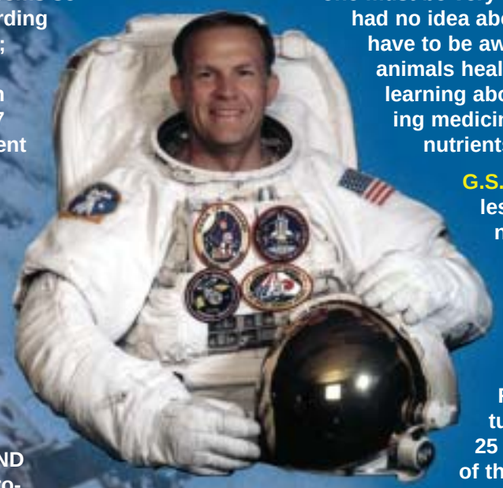
One on One with an Astro-Agriculturalist

"One of the most impressive things about life in space is seeing the entire Earth from that distance. From space, the Earth seems so small and fragile." This is according to Mark Lee. Mark should know; he's been there… a lot! He has traveled over 13 million miles in space and orbited the Earth 517 times during the 33 days he spent on four Shuttle missions from 1989 to 1997! Mark now manages development of spaceflight hardware for plant research at Orbitec.



Each time he went into space, Lee carried a bit of agriculture with him. Accompanying Mark on each of his shuttle missions were pictures of Angus cattle (the breed that he raises). Mark is an Astronaut AND an Agriculturalist – he's an Astro-Agriculturalist. In fact his cattle ranch is called Astro Angus! We had a chance recently to catch up with Mark and ask a few questions. Here's what he had to say about life in space and on the farm.

Growing Space (G.S.): What is one thing the average person doesn't know about life in space?

Mark Lee (M.L.): It's fun to float and operate in space. You are always adjusting to zero gravity – it affects everything you do. Looking out the window, you can see the Earth, and you cross the entire US or the Atlantic Ocean in only 10 minutes. It takes 30 seconds to cross Florida!

G.S.: What is one thing the average person doesn't know about agriculture?

M.L.: Agriculture is more complicated than I ever imagined – it's a highly technical process and one must be very committed to it to succeed. I had no idea about all the diseases that you have to be aware of to keep plants and animals healthy. I spent a lot of time learning about health care and managing medicines for animals and the nutrients plants need.

G.S.: Tell us about your tetherless space walk; were you nervous knowing you weren't connected to the shuttle?

M.L.: I was the Astronaut leader in the development of a new jet pack called Simplified Aid For EVA Rescue (SAFER). In the picture (background), I am 20 to 25 feet above the payload bay of the orbiter. No, I wasn't nervous at all. I had so many things to do while I was up there and had been training (using virtual reality) for so long, I didn't have time to be nervous. I had to perform over 200 maneuvers, so all my focus was on completing the process with the precision the SAFER engineers needed.

G.S.: When you were a kid, did you have any idea you would accomplish the things you have accomplished in your life?

M.L.: Absolutely. When I was nine, I saw Alan Shepard (the first American in space) and decided I would become an astronaut. I began to do everything I could to prepare myself for that goal.

G.S.: Any final advice you'd like to give our readers?

M.L.: Start early seriously thinking about your future. The world is full of opportunity. Just reach out and grab it. Work hard and do your best – don't let life pass you by.

