the sun has many different wavelengths, and only a few of them are visible. Ultraviolet light cannot be seen by humans, but it can damage your skin. Prolonged exposure can wrinkle skin after many years, or skin cancer may form.

SPF (sun protection factor) is a number on a scale of 2-100, and describes a product's ability to block out the sun's burning rays.

The Space Nutrition team members want to stop the free-radical thief from taking their body's vitamin E. Eating a diet rich in antioxidants, such as foods containing vitamin C, is a good way to stop free radicals from forming.

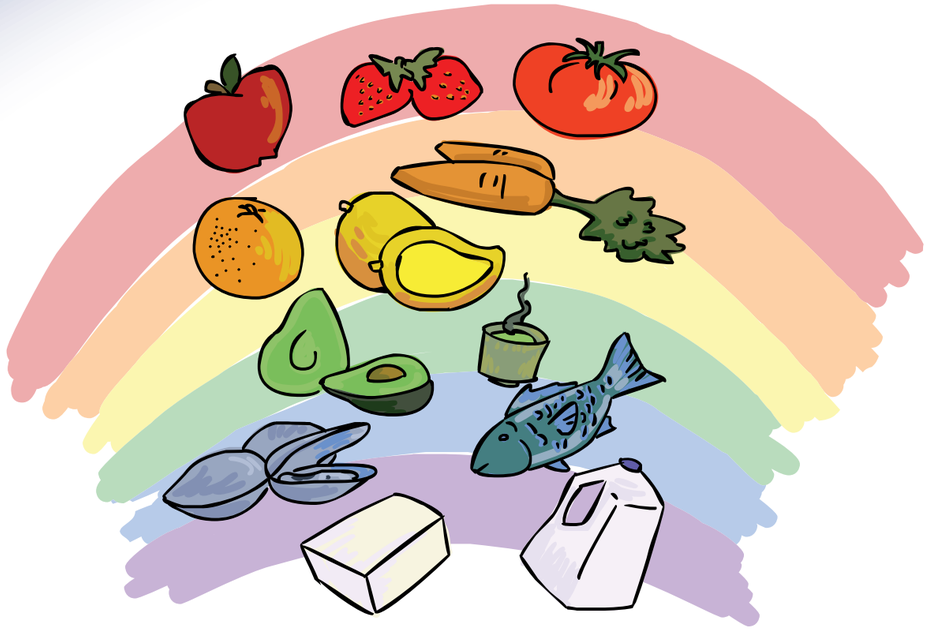
Oxygen Damage (Oxidation)

Have you ever wondered why an apple turns brown after being cut? The brown color is caused by a process called oxidation (ox-ih-day-shun). Oxidation happens when oxygen molecules react with other molecules such as protein or fat, and damage their structure. Just as apples can be damaged, our bodies can also be damaged by oxidation. Why is oxidation a bad thing? The process of oxidation produces molecules called free radicals that can damage cells in our body. Free radicals are missing an electron, and therefore they steal from healthy (normal) molecules. Years of exposure to free radicals may cause serious health problems, such as cancer or heart disease.

Oxidation in our bodies can be caused by environmental factors such as exposure to air pollution and cigarette smoke, and radiation from overexposure to sunlight. Space flight exposes astronauts to oxidation from the sun's radiation and from the high concentrations of oxygen in the atmosphere of the spacecraft and the spacesuit.

Antioxidants

How do we stop oxidation? Antioxidants are substances that slow or stop oxidation in our bodies.
If you sprinkle a cut apple with orange juice, then it will not turn brown. This is because citrus fruits are a great source of antioxidants, such as vitamin C. Natural foods with a lot of color are usually good sources of antioxidants. Here are a few that can be found in the diet: beta-carotene (mangos, carrots), zinc (milk, nuts, shellfish), vitamin C (oranges, strawberries), flavonoids (green tea, apples), vitamin E (avocados, nuts, seeds), and selenium (seafood, lean meats). The Space Food Systems Lab does a great job of incorporating all of these important nutrients in the space food system to keep astronauts healthy and minimize oxidative damage.



Did you know?

The number of food components that act as antioxidants is greater than 4,000.

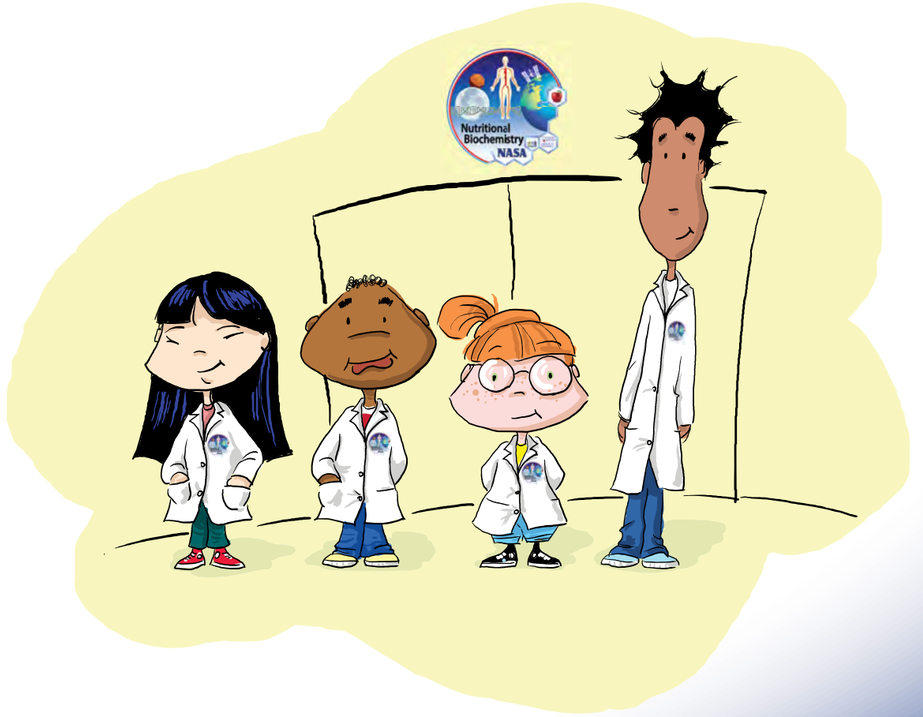
A good source of the antioxidants called polyphenols is dark chocolate.

The foods you eat at every meal should include antioxidants. Look at what you are eating. Do the colors of your foods look like a rainbow? A variety of colors at every meal are a good indication that you are getting enough antioxidants.

Section Three

Research

In this Section, ***Lin, Tim, Thea, and Diego*** — the Space Nutrition Team—help us understand more about research, and how the Nutritional Biochemistry Lab uses the scientific method to understand how space flight affects astronaut's nutritional status, and how nutrition might be able to help keep astronauts healthy!



Research

So, what is meant by the word “research”? Scientists conduct research by performing experiments to learn about things in the world. Just as you do in your science fair experiments, researchers learn new things by asking questions, testing theories or hypotheses, observing how things happen, and making conclusions about things they learned. Once you know and understand how something works, you can predict how it will behave in the future. This process is called the scientific method. You have used the scientific method if you’ve ever entered a science fair competition, and it is exactly what we at NASA use every time we do an experiment—on the ground or in space.

Now, as an example, let’s walk through the first steps of an experiment we have done in NASA’s Nutritional Biochemistry Laboratory.

Our Observation

To evaluate a person’s health with respect to a specific nutrient, doctors or scientists will often collect blood or urine samples. To evaluate a person’s vitamin D status, we collect blood. When we collected and analyzed blood from astronauts, we found that they had lower concentrations of vitamin D than they did before flight. Vitamins are important and they each do specific jobs in our body. If we don’t have enough of any one vitamin, that is, if we are deficient in it, we can become very sick. The symptoms of the sickness will depend on which vitamin is missing. In general, a balanced diet can help prevent vitamin deficiencies. That means eating a variety of foods and food types, and even a variety of colors.

Did you know?

“Deficient” means that you are missing something that is necessary.

