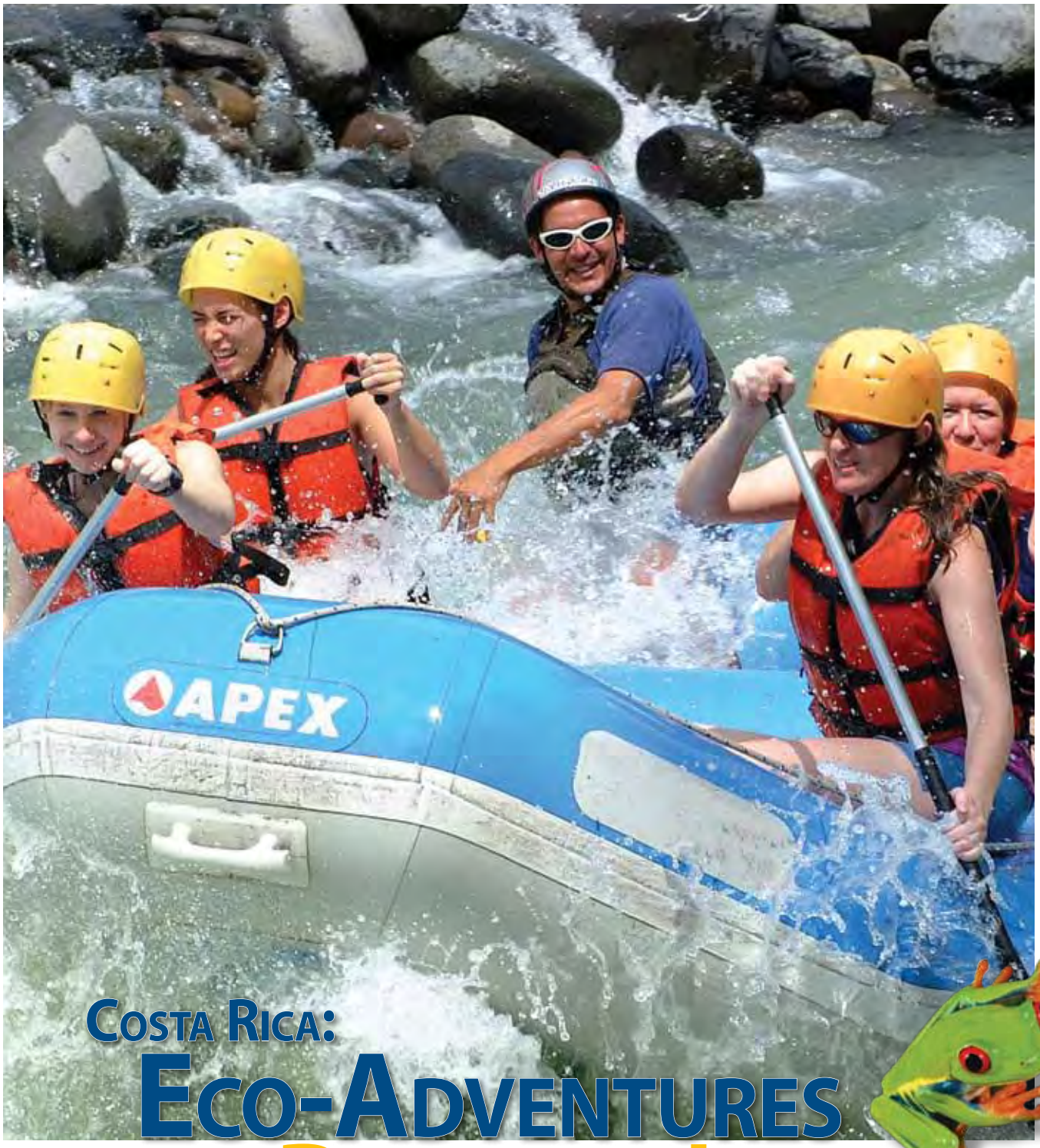


Costa Rica: Eco-Adventures Discovery Journal

WORLD STRIDES®

DiscoverNow! PROGRAMS

In case of emergency

If you have lost contact with your group or need assistance for a medical condition, injury, or any other emergency, please call a staff member immediately at the toll-free number listed below.

In Costa Rica call 2293-6314

This number should be used for emergencies only. When you call, please be prepared to give your name, the number you are calling from, your location, your group name or teacher's name, and the reason for the call. The person you speak with will give you further instructions.

Acknowledgements

This Costa Rica: Eco-Adventures Discovery Journal features activities developed by the WorldStrides staff in surveying the best available environmental science curricula offered by educational, environmental, and scientific organizations throughout the nation and abroad. We wish to acknowledge the many individuals who assisted us with this effort.

Special thanks to the Course Leader staff in Costa Rica, for their guidance, encouragement, and use of program materials. We also owe special thanks to the team of guides at Tirimbina Forest in Costa Rica, for providing us with a wealth of materials.

Table of Contents

Welcome to Costa Rica

Ecosystems, Tropical Rainforests, Biodiversity, and Adaptation – What does this all mean?

In 1947, biologist L.H. Holdridge introduced a system of classifying vegetation types, or "zones," according to a matrix based on combinations of temperature, rainfall, and seasonality. Each zone has a distinctive natural vegetation and ecosystem. Costa Rica has 12 such zones, ranging from tidal mangrove swamps to the high mountains. Its most prominent zone is the tropical rainforest.

What is a tropical rainforest?

While covering less than six percent of Earth's surface, rainforests are home to more than 50 percent of the world's plant and animal species. A tropical rainforest gets more than 60 inches (1.5 meters) of rain per year, although some regularly get more than 200 inches (five meters)! The average temperature in a tropical rainforest remains between 68 and 82 degrees Fahrenheit (20 and 28 degrees Celsius). Tropical rainforests are some of the world's most important natural resources, filled with biological treasures. A typical four-square-mile (10.36-square-kilometer) section can contain over 1,500 species of flowering plants, 750 species of trees, 125 species of birds, 100 species of reptiles, 60 species of amphibians, and 150 species of butterflies. Many species have not even been discovered by scientists yet. It will take scientists years to classify and name all of the recently discovered insects. Plants holding secrets to new medicines are being found in the rainforests. One example is the periwinkle plant which is now used to treat many forms of childhood leukemia. Who knows what will be found next? Your interest in the rainforest now could lead you to an important scientific discovery in the future!