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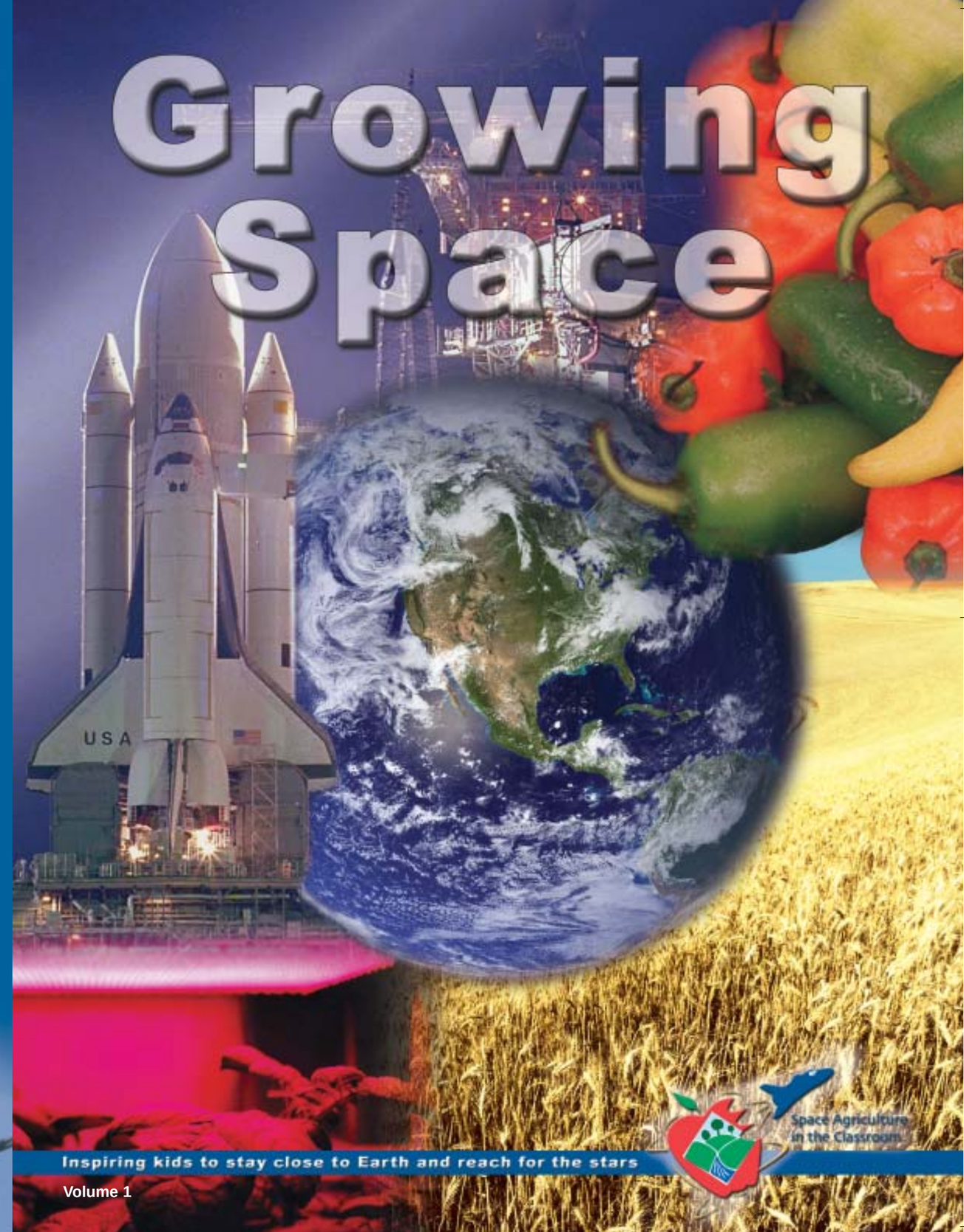
Growing Space



Inspiring kids to stay close to Earth and reach for the stars

Space Agriculture in the Classroom

Volume 1

Right now, 240 miles above us, scientists are living and working on the multi-billion-dollar International Space Station. You probably never would have guessed it, but agricultural research is an enormous part of what the Space Station scientists are doing. Our Space Station scientists are:

- Developing technologies to efficiently use and recycle water
- Planting specialized crops that live and thrive in microgravity
- Working on ways to apply space technology to more effectively fertilize plants on Earth

Photo courtesy of NASA

- Testing new ways to package and preserve foods for future space missions and for consumers on Earth.

At the same time, growers, producers and agricultural scientists all over the world are doing some pretty amazing things as well. Our farmers and agricultural scientists are:

- Preserving soil and water through high-tech conservation practices
- Planting, fertilizing and harvesting crops
- Feeding and caring for animals
- Developing new technologies to grow plants and animals more efficiently
- Packaging, processing, marketing and delivering the food and clothing we count on every day.