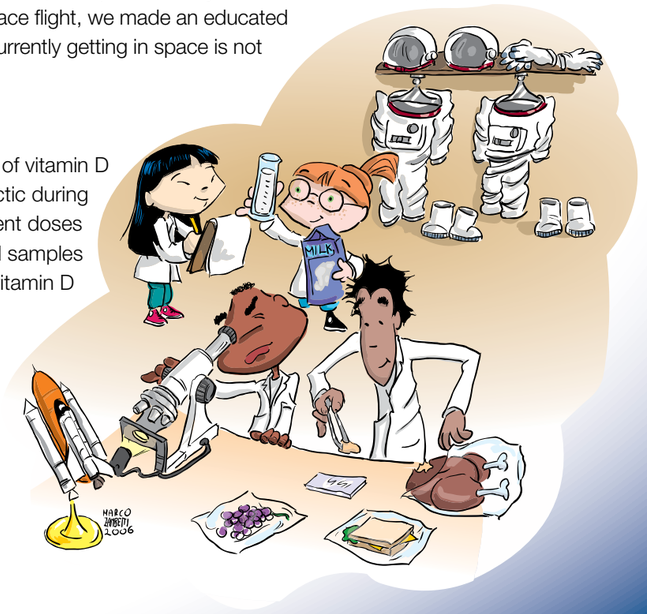
Our Hypothesis

We didn’t know the exact reason why the astronauts’ vitamin D levels were lower after flight, but we hypothesized that the crewmembers were simply not getting enough vitamin D from their food or their environment. Our hypothesis was based on several pieces of information, so it wasn’t just a random guess but rather an educated guess. We knew that space foods are low in vitamin D. Vitamin D is not present in many foods naturally, except for fish such as salmon, and there are not many space food items that contain vitamin D. Also, vitamin D is a unique vitamin because your body can make it when you are exposed to the sun. Because astronauts are shielded from the sun by their space craft or space suits, their bodies cannot make any vitamin D while they are in space.

So, because astronauts’ bodies cannot make vitamin D, the space food system is low in vitamin D, the astronauts vitamin D levels were lower after space flight, we made an educated guess that the amount of vitamin D that they are currently getting in space is not enough to meet their needs.

Our Experiment

We tested our hypothesis by evaluating the levels of vitamin D in people who spent about 5 months in the Antarctic during the winter. We gave groups of these people different doses of vitamin D supplements, and we analyzed blood samples collected during the winter to see which dose of vitamin D provided the best protection.



Our Results

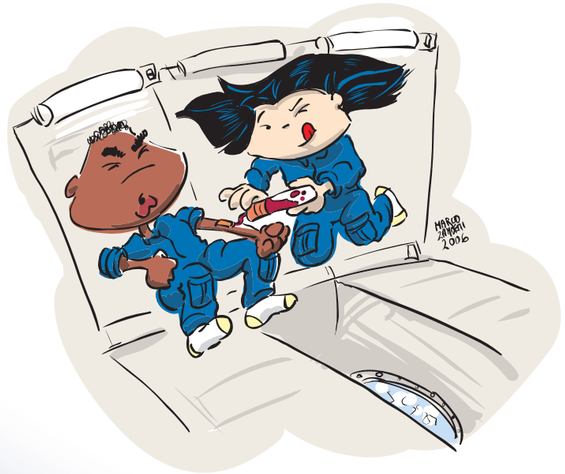
From this research, we were able to determine how much vitamin D astronauts need. We used our results to update how much vitamin D we provide to ISS astronauts. These results were also helpful when physicians and scientists reevaluated and updated the vitamin D requirements for people living in North America.

Space Flight Research

Conducting experiments during space flight can be tough, especially nutritional biochemistry experiments. Obtaining some of the most basic measurements, even something as simple as measuring body weight, is challenging in a weightless environment. In fact, body weight is defined by Earth's gravity. But your body has the same mass whether it is on Earth, on the Moon, or in a weightless environment. So, we measure body mass (but not body weight) during flight using special equipment, called a Space Linear Acceleration Mass Measuring Device, or SLAMMD, as we like to call it. The SLAMMD, uses some basic math and science (physics) principles to determine an astronaut's body mass.

Working with fluids in space is difficult as well, especially when you are trying to transfer a fluid from one container to another. Pouring things is impossible (well, everything is possible, but let's say that pouring things without a major spill is impossible). One of the main ways that we determine whether astronauts are healthy in terms of nutrition is to analyze blood and urine samples, both of which, as you know, are liquids. They are collected from astronauts before, during, and after space flight.

Astronauts can collect blood samples from each other, and scientists use these samples to see how the human body changes in space.



Did you know?

Most astronauts are not medical doctors. Astronauts are trained to do medical procedures that might be needed in space flight. One such procedure is drawing blood for the experiments.

Blood makes up about 10% of your body weight.

The process for collecting blood in space is actually very similar to the process performed on the ground. A small needle that is connected to a vacuum tube is inserted into a vein. The blood is pulled into this tube. Once in the tube, the blood is processed to separate the cellular and liquid components of the blood, which are called plasma or serum. Scientists use a machine known as a centrifuge to separate blood cells from the serum. A centrifuge is kind of like a carousel, only it is a smaller version that fits on a lab counter and spins much faster, typically rotating about 3000 times per minute! The centrifuge holds test tubes of blood in little compartments. After 15 to 30 minutes the centrifuge stops spinning and the serum is now separated from the blood cells. The tubes are frozen to keep the chemicals from breaking down. After they are returned to Earth, scientists can then use the serum to perform various tests.

Thea and her friend Lin are taking a tube of blood out of the centrifuge on the ISS.

Did you know?

A man by the name of Antonin Prandtl invented the first centrifuge to separate cream from milk.

Space Research on Earth

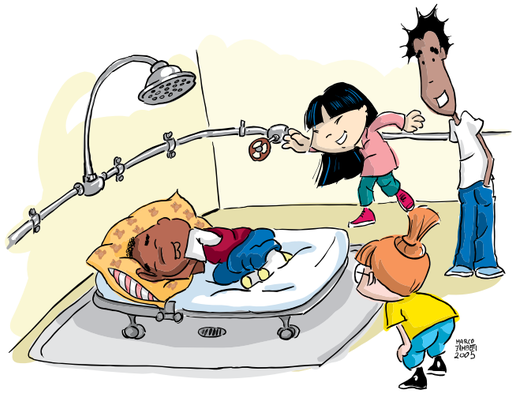
What's an Analog?

An "analog" is something that is similar in some ways to something else. Doing research in space is very difficult, expensive, and can take a long time because not many people are launched into space each year. For this reason, we are always looking for ways to do research here on the Earth using analogs of space flight, sometimes called "ground analogs." Each analog has benefits and limitations, and depending on what you want to study, some are better than others.

Bed Rest

One of the most common ground analogs to study the effects of space flight on humans is bed rest. Men or women volunteer to be research "subjects," and can spend anywhere from a few days to several months lying in bed! While in bed, your body doesn't use muscles and bones for their usual functions of working against gravity and helping you stand up and move around. Bed rest subjects are in bed throughout the entire study. They eat and read in bed, and even use bed pans to go to the bathroom. They can take sponge baths, or if it is available, use a device that lets a person shower while lying down. During bed rest, subjects lose muscle and bone just as astronauts do, although the speed of loss is slower during bed rest. This is probably because these bed rest volunteers still experience gravity while they are in bed. Bed rest studies help scientists study changes that occur in the human body in space, and test ways to counteract these changes.

Bed rest studies often involve head-down tilt, meaning the beds are tilted so the body fluids move from the lower extremities (legs) into the torso and head. This is to mimic the same phenomenon that happens in microgravity. Like all analogs, it is not an exact match of what happens in space, but is the best we can do on Earth.



Did you know?

The weather can impact research. We have had to stop bed rest and other studies when the NASA Johnson Space Center was shut down because of hurricanes and flooding. Keeping our subjects and employees safe is our highest priority.

Tim can't get up for a shower because he is a volunteer for a 90-day bed rest ground analog study at NASA. In these studies, the subjects are not allowed to get up for anything - for a full 90 days.

Ground analog bed rest studies require a great deal of work and many people. A lot of teamwork is involved to make sure everything gets done exactly as planned. These studies are difficult, but scientists can study more subjects, and collect more data, than is usually possible during real space flight.

The fact that scientists use bed rest as a way to study changes in bone, muscle, and other body systems should show you just how important physical activity is for good health. Sitting in front of a TV, computer, or phone too long will cause your bones and muscles to start breaking down, too!

Simulating Gravity (also known as: Artificial Gravity)

Astronauts' bodies adapt to weightlessness, but some of these changes can be harmful to their health during their mission or even after they return to Earth (or when they land on the Moon or Mars). One way to lessen the effects of microgravity on the body is to use "artificial gravity," which can be induced by spinning the spacecraft, for example. To test whether artificial gravity would lessen the effects of adaptation to weightlessness, we conducted bed rest studies where some of the subjects were exposed to artificial gravity for 1 hour each day.

