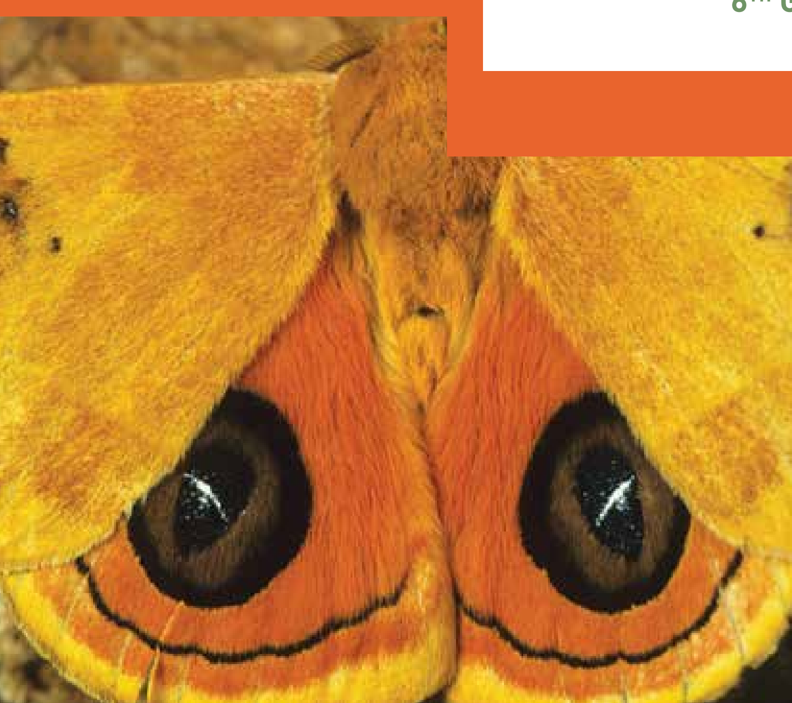
EDUCATION PROJECT

Desert to Rainforest

A middle school learning experience for diverse cultures and habitats in Arizona and Panama

TEACHER'S GUIDE

6TH GRADE



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Smithsonian Tropical Research Institute

ASU SCHOOL OF Life Sciences ARIZONA STATE UNIVERSITY

ASU Mary Lou Fulton Teachers College ARIZONA STATE UNIVERSITY

Audubon ARIZONA

MEDUCA PARA TODA LA VIDA MINISTERIO DE EDUCACIÓN

PHOENIX UNION HIGH SCHOOL DISTRICT

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INTRODUCTION

Desert to Rainforest

INTRODUCTION

Dear Educators:
Welcome to Desert to Rainforest! This curriculum aims to teach middle school children in two countries, Panama and the United States, about the wonders of deserts and tropical rainforests, the unique plant and animal diversity found in each ecosystem, and how organisms have adapted to life in these very distinct environments. Children may be surprised to learn just what these environments have in common. For example, water plays a vital role in both ecosystems, and many of the same animal and plant species occur in both. And, of course, there are the people living in these areas – offering children an opportunity to explore life in the Rio Salado and the Panama Canal watersheds, learn about each other's cultures, and think about the conservation challenges these communities face.

The curriculum targets children at a Grade 6 level. The activities herein align with several of the content standards and science and engineering practices of the National Research Council's *A Framework for K-12 Science Education Standards*, as well as the Common Core State Standards. The major thematic concepts woven into the activities are:

1. How does life for people differ between the Rio Salado and Panama Canal watersheds?
2. What are tropical rainforests? What are deserts?
3. How have plants, animals and other organisms adapted to life in these unique environments?
4. What role does water play in the desert and in tropical forests? Is water more important in the one environment than the other? What are water cycles and watersheds?
5. Does the diversity of life in deserts and rainforests differ? Why?
6. What are some conservation issues in these areas? How can we address them?

Some of the modules require or suggest the use of materials that will need to be procured well in advance of the lesson. The water monitoring kits in Module 2C can be ordered from www.lamotte.com.

You are welcome to reproduce any of the classroom lesson plans and field activities. Please give credit to the originating institution and Desert to Rainforest. We welcome your comments and suggestions for additional activities at any time.

— Desert to Rainforest Education Team

OBJECTIVES AND IMPACTS

Desert to Rainforest

OBJECTIVES AND IMPACTS

The goals of the Desert to Rainforest curriculum are to improve critical thinking skills and science know-how among middle school students; heighten student interest in scientific research and the scientific process; deepen knowledge of diverse habitats; and, foster greater understanding and appreciation of cultural diversity. The modules also capitalize on new educational technologies.

Most curriculum modules includes activities that stress key skills in scientific inquiry:

- Asking questions
- Conducting investigations
- Constructing explanations
- Analyzing and interpreting data
- Obtaining, evaluating, and communicating information

> ***Science cannot advance if scientists are unable to communicate their findings clearly and persuasively or to learn about the findings of others. A major practice of science is thus the communication of ideas and the results of inquiry - orally, in writing, with the use of tables, diagrams, graphs, and equations, and by engaging in extended discussions with scientific peers.***
>
> \- The Framework for K-12 Science Education

A NOTE ABOUT COMMUNICATING RESULTS...

Communicating results is an essential part of this curriculum and the scientific process generally. Both the Next Generation Science Standards and the Common Core State Standards stress the role communication plays in advancing both the education of our children and science itself.

While the modules have been designed with specific communication tools and activities in mind, they represent but one way students can communicate the results of their inquiry. If these tools are unavailable, teachers have a range of creative possibilities. "Low-tech" options include discussions among classmates or with students in neighboring classes, or presentations at a parent "Science Night." Depending upon available resources, students could make videos or audio-record themselves as "guest scientists" on a fictitious radio program.

CURRICULUM

Desert to Rainforest

CURRICULUM

THE MODULES ARE ORGANIZED AS FOLLOWS:

MODULE 1 | BUILDING BRIDGES
Life in Arizona and Panama

MODULE 2 | THE IMPORTANCE OF WATER
The role of water in the desert and rainforest

MODULE 3 | BIOMES
How plants, animals and other organisms adapt to these unique habitats

MODULE 4 | DIVERSITY
The diversity and wonders of life in deserts and rainforests

MODULE 5 | CONSERVATION
Exploring conservation challenges in both environments and coming up with solutions

MODULE 1

BUILDING BRIDGES

Desert to Rainforest

MODULE 1 | BUILDING BRIDGES

Question: How does life differ between the Rio Salado and Panama Canal watersheds?

Background research: Students will answer a series of questions (see below), then form collaborative answers as a class. Students will then be introduced (via research or provided materials) to the culture of their counterparts.

Hypothesis: In groups, students will hypothesize how the answers to these questions will differ between countries. Students will then share their hypothesis with the class and form a collaborative hypothesis.

Test hypothesis: Students share their responses with their counterparts in the other country.

Analyze data: Using the answers they obtained, students will analyze their hypotheses for accuracy.

Communicate results: Using Vidyo to share with their counterparts, students will report on their initial responses, what they learned, and their final conclusions.

Optional homework: Students have parents answer the same list of questions and repeat this activity to see how the lives of adults differ between countries.

DESERT TO RAINFOREST CLASSROOM INTRODUCTIONS

Describe your community and explain whether it is urban, rural, or suburban?

What major landforms or waterways are in your area?

What are some interesting tourist attractions near your community?

If you could have your favorite food, what would it be?

When does your school year start and end?

What time does the school day begin and end?

What types of sports do you play?

What kinds of music do you like?

How do students arrive at school?

What important holidays does your school observe? Are these holidays considered vacation days from school?

MODULE 2

THE IMPORTANCE OF WATER

Desert to Rainforest

MODULE 2 | DESERTS, RAINFORESTS AND WATER

In this module, students use journaling, lab and water monitoring activities, and interactions with scientists to learn about tropical rainforest and desert ecosystems, the water cycle, and watersheds. Students will better understand concepts and scientific processes, and learn about human impacts on the systems.

MODULE 2A | LECTURES

PROCEDURE

Duration: Three 50-minute class periods

DAY 1

1. **Readings (hand out readings the day before):** Teachers will print and hand out Readings 1 & 2 to students to acquaint them with two distinct ecosystems. The first reading pertains to the importance of tropical rainforests and how water moves through the rainforest. The second describes a desert, its extremes conditions, and the role water, or lack of it, plays in the desert.

2. **Viewing (20 minutes):** Students view video / PowerPoint on the rainforest: *Barro Colorado: The Rainforest Biome (*English or Spanish*)*; *River Pathways: Introduction to Riparian Areas*.

3. **Viewing (Optional):** Students can view two other videos by the same videographers: *Barro Colorado Island: A Behind the Scenes Look at the Science and Scientists of the Island* (in English /Spanish); *Barro Colorado: Biodiversity* (in English/Spanish); *River Pathways, Audubon Arizona*. (www.youtube.com/watch?v=GGLZKqVW7MQ)

4. **Journaling activity (15 minutes):** Ask students to write definitions of a desert or rainforest in their own words, and make sketches of some of the terms or ideas (e.g., rainforest, desert, canopy, throughfall, virga rain, evaporation, condensation, transpiration). Give students time to reflect on the terminology.

DAY 2

1. **Scientist Presentations / Field Trips (2 hours):** Following completion of the readings and activities, scientists from the Smithsonian Tropical Research Institute talk to students in Panama about the benefits of tropical forests, and how forests act like sponges. Options for the location of the talk are Punta Culebra Nature Center and / or via Vidyo. Students in Arizona may watch via Vidyo. Likewise, a scientist from Arizona State University or guest speaker from Audubon Arizona will be invited to talk to students about the desert, in person or through Vidyo, with Panamanian counterparts invited to join in by Vidyo.

2. **Letter to the Principal (Homework Assignment):** After the guest speakers have given their presentations, ask students to write a short letter to their principal in their journal. (1-2 pages) The letter should explain what they are learning in class. Encourage students to use vocabulary words from the readings and the last guide. Guide the students with questions such as: What have you learned about tropical rainforests and their diverse benefits? What have you learned about deserts? What have you learned about the movement of water in deserts or rainforests? How does deforestation affect water flows and climate change in forests?

READING 1 | WHY ARE TROPICAL FORESTS IMPORTANT?

Forests provide homes for plants and animals, and houses for humans

Tropical rainforests provide numerous benefits, including habitats for about 30 million plants, animals, and other creatures - that is half of the world's wildlife and at least two-thirds of its plants! Scientists continue to discover new species every day.

Think about all the things you use every day that come from the forest. People use timber to build houses, furniture, and a variety of household products. It may surprise you to know that many medicines that help us when we are sick also originate from tropical plants. Many foods, such as fruits, nuts, coffee, and spices, and industrial materials such as fibers for making items from bamboo or liana (vines), as well as resins and rubber were originally found in tropical rainforests.

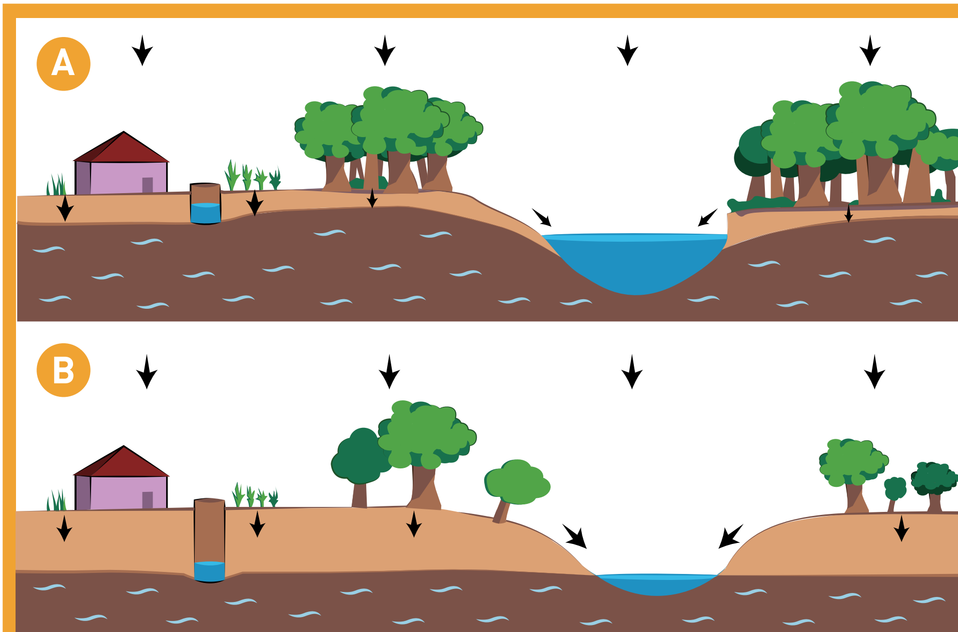
Forests regulate climate

Forests provide many valuable functions. Trees cleanse the atmosphere by absorbing the carbon dioxide that we exhale and providing the oxygen we need to breathe. They also store carbon. Like water, carbon is a building block of life. When people cut down or burn forests, a lot of carbon is released into the air in the form of carbon dioxide, which traps heat from the sun and changes the climate. Deforestation is a major cause of climate change, more so than the entire global transportation sector. Keeping natural forests intact is one way to regulate carbon dioxide and mitigate, or moderate, the effects of climate change.

The forest acts like a sponge

Rainforests store water like huge sponges. If rainwater falls directly on bare, dry soil where the plant cover has been eliminated, very little of this water will enter the soil and become part of ground water reserves. Most will flow toward rivers, carrying with it a great quantity of fertile topsoil. An intact forest acts as a sponge that stores huge amounts of water and regulates water flows. The forest stores water during the rainy season, and slowly releases water in dry periods just like a sponge! This water eventually enters the ground water system. Forests reduce the occurrence of flooding and the loss of topsoil in adjacent areas. In this way, forests help control the runoff of water, and help water better infiltrate the soil in the wet season. During heavy rains, which may cause flooding, forests can temper or moderate the extent of flooding.

Effects of Deforestation on Water Supply



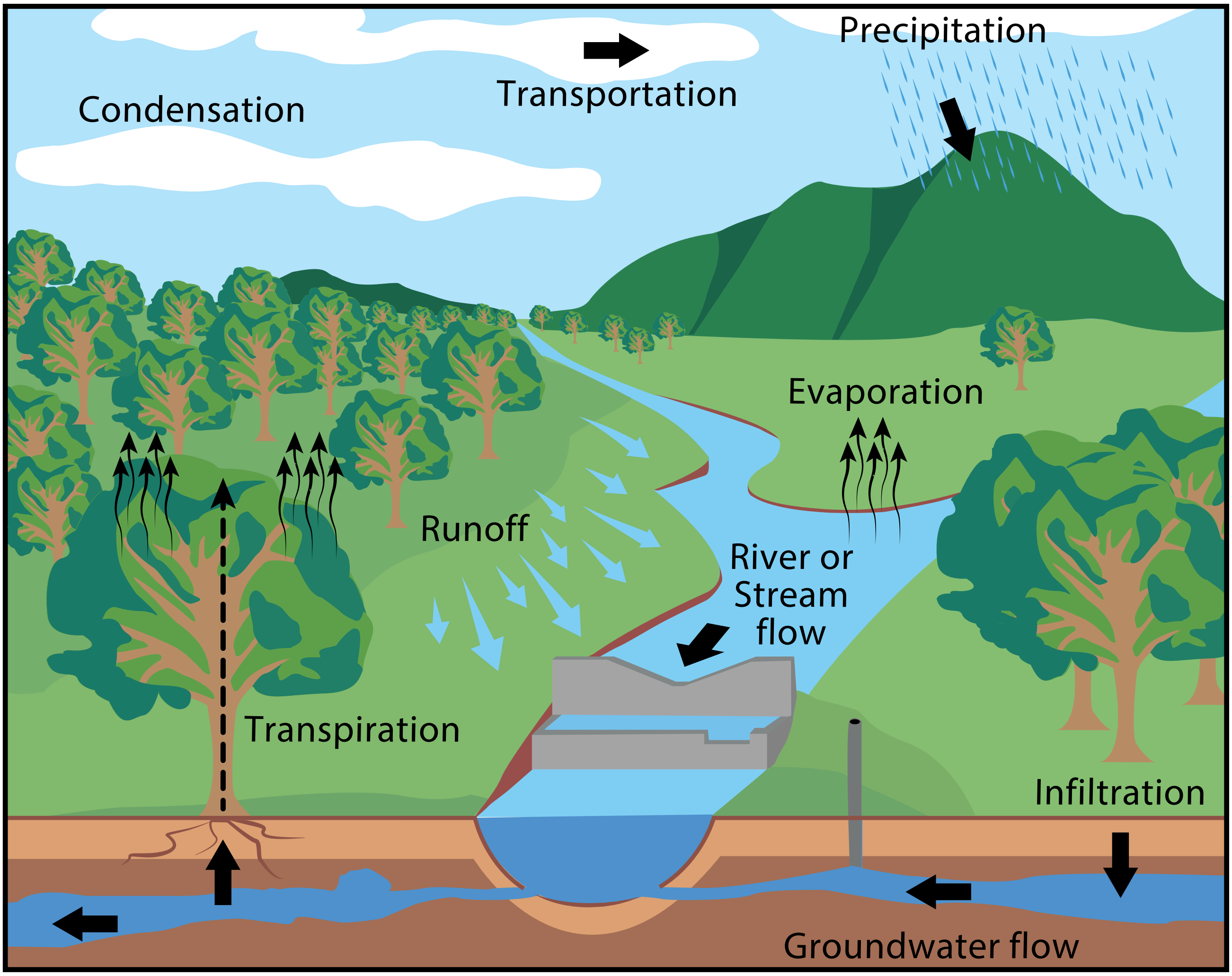
The size of the arrows represents the volume of water moving in the directions indicated. After deforestation (Figure B), more rainwater runs into rivers carrying away topsoil and nutrients. Less rainwater enters the ground water system than before deforestation (Figure A). Wells must be dug deeper to reach the lowered water table. Wild plants and crops suffer greater water and heat stress with the removal of the forest. (Figure adapted from: ***A Day on Barro Colorado Island*** (1986).

Where does water in the rainforest come from?

Water is essential for life. We drink water, bathe and swim in it, and use it for recreational activities. Our waters also provide habitats for a variety of plant and animal species, and provide wonderful opportunities for viewing wildlife. But where does water come from?

In Panama's rainforests, water comes primarily in the form of rain. When it rains, water flows down the mountains and hills into the forest and then becomes what is called *overland flow* water. Water can go many places once it hits the rainforest. It can travel as overland flow into rivers. Water can also fall through the treetops (a process known as *throughfall*) and infiltrate or seep into the soil. Plants and trees use the water that has seeped into the soil and release it back into the atmosphere in the form of mists and clouds. This water, along with rainwater that evaporates directly off the surface of leaves, forms clouds through a process known as *evapotranspiration*. Then the cycle begins again.

Rainforests have so much rain largely because they produce much, if not most of it, themselves. Because tropical rainforests are near the equator, they receive a lot direct sunlight all year round - more than anywhere else on the planet. These direct rays play a key role in producing the high amounts of rain in Panama's rainforests. Trees use water to transport nutrients from the soil throughout the plant in a process called *transpiration*. All this water eventually moves up into the canopy where trees "sweat" it out through pores in the leaves called *stomata*. Here the warm sun evaporates the water emerging from the trees' stomata, producing clouds of water vapor. One tree can release over 755 liters (1600 pounds) of water every year. The warmth produced by the directness of the sun's rays at the equator is more effective at lifting the water vapor high enough to form clouds and, eventually rain.