You may have noticed the research and development described on the Space Station sound very similar to what Earth-based agriculturalists are doing! If you did, you're exactly right. Astronauts and agriculturalists have many things in common. They are both concerned about finding ways to provide enough food for themselves and others while making sure that their limited natural resources (like water, oxygen and soil) are preserved and well managed.

Photo courtesy of NASA

If you're like many Americans, you don't think about agriculture very often; most of us have plenty of safe and affordable food. On a long-term mission in the Space Station, however, steady sources of food, water and oxygen are some of astronauts' most critical concerns. Agricultural scientists are addressing those concerns and making life in space possible. Likewise, the discoveries being made and research being done on the Space Station will help Earth-based agriculturalists improve the ways they grow and process the food we all need. Growing Space is all about helping you understand how space technology is being used to improve our agriculture and our lives on Earth. Welcome to Growing Space; we hope you enjoy the journey!

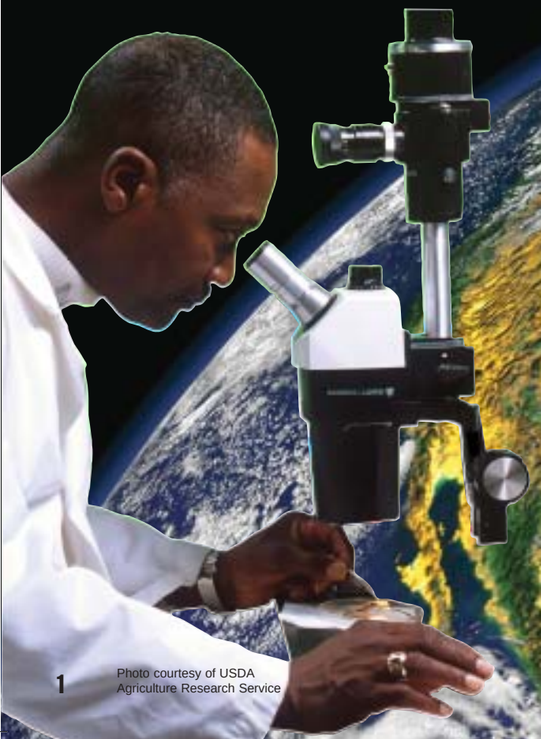


Photo courtesy of USDA Agriculture Research Service

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Photo courtesy of USDA Agriculture Research Service

Food - From Seed to Space

Agriculture: It's More Than You Think!

When we think of agriculture, we often do not realize that growing food is only the starting point of our food system. Getting food from the farm to those who eat it involves many more people than its actual production does. For example, let's look at how bread is made from wheat.


Photo courtesy of John Deere

From Field to Food

You may already know that bread comes from wheat. What you might not know is that before we buy a loaf of bread at the store, wheat must undergo many changes. Before wheat becomes bread, it must first be planted, grown and harvested by the farmer. It is then shipped to a processing plant where it is cleaned to remove dirt, debris and insects. The wheat seeds (called kernels) are then crushed into smaller pieces so they can be processed more efficiently. They are now ready to be ground into the fine powder we call flour. Flour is shipped from the processing plant to a flour mill, where it undergoes further refining and processing. From the mill, wheat flour is transported to the bakery. At the bakery, flour is mixed with other ingredients, formed into loaves and baked. After baking, the product is cut into slices and packaged for delivery to grocery stores.


Photo Courtesy of USDA Agriculture Research Service

An Expensive Bread Truck!

This is a pretty complicated process just to get a couple of slices of bread for a sandwich. However, think of how much more difficult it is to get a sandwich in space. There are no farms in space, and no flour or bakeries. All food on the Space Station is delivered from Earth by the space shuttle or unmanned Russian delivery rockets. There may be as many as six months between deliveries. Food that astronauts eat must be packaged and stored differently than the food we eat. Also, since the shuttle can only lift off with a certain amount of weight on board, it is necessary for food to be processed and packaged in a form that makes it as light in weight as possible.