We created artificial gravity by using a centrifuge, a device that spins people in a way that made them feel like they were standing up (even though they were lying down at the time). This device produces effects much like those of amusement park rides that spin and make you feel like you are stuck to the wall. This spinning produces a force that imitates the gravitational pull of the Earth, the "force of gravity." Because the "centrifugal" force produced on the body by the centrifuge isn't the same as gravity, it is called artificial gravity. Doing this allowed us to assess the effects of artificial gravity, which can help engineers designing future spacecraft know whether they should build spinning vehicles, for one example.

Thea and Diego are participating in a study in which scientists are testing the effects of extra gravity (artificial gravity) on bones and muscles. This is a "human-rated" centrifuge that spins the subjects around while they are lying down. Because they are spinning, there are extra gravity loads on the body. You can feel artificial gravity if you spin around in a circle with your arms out. Your hands will start to feel heavier because you have put additional centrifugal forces on them.

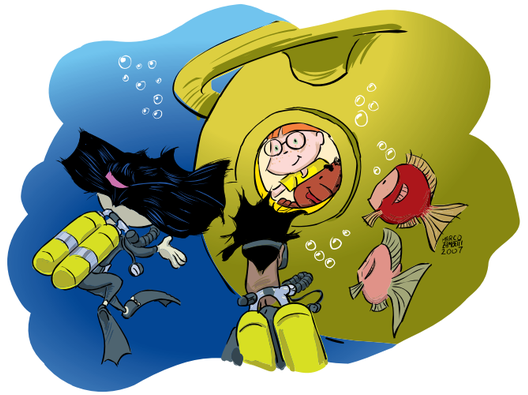
Did you know?

Most scientific experiments have a control group and an experimental group. The experimental group is "treated" in some way - they may exercise, take a pill, or receive some other "treatment." The control group does not receive the treatment, and the data collected from them are compared with data from the experimental group. In the bed rest experiment, artificial gravity was the experimental condition. We tested whether artificial gravity protected different body systems by comparing data from the experimental group to data from the control group.

Under Water

Imagine living in the ocean, 62 feet below the surface, for 2 weeks, and you couldn't come up for air! Several times in recent years 6 crew members (including astronauts, scientists, and engineers) have done just that. They lived in an underwater habitat called Aquarius off the coast of Florida for a week or two. The underwater project is called NEEMO, which stands for NASA Extreme Environment Mission Operations. The crews who live and work underwater complete scientific experiments to help us figure out what happens to their bodies, and how "aquanauts" perform in an environment with similarities to space flight.

A unique aspect of living in the habitat is that the air pressure inside the habitat is increased because it is under water, so the aquanauts actually breathe more oxygen in one breath than when they are at the surface. We studied the nutritional status of the aquanauts by measuring the effects of this high-oxygen environment on molecules in their bodies such as iron, protein, DNA, and fats. We can investigate these effects by measuring chemicals in the aquanauts' blood and urine to identify which molecules are affected.



Did you know?

A habitat is a place or environment where people (or other creatures) can live.

An aquanaut is a scuba diver who can live inside and outside an underwater habitat for an extended period of time.

Diego and Lin are working outside the NEEMO habitat, and Thea and Tim are monitoring them from inside the underwater habitat. Living and working in extreme environments is a challenge that astronauts and aquanauts face.

...Space Research on Earth

Because the NEEMO crews live in the underwater habitat, they do not always have immediate access to medical doctors to help with medical problems that might come up. Scientists are testing remote-controlled robots to find out if they can treat patients, and are testing computer programs to see if they can lead an aquanaut through the proper steps to treat a medical problem. These technologies will be important for the future when astronauts go to the Moon and Mars!

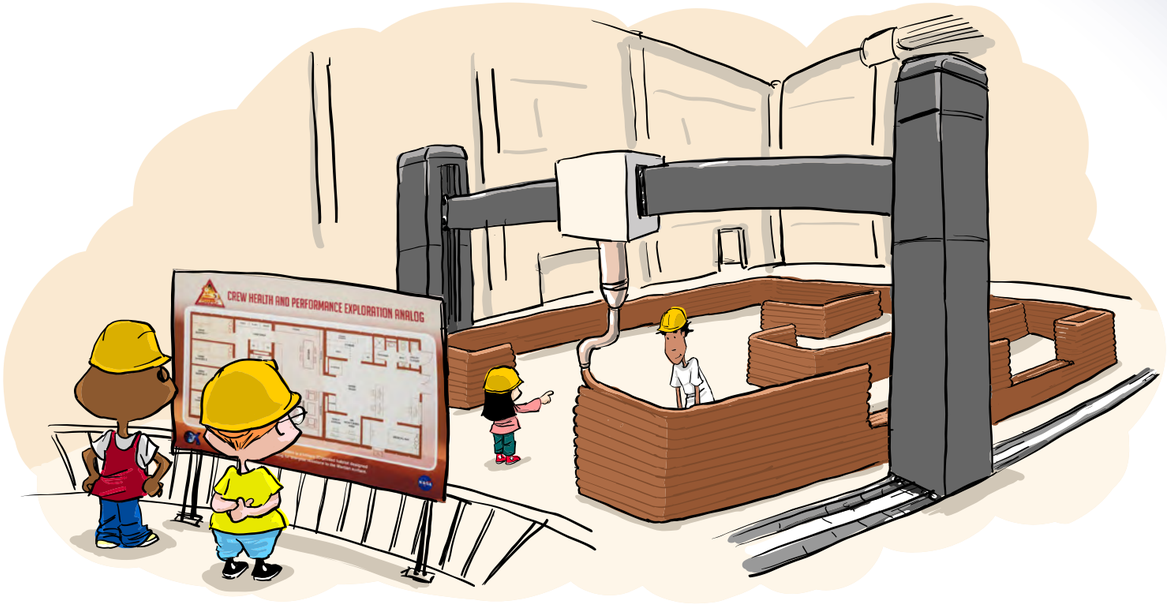
The Bottom of the World

Antarctica is a good place for studying vitamin D. Like astronauts in space, people living in Antarctica are not exposed to any sunlight for almost 6 months at a time during their winter months (February through September). By doing research in Antarctica, we were able to determine the dose of vitamin D that astronauts should take during their space flight. We are also studying how stress, isolation, and lack of sunlight affect nutrition and immune system function in people living in Antarctica.

Did you know?

98% of Antarctica is covered by a thick layer of ice. The average thickness of the ice sheet is 7,200 feet.

No one country owns Antarctica. The Antarctic Treaty, which has been signed by 57 countries, reserves that area as a zone for the peaceful conduct of research.



Chamber Studies

Space flight is challenging for a number of reasons, including that a crew needs to live in a small space together, with limited communication with family and friends, and eat from a limited, repetitive set of foods. While we don't have a zero-gravity room on Earth (even though many people ask if we do), we can simulate these other elements of flight by doing what we call chamber studies. Habitats have been built in many places around the world to allow crews to live in them and simulate space missions. We have a few of these at the Johnson Space Center in Houston. The Human Exploration Research Analog (HERA) facility has crews of 4 living inside for 4-6 weeks at a time. Depending on the experiments, scientists can control the food system, the schedule, and other activities. In one study, we tested crews in HERA who ate space food and other crews who ate an "enhanced" space food system, with some healthier foods added to the pantry, and found that crews who ate healthier foods (more fruits and vegetables, more fish) were healthier!

In 2023, we started a 378-day study in a habitat called Crew Health and Performance Exploration Analog, or CHAPEA, that simulated a Mars surface mission. The 1700 square foot CHAPEA habitat was 3-D printed using cement, and it even has a very large (1200 square foot) sandbox filled with red sand outside the habitat so the crew can do Mars walks! The CHAPEA habitat and sandbox are both inside a building, with their own mission control nearby. Because we were simulating a Mars surface mission, all communications between the crew and the mission control were delayed by about 22 minutes in both directions. So, if the crew sends an email, the people in mission control can't read it for 22 minutes. And once the team in mission control replies to the email, it takes another 22 minutes before the crew can read it. The first CHAPEA mission was completed in July 2024. Future missions are being planned!