Because rainforests have millions of trees, they produce tons of water vapor. Warm air can hold a lot of water vapor, but as the air rises, it cools and becomes less able to hold water vapor. When the warm air meets cooler air higher in the atmosphere, *condensation* occurs which transforms the water vapor into droplets, and clouds develop. Eventually those droplets fall to Earth in the form of rain. In other habitats, water vapor typically blows away and later falls as rain in far off areas. In rainforests, though, more than half the precipitation falls back down on the same forest. However, about 20 percent of the rain that falls on the rainforest never reaches the ground because the leaves of rainforest trees act as umbrellas. When these leaves are exposed to the sun, the water evaporates.

READING 2 | WHAT IS A DESERT?

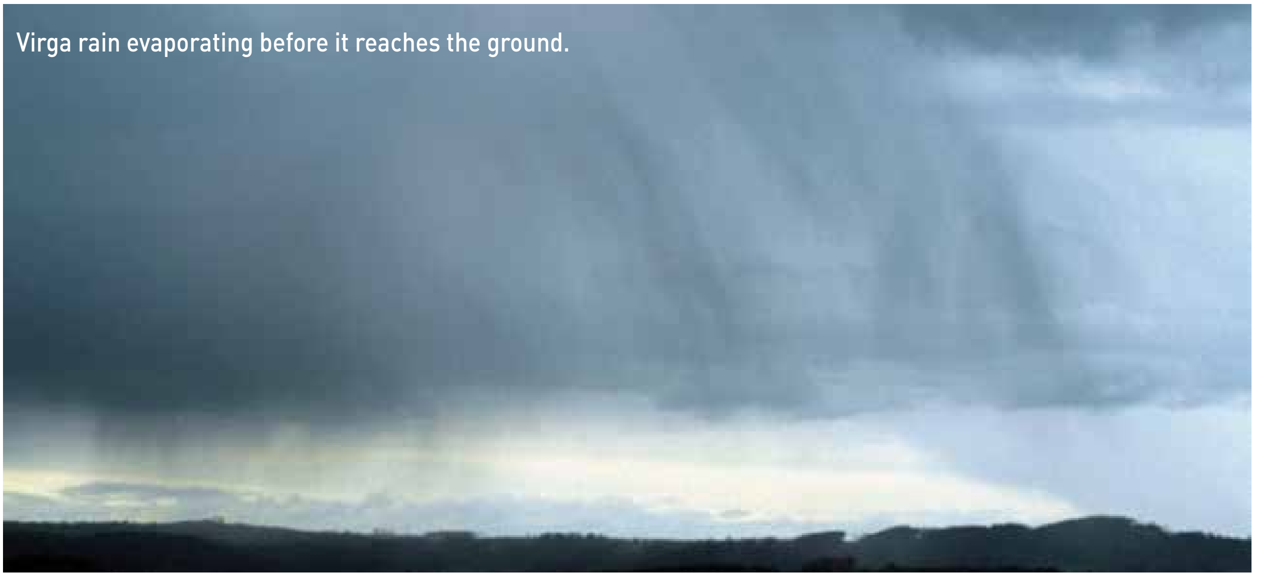
About 20 percent of the Earth's land surface is desert. Deserts have three characteristics that distinguish them from other areas: low rainfall, extreme temperatures, and rapid evaporation. Deserts have so little rainfall that they support little to no vegetation and only small populations of people and animals. They may be regions of sand dunes or vast areas of rocks and gravel with scattered plants. Deserts occur on every continent, including Antarctica, but Africa has the largest area of desert. The most extreme arid desert in the world is the Atacama Desert of coastal northern Chile, where no rain has been recorded in more than 500 years! Less arid deserts have no more than 250 millimeters of annual rainfall, and semiarid deserts have an annual precipitation of between 250 and 500 millimeters.

A Place of Extremes

Deserts are habitats of extremes: heat, dryness, flash floods and cold nights and winters. What little rain does fall often falls in a downpour during short seasons of the year separated by long dry periods. Deserts typically have five seasons: winter, spring, foresummer, summer, and fall. The foresummer is a hot, dry period between the winter and summer rainy seasons. During foresummer, the skies are usually clear and the days grow progressively hotter. By summer, daytime temperatures in many deserts can reach 120 to 140 degrees Fahrenheit. But the nighttime temperatures can fall to the 40s or 50s and some deserts even have winter snow!

The extreme conditions found in most deserts are largely caused by the dry air over deserts. Phoenix, Arizona, located in the Sonoran Desert, sometimes has *relative humidity* (a measure of water vapor in the air) as low as 4 percent, and it rarely rises above 45 percent. Often the air near the earth is so dry that when rain falls, it evaporates before it hits the ground. This type of rain is known as *virga*.

Most other habitats are moister and are insulated by their humidity and the denser vegetation they support. Unlike deserts, forests both in North America and in the tropics often have humidity over 80 percent. Because the water in the air reflects and absorbs sunlight energy, temperatures in the forest never rise very high. At night, the water in the air acts like a blanket, trapping heat inside the forest, preventing temperatures from falling very far. Dense trees and other vegetation in forests also help retain heat at night and provide shade in the daytime to keep temperatures from changing rapidly. The dry air of the desert, on the other hand, cannot hold its temperature, and that, together with the sparse vegetation, causes deserts to cool rapidly when the sun sets, and heat up quickly after the sun rises.


Virga rain evaporating before it reaches the ground.

When it rains, it pours!

When rain does fall in the desert, it often comes in the form of violent storms. These quick, heavy rains create flash floods which flow into dry stream channels called *arroyo* or *wadi*. Water running in an arroyo eventually slows and spreads, typically at the exit of a canyon, onto a flatter plain to form a broad area of loose particles of silt, clay, sand and gravel called a *bajada* or *alluvial fan*.


Bajada or alluvial fan spreading out at the base of a mountain canyon.

In other areas, rainfall or melting snow in neighboring mountains can produce *ephemeral streams* that last only for a few days or weeks. These streams fill the channel with a mixture of mud, rocks, tree limbs, and other materials that are carried some distance before settling. Other desert streams carry water throughout much of the year, and strips of trees and water-adapted vegetation form along the lengths of these rivers. These habitats are called *riparian areas*. Many of these riparian areas have no surface water flowing during the driest part of the year, but underground water often continues to flow below the dry sandy bed.

MODULE 2B | THE CYCLE OF WATER

In module 2B, students will learn about the water cycle and its different components, and explore differences between water cycles in the desert and the rainforest.

Duration: Two 50-minute class periods

DAY 1

1. **View Water Cycle (10 minutes):** Review the components of the water cycle with students using the definitions below and the diagram (below or in Module 2A), or use the interactive Water Cycle diagram available at the link below as you move through the different parts of the water cycle:
   http://earthguide.ucsd.edu/earthguide/diagrams/watercycle/

2. **Make a Water Cycle (15 minutes):** Have students work in pairs to make their own water cycle.

3. **Explore Where Water Goes (assemble experiment in the morning; complete overnight):** Evaporation activity

4. **Journaling Activity (10 minutes):** Ask students to sketch the water cycle (they can choose a desert or rainforest water cycle and can explore how these might look different) in their journals. Remind them of the importance of the sun in their water cycle sketches.

Components of the water cycle

The water cycle is made up of four main parts:

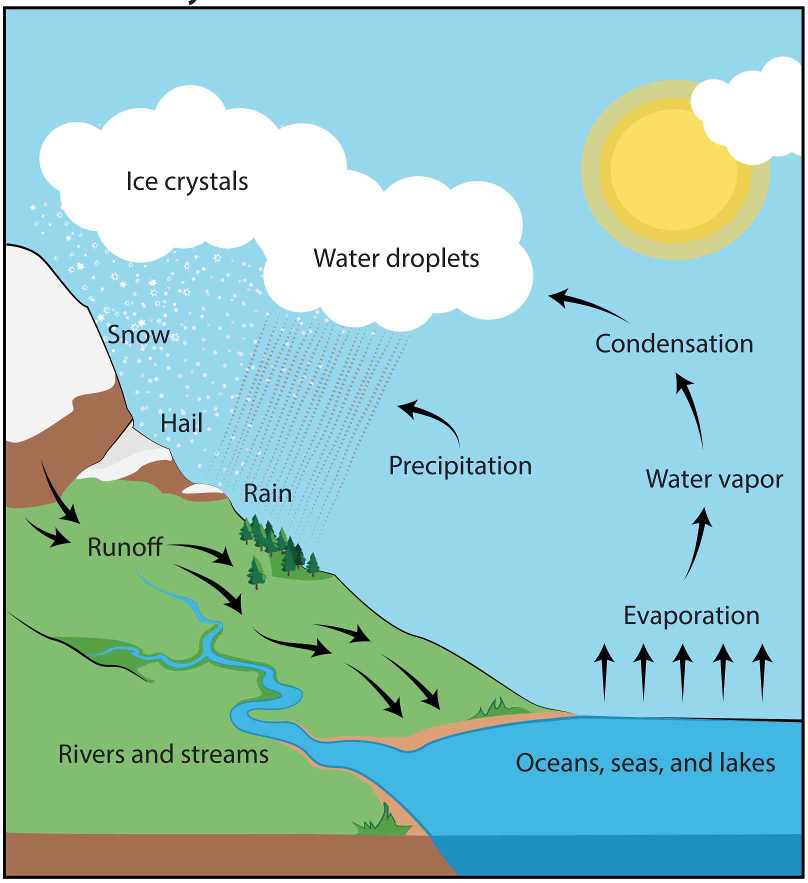
- **Evaporation (and transpiration):** *Evaporation* is when the sun heats up water in rivers or lakes or the ocean and turns it into vapor or steam. The water vapor or steam rises from the river, lake, or ocean and enters the air. *Transpiration* is the process by which plants release water vapor, returning it into the air through their leaves and stems.

- **Condensation:** *Condensation* occurs when water vapor in the air cools and changes into liquid, forming clouds.

- **Precipitation:** *Precipitation* occurs when so much water vapor has condensed into water that the air cannot hold it anymore. The clouds become heavy with water and are eventually forced to release that water in the form of rain, hail, sleet, or snow.

- **Collection:** When water falls back to earth as precipitation, it may fall back in the oceans, lakes, or rivers, or it may end up on land. When it falls on land, water either soaks into the earth and becomes *groundwater* that plants and animals use or it may run over the soil and collect in the oceans, lakes, or rivers, where the cycle starts over again.

The Water Cycle



The sun's energy is the driving force behind the water cycle. The sun heats up water on land and in the oceans, lakes, and seas. The water changes from liquid to vapor in a process called evaporation. The water vapor cools and in a process called condensation forms droplets in the atmosphere. These droplets become clouds. The droplets (or ice crystals if it's cold enough) gather and then fall from the sky in a process called precipitation. This precipitation gathers in streams and rivers and flows and becomes run off, flowing back down to the oceans, seas, and lakes.

ACTIVITY: MAKE YOUR OWN WATER CYCLE[1]

Materials

- Large metal or plastic bowl
- Pitcher
- Sheet of clear plastic wrap
- Dry ceramic mug (like a coffee mug)
- Large rubber band
- Water

STEPS

1. Divide students into pairs and have each pair put the bowl in a hot, sunny place outdoors. Using the pitcher, pour water into the bowl until it is about ¼ full. Place the mug in the center of the bowl, but be careful not to splash any water into it. Cover the top of the bowl tightly with the plastic wrap. Wrap the rubber band around the bowl to hold the plastic wrap in place.

2. Students should observe the bowl to see what happens and record their observations in their journals.

The "mist" or condensation that forms on the plastic wrap will change into larger drops of water that will begin to drip. (You can speed up the dripping by carefully moving the bowl into the shade.) When this happens, continue watching for a few minutes, then carefully peel back the plastic. Is the coffee mug still empty? You can see that water from the "ocean" of water in the bowl evaporated. It condensed to form misty "clouds" on the plastic wrap. When the clouds became saturated or too heavy it "rained" into the mug!

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[1] Experiment adapted from Monroe County Water Authority, "Kids Water Fun," 2011, http://www.mcwa.com/MyWater/KidsWaterFun.aspx#cycleReferences.

ACTIVITY: EVAPORATION | WHERE DOES THE WATER GO?[2]

Materials[2]

- 2 dishes
- Sunlight or light source
- Water

STEPS

1. Use the same student pairs as in the "Make Your Own Water Cycle" activity.

2. Have student pairs get two dishes. Put about 10 milliliters (two teaspoons) of water in each dish. Place one dish in the sunlight, or under or close to a light source. Place the other dish in the shade.

3. Have students observe each dish every 4 hours during the day and then leave the dishes in place overnight. The next day, students should record what has happened to the water in their journals the next day. The students should answer these questions:
   - **Where did the water go?**
   - **From which dish did the water disappear faster?**
   - **What caused the water to disappear?**

The process of water diffusing or "going" into the air is called evaporation. Students should list some other examples of evaporation and discuss with their partners what happens to water after it evaporates. Students should write down what they think and hand in their journals at the end of the lesson. The next day, the student pairs share their findings with rest of the class.

DAY 2
TRANSPIRATION

1. **Do Plants "Sweat"? (15 minutes):** Start the transpiration activity.

2. **Reporting (15-20 minutes):** Students finish observations of Evaporation experiment in pairs and share findings with the rest of the class.

3. **Journaling Activity (15 minutes):** Ask students to record their observations on the Transpiration activity in their journal, noting any differences in transpiration between the different kinds of plants. Ask them to sketch a visual representation of transpiration.

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[2] Experiment adapted from resources developed by Live from Earth and Mars, "Water: A Never-Ending Story: Evaporation," University of Washington, n.d., http://www-k12.atmos.washington.edu/k12/pilot/water_cycle/evaporation.html

ACTIVITY: DO PLANTS "SWEAT" DIFFERENTLY IN DESERTS AND RAINFORESTS?

Materials

- Small potted plant (groups of students in Arizona and Panama could use a cactus from the desert and a tropical ornamental plant, such as a fern; the groups can compare differences, if any, in the amount of water the plants transpire.)
- Clear plastic bag
- Twist tie

STEPS

1. Use the same student pairs as in the "Make Your Own Water Cycle" and "Evaporation" activities.

2. Have students place a plastic bag over the small potted plant or over one of its branches and secure the base of it with a twist tie around the stem. For quicker results, put the plant in a warm, preferably sunny location and observe throughout a 40-50 minute period.

3. Ask students to record their observations in their journal, answering these questions:
   - How do you explain what you observed on the inside of the plastic bag? (Water form the plant diffused into the air and collected on the inside of the bag.)
   - Did you observe any differences between the desert and tropical plants? If yes, how might you explain those differences?

EXTENSION ACTIVITY

Regional elevation maps and mean monthly precipitation and temperature graphs can be supplied to the students for Phoenix, Arizona and for Panama City, Panama. Students can compare precipitation and patterns in desert and rainforest areas and discuss the differences.

MODULE 2C | HOW HEALTHY IS THE WATER WHERE YOU LIVE?

Water quality studies help us determine the health of a body of water. This module will assist students in understanding what a watershed is and what water quality is. Students will learn how to conduct simple water monitoring tests, identify and monitor problems in water quality, and assess how rainfall or runoff might affect water quality. Students will work with a nearby creek, river, or lake – teachers decide where the study area will be.

Materials

- Lamotte Green Low Cost Water Monitoring Kits
- Water Quality Indicators PowerPoint presentation
- Teacher's Guide
- Student Worksheets

Duration

- One 50-minute class period to introduce students to concepts and show presentation
- 10 separate blocks of time for carrying out water monitoring tests

Procedure

Students will learn about watersheds and water quality, then carry out water tests, record their observations over time, learn about their local environments, and share the information they have gathered with their counterparts.

Question

How do changes in rainfall affect how healthy water is?

Background research: Students will break into groups and conduct simple water quality tests over a period of 10 weeks. During the same period students collect and record daily weather data through, for example, weather reports or official rain gauges online.

Form a hypothesis: In their groups, students will form hypotheses about how rainfall (or a lack of rainfall) might affect water quality. Students should first be asked to explore various questions: What do they see when it rains? Does the water in the pond or creek change its appearance? What happens to a pond or creek when it rains? These observations should then lead to causal questions. For example, are there things happening with the runoff, as well as the rainfall itself, that might change the quality of the water in the pond? The students can make some specific hypotheses and predictions that will make the type of data needed obvious. Students then come up with several different predictions that could be tested for the hypothesis.

SAMPLE

Hypothesis: Water quality is controlled by the amount of rainfall and runoff.

- Prediction 1: More rainfall and runoff causes the quality of the water to go down.
- Prediction 2: More rainfall and runoff causes the quality of the water to go up.
- Prediction 3: More rainfall and runoff has no detectable impact on the quality of the water.

The students should discuss ahead of time why they might logically expect each of these outcomes.

Test hypothesis: Students collect and test water samples, make observations, take photos, and compare changes in weather to changes in water quality.

Data analysis: Students will review their data and be able to assess if the water is doing well or doing poorly, and whether water quality relates to rainfall.

Communicate results: The students complete a 2-3 page report or presentation with scientific data, suggesting which prediction is best supported by the data gathered, and outlining their ideas for what can be done to keep the quality of the water as healthy as possible. The reports can contain graphs or other techniques for communicating data in an easy to understand way. Using classroom conference tools like Vidyo, students can communicate the results of their monitoring activities, and discuss ways for either keeping the water source clean (if it is clean) or improving the water quality in their individual research sites (if the water is found to be unclean).

If video conferencing is not an option, communicating results between classrooms, other local schools, or even at a parent night are all viable alternatives.

EXTENSION ACTIVITY

Using maps of your community, teachers can work with students to identify the watersheds in your area. Take a fieldtrip to one or two of those watershed areas and observe the conditions there. Do you see any conditions that might cause pollution in that watershed? Where does the runoff from that watershed go?

What is water quality?

Prior to starting the water monitoring activities, discuss the term "water quality" with students. Have the students talk about what they notice about the condition of water when observing a body of water such as a creek, river, or canal. Does the water appear clear? Does it have a smell? Is the water moving, or is it still? How do you know if water is healthy or unhealthy? What makes water of "good" quality or healthy? What makes it unhealthy or of "poor" quality? Answering these types of questions tell us about the quality of the water.

How do scientists measure water quality?[3]

Scientists use instruments like Secchi (sek'-ee) disks, probes, nets, gauges, and meters to determine the health of a body of water. They take measurements of the physical and chemical condition of the water and the health of the plants and animals that live in it.

Scientists collect water in different ways – from boats in the middle of lakes or ponds, by wading into streams, or dropping buckets over the sides of bridges. Water samples aren't the only things scientists collect when investigating water quality. They use their eyes to observe what's happening along streams, lakes, and bays to get an overall sense of the health of the water. They take photographs from airplanes and even satellites. They also collect fish, plants, dirt, and aquatic bugs, and study what's happening on the land next to the water.

What is a watershed?

"We all live, work, and play in watersheds, and what we do affects everything and everyone else in the watershed." — Environmental Protection Agency

Introduce the concept of watersheds to students (show photos of desert and rainforest watersheds included in Worksheet 2C and view the watershed illustration at http://www.recycleworks.org/kids/watershed.html.)

A *watershed* is an area of land that drains all the surface water runoff (rainwater or snow) into one location such as a stream, river, lake, or wetland. This means that the runoff from streets, fields, and lawns will eventually drain into those streams, rivers, lakes, or wetlands. Watersheds come in many sizes and shapes; they can be anywhere from a couple of square miles to hundreds of thousands of square miles in size. The Panama Canal Watershed, for example, provides freshwater to more than half the citizens of Panama and is 552,761 hectares or about 2,134 square miles.

Point versus nonpoint source pollution

Most of the problems in our waters, whether in the desert or tropics, come from polluted runoff draining into rivers, lakes, and bays. Rainwater washes dirt, fertilizer, oil, paints, pesticides, animal waste, and other pollutants over the land and into our waterways. Because it comes from many different sources, this pollution is called *nonpoint source pollution*. Scientists refer to pollution that can be traced to a single source as *point source pollution*.

