Why Follow the Water?
Teacher Guide

GOAL
Students gain a better understanding of why liquid water is important for life and why NASA plans to "follow the water" in its effort to find evidence for life on Mars.

OBJECTIVES
- Students characterize the solubility of three solutes (salt, sugar, and cornstarch) in three solvents (water, vegetable oil, and rubbing alcohol).
- Students compare the abundance of three solvents (water, crude oil, and alcohol) found at and near the surface of Earth.
- Students discuss relative ease of evaporation of water, oil and alcohol.
- Through the above explorations, students draw conclusions regarding possible reasons why liquid water is important for living systems on Earth.
- Through an extension activity, students explore the relationship between plant productivity and annual precipitation.

NATIONAL SCIENCE STANDARDS

Grade Level	Content Area	Content Standard	Guides to Content Standards
5-8	Science as Inquiry	Abilities necessary to do scientific inquiry	Design and conduct a scientific investigation
5-8	Science as Inquiry	Abilities necessary to do scientific inquiry	Think critically and logically to make relationships between evidence and explanations
5-8	Science as Inquiry	Abilities necessary to do scientific inquiry	Communicate scientific procedures and explanations
5-8	Life Science	Structure and function in living systems	Cells carry on the many functions needed to sustain life.
5-8	Physical Science	Properties and changes of properties of matter	A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample
5-8	Earth and Space Science	Structure of the earth system	Water is a solvent.

TIME FRAME
- 2.5 class periods (each 50 minutes)

MATERIALS
- Pens
- Butcher paper
- Student worksheets (1 per student)
- Small, clear plastic cups (6 per group)
- Graduated cylinders
- Coffee stirrers (or Popsicle sticks to stir solutions, 3 per group)
- Permanent markers
- Small spoons (3 per group)

- Paper towels
- Water
- Isopropyl alcohol (rubbing alcohol)
- Vegetable oil (Canola, or other light-colored oil)
- Sugar
- Kosher salt
- Cornstarch
- NASA article: Mars: A Dry Planet Compared to Earth (Intro reading)

OVERVIEW

Students will read a short background article to familiarize them with the NASA strategy to "follow the water" in searching for life on Mars. They then complete an activity demonstrating that water is important to life on Earth because it is a good solvent that is abundant and relatively stable at Earth temperatures and pressures. They will relate these characteristics to the need for living systems on Earth to use liquid water to dissolve and transport materials throughout cells.

In an extension activity, students can explore the connection between the amount of liquid water available and the plant productivity in different biomes, which helps reinforce student understanding of the importance of water on Earth.

BACKGROUND

Embedded within NASA science goals related to Mars exploration is a strategy to "follow the water" (Mars Exploration Program Public Engagement Plan, 2002). Scientists plan to look for evidence of past or present life where they think liquid water once existed on the planet. Since water is a necessity for life on Earth, and since the only life we know of is water-based, many scientists think that the best place to start looking for life as we know it on Mars is where liquid water was once or currently is present. Other types of life forms (nonwater-based) may be possible on other planets, but since we have no experience with this type of life, we may not recognize it as easily. Students will be given a short background reading to familiarize them with NASA's "follow the water" theme.

In this activity, students first describe preconceptions regarding why water is important for living things on Earth. Student preconceptions will vary. Only rarely do students describe fundamental properties of water that make it useful for life on Earth, including its abundance, stability, polarity, lower density as solid than liquid, specific heat, adhesion, cohesion, and solubility. In the interest of time, this lesson focuses on the solubility, stability, and abundance of liquids, rather than delving into all the properties that make liquid water an essential substance for life on Earth.

Students test the solubility of three solutes (salt, sugar, and cornstarch) in three solvents (water, vegetable oil, and rubbing alcohol) to discover that water is a good solvent. Cells need to transport nutrients, waste products, sugars, salts, and other chemicals. Much of this transport can happen because the chemicals are dissolved in water and are transported as a solution. Cells also need water to allow chemical reactions to occur among molecules within its membrane. Atoms and molecules need to be able to disconnect and reconnect in an aqueous environment in order to metabolize food, reproduce, and perform other essential cellular functions. Without water, these processes could not occur easily or at all.

Water, however, may not be the only solvent that could perform these functions for a cell. In terms of life on Earth, water appears to be the best solvent for life because it can dissolve many necessary molecules needed to carry on life's functions and it is stable and abundant as a liquid within the temperature range on Earth. Students may ask about the possibility of oil-based life, or other solvent-based life on other planets, which evolved differently from water-based life. While the polar nature of water appears to be an important characteristic for its use as a solvent for life on Earth, the possible use of different solvents by life on other planets cannot be completely discounted. In our current search for life, however, the focus is on living systems that are most similar to life we already recognize.

In an extension activity, students study plant productivity and average yearly rainfall data for several biomes in order to relate the quantity of water available to the amount of life present in those areas. The data show that areas that are dry, like the arctic and the desert, have fairly low plant productivity. Areas of higher rainfall have more plant productivity. This reinforces the concept that plant life on Earth relies heavily on water.

RECOMMENDED LESSON SEQUENCE

The lesson described here spans over more than one class period and includes several different activities. These activities are presented in more detail below and have been grouped into four parts. Below is a recommended sequence for these activities:

<u>Day 1:</u>

- Part 1: Preconception Activity (15 min)
- Part 2: Class Discussion, Evaporation Demonstration, and Pre-Lab Questions (35 min)

<u>Day 2:</u>

- Part 2: Discuss results of Ease of Evaporation Demonstration (10 minutes)
- Part 3: Solubility Lab (30 min)
- Part 4: Post Lab Questions (10 min)

<u>Day 3:</u>

- Part 4: Post-Lab Questions continued and Final Discussion (30 min)

PART 1: PRECONCEPTION ACTIVITY

Objective

- Students describe preconceptions they bring to the class regarding why water is important for life. This serves as a springboard for discussing more fundamental physical properties of water.
- The activity also provides useful information for assessing student learning following the activity.

Time Frame

- 15 minutes

Teacher Preparation

Prepare the following materials for each group:

- Pens (several per group)
- Butcher paper (1 per group)
- Copies of Background Article for each student (1 per student)

Procedure

Divide students into groups of three or four and give each student a copy of the background reading. Have students read article either silently or aloud as a class. Once finished reading, give each group several markers and a large sheet of butcher paper. Ask students, "Why is water important to life?" Students should write their ideas on butcher paper. All ideas should be written down. Students can present their group's ideas to the rest of the class and then the ideas should be posted so students can refer back to their ideas during the remainder of the lesson. After this, ask students "What other liquids could do the same thing?" They can brainstorm either in their small groups or as a class.