Photo courtesy of USDA Agriculture Research Service

Did You Know?

Astronauts eat tortillas or bagels instead of sliced bread. Floating breadcrumbs would clog the Space Station's air-filtering system.


Photo courtesy NASA

Fighting Floating Food

Because food will float freely on the Space Station, it is packaged, stored and served to prevent it from moving about and causing problems for the equipment and crew. Food for astronauts is processed and packaged in several ways – everything from freeze-drying to irradiating. Nonrefrigerated food is stored in food bins to keep it from floating around, and is removed only at meal time. All astronauts are on special diets to make sure they get the nutrients and amount of food energy needed to work a full day in space. This works out to about four pounds of food each day.

Pass the Pudding, Please

Many foods that astronauts eat are packaged much like those we eat on Earth. For example, oatmeal and beverages are often packaged as dehydrated or "freeze-dried" food. Tuna, puddings and fruits are often packaged in cans or plastic cups with pull tops so they can be stored at room temperature. Dried fruit, beef jerky, and snacks such as nuts, granola bars, and cookies are packaged just like those here on Earth.


Photo courtesy NASA

No Pizza Delivery Here

Several types of food are packaged for astronauts so that they get a variety in their diet. Frozen foods, like quiches, casseroles, and chicken pot pie, are used in space just as they are on Earth. Astronauts also have refrigerated foods such as cream cheese and sour cream. Some fresh foods like tomatoes and oranges are available, but storage is more of a problem with fresh foods. Foods that we would refrigerate, like beef steak and smoked turkey, are irradiated to kill bacteria because refrigeration takes up too much space.


Photo courtesy NASA

Velcro: It's Not Just for Shoes Anymore!

While astronauts are eating, Velcro is used to hold food containers on a tray that is attached to a table, or strapped to the astronauts' laps, or attached to a wall. Eating utensils consist of a knife, fork, spoon, and a pair of scissors for cutting open packages. Following the meal, food containers are discarded and the utensils and serving trays are cleaned with premoistened wet wipes.


Photo courtesy NASA

Growing Plants Using Space Technology


Photo courtesy of John Deere

Vitamins for Plants?

Just as we need to get proper nutrition from our food, so do plants. But instead of eating hamburgers or apples to get nutrients, like we do, plants make their own food in their leaves. Many people think plants get all their food through their roots, but that really isn't true. They do take nutrients from the soil to help their leaves make food more efficiently, but they couldn't survive without the food produced in their leaves. You might compare the nutrients plants get from the soil to the vitamin pills people take to stay healthy. People can live without taking vitamins, but if they don't get all the vitamins they need, they don't function as well and get sick more easily. Plants are much like this. If they don't get important nutrients from the soil, they don't function as well.

As a farmer's crop grows, it produces the product the farmer sells, called its yield. For example, the amount of oranges produced in an orange grove is referred to as the crop yield from that grove. In order for crops to produce high yields, they must receive the proper nutrients. Plants depend on farmers to deliver those nutrients. Farmers want to make sure they apply these expensive nutrients at the right time and in the right amounts to keep the plants healthy and produce high yields.

Hard Work for Healthy Plants

A farmer treats crop fields with vital nutrients by using a tractor to deliver fertilizer. It sounds simple, but it's not. Here's what the farmer has to take into consideration:

Delivery of fertilizer - Farmers have the difficult job of trying to match their use of fertilizers to the times when the plants need them and when conditions in the field are best for fertilizers to be applied.

Different soil types - Different parts of a farmer's field need different amounts of fertilizer. If a farmer put the same amount of fertilizer on every part of the field, some plants would get more than they needed, and others would not get enough.