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[3] Materials adapted from Guadalupe-Blanco River Authority (in cooperation with Texas Commission on Environmental Quality and US Environmental Protection Agency), *Intermediate Student Guide to Water Charts,* n.d., available at http://txstreamteam.meadowscenter.txstate.edu/educators/curriculum.html; U.S. Environmental Protection Agency, "Water," http://www.epa.gov/water/education.html.

WATER QUALITY MONITORING TESTS

What tests do scientists use to measure water quality?

View the *Water Quality Indicators* presentation:
http://step.nn.k12.va.us/science/6th_science/ppt/6sci_ppt.htm
to introduce students to the different tests scientists use to measure water quality.

When scientists monitor water bodies they give one of the following scores:

GOOD - The water fully supports its intended uses.

IMPAIRED - The water does not support one or more of its intended uses.

Water Quality Indicators (tests to be conducted by students)

Temperature:

Scientists measure water temperature for several reasons. Temperature determines the kinds of animals that can survive in a body of water. Some organisms die if the temperature becomes too hot or too cold. Temperature also can affect the chemistry of the water. For example, warm water holds less oxygen than cold water.

- Follow kit instructions for testing water temperature

Dissolved Oxygen:

Scientists measure dissolved oxygen, or DO (pronounced dee-oh), which tells them how much oxygen is available in the water for fish and other aquatic organisms to breathe. Healthy waters generally have high levels of DO (some areas, like swamps, have naturally low levels of DO). Just like people, aquatic life needs oxygen to survive, and most organisms need at least 5 or 6 ppm (parts per million) of oxygen in order to survive.

Rain, wind, and waves all function to incorporate oxygen into water. Through photosynthesis, underwater plants and algae also add oxygen to water.

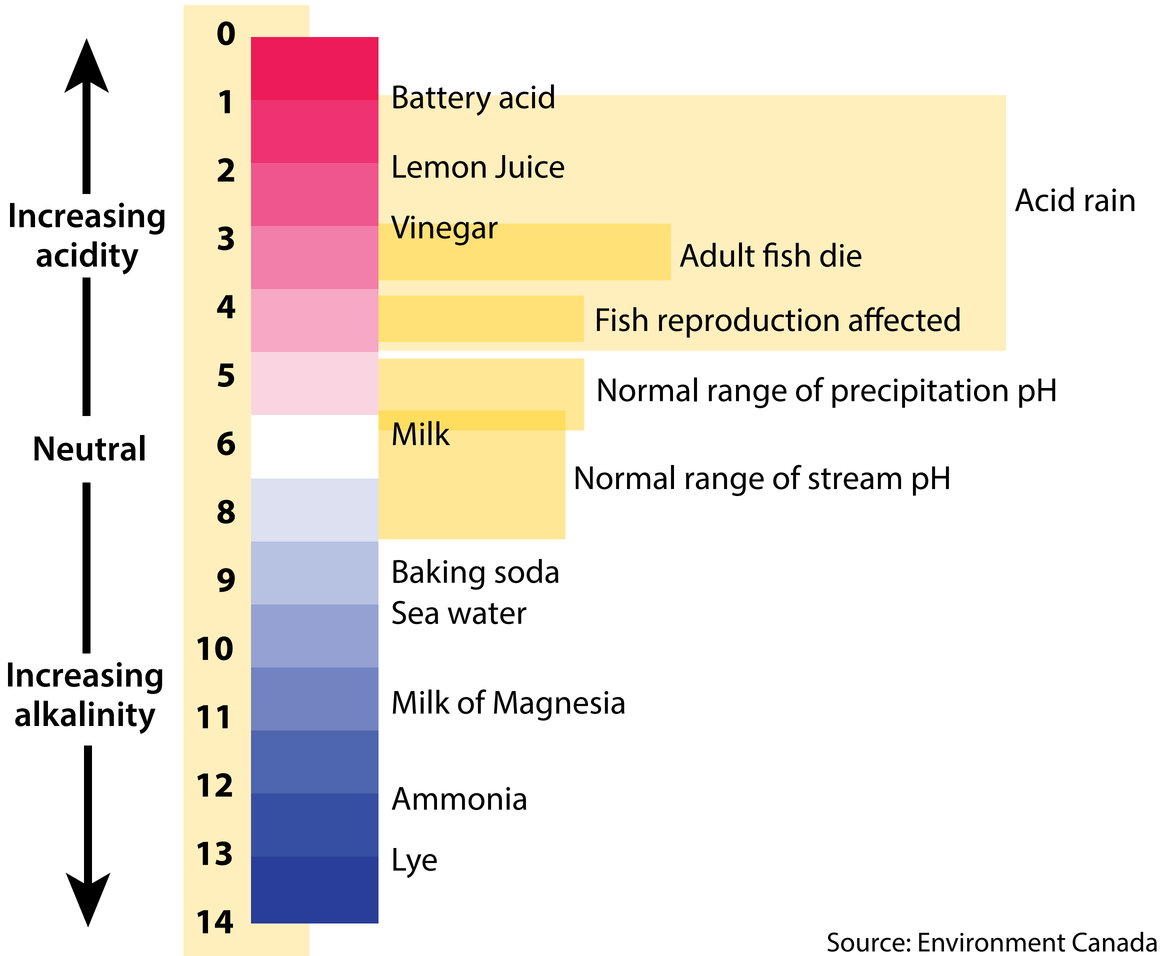
Factors affecting how much DO is in the water include: 1) temperature (the warmer the water, the less oxygen it can hold), 2) the amount and speed of flowing water, 3) the plants and algae in the water (which produce oxygen during the day and take it back in at night), 4) pollution in the water, and 5) the composition of the bottom of the water body, like streams, lakes, and ponds.

- Follow kit instructions to test for dissolved oxygen

pH:

Scientists measure *pH* to determine the concentration of hydrogen in the water. The "p" in pH stands for "potential of" and the "H" stands for is hydrogen. pH ranges from 0 (very acidic) to 14 (very basic), with 7 being neutral. The pH in most waters ranges from 6.5 to 8.5.

Diagram of pH: As this diagram illustrates, pH ranges from 0 to 14, with 7 being neutral. pH levels less than 7 are *acidic*, while pHs greater than 7 are *alkaline* (*basic*). Normal rainfall has a pH of about 5.6—slightly acidic due to carbon dioxide gas from the atmosphere. You can see that acid rain can be very acidic, and it can affect the environment in a negative way.



Changes in pH can affect how chemicals dissolve in the water and can impact organisms. High acidity can be deadly to fish and other aquatic organisms. Pollution can change a water's pH, which in turn can harm animals and plants living in the water. Polluted air from automobiles and smokestacks, for example, can combine with water while in the atmosphere to form acids that fall to the earth as acid rain. Rainwater also picks up pollutants from fertilizers, driveways, and pet waste, which can affect the pH of the water, making it more acidic.

- Follow kit instructions for pH tests

Turbidity:

Scientists measure the clarity of water to determine how many particulates are floating around in the water. If you are sitting on a dock in a pond on a warm summer day, you might be able to see to the bottom of the pond. The water in this pond has a low level of *turbidity*. But if you visit the dock after a rainstorm when all the muck on the bottom has been stirred up, you won't be able to see the bottom; now that water has a high level of turbidity. Scientists use turbidity measurements to calculate the inputs from erosion and nutrients. High turbidity is often the result of dirt that is washed into streams and rivers by rain. Dirt smothers aquatic animals, kills fish eggs, and clogs the gills of fish, which leads to suffocation. Water with a high level of turbidity can harm plants by preventing them from getting enough sunlight to make food (photosynthesis).

Nutrients:

Nutrients are critical to the health of plants and animals, including humans. The presence of too many nutrients can hurt aquatic organisms by causing lots of algae to grow in the water, which can turn the water green or even red. If algae grows out of control, it sucks all of the oxygen out of the water, making it impossible for fish and other organisms to breathe. Nutrients can also affect pH, water clarity, and temperature, and cause water to smell or look bad.

The two major nutrients scientists measure are nitrogen (nitrates) and phosphorus (phosphates). Nitrates are necessary food for plants. They can be dissolved in water, which allows them to seep into the groundwater, making them accessible to plants. Excessive amounts of nitrates cause algal blooms that reduce water quality. The concentration of phosphates in clean water is generally low, even though phosphorus is used extensively in fertilizer and other chemicals. The primary sources of phosphates in surface water are detergents, fertilizers, and natural mineral deposits. High levels of phosphates can over stimulate the growth of aquatic plants and algae. This, in turn, will produce high DO levels and cause fish and many aquatic organisms to die.

TESTING KIT AND STUDENT WORKSHEET

Students will perform water quality tests using the Lamotte Green Low Cost Water Monitoring Kits. Be sure to review the water testing kit instructions before having students test nitrates and phosphates.

Students record the results of each test under the appropriate column and corresponding row of the Monitoring Test Results Chart. They can then rank all test results with the exception of Dissolved Oxygen (ppm) using the Ranking Test Results table.

Students calculate Dissolved Oxygen (ppm) using the Percentage Saturation table. The results are entered in the Water Quality Test Chart. Students enter a '+' or '-' to show if the Dissolved Oxygen (ppm) is above or below 5 ppm (the minimum amount of oxygen required to support most life).

Students will use the completed Water Quality Test Chart when discussing the overall Water Quality Score.

STUDENT NAME ______________________

MODULE 2C | WATER QUALITY WORKSHEET

ENTERING DATA

Be sure you follow the water testing kit instructions when making your water quality measurements. After you test your water samples, use the Water Quality Test Chart to enter the results from the water quality tests.

RANKING RESULTS

Use the Ranking Test Results Table to find the corresponding rank. For example if the pH of the water is 8 the rank would be entered as 3 (good).

CALCULATING DISSOLVED OXYGEN

Find the temperature of the water on the left side of the Percentage Saturation Table. The Percentage Saturation (%) of the water is where the Temperature row and the Dissolved Oxygen column intersect. For example if the water temperature is 13 C and the dissolved oxygen result is 2ppm, then the Percentage Saturation is 19.

Record the temperature, dissolved oxygen, and percentage saturation on the chart below.

WATER QUALITY TEST CHART

Month						
	Results	Rank*	Results	Rank*	Results	Rank*
Water Temperature (°C)						
pH						
Turbidity (JTU)						
Nitrates (ppm)						
Phosphates (ppm)						
Dissolved Oxygen (% Saturation)						
Dissolved Oxygen (ppm)						

*Use the tables (Ranking Test Results and Percentage Dissolved Oxygen Saturation Chart) to rank results. For Dissolved Oxygen (ppm) enter a + or – to show if ppm is above or below 5 (minimum amount to support most organisms). Turbidity is measured in Jackson Turbidity Units (JTU).

MODULE 2C | WATER QUALITY WORKSHEET

RANKING TEST RESULTS TABLE

Test Factor	Result	Rank
Disolved Oxygen	Saturated	4 (excellent)
	Saturated	3 (good)
	Saturated	2 (fair)
	Saturated	1 (poor)
pH	5	1 (poor)
	6	3 (good)
	7	4 (excellent)
	8	3 (good)
	9	1 (poor)
	10	1 (poor)
Nitrate	5 ppm	2 (fair)
	20 ppm	1 (poor)
	40 ppm	1 (poor)
Phosphate	0-1 ppm	4 (excellent)
	2 ppm	3 (good)
	3-4 ppm	2 (fair)
Turbidity	0 JTU	4 (excellent)
	40 to 100 JTU	3 (good)
	Over 100 JTU	1 (poor)

PERCENTAGE SATURATION TABLE (DO / TEMPERATURES)

Dissolved Oxygen (ppm)

Temperature (PC)

	0 ppm	2 ppm	4 ppm	6 ppm	8 ppm
9	0	17	34	51	67
10	0	18	35	53	71
11	0	18	36	54	72
12	0	19	37	56	74
13	0	19	38	57	76
14	0	20	39	59	78
15	0	20	40	60	80
16	0	21	41	61	81
17	0	21	41	62	83
18	0	21	42	63	84
19	0	22	43	65	86
20	0	22	44	66	88
21	0	23	45	68	91
22	0	23	46	69	92
23	0	24	47	71	95
24	0	24	48	72	96
25	0	25	48	73	98
26	0	25	49	74	99

Calculations based on solubility of oxygen in water at sea level.

Comparing Rainforest and Desert Watersheds

Examine the rainforest and desert watersheds below. Write down any differences and similarities in your journal.

Desert watershed

Rainforest watershed

STUDENT NAME ______________________

1. Describe a watershed.

2. Why is temperature important to the health of a body of water?

3. How is oxygen added to the water?

4. What factors affect the amount of DO in the water?

5. What do the scores of GOOD and IMPAIRED mean to scientists?

6. How does high turbidity affect the health of aquatic animals?

7. Where do human-made nitrates and phosphates come from, and how do they affect the health of plants, animals and other lifeforms?

REFERENCES / RESOURCES (FOR MODULE 2)

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Sixth Grade PowerPoint Presentations: *Water Quality Indicators*. Available at:
http://step.nn.k12.va.us/science/6th_science/ppt/6sci_ppt.htm

Water Cycle:
http://www.kidzone.ws/water/

U.S. Environmental Protection Agency: Water.
http://www.epa.gov/water/education.html

The Water Cycle:
http://www.epa.gov/safewater/kids/flash/flash_watercycle.html

MODULE 3

BIOMES

Desert to Rainforest

Questions

What are the main characteristics of the Sonoran Desert and the Panamanian Rainforest?

What challenges do the native plants and animals of these areas face?

How do the plants and animals deal with these challenges?

Background research: Teachers will divide their classes into two groups: one group will be assigned the Sonoran Desert, the other will be assigned the Panamanian rainforest.

Observation: Students will read the materials associated with their assigned biome. Have students write down something that interested them in the materials. This will be their observation.

Ask a question: Based on what students learned from their observations they made about their assigned biome, students will form questions about the other biome.

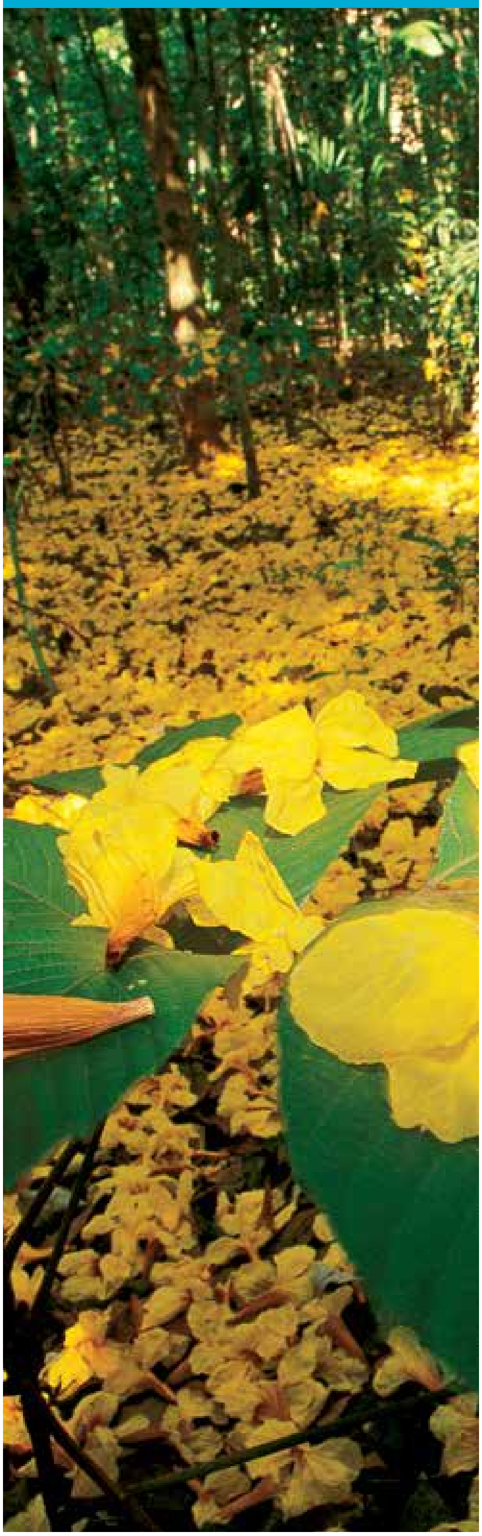
Form a hypothesis: In their groups, students will develop hypotheses about the characteristics of their assigned biome. They will then predict the challenges its plant and animal communities face and how plants and animals meet these challenges.

Test hypothesis: Students read the provided paragraphs about their biome and answer the above questions.

Analyze data: Using answers they obtained from the reading, students will analyze their hypothesis for accuracy.

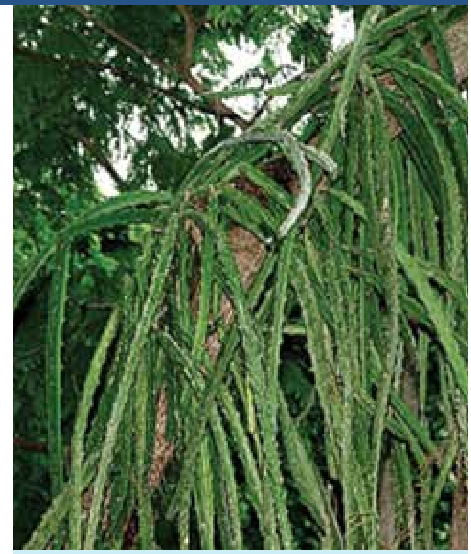
Communicate results: Using Vidyo, students will share with their counterparts and report on their initial responses, what they learned, and their final conclusions.

PANAMANIAN RAINFOREST PLANTS

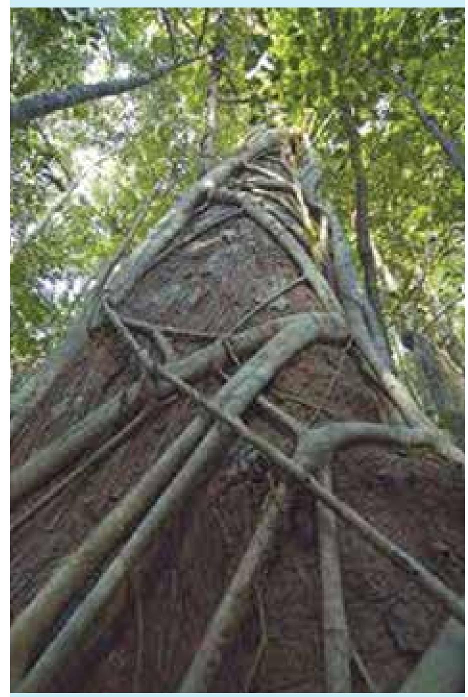


The sun is rising over the tropical rainforests of Panama, but very few of the forest's inhabitants are yet aware of this early morning light. Only residents such as the **fishbone cactus**, which grows from the trunks of trees high in the forest's canopy, have a vantage point that allows them to bask in these first rays of light. Epiphytes, such as this cactus, are specially adapted to root into existing plants rather than into the forest floor below. From their high perch, these plants have access to the sunlight that is so lacking in the shadowy understory beneath the forest's dense canopy.

As the day progresses, the sun ascends higher into the sky, allowing its rays to meander through small gaps in the forest's upper canopy to offer vital energy to the flora below. Here the leaves of the **strangler fig** are ready and waiting to absorb this valuable resource. This tree begins its life as an epiphyte just like the fishbone cactus, but must grow lower on the trees' trunks as it lacks the thick skin that allows the cactus to hold onto moisture despite the hot dry winds of the upper canopy. From its chosen position, the tree sends leaves and branches upwards to catch sunlight while sending a tangled mess of roots down to forage for water and nutrients below. Eventually, these roots reach the ground, become thicker and thicker, and finally kill the host tree, leaving a free-standing fig tree hundreds of feet tall. A young fig that tried to grow from the ground up would never survive in the sunless undergrowth.



