



EARTH SYSTEMS SCIENCE

This lesson is taken from an education module developed for Challenger Center's *Journey through the Universe* program. *Journey through the Universe* takes entire communities to the space frontier.

Start the *Journey* at www.challenger.org/journey.

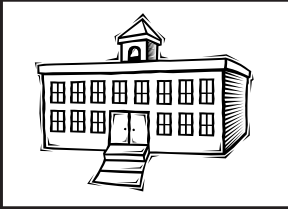
Funded by grants from NASA's Minority University Research and Education Division and Offices of Space Flight, Space Science, and Earth Science



Challenger Center, Challenger Center for Space Science Education, and the Challenger Center logotype are registered trademarks of Challenger Center for Space Science Education. No portion of this module may be reproduced without written permission, except for use within a *Journey* community. ©2002, Challenger Center for Space Science Education.

January 2002

Grade Level
K-4



Lesson 3: Soil, Water, and Plants

Lesson Summary

The interaction of soil with water and plants can be optimized to produce edible plants and to protect the Earth's surface from erosion and weathering. In this lesson, students will investigate the interactions among the biosphere, geosphere, and hydrosphere. In the warm-up, students will observe three different types of soil, and in Activity 1 they will test each one for its ability to retain water. In Activity 2, students will grow plants in the three types of soil to determine which is best for growing plants.

Lesson Duration

Two to three 45-minute class periods and 5 minutes for 10 days to monitor and observe experiment.



ESSENTIAL QUESTION

Is there a relationship between water retention and plant growth?



OBJECTIVES

Students will be able to:

- ▶ Analyze different types of soil for composition, texture, and water retention.
- ▶ Determine how a soil's ability to retain water affects plant growth.



CORE K-4 STANDARDS

NRC Standards

- STANDARD D1:** Soils have properties of color and texture, capacity to retain water, and ability to support the growth of many kinds of plants, including those in our food supply.
- STANDARD C1:** Organisms have basic needs. For example, animals need air, water, and food; plants require air, water, nutrients, and light. Organisms can survive only in environments in which their needs can be met. The world has many different environments, and distinct environments support the life of different types of organisms.
- STANDARD C3:** All organisms cause changes in the environment where they live. Some of these changes are detrimental to the organism or other organisms, whereas others are beneficial.

Science Overview

Soil is one of the most important ingredients for life on land. Many creatures find a home within the Earth's soil, which covers about 25% of the surface of the Earth and ranges from a few centimeters to several meters deep. In addition to air and water, soil provides the means by which most terrestrial plant life is supported, both physically and biologically.

Soil Composition

Plants can grow in many environments, and in many soil types. Some soils are better than others, depending on the needs of a particular plant. Some types of soil will never sustain life, no matter what the conditions. The properties a soil contains influences its fertility, water retention, gas exchange, and physical support for plant roots. All soils, however, are made up of the same general materials, and it is the proportions of these materials that make the soils unique. These materials are organic matter, mineral matter, water, and air.

The organic matter (carbon compounds) within soil is material that used to be alive, or part of something that was once alive. Partially disintegrated or decomposed plant life, animal residues, and other organic compounds are digested by soil microbes as the decomposition process occurs. Organic matter is the soil's food supply. It replenishes nutrients used by growing plants; everything taken out of the soil must be replaced in order to keep the soil healthy and thriving.

Silicates, iron compounds, and other minerals make up the solid part of the soil, which is not, and never was, alive. The minerals also provide the necessary nutrients for plant growth, the structure of the soil, and a home for plants to take root.

The third component of soil is water. It is the most crucial element of a plant's strength and vivacity. Nutrients are transported to and from plants by water. This is how plants receive the essential nutrients required for growth. You can think of it as blood in a human body, taking essential nutrients (such as oxygen) to every part of the body. Water is transported laterally within the soil, and vertically within the plant

itself. Photosynthesis, the process by which plants make their own food, is impossible without sufficient water. However, there can be too much of a good thing; plants that receive too much water are in danger of drowning. Animals drown because they are unable to get enough air into their lungs; water enters instead. It works the same way in plants; roots need a certain amount of air to survive. When a plant gets too much water, the air cannot get to the roots and it cannot survive.