Summary

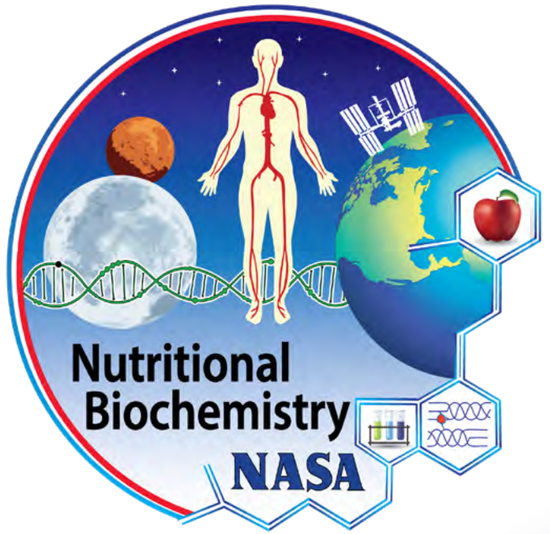
Doing experiments with all of these space analogs gives us a better understanding of the effects of space flight on the body. The knowledge gained from experiments performed during space flight and in analog conditions will allow astronauts to live and work for the long periods of time that it will take to fly to the Moon or even farther—to Mars. This research also helps us understand how the human body works in general, which can help scientists studying humans on Earth!

Section Four

Being Healthy is Not Just About Nutrition

(Even Though We Like to Think it is)

The Nutritional Biochemistry Lab is part of a larger group of NASA research laboratories working to understand the changes in the human body as it gets used to weightlessness.

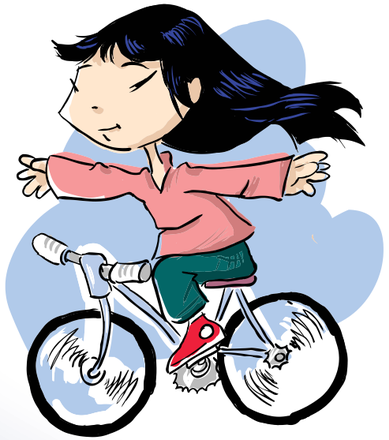


Exercise Physiology and Countermeasures Lab

Exercise affects almost all systems of the human body, in people on Earth as well as in astronauts during space flight. Exercise is one of the most common means of trying to lessen, or reverse, the negative effects of space flight on the heart, blood vessels, muscle, and bone. Scientists and engineers in the Exercise Physiology and Countermeasures Laboratory at the Johnson Space Center are trying to understand the effects of weightlessness on human performance (or fitness), and to develop exercises that will help keep astronauts healthy during and after their missions.

Exercise and nutrition are important components of a healthy lifestyle, whether you live on the ISS or here on Earth. Developing good eating and exercise habits when you are young will help keep you healthy as you get older.

What you do when you are 10 to 20 years old can have big effects on how healthy (or sick) you are when you get older. Bone is a great example of this. If you eat a healthy diet and exercise through your teen (and pre-teen) years, you'll be less likely to get osteoporosis when you are older. Osteoporosis is a disease that makes the bones get very weak and brittle, and break easily. It is usually thought of as a disease of the elderly, but prevention of this disease is best started when you are 10 to 15 years old!



Lin is riding her bicycle. She rides it at least 3 times a week to make sure her bones, muscles, and heart remain healthy. What exercises do you do each week to stay healthy? Do you have physical education class in school? What else can you do to keep your body healthy?

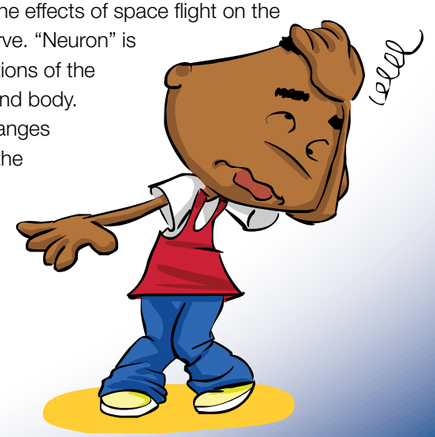
Cardiovascular and Vision Lab

The circulatory or cardiovascular system is made up of the heart, blood vessels, and blood. The blood vessels that carry blood away from the heart are called arteries, and those carrying blood to the heart are called veins.

Many changes occur in the cardiovascular system during space flight. The heart does not have to work against Earth's gravity to supply blood and oxygen to the body. Not having to work so hard can weaken the heart muscle and can reduce its ability to provide blood and oxygen to the brain when the astronauts return to Earth. This can cause light-headedness and reduce the astronauts' ability to walk or exercise. Another change is the fluid shift that happens during space flight. Approximately 2 liters of fluid from the lower body move up to the head and upper body. This fluid shift can affect the cardiovascular system, the eyes, and the brain. Scientists and engineers in the Cardiovascular and Vision Laboratory at the Johnson Space Center are trying to understand the changes in the cardiovascular system that are caused by microgravity and find ways to improve the astronauts' ability to adapt to these changes, both during and after space flight.

Neurosciences Lab

Have you ever spun yourself around to make yourself dizzy? The nervous system (nerves, brain, eyes, and inner ear) is affected when you spin around. This system is also affected by lack of gravity. The Neurosciences Laboratory at the Johnson Space Center investigates the effects of space flight on the nervous system. "Neuro" comes from "neuron," the Greek word for nerve. "Neuron" is also an English word for nerve cell. The nervous system controls all actions of the muscles, including those that result in movements of the eyes, head, and body. Scientists and engineers in the Neurosciences Laboratory measure changes in what the eyes see, what the brain tells the muscles to do, and how the muscles respond to this information before and after space flight.



Tim is dizzy from spinning around and then standing up. This is the same type of effect that reduced gravity has on the neurovestibular system. Tim is dizzy because the fluid in his ears has been affected by his movement as he travels in circles.

The Neurosciences Laboratory also studies the effects of space flight on the neurovestibular system (NVS), the nerves and organs that keep the body in its proper orientation. The inner ear is a very important part of the NVS. Organs in the inner ear help us to keep our balance by telling our brain about the motion and position of our body. Without gravity, the NVS needs to readapt, and the brain has a hard time figuring out which way is up. Scientists and engineers work together to develop training programs to help the NVS so that astronauts can stay in space longer.

Behavioral Health and Performance Lab

Do you think you could share your classroom with 2 or 3 of your closest friends for 6 months, 24 hours a day, away from everyone else you know? Would you be homesick? Would you worry about your family? Would you get tired of working in the same room with your friends every day? The members of the Behavior and Performance Lab try to understand what the astronauts will experience emotionally while they are in space. They work with other medical team members to determine the stresses involved with each mission into space, such as differences between crew members, the isolation of being in space, and the work required of the crew during their mission. Scientists develop techniques that help astronauts deal with the stress of being away from home and working with the same people every day (all day) for weeks to months at a time. Some of the techniques that astronauts are encouraged to use are making phone and video calls to family members, and participating in a hobby during the flight (activities like playing the guitar, reading books, or watching movies). Exercise is another great way to help reduce stress, and it helps your muscles too!

Immunology/Virology Lab

When you have a cold or the flu, your body fights the infection using your immune system. The immune system includes cells, organs, and tissues that help protect the body. When the cells of the immune system are not working as well as they should be, this can affect your susceptibility (or likelihood) to getting sick, or you might be sick longer than someone with an immune system that works well. Research has shown that some astronauts' immune systems don't work as well during space flight. The Immunology/Virology Lab is working hard to develop ways to protect the immune system during flight so astronauts can stay healthy. Did you know that the ability of the immune system to fight off infection can be influenced by what you eat? In one of our research studies conducted in Antarctica, we found that people with a lower vitamin D status and those that were experiencing more stress, had more reactivation of some viruses. Based on our Antarctic studies, we hypothesized that this might help explain why some people had a harder time with COVID infections than did others.

Section Five

The Next Frontier—Exploration

The International Space Station flies in what we call "low Earth orbit," meaning that it is about 250 miles above their Earth's surface. In the big picture, there's a LOT more out there to explore.