Fishbone cactus



Strangler fig

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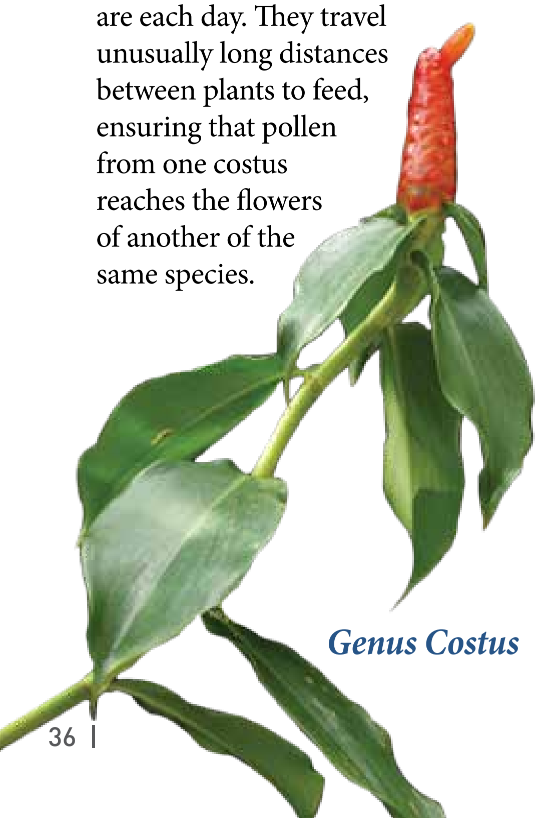
Even as the sun reaches its highest point in the sky, the plants below sit in shadow. Making the most of the little light that percolates down, ginger plants in the genus **Costus** arrange their broad leaves in a spiral formation with no one leaf preventing sun from reaching another. This ingenious adaptation allows the plant to survive, but this is only part of its ultimate goal: reproduction. These plants depend on pollinators, such as bees and hummingbirds, to transfer pollen from plant to plant in order to produce seeds. With a veritable buffet of flowers to choose from, the Costus must entice its pollinators to visit. Deep within its flowers, the plant produces potent nectar that contains a mixture of sugars and other nutrients that is irresistible to pollinators. The sugary liquid is so prized that many plants in the Costus genus have pollinators that pollinate nothing else.

In addition, the Costus plant produces only a single flower each day for many days. This way hummingbirds can learn and use the same route to where the flowers are each day. They travel unusually long distances between plants to feed, ensuring that pollen from one costus reaches the flowers of another of the same species.



Genus Costus

When the flowers become fruits, fruit-eating birds learn to follow a daily route that leads them to the single fruits that are formed each day on the plants.

Despite the high level of investment plants give to seed production, there is no guarantee those seeds will ever germinate. Many will be lost to fungal infections resulting from sitting on the waterlogged forest floor and more still will be lost as seedlings to countless foraging animals. To combat these stressors, plants such as those from the genus **Piper** produce fruits containing thousands of tiny seeds in the hopes that a few may make it. They house these seeds in protein and carbohydrate rich fruits that bats cannot resist. The bats gather these fruits and take them to nearby trees where they eat them and then excrete the seeds in their waste. This process brings seeds to locations away from the parental plant where fewer animals are likely to be foraging and can disperse up to 60,000 seeds per bat per night.

Once a plant emerges from its seed, its challenges only escalate. In a biome that boasts more species than anywhere else on earth, animals looking for fresh foliage to munch on are always afoot. Some plants spend vital energy producing poisons or spines for their own defenses, but the plant genus **Cecropia** instead recruits guards from the vast array of forest creatures. The hollow stems of these plants provide a protected home for colonies of small ants that can administer painful stings. These ants never leave their host tree, taking advantage of it both for shelter and for all of the food they need to survive. In return for the cecropia's hospitality, the ants actively defend the plant from any hungry animals that attempt to munch on its leaves.

Genus Piper

Genus Cecropia

For the many plants of Panama's rainforests that may never see a direct ray of sunlight, the sunrise and sunset mean little. Each plant has its own obstacles to overcome depending on where it resides in the habitat. Whether trying to stay moist and cool in the hot upper canopy or scrounging for dry land and a scrap of sunlight on the forest floor, the rainforest's ingenious plants are up for the challenge.

PANAMANIAN RAINFOREST ANIMALS

As the morning breaks over the rainforests of Panama, the sounds of shredded leaves dropping from the high canopy are evidence that some of the forest's most industrious residents are already hard at work. ***Leafcutter ants*** are busy harvesting small circular patches of leaves. Each ant carries its freshly cut leaf patch down the trunk of the tree, forming a long line of workers returning to their nest deep in the ground. Here, the harvested leaves will not be eaten, but rather they will be used as part of a huge farm. The leafcutter ants grow delicious fungi on the leaves and feed on this crop. Harvesting the leaves of the tallest of rainforest trees to fuel an underground fungal farm may seem like a roundabout way to feed themselves and their young larvae, but leaves aren't as available in the relative darkness of the rainforest's understory.

Not concerned by the falling foliage, a ***tamandua*** crawls into a hollow portion of the harvester ants' chosen tree. As the sun continues to rise, this nocturnal anteater is full and ready for a good day's rest. Thanks to an equally ingenious, but far less energy-intensive strategy, it will be falling asleep with a full stomach. Using its strong prehensile tail to climb through trees, strong forearms to tear open nests, and its long nose - packed with a 40-centimeter sticky tongue - to grab larvae, this animal lives entirely on ants and termites. Never getting too greedy, the tamandua avoids eating too many larvae from a single colony so that it doesn't exhaust the nests' resources. This ensures that the tamandua can visit nests in its territory over and over again.

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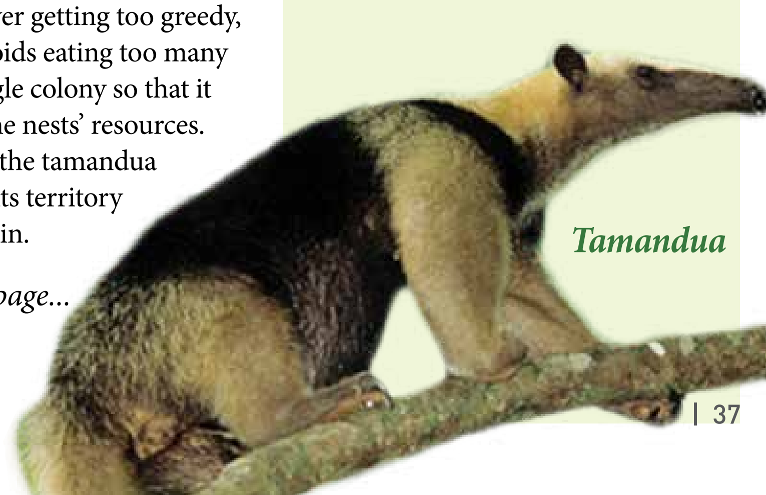
Leafcutter ants

photo: Geoff Gallice via Wikimedia



Tamandua

Early in the morning, as the tamandua goes to sleep, an equally specialized and clever animal is just beginning to forage. With its long tongue, extremely curved bill, and its ability to hover, fly straight up, straight down, forward, and backward, the ***long-billed hermit*** is perfectly designed to feed on nectar held deep within the many curved flowers found throughout the rainforest. This hummingbird's curved bill is exactly the right length to reach the sweet nectar stored inside the curved flowers. No other birds or insects have the right mouth parts to be able to get to the nectar. For this reason, sicklebills spend the day flying between stands of these oddly shaped flowers, almost guaranteed to find a nutritious reward at each stop. Of course the flowers get a gift from the sicklebills' visits, too. When the birds visit, yellowish pollen sticks to their heads and faces and is deposited on the next flower the bird visits, causing new seeds to form.

While the sun climbs higher into the sky, some animals are working hard to find food and others are putting an equal amount of effort into not becoming someone else's food. A ***green basilisk*** sits on an exposed branch above a rainforest pool, gorging on a buffet of insects, seemingly at ease despite the fact that it is a small lizard in a forest full of countless predators. If threatened, this lizard will drop onto the water below and run across its surface to the nearest shore. Its fringed feet create tiny air pockets when slapped against the water, keeping the lizard afloat. Its ability to run over 4.5 meters at 1.5 meters per second on the surface of water might explain its apparent lack of caution.

On a nearby tree, a ***green and black poison dart frog*** is equally confident despite its tiny size. As the day progresses into night, this frog will move from tree to tree in search of small insects to eat. Being so small, it cannot jump from tree to tree, but must climb down to move between them, This seemingly treacherous journey does not worry the miniscule animal, though. Its bright colors warn potential predators of the strong poison it can secrete from its skin. Thanks to this poison, the poison dart frog can travel safely from tree to tree until the day is done.

Long-billed hermit

photo: Michelle Reback via Wikimedia

Green and black poison dart frog

Green basilisk

Night falls over the Panamanian rainforest, but the activity doesn't diminish in the least. As the *diurnal* creatures go to sleep at night, another equally specialized and clever group of animals awakes to take advantage of the nighttime hours. In an area with a density of life higher than that of nearly anywhere else on earth, every resource must be used regardless of whether it is day or night.

SONORAN DESERT ANIMALS

Couch's Spadefoot

It is towards the end of the rainy season in the Sonoran Desert, and much of the standing rainwater has evaporated in the hot summer sun. Only a little water remains to feed the thirsty roots of the desert's plants or fill the desert's few bodies of standing water. These rare patches of water are essential to the survival of desert animals.

As the summer progresses, evaporation has reduced these patches of water to muddy, salty, warm little ponds. The ponds are perfect for ***Couch's spadefoots*** who, having waited over a year buried underground, use the ponds to breed. Spadefoots don't worry about the water drying up; their eggs can hatch in less than a day and offspring can develop into land-dwelling adults in as few as eight days.

Other desert creatures, such as the ***desert pupfish***, are equally well adapted to the desert's extreme conditions. Pupfish can survive water temperatures up to 95°Fahrenheit and salt levels up to three times those of the sea.

While water pools for a short time on the surface, ***desert tortoises*** quickly drink as much as they can, using their bladders to store up to 40 percent of their body weight in water. Cold weather will soon prompt these tortoises to bury deep beneath the desert soil to hibernate through the winter. Being cold blooded, they will not be able to take advantage of the desert's winter rains, but will need to survive the winter on the stores they developed earlier in the summer.

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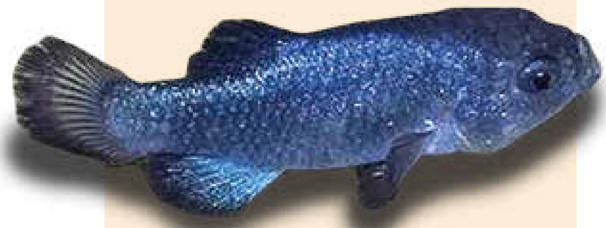
Desert Pupfish



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Not all animals conserve resources by shutting down for half the year, and very few have mobile water tanks like desert tortoises. These animals are very good at finding water in unexpected places. The ***Merriam's kangaroo rat*** spends the hot summer months the same way it spends all others: collecting and storing foods with high water content. By focusing on high-moisture seeds, fruits, and insects, these rats can go their entire lives without drinking a single drop of water.

The animals of the Sonoran Desert seem to know that the times when water is around pass quickly, and they prepare accordingly. The ***verdin***, a tiny desert bird, spends much of its time building spherical nests within the desert's few shade-providing trees. Not only do these nests provide protection from the desert sun, but they are also almost always positioned with their entrance facing into prevailing winds for added cooling. During the winter, the verdins will use their nests' insulation to keep warm. Even when the desert is at its greenest, these birds are actively working on their nests, always preparing for the desert's extreme conditions.

Desert tortoises

Verdin

Merriam's kangaroo rat

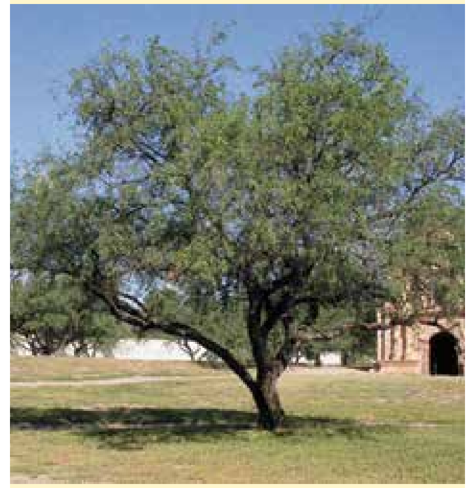
The western banded gecko is perfectly suited to the desert environment. It feeds on the many spiders, termites, beetles, and grasshoppers that populate the desert. Geckos are generally nocturnal animals, avoiding activity during the hottest part of the day. They also go dormant during the cold winter months - this means that their physical activity and development slows considerably during these times, allowing the animal to conserve energy. The gecko's tail plays an important role in a gecko's survival. The tail is a mini-warehouse, storing fat and water that can be used during lean times or dormant periods. The gecko will also shed its tail to distract predators, who focus on the tail as the gecko scampers to safety.

SONORAN DESERT PLANTS

The end of summer is approaching in the Sonoran Desert and the extreme heat is beginning to fade. But as the heat abates, so do the monsoon storms that keep the desert hydrated through hottest summer months. Although the desert's residents no longer have to grapple with as temperatures above 100° Fahrenheit, it is no time to rest. The next rains likely won't arrive until winter.

For now, the desert is thriving. Young ***saguaro cacti***, having survived their first summers shaded from the sun under unsuspecting desert trees, are filled to the brim with water. They store water in the expandable ribs that extend up their sides. An adult saguaro can store so much water that, after a good rain, it can weigh up to six tons.

Forced to compete with such greedy neighbors living below them, trees like the ***velvet mesquite*** use extremely long taproots to drink directly from the water table deep below the desert floor. This hidden water resource allows their small leaves, composed of many tiny leaflets, to remain open to the blazing sun, photosynthesizing vital energy. As long as the mesquite has access to the water table, its leaves can do their work. But as the water table lowers over the course of the season, the mesquite must drop its leaves to conserve water. When access to water returns, the mesquite will produce new leaves.



Velvet mesquite

Saguaro cacti

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Competition for the desert's water is fierce, so plants like the ***agave*** do what they can to store water to survive the post-monsoon months. Their pointed leaves, which can expand to store water like the saguaro, act like gutters, directing rain down towards the center of the plant where the roots can soak it up before any other desert plants get a chance.

Not all desert plants store water, though, meaning that some plants must use other methods to survive the desert's extreme conditions. Plants such as the ***ocotillo*** drop their leaves, nearly eliminating their need for water. These leaves can grow and fall many times throughout the course of the year, depending on weather conditions. Other plants, such as the ***desert marigold***, take a less dramatic approach. These low-lying plants have lightly colored leaves covered in fine hairs that help reflect the summer sun. This subtle strategy allows the desert marigold to produce beautiful yellow flowers, even when other desert wildflowers cannot afford to spend energy blooming.

Agave

Ocotillo

photo: Stan Shebs via Wikimedia

Desert marigold

STUDENT NAME ______________________________

MODULE 3 | WORKSHEET #1

Instructions: Read your assigned paragraph. As a group, discuss what you've read in order to answer the following questions:

1. List three characteristics of your assigned biome (Sonoran Desert or Panamanian Rainforest)

____

____

____

2. Describe two ways that plants have adapted to your biome and give examples of each.

____

____

____

____

3. Describe two ways animals have adapted to your biome and give examples of each.

____

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____

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MODULE 4

DIVERSITY

MODULE 4 | DIVERSITY

** Before embarking on the scientific method, students should complete at least two regionally-specific *Science Takes Wing* (STW) activities: "Bino Blitz" and "Bird Sounds." These activities focus on 10 bird species common to the region.

Question

How does the number of bird species found around the school yards differ between countries? Why?

Background research: In class, students complete the STW activities outlined above.

Form a hypothesis: Students predict both how many birds will be detected in their schoolyard and how that number will compare with their partner classroom.

Test hypothesis: Students conduct a school yard bird survey.

Analyze data: Students use their data to analyze their hypothesis for accuracy.

Communicate results: Using Vidyo to share with their counterparts, students will report, compare, and discuss the number of bird species found in each area.

STUDENT NAME ______________________

MODULE 4 | WORKSHEET # 1

What is a bird?

Compare and contrast these two animals:

List one thing that is similar between the animals:

____

List one thing that is different between the animals:

____

Birds are the only animals with feathers. Have you ever found a feather? Where?

____

Feathers have several functions, including flight. Can you name another feather function?

____

____

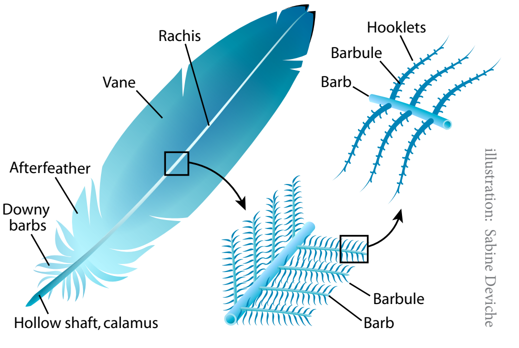


illustration: Sabine Deviche

All birds lay eggs and most birds build nests to hold their eggs. Bird nests and eggs vary greatly, depending on the size of the bird and where its lives. Have you ever found a nest?

____

STUDENT NAME ______________________________

MODULE 4 | WORKSHEET # 2

Why is it important to study birds?

____

Bird-watching is the second most popular hobby in the United States, just behind gardening. Why do you think people like to watch birds?

____

Birds come in an incredible range of sizes, shapes, and colors and exhibit different types of behavior. There are over 300 different kinds of birds in Arizona. One way to learn something about birds is to observe them. For example, we can tell what birds eat by looking at their beaks and feet.

What do the birds above eat? *Circle the correct answer for each bird.*

1. Hummingbird (left picture): seeds vegetables meat nectar
2. Hawk (right picture): seeds vegetables meat nectar

How did you know the answers?

____

Hummingbirds are important pollinators. Would people be affected if hummingbirds disappeared? Why or why not?

____

Hawks eat pests such as rats and mice. Would people be affected if hawks disappeared? Why or why not?

____

MODULE 4 | TEACHER RESOURCE – INTRODUCTION TO BINOCULARS

OVERVIEW

Students will learn how binoculars work, as well as how to properly care for this important bird-watching tool. By playing the Bino Blitz Game and completing the Mystery Bird Worksheet, students will practice using binoculars and will simultaneously learn about 10 birds commonly found in Arizona.

Materials

Binocular Parts Worksheet

Bino Blitz Answer Sheets

Bino Blitz Bird Cards

Mystery Bird Worksheets

Time: 30 minutes for lecture, worksheet completion, Bino Blitz game and Mystery Bird Activity.

Directions: Lecture briefly about binoculars, using information below.

1. Show the class a pair of binoculars and point out the various parts and functions.
2. Have students complete the Binocular Parts Worksheet. Encourage them to discuss their answers as a group.
3. Pass out binoculars to each student (or divide students into teams as necessary).
4. Instruct the students to properly focus the binoculars and then let them practice.
5. Pass out the Bino Blitz Answer Sheets and play the game. If possible, provide a small gift for the winning student/team.

How to Focus Binoculars:

1. Place the strap around your neck.
2. Close your left eye and look only through your right. Turn the right eyepiece until you can see clearly through the right eye.
3. Open both eyes and adjust the binoculars (lifting them up or crunching them down) so that they fit your face and you can see through both eyepieces.
4. Use the center focus wheel to sharpen your view.

STUDENT NAME ______________________________

MODULE 4 | WORKSHEET #3

PLAY THE BINO BLITZ GAME

Be the first student to use your binoculars to read the bird names from the bird pictures placed around the room. These are all common birds in your area. Yell "Blitz" when done.