Some sample comments that your students may offer include:

- "I don't know why, but life just needs it."
- "We're made mostly of water, so if we don't have it, we get dehydrated and die."
- "We need it to help with eating and digesting food."
- "We need the nutrients that are in water to survive."
- "I heard that we are made of 80-90% water so it must be important."
- "It's cool and refreshing."

Only rarely do students describe fundamental properties of water that make it useful for life on Earth, including its stability, solubility, abundance, polarity, lower density as solid than liquid, adhesion, cohesion, and specific heat. In the interest of time, this lesson focuses on the first three (evaporation, solubility, and abundance), rather than delving into all the properties that make water a favorable substance for life on Earth. Extension Activity 2 explores several of the latter properties.

PART 2: EASE OF EVAPORATION DISCUSSION AND PRE-LAB SETUP

Objectives

- Students discuss the concept of ease of evaporation. Through a class demonstration, students test the ease of evaporation of three solvents (water, oil, and rubbing alcohol).
- Introduce the property of solubility. Prepare students to conduct experiments on solubility.

Time Frame

- 40 minutes

Teacher Preparation

Prepare the following materials for the class discussion:

- Copies of Pre-Lab Questions (1 per student)

Prepare the following materials for the demonstration:

- 3 cups/graduated cylinders/containers
- Vegetable Oil
- Water
- Isopropyl Alcohol
- Permanent Marker

Procedure

1) Introduce Pre-lab

Pass out copies of the Pre-Lab Questions and explain that students will be considering the following characteristics of water and other liquids: solubility, stability, and abundance. Mention to students that due to limitations in time and easily testable materials, this investigation will be limited to three liquids: water, rubbing alcohol, and vegetable oil. These three liquids were chosen to help compare some fundamental differences between liquids on Earth. Explain that the class will first discuss ease of evaporation and do a demonstration using these liquids. Next, students will discuss solubility and conduct a laboratory experiment to test the solubility of each liquid. Finally, the group will discuss the abundances of these liquids during the post-lab.

2) Discuss and Demonstrate Ease of Evaporation

For ease of evaporation, discuss the three common phases of matter (solid, liquid, and gas) and the concept of phase changes. Ask students how you can convert liquid water into water vapor. Most students will respond that you can heat up the liquid water until it boils. Fewer students will discuss the possibility that water can evaporate below the boiling point of water. Have students answer the Pre-Lab Questions on Ease of Evaporation.

To demonstrate the ease of evaporation, measure a cupful of oil, water, and isopropyl alcohol into three separate labeled cups. *Use plastic cups since the alcohol tends to make paper cups leak if left overnight.* The amount of liquid does not matter as long as 1) there is enough that not all will evaporate before the next day (roughly 30-50 mL of each liquid, roughly a Dixie cup filled 2-3 cm, should work), and 2) the amounts of each liquid are exactly the same for all three

liquids. Note the amounts of each liquid by marking the liquid level on the cup, or by recording the precise volume using a graduated cylinder.

At the start of the next day, have students look at the cups and note changes to the liquid levels. The level on the oil should not change much at all. The water level should fall slightly, and the alcohol level should fall significantly. Have students add their observations to the first page of the Pre-Lab.

Discuss with students that some liquids evaporate more quickly than others at Earth temperatures and pressures. Note also that results depend on the local relative humidity. This difference is referred to as the liquid's ease of evaporation. Rubbing alcohol is not very stable as a liquid and therefore evaporates easily. Oil is very stable as a liquid and has a low ease of evaporation. Water will evaporate more quickly than vegetable oil but not as quickly as rubbing alcohol.

Some students may ask about differences in humidity and its effect on the evaporation rate of the liquids. Humidity is the amount of water in the air. When the air is dry, it has low humidity and will therefore take in liquid water more readily than air that is already full of water. This is an interesting discussion, but it should not affect student results significantly. Alcohol will still evaporate the most followed by water and then oil. If the air is too dry, both the alcohol and the water may evaporate completely. Be sure to add enough of all the liquids (roughly 30-50 mL) so that there is some left the next morning for students to observe the relative differences in evaporation.

End the conversation with a set of questions about why there are liquid bodies of water on Earth. Sample questions could include:

- If water eventually evaporates from the surface of Earth, why are there liquid oceans? *(Even though water is continually evaporating off the oceans, the oceans are refilled by precipitation.)*
- Where does the water go when it evaporates? *(Water that evaporates goes into the atmosphere. The atmosphere quickly saturates, though, resulting in clouds and precipitation.)*
- How do lakes/oceans get replenished with water? *(Through rain, snow, and other forms of precipitation.)*

Be sure to clarify that water is fairly easy to evaporate but is replenished through the water cycle on Earth. Water that evaporates into the atmosphere precipitates back to the surface through the water cycle.

3) Discuss Solubility and Prepare for Solubility Lab

After setting up the Ease of Evaporation Demonstration, continue class on the first day by explaining that next you will discuss another characteristic of liquids known as solubility. Discuss the following vocabulary terms:

Solubility	The amount of a substance (called the solute) that can be dissolved in a given amount of liquid (known as the solvent).
Dissolve	The act of taking one substance and combining it with another substance so that they mix to make a uniform solution of the two – when a substance disappears into a liquid.
Solute	A substance that is dissolved in another substance.
Solvent	Substances (usually liquid) capable of dissolving or dispersing one or more other substances.
Soluble	Capable of being dissolved in a solvent.
Partially soluble	When only part of a solute dissolves leaving the other part non-dissolved and usually still visible.
Insoluble	The inability of a substance to be dissolved in another substance.

Ask students to discuss what they already know about solubility. Below are some sample questions:

- Can solids change into liquids? *(Yes, by melting or dissolving in a liquid.)*
- Does sugar dissolve in anything? *(Yes, water. In this case, the sugar is called the solute and the water is called the solvent.)*
- What is a solute? *(Something that dissolves in a liquid.)*
- What is a solvent? *(A liquid in which something dissolves.)*
- Are there liquids in which sugar does not dissolve? *(Yes, oil.)*
- How do you know when something has dissolved in a solvent? *(You can't see any more solid on the bottom of the cup of liquid.)*

Sometimes you need to look carefully at the solvent because the solute particles may be suspended but not dissolved in the liquid. Tell students that during the lab, they may need to wait a few minutes after adding solid to the solvent in order to determine if the solid particles will settle out of the suspension, or if they are really dissolved.