Artemis missions will bring the first woman and the first person of color to the Moon. NASA is also starting to plan missions that will travel even farther, including missions to Mars. Given the technology we have today and the nature of travel to other planets, a Mars mission is expected to take about 6 months to get there, about 18 months for a stay on the planet surface, and then about another 6 months to get back. In total, this is about 30 months, or 2 and a half years. This is a much bigger challenge than our current missions (which are by no means "easy"). Imagine how much food you would eat in 2½ years, or how much water you would drink. These are just two of the issues that we in nutrition think about now. Future exploration will require planners to consider even more—everything from how many clothes to pack, how much oxygen is needed, and what exercise devices will fit in the vehicle. There's no store or restaurant along the way where you can pick up anything you forget. These will be difficult missions, but they represent the next major leap in human exploration of space.

Our Space Nutrition team - Lin, Tim, Thea, and Diego - have enjoyed sharing their space adventures and look forward to learning about the challenges and exciting opportunities that future space exploration will bring.

Summary

Space travel is exciting, challenging, and even dangerous. Space travel is a team sport, with many groups bringing their expertise to the mission, including engineers and scientists from many diverse backgrounds. Aeronautical, Biomedical, Electrical, Mechanical, Chemical, Civil, and Management are only a few of the types of engineers involved with planning, designing, building, and flying spacecraft. Scientists support these missions by proposing and implementing many types of experiments, including life sciences (biology), geology, physics, astronomy, and more. Life sciences includes scientists who study the cardiovascular system, exercise, neuroscience, immunology, microbiology, and even food science and nutrition.

Nutrition represents a broad field itself, including work to understand specific nutrients the body needs, how the body uses those nutrients (what we call metabolism), and what foods astronauts should eat. It also includes keeping track what of the astronauts eat to be sure they really are eating those foods while on space missions. Understanding the importance of nutrition for astronauts also helps you realize that nutrition – what you eat and how much – is important for those of us on Earth, too!

Many nutrients are required by our bodies, and they all serve different functions. Some, like protein, carbohydrate, and fat, provide energy. Others, like vitamins and minerals, carry out important activities to help in almost every aspect of how your body functions. Knowing some of these details might help us understand why a balanced diet is critical, and to make sure we consume the nutrients we need to keep us healthy. Too little, or often too much, of any single nutrient can cause health problems. Balance is the key!

Just as your body needs nutritional balance on Earth, so do the bodies of the space explorers while on journeys in space. Throughout the history of humans in space we have been working to use nutrition to lessen the effects on the body caused by weightlessness. If we can reduce the stress the astronauts' bodies experience while in space, they will be able to complete exciting and successful exploration missions to the Moon and Mars. We have a lot to learn about space nutrition, but with the data we collect, the analogs we use, and the determination of the NASA team, our goals to travel and explore the Moon and Mars are within reach. Maybe someday you too can join the NASA team as an explorer, scientist, part of our ground analogs, or even fly on one of the Artemis missions to the Moon or to future missions to Mars!

Glossary

adaptation—the process of adjusting to the environment or to specific conditions (in space flight, adaptation is the process of adjusting to the lack of gravity and being in a closed environment).

airlock—an air-tight chamber or room that allows passage to or from the vacuum of space. On the International Space Station, the airlock module is named "Quest."

Apollo—in Greek mythology, the name of a god. In space flight the Apollo missions were a series of manned and unmanned space flights to and from the Moon.

aquanaut—an underwater explorer. In the U.S. space program, aquanauts are the research subjects participating in studies in an underwater habitat.

Artemis—in Greek mythology, Artemis was the twin sister of Apollo. NASA will land the first woman and first person of color on the Moon as part of the Artemis campaign. Artemis missions will use innovative technologies to explore more of the lunar surface than ever before.

astronaut—a space explorer. This is the name given to U.S. space explorers; the Russian counterparts of astronauts are called cosmonauts.

bed rest—a type of study often used to simulate weightlessness and evaluate effects on the body.

biochemistry—the chemistry of living matter.

blood serum—the clear yellow liquid that can be separated from blood cells when whole blood clots. Blood serum is tested to understand what is happening to the human body before, during, and after space flight.

CHAPEA—Crew Health and Performance Exploration Analog. A 3-D printed habitat at the Johnson Space Center in Houston. Designed for Mars surface simulation missions.

...Glossary

coagulation—formation of a blood clot.

Columbia—poetic name for the USA. In the U.S. space program Columbia was the first Space Shuttle orbiter to orbit and return to Earth. On February 1, 2003, the Space Shuttle Columbia disintegrated over Texas during its return to the Earth's atmosphere, resulting in the death of all seven crew members.

convection oven—an oven equipped with a circulating fan that intensifies the amount of heat in the oven and decreases the normal cooking time. In space flight a convection oven is used to reheat food in the kitchen area of the spacecraft.

cosmonaut—a space explorer in the Russian space program. (Space explorers from the U.S. and other nations are called astronauts.)

deficit—a lack or shortage.

docking or docked—attaching or attached to a site such as a pier. In space flight this is the joining of one space vehicle with another or with a space station in space.

EVA—extravehicular activity. In space flight, this is the term for space walks. EVAs are used to repair or construct parts of the space vehicle.

Gemini—in astronomy, a constellation (the Twins); it is used in astrology for people born between May 21 and June 20. In space flight, Gemini was a U.S. program in the 1960s, in which two-person space vehicles were flown to prepare for the Apollo Moon landings.

habitat—a place or environment where people (or other creatures) can live.

HERA—Human Exploration Research Analog. A habitat at the Johnson Space Center designed to support 4-6 week space analog missions.

International Space Station—a giant environment for living and working that orbits the Earth once every 90 minutes. The ISS was built in sections called "modules" that were taken to space either in the Space Shuttles or on Russian launch vehicles.

LEO - low Earth orbit—the area around the Earth where the Space Shuttle and International Space Station fly.

Mercury—the United States' first space program in which humans were sent to space. Mercury astronauts were launched into space on either a Redstone or Atlas rocket, depending on how far they traveled.

MERLIN—the Microgravity Experiment Research Locker/Incubator, a small refrigerator/freezer for the ISS.

mid-deck—one of the 2 levels (flight deck and mid-deck) of the crew compartment on the Space Shuttle orbiter. The mid-deck is "downstairs," and is where most experiments are conducted, where the "kitchen" is, and where the bathroom is.

Mir—the first Russian space station.

Mission Control Center—the center that controls activities of space flight, or dive activities for the NEEMO program.

muscle atrophy—a process by which muscles weaken during space flight.

NEEMO—NASA Extreme Environment Mission Operations. These missions are conducted in an underwater habitat off the coast of Florida on the bottom of the ocean (about 50 feet below the surface).

neuroscience—the science of studying the nervous system. The Neuroscience Laboratory at NASA's Johnson Space Center studies changes in what the eyes see, what the brain tells the muscles to do, and how the muscles respond to this information before and after space flight.

...Glossary

Neutral Buoyancy Laboratory—a giant swimming pool for diving that allows astronauts to train for space missions involving space walks.

nutritional biochemistry—the study of how nutrients in food affect how our bodies work. Every cell in your body requires many different vitamins and minerals as well as energy to keep you alive and healthy.

nutrients—energy (carbohydrates, fats, proteins), vitamins, and minerals that are needed for growth and development and that must be obtained from the environment (i.e., outside the body).

NVS—the neurovestibular system, which includes the nerves and organs that keep the body in its proper orientation. The inner ear is a very important part of the NVS.

orbit—the path an object takes around another object. The Shuttle and International Space Station orbit the Earth, and they do this once every 90 minutes.

orbiter—a vehicle that can travel around the Earth. There are some sub-orbital vehicles that can provide seconds to minutes of weightlessness, but they do not travel around the Earth. Six Space Shuttle orbiters were built: Enterprise (never flown in space, was used for testing landings), Columbia, Challenger, Discovery, Atlantis, and Endeavour.

osteoporosis—a disease that makes the bones get very weak and brittle, and break easily.

planetary travel—travel between planets, such as Earth and Mars.

rehydratable—a food that is dehydrated, meaning all of the water has been taken out. Water can be added back to the food to rehydrate it before it is consumed.

SANS—spaceflight-associated neuro-ocular syndrome. An eye problem that some astronauts develop. Multiple factors are likely involved in affected crewmembers,genetics and B vitamin status being two key factors.

solar—relating to the sun.

shelf-stable—refers to a food item that is not likely to spoil for at least 6 to 12 months.