Air is the fourth ingredient in soil. Soil air is different from breathable air. Soil does, however, interact with air in the same way our lungs do; some gases are consumed by the soil and some are released.

Soil Types

All soil contains the four ingredients above. However, there are many types of soil – what is the difference? A soil is classified according to the proportions of the different size particles it contains. Particle size determines which of the four ingredients – organic matter, minerals, water, and air – dominates the soil, and, therefore, plays a huge role in soil characteristics, especially water retention and fertility. There are three main types of soil – sand, silt, and clay.

Sand is coarse to the touch and individual particles can be seen with the naked eye. It has the largest particle size of the three types of soil, even though we usually think of sand as small grains. Grains vary in size from 0.06 mm to 2 mm in diameter (grains larger than 2 mm are considered gravel). Sand forms as a result of weathering. Wind and water erosion cause rocks and large minerals to break apart and create tiny particles. Most sand is made of silica, which is most often in the form of quartz, but many other minerals are often present.

When quartz mineral particles are broken up into even finer particles (by the same weathering process by which sand is created), the result is silt. Silt is made of particles between 0.06 mm and 0.002 mm (1,000 times smaller than large grains of sand). Silt is smooth and slippery when wet, and particles can only be seen using a microscope.

Particles smaller than 0.002 mm in diameter constitute clay, which is usually made of aluminum silicates. Clay also usually contains small amounts of other elements, including iron, potassium, so-

dium, and calcium. When wet, clay is sticky and plastic-like, but when dry, it can feel as hard as cement. Clay is extremely fine-textured, and particles can only be seen when using an electron microscope.

Most soil is not strictly one kind or another. There can be many combinations of these three types of soil; and any combination is considered a loam. Loams are classified as sandy, clay, or silt loams depending on the abundance of each constituent. Most soils used in agriculture (farming) and horticulture (gardening) are some sort of loam.

Below is a diagram showing a three-sided grid, each side representing the content of a particular particle type on a scale from 0% to 100%. If you know the percentage of sand, silt, and clay in a sample of soil, you can determine its classification. To do so, begin with sand. Find the percentage of sand in your soil, and draw a line upwards and to the left (parallel with the right side of the triangle). Next find the percentage of clay and draw a line horizontally across the triangle, parallel with the bottom. Next find the percentage of silt, and draw a line from that point downwards and to the left, parallel with the left side of the triangle. The three lines intersect in a section of the triangle labeled for the type of soil that you have.