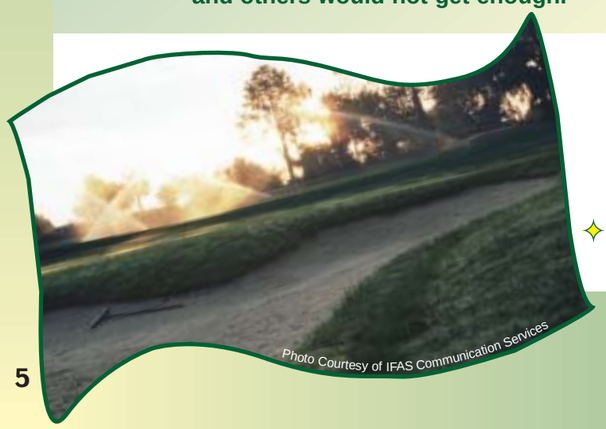


Photo Courtesy of IFAS Communication Services

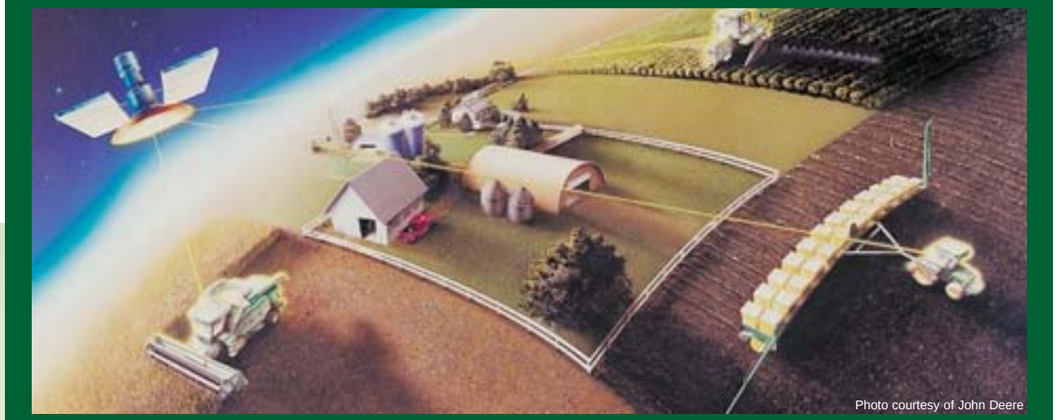


Photo courtesy of John Deere

Apply it Right!

Incorrectly fertilized lawns, golf courses and crop fields may cause problems for plants, but also can harm the environment. Let's take a look at how this happens.

- When more nutrients are added to the soil than the crop can use or the soil can hold, some of the nutrients may end up in groundwater or surface water instead of being used by the crop. When that happens, the excess nutrients are of no value to the crop, the farmer has wasted money, and a poor crop yield may result.
- Excess plant nutrients can be a major source of groundwater contamination.

Farming by Satellite

This is where space comes in. Maybe you've heard of the cool new technology called GPS, which stands for Global Positioning System. It is the only system today able to help people know their exact position on the Earth anytime, in any weather, anywhere. Here's how it works: GPS satellites, 24 in all, orbit at 9,600 miles above the Earth. The satellites in space transmit signals that can be detected by anyone on Earth with a GPS receiver.

Using GPS to identify soil characteristics, farmers are now able to precisely:

- Plant crops
  - Apply sprays to kill harmful weeds and insects
- Apply accurate amounts of fertilizer
- Water crops when and where they need it most
- Check how well the crop is performing in all parts of a field.

Solutions from Space

GPS uses space technology to solve a lot of problems for the farmers who use it. You've read about how GPS is used to control the amount and location of fertilizer applied. Farmers can use GPS for many other things as well, such as controlling the number of seeds planted in a certain part of the field, knowing how deep to plant seeds in the soil, controlling the amount of irrigation water applied to the field, finding the places in the field where harmful weeds like to grow, and measuring the yield of the field during harvest. All of these things save time and money and minimize work while helping the environment. None of this would be possible without technology in space!