Space Shuttle—a NASA reusable launch vehicle that included an orbiter capable of orbital flights. The first Shuttle launched in 1981 and the last Shuttle mission flew in 2011.

space flight—travel through outer space.

space walk—NASA calls space walks “extravehicular activity” (EVA). It is a very important part of many space missions. When astronauts need to go outside the Space Shuttle or International Space Station, they have to put on a special suit that acts like a personal spacecraft. The EVA suit provides pure oxygen for the astronauts to breathe, and is cooled with a special suit underneath that can have cool water circulating throughout it. During an EVA, astronauts can be in these suits for up to 10 hours.

SPF—sun protection factor. The SPF number is listed on sunscreen containers to let you know how much ultraviolet radiation can reach your skin. The higher the number, the more protection the sunscreen provides.

thermostabilized—heated to very high temperatures to destroy bacteria and then packaged in cans or closed pouches. Examples of thermostabilized foods are canned ravioli and soups.

ultraviolet (UV) radiation—a type of radiation from the sun that can cause damage to the skin, commonly known as sunburn. On Earth, the ozone layer and lower atmosphere help to protect us from some of the UV radiation given off by the sun. Some of the UV light filters through the atmosphere and still reaches us here on Earth, which is why we protect ourselves with sunglasses and sunscreen with sun protection factor (SPF) 15 or higher.

Next Generation Science Standards

Science Content Standards 5-8

These Next Generation Science Standards can be introduced using *Space Nutrition, 2nd Edition*.

MS-PS1-1.A Matter and its Interactions: Structure and Properties of Matter
MS-PS1-1.B Chemical Reactions/Oxidation/Reduction
PS3.C: Relationship Between Energy and Forces
MS-LS1.A: Structure and Function
Crosscutting Concepts
Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural systems. (MS-LS1-8)
- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (MS-LS1-4),(MS-LS1-5)

Scale, Proportion, and Quantity

- Phenomena that can be observed at one scale may not be observable at another scale. (MS-LS1-1)

Systems and System Models

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. (MS-LS1-3)

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes. (MS-LS1-7)
- Within a natural system, the transfer of energy drives the motion and/or cycling of matter. (MS-LS1-6)

Structure and Function

- Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function. (MS-LS1-2)

NASA Agency Strategic Goals and Objectives Learning Agenda

Discover

1. Expand human knowledge through new scientific discoveries
   - 1.3 Ensure NASA's science data are accessible to all and produce practical benefits to society

See more at https://www.nasa.gov/wp-content/uploads/2023/09/fy-22-strategic-plan-1.pdf?emrc=ff1a1e

NASA Strategy for STEM Engagement

Mission-driven authentic STEM experiences
Design experiential opportunities, design and development activities, research experiences, and/or products to enable students to contribute to NASA's endeavors in exploration and discovery, and help solve problems and address needs and priorities that are critical to NASA's mission. See more at https://www.nasa.gov/wp-content/uploads/2020/07/nasa-strategy-for-stem-2020-23-508.pdf

Space Nutrition Educator Guide

Strategies for teaching and learning using *Space Nutrition, 2nd Edition*

Although these strategies may be in outline form, take them and make them appropriate for your learners; personalize them to fit your and your student's interests and needs. You will find some strategies are to be used before reading *Space Nutrition 2nd Edition* to get students ready to learn; other strategies are useful in processing the information that was read. Some of these strategies will allow students to hold on to the learning by reflecting and retaining information. At the end of the *Space Nutrition 2nd Edition* Educator Guide you will find links to complete activities with student and educator guides at NASA.gov and partner agencies.

Getting Ready to Learn: Priming (before you read)

A Taxonomy of Words for *Space Nutrition, 2nd Edition*: Rothstein, E. & Lauber, G. E. (2007). *Writing As Learning*. Second Edition. Thousand Oaks, CA: Corwin Press.

- Begin by folding a sheet of notebook paper into two columns by using a "hot dog"-style fold.
- Use the letters A-M and N-Z to name the column for your words.
- Build your taxonomy of words for ***Space Nutrition, 2nd Edition*** by adding new words to the list before, during, and after reading, using each letter of the alphabet as a category heading.
- Display the words on a classroom version of taxonomy of words for ***Space Nutrition, 2nd Edition***.
- Use the words for quick reference when writing about, discussing, or working with ***Space Nutrition, 2nd Edition***.

Anticipation Guide: Nessel, D. D. & Graham, J. M. (2007). *Thinking Strategies for Student Achievement: Improving Learning Across the Curriculum K-12*. Second Edition. Thousand Oaks, CA: Corwin Press.

- Create a set of questions from a section of ***Space Nutrition, 2nd Edition*** on specific points you want to emphasize. Use the "Did You Know" questions for possible topics to.
- Make sure the questions can be agreed/disagreed with by the learners.
- Pose no more than 5 questions.
- Present the questions to the class. Ask the class to quietly agree or disagree with the questions.
- Ask groups of students to discuss their answers, using facts to defend their choices.
- In any manner you choose (round robin, reading aloud, silent reading), have the students read the selected portion of the text from which you developed the questions.
- Again, present the questions to the class. Ask them to quietly rethink their former decision.
- Ask groups of students to discuss their answers, and defend their choices. If they have changed their answers, ask them to explain why.

Key Word Prediction: Nessel, D. D. & Graham, J. M. (2007). *Thinking Strategies for Student Achievement: Improving Learning Across the Curriculum K-12.* Second Edition. Thousand Oaks, CA: Corwin Press.

- Choose a topic from ***Space Nutrition, 2nd Edition*** using the chapters and sections. For example, use Section 3 for Space Flight Research.
- Choose 8–15 words from The Space Flight Glossary that coincide with the chosen topic.
- Display the words and the topic for the students to view.
- Have students predict the relationship of the words to the topic.
- Have students read the designated portion of ***Space Nutrition, 2nd Edition***.
- Students then discuss the relationship of the words to the topic based on their reading.
- Were their predictions correct?

List, Group, Label: Nessel, D. D. & Graham, J. M. (2007). *Thinking Strategies for Student Achievement: Improving Learning Across the Curriculum K-12*. Second Edition. Thousand Oaks, CA: Corwin Press.

- Choose a specific set of vocabulary words from ***Space Nutrition, 2nd Edition***. Perhaps use the section headers to divide the vocabulary into parts.
- Have groups of students group the vocabulary words, using whatever method they choose.
- Extend the activity by having students label the groups of words.
- Have groups of students discuss why they chose each label.

Unpacking the Meaning: Processing (while you are reading)

Key Word Notes: Nessel, D. D. & Graham, J. M. (2007). *Thinking Strategies for Student Achievement: Improving Learning Across the Curriculum K-12*. Second Edition. Thousand Oaks, CA: Corwin Press.

- Separate a portion of text from ***Space Nutrition, 2nd Edition*** into 4 sections. Each section should be able to be completely read in about 2 minutes. For example, choose a section, then separate that section into subsections.
- Each student should design a layout for Key Word Notes on their paper as follows:

Key Word Notes for (topic here)

1.	2.
3.	4.
Summary:	

- Have each student read the chunked text labeled section one, and take notes from their reading in box 1 of the Key Word Notes, using 3-5 words that resonate with them from the text.
- After a specified time limit, have the students stop and discuss what they read with other students in their group, using the words from box 1.
- Begin reading again with section 2, jotting words in the box labeled 2 and stopping after a specified time to discuss your words with your group.
- Continue onto sections 3 and 4.
- After the text is read, put it away.
- Without looking at the text, have students summarize their reading in the summary box on the Key Word Notes.
- Have students share their summaries with the group.
- Display the Key Word Notes pages for the class to read and share.

Holding onto the Learning: Retaining for Mastery (after reading)

Assessing student knowledge acquisition using strategies other than formal testing:

- **Flow Map:** from David Hyerle's "Thinking Maps," 2007, Thinking Maps, Inc.
  - Using sequencing, formulate a flow map to show the progression of human space flight.
  - Design a flow map to show the steps of the scientific method. Where would you place each of the steps of the experiments provided in ***Space Nutrition, 2nd Edition*** on the flow map?
- **A taxonomy** of words can be used as an assessment of learning. Add additional words students are curious about from class discussions. Choose words to test students on, use words in writing, ask students to combine words based on their own topic headings, etc.
- **Squared Away (a great exit strategy)**: What are you squared away on? What is still rolling around in your head? What will you make a point of doing?

Summative Assessments:

- Develop **projects** from this publication.
  - Have students choose a portion of the book which is most interesting to them.
  - Allow students to choose the medium in which they would like to report their learning: a drawing, a collage, a story, etc. or you choose.
  - Display student work.
  - Have the students conduct a **Gallery Walk** and give affirmations.