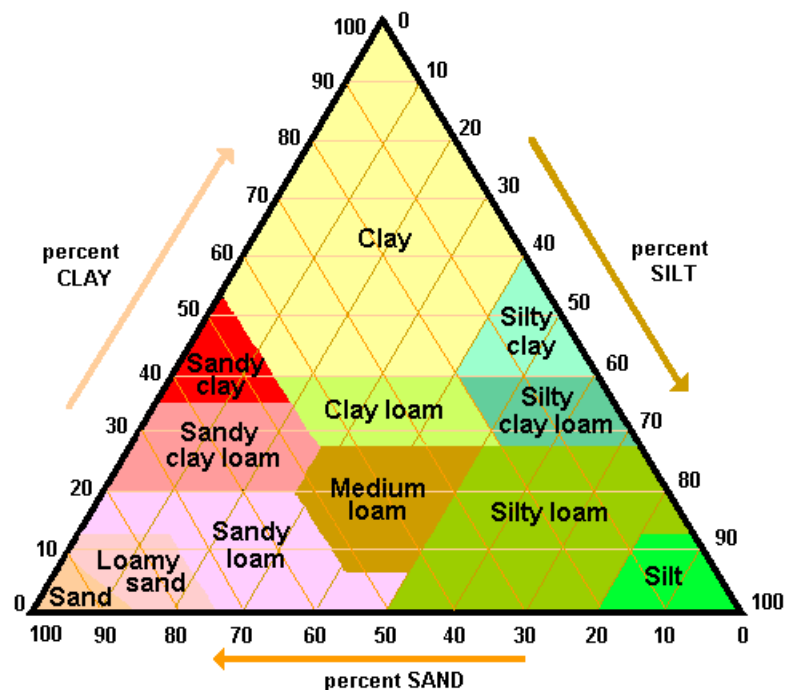


Figure 1. Diagram for determining the type of soil. <http://homepages.which.net/~fred.moor/soil/formed/f0107.htm>

Advantages and Disadvantages of Soil Types

Depending on your environment and purpose, you may want to choose one type of soil over another for growing plants. There are characteristics of each soil that may make it ideal in certain situations.

A sandy, coarse-textured soil drains quickly after a rain, as the water can pass through gaps between the large particles. It is very light to handle, quick to warm up in the spring, and workable for most of the year. It permits free movement of air in the soil, and therefore plants in sandy soil can easily grow. However, because it drains quickly, sandy soil has to be watered very frequently. In fact, soils composed entirely of sand are too dry and lack enough nourishment for plant growth. Like water, nutrients will slip through the cracks between the grains and cannot support organic materials well. Since the sand particles do not stick to each other, the soil is also subject to wind and water erosion. Plants that do not need much water, but whose roots require much air would be ideal for this category of soil. (Sand, loamy sand, and sandy loam are included in this category.)

Fine-textured soil that is rich in clay binds particles together with its stickiness, and, as a result, holds a lot of moisture and nutrients. Not nearly as much watering or fertilization is needed for plants living in clay soil. However, soils extremely rich in clay are too sticky to farm, and can damage machinery as well as retard the growth of the plants. Air is unable to reach the roots of the plant in a clay-rich soil, and plants could suffocate. Plants that need a lot of water but not much air would grow well in this type of soil. (Clay, sandy clay, clay loam, silty clay loam, silty clay, and silt are included in this category.)

A good balance between the amount of attention needed by the soil and its productivity can be found. The medium loam group, which includes medium loam, sandy clay loam, and silt loam, is desirable in many circumstances and for many plants. Most plants grow well in a medium loam, and most farmers take this option.

All types of soils can be improved by the addition of organic matter. Plants grow better if they are provided with additional food and nutrients mixed thoroughly into the soil. If large enough amounts of organic material are added, your soil may become peat type soil, peat moss, or fen soil. These types of soils drain

effectively, but also retain enough water and nutrients to support plant life. They are also fairly resistant to erosion, a major concern for any soil type.

Preventing Soil Erosion

Wind and water can move the top layers of soil through a process called erosion. When soils suffer from degradation, the number one factor being erosion, they can lose their ability to house plant life and produce food. There are many types of degradation, including chemical and physical degradation, but the number one type, overwhelmingly, is erosion. Water erosion accounts for 56% of all degradation, while wind erosion accounts for 28%.

Soils are protected from erosion in various ways, and there are many things that farmers and gardeners can do to prevent heavy damage. The plants themselves protect the soil from erosion; the above-ground part of the plant prevents wind damage, and the below-ground part can anchor soil particles to roots, preventing them from slipping away.

Many traditional farming practices are not ideal for preventing erosion damage. Some farmers plant a monoculture (one type of crop only), which means that they harvest their crop all at once. This leaves the field bare, and the soil will not retain water very well. Rain water simply runs over the surface, taking with it the topsoil, and eroding away the nutrients needed to grow next year's crop. Another tactic used to plant crops is called row cropping. In this case, the soil between each row of crops is exposed, without plants preventing erosion. One of the oldest agricultural practices is called tilling, or plowing. In this case, the soil is mixed up, loosening soil particles and introducing an abundance of air to the soil. Though this may help root the plants, it also increases the chances of erosion because the particles of soil are no longer bound to one another. Another factor that helps prevent erosion is the presence of crops. If the soil was exposed, and organic materials removed, erosion would almost certainly ensue. Organic materials have the ability to sop up most of the rain water, otherwise it would run right over the top.