During the remainder of the class, students should write up their procedures for conducting the solubility lab. Note that the current student worksheet sheet provides the lab objective and the materials list, but the rest of the lab is open-ended. It may be helpful to show students a sample setup with cups of solute, empty cups for solvent, and dispensers of water, alcohol, and oil. This may help them have a better idea of how to use these materials. Remind students that they do not need a large amount of solvent for each test (30-50 ml of solvent, roughly a Dixie cup filled roughly 2-3 cm, should work). A sample laboratory procedure is in included in Lab Answer Key. You may use this to help guide students who are having difficulty designing the experiment.

PART 3: SOLUBILITY LAB

Objective

- Students characterize the solubility of three solutes (salt, sugar, and cornstarch) in three solvents (water, vegetable oil, and rubbing alcohol).

Time Frame

- 30 minutes

Teacher Preparation

Prepare the following materials for each group:

- Cup 1 = sugar (half cup – enough for the entire experiment)
- Cup 2 = kosher salt (half cup)
- Cup 3 = cornstarch (half cup)
- 3 empty cups to use for testing
- 3 spoons (one for each of Cups 1-3 to dispense solutes)
- 3 coffee stirrers (or Popsicle sticks)
- Permanent marker (for labeling the testing cups)
- Graduated cylinder (optional)

Hazards

Isopropyl alcohol is poisonous. Alcohol should be used only in a well-ventilated room. Avoid contact with skin and ingestion. Caution students not to drink or taste any of the materials used in the lab.

Procedure

See Pre-Lab description above for details on preparing students for lab activity the day before. The lab is conducted on the second day after the class has looked at the results from the Ease of Evaporation Demonstration.

Pass out cups of the sugar, salt, and cornstarch as students review their lab procedure from the previous day. This will help students get a better idea of what these solutes look like and think about strategies for adding solutes to the three cups of solvents. Spoons should be used for one type of solute only in order to avoid contamination of the cups of solute. The teacher should pour the solvent into student testing cups after students have determined their lab procedure and decided how much solvent they will need. Remind students to use avoid using excessive amounts of solvent to conduct the experiment; rather, have them use a moderate amount of solvent (30-50 ml) with smaller amounts of solute. Explain that students will need to use a new cup of solvent for each solute test, even if the used solvent cup looks uncontaminated. Set up one or several liquid waste buckets in the classroom for students to quickly and cleanly dispose of their solvents in between experiments.

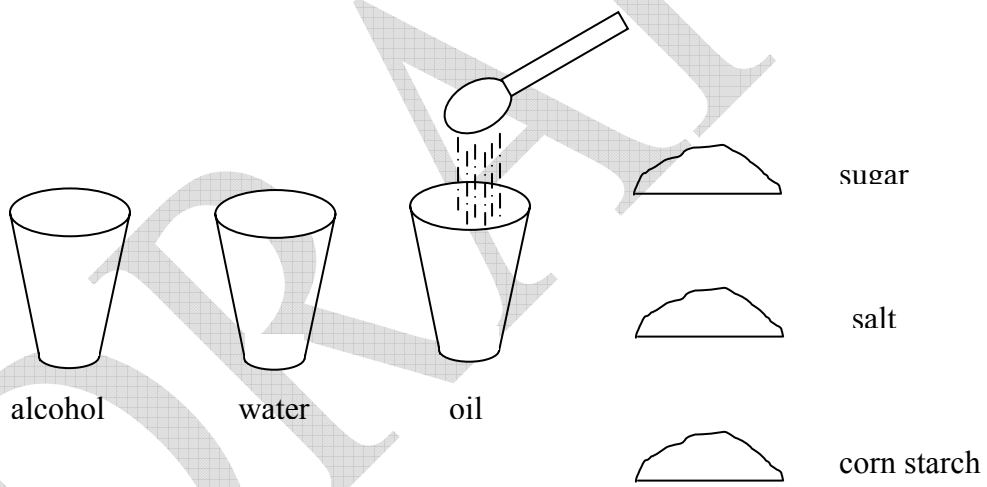
Have students complete the Solubility Lab. Show students the solvents and explain that they need to test all three solvents with all three of the solids in order to determine which solvents are

better than others. Explain that a solvent that dissolves a large amount of solute is defined as a "good solvent" and one that does not dissolve as much solute is a "poor solvent."

Students will use the worksheet to help them design their experiment. They should write a clear purpose, materials list, and procedure with their groups. Student groups should get their plan approved (with careful attention to the detail of the procedures) before they start the lab.

Students may need help with the idea that the quantities of solvent must be the same for all trials. Students should note if they think a solute is partially soluble, meaning that only some of the solute dissolved, since this may help students rank their solvents. If students are stuck, suggest that they add a spoonful of one solid to each solvent and see what happens. They can keep adding another spoonful to each solvent until only one solvent is able to dissolve the solid completely. (For example, if students add one spoonful of sugar to the oil, alcohol, and water, the oil will not dissolve any of the sugar, the alcohol may dissolve some, and the water may dissolve all. If this is the case, students should infer that oil is not a very good solvent for sugar, alcohol does fairly well, and water works the best.) Discuss the idea of a data table to help students keep their data organized.

The diagram below provides a cartoon sketch of the materials of a possible lab setup.



PART 4: POST-LAB QUESTIONS

Pass out the Post-Lab Questions handout and have students answer these questions in groups. Use the post-lab questions as an assessment of their understanding of solubility and evaporation and then discuss the results with students.

Emphasize to students the importance of considering more than just one property or characteristic of the liquids in deciding which is most important for life on Earth. Ask students what other properties of liquids could be considered in determining their importance for life. Also, ask students if there are other liquids that should be considered besides water, rubbing alcohol, and vegetable oil. Explain that due to limitations in class time and accessibility to safe

materials to test, the class was limited to these materials, but brainstorm other possible experiments and materials to use.

Finish by returning to the NASA strategy to "follow the water" in its current missions to Mars. Discuss reasons for this research goal with students based on what they have learned so far about evaporation, solubility, and abundance. It is useful for students to begin to think about why scientists are interested in planets that have, or have had, liquid water.

WHY FOLLOW THE WATER?
Pre-Lab Questions *(Answer Key)*

A key NASA strategy to look for current or past life on Mars involves "following the water" – looking for places where water currently or once existed on the planet. In this activity, we will consider some of reasons why liquid water is important for life on Earth and may be important for life on Mars. In particular, we will consider the properties of ease of evaporation, solubility, and abundance.