- In groups, **devise studies** based on the scientific method. (See "Let's Investigate Mars" activity at NASA.gov below.)
  - These studies, following the scientific method, could be directly from ***Space Nutrition, 2nd Edition***, or something that interests them concerning human spaceflight. Important note: this is a design and the study may or may not be able to be tested.
  - Have student groups display the study developed.
  - Allow students to choose one affirmation for each project and report their good news to the developers.
- Develop a **radio show** based on ***Space Nutrition, 2nd Edition***. Deliver it to your school in the morning announcements each morning. Written scripts can be distributed to incorporate them into classroom activities.
- Conduct **lessons** for children in previous grades from your experience with ***Space Nutrition, 2nd Edition***. Topics could include nutrition, space, and how nutrition may affect their performance in school just as nutrition affects humans in space. Distribute lesson plans for others to assess.
- Put on a **play** for your school that includes skits, songs, and dances based on ***Space Nutrition, 2nd Edition***. Allow groups to choose topics based on their interests and strengths. Display the scripts, along with pictures from the dramatization. Have students give accolades.

Some questions for reflection: from Dr. Yvette Jackson's *"The Pedagogy of Confidence: Inspiring High Intellectual Performance in Urban Schools,"* March 2011, Teacher's College Press.

Select a section of ***Space Nutrition, 2nd Edition*** to read; ask the following questions during and/or after reading.

- What else does this remind you of?
- Where else have you heard this information?
- Where else might you use this information?
- How can you apply this space research to your life?
- What type of pattern do you see between food intake and exercise, and physical health?
- How would you feel about what you read if you were an astronaut?
- Any other questions specific to the section where student interest was high.

Additional ways to use and share:

- Correlate with the physical education instructor for good health and nutrition studies or as an exercise precursor in gym class.
- Interdisciplinary studies in health, physical education, using the Next Generation Science Standards.
- Share with the social studies instructor to study the history of spaceflight.
- Incorporate the real-life research examples to teach the scientific method.

Activities from NASA.gov and partner agencies:

- **Planning Meals** and ideas for nutrition for specific audiences: http://www.choosemyplate.gov/
- **Radiation Shielding:** Which of the materials provided will block the most simulated space radiation, and be the best material to build a spacecraft? https://www.nasa.gov/stem-content/ray-shielding-activity/
- **Get A Leg Up:** On Earth, how can I simulate the fluid shift felt by astronauts when they enter space? https://www.nasa.gov/stem-content/get-a-leg-up-activity/
- **Living Bones; Strong Bones:** Observe and compare bones, and design bone models to investigate ways to keep bones healthy. https://trainlikeanastronaut.org/living-bones-strong-bones/
- **Energy of an Astronaut:** Create a five-day menu based on recommendations and individual dietary needs. https://trainlikeanastronaut.org/energy-of-an-astronaut/
- **Food for Spaceflight:** What foods are best suited for spaceflight and what makes foods suitable for spaceflight? https://www.nasa.gov/stem-content/food-for-spaceflight-activity/

For more information on education and NASA please visit **www.nasa.gov**.

About the Authors

Scott M. Smith

Dr. Smith has been a member of the NASA Nutritional Biochemistry Laboratory team since 1992. This group is charged with keeping crews healthy with respect to nutrition, including using nutrition to optimize astronaut health and safety. This work includes ground-based and spaceflight research to understand how nutrition can mitigate the risks of spaceflight.

Smith has ongoing spaceflight research projects on the International Space Station. His past projects have been flown on the International Space Station, Space Shuttle, and the Russian space station Mir. Smith has also led several ground-based research projects to better understand astronaut health in space, including studies of vitamin D in crews in Antarctica, studies of crews living on the bottom of the ocean, and studies of subjects who spend months in bed or a year in an enclosed habitat. He is co-author of many scientific publications, chapters, and books.

Dr. Smith participated in the definition of the current nutritional recommendations for extended-duration space flight, and is Co-Chair of the Multilateral Medical Operations Panel - Nutrition Working Group, which includes representatives of the 5 ISS partner space agencies: Canada, Europe, Japan, Russia, and the U.S. Dr. Smith has served on the Editorial Board of the *Journal of Nutrition*. He is a member of the American Society for Nutrition, the American Physiological Society, and the International Academy of Astronautics.

Dr. Smith received a B.S. in Biology and a Ph.D. in Nutrition, both from the Pennsylvania State University. After completing a postdoctoral fellowship in North Dakota, he moved to Houston in 1992 to work at the Johnson Space Center.

Janis Davis-Street

Dr. Davis-Street is the Manager of Workforce and Community Health in Chevron's Health and Medical department. This group manages health and well-being programs for the workforce through education, awareness, and preventive programs. The Workforce and Community Health team also addresses health issues in the communities where we operate and uses epidemiological tools to evaluate employee and community health issues.

Dr. Davis-Street has served as a member of the National Business Group on Health's Racial/Ethnic Health

Disparities Advisory Board and is a current board member of HERO (Health Enhancement Research Organization), The Health Project and Kairos University.

She obtained her M.S. in nutrition from the University of Alberta, her Ed.D. in health education from the University of Houston, and her MA in Organizational Leadership from George Washington University. Before working at Chevron, she spent 15+ years as a nutritionist at the Johnson Space Center, where for much of her tenure she partnered with Dr. Smith and others to support K-12 education outreach efforts. At JSC, Dr. Davis-Street was involved in nutrition research on International Space Station missions, Space Shuttle missions, and joint U.S./Russian missions to the Mir Space Station. She also participated in the experiment design and evaluation of several ground-based research projects, including extended-duration bed rest studies and exercise countermeasure protocols.

Dr. Davis-Street is a Certified Health Educator Specialist whose interests include public health informatics, corporate wellness, health and productivity, health disparities, and the roles of nutrition and exercise in preventing chronic diseases such as osteoporosis, cardiovascular disease, diabetes, cancer, and obesity. She has co-authored more than 20 peer-reviewed scientific papers in the areas of nutrition and space flight.

Lisa Neasbitt

Supporting NASA education, Lisa designed elementary and middle-school STEM educational materials concerning the U.S. Vision for Space Exploration. Before she joined the NASA Human Research Program Education & Outreach team, Lisa's previous work experience included science teaching, science and technology facilitation in public schools; internal facilitation for Federal Teaching and Learning Grant recipients; curriculum correlation for textbook publishers; and curriculum development, publication, and instruction for the Michael Dell Children's Museum. She was nominated by her students for Educator Astronaut, and was an Educator Astronaut applicant. Lisa has worked with educators across the United States and internationally as a mentor and facilitator.

Lisa holds a B.S. in Science Education from Texas A&M University. She obtained both her M.S. in Educational Leadership, and Ed.D. in Educational Leadership with a specialization in Transformational Leadership from Concordia University, Portland. She holds a Texas lifetime teaching certification in elementary and science education. Lisa enjoys working in her herb and vegetable gardens, and spending time with her family outdoors looking at the stars and exploring uninhabited islands searching for seashells.

Sara R. Zwart

As a member of the Nutritional Biochemistry Laboratory at the Johnson Space Center, Dr. Zwart has been involved with research that investigated relationships between nutrition and physiological effects of space flight, including bone and muscle loss, changes in iron metabolism, oxidative damage, and ocular changes. The Nutritional Biochemistry Laboratory is charged with defining the nutritional requirements for extended-duration space flight. Operational and research activities are being conducted to define the impact of space flight on human physiology and nutritional requirements.

Dr. Zwart is leading a spaceflight study to assess a nutritional countermeasure for spaceflight associated neuro-ocular syndrome in astronauts on long-duration space missions to the International Space Station. Other space flight studies she is involved with include nutritional assessments during long-duration space flight and modification of the diet to improve immune function and prevent bone loss associated with space flight. Ground-based research is used to understand the role of nutrition in ground-analog studies that simulate varied aspects of space travel. These include rotating cell culture models, NASA Extreme Environment Mission Operations (NEEMO) undersea missions, extravehicular activity analogs at the Neutral Buoyancy Laboratory at the Johnson Space Center, bed rest, and Antarctic winter.

Dr. Zwart earned her Bachelor of Science degree in biological sciences from the University of Notre Dame, and her doctorate in nutritional sciences from the University of Florida. She joined the Nutritional Biochemistry Laboratory at NASA's Johnson Space Center as a National Research Council Post-doctoral Fellow. She currently serves as Senior Scientist and Deputy Manager for Nutritional Biochemistry.