Biodiversity and adaptation

Biodiversity is the total complexity of all life – the variety of plants, animals, and other living things – that exists in a particular region, such as the tropical rainforest. *Adaptation* is a characteristic of an animal or plant that allows it to survive in its environment. Adaptations help protect, defend, and camouflage an animal as it eats, sleeps, and lives. Animals have adapted over many generations to survive well in the habitat where they live.

Threats to the rainforest and biodiversity

Too much of the world's tropical rainforests have already been destroyed because of burning, logging, cattle ranching, dam building, and poor farming practices. Many international organizations and companies are finding ways for the people of the rainforest to safely harvest its bounty, instead of destroying it for logging or converting it to infertile farmland. If people work together, we can find many ways to use the rainforest without destroying it.

Source: *Moon Handbooks: Costa Rica,* Christopher P. Baker, Avalon Travel Publishing, CA, USA, 2001. 4th edition. ISBN: 1-56691-344-6

Welcome to Costa Rica

Costa Rica Culture & Spanish Language

As you journey across the Costa Rican landscape, you will find yourself immersed in learning about the culture, history, and language of others. You will learn through direct experience and find many opportunities to practice learning the Spanish language.

You may find these terms useful throughout your adventure.

What's your name?	¿Cómo se llama usted?	I'm sick	Estoy enfermo
Hello!	Hola!	where	dónde
Good Morning	Buenos días	what	qué
Good Afternoon	Buenas tardes	when	cuándo
Good Night	Buenas noches	how much	cuánto
How much is it?	¿Cuánto es?	how	cómo
How much is it worth?	¿Cuánto vale?	which	cuál or cuáles
I like	Me gusta	why	por qué
My pleasure	Mucho gusto	breakfast	el desayuno
You like	Le gusta	lunch	el almuerzo
Where is...?	¿Dónde está...?	dinner	la cena
Help!	Socorro!	cabin	la cabina

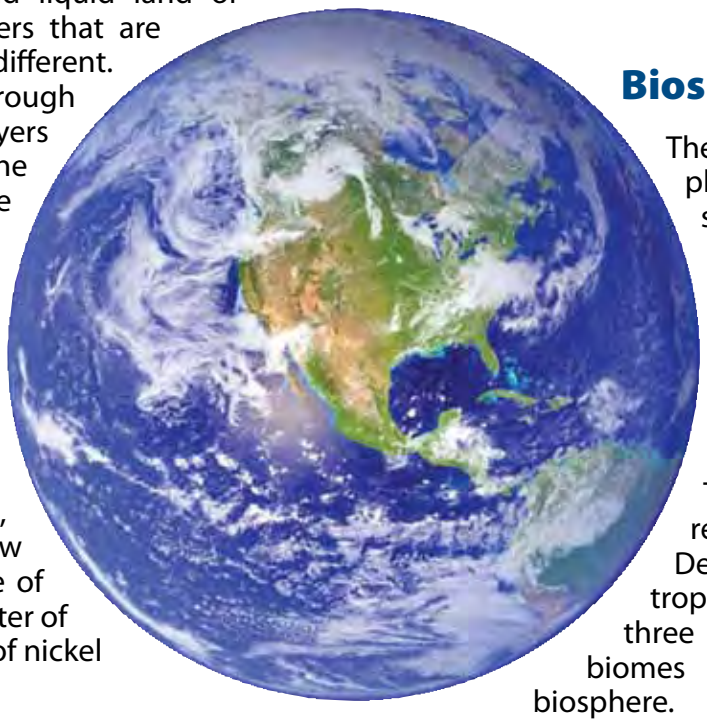
Pura Vida (pure living) is a favorite phrase of Costa Ricans. It is an exuberant greeting and exultation of their joy of living. What other words or phrases have you learned throughout your travels?

The Spheres

Lithosphere

The lithosphere contains all of the cold, hard, solid land of the planet's crust (surface), the semi-solid land underneath the crust, and the liquid land near the center of the planet. The surface of the lithosphere is very uneven. There are high mountain ranges like the Rockies and Andes, huge plains or flat areas like those in Texas, Iowa, and Brazil, and deep valleys along the ocean floor.

The solid, semi-solid, and liquid land of the lithosphere form layers that are physically and chemically different. If someone were to cut through Earth to its center, these layers would be revealed like the layers of an onion. The outermost layer of the lithosphere consists of loose soil rich in nutrients, oxygen, and silicon. Beneath that layer lies a very thin, solid crust of oxygen and silicon. Next is a thick, semi-solid mantle of oxygen, silicon, iron, and magnesium. Below that is a liquid outer core of nickel and iron. At the center of Earth is a solid inner core of nickel and iron.



Hydrosphere

The hydrosphere contains all the solid, liquid, and gaseous water of the planet. It ranges from 10 to 20 kilometers in thickness. The hydrosphere extends from Earth's surface downward several kilometers into the lithosphere and upward about 12 kilometers into the atmosphere.

A small portion of the water in the hydrosphere is fresh (non-salty). This water flows as precipitation from the atmosphere down to Earth's surface, as rivers and streams along Earth's surface, and as groundwater beneath Earth's surface. Most of Earth's fresh water, however, is frozen.

Ninety-seven percent of Earth's water is salty. The salty water collects in deep valleys along Earth's surface. These large collections of salty water are referred to as oceans. Water near the poles is very cold, while water near the equator is very warm. The differences in temperature cause water to change physical states. Extremely low temperatures like those found at the poles cause water to freeze into a solid such as a polar icecap, a glacier, or an iceberg. Extremely high temperatures like those found at the equator cause water to evaporate into a gas.