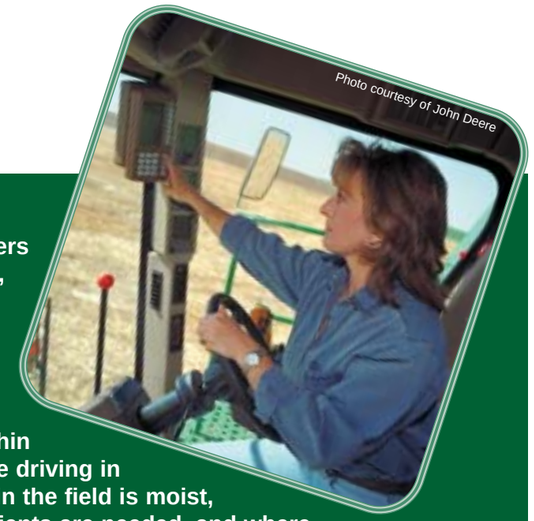


Photo courtesy of John Deere

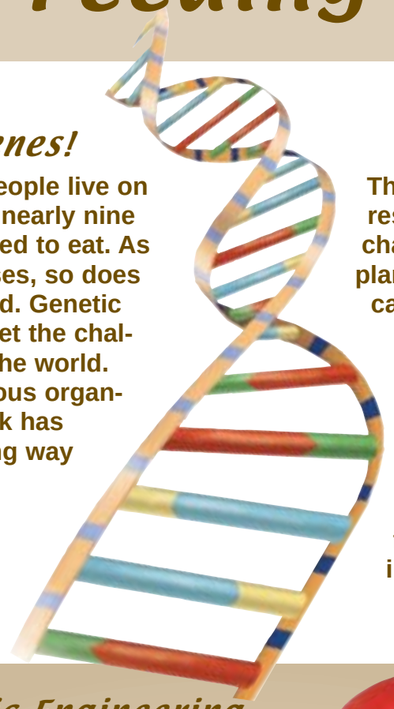
Space-Age Farmers

By combining soil sensors with GPS information, farmers can use hundreds of soil measurements while planting, fertilizing and harvesting, and then return days and weeks later to repeat the measurements in the exact same location! GPS receivers are mounted on tractors, fertilizer applicators and combines (a machine that harvests crops). With the touch of a button, GPS can pinpoint the tractor's exact location in the field within ten inches! A computer screen that farmers watch while driving in the field shows them maps that display where the soil in the field is moist, where the soil eroded over the winter, where more nutrients are needed, and where other factors in the soil might be bad for crop growth. Information is sent to a computer in the tractor to identify thriving areas and areas in trouble. Then this data is transmitted to a machine that automatically regulates the application of nutrients in the exact amounts and exact locations that they are needed.

Feeding the World with Space-Age Science

Solutions in Our Genes!

Right now, over six billion people live on Earth. By 2050, there will be nearly nine billion people who will all need to eat. As the world population increases, so does the demand for land and food. Genetic engineering may help us meet the challenge of continuing to feed the world. Introducing genes from various organisms into crops and livestock has been regarded as a promising way to ensure the continued productivity of agriculture.



Through high-tech science, researchers have found ways to change the genetic makeup of plants and animals. This is often called genetic engineering. Genetic information is modified by moving genetic material from one plant or animal to another. This is done in the tiny DNA in a cell. A plant or animal with better characteristics for farmers and consumers is the result. Read on for examples of some genetically improved plants.

Examples of Genetic Engineering

Fresh tomatoes do not freeze very well without getting mushy. A tomato that kept its firmness after freezing would be more valuable. A genetically engineered tomato was designed with the hope of finding a solution to this problem. An "anti-freeze" gene from a flounder (a fish) was moved into the genetic material of a tomato plant. The resulting tomatoes possessed the "anti-freeze" protein, but unfortunately, the tomatoes still got mushy during freezing. Although this experiment didn't produce the desired results, it's a great example of the work scientists are doing to solve agricultural problems through genetic engineering.

Photo courtesy of USDA Agriculture Research Service

Cotton is a crop with many insect pests. In the past, pesticides have been used to control the pests. Some pesticides damaged the environment. Scientists have genetically engineered cotton to resist a common cotton pest called the bollworm. Here's how they did it. They knew that bollworms died after eating the bacteria *Bacillus thuringinesis*. The gene in the bacteria that is responsible for killing bollworms was moved into the cotton's DNA. Now bollworms that eat the cotton are killed without pesticides!