About the Illustrator, Marco Zambetti

Currently a Creative Director at Tietronix Software, Inc., an information technology company, Marco Zambetti is involved in the art production for serious games and interactive applications, as well as promotional and informational material.

Originally from Italy, in 1979 Mr. Zambetti moved to the United States where, after a period of doing odd jobs as an illustrator and portrait artist, he landed a position as a graphic designer at a large computer manufacturer. There, from the summer of 1984 to the fall of 1988, he produced numerous computer-generated graphics and animated videos. In 1988 he accepted a position as a staff artist/animator at NASA's Johnson Space Center, where he produced videos aimed at informing and educating the public on the activities and goals of the space program.

Mr. Zambetti attended the University of Milan department of physics (1974-1975), the Los Angeles Trade Technical College commercial art department (1982-1984), Boston University department of computer science (1985-1986), and the University of Houston – Clear Lake (2006-2011). He has a Bachelor of Arts in applied visual arts and a Master of Science in mathematics.

About the Graphic Designer, Cory Duke

As a Sr. Graphic Designer with Rothe Industries, supporting NASA and Johnson Space Center, Cory Duke helps to lead the creative development and execution of a wide range of visual design projects, with the goal of inspiring and educating the public.

Ms. Duke is a Gulf Coast native who lived in coastal Louisiana and Mississippi before landing in the Houston area, where she graduated from The Art Institute of Houston in 2000. After completing local Graphic Design internships, she was hired into the publishing industry, first in transportation, then to the Oil and Gas industry. Cory's dream of designing in the space and aeronautics industry started in 2005, marketing on the corporate side for a NASA contractor by creating marketing materials including business cards, brochures, software labeling and materials, full exhibits, and more. In 2011 Cory was hired as a Senior Graphic designer on-site at the Johnson Space Center under a multimedia contract. For the last 13 years she has worked with multiple Agency programs across NASA. She has been awarded a NASA Power of One Award, NASA Silver Achievement Award and a NASA Space Flight Awareness Team Award. From space flight expedition posters and patches to published books, and multiple public facing marketing materials and exhibits, Cory has helped to creatively represent all things NASA.

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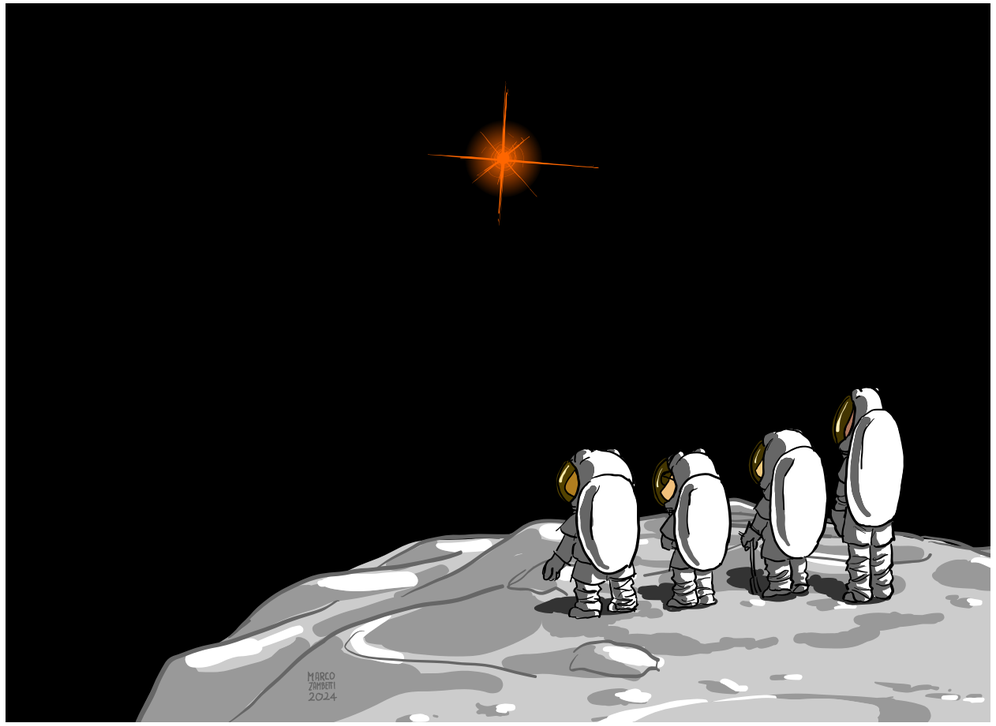

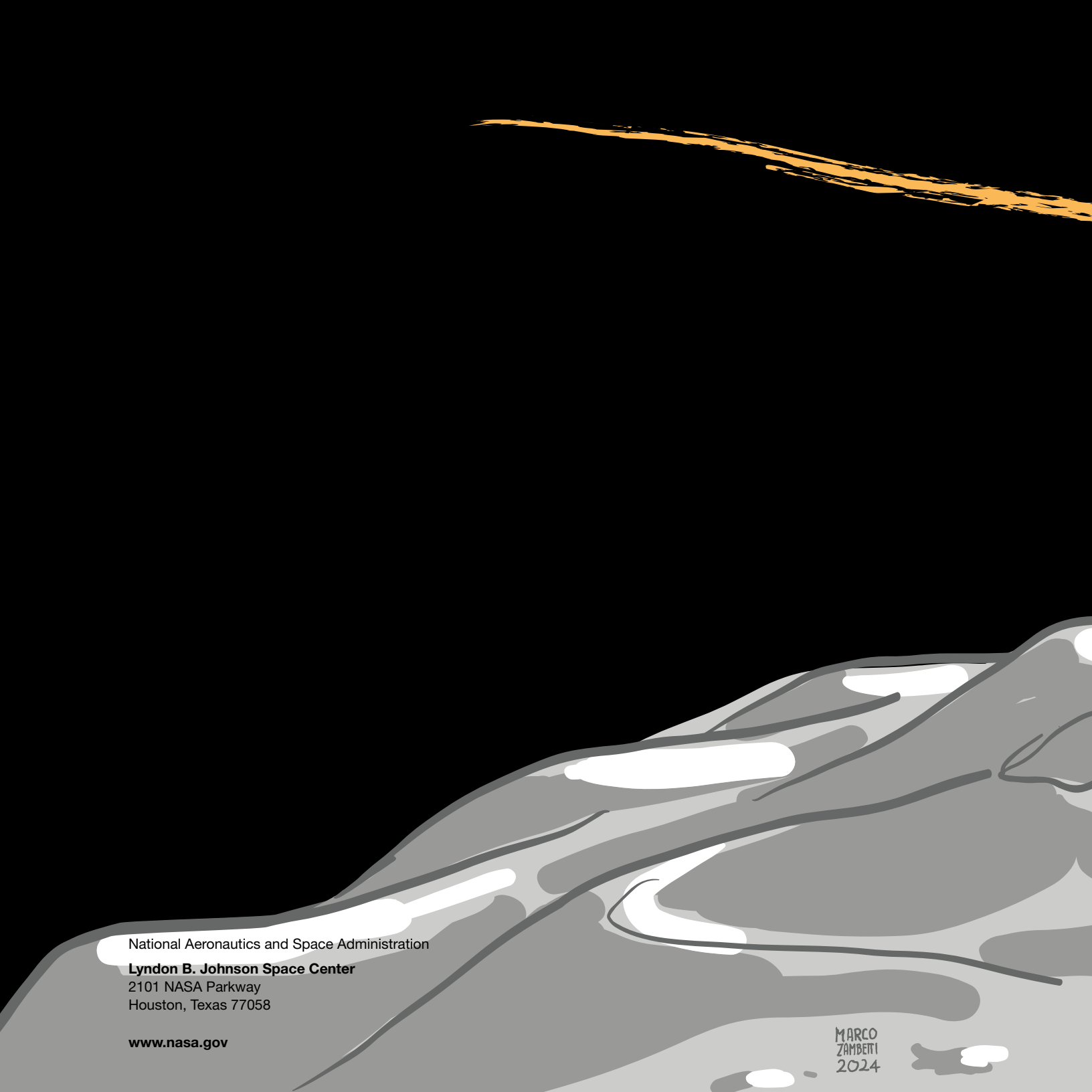

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