Biosphere

The biosphere contains all the planet's living things. This sphere includes all of the animals, microorganisms, and plants of Earth. Within the biosphere, living things form ecological communities based on the physical surroundings of an area. These communities are referred to as biomes. Deserts, grasslands, and tropical rainforests are three of the many types of biomes that exist within the biosphere. It is impossible to detect from space each individual organism within the biosphere. However, biomes can be seen from space.

Atmosphere

The atmosphere contains all the air in Earth's system. It extends from less than one meter below the planet's surface to more than 10,000 kilometers above the planet's surface. The upper portion of the atmosphere protects the organisms of the biosphere from the sun's ultraviolet radiation. It also traps heat. When the air temperature in the lower portion of this sphere changes, weather occurs. As air in the lower atmosphere is heated or cooled, it moves around the planet. The result can be as simple as a breeze or as complex as a tornado.

Biodiversity Index

Throughout your adventure in Costa Rica, you will study the diverse biotic and abiotic organisms and materials found in all of these different systems. One of the first tasks you will complete at each location will be a **biodiversity index**. The number of species existing in a particular environment is central to the understanding of why it is important to promote and preserve species diversity. A uniform population of a single species of plants adapted to a particular environment is more at risk if environmental changes occur. A more diverse population consisting of many species of plants has a better chance of including individuals that might be able to adapt to changes in the environment.

Scientists use a formula called the biodiversity index to describe the amount of species diversity in a given area. A simple biodiversity index is calculated as follows:

$$\frac{\text{The number of species in the area}}{\text{The total number of individuals in the area}} = \text{biodiversity index}$$

For example, a 4 x 4 meter square area in a carrot patch has 300 carrot plants, all the same species. It has a very low biodiversity index of 1/300, or 0.003.

A 4 x 4 meter square area in the forest has one pine tree, one fern, one conifer tree, one moss, and one lichen, for a total of five different species and five individuals. The biodiversity index here is high, 5/5 or 1.

Use this chart to record the biodiversity index at different study locations in Costa Rica:

Location	Date and Time	Biodiversity Index

What Exactly is a Biosphere?

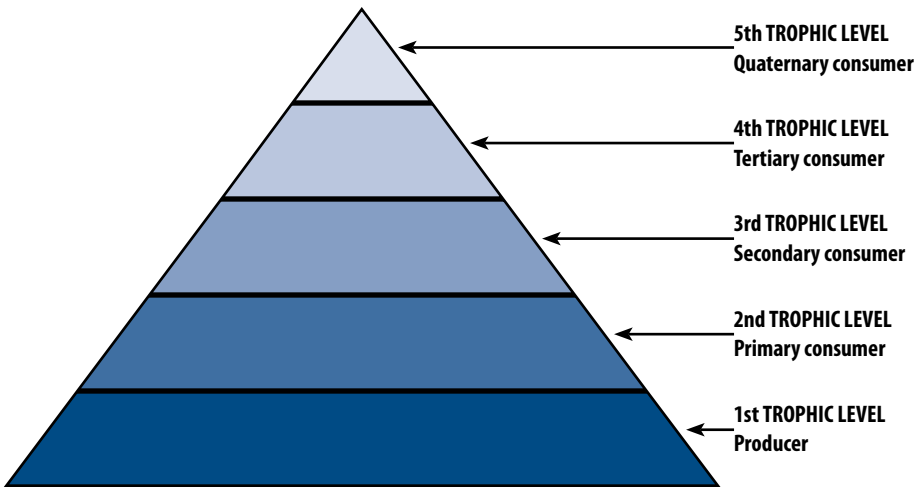
An environmental biosphere consists of all the organisms and non-living materials found in a particular area. The organisms interact with one another as well as with the non-living components of the environment.

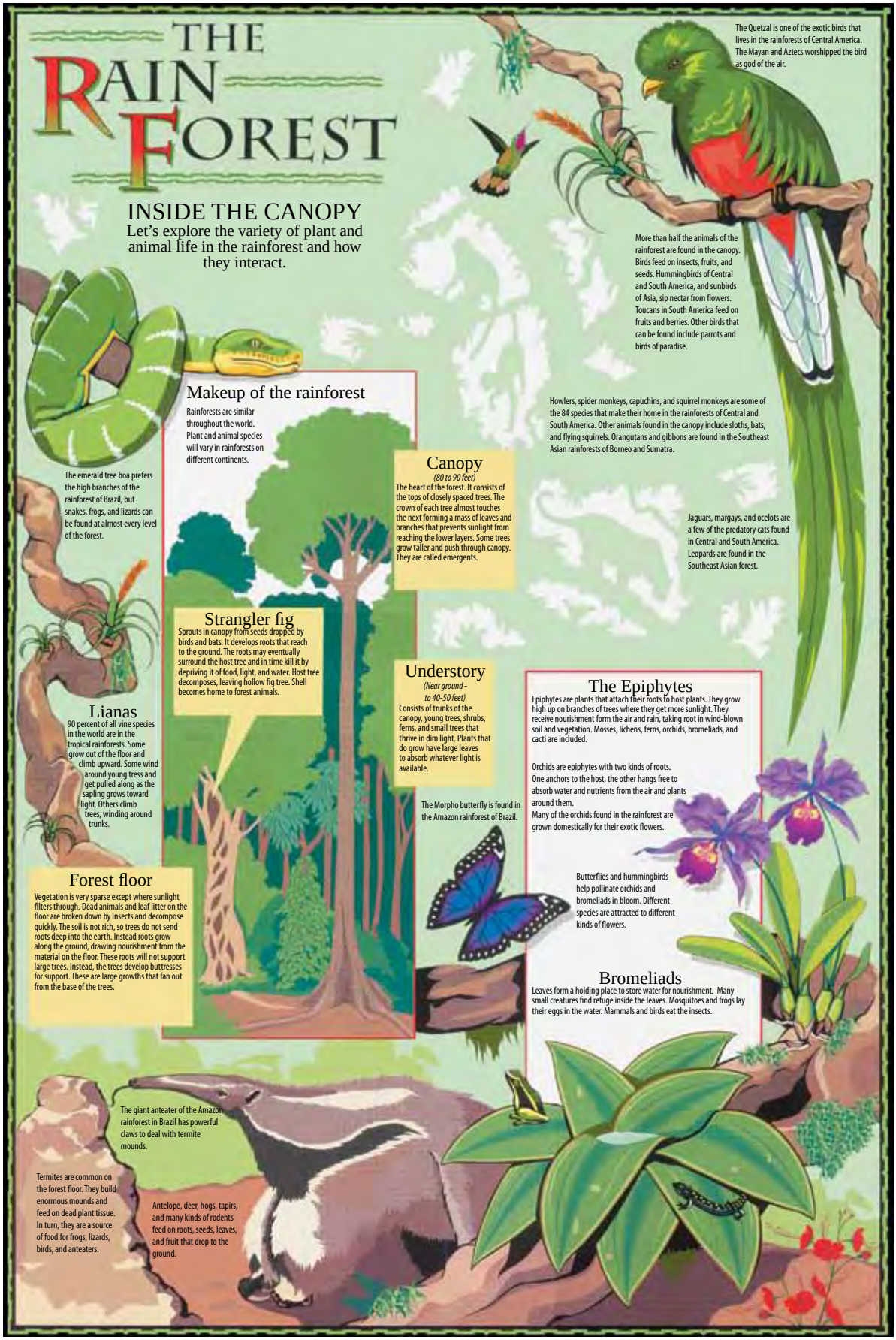
To understand the interconnectedness of organisms, it is necessary to study **ecosystems**, or biological communities interacting with one another and their environment. Ecosystems have many components that can be broken into two major categories, **biotic** and **abiotic**. The biotic or living parts of an ecosystem include species, populations, and biological communities. The abiotic influences are non-living, such as temperature, light, soil, and water.