#	BIRD NAME
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

MODULE 4 | TEACHER RESOURCE – BINO BLITZ

Directions:

Before class, cut out the 10 bird pictures on the following page and either paste them on a poster board or hang them around the room.

Pass out binoculars and Bino Blitz Answer Sheets and remind students how to focus binoculars. Make sure that everyone can see clearly through their binoculars, assisting individuals as necessary. Have students use their binoculars to view the bird pictures/names and then to write the correct bird name on the Bino Blitz Answer Sheet. This is a race - you may wish to reward the winner with a small prize.

FIELD MARKS

Following the Bino Blitz activity, lead a discussion about "Field Marks".

Field marks are characteristics such as size, color, beak and tail shape, and special markings on birds, such as eyebrows or spots that enable people to identify them.

Have students select one of the 10 pictured birds and describe it in terms of the bird's field marks using the Mystery Bird Worksheet. Next, have students partner up and trade papers. Partners must guess which bird their partner is describing. Do this activity multiple times if time allows. Then have the students each pick one bird to research in a field guide or other resource.

1. RED-TAILED HAWK

2. ANNA'S HUMMINGBIRD

3. HOUSE SPARROW

4. MOURNING DOVE

5. NORTHERN MOCKINGBIRD

6. HOUSE FINCH

7. GILA WOODPECKER

8. GREAT-TAILED GRACKLE

9. KILLDEER

10. CURVE-BILLED THRASHER

* Be certain to emphasize that the birds pictured here are all very common to Arizona. Ask the students if any of these species are familiar to them.

SELECT ONE OF THESE BIRDS TO DESCRIBE ON YOUR WORKSHEET


GILA
WOODPECKER


RED-TAILED
HAWK


ANNA'S
HUMMINGBIRD


HOUSE
SPARROW


MOURNING
DOVE


NORTHERN
MOCKINGBIRD


KILLDEER


HOUSE
FINCH


GREAT-TAILED
GRACKLE


CURVE-BILLED
THRASHER

STUDENT NAME ______________________

MODULE 4 | WORKSHEET #4

MYSTERY BIRDS

Directions: Pick one of the birds pictured here and describe it to your partner without using the bird's name. Make your partner guess! Use the clues below. Trade papers with a partner and see if you can guess each others' birds. If you have time, repeat the activity with another partner.

My mystery bird is mostly: ______________________

My bird's tail is: ______________________

My bird's beak is: ______________________

My bird's eyes are: ______________________

My bird probably eats: ______________________

My bird probably lives (where?) ______________________

My mystery bird was: ______________________

Scientific Name: ______________________

Size: ______________________

Habitat: ______________________

Other comments: ______________________

MODULE 4 | TEACHER RESOURCE – THE SOUNDS OF BIRDS

OVERVIEW

Students will learn to identify 10 common Arizona birds by sound by watching a PowerPoint presentation and answering questions as prompted.

Materials

- Bird Song Answer Sheets
- Science Takes Wing Bird Sounds PowerPoint presentation (available in both English and Spanish at http://askabiologist.asu.edu/birding-educational-tools)
- Computer/projector with speakers

Time: 45 minutes for presentation and discussion

Background: Birds can be identified by the sounds they make. Birds make several different sounds. They sing to attract mates and call to alert other birds to danger or to food. Listening to bird sounds is an important skill to develop if you wish to be a skilled bird observer.

Directions

Watch the Science Takes Wing Bird Sounds PowerPoint presentation and have students use the Bird Sounds Answer Sheet to record their answers.

After completing the PowerPoint presentation, have students go outside and listen for birds for as long as time permits.

Questions

What did the group hear?

What would be the best time to listen for birds? (Morning)

Where would be the best place to listen for birds? (Quiet area with cover).

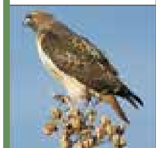
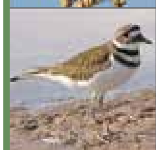
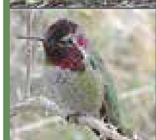
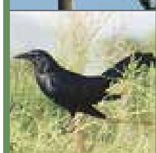
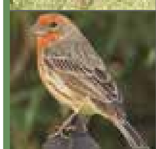
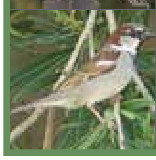
Did the group hear other sounds? If so, what did you hear?

To learn more Arizona bird sounds, visit "The Virtual Aviary" created by Arizona State University's "Ask a Biologist" program. http://askabiologist.asu.edu/activities/birds

Bat photo: C. Robiller via Wikimedia • Harris Hawk photo: Robert Shantz
All other bird photo credits can be found at http://askabiologist.asu.edu/activities/birds

STUDENT NAME____

MODULE 4 | WORKSHEET #5 BIRD SOUNDS

PICTURE	BIRD NAME	SONG DESCRIPTION (Some helpful words: chirping, cooing, whistling)	QUIZ ANSWERS (print the correct letter for each question below)
	Red-tailed Hawk		
	Killdeer		
	Mourning Dove		
	Anna's Hummingbird		
	Gila Woodpecker		
	Northern Mockingbird		
	Curve-billed Thrasher		
	Great-tailed Grackle		
	House Finch		
	House Sparrow		

MODULE 4 | TEACHER RESOURCE – BIRD SURVEY / eBIRD DATA ENTRY

OVERVIEW

Students will use binoculars to find and identify common birds in the schoolyard. They then enter data online at the Cornell Lab of Ornithology's eBird website. Students may formulate questions and use eBird data to arrive at answers. *Note: Instructors should familiarize themselves with the eBird resource and set up an online profile prior to the lesson.

Materials

Binoculars
Bird Survey Data sheet and Can You Find These Birds handout (Double-side copy these and provide one for each student)
Computer (with internet access)

Time: 45 minutes for survey and data entry

DIRECTIONS:

1. Inform students they will be going outside to look for birds and become what we call "birders". Birders follow some basic rules when they look for birds. The basic guidelines for a bird walk are to: 1) stay with your group, 2) whisper and use indoor voices, 3) tip toe (don't run), and 4) respect each other's space (i.e., students should keep their hands to themselves)

2. Pass out the binoculars and break students up into small groups of 3-4 students if possible. Assign each group a different section of the school yard or park to survey. Make sure that each group has at least one survey data sheet with common bird photos. The groups should work together to fill out ONE form.

3. Take students outside and direct them to find and record all the birds in their area (10-20 minutes is usually plenty of time).

4. Return to classroom and build a class bird list by having each group share their findings and record on the blackboard the total number of each species they detected. Which group found the most birds? Why?

5. Log on to the eBird website at http://www.eBird.com. If possible, project the screen view so that the class can observe the website and watch as data is entered. Have students take turns entering data into this free, online database. Make sure that you are not double counting birds (e.g., two or more students are entering the same bird). To prevent this, you may want to assign each student a single species (e.g., John enters the Mourning Doves, Mary enters the House Finches). Have students not entering data fill out the Bird Survey Worksheet.

6. Play with eBird data by inviting the class to choose a species they observed and look at that birds' range map. Look at other eBird features (such as frequency graphs) depending upon students' interest and available time.

GILA WOODPECKER

RED-TAILED HAWK

ANNA'S HUMMINGBIRD

HOUSE SPARROW

MOURNING DOVE

CAN YOU FIND THESE BIRDS?

NORTHERN MOCKINGBIRD

HOUSE FINCH

KILLDEER

GREAT-TAILED GRACKLE

CURVE-BILLED THRASHER

STUDENT NAME ______________________________

MODULE 4 | WORKSHEET #6 BIRD SURVEY

Date: ________________________ Survey time: ____________________________

Survey Location: ____

Sky (Circle one): clear 30% clouds 60% clouds 100% clouds

How windy was it? (Circle one): calm slight wind windy enough for a kite blustery

Do you think weather conditions can influence how many birds observers can detect? If so, how?

____

Number of birds seen: ____________ Number of bird species seen: _____________________

Which bird was your favorite? Why?

____

How could you attract more birds to your school yard?

____

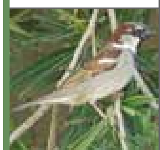
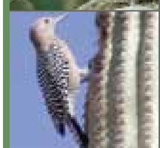
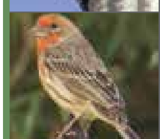
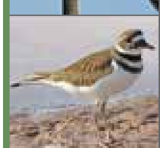
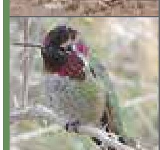
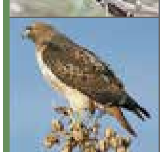
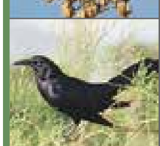
What can you do to help birds?

____

STUDENT NAME ______________________________

MODULE 4 | WORKSHEET #7

BIRD SURVEY DATA FORM

BIRD PICTURE	BIRD NAME	COUNT (Use hatch marks)	OTHER BIRDS (Describe)	COUNT (Use hatch marks)
	HOUSE SPARROW			
	NORTHERN MOCKINGBIRD			
	GILA WOODPECKER			
	HOUSE FINCH			
	CURVE-BILLED THRASHER			
	KILLDEER			
	ANNA'S HUMMINGBIRD			
	RED-TAILED HAWK			
	GREAT-TAILED GRACKLE			
	MOURNING DOVE			

MODULE 5

CONSERVATION

Desert to Rainforest

MODULE 5 | CONSERVATION

Question

How are conservation concerns different or similar between countries? How are conservation efforts different or similar between countries?

Background research: Each class will be given at least one environmental issue pertinent to their country. They will research the issue using books, the internet, provided materials, and/or local scientists. As a class they will decide on a solution for the issue, keeping the resources and constraints of their country in mind.

Form a hypothesis: Using the information about their counterparts' country learned in Module 1, the climate and plant data for both regions from Module 2, and the animal information learned in Modules 3 and 4, students will work in groups to form hypotheses about what conservation issues the other country might have and what solutions they might propose to address them.

Test hypothesis: Students compare data gathered from their background research.

Analyze data: Using the answers they obtained, students will analyze their hypotheses for accuracy.

Communicate results: Using Vidyo to share with their counterparts, students will report on their initial responses, what they learned, and their final conclusions.

THE PANAMA CANAL EXPANSION

In the last few decades, ships have become so large that the Panama Canal is now barely wide enough to let them pass, and Panamanians have decided to widen the canal. The expansion, which will be finished in 2014 at a cost of about $6 billion, could seriously impact animals and plants that live along the canal, particularly in the area's sensitive coral reefs and forests, as well as on the fresh water supply.[4]

The Panama Canal today

On the other hand, widening the Panama Canal may help slow climate change. The project might reduce greenhouse gas emissions from huge oceangoing vessels by letting more ships take the short cut through the canal, rather than burning tons of fuel by going thousands of miles around the South America.[5]

Ships that move through the canal carry containers loaded with goods we use every day. The present canal can handle ships carrying up to 4400 containers. With the new locks and wider canal, ships - called Post-Panamax - would be able to carry up to 14,000 containers.

Just as when the original canal was built more than 100 years ago, the Panama Canal expansion provides lots of opportunities for paleontologists, geologists, and biologists to discover more about the past and the diversity of life in Panama. Scientists at the Smithsonian Tropical Research Institute have made new discoveries during the canal construction. Some of these discoveries have already led to new theories about the geological origins of the Isthmus of Panama, and even about weather and creatures that existed millions of years ago.

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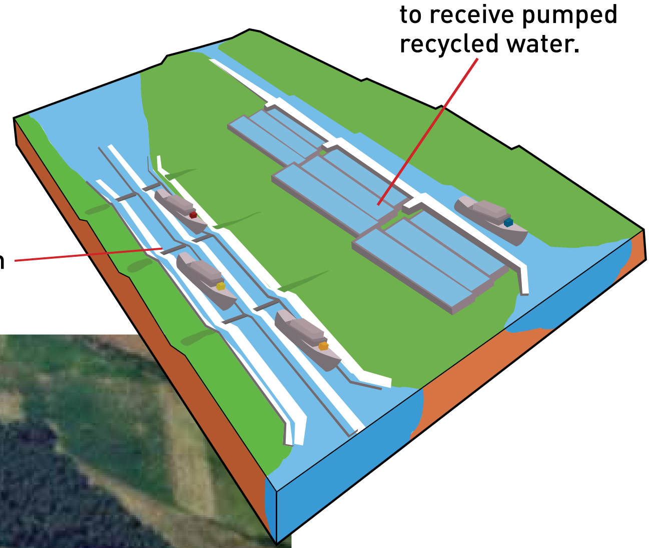
[4] H.M.R. Guzman, R. Cipriani and J.B.C. Jackson,
"Historical decline in coral reef growth after the Panama Canal," *Ambio* 37 (2008): 342-346

[5] STRI News, "STRI Hosts IPPC Working Group in Panama," November 16, 2009,
http://www.stri.si.edu/Inglés/about_stri/headline_news/noticias/article.php?id=1060

STUDENT NAME ________________________________



The Canal Expansion

Food for Thought:

Do you think the canal needs to be bigger? Why?

Can you create a list of potential benefits or negative effects you think the expansion of the Panama Canal could yield?

Can you think of ways the Panama Canal impacts your life (think of food you eat, consumer goods you buy, and electronic equipment you use)?

Is Arizona Running Out Of Water?

Over the next ten years, water shortages will be one of the biggest issues facing U.S. cities. According to a 2010 report, several large U.S. cities, including Tucson and Phoenix in Arizona, will face severe water shortages in the next few years.[6] Drought conditions will make the impacts of water shortage more severe. And, as U.S. government officials note, "When water shortages occur, economic impacts to sectors such as agriculture can be in the billions of dollars. Water shortages also harm the environment." Government officials further point out that reduced water flows have caused the Florida Everglades to shrink by half. Water shortages can also create tension in communities because people "compete for limited supplies."[7]

Because they are situated in a desert environment with limited rainfall, Tucson and Phoenix are two cities that are very sensitive to water shortages.

PHOENIX

Major Water Supply: Colorado River Basin

Population (U.S. rank): 1,593,659 (5th)

Population Growth Rate: 21.2% since 2000

Average annual rainfall: 8.3 in.

Phoenix is extremely dependent on water imported from the Colorado River. Nearly half of the water used by city residents comes from this river. As nine of the past 13 years have produced below-average flows in the Colorado River, the city's reliance on the river may soon become a serious problem.[8] If the drought pattern continues, water deliveries from the Colorado River could be cut back. To maintain a sufficient water supply, Phoenix has adopted a campaign to recycle water, replenish groundwater, and try to prevent over-consumption.[9] However, the city has neither voluntary nor mandatory water restrictions in place.[10]

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[6] National Resources Defense Council, "Climate Change, Water, and Risk: Current Water Demands Are Not Sustainable," July 2010; Charles B. Stockdale, Michael B. Sauter, and Douglas A. McIntyre, "The Ten Biggest American Cities That Are Running Out Of Water," *Yahoo! Finance*, November 1, 2010, http://finance.yahoo.com/news/pf_article_111186.html

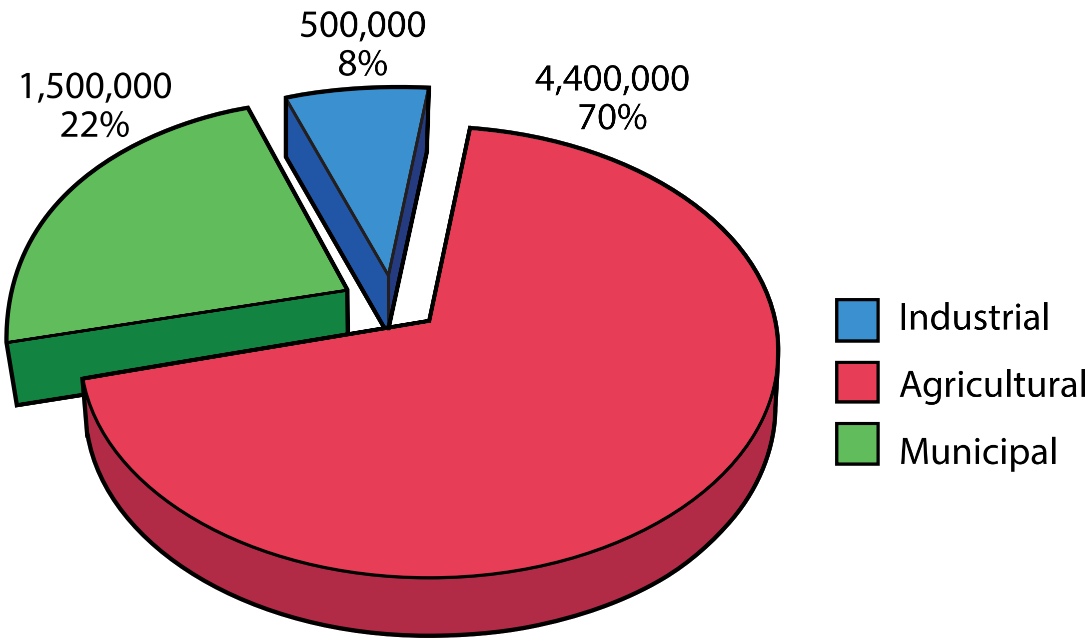
[7] Government Accounting Office, "Freshwater Supply: States' Views On How Federal Agencies Could Help Them Meet the Challenges of Expected Shortages," July 2003, http://www.gao.gov/new.items/d03514.pdf; John Hazelhurst, "Smoke on the Horizon," *Colorado Springs Independent*, June 6, 2012, http://www.csindy.com/coloradosprings/smoke-on-the-horizon/Content?oid=2483884

[8] "Residential Water Efficiency: How Building Professionals Can Save Our Cities," Delta Water Faucet Efficiency Summit 2011, http://www.residentialwaterefficiency.com/wp-content/uploads/2012/04/Delta_WES_WhitePaper12_REV.pdf

[9] Stockdale, 2010

[10] "Residential Water Efficiency"

Percentage of water used by each major use category in Arizona.
Source: Arizona Department of Water Sources (2005).



TUCSON

Major Water Supply: Local ground water

Population (U.S. rank): 543,000 (32nd)

Population Growth Rate: 20% since 2000

Average Annual Rainfall: 12.17 in.

Tucson is a city in the Sonoran Desert, an extremely arid region that receives less than 12 inches of rainfall each year. In 2010, the Tucson region used about 114 billion gallons water. At this rate, Tucson's groundwater supply, which provides the majority of the city's water, would not last very long. The city also brings in about 102 billion gallons per year from the Colorado River. Tucson is also growing rapidly and water sharing agreements between states in the Southwest might change, placing the city at a higher risk for water shortages.[11]

[11] Stockdale, 2010

Questions

How might a water shortage impact your daily life?

How might water shortages affect industry, such as the impact on jobs?

What are some things city and state governments might do to tackle water shortages?

Should water use be restricted? Why or why not?

ACTIVITY: JUNIOR SCIENCE JOURNALISTS

Materials

- Newspaper articles or online searches (local, state, national) on water issues
- Pencils, markers, crayons
- Composition paper
- Glue
- Scissors
- Computer
- Publishing software (optional)
- Video camera and editing software (optional)

STEPS

1. Develop a list of ways people might conserve water during times of drought.

2. Tell students they are going to develop their own newspaper articles, YouTube clips, videos, posters, or other informational pieces on water. Their piece should investigate some aspect of one of the two topics discussed in Module 5 (Panama Canal extension and Phoenix/Tucson water shortage), analyzing different sides of the story and using a variety of news sources, (for example, interviews with resource managers, scientists, or students/teachers who live in Arizona or Panama).

2. Divide the class into groups. The groups should brainstorm and research water topics.

3. The students should be given a deadline of five days to complete the project.

4. The layout could be done one of two ways: either on the computer using a newsletter or other publishing software, or it could be done by hand.