Space Farming?

Absolutely…especially if people are to travel and live for months and years in space stations or on other planets. It would be impossible to send enough food and water to sustain space pioneers for these lengthy journeys. Instead, food and water production over a full life cycle is essential for extended space exploration. There is not enough time, money or room to continually supply inhabitants of a space station with provisions from Earth.

Photo courtesy of NASA

Plants in Space

Researchers originally became interested in having plants in space because they knew we needed them there for the same reasons we need them down here. Can you guess what these reasons are? Yes: to provide food and air! Plants are so important that we couldn't breathe without them. Plants use the carbon dioxide we exhale for photosynthesis and in doing so, cleanse our air and give off oxygen as a byproduct. A plant breeder who developed wheat for space comments, "A very big reason plants are up there in the first place is to get the carbon dioxide out of the atmosphere."

Photo courtesy of NASA

It took more than a decade to develop wheat suitable for space farms, where artificial sun always shines, carbon dioxide levels are high and space is at a premium. This unique wheat grows perfectly in this environment. Two official space wheat varieties are Apogee and Perigee.

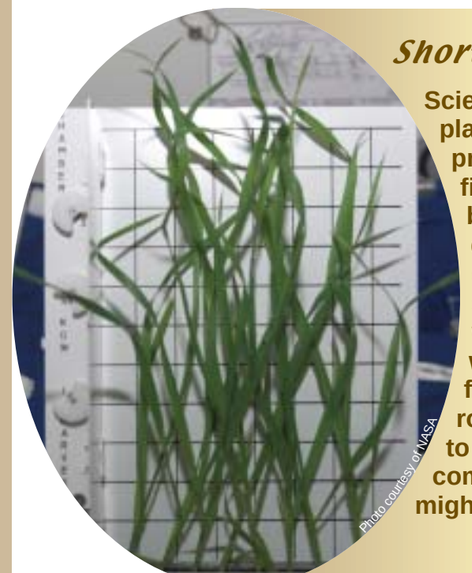


Photo courtesy of NASA

Shorter Plants, More Grain

Scientists quickly found out that plants had to have special traits to produce food in space. In order to find a solution, scientists have been breeding crops for over a decade that grow shorter and closer together for use in space. Apogee and Perigee wheat produce three times more wheat than top yields from fields, while requiring minimal room to grow. They are only 12 to 18 inches tall when mature, compared to normal wheat that might grow to 3 feet or higher.

Q&A's

Where did the names Apogee and Perigee come from?

Apogee is the term for the point in orbit that is farthest from the Earth, and perigee is the term for the point in orbit that is closest to the Earth.

If space wheat is so great, why isn't it grown here?

It grows too short to be harvested using current Earth Ag technology.

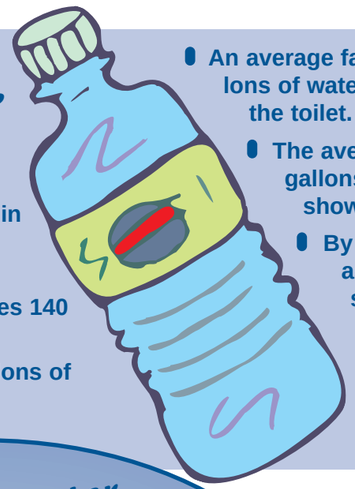
Are You Really Gonna Drink That?

A Lot of Water???

Although the Earth's surface is about 75% water, only 3% is fresh water. Three-fourths of the fresh water on our planet is found in polar ice caps and glaciers, making it economically impractical to use. That leaves less than 1% of the water on Earth available for human consumption. The same water is continually recycled all around the globe. You could be drinking the same water today that your great-great-grandparents drank years ago! Even though our water supply is firmly fixed, the human population continues to grow rapidly. Water is essential for life, and it is our responsibility to conserve it for future populations.

Photo courtesy of NASA

Water Conservation Facts: Did You Know???