Organisms within biospheres can be classified into two different categories: **producers**, or **autotrophs**, which make their own food, as green plants do; and **consumers**, or **heterotrophs**, which cannot make their own food and must eat producers or other consumers. Consumers can be further divided into **herbivores**, which eat plants; **carnivores**, which eat animals; **omnivores**, which eat both plants and animals; and **detrivores**, which feed off dead and decaying organisms.

The sequence of who eats whom in an ecosystem is called a **food chain**. All ecosystems have complex feeding networks, made up of many different food chains. This feeding network is called a **food web**.

Scientists assign every organism in a biosphere to a feeding level, or **trophic level**, depending on whether it is a producer or consumer and on which type of consumer it is. The producer is on the first trophic level; the primary consumer is on the second trophic level; the secondary consumer is on the third trophic level; the tertiary consumer is on the fourth trophic level; and the quaternary consumer, if present in a food chain, would occupy the fifth trophic level.





Reprinted with permission from the South Florida Sun-Sentinel

Rainforest Color Challenge at Tirimbina

To become familiar with Costa Rica and the many animals, plants, reptiles, arthropods, birds, and amphibians that you will observe and study, you have been tasked to complete the following Rainforest Color Challenge.

Your challenge is to find animals (reptiles, amphibians, birds, insects, etc.) and plants (trees and flowers) that have your team colors.

1. Divide your group into teams and each team chooses one of the following color schemes:
   Orange and/or black
   Red and/or gray
   Pink and/or brown
   Yellow and/or blue
   * *Different shades of colors and different color names (scarlet, buff, silver, pink…) do count.*
   * *Black eyes do not count for the orange and/or black team.*

2. Write down your team colors.
   Our team colors are _____ and _____ .

3. Work with your team to spot animals, plants, etc., that have your team colors.

4. Your team will receive points each time you see and write down an animal or plant, etc.
   - When you see an animal, plant, etc., that has **one of your team's colors**, your team scores **one point**.
   - When you see an animal, plant, etc., that has **many colors, including both of your team's colors**, you score **two points**.
   - When you find an animal, plant, etc., that has **only your team's two colors**, you score **three points**.
   - When you find an animal, plant, etc., that has **one or both of your team's colors** in it's name, you score **five points**.

5. If you see **a picture of an animal, plant, etc., with your team's colors** (in any of the categories above), but you do not see the actual animal, you only score **½ point**.

Rainforest Color Challenge at Tirimbina

6. Write each animal you see in the appropriate column.

One team color = 1 point	Many colors with both team colors = 2 points	Only two team colors = 3 points	One or both team colors in name = 5 points	One or both team colors in picture = ½ point
Totals:				

Total Score: _____

Bats

SEED DISPERSAL BY BATS IN A COSTA RICAN RAINFOREST

The purpose of this activity is to introduce you to the work of a field researcher in the quest to answer a biological question. By understanding the bases of the scientific method, you can develop an investigation in the form of a hypothesis-based project, to look into a very important issue for the ecology of a tropical rainforest: animal-mediated seed dispersal.

Seed dispersal is a very broad subject of study, and it involves many different actors and factors which are complicated to investigate all at the same time. Therefore, we will concentrate on studying the role of only one type of animal involved in this process: the fruit-eating bat.

Fruit-eating bats are the most abundant seed-dispersing mammal in the world. Costa Rica is no exception, with a total of 30 species of frugivores, besides the remaining 90 species that prefer other food sources (insects, nectar, small vertebrates, fish, and blood). Every night, bats can commute several kilometers to find their food, sometimes also venturing outside of the forests into open areas in the search of a certain fruiting tree or bush of their liking. In this process, most of the seeds ingested with the fruit pulp eaten by the bats go through their digestive system intact and are defecated during flight. Thus, these seeds "raining" over altered landscape soil can eventually germinate and be pioneer plants in the process of reforestation of the area.

In this field exercise, we will try to answer the following questions for the case of Tirimbina Rainforest Center:

- Do bats disperse seeds in open areas, outside of the forest?

- If so, where are these seeds coming from?

- Which types of plants do these seeds belong to?

Brainstorm with your group and follow the instructions of your guides carefully to develop a method to answer these questions.