In order to reduce the amount of erosion, there are certain approaches farmers may take. Tilling the field at a right angle to the slope of the land, for example, prevents water from simply flowing down the side of the hill, taking with it important nutrients

needed for plant growth. Some farmers wait until the spring (rather than fall) to plow their fields so that there is not as much time for erosion to take place by melting snow or spring rain. Specialized machinery has been developed to loosen the soil without plowing, avoiding major disturbances to the soil. Some farmers will fill in rows of crops with another type of crop, so that the ground is completely covered. This way, the crops can be harvested at different times, lessening conditions which are conducive to erosion. Adding organic materials (fertilizers) also can help, since they absorb much of the water.

Although there are measures that farmers may take to prevent soil erosion, many do not engage in these methods. Sometimes benefits of erosion prevention are outweighed by the cost, in time or money. For example, it can be expensive, as well as time-consuming, to plant two or more crops in the same plot of land. Farmers and gardeners need to find which planting methods, as well as soil types, will help them grow the best plants with the least amount of interference.

Lesson Plan

Preparation and Management

- ▶ Get local soil from around the community or school.
- ▶ Assemble one set of soil samples for each group to observe. A set should include one resealable bag of potting soil, one bag of sand, and one bag of local soil.

TEACHING TIP

- ▶ *One 10 lb bag of potting soil, 10 lb bag of sand, and 10 lb of local soil should be sufficient for a class of 25 students.*

Warm-Up

Give students three different soils to observe –potting soil, sand, and local soil. They should note the color and texture, especially particle size, of each soil and record their observations on Student Worksheet 1.

Pre-assessment

Ask students to hypothesize which soil will hold the most water. Have them rely on their observations and personal experiences. Students should record their hypothesis on Student Worksheet 1 for future comparison.



TEACHER MATERIALS

Activity 1:

- ▶ Single hole-punch
- ▶ Small screens for each pan
- ▶ Scissors
- ▶ Tape

STUDENT MATERIALS

Warm-Up(per group of three)

- ▶ Student Worksheet 1
- ▶ Resealable sandwich bag filled with potting soil
- ▶ Resealable sandwich bag filled with sand
- ▶ Resealable sandwich bag filled with local soil

Activity 1 (per group of three)

- ▶ One 6" x6" aluminum cooking pan filled with potting soil
- ▶ One 6" x6" aluminum cooking pan filled with sand
- ▶ One 6" x6" aluminum cooking pan filled with clay or local soil
- ▶ 10 gallon bucket
- ▶ 500 ml graduated cylinder
- ▶ Water

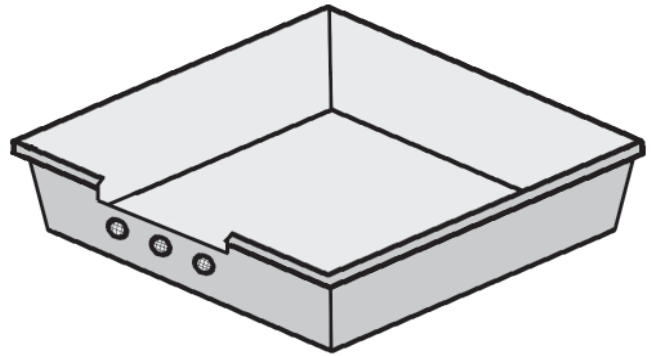
Activity 2 (per group of three)

- ▶ 45 Bean Seeds
- ▶ Ruler
- ▶ Calculator
- ▶ Watering Can

ACTIVITY 1: Which Type of Soil Retains the Most Water?**ACTIVITY 1: Which Type of Soil Retains the Most Water?****Preparation & Management**

Modify the aluminum cooking pans for the experiment.