Ease of Evaporation

Even though a liquid may not boil at room temperature, it can still evaporate depending upon atmospheric conditions. If a liquid evaporates over the course of a few hours when set on a counter top, it is easy to evaporate. If a liquid can remain on a countertop for several days without evaporating, it is difficult to evaporate.

---

1) If you place a full cup of water out on a table in your classroom, will it start to boil? Why or why not?

   Water is stable to boiling at room temperature because the temperature is below the boiling temperature of the water at pressures found in the classroom.

2) If you leave a full cup of water out on the table overnight, would you expect the level of the water to increase, decrease, or stay the same by the next day? Explain your reasoning.

   Unless the atmosphere is at 100% relative humidity, some water can still evaporate away from the cup into the atmosphere. The water is not stable to evaporation. We would expect that some of the water will have evaporated into the air, reducing the amount of water in the cup. Students should not expect the cup to be completely empty because water does not evaporate quickly enough. A discussion about the differences in relative humidity of the air and how it would affect how much water would evaporate is relevant here if students understand what humidity is.

3) Now imagine that you leave three cups out on a table overnight. One is filled with water, the second with rubbing alcohol, and the third with vegetable oil. They are all filled with exactly the same amount of liquid. How would you expect the levels of each liquid to change by the next day? Which will evaporate the most? Explain your reasoning.

   This question requires students to hypothesize about the relative evaporation rates of three liquids. Answers will vary, and all answers are acceptable as long as students explain their reasoning.

Solubility

The *solubility* of a liquid describes how easy it is for another substance to dissolve in the liquid. If you dissolve a solid in a liquid, the solid is called the *solute* and the liquid is called the *solvent*. Following this pre-lab, you will design and conduct an experiment to test the solubility of three solvents (water, vegetable oil, and rubbing alcohol) using three solutes (salt, sugar, and cornstarch).

1) Two students dissolve a spoonful of salt into a container of water. Which substance is the solvent and which is the solute?

   A solvent is a liquid that can dissolve things, and a solute is the substance that is dissolved in the solvent. In this case, the salt is the solute and the water is the solvent.

2) Chocolate powder is soluble in milk. What does soluble mean?

   Soluble means that something will dissolve in the solvent listed. In this example, the chocolate powder will dissolve in the milk. There will be no more chocolate powder on the bottom of the glass once it has mixed.

3) Two students are preparing to do a solubility experiment. They carefully measure equal amounts of three solvents (water, oil, and rubbing alcohol) into different containers. They are now discussing ideas for testing the solubility of sugar in these liquids.

   Student 1: I think we should put ten spoonfuls of sugar into each cup. If the sugar is soluble, the solvent should be able to dissolve all of it. After we stir up the liquid, we'll see if the sugar has disappeared.

   Student 2: What if the solvent can dissolve one spoonful but not ten? If we dump too much sugar in at once, we won't know if the solvent could have dissolved a smaller amount. I think we should add a spoonful of the sugar at a time.

   Do you agree or disagree with either or both of these students? Explain your reasoning.

   If students follow the suggestion of Student 1, they may have difficulty determining if at least some of the sugar could dissolve in each liquid. Using the method suggested by Student 2, students will be able to see more easily if a small amount of solid dissolves. It is also important to note that both students suggested correctly that they should add the same amount of solute to each solvent in order to perform the experiment.

WHY FOLLOW THE WATER?
Solubility Lab *(Possible Procedure)*

Lab Objective: The purpose of this lab is to determine the relative solubility of the following solvents: water, rubbing alcohol, vegetable oil. You will have the following solutes to conduct this experiment: sugar, salt, and cornstarch.

Materials: Below is a list of materials for the lab. In the Procedure Section below, describe how you will use these materials to complete the lab objective.

Solvents:	water, rubbing alcohol, vegetable oil
Solutes:	sugar, cornstarch, salt
Other materials:	empty cups for solvents (3), spoons (3), stirrers (3), markers (1)

Procedure: (How will you do your experiment? Be sure to include step-by-step instructions, including the amounts of each substance you are using.)

1. *Obtain containers of solute and containers for solvents.*
2. *Label each of the 3 empty cups with the name of one of the solvents. Into one of the cups measure the amount of water students want to use and draw a line on the cup at the surface of the liquid. Then pour the water into another cup and mark the water level. Then pour the water into the third cup and mark the level again. This method will ensure that the volumes of the three solvents will be the same. (The volume of the solvents is not critical. A volume of 30 – 50 ml of solvent with good results.)*
3. *Add rubbing alcohol to the marked line in the cup labeled "ALCOHOL," add water to the marked line in the cup labeled "WATER," and add oil to the marked line in the cup labeled "OIL." Now there are three cups containing the same volumes of three different solvents.*
4. *Add a spoonful of sugar to each cup, stir with a coffee stirrer, and note if the solid dissolves in any of the solvents. If the sugar dissolves completely in two or more solvents, add an additional spoonful of solute to each solvent and stir. Keep adding a spoonful at a time until there is only one solvent which is still able to dissolve the sugar completely. This last solvent is not yet "saturated" with the solute and you could conceivably continue to add more.*
5. *Note the number of "doses" of sugar added to the solution before the solvent was saturated since it will be helpful in ranking the solvents if students know which solvents dissolved more of each solute. A suggested data table is below.*

Solvent	***Solute***	***# of spoonfuls***	***Observations (soluble, insoluble, partially soluble)***
Water	*Sugar*	*Answers will vary.*	*Soluble*
Oil	*Sugar*	*Answers will vary.*	*Insoluble*
Alcohol	*Sugar*	*Answers will vary.*	*Partially Soluble*
Water	*Salt*	*Answers will vary.*	*Soluble*
Oil	*Salt*	*Answers will vary.*	*Insoluble*
Alcohol	*Salt*	*Answers will vary.*	*Partially Soluble*
Water	*Cornstarch*	*Answers will vary.*	*Insoluble*
Oil	*Cornstarch*	*Answers will vary.*	*Soluble*
Alcohol	*Cornstarch*	*Answers will vary.*	*Insoluble*

6. *After all observations using sugar as the solute are recorded, pour the solvents into a waste bucket (or down the sink).*
7. *Redo Steps #3-#6 for salt*
8. *Redo Steps #3-#6 for cornstarch.*
9. *Analyze the results and rank the solvents in terms of their ability to dissolve the solutes in the experiment.*

Observations and Results: (What did you find out? Rank the solvents from best solvent to worst solvent.)