MATERIALS FOR THE FIELD:

Mist nets
Leather gloves
Cloth capture bags
Ruler + Spring scale
Seed traps with cloth
Plastic frames to cover traps
Forceps
Paper envelopes + absorbent paper
Clipboard + Data sheet
Pencil + Marker

MATERIALS FOR ANALYSIS:

Seed identification guide
Dissecting microscope
Blank newspaper
Pencil + Markers

Methods:

1. MIST NETS.

You will learn how to set up the nets used by researchers to capture bats in order to identify and study them.

- Why do bats get caught in these mist nets? Can they detect them?

- Do all types of bats existing in an area have the same chances of being caught with mist nets?

- List 3 security measures needed for handling bats out of a mist net, to avoid getting hurt and hurting the animals.

2. SEED TRAPS.

Despite their simple construction, these traps are efficient in serving as collectors for the seed rain left by bats flying over the gardens at night.

- In order to avoid getting other sources of seed rain into the traps, some measures must be taken when setting up the traps. Mention 2 of these important measures to avoid getting seeds from birds or from nearby trees.

3. BATS UP CLOSE.

Listen carefully to your guides as they show you the bats captured in the mist nets and tell you about their life history. There is some basic data about each animal that needs to be collected by bat researchers. Fill in your own data sheet to gather all the necessary information about each specimen captured.

Common name	Species	Sex	Forearm length	Weight	Observations

4. COLLECTION AND CLASSIFICATION OF SEED SAMPLES.

Early in the morning, hurry to the seed traps to discover what the flying bats left last night for you to examine. Using forceps, carefully collect the seeds found on the cloth surface of the trap and put them into plastic containers filled with alcohol. This will clean the seeds and make them ready for closer observation.

In the classroom, transfer the seeds from the alcohol to individual paper envelopes inlaid with absorbent paper towels for safekeeping.

Examine each sample under the dissecting microscope and classify them by comparison with already identified seeds in the guide. Record your results in the data chart.

Sample #	Seed morphotype	# of seeds
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		

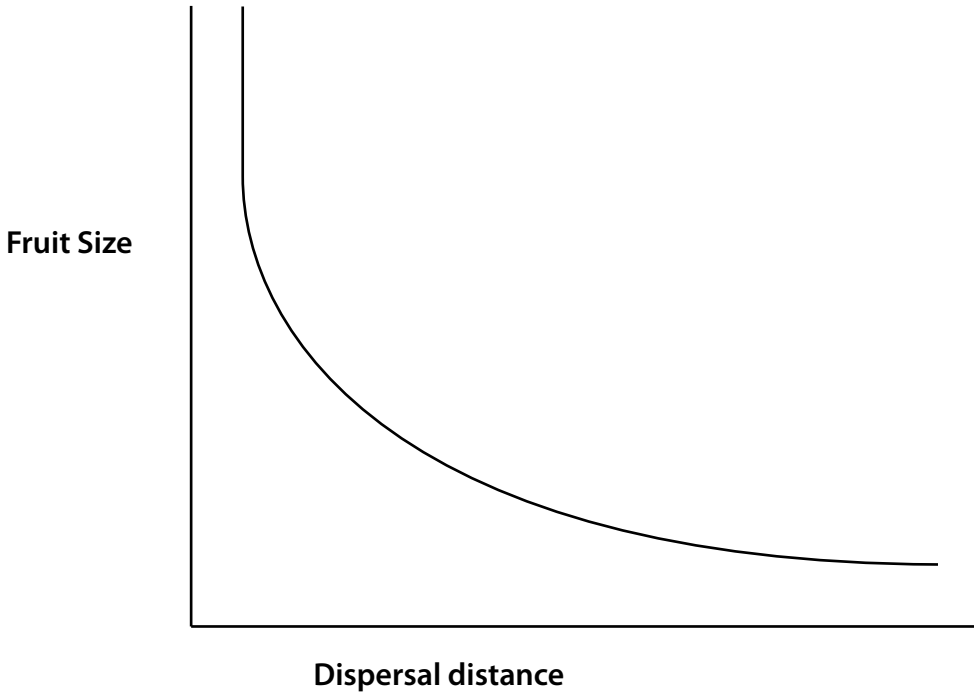
5. LOCATING THE PLANTS

Follow your guide in a walk through the gardens and into the rainforest, while you search for the plants that produce the seeds dispersed by the bats.

- How many source plants could you find?
- Were they found mostly in the forest or around the gardens?
- Describe the fruits of these plants. Do they have common characteristics in their shape, size, color, or smell? Explain.

6. FOLLOW UP QUESTIONS

- How do you think the bats find the fruits?
- Why don't we find large seeds (larger than 1 cm) in the traps? Are bats not dispersing these? Is it due to a sampling error?



Bats

The most misunderstood mammal on our planet is often the bat. Half of the approximate 200 mammal species found in Costa Rica are bats.

What are your first reactions or ideas when you think of bats?

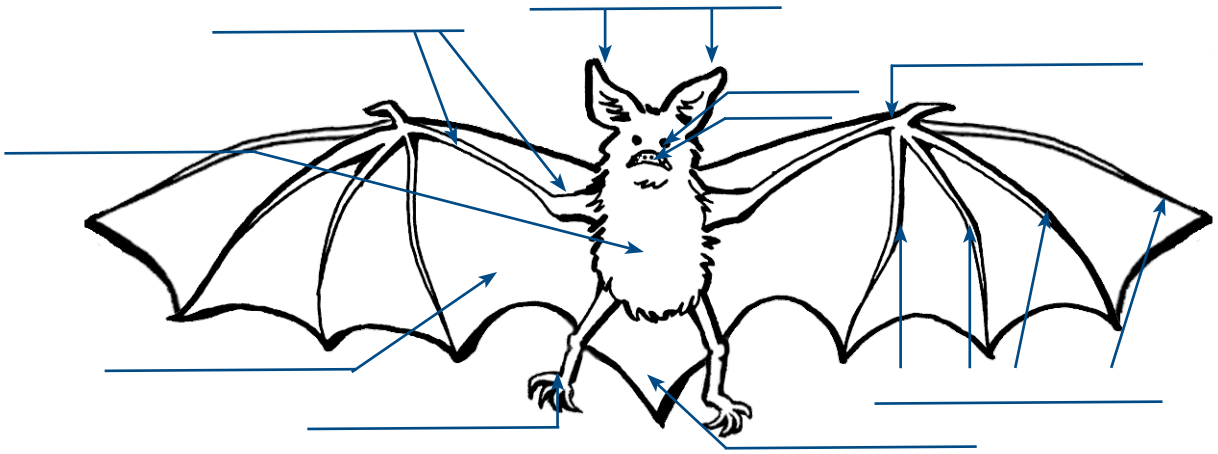
How many references to bats can you find in movies or stories? Investigate some of the legends about bats. Compare the myths to reality. For example, how did the vampire bat get its name?