- ▶ Using a single hole-punch, create 4 or 5 individual holes (the same size as the punch) spread out on one side of each pan.
- ▶ Using tape, attach a screen to the inside of the pan over the holes, to prevent soil from escaping.
- ▶ On the same side of the pan as the holes, create a centered 3" x 1" flap at the top of the side.
- ▶ Fill one pan with potting soil, one pan with sand, and one pan with local soil up to the level of the flap.

**TEACHING TIP**

- ▶ Older students, in grades 3-4, can prepare their own aluminum soil pans to reduce the amount of teacher preparation.

Procedures

1. Put students into groups of three. Give each group the materials necessary to complete the activity: three aluminum baking pans (one filled with potting soil, one filled with sand, and one filled with local soil), a 500 ml graduated cylinder, water, and a bucket to collect run-off.
2. Have students follow the directions on Student Worksheet 1.

TEACHING TIP

- ▶ Make sure students elevate the three pans to the same height. For example, each pan should be elevated by one book or block. Pan height can vary between the groups as long as it is consistent within each group.

ACTIVITY 1: Which Type of Soil Retains the Most Water?**Reflection & Discussion**

Ask students, based on their observations which soil held the most water. (*Answer: in most cases the topsoil will hold the most water and the sand will hold the least*) Ask students if the soil that had the most runoff held the most water. (*Answer: no, the soil with the most run-off held the least amount of water*) Have students refer back to their warm-up to determine if their hypothesis was correct regarding which type of soil retains the most water. If their hypothesis was not correct, have students explain why. Ask students if the soil affects any other parts of the Earth? (*Answer: yes, living things like plants*) Ask students how they think a soil's ability to hold water might affect plants. (*Answer: plants need water so if the soil can not hold it, plants might not survive*)

Transfer of Knowledge

Ask students to answer the following question on a piece of paper and have them turn it in for assessment:

A local farmer is planning to dissolve fertilizer in water and then spray it on his or her field. The fertilizer is very expensive and the farmer wants to make sure that the fertilized water will stay in the soil so it can be absorbed by the plants. What would suggest to the farmer before the fertilizer is sprayed. Develop a plan to help the local soil retain more water.

Answer: Adding a top layer of potting soil or topsoil will increase retention.

ACTIVITY 1: Which Soil Retains the Most Water?**ASSESSMENT**

Students can be assessed on their answers and data tables on the Student Worksheet 1.

4 Points

- ▶ All trials are complete and accurate.
- ▶ Answers to questions are complete and demonstrate a clear understanding of the concepts.
- ▶ Answers correctly reference the hypothesis and data.
- ▶ *Transfer of Knowledge* question is answered based on results from the experiment and demonstrates a clear understanding of the concepts

3 Points

- ▶ 3 of the 4 above criteria are met.

2 Points

- ▶ 2 of the 4 above criteria are met.

1 Point

- ▶ 1 of the above criteria is met.

0 Points

- ▶ No trials completed.
- ▶ Questions unanswered.

Placing the Activity Within the Lesson

Have students reflect on what they have learned about water retention and use their new knowledge to hypothesize which soil will generate the best plant growth. In Activity 2, students will actually experiment to determine if their hypotheses were correct.

ACTIVITY 2: Which Type of Soil is Best for Growing Plants?

Preparation & Management

- ▶ Collect the materials from Activity 1. Students will still need to use the aluminum pans but will no longer need the buckets.
- ▶ Place seeds in a central location in the classroom.

Procedures

1. Students will plant 15 seeds in each of their aluminum pans. Students should create 15 half-inch holes, evenly spaced, using a ruler. Students should then drop one seed into each hole and gently cover with soil.
2. Students will monitor and record seed germination, plant height, changes to the plants and soil, and water retention for 10 days, or longer if desired.
3. Using a graduated cylinder or a measuring cup, students should give each pan 100 ml of water daily.