Water dissolved sugar and salt, alcohol dissolved some sugar and some salt, and oil dissolved cornstarch. Water is the best solvent for these three solutes tested. Best solvent to worst solvent: Water, Alcohol, Oil. Since this is a qualitative experiment, students may have ranked their solvents differently. Discuss reasons for the differences in results (different quantities of solvent, differences in observations, experimental error, differences in criteria for measuring good solvents, etc.) Students should have reasons for ranking the solvents the way they do. For example, students may say the oil looks like it dissolved the cornstarch but it is possible that it could be a suspension of particles, and therefore oil is the worst solvent. Students may say that the alcohol is the worst solvent because it took a lot longer than to dissolve solutes than the other solvents.

WHY FOLLOW THE WATER?
Post-Lab Questions *(Answer Key)*

Ease of Evaporation

1) Based on your discussion about ease of evaporation, rank water, oil, and alcohol from the easiest to evaporate to the hardest to evaporate.

   Rubbing alcohol is the easiest to evaporate, water is next, and vegetable oil is the hardest to evaporate.

2) Based upon the results regarding evaporation ALONE, which liquid would you expect to be the most useful for life? Explain your reasoning.

   Based ONLY on the fact that vegetable oil is more stable to evaporation than water or rubbing alcohol, students might guess that vegetable oil is the most important liquid for life. This experiment introduces the concept that we can measure and compare properties of various substances.

Solubility Experiment

3) With the three solutes tested in the solubility lab, which liquid was the worst solvent (water, rubbing alcohol, or vegetable oil)? Explain your reasoning.

   Students will find that the vegetable oil was a worse solvent than water and rubbing alcohol for the solutes tested.

4) Sugars, salts, and other solutes need to be able to move into, out of, and inside cells in order to carry out the basic functions of life. If a cell composed of mostly the liquid you listed in Question 3, would the cell still be able to transport solutes easily around the cell? Explain your reasoning.

   If a cell were composed of mostly oil, sugars and salts would not be easily dissolved and would therefore not be able to move around inside the cell as easily as with a cell filled with water. The sugars and salts also would not be able to react with other molecules because they would remain in their less active, solid state.

5) Based upon the results of the solubility experiment, rank the three liquids from highest solubility to lowest solubility.

   Students should find that water has the highest solubility, rubbing alcohol is next, and vegetable oil has the lowest solubility. Some students may have difficulty distinguishing between the solubility of rubbing alcohol and water.

6) Based upon the results of the solubility experiment ALONE, which liquid would you expect to be the most useful for life? Explain your reasoning.

   Water is important to living things because it can be used to dissolve solids such as sugars and salts Chemical reactions can occur more easily when these molecules are dissolved in a solvent such as water. Water can serve as a good solvent for dissolving and transporting these molecules necessary for life.

Abundance at the Surface of the Earth and Other Properties

A final characteristic we will consider is the abundance or amount of liquid present at or near the surface of the Earth. The table below lists the abundances of rubbing alcohol, crude oil, and water at or near the surface of the Earth in units of cubic miles. Crude oil and vegetable oil have similar solubility and evaporation properties, but there is much more crude oil present at or near the surface of the Earth than vegetable oil.

Solvent	**Abundance (in cubic miles)**
Rubbing Alcohol	Trace amounts
Crude Oil	42
Water	330,000,000 (330 million)

7) What do you notice about the abundance of water near the surface of the Earth compared to other two liquids?

There is way more water at the surface of the earth than there is crude oil or alcohol. Given that the amount of vegetable oil is significantly lower than crude oil, we still conclude that water is much more abundant than the two liquids testing in the solubility and evaporation labs.

8) Based upon abundance ALONE, which liquid would you expect to be the most useful for life? Justify your answer.

Because water is so much more abundant than the other two liquids, students will guess that water is the most important liquid for life.

9) In this activity, we have tested only three liquids (water, vegetable oil, and rubbing alcohol) for three properties (solubility, evaporation, and abundance). List some other liquids we could test if we had more time and resources. What are some additional properties that could be investigated?

Due to limited time and resources along with safety concerns, we only tested three solutes in three solvents. There may be other solvents that are effective at dissolving solids and we could have also tested many additional solutes. While the lab shows that water is a "good" solvent, it does not prove that it is the "best" solvent for all materials. Other possible liquids include ammonia, vinegar, and hydrogen peroxide. Other properties to test for include specific heat, density, boiling point, melting point, and polarity.

Conclusions

10) Now consider all three liquid characteristics we have investigated. Complete the following table based upon the results of our three investigations. In each column, rank the solvents from high (1) to low (3) in terms of their solubility, ease of evaporation, and abundance at or near the surface of the Earth.

Solvent	**Solubility**	**Ease of Evaporation**	**Abundance**
Water	Higher than oil (1 or 2)	2	1
Oil	Lower than water (2 or 3)	1	2
Rubbing Alcohol	Answers will vary (1, 2, or 3)	3	3

11) Based upon all three properties considered TOGETHER, decide which liquid (water, oil, rubbing alcohol) is probably most important for life on Earth. Explain your reasoning.

Based upon the table, water is the most suitable solvent for life on Earth. While oil is more stable to evaporation, there is simply more water present at or near the surface of our planet and water also is a better solvent. While rubbing alcohol is a reasonable solvent, it is very unstable to evaporation and has very low abundance.

12) NASA scientists looking for evidence of life on Mars think it is important to "follow the water." Why do you think scientists link the presence of water on other planets to possible life there?

Finding signs of liquid water on other planets is exciting because scientists know that water is an important solvent to life forms on Earth. Since scientists know that water is important to life as we know it, they can guess that if there is water-based life on another planet, it should be located where there is liquid water. With water available, there is a possibility that water-based life could have been present. On Mars, the best possibility for finding evidence of water-based life is to look where there is or was liquid water.

OVERALL ASSESSMENT

Ask students to write a response to the following questions:

- Why is water important to life on Earth?
- Why should NASA "follow the water" on Mars?

In their responses, students should demonstrate their knowledge of the solvent nature of water and the abundance and evaporation of water on Earth. Students should be able to use the information they have learned about water to describe why water is important to life on Earth. They should also discuss why scientists plan to look for evidence of life where liquid water exists on other planets. Use the following rubric for grading.