What attributes separate bats from other mammals?

Bats belong to the animal order Chiroptera. This order is divided into two main groups: micro-chiroptera (microbats) and mega-chiroptera (megabats).

Bats have specific adaptations to allow them to eat different things. List several things bats eat and compare between microbats and megabats.

Use the terms below to label the following diagram.



arm bones – consist of an upper arm (humerus) and a forearm (with a radius and reduced ulna), with an elbow between them.

body – covered with fur.

ears – bats have ears adapted for their habits. Carnivorous (meat-eating) bats have larger ears than herbivorous (plant-eating) bats.

eyes – bats have good eyesight and can see very well in the dark.

finger bones – bats have four very long finger bones that support the outer wing (and a short thumb).

five-toed feet – bats have two, five-toed feet and short legs with knees.

nose – many bats have an incredible sense of smell.

thumb – usually visible but small.

uropatagium – the flap of skin between the bat's hind legs and the tail.

wings – bats have large wings supported by the arm and finger bones. The wings are covered with leathery skin (called the patagium) and are powered by large muscles in the body. Bats are the only flying mammal.

Bats that use echolocation gauge distance by sending high-frequency, ultrasonic calls (as pulses) and measuring the time it takes for the reflected pulses to return (echo + location). Signals reflected back can also provide information on the type and size of a prey item. Humans can't hear many of the signals bats generate. Bat calls can range from low frequencies (9 kHz) to very high frequencies (greater than 200 kHz).

Below are the steps in the process of echolocation, the way the bat locates its prey. However, the steps are not in the right order. Help the bat find its next meal by putting them in the correct order.

_____ When these noises hit an object, they bounce back toward the bat as an echo.
_____ As the bat hunts for its next meal, it sends out high-pitched noises.
_____ The bat listens for the echo to learn what type of prey it has found and where it is located.
_____ As it closes in on the prey, it sends out more sounds to finally locate and catch its meal.
_____ After locating its prey, the bat moves in.

Compare the ways bats and other animals (dolphins, whales, some birds, and shrews) use echolocation.

After completion of the bat lab at the Tirimbina Rainforest Center, has your perception about bats changed? Please explain.

Birding 101

Birding is the technique of observing birds. It is an activity you can take part in almost anywhere outdoors. There are many characteristics to look for when attempting to identify birds. Some of the most common are the color, spots, or bars which can describe the plumage. Next, you might use size or shape to identify the bird. As you become more advanced you will learn the songs and calls of species which will add to your birding technique. One technique that is commonly overlooked, which at times can be the most important, is the habitat where you are observing the species. Perhaps you want to study birds for a research project. The act of studying birds is called *ornithology*. In your journal be sure to record the species that you have seen throughout your trip.

As you learn the art of birding, fill in the chart below:

Scientific name	English name	Plumage	Resident or Migrant	Feet type	Beak type

Feet type:

					
Swimming	Swimming/ walking	Walking	Perching	Seizing prey	Climbing

Beak type:

					
Filtering	Probing	Catching insects	Cracking seeds	Tearing meat	Drilling holes

Introduction

Rivers are an important source of water for human settlement. They are used for different purposes including irrigation, drinking water, and recreation. However, more and more rivers and streams are being polluted by humans on a daily basis.

Different analyses have to be performed in order to get a total picture of the condition of a river. The **physical** and habitat surveys give an idea of the primary conditions of the river. **Chemical** surveys tell us about water quality at a particular moment; however, they won't detect pollution events that happened a few days before. Nevertheless, we can rely on the aquatic macroinvertebrates as **biological** indicators of the events in the recent past.

Macroinvertebrate community structures are important in determining the history of the river. A river with high diversity indicates a healthy ecosystem, whereas a high abundance of certain species of macroinvertebrates can be due to pollution resistance.

How can we use living things as indicators of water quality?

All organisms need certain conditions to survive and multiply. Since each aquatic organism has specific tolerances to chemical and physical conditions, the presence or absence of particular organisms can tell us a lot about the body of water we are studying. Compared to complex chemical analysis, using surveys of organisms to determine water quality can be relatively simple and effective. A species which is normally present in an aquatic ecosystem under specific conditions is called an *indicator organism.*

Conducting a Hydrology Study in a Freshwater Ecosystem

Hydrology tests are usually done with basic field testing kits. These tests measure concentrations in the water. During your program, you will perform tests to determine the following basic indicators of water quality:

1. Dissolved Oxygen (DO)
2. pH
3. Hydrogen Sulfide (H_2S)
4. Temperature (air and water)
5. Turbidity
6. Nitrates (NO_2) (NO_3)
7. Phosphate (PO_4)
8. Carbon Dioxide (CO_2)

Dissolved Oxygen (DO)