TEACHING TIP

- ▶ *Make sure that the students do NOT pack down the soil over their seeds. Otherwise they will not be able to grow.*

Reflection & Discussion

Ask students what connection they observed regarding a soil's ability to retain water and its ability to support plant life. (*Answer: the more water a soil can hold, the more plant life it can support*) Ask them if the plants, in turn, had any affect on the soil. (*Answer: yes, the plants improved each soil's ability to hold water*) Ask students to offer some explanations for their observation. (*Answer: plant roots hold down the soil and their root system traps water for the plant to absorb*)

Transfer of Knowledge

Ask students to answer the following questions on a piece of paper and have them turn it in for assessment:

In Activity 1, you developed a plan for local farmers to increase water retention in local soils. Add a second step to your plan, based on what you learned in Activity 2.

Answer: Planting plants on the soil increases the soil's water retention. By keeping plants on the soil all year round (even in the winter) you will be protecting your topsoil which holds water quite well. TIP: After crops produce their yield, don't cut them down or remove them until the spring and you are ready to plant again.

ACTIVITY 2: Which Soil is Best for Growing**ASSESSMENT**

Students can be assessed on their answers and data tables on Student Worksheet 2.

4 Points

- ▶ All trials are complete and accurate.
- ▶ Answers to questions are complete and demonstrate a clear understanding of the concepts.
- ▶ Answers correctly reference the hypothesis and data.
- ▶ Student described a realistic way to improve water retention of local soils.

3 Points

- ▶ Student completed 3 of the 4 above criteria.

2 Points

- ▶ Student completed 2 of the 4 above criteria.

1 Point

- ▶ Student completed 1 of the 4 above criteria.

0 Points

- ▶ No trials completed.
- ▶ Questions unanswered.

Placing the Activity Within the Lesson

This activity allows students to see that the quality of water retention affects our lives and is dependent on more than one variable. Plants can help improve a soils ability to hold water.

Lesson Closure

Have students review the results from both activities and discuss the different ways in which the soil (geosphere), water (hydrosphere), and the plants (biosphere) interacted in this lesson. Have students discuss how different regions have different soils and how that might affect people living there. Students should also discuss how farmers could use different planting methods to prevent erosion, which carries away the nutrient-rich topsoil.

Supplemental Resources

How Soil Holds Water

<http://www.ianr.unl.edu/pubs/fieldcrops/g964.htm>

Soil Science Education Home Page

<http://ltpwww.gsfc.nasa.gov/globe/>

Soil Web

<http://soilweb.tripod.com>



STUDENT WORKSHEET 1 - WHICH TYPE OF SOIL RETAINS THE MOST WATER?



Name _____ Date _____

Is all soil the same? Examine three different soil samples to see their similarities and difference.

Directions:

1. Collect three resealable bags, one filled with potting soil, one with sand, and one with local soil.
2. Examine the color and texture of each soil and record your observations in the data table below.

Type of Soil	Color	Texture
<i>Potting Soil</i>		
<i>Sand</i>		
<i>Local Soil</i>		

3. Based on your observations, **HYPOTHESIZE** which soil will hold the most water: Explain your decision.



STUDENT WORKSHEET 1 - WHICH TYPE OF SOIL RETAINS THE MOST WATER?



Name _____ Date _____

Which Type of Soil Retains the Most Water?

Directions:

1. Collect three aluminum cooking pans, each filled with a different soil.
2. Elevate the side of the pan without holes using one book to create a slope. The run-off water should flow out of the holes on the other side of the pan and fall into a bucket on the floor.
3. Using a graduated cylinder, measure out 500 ml of water and pour it into a watering can. Pour the water, moving it back and forth, over the pan of potting soil.
4. After 5 minutes, measure the amount of water that has collected in the bucket, using a graduated cylinder, and record it in Data Table 1. Dispose of the water.
5. Repeat this process three more times and compare your results.
6. Repeat steps 3-5 for the sand and local soil.