	Exceeds Standards	**Meets Standards**	**Approaches Standards**	**Falls Far Below Standards**
Solvent Content	Solvent lab conclusions reported and extended to include predictions about other solvents, conclusions justified, many details and evidence used to relate results to the importance of water. (4)	Solvent lab conclusions reported, conclusions justified, results related to the importance of water using several details and evidence. (3)	Solvent lab conclusions reported, one of the following incomplete or missing: -conclusions justified -results related to the importance of water using several details and evidence. (2)	Two or more of the following missing or incomplete: -solubility lab conclusions reported -conclusions justified -results related to the importance of water using several details and evidence. (1)
Evaporation Content	Evaporation lab conclusions reported and extended to include predictions about other liquids, conclusions justified, many details and evidence used to relate results to the importance of water. (4)	Evaporation lab conclusions reported, conclusions justified, results related to the importance of water using several details and evidence. (3)	Evaporation lab conclusions reported, one of the following incomplete or missing: -conclusions justified -results related to the importance of water using several details and evidence. (2)	Two or more of the following missing or incomplete: -evaporation lab conclusions reported -conclusions justified -results related to the importance of water using several details and evidence. (1)
Plant Productivity Content	Plant productivity connections reported and extended to include predictions about unlisted biomes, conclusions justified, many details and evidence used to relate results to the importance of water. (4)	Plant productivity connections reported, conclusions justified, results related to the importance of water using several details and evidence. (3)	Plant productivity connections reported, one of the following incomplete or missing: -conclusions justified -results related to the importance of water using several details and evidence. (2)	Two or more of the following missing or incomplete: -plant productivity connections reported -conclusions justified -results related to the importance of water using several details and evidence. (1)
"Follow the water" Defense	Detailed description of NASA's "follow the water" goal, many reasons and details explaining why NASA should follow the water. (4)	Detailed description of NASA's "follow the water" goal, several reasons and details explaining why NASA should follow the water. (3)	Incomplete or missing one of the following: -description of NASA's "follow the water" goal -reasons and details explaining why NASA should follow the water. (2)	Incomplete or missing both: -description of NASA's "follow the water" goal -reasons and details explaining why NASA should follow the water. (1)
Writing		Paper is well organized, detailed, clear, and free of spelling/grammar mistakes. (3)	Missing one of the following traits: -well organized -detailed -clear -free of spelling/grammar mistakes (2)	Missing two or more of the following traits: -well organized -detailed -clear -free of spelling/grammar mistakes (1)

REFERENCES

http://mars-scout.larc.nasa.gov/PDF_FILES/MPE_Plan-Signed_2005log-3_2.pdf

EXTENSION ACTIVITY

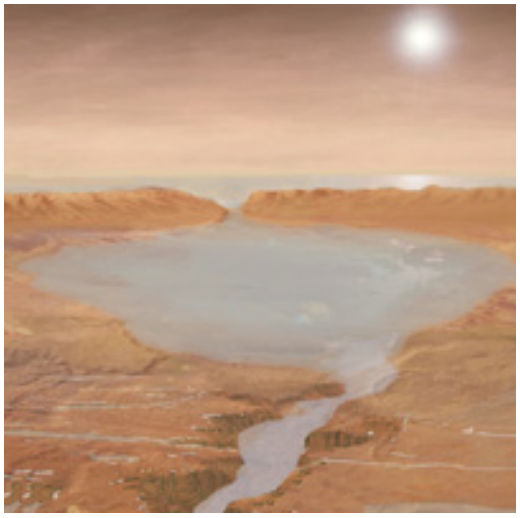
Extension Activity: Connection Between Plant Productivity and Soil Moisture

Mars: A Dry Planet Compared to Earth

When we look at Mars today, we see a planet without the deep blue oceans, lakes, and rivers that our own planet has in abundance. If Earth is the "big blue marble," then Mars is the red, dusty one. Many scientists believe, however, that Mars once had much more water than is visible today. Billions of years ago, Earth and Mars might have been very similar places.

But if Mars once had lots of water, where did it go? The answer to that question is one of the greatest mysteries we hope to solve in our exploration of Mars.

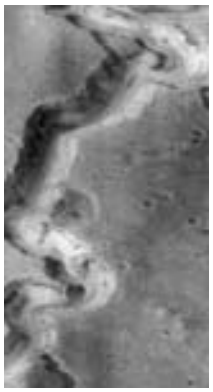
Follow the Water



If there is any liquid water flowing onto the surface of Mars today from below ground, it doesn't last long. Temperature and pressure conditions on the surface would either freeze or "evaporate" it right away.

Without a clear presence of surface water, it may seem strange that the science strategy for Mars exploration is "to follow the water." How can we do that, when it doesn't seem like there is any to be found?

Following the water really means looking for scientific evidence that water was present in the past or is present today, either below the surface or possibly in rare locations near small, hydrothermal vents like those we might find at Yellowstone. Our Mars missions have already sent back views of the Martian surface that seem to show evidence of dry riverbeds, flood plains, rare gullies on Martian cliffs and crater walls, and sedimentary deposits that suggest the presence of water at some point in the history of Mars.



The Story of Water on Mars: Follow the Evidence

Take a look at our images from Mars, and be your own detective in looking for clues that indicate the past or present presence of water.

Coming Soon! In the meantime, follow "The Case of the Missing Mars Water," brought to you by NASA Science News.

FUN ZONE: **Extreme Planet! | Follow the Water | Mars Rocks | Life on Mars? | The Martian Mystique | Just for Kids**

Last Updated: 17 Oct 2002
22:44:11 UTC

Why Follow the Water?
Student Guide

Pre-Lab Questions

A key NASA strategy to look for current or past life on Mars involves "following the water" – looking for places where water currently or once existed on the planet. In this activity, we will consider some of reasons why liquid water is important for life on Earth and may be important for life on Mars. In particular, we will consider the properties of ease of evaporation, solubility, and abundance.

Ease of Evaporation

Even though a liquid may not boil at room temperature, it can still evaporate depending upon atmospheric conditions. If a liquid evaporates over the course of a few hours when set on a counter top, it is easy to evaporate. If a liquid can remain on a countertop for several days without evaporating, it is difficult to evaporate.

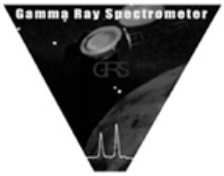
---

1) If you place a full cup of water out on a table in your classroom, will it start to boil? Why or why not?

2) If you leave a full cup of water out on the table overnight, would you expect the level of the water to increase, decrease, or stay the same by the next day? Explain your reasoning.

3) Now imagine that you leave three cups out on a table overnight. One is filled with water, the second with rubbing alcohol, and the third with vegetable oil. They are all filled with exactly the same amount of liquid. How would you expect the levels of each liquid to change by the next day? Which will evaporate the most? Explain your reasoning.