5. Once finished, students present it to the class and to their counterparts in either Phoenix or Panama City.

SUPPLEMENTAL READINGS

Desert to Rainforest

SUPPLEMENT #1: WHAT IS A TROPICAL RAINFOREST?

A ***rainforest*** is a region that receives, on average, between 50 and 260 inches (125 to 660cm) of rain every year. Rainforests are typically warm, moist places, although most have short dry seasons with little rain.

Most rainforests are found on or within 1500 miles (2400 km) of the equator in Western and Central Africa, Southeast Asia, the Pacific islands, and Central America. The largest tropical rainforest is in Amazonian South America.

Rainforests usually exist in ***lowland*** areas below 1500 m elevation. However, ***cloud forests*** - foggy forests that generally receive a lot of rain - are found on cooler mountain slopes between 5000 and 11,000 ft (1500 and 3300 m).

Tropical rainforests of all types make up about 6% of the Earth's land surface but hold more than half of the earth's plant and animal species. Tropical rainforests convert more sunlight energy into sugars and useful energy through photosynthesis (***primary productivity***) than any other land biome in the world, producing a staggering amount of vegetation. These plants are highly specialized to survive in rainforest conditions. Some fight the insects that would eat them with a wide range of chemicals. Others are specialized to survive the high salt conditions of tropical coastlines and estuaries.

These adaptations also make rainforest plants valuable to human society. Many plant chemicals (***toxins***) act as medicines for humans. Perhaps a third of all our medicines originally came from tropical plants. The amassed roots of coastal ***mangrove*** forests help stabilize the coastline and buffer it from storm surges, currents, waves, and tides. Their roots and trapped soil provide shelter and food for many marine fishes and invertebrates.

Most tropical trees have smooth, tall trunks that branch out only near their tops. These umbrella-like tops produce a relatively continuous ***canopy*** that blocks much of the sunlight from reaching the lower levels of the forest. Many ***vines*** and ***woody lianas*** grow up into the sunlight of the canopy by snaking up the trunks of trees for support. ***Strangler figs*** start at the canopy and grow down the trunk of a host tree. Some individual trees called ***emergents*** grow up to 300 feet (90 m) tall and tower above the canopy. Other plants called ***epiphytes*** grow high in the canopy by using the branches of the tall trees as an anchor for their own roots. The lower levels of the forest (***understory***) are often quite shaded, and the plants here must struggle to capture what little sunlight gets through to drive photosynthesis.

Bottle-trunk tree

Because of the warm, moist conditions of the ***forest floor***, dead plant and animal material is quickly broken down by abundant fungi and bacteria and a rich soil has little chance to build up in the sparse ***leaf litter***. Trees must have shallow root systems to take up nutrients as they are broken down. As a result, the greatest part of nutrients in the forest is stored in the plants themselves, not in the soil. With such shallow root systems, many large tropical trees require huge ***buttresses*** at their bases.

The density of leaves and branches in the canopy of the rainforest blocks most of the sunlight and severely limits the growth of young trees. Many tropical forests are dependent on the formation of light gaps to ensure that young trees receive enought light to reach maturity, thus maintaining the forest over time. ***Light gaps*** form when large trees fall over. As they fall, the trees also bring down neighboring trees, resulting in a clearing that lets in light to the forest floor. Young ***saplings*** that may have been waiting for decades are now able to grow and replace the fallen old trees.

Trees rely on a number of ways to spread their seeds. Birds, monkeys, and fish eat the trees' fruits, which contain the trees' seeds. The indigestible seeds are then carried away by the animals or passed through the animal's digestive system and deposited far from the parent tree. A few trees produce seeds with wings that take advantage of the wind, which disperses the seeds. Many of these seeds are large and have enough energy to grow into small saplings to await the formation of a light gap. Others are ***pioneer species*** whose small seeds wait in the ground litter (*seed bank*) to germinate with the sudden opening of a light gap.

Light gap in the rainforest

A common agricultural practice in tropical forest areas is to cut a small area of forest, burn it, and plant basic crops (***slash-and-burn*** or ***swidden farming***) like corn and yucca. This method is used to support a family and usually not to sell crops on the market (***subsistence agriculture***). Because these crops can quickly exhaust the few nutrients found in the soil, the farmers using this method must move on after a few years and start the process over again at a new site (***shifting agriculture***). A ***secondary forest*** (or second-growth forest) is a forest that has re-grown after having been extensively disturbed or cut down. Forest that has not been extensively disturbed is a ***primary*** or old growth forest.

Pear-shaped seed with wings to help it catch the wind

SUPPLEMENT #2: RAINFOREST BIODIVERSITY

Biodiversity is the variety of life and how life interacts with other living and the non-living parts of the world.

One handy indicator of biodiversity is the number of species found in an area. In general, tropical rainforests hold many more species than other ***terrestrial*** habitats. Insects by far have more species than any other group of organisms. Tropical forests may hold more than 5 million species of them, but because most of them have not yet been seen or described by scientists, we don't know exactly how many insect species there are. And rainforests house 170,000 of the world's 250,000 known plant species. With few exceptions, whatever group of plants or animals you compare, tropical rain forests always win big. Why?

One explanation for this tremendous richness of species is that tropical rainforests are physically complex. They are tall, with many layers of trees and plants that range from the ***forest floor*** to the ***low undergrowth, midlevel trees, canopy***, and, finally, huge ***emergent trees***. Some plants are ***parasitic*** on other plants, but many are ***epiphytes*** and use the branches of large trees as a base, but do no harm to the host tree. Vines are abundant: some thin and short; others such as the ***liana***, are thick and stretch from the canopy to the ground. This physical complexity allows for many other plant and animal species to live in or on different parts of the forest (***specialization***).

A second explanation involves climate. Because rainforests are located in tropical regions, they receive a lot of rainfall and a lot of sunlight. The abundant and reliable water may help species avoid extinction from unpredictable droughts and other weather patterns common elsewhere.

Because there is a lot of direct and powerful sunlight in the tropics, there is a lot of energy in the rainforest. Through the process of photosynthesis, plants convert sunlight into energy, which they store in their leaves, trunks and other parts. These plants become food for the rainforest's many plant-eating animals, who in turn become food for carnivores. The combination of relatively reliable and consistent weather, together with an abundance of energy, reduces the chance of extinction for the species that evolve in rainforests and result in an extraordinary abundance of plant and animal species.

A third explanation is that competition for things like food, nest sites, or energy sources among tropical rainforest species is much more intense than in other habitats. As a result, species have had to evolve specialized ways of dividing up resources so they do not kill each other off fighting for what they need to survive. This specialization permits more and more species to coexist and pack into the forest.

A fourth possible explanation is that high levels of predation in the rainforest enable more species to coexist. Many rainforest predators learn to hunt whatever prey are the easiest to catch. They seek out prey that are abundant and ignore less common species. When the population of abundant prey species falls, making them less common and harder to find, predators will shift to other species. Over time, predators could play an important role in keeping the numbers of certain species down, which permits a greater variety of species to live in the same area.

A fifth explanation for the rainforest's biodiversity is that disturbances in the rainforest are neither too extreme nor too mild. This explanation is known as the ***Moderate or Intermediate Disturbance Hypothesis***. If a huge hurricane hits the rainforest every year for fifteen years, only a very few hardy plants and animals would remain in that ravaged habitat.

On the other hand, if a habitat was too predictable and never experienced unexpected change, it would come to be dominated by a few of the most competitive plants and animals, or those best able to avoid their predators or survive diseases. Populations of species unable to handle these pressures would dwindle and would likely go extinct.

In rainforests, change caused by trees or large branches falling is considered an intermediate or moderate disturbance. The light gaps opened up by falling trees create a checkerboard of differently aged forest patches. No tree or animal species can take over. Instead many species, each adapted for different amounts of light and openness, are scattered throughout the forest and the result is high species richness.

The tropical rainforest is so complex that it is likely that there is no one explanation for why there are so many species in rainforests. Whatever the cause of the rainforest's tremendous biodiversity, the consequences of the extinction of species is hard to predict. Some species help many other species survive in the community (***keystone species***). Other species are less important. This complexity of interactions among the many species may actually make the tropical forest ecosystem better able to bounce back from change.

Because we know so little about rainforests, we are taking a chance with any extinction that humans might have helped cause. Besides many medicines, rainforest biodiversity helps supply everyday products we use, including chicken, vanilla, rubber, and chocolate. The search for more useful products like these, as well as money-making businesses like ***ecotourism***, are great economic incentives to better manage and use these forests for long term benefits (***sustainable***).

The value of biodiversity and forest management are clear in Panama. The Panama Canal is the major source of income in Panama and is also important to the United States economy. Built in 1914, the Panamanian isthmus was too high and rocky for a sea-level passage, so Atlantic-bound ships have to be lifted 85 ft (26 m) to enter Gatun Lake midway through the canal, and lowered again on the Atlantic side using locks (fixed chambers in which the water level can be manipulated). The forests bordering the passage prevent soil eroding into the canal and enhance the rainfall needed to replace the water lost through the locks every day. The forests cannot be thinned or removed without devastating economic losses.

Number of bird species:
North America
(2 billion+ hectares) = about 750
Panama
(7.8 million hectares) = over 970

Number of frog species:
North America
(2 billion+ hectares) = 81
Madagascar
(58.7 million hectares) = nearly 500

Number of tree species/hectare:
United States = around 20
Brazil = around 400

Number of butterfly species:
Europe = 570
Peru = 1200

SUPPLEMENT #3: REPRODUCTION IN THE RAINFOREST

When it comes to sex, plants have a problem. To produce the fruits and seeds necessary to generate offspring, they have to get pollen from the male's flower to the female's flower. But plants don't have legs or wings to take them to potential mates; they are literally rooted to the spot they are in. So plants rely on having their pollen moved and delivered to mates for them.

Some plants rely on the wind to assist in sexual reproduction. But in tropical forests, wind is often not an efficient way to spread pollen. There are too many different species of trees close together, and the pollen is unlikely to find its way to the female flowers of the same species.

So most rainforest plants use animals to more efficiently direct their pollen to the right female flowers. And it turns out that there are quite a few organisms who can transfer pollen; in fact, many animals are specialized to make sure the pollen from the male part of a flower species makes it to the female parts of a flower of the same species.

To attract these helpful animals, plants place rewards such as sugar or nectar near or around the pollen. When the animal goes after the reward, the pollen rubs off or falls on the animal's head, neck, body or legs and is carried to the next flower. Flowers pollinated by hummingbirds often have red, cup-shaped flowers. The shape of the entrance to the nectar and pollen can be long or shaped in a curve that will let only those species of hummingbirds with bills curved and long enough to fit into the flower and get to the nectar.

Flowers pollinated by bats and moths open after sunset and tend to be lighter in color, often white or yellow.

Flies, on the other hand, are drawn to bluish flowers that have a rotting or mildew-like smell. Butterfly-pollinated flowers have a mild odor and are red or orange.

Not all pollinators are specialized to pollinate only one species of flower. Orchid bees are beautiful insects common in tropical rainforests. The males of each species are attracted to many species of flowers where they gather fragrances that smell like vanilla, camphor, wintergreen, or cinnamon. The male bees use specific mixtures of these chemicals to attract females. The flowers keep their pollen in packets called ***pollinaria*** that attach to the male bees when they enter to harvest the fragrances. Each flower species sticks its pollinaria on a different part of the bee's body, head, or legs. When the bee enters the next flower, a super sticky part of the female flower pulls off the right packet of pollen that matches its species.

Orchid Bees

Sexual reproduction in rainforests can also takes some strange twists. The vividly-colored poison dart frog female lays its clutch of eggs in a particular part of the forest floor or vegetation. A male fertilizes them where they have been laid, a process called ***external fertilization***. Male poison dart frogs sometimes wrestle each other for the privilege of fertilizing these eggs. The male will also fight for the most prominent roost from which to broadcast his mating call, usually overlooking a prime egg-laying site. Females fight, too, sparring over desirable nests, and even invading the nests of other females to devour competitor's eggs.

Adults of some species of poison dart frogs that lay their eggs on the forest floor stick newly hatched tadpoles to their backs and carry them up into the canopy. Here the parents deposit the tadpoles into small tanks of water created by epiphytic plants, such as bromeliads. The tadpoles feed on invertebrates in their arboreal nursery, and their mother will even add to their diet by putting her unfertilized eggs into the water. Other poison frogs lay their eggs on the forest floor, hidden beneath the leaf litter.

Rather than ward off competitors, some species attract mates with elaborate displays of color, dancing, and singing. Manakins are tiny birds that live among the forest's lower levels. While the males are spectacularly-colored, the females have dull brown or green feathers. Because they eat mostly berries that are abundant year-round, manakins don't have to worry about constantly searching for food. Instead, they are free to engage in elaborate courtship displays by the outlandishly plumaged males. In some species, males form ***leks***, where several subordinate males dance and sing together with a dominant male. When the female approaches the lek, all the males increase the intensity of their display. But the female only mates with the dominant male. The subordinate males often have to wait years until they can assume the role of the dominant male. Females will not approach any male singing by himself. The ***cryptic*** female builds the nest, lays eggs, and raises the young alone.

Finding, attracting, and coupling with suitable mates can be quite an intensive process. But some animals cannot afford such high expenditures of energy. The mantled howler monkey, common to Panama, is one such species. Howlers get their name from the lion-like roaring of the males, who can weigh up to 9.8 kg (22 lb). They feed almost entirely on leaves, which are difficult to digest and provide little energy. As a result, mantled howlers spend most of their time resting and sleeping. The vivacious, energy-intensive dancing and singing of the manakin would simply cost the howlers too much energy.

To find suitable partners, mantled howlers have evolved a social system in which young males and females are kicked out of the social groups into which they were born. Finding a new group to join is important because solitary howlers do not survive long and because it is in the new group that the young adults will find and compete for mates. Young howlers vie to become dominant individuals in the new troop, so they can get preference for the best food, safest resting sites and strongest mates. Although its leaf-based diet places severe restrictions on its activities, the abundance of the leaves preferred by the mantled howler allows the species to be able to survive on a relatively small patch of forest, which makes it easier to breed and raise young compared to other more active fruit-eating monkeys.

photo: Rainforest Harley via Wikimedia

Mating Orange-thighed Tree Frogs

SUPPLEMENT #4: PHOTOSYNTHESIS & CARBON CYCLING IN THE RAINFOREST

photo: Geoff Galice via Wikimedia

Carbon-based molecules are essential for sustaining life on Earth. Scientists call the cycle in which carbon moves through a habitat and, ultimately, through the environment and atmosphere, the ***carbon cycle***.

There are many paths that carbon can follow as it moves through a habitat, but perhaps the most important path for life is ***photosynthesis***. During photosynthesis, plants absorb carbon dioxide from the air. Then using the energy of the sun, a chemical process separates out the carbon from carbon dioxide and combines it with hydrogen and oxygen from water to make energy-rich sugars. Plants, and the animals that eat them, use these sugars to grow. The transformation of non-living (***inorganic***) carbon from the air into carbon as part of a sugar in a living organism (***organic***) is called ***carbon fixation***.

Even though tropical rainforests only make up 6% of the world's land surface, the carbon they convert from carbon dioxide into sugars makes up almost half of all the carbon stored in the world, making the rainforest into what scientists call a ***carbon sink.*** Rainforests are also responsible for 28% of the world's oxygen turnover, another result of photosynthesis. Acting like miniature solar panels, the billions of leaves in tropical rainforests convert more sunlight into sugars than any other terrestrial habitat on Earth (***primary productivity***).

However, not all light is equal. Take a rainbow, for example. When sunlight passes through water vapor it reveals the separate color bands - red, orange, yellow, green, blue, indigo and violet. The colors are always in this order and represent a progression from the weakest amount of energy (red) to the greatest amount of energy (violet).

Violet and ultraviolet light is so high in energy that it can harm living cells. Sunburn is an example of the damaging effects of violet and ultraviolet light.

Red and infrared light is much lower in energy. Plants can use red light to drive photosynthesis but it is so weak that it has a hard time getting through obstacles in the leafy canopy. Blue light, therefore, is most useful for photosynthesis.

But not all plants in the rainforest have ready access to the sun's energy. High up in the rainforest, a continuous roof of leaves and branches, called the ***canopy***, connects the trees. This canopy protects the ***understory*** from harsh and intense sunlight, drying winds, and heavy rainfall, and keeps the lower parts of the forest and ***forest floor*** moist and at a more constant temperature. However, the canopy also blocks much of the light from the sun needed to drive photosynthesis, limiting the rate of growth for plants in the understory. So how do young trees survive long enough to replace older mature trees?

photo: Takkk via Wikimedia

Bands of color in a rainbow

Many tropical forests depend on the formation of ***light gaps*** to maintain the forest over time. Gaps form when big branches break off or large trees fall over and bring down neighboring trees. Such an event breaks a hole in the canopy and lets light reach the forest floor. Young saplings that may have been waiting for decades can now photosynthesize and grow to replace old fallen trees. Because the rate of photosynthesis is so high, rainforests have more energy to grow quickly and produce tons of fruit, seeds, flowers, and leaves. This abundance of plant material attracts and supports a wide diversity of animal life.

Plants are the only organisms on Earth that can take the energy of the sun and convert it to food.

Animals that subsist on plants are called ***herbivores***. By eating plants, these animals transfer the energy stored in the plants to their own bodies, just as the plants transferred the sun's energy to their cells through photosynthesis.

Most of the herbivores in the rainforest are insects. Tropical plants fight the insects that would eat them with a wide range of chemicals. Some insects get around the defenses with special enzymes that detoxify the effect of the plant chemicals.

Other insects, like leafcutter ants, have developed remarkable relationships with plants. Using their mandibles, leafcutters cut discs of leaves which they carry into deep underground galleries. Here the ants actively farm a special fungus, feeding it with the freshly cut plant material and keeping it free from pests and molds. If a particular type of leaf is toxic to the fungus, the leafcutter colony will no longer collect it.

Why would leafcutters cultivate fungus? It turns out that the fungus is great food for ant larvae. The fungus needs the ants to stay alive, and the ant larvae need the fungus to stay alive - a relationship known as ***mutualism***. The adult ants transport used leaves and fungi to a nearby waste heap called a refuse dump. The colony has special members that work to arrange the waste and constantly shuffle it around to aid in ***decomposition***.

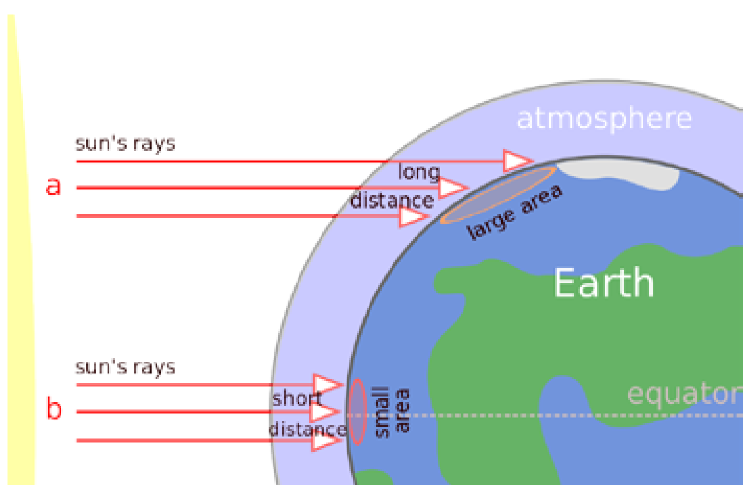
Because of the warm, most conditions of the forest floor, decomposition happens fairly quickly in tropical rainforests. Abundant fungi and bacteria quickly break down dead plant and animal material, preventing the development of a rich ***topsoil***. As a result, most nutrients in the rainforest are quickly taken up and stored in the plants themselves, not in the soil.