- The human body is about 75% water.
- About 27% of all the water used in the US goes to showering and bathing.
- The average American family uses 140 to 170 gallons of water per day.
- An average bath requires 37 gallons of water.
- An average family of four uses 881 gallons of water per week just by flushing the toilet.
- The average shower uses about 20 gallons of water. A ten-minute shower uses 40 gallons of water.
- By comparison, Space Station astronauts are allowed only six gallons of water for all their personal needs each day – including washing clothes, bathing, toilet flushing, cooking and drinking!

Nature's Way of Recycling Water

Water Recovery is not man's invention. The Earth has been recycling water forever with a natural process that we call the hydrologic cycle, also known as the water cycle. This process operates continuously, and is powered by the sun. The cycle includes:

– Evaporation
– Transpiration
– Condensation
– Precipitation

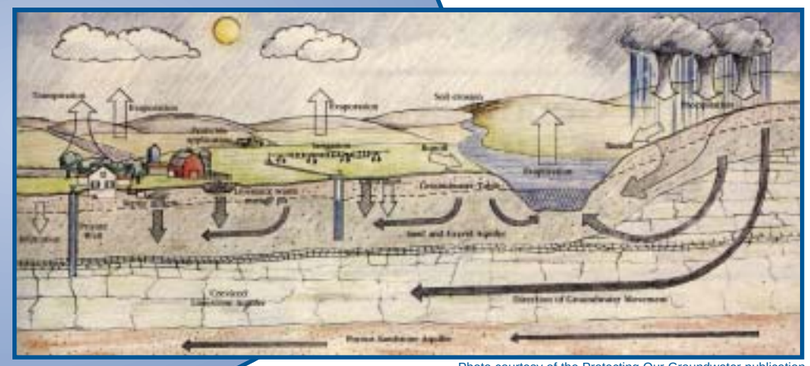


Photo courtesy of the Protecting Our Groundwater publication

It's Gotta Be Purified!

In space, recycled water comes from respiration, perspiration, shower and shaving water, and urine.

All of these wastewaters will be purified and then used as drinking water! This might sound unappetizing, but the processed water will be as clean as the water that most of us drink on earth.

Photo courtesy of NASA

Those Pesky Scrubbing Bubbles

Researchers are trying to replace the bulky and inefficient water-cleansing machinery now used in space (pictured above) with a system that filters wastewater through plants! The whole idea is that plants needed for food on long-term space missions can be watered with wastewater. Early research indicates that water transpired by plants is clean enough to drink, and the other parts of the plant are perfectly healthy to eat.

One problem with this system is that soap in the astronauts' wastewater can get foamy and interfere with the ability of the plants to absorb water. Special research is being done to identify microbes that can be added to the water to break down the soap so plants can absorb the water. Most soaps are biodegradable, but only if the right microbes are matched with the type of soaps astronauts want to use. This sudsy research being done for the space program might lead to more environmentally friendly soap for Earth and better ways to process our wastewater down here.

Space Hydrologic Cycle

Photo courtesy of NASA

Condensation: On Earth, water is naturally reclaimed by the process of condensation, which moves water vapor back into the clouds. In space, any activity that produces water particles is a source of water for future use, including bathing, urinating, breathing, shaving, and brushing teeth.

Transpiration: Transpiration is the process of plants returning moisture to the air through their leaves. Transpiration results in nutrient-rich water being converted to purified water as it evaporates. This process provides an excellent means of purifying water in space.

Collection The International Space Station has a system that collects and recycles all the water in the environment, including humidity from respiration, perspiration, moisture from plant leaves, and microwave use; wastewater from showers, hand washes, shaves, and toothbrushes; and urine.

Photo courtesy of NASA

Photo courtesy of NASA

Precipitation: Obviously it doesn't rain on the Space Station, but astronauts need water. The first room of the Space Station (called Zarya) is where water and other supplies are stored. Water is held in containers that resemble large duffel bags, holding 90 pounds each! They were transported to the Space Station via the space shuttle during an assembly mission.