Why Follow the Water?
Student Guide



Solubility

The *solubility* of a liquid describes how easy it is for another substance to dissolve in the liquid. If you dissolve a solid in a liquid, the solid is called the *solute* and the liquid is called the *solvent*. Following this pre-lab, you will design and conduct an experiment to test the solubility of three solvents (water, vegetable oil, and rubbing alcohol) using three solutes (salt, sugar, and cornstarch).

1) Two students dissolve a spoonful of salt into a container of water. Which substance is the solvent and which is the solute?

2) Chocolate powder is soluble in milk. What does soluble mean?

3) Two students are preparing to do a solubility experiment. They carefully measure equal amounts of three solvents (water, oil, and rubbing alcohol) into different containers. They are now discussing ideas for testing the solubility of sugar in these liquids.

   Student 1: I think we should put ten spoonfuls of sugar into each cup. If the sugar is soluble, the solvent should be able to dissolve all of it. After we stir up the liquid, we'll see if the sugar has disappeared.

   Student 2: What if the solvent can dissolve one spoonful but not ten? If we dump too much sugar in at once, we won't know if the solvent could have dissolved a smaller amount. I think we should add a spoonful of the sugar at a time.

   Do you agree or disagree with either or both of these students? Explain your reasoning.

WHY FOLLOW THE WATER?
Solubility Lab

Lab Objective: The purpose of this lab is to determine the relative solubility of the following solvents: water, rubbing alcohol, vegetable oil. You will have the following solutes to conduct this experiment: sugar, salt, and cornstarch.

Materials: Below is a list of materials for the lab. In the Procedure Section below, describe how you will use these materials to complete the lab objective.

Solvents:	water, rubbing alcohol, vegetable oil
Solutes:	sugar, cornstarch, salt
Other materials:	empty cups for solvents (3), spoons (3), stirrers (3), markers (1)

Procedure: (How will you do your experiment? Be sure to include step-by-step instructions, including the amounts of each substance you are using.)

Observations and Results: (What did you find out? Rank the solvents from best solvent to worst solvent.)

WHY FOLLOW THE WATER?
Post-Lab Questions

Ease of Evaporation

1) Based on your discussion about ease of evaporation, rank water, oil, and alcohol from the easiest to evaporate to the hardest to evaporate.

2) Based upon the results regarding evaporation ALONE, which liquid would you expect to be the most useful for life? Explain your reasoning.

Solubility Experiment

3) With the three solutes tested in the solubility lab, which liquid was the worst solvent (water, rubbing alcohol, or vegetable oil)? Explain your reasoning.

4) Sugars, salts, and other solutes need to be able to move into, out of, and inside cells in order to carry out the basic functions of life. If a cell composed of mostly the liquid you listed in Question 3, would the cell still be able to transport solutes easily around the cell? Explain your reasoning.

5) Based upon the results of the solubility experiment, rank the three liquids from highest solubility to lowest solubility.

6) Based upon the results of the solubility experiment ALONE, which liquid would you expect to be the most useful for life? Explain your reasoning.

Abundance at the Surface of the Earth and Other Properties

A final characteristic we will consider is the abundance or amount of liquid present at or near the surface of the Earth. The table below lists the abundances of rubbing alcohol, crude oil, and water at or near the surface of the Earth in units of cubic miles. Crude oil and vegetable oil have similar solubility and evaporation properties, but there is much more crude oil present at or near the surface of the Earth than vegetable oil.

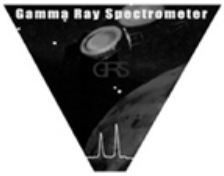
Solvent	**Abundance (in cubic miles)**
Rubbing Alcohol	Trace amounts
Crude Oil	42
Water	330,000,000 (330 million)

7) What do you notice about the abundance of water near the surface of the Earth compared to other two liquids?

8) Based upon abundance ALONE, which liquid would you expect to be the most useful for life? Justify your answer.

9) In this activity, we have tested only three liquids (water, vegetable oil, and rubbing alcohol) for three properties (solubility, evaporation, and abundance). List some other liquids we could test if we had more time and resources. What are some additional properties that could be investigated?

Why Follow the Water?
Student Guide



Conclusions

10) Now consider all three liquid characteristics we have investigated. Complete the following table based upon the results of our three investigations. In each column, rank the solvents from high (1) to low (3) in terms of their solubility, ease of evaporation, and abundance at or near the surface of the Earth.

Solvent	**Solubility**	**Ease of Evaporation**	**Abundance**
Water			
Oil			
Rubbing Alcohol			

11) Based upon all three properties considered TOGETHER, decide which liquid (water, oil, rubbing alcohol) is probably most important for life on Earth. Explain your reasoning.

12) NASA scientists looking for evidence of life on Mars think it is important to "follow the water." Why do you think scientists link the presence of water on other planets to possible life there?

Why Follow the Water? Extension
Teacher Guide
Connection Between Plant Productivity and Soil Moisture

OBJECTIVE
Students note the correlation between annual precipitation and plant productivity in different biomes (major regional biological communities) on Earth.

TIME FRAME
- 1 class period (50 minutes)

MATERIALS
- Copies of Student Worksheet (1 per student)
- Images of various biomes (optional)

PROCEDURE

Discuss the idea of annual precipitation with students. Students should understand that this is a measure of all the precipitation collected for a full year in a region. Annual precipitation is averaged over several years to determine a value that shows trends over time, averaging out extremes like drought and flood years. Next, discuss the idea of plant productivity with students. The plant productivity of a region is the mass of all plant matter produced in a year in a given area. Plant productivity characterizes the quantity or mass of plants that a given region supports.

Discuss the idea of biomes with students. A biome is a major regional biological community, typically characterized by the dominant forms of plant life and the climate of the region. Provide examples of various biomes, such as desert, grassland, rainforest, and arctic tundra. It may be useful to show pictures of the biomes during the discussion. As an extension, students can research particular biomes before class and present information about the flora, fauna, and climate to the class as an introduction to the activity. This data can be posted for reference throughout the activity. The following website may be a useful reference:

http://www.blueplanetbiomes.org/climate.htm

Two slightly different versions of the student worksheet are provided. The first provides information about plant productivity and annual precipitation in a sorted table format. The second provides this same information in a graph format. You can choose to use either or both of these extension activities. Finally, you could have students graph the information from the table in the first version of the lesson to reinforce graphing skills. Students should complete the worksheet in pairs and discuss the idea that where there is a lot of water available, more life is supported. Where there is less water available, there is not as much life.