For trees to grow, they must have shallow roots systems to harvest the nutrients released on or near the soil surface during decomposition. Because they have only shallow root systems, many tropical trees grow huge ***buttresses*** to support their weight.

The rainforest's trees use water to transport nutrients from the soil throughout the plant in a process called ***transpiration***. All this water moves up into the canopy and "sweats" out through pores called stomata. The warm sun evaporates the water escaping from the stomata, along with any rainwater resting on the leaf surfaces, producing clouds of water vapor (***evapotranspiration***). One tree can release over 755 l (1600 lbs) of water every year! When you multiple this by millions of trees, tons of water vapor are released and heated over the rainforest canopy each year.

It may seem hard to believe, but besides helping produce food for plants, the sun is also responsible for producing the massive amount of rain that falls on tropical rainforests. Because tropical rainforests are near the ***equator***, the sun's light hits the land and water more directly and consistently than anywhere else, keeping the air over rainforests relatively warm.

Warm air can hold a lot of water vapor, but as it rises, it cools, lessening its ability to hold water vapor (***dew point temperature***). As the air cools, the vapor changes into droplets (***condensation***) and clouds form. This makes rainforest climates very different from other habitats where water vapor blows away and falls somewhere else. In most rainforests, more than half the precipitation falls on the same forest.



The sun's energy reaches areas near the equator more directly and in a more concentrated form, boosting evaporation and growth rates.

diagram Peter Halasz via Wikimedia

SUPPLEMENT #5: WHAT IS A DESERT?

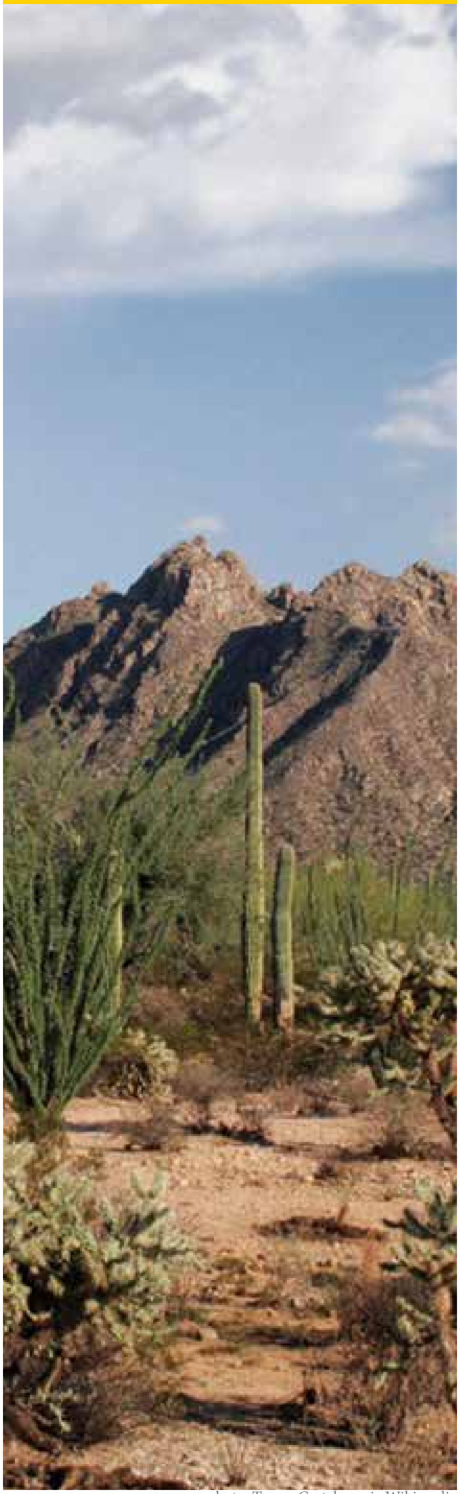


photo: Tomas Castelazo via Wikimedia

Deserts are areas that receive so little rainfall that they support little or no vegetation and only small populations of people and animals. They may be regions comprised of sand dunes or vast areas of rocks and gravel with scattered plants.

About 20% of the Earth's land surface is desert. They occur on every continent, including Antarctica, but Africa has the largest area of desert.

The most extreme arid desert in the world is the Atacama Desert of coastal northern Chile. No rain has been recorded here in more than 500 years of records! Less arid deserts receive no more than 250 millimeters (10 inches) of annual rainfall, and semiarid deserts have an annual precipitation of between 250 and 500 millimeters (10 and 20 inches).

As the Atacama suggests, deserts are habitats of extremes, with searing heat and dryness, dangerous flash floods and frigid nights and winters. What little rain deserts do receive often falls in quick downpours during short rainy seasons that are separated by long dry periods.

Most deserts have five seasons: winter, spring, foresummer, summer and fall. ***Foresummer*** is a hot, dry period between the winter and summer rainy seasons. During foresummer, the skies are dependably clear and the days become progressively hotter.

Daytime temperatures in the desert can be very hot, often reaching 120 to 140 degrees F (4 to 10 C) in the sun. Temperatures at night, on the other hand, can fall into the 40s or 50s Fahrenheit. And it is not uncommon for snow to fall in many deserts during the winter season!

Most of the desert's extremes are caused by dry air. Deserts are dry for one reason – the amount of evaporation in deserts exceeds is the rainfall they receive. Often the air near the ground is so dry that even if rain falls, it evaporates before it hits the ground (***virga***). Phoenix, Arizona sometimes has ***relative humidity*** (water vapor in the air) as low as 4%, and it rarely rises above 45%.

Most other habitats are moister and are insulated by their humidity and the denser vegetation they can support. Forests both in North America and in the tropics often have humidity over 80%. During the day, this water in the air reflects and absorbs sunlight energy so that temperatures do not rise very high. At night the water in the air acts like a blanket, trapping heat inside the forest, and temperatures do not fall very far. Dense trees and other vegetation in forests help retain heat at night and provide shade in the daytime, which keeps temperatures from changing rapidly.

The dry air of the desert cannot hold its temperature, and that, together with the sparse vegetation, causes it to cool down rapidly when the sun sets, and heat up quickly after the sun rises.

photo: Simon A. Eugster via Wikimedia

Virga

Why do deserts receive so little rainfall? Many of the world's deserts are located at ***midlatitudes*** (between 30° and 50° from the equator). They receive descending dry air displaced north and south by rising columns of high energy air in equatorial regions. Most of the moisture has already been squeezed out of the air to rain down on the tropical forests. The Sonoran Desert of Arizona is a typical midlatitude desert.

Many deserts are also far from the ocean, which prevents the moisture in the air over the ocean from reaching these inland deserts.

Sometimes mountains contribute to the desert's aridity. ***Rain shadow*** deserts form when tall mountain ranges prevent the moisture-rich clouds from reaching areas on the ***lee***, or protected side, of the range. As air rises over the mountain, it cools and rains on the ***windward*** slope. The now dry cool air is forced up by prevailing winds until it reaches the crest of the mountain, and descends down the far (lee) side with little or no moisture, contributing to the development of a desert habitat.

Some interior mountains are surrounded by desert. The mountains themselves are tall enough to be cool even in the summer and capture regular rain so that forests of pines and oaks grow at their tops. The plants and animals at the tops of these ***sky islands*** are separated by long distances from the next mountain top.

Deserts typically have soils rich with minerals but lacking much organic content. Soils in deserts are usually a mixture of clay and sand, which allows water to quickly soak deep into the ground, making it unavailable to shallow rooted plants.

Where there is some vegetation, concrete-like patches called ***caliches*** form. A caliche is usually the result of chemical reactions between water and carbon dioxide released by plant roots or decaying organic material.

When rain does fall in the desert, the storms that bring the rain are often violent. Dry stream channels, called arroyo or wadi, can quickly fill after heavy rains, and flash floods make these channels dangerous. Water running down an arroyo flattens, slows, and spreads onto a flatter plain to form a broad area of loose particles of silt, clay, sand and gravel called a ***bajada*** or ***alluvial fan***.

In other areas, rainfall or melting snow in neighboring mountains can cause runoff from ***ephemeral***, or short-lived, streams that last for days or weeks. These streams fill the channel with a mixture of mud, rocks, tree limbs and other material that is carried some distance before settling out on the desert.

Some desert streams carry water throughout much of the year, and strips of trees and water-adapted vegetation form along the lengths of these rivers, producing what is known as a ***riparian*** habitat. Many of these riparian areas have no surface water flowing during the driest part of the year, but underground water often continues to flow below the dry sandy bed.

With little vegetation to hinder it, the wind regularly moves soil and other minerals around the desert. Many deserts experience regular dust storms. Some dust storms, called ***haboobs***, can produce walls of dust thousands of feet/meters high. In some areas where the sand, prevailing winds and position of mountains or other obstructions line up just right, sand dunes form.

Dust hanging high in the air during the evening can produce beautifully colored sunsets. But the dust can also carries spores of a fungus that can cause an illness known as ***Valley Fever*** or coccidioidomycosis infection.

Vast alluvial fan in China's Taklimakan Desert. The blue is water flowing in the fan's many small streams.

SUPPLEMENT #6: REPRODUCTION IN THE DESERT

Reproduction – the creation of new individuals – is a process fundamental to the biological world. But not all organisms reproduce in the same way. Plants and animals employ a variety of reproductive strategies to ensure the survival of their species. In general, species either engage in asexual or sexual reproduction.

Many plants and some animals reproduce without engaging in sexual relations with another individual (***asexual reproduction***). This method produces offspring that are genetically identical to the female parent. That means that all of the offspring of asexual reproduction are ***clones*** of the mother.

The oldest individual plants in the deserts of the North American Southwest are creosote bushes that can reproduce asexually by sending out new roots. Some creosotes may be several thousand years old! For creosotes, asexual reproduction is handy because only females are needed, reducing competition for valuable water and nutrients from males.

Asexual reproduction only works, though, when the environment to which the plant or animal is adapted is similar over large areas or is highly predictable. This is because asexual reproduction produces little ***genetic variation***. Variation is typically a benefit in environments with a lot of variety and change. Besides plants, some insects, including aphids, midges and some wasps, and several species of whiptail lizards in the desert Southwest reproduce asexually (***parthenogenesis***).

In contrast, ***sexual reproduction*** combines half the ***genes*** from each of two parents, so the resulting offspring are different from each parent and from one another. This variation is the raw material of the ***natural selection*** that drives ***evolution***. Sexually reproducing species stand a better chance of surviving disease and unexpected changes in the environment. If each offspring has a different genetic makeup, some are more likely to have the right combination of genes and physical characteristics to handle changes that come along. A species that cannot reproduce sexually is at greater risk of extinction, because it cannot adapt as quickly to changes in its environment.

When it comes to sexual reproduction, however, plants face a serious challenge. They cannot move around to find mates, but are literally rooted in one place. Somehow they have to get the ***pollen*** from the male's flower to the female's flower to make fruits and seeds needed to produce offspring.

So how do plants move their pollen? The answer is: they don't - they rely on other forces to move it for them through a process called ***pollination***.

photo: Will Herron via Wikimedia

White-winged Dove pollinating a saguaro. It will also eat saguaro fruit and disperse its seeds.

In some cases, plants rely upon animals to move their pollen. While some plants use many different animals as pollinators (***generalists***), others rely on highly specialized animals to ensure that pollen from one species of plant makes it to the female of the same species. Plants attract these helpful animals by producing colorful petals or placing rewards such as sugar or ***nectar*** around the pollen. When the animal goes after the reward, the pollen rubs off or falls on its head, neck, body or legs to be then carried to the next flower.

A wide range of ***animal-pollinated*** systems exist in the desert. Some cacti, such as the saguaro, are generalists, blossoming late at night and into the next day to attract migratory birds, as well as daytime (***diurnal***) and night time (***nocturnal***) insect pollinators. The senita, on the other hand, is highly specialized and attracts only non-migratory senita moths as pollinators.

Other plants use wind to assist their reproductive process. Instead of producing nectar, fragrance, or showy parts, these plants invest their energy in producing huge amounts of pollen that can be released into the wind. Because only a tiny percentage of this pollen will make it to a receptive female part of another plant of the same species, ***wind pollination*** works best where many individuals of the same species live close together. In deserts, wind pollination is most common in ***riparian*** areas where plants such as willows and sycamores grow in dense groves.

Reproduction doesn't end with successful pollination, though. After they've been pollinated, flowers turn into fruits containing seeds. To have the best chances of reaching maturity, seeds need to grow up away from their parents, who would only compete with the young plant for water and nutrients.

Once again, plants rely on animals or wind to help move seeds to suitable locations. Some seeds are small with wing-like appendages that catch the wind. Others are wrapped in sweet pulp in the form of fruits. This fruit attract animals, who eat or transport the seeds to other locations. Indigestible seeds pass through an animal's system and are deposited far from the parent plant in a pile of valuable nutrients when the animal defecates. While it sounds gross, this type of seed dispersal increases the chances for ***germination***.

How do seeds survive in the dry desert? Many desert wildflower seeds will not germinate until enough water has washed away a chemical on the seed surface that prevents germination. Some seeds can survive years in the ground (***seed bank***) until conditions favor growth. More than average rainfall, even after years of drought, can produce annual wildflower explosions in the desert.

Like plants, desert animals have adaptations that aid reproduction. Seed eating (***granivorous***) ants typically build colonies near seed producing plants. Most pollinator insects, such as bees, butterflies, and flies, time their mating to correspond with flowering periods.

Insects also choose to lay their eggs in locations that will support the development of offspring. Digger bees build nests underground to protect newly laid eggs. Butterflies and moths often lay clusters of eggs on the undersides of certain leaves, which the caterpillars that hatch from the eggs can use as ***food plants***.

Other animals time their mating activity to coincide with times when food and water is most abundant. Insects time their mating reproduction to the coming of the rains. Birds typically begin mating as the days lengthen, but many desert breeding birds, such as the Rufous-winged Sparrow, also use rainfall and food availability to cue their breeding. As insects become more abundant, birds begin mating. Conversely, the desert Kangaroo Rat, which typically breeds from February to October, will shorten their breeding periods during drought when food is scarce.

Couch's spadefoot

Couch's Spadefoot, named for the wedge-shaped "spade" on its hind feet it uses to dig burrows, emerges from the ground and breeds after spring or summer rains. Females lay eggs pools in small packets containing 20 to 40 eggs that they deposit in pools of water. The eggs hatch within days, but newborns remain tadpoles for only a few days, quickly growing into tiny adult forms before the water dries up.

The Gila Monster lives to be 20 years or more in the Sonoran Desert, and it is one of only two venomous lizards in the world. It ***hibernates*** underground all winter long and then emerges in late April to early June for male-to-male combat, which stimulates breeding activity. This is also the time that their favorite food, bird and tortoise eggs, are widely available. Females lay two to 12 leathery eggs that remain below ground through the winter and hatch ten months later in the spring.

SUPPLEMENT #7: DESERT ANIMAL & PLANT ADAPTATIONS

photo: Stan Shebs via Wikimedia

Plants need water to move material internally (***diffusion***), as well as for photosynthesis. Because water is a rare commodity in deserts, plants have evolved many adaptations to use it efficiently. Plants that have adapted to dry habitats by altering their physical structure are called ***xerophytes***.

Many desert plants have developed adaptations to reduce the water lost to evaporation during ***transpiration***. These adaptations can be grouped into three basic drought-coping strategies—succulence, drought tolerance, and drought avoidance.

Succulent plants like cactus, agave, and euphorbs store water in fleshy leaves, stems, or roots so that it is not easily lost. Succulents must be able to absorb large quantities of water during brief rains or flooding. To grab ground water quickly, nearly all succulents have extensive, shallow root systems.

A giant saguaro's root system lies immediately beneath the soil surface and radiates as far as the plant is tall. Although agaves are succulents, they horde water using specially-shaped leaves that channel rain to the plant's base, rather than through an extensive root system.

Plants that live for only a season (***annuals***) grow up quickly when it rains and then die at the end of the short wet period. Those that persist for several years (***perennials***) survive by remaining dormant during dry periods of the year but springing to life when water becomes available.

Plants have also evolved ways to keep cool, access water, or conserve water - all drought tolerance strategies. Spines on succulents like cacti serve to shade the plant. Other desert plants, like mesquite trees, have very long ***tap roots*** to reach deep groundwater.

Many plants regulate the size and number of leaves to reduce the amount of water lost through transpiration. Most succulents have few leaves (agaves), no leaves (most cacti), or leaves that are deciduous in dry seasons (boojum). Plants like ocotillo resist drought by shedding leaves and growing new ones only after sufficient rain has fallen. And the tiny leaves of the palo verde tree minimize evaporation because less surface area is exposed to the sun and wind, and green photosynthetic surfaces are largely shifted to trunks and stems.

While root systems and water conservation strategies are important, desert plants also strive to reduce competition for water from nearby plants. Some plants, like the creosote, release chemicals into the soil that inhibit other plant seeds from germinating nearby. This is called ***allelopathy***. When viewed from the air, creosotes seem to be evenly spaced throughout their habitat. This even spacing reflects the regular distance at which the chemicals they release effectively prevent other plants from taking root.

photo: Stan Shebs via Wikimedia

Cactus with very long taproot

Besides heat and drought, plants also face hazards from plant-eating animals (***herbivores***). Some plants rely on their short life cycles to reduce the likelihood that they will be found by an herbivore.

Other plants have developed physical defenses, such as spines, thick outer layers, bad tastes, or even ***toxins*** to discourage herbivores.

Desert animals also have many adaptations to survive the desert's extremes. Many bat and bird species ***migrate*** out of the deserts during the winter to escape the cold and the early part of the summer dry season. Most desert insects and some mammals do not need free water to drink. Their water needs are supplied completely from the plants and insects they eat.

Mammals, which use internal physiology to maintain a constant temperature regardless of the outside temperature, are more susceptible to the heat than other animals. To cope with hot desert temperatures, most mammals try to be active only during the cooler night (***nocturnal***) or at dawn-dusk (***crepuscular***).

Insects and reptiles, on the other hand, need outside sources of heat to raise their internal temperatures so that they can move around. They tend to be active during the day and on warm nights. However, if it gets too hot, they rely on behavior to cool down – shuttling in and out of shade, orienting their bodies to minimize sunlight energy, and digging into the cooler soil.

During cold nights and the winter season, lizards and insects spend most of their time inactive underground or among rocks (***hibernation***).

Desert birds don't hibernate, but use their feathers as insulation to survive the desert's extreme temperatures. The greater roadrunner has light colored feathers that reflect much of the sun's energy during the daytime, but on cold winter mornings the roadrunner needs to absorb heat. So it turns its back to the rising sun and lifts its feathers up to expose a large patch of black skin on its back. This black patch absorbs heat and saves the roadrunner from using up fat reserves to warm itself.

As in most biomes, animals need to develop strategies both to cope with climatic factors and to avoid being eaten. Some animals defend themselves by being active only when their predators are inactive. Others, especially insects, can make themselves distasteful by storing plant toxins in their bodies. Often these bad-tasting insects, such as the tarantula hawk wasp, advertise how bad they taste by having bright colors. This way even dumb enemies quickly learn to avoid them after one experience. Cleverly, some good-tasting species sometimes cheat and display similar bright colors in an attempt to fool predators. These cheaters are called ***mimics*** and the bad-tasting species are called ***models***.

Just like insects and plants, humans need adaptations to survive in deserts. Phoenix, Arizona is one of the world's largest desert cities. Its inhabitants have prospered primarily because rivers, such as the Salt, Verde, and Colorado, have been dammed and much of their water diverted by canals to meet the demand. Urban desert populations also pump water out of huge underground lakes called ***aquifers***.