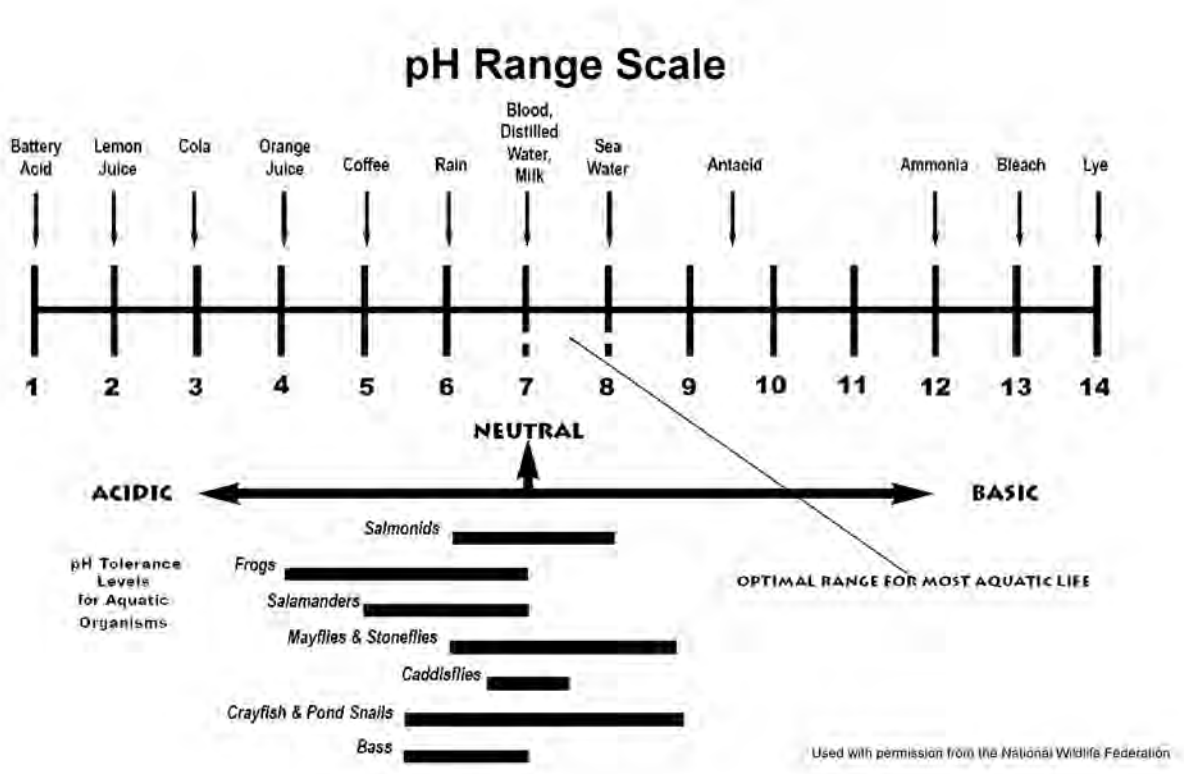
All living things depend on oxygen to survive. In a water environment, molecules of oxygen gas dissolve in the water. This is called dissolved oxygen (DO). In air, 20 out of every 100 molecules are oxygen. In water, only one to five molecules out of every million molecules are oxygen. This is why dissolved oxygen is measured in parts per million (ppm). Water temperature and altitude influence how much oxygen water can hold. Natural waters with consistently high DO levels are likely healthy and capable of supporting a diversity of aquatic organisms.

pH

pH is an indicator of the acid content of water. The pH scale ranges from 1 (acid) to 14 (alkaline or basic) with 7 as neutral. The scale is logarithmic, so a change of one pH unit means a tenfold change in acid or alkaline concentration. For instance, a change from 7 to 6 represents a solution 10 times more acidic; a change from 7 to 5 is 100 times more acidic, and so on. The pH of a water body has a strong influence on what can live in it. Immature forms of salamanders, frogs, and other aquatic life are particularly sensitive to low pH.

Hydrogen Sulfide (H_2S)

Hydrogen sulfide can be present in ground water containing sulfur under anaerobic (no oxygen) conditions. It is also the product of a bacterial reaction in the presence of sulfate. Hydrogen sulfide gives water a "rotten egg" taste and odor and is often more noticeable in hot water than cold water.



Conducting a Hydrology Study in a Freshwater Ecosystem

Temperature (°C)

Water temperature is the temperature of a body of water and can vary greatly according to altitude, time of day, season, depth of water, and many other variables. Water temperature is important because it plays a key role in chemical, biological, and physical interactions within a body of water. The temperature of the water determines what aquatic plants and animals may be present since all species have natural limits of tolerance to upper and lower temperatures.

Turbidity

Turbidity is the measurement of water clarity. How clear the water is at the site will depend on the amount of soil particles suspended in the water and on the amount of algae growth. Turbidity may change with the seasons and with changes in plant growth rates, in response to precipitation runoff, or for other reasons. The clarity of the water determines how much light can penetrate. Since plants require light, transparency becomes an important measurement in determining the productivity of the water.

Nitrates (NO_2) (NO_3)

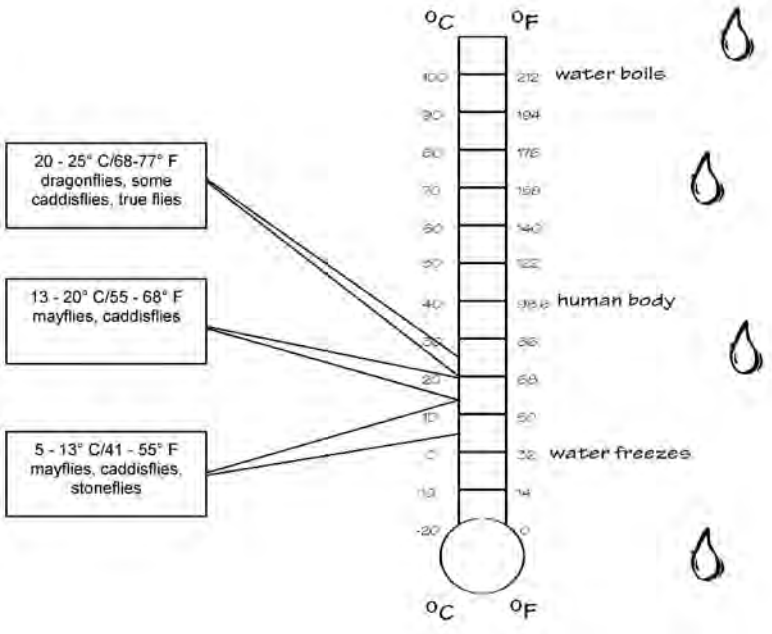
Nitrogen is one of the three major nutrients needed by plants. Most plants cannot use nitrogen in its molecular form (N_2). In aquatic ecosystems, blue-green algae are able to convert N_2 into ammonia and nitrate (NO_3), which can then be used by plants. Excessive nutrients like nitrate might at first sound good; however, too many nutrients can cause an abundance of phytoplankton or algae to grow. When the algae dies and begins to decompose, DO is depleted. When DO is too low, it will not allow other living species to breathe.