WHY FOLLOW THE WATER?
Precipitation and Plant Productivity Table *(Answer key)*

The following table lists annual plant productivity and annual precipitation for different biomes (major regional biological communities) around the world. A*nnual plant productivity* is the amount of plant material produced over the course of a year in a given amount of land area. It is measured in grams per square meter. *Annual precipitation* is the total amount of water falling over a region over the course of a year. This water typically falls as rain or snow. Annual precipitation is measured as collecting rain, snow, and other forms of precipitation and is measured in units of centimeters.

Biome	Annual Plant Productivity (grams/square meter)	Annual Precipitation (centimeters)
Extreme desert	3	0-30
Tundra and alpine	140	10-80
Temperate grassland	600	20-100
Boreal forest	800	40-170
Savanna	900	30-130
Temperate deciduous forest	1200	50-220
Temperate evergreen forest	1300	140-350
Tropical rainforest	2200	110-450

1) Which of the biomes has the smallest annual precipitation?

   Extreme desert

2) Which of the biomes has the least plant productivity?

   Extreme desert

3) Which of the biomes has the highest reported annual precipitation?

   Tropical Rainforest

4) Which of the biomes has the most plant productivity?

   Tropical Rainforest or temperate evergreen forest

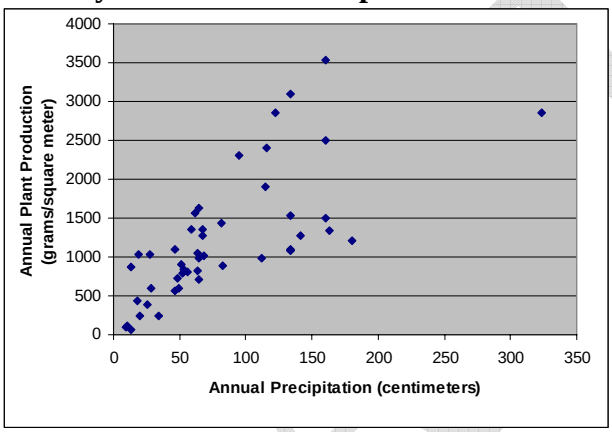
5) What conclusions can you draw regarding the relationship between precipitation and plant productivity?

   It looks like there is a relationship. Where there is low precipitation (extreme desert), there is a low amount of plant productivity. Where there is high precipitation (tropical rainforest), there is a high amount of plant productivity. This makes sense because where there is a lot of water, more plants can live and where there is not very much water available, there will be few plants.

WHY FOLLOW THE WATER?
Precipitation and Plant Productivity Graph *(Answer key)*

The following graph shows the relationship between annual plant productivity and annual precipitation for different biomes (major regional biological communities) around the world. A*nnual plant productivity* is the amount of plant material produced over the course of a year in a given amount of land area. It is measured in grams per square meter. *Annual precipitation* is the total amount of water falling over a region over the course of a year. This water typically falls as rain or snow. Annual precipitation is measured as collecting rain, snow, and other forms of precipitation and is measured in units of centimeters.

Plant Productivity and Annual Precipitation for Different Biomes



1) What are the units of precipitation shown on the graph above?

   Centimeters.

   What are the units of plant productivity shown on the graph above?

   Grams per square meter.

2) Do you think that it is easier or harder for plants to grow in a place with high plant productivity?

   Easier.

3) In general, does annual plant productivity increase, decrease, or stay the same as annual precipitation increases? Justify your answer.

   It increases.

4) What conclusions can you draw regarding the relationship between precipitation and plant productivity? Explain your reasoning.

   As precipitation increases, plant productivity increases. This shows that the more water available to plants, the more they will grow.

WHY FOLLOW THE WATER?
Precipitation and Plant Productivity Table

The following table lists annual plant productivity and annual precipitation for different biomes (major regional biological communities) around the world. A*nnual plant productivity* is the amount of plant material produced over the course of a year in a given amount of land area. It is measured in grams per square meter. *Annual precipitation* is the total amount of water falling over a region over the course of a year. This water typically falls as rain or snow. Annual precipitation is measured as collecting rain, snow, and other forms of precipitation and is measured in units of centimeters.

Biome	Annual Plant Productivity (grams/square meter)	Annual Precipitation (centimeters)
Extreme desert	3	0-30
Tundra and alpine	140	10-80
Temperate grassland	600	20-100
Boreal forest	800	40-170
Savanna	900	30-130
Temperate deciduous forest	1200	50-220
Temperate evergreen forest	1300	140-350
Tropical rainforest	2200	110-450

1) Which of the biomes has the smallest annual precipitation?

2) Which of the biomes has the least plant productivity?

3) Which of the biomes has the highest reported annual precipitation?

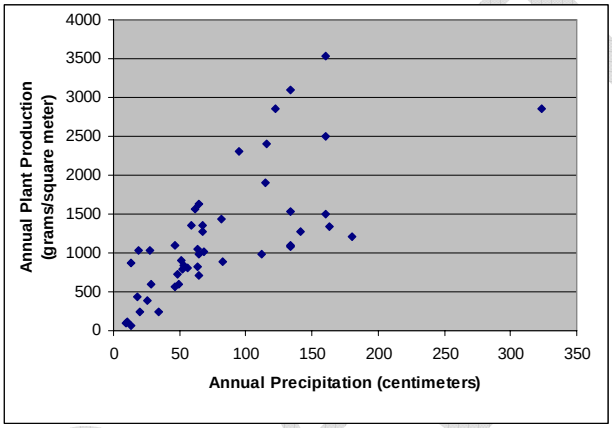
4) Which of the biomes has the most plant productivity?

5) What conclusions can you draw regarding the relationship between precipitation and plant productivity?

WHY FOLLOW THE WATER?
Precipitation and Plant Productivity Graph

The following graph shows the relationship between annual plant productivity and annual precipitation for different biomes (major regional biological communities) around the world. A*nnual plant productivity* is the amount of plant material produced over the course of a year in a given amount of land area. It is measured in grams per square meter. *Annual precipitation* is the total amount of water falling over a region over the course of a year. This water typically falls as rain or snow. Annual precipitation is measured as collecting rain, snow, and other forms of precipitation and is measured in units of centimeters.

Plant Productivity and Annual Precipitation for Different Biomes



1) What are the units of precipitation shown on the graph above?

   What are the units of plant productivity shown on the graph above?

2) Do you think that it is easier or harder for plants to grow in a place with high plant productivity?

3) In general, does annual plant productivity increase, decrease, or stay the same as annual precipitation increases? Justify your answer.

4) What conclusions can you draw regarding the relationship between precipitation and plant productivity? Explain your reasoning.