This strategy, though, is not sustainable. Most rivers in Arizona no longer flow regularly because so much of their water has been used for human consumption. This loss of water severely impacted some desert animals and plants, especially those that are aquatic and depend on natural rivers and ponds, such as the desert pup fish.

Endangered Desert Pupfish

Arizona's future economic plans point to increased water consumption by humans, industry, agriculture, and mining. Tourist and recreational sites like golf courses use a great deal of water. But with so little water available to meet growing demand, humans need to explore better ways to exist in desert environments. Ecotourism, for instance, does not demand as much water, and it helps support habitat management, environmental education, and jobs for local residents.

Satellite view of Phoenix, Arizona with the now empty Salt River (highlighted in yellow).

SUPPLEMENT #8: PHOTOSYNTHESIS & CARBON CYCLING IN THE DESERT

photo: US Botanic Garden via Wikimedia

Cactus with spines and trichomes at the United States Botanic Garden

The ***carbon cycle*** in deserts is much like those found in rainforests and other habitats. Through this cycle, in carbon moves through a habitat and, ultimately, through the environment and atmosphere.

There are many possible paths that carbon can follow as it moves through a habitat, but perhaps the most important path for life is ***photosynthesis***. During photosynthesis, plants absorb carbon dioxide from the air. Then using the energy of the sun, a chemical process separates out the carbon from carbon dioxide and combines it with hydrogen and oxygen from water to make energy-rich sugars. Plants use these sugars to grow and animals who eat these plants use the sugars as energy that fuels growth and reproduction. The transformation of non-living (***inorganic***) carbon from the air into carbon as part of a sugar in a living organism (***organic***) is called ***carbon fixation***.

The most unique parts of desert carbon cycles are in the adaptations plants and animals have developed for handling and processing the carbon under extreme dryness, heat, and temperature fluctuation.

One way desert plants cope with the desert's aridity is by using a different type of photosynthesis called crassulacean acid metabolism or ***CAM***.

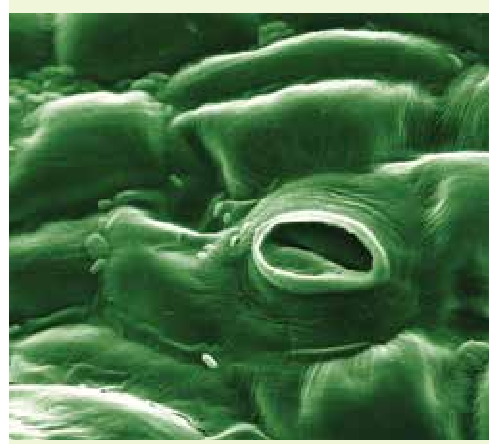
For photosynthesis to happen, plants must open pores called ***stomata*** to pull up water and nutrients through the roots in the soil and to access carbon dioxide in the air. This process, called ***transpiration***, helps distribute water and nutrients to the entire plant. However, it is a process that costs the plant valuable water because as the pores open, water vapor escapes the plant into the air.

To survive and thrive, desert plants need to find ways to minimize water loss. One way they might do that would be to engage in transpiration at night when the temperature is lower and humidity higher than during the day. But photosynthesis cannot breakdown carbon dioxide and combine it with elements of water to make sugars without the sun's energy.

Instead, many desert plants have adapted by altering steps in standard photosynthesis, known as ***C3 photosynthesis***.

What the plants do is gather valuable carbon dioxide at night and store it as an ***organic acid***. During the following day, the stomata close and almost completely seal the plant's surface to prevent water loss. The daytime sun initiates photosynthesis, using the stored carbon dioxide.

Plants using CAM lose about one-tenth as much water per unit of sugar produced as do those using standard C3 photosynthesis. But the trade-off is that the overall rate of photosynthesis is slower, so CAM



Microscopic photograph of stomata on the surface of a leaf

plants grow more slowly than most C3 plants. Some succulents, such as agaves, can switch from CAM to C3 photosynthesis when water is abundant, speeding growth.

Other desert plants enhance standard photosynthesis and reduce water loss by having small or no leaves, and much of the green photosynthetic surface exists instead on trunks and branches (Palo Verde trees, cactus). Silver, hair-like ***trichomes*** on some desert plants reflect light energy to reduce evaporation. Waxy coverings on leaves help make some desert leaves water tight. The leaves of other desert plants are angled nearly vertical to receive the most direct rays of the sun's energy when it is low in the sky during cooler mornings and late afternoons. This also reduces the amount of leaf surface exposed to the sun during the midday heat.

Besides adapting to the extremes of the desert climate, plants also have to protect themselves against ***herbivores***, who can eat away a plant's valuable photosynthetic surfaces. Some plants have evolved hard coverings, spines, and toxic or distasteful chemicals to discourage herbivores.

Nevertheless, herbivores are an important part of the carbon cycle and have evolved ways around these defenses, such as tough mouths to eat spines. As they munch on plants, herbivores ingest the carbon and energy held in plant sugars. When herbivores are eaten by predators, that energy transfers once more, this time to the predatory animal.

Eventually, the carbon that plants extracted from the air through photosynthesis ends up on the soil surface as organic matter in the form of dead animals and plants or nutrient-rich feces. Here it undergoes a process of ***decomposition***.

Like rainforests, there is very little ***topsoil*** in deserts. It can take hundreds of years for a millimeter (.04 inch) of topsoil to develop in the desert! In the rainforest, rapid decomposition and re-uptake of nutrients by the rainforest's tons of biomass prevent the development of topsoil. The desert has significantly less biomass than the rainforest and that explains the lack of topsoil. Desert plants and animals evolved through selection to be less reliant on water, and one trade off is that they grow slowly. Fewer plants and animals result in less organic matter available to decompose in desert soils.

Besides a smaller amount of plant and animal material, deserts are also not typically hospitable environments for the growth of common agents of decomposition, such as bacteria and fungi, which need warm and moist conditions to do their job.

Termites are arguably the most important agents of decay in the desert. A diverse and sizable population of termites lives in ***subterranean*** nests throughout the desert. With the aid of their ***gut flora*** with which they have a ***mutualistic*** relationship, termites can quickly digest complex ***cellulose*** and other plant cell structures.

If we didn't have termites in our deserts, tree trunks, branches, leaves, dead grasses, cactus skeletons, and dung would accumulate over the years. Eventually, few living plants would be left to produce food for animals because there would be no space for new plant seedlings to establish. There would also be no nutrients broken down and available in the soil to be taken up by their roots. And without plants most animals would disappear. So, without termites, the carbon cycle would be slowed or even halted, and the whole desert ecosystem as we know it would probably collapse.

photo: Bernard Gagnon via Wikimedia

Dead saguaro undergoing decomposition

GLOSSARY

Desert to Rainforest

DESERT TO RAINFOREST GLOSSARY

Acidic – substances with a pH less than 7

Alkaline soil – a basic soil with high pH (> 8.5) usually caused by high percentage of sodium carbonate

Allelopathy – the production and release of biochemicals that inhibit the growth, survival, and reproduction of other nearby organisms

Alluvial fan – a fan-shaped deposit of soil types formed where a fast-flowing stream flattens, slows, and spreads onto a flatter plain, typically at the exit of a canyon (see *bajada*)

Animal pollination – the transfer of pollen from the male parts of one flower to the receptive female parts of another flower by animals whose bodies have acquired pollen during their visit to a flower; typically results in fertilization

Annuals – plants that go from seed to mature plant and then die in one year

Aquifer – an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, or silt) from which groundwater can be usefully extracted using a water well

Arroyo – a wash or gulch, usually in a dry creek or stream bed, that temporarily or seasonally fills and flows after sufficient rain (see *wadi*)

Asexual reproduction – a mode of reproduction by which offspring arise from a single parent and inherit the genes of that parent only

Bajada – a fan-shaped deposit of soil types formed where a fast-flowing stream flattens, slows, and spreads onto a flatter plain, typically at the exit of a canyon (see *alluvial fan*); the convergence of neighboring alluvial fans into a single apron of soil deposits against a slope

Basic – substances with a pH greater than 7

Biodiversity – the variation of life forms within a given species, ecosystem, biome, or an entire planet; often used as a measure of the health of an ecosystem

Buttress root – a tree root that extends above ground as a plate-like outgrowth of the trunk that functions to support the tree

C3 photosynthesis –a form of photosynthesis used by 95% of Earth's plants; most efficient in areas where sunlight intensity and temperatures are moderate and ground water is plentiful

Caliche – a hardened soil deposit of calcium carbonate that cements together other materials, including gravel, sand, clay, and silt; generally found in arid or semiarid regions; also known as "hardpan"

CAM photosynthesis – a form of photosynthesis commonly used by plants adapted to arid conditions to increase efficiency in the use of water; stomata in plant leaves close during the daytime to prevent the loss of water vapor and open at night to collect carbon dioxide, which is then used in photosynthesis during the following day

Canopy – the upper layer or habitat zone of a forest, formed by mature tree crowns and including other biological organisms

Carbon cycle – the combined processes, including photosynthesis and decomposition, by which carbon, as a component of various compounds, cycles among the atmosphere and living organisms

Carbon dioxide – a naturally occurring chemical compound composed of two oxygen atoms bonded to a single carbon atom; a trace gas in the atmosphere that, through photosynthesis, provides carbon to make sugars; also a greenhouse gas

Carbon fixation – a change of inorganic carbon (carbon dioxide) to organic compounds (sugars) by living organisms, especially in photosynthesis

Carbon sink – a natural or artificial reservoir that accumulates and stores some carbon-containing chemical compound for an indefinite period

Cellulose – a structural component of the primary cell wall of green plants and the most common organic compound on Earth; a sugar consisting of a long linear chain of several hundred to over ten thousand units

Clone – an organism with genetic information identical to that of its parent organism

Cloud forest – a forest found at elevations between 500-4000 m characterized by persistent, frequent or seasonal low-level cloud cover, usually at the canopy level; also called a "fog forest"

DESERT TO RAINFOREST GLOSSARY

Competition – the contest between organisms for resources such as food, water, territory, mates, and sunlight; results in the ultimate survival and dominance of the variant of the species best suited for survival

Condensation – a change of the physical state of matter from gaseous phase into liquid phase, often occurs when a vapor is cooled

Crepuscular animals – animals that are active primarily during dawn and dusk

Cryptic – a word used to describe an organism with the ability to avoid observation or detection by other organisms

Decomposition –the process of rotting by which organic substances are broken down into simpler forms of matter

Diffusion – the tendency of molecules to spread evenly into an available space, making possible the transport of materials dissolved in water

Dew point temperature – the temperature below which water vapor will condense into liquid water; the higher the dew point, the more moisture contained in the air

Diurnal – animals primarily active during the daytime

Dominant competitor – the species that tends to outcompete other species and become increasingly common in a community unless a predator or disease impacts it

Ecotourism – a form of tourism involving visiting fragile, pristine, and usually protected areas, intended as a low-impact and often small scale alternative to standard commercial (mass) tourism, often aimed at educating travellers and funding conservation efforts

Emergent layer – the tallest of the giant trees that protrude high above the surrounding canopy of a forest

Ephemeral stream – a stream that flows only during and immediately after precipitation

Epiphyte – a plant that normally grows on another plant, but is not parasitic, only using the host plant for support

Equator – an imaginary line around the world halfway between the North and South Poles

Evaporation – the physical process by which a liquid or solid substance is changed into its gaseous state

Evapotranspiration – the combined water loss from a plant through evaporation of leaf surface water and transpiration

Evolution – the biological process by which all living things have evolved over many generations from shared ancestors; change across successive generations in the proportion of an inherited characteristic represented in a population; this process explains both the unity and the diversity of species

External fertilization – a form of fertilization in which a sperm cell is united with an egg cell outside the body

Extinction – the state or process of a species, family, or other group of organisms being or becoming extinguished

Flash flood – a sudden and destructive rush of water down a narrow gully or over a sloping surface, caused by heavy rainfall

Food plant – the type of plant eaten by a particular herbivorous species

Forest floor – the bottom layer of the forest where plant and dead animal matter quickly decompose

Foresummer – the dry, hot season in the desert that follows the spring and precedes the summer rainy seasons

Gene – a molecular unit of heredity of a living organism; an identifiable stretch of DNA on a chromosome

Generalist – a species that can survive in multiple habitats or eats food from multiple sources

Genetic variation – a range of genetic differences both within and among populations

Germination – the process in which a plant emerges from a seed and begins to grow

Granivorous animals – animals that feed on seeds

DESERT TO RAINFOREST GLOSSARY

Gut flora – protozoa and other microbes in the digestive tracts of animals; microorganisms that help termites digest plant cellulose

Haboob – an intense duststorm carried on strong downdraft winds and regularly observed in arid regions throughout the world

Herbivores – animals adapted to eat plants or plant parts

Hibernation – a period or state of inactivity by animals attempting to conserve energy

Infiltration – is the process by which water on the ground surface enters the soil

Leaf litter – dead plant material, such as leaves, bark, needles, and twigs, that has fallen to the ground

Lee – direction downwind from the point of reference

Lek – a gathering of males in certain species aimed at attracting female mates through competitive mating displays

Lianas – long-stemmed, woody vines that are rooted in the soil at ground level and use trees to climb up to the forest canopy to access sunlight

Light Gap – a hole in the canopy that allows full sunlight to reach the forest floor; often caused by falling trees and large broken branches

Lowland tropical rainforest – a forest that occurs below 500 m elevation roughly within the latitudes 28 degrees north or south of the equator, characterized by high average temperatures and significant rainfall

Mangrove forest – a forest of medium height trees and shrubs that grow in saline coastal sediment habitats in the tropics and subtropics

Midlatitudes – the areas between Earth's tropics and polar regions, approximately 30° to 60° north or south of the equator and where most of the world's deserts are located

Migration – relatively long-distance movement of individuals, usually on an annual or seasonal basis

Mimic – a species that has evolved characteristics similar in appearance, behavior, sound, or scent to another distasteful or toxic species, which protects one or both species from predators

Model – a distasteful or toxic species whose color, behavior sound or scent are readily learned and avoided by predators and imitated by mimics who attempt to simulate the model's characteristics for their own protection

Moderate disturbance hypothesis – a proposed scientific explanation that suggests that communities that experience fairly frequent but moderate disturbances have the greatest species diversity (also called "intermediate disturbance hypothesis")

Mutualism – the interaction between organisms of different species that is beneficial to both

Natural selection – a gradual, non-random, process by which biological traits become either more or less common in a population as a function of differential reproduction (i.e., traits that give individuals a reproductive advantage will be more likely to be passed from parent to child and enjoy more representation in the species population)

Nectar – a sugar-rich liquid produced by plants within their flowers to attracts pollinating animals

Nocturnal animals– animals primarily active during the night time

Organic acid – a class of weak acids that are very soluble in organic solvents

Overland Flow – water that runs across the land after rainfall, either before it enters a watercourse, after it leaves a watercourse as floodwater, or after it rises to the surface naturally from underground

pH – a measure of how acidic or basic a substance is

Parthenogenesis – form of reproduction in which an unfertilized egg develops into a new individual

Perennials – plants that live for more than two years

Photosynthesis – the bonding of CO_2 (carbon dioxide) with H_2O (water) to make CH_2O (sugar) and O_2 (oxygen), using the sun's energy

DESERT TO RAINFOREST GLOSSARY

Pioneer species – a species that is first to establish itself in an area where little is growing or in an area that has been influenced by fire, flood, landslides or lack of light

Pollen – dust like protein particles produced by male parts of plants and spread to female parts of plants to initiate fertilization

Pollinaria – a sticky mass of pollen grains in a plant that are transferred, during pollination, as a single unit

Pollination – a process by which pollen is transferred in the reproduction of plants, enabling fertilization and sexual reproduction

Predation – the biological interaction where an organism that is hunting feeds on another organism it has attacked

Precipitation – water that falls to the Earth's surface

Primary forest – untouched, pristine forest that has been relatively unaffected by human activities

Primary productivity – a measure of the rate at which plants develop new organic matter is developed through photosynthesis

Rain shadow – the dry area on the lee or back side of a mountainous area

Relative humidity – the amount of water vapor in the air, expressed as a percentage

Riparian – describes the habitat and wildlife found along the banks of a river, stream, lake or other body of water

Sapling – a young perennial woody plant having a main trunk and branches forming a distinct elevated crown

Secondary forest – a forest that has been disturbed, often as a result of human actions such as clear cutting, selective logging, and slash-and-burn agriculture

Seed bank – the natural storage of seeds, often dormant, within the soil of most ecosystems

Sexual reproduction – the creation of a new organism by combining the genetic material of two organisms

Shifting agriculture – a system of cultivation in which a plot of land is cleared and cultivated for a short period of time, during which the soil's fertility is depleted, after which the plot is abandoned and allowed to revert to producing its normal vegetation while the farmer cultivates a new plot

Sky island – a mountain that is isolated by surrounding lowlands of a dramatically different environment

Slash-and-burn farming – a farming technique in which patches of forest are cleared for agriculture by cutting and burning the undergrowth (see *swidden*)

Specialist– species that can only thrive in a narrow range of environmental conditions or has a limited diet

Species richness – the number of different species in a given area

Stomata – the pores in leaves (and stems) through which a plant takes in carbon dioxide and releases water and oxygen during photosynthesis; regulated by two guard cells that expand and contract to determine the opening, closing, and width of the stomata

Strangler fig – a tree that begins as a seed, often bird-dispersed, that germinates in crevices atop another tree, growing its roots downward and branches upward toward the canopy, eventually enveloping and starving the host tree of sunlight

Subsistence agriculture – a form of farming in which farmers focus on growing enough crops or livestock to feed themselves and their families, with little surplus for sale

Subterranean – underground occurring underground

Sugar – a carbohydrate composed of carbon, hydrogen and oxygen; a product of photosynthesis that stores chemical energy converted from the sun's energy

Swidden farming – a farming technique in which farmers clear patches of forest are cleared for agriculture by cutting and burning the undergrowth (see *slash-and-burn*)

DESERT TO RAINFOREST GLOSSARY

Taproot – an enlarged, straight, tapering plant root that grows vertically downward

Terrestrial organism – an organism that lives on land as opposed to living in water; or, sometimes an animal or plant that lives on or near the ground, as opposed to in trees

Throughfall – rainfall that is not intercepted by the canopy and reaches the forest floor

Topsoil – the upper, outermost layer of soil, usually the top 2 inches (5.1 cm) to 8 inches (20 cm) which has the highest concentration of partially decomposed organic matter and microorganisms and is where most of the Earth's biological soil activity occurs

Toxin – a poisonous substance produced within living cells or organisms

Transpiration – the process during which water evaporates from a plant through open stomata, which functions to cool the plant and facilitate the flow of minerals from roots to shoots; potentially dehydrating for plants in arid regions

Trichomes – fine hair-like outgrowths or appendages on plants

Turbidity – the measure of the relative clarity of a liquid

Understory – the area of a forest which grows at the lowest height level below the forest canopy

Vine – any climbing or trailing plant

Valley fever – a fungal disease caused by coccidioides immitis and found only in the soil of certain parts of the American Southwest and northwestern Mexico. Infection caused by the inhalation of spores swept into the air by disruption of the soil, such as during construction, farming, or an earthquake

Virga – the observable streak or shaft of rain that falls from a cloud but evaporates before reaching the ground

Wadi – a wash or gulch usually in a dry creek or stream bed that temporarily or seasonally fills and flows after sufficient rain (see *arroyo*)

Watershed – the land area that drains water to a particular stream, river, or lake. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large watersheds, like the Mississippi River basin contain thousands of smaller watersheds

Windward – direction upwind from the point of reference

Wind pollination – a form of pollination whereby pollen is distributed by wind

Xerophyte – plant that has adapted to survive in an environment that lacks water

Desert to Rainforest

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TEACHER'S GUIDE

6TH GRADE