DATA TABLE 1

Type of Soil	Run-off Trial 1	Run-off Trial 2	Run-off Trial 3	Run-off Trail 4
<i>Potting Soil</i>				
<i>Sand</i>				
<i>Local Soil</i>				

7. Based on your data, which type of soil holds the most water? Was your hypothesis correct? Explain.

8. Plants need water to survive, based on your observations, HYPOTHESIZE which soil will grow the best plants:



STUDENT WORKSHEET 2 - WHICH SOIL IS BEST FOR GROWING PLANTS?



Name _____ Date _____

Directions:

1. Create 15 half-inch holes, evenly spaced, using a ruler.
2. Drop one seed into each hole and **gently** cover with soil.
3. Using a graduated cylinder, give each pan of seeds 100 mL of water for ten days.
4. Monitor and record the number of seeds that germinate, the average plant height (in cm), and observations such as changes in soil or plants in the Data Tables below.

DATA TABLE 2

Day	Number of Seeds Germinated in Potting Soil	Number of Seeds Germinated in Sand	Number of Seeds Germinated in Local Soil
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			


STUDENT WORKSHEET - ACTIVITY 2


DATA TABLE 3

Day	Height of Plants in Potting Soil	Height of Plants in Sand	Height of Plants in Local Soil
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

DATA TABLE 4

Day	Potting Soil Observations	Sand Observations	Local Soil Observations
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			



STUDENT WORKSHEET - ACTIVITY 2



Name _____ Date _____

Questions:

1. Based on your data, which type of soil grows plants the best? Was your hypothesis correct? Explain.

2. Is there a relationship between the amount of water that soil can hold and how well plants grow in that soil? If so, describe the relationship.

3. Drawing Conclusions: Do you believe that plants affect the soil's ability to hold water? Explain your answer.

Challenger Center Programs



The internationally acclaimed **Challenger Learning Center** Network currently consists of state-of-the-art, innovative educational simulators located at 49 sites across 29 states, Canada, and the United Kingdom. Staffed by master teachers, the core of each Center is a two-room simulator consisting of a space station, complete with communications, medical, life, and computer science equipment, and a mission control room patterned after NASA's Johnson Space Center. See www.challenger.org for information.

A joint initiative of Challenger Center for Space Science Education, the Smithsonian Institution, and NASA, *Voyage — A Journey through our Solar System* is a space science exhibition project that includes permanent placement of a scale model solar system on the National Mall in Washington, DC, and at locations all over the world. See www.voyageonline.org for information.



Space DaySM launches new *Design Challenges* created by Challenger Center each school year. The inquiry-based challenges are designed to inspire students in grades 4-8 to create innovative solutions that could aid future exploration of our solar system. See www.spaceday.org for information.

Challenger Center's *Journey through the Universe* program provides under-served communities with diverse national resources, including K-12 curriculum materials, teacher workshops, classroom visits by scientists from all over the country, and Family Science Nights. See www.challenger.org/journey for information.



The **MESSENGER** spacecraft (MErcury Surface, Space ENvironment, GEOchemistry and Ranging) is to be launched in 2004 and go into Mercurian orbit in 2009. Challenger Center is one of the partner organizations charged with MESSENGER education and public outreach activities. See www.messenger.jhuapl.edu for information.

Through the Challenger Center **Speakers Bureau, Voyages Across the Universe**, staff members speak to student audiences of 30-1,000, conduct workshops for 100-300 educators, give keynote and featured presentations at conferences, as well as conduct Family Science Nights at the National Air and Space Museum, and other facilities across the nation, for audiences of 300-1,000 parents, students, and teachers. See www.challenger.org/speakers for information.

For information about other Challenger Center programs, or to purchase our classroom resources, visit www.challenger.org/store.