Phosphate (PO_4)

Phosphate is another nutrient needed for plant and animal growth. Increased levels of this nutrient can lead to overgrowth of plants, increased bacterial activity, and decreased DO levels.

Carbon Dioxide (CO_2)

Carbon dioxide is produced by respiratory processes. High levels of CO_2 can lead to excessive growth of organisms, which can cause a decrease in DO, the necessity for animals to survive.



Water Quality Analysis: Range Chart

Test	Description	Range of values
Water Temperature (ºC)	Water temperature is the temperature of a body of water and can vary greatly according to altitude, time of day, season, depth of water, and many other variables. Water temperature is important because it plays a key role in chemical, biological, and physical interactions within a body of water. The temperature of the water determines what aquatic plants and animals may be present since all species have natural limits of tolerance to upper and lower temperatures.	
pH	pH is an indicator of the acid content of water. The pH scale ranges from 1 (acid) to 14 (alkaline or basic) with 7 as neutral. The scale is logarithmic, so a change of one pH unit means a tenfold change in acid or alkaline concentration. For instance, a change from 7 to 6 represents a solution 10 times more acidic; a change from 7 to 5 is 100 times more acidic, and so on. The pH of a water body has a strong influence on what can live in it. Immature forms of salamanders, frogs, and other aquatic life are particularly sensitive to low pH.	Between 5.6 and 8.5 for aquatic organisms. 6.5-8.5 (EPA recommendation)
Nitrates (NO_2 and NO_3)	Nitrogen is one of the three major nutrients needed by plants. Most plants cannot use nitrogen in its molecular form (N_2). In aquatic ecosystems, blue-green algae are able to convert N_2 into ammonia and nitrate (NO_3), which can then be used by plants. Animals eat these plants to obtain nitrogen that they need to form proteins. When plants and animals die, bacteria break down protein molecules as part of the decomposition process. Different bacteria produce different nitrogen compounds, such as nitrates (NO_2 and NO_3), and ammonia. The cycle begins again. Typically, nitrogen levels in natural waters are low (below 1.0 ppm nitrate nitrogen). Nitrate levels are measured in milligrams per liter nitrate nitrogen.	**NO_3** 0.050-0.100 ppm for animals <.10 ppm (EPA recommendation) **NO_2** 0-10 ppm (range) <1 ppm (ideal)
Carbon Dioxide (CO_2)	Carbon dioxide is a colorless, tasteless, odorless, noncombustible gas that is soluble in water.	1,000-5,000 ppm Outdoor air concentration ranges from 300-400 ppm.
Dissolved Oxygen(DO)	All living things depend on oxygen to survive. In a water environment, molecules of oxygen gas dissolve in the water. This is called dissolved oxygen (DO). In air, 20 out of every 100 molecules are oxygen. In water, only one to five molecules out of every million molecules are oxygen. This is why dissolved oxygen is measured in parts per million (ppm). Water temperature and altitude influence how much oxygen water can hold. In general, warmer water cannot hold as much oxygen as colder water. Similarly, at higher altitudes water cannot hold as much oxygen as water at lower altitudes.	Cold water holds more than warm water. Lower hardness (salinity) enables higher dissolved oxygen levels. Fish die in lower than 4 ppm.
Hydrogen Sulfide (H_2S)	Hydrogen sulfide can be present in ground water containing sulfur under anaerobic (no oxygen) conditions. It is also the product of a bacterial reaction in the presence of sulfate. Hydrogen sulfide gives water a "rotten egg" taste and odor and is often more noticeable in hot water than cold water.	The acceptable level of hydrogen sulfide is 0.05 mg/l or less.
Phosphate (PO_4)	The nutrient phosphorous comes from natural sources such as phosphate-containing rocks and from anthropogenic (human) sources such as fertilizers, pesticides, detergents, and industrial compounds.	Levels over 0.03 ppm contribute to higher plant growth. The acceptable range is 0.05 - 0.1 ppm.
Turbidity	Turbidity is the measurement of water clarity. How clear the water is at the site will depend on the amount of soil particles suspended in the water and on the amount of algae growth at the site. Turbidity may change with the seasons and with changes in plant growth rates, in response to precipitation runoff, or for other reasons. The clarity of the water determines how much light can penetrate. Since plants require light, transparency becomes an important measurement in determining the productivity of the water.	Current Environmental Protection Agency (EPA) regulations require turbidity in drinking water not to exceed 5 NTU. The ability of salmonids to find and capture food is impaired at turbidities in the range of 25-70 NTU. EPA studies indicate that fish growth is reduced and gill tissue is damaged after five to ten days of exposure to water with a turbidity of 25 NTU. During a flood event, turbidities can jump to 100 NTU or more than 1,000 NTU.

Surveying the Living Organisms: Biological Analysis

Learning about the health of an ecosystem from a biological perspective can be easy. Looking at the vegetation and composition of the plant community often reflects the biological integrity. Additionally, birds and fish can indicate the health of an ecosystem by being sensitive to certain environmental influences.

Since each aquatic organism has specific tolerances of chemical and physical conditions, the presence or absence of particular organisms or species can tell us a lot about the body of water we are studying. If an abundance of organisms are found living in the water, then the water quality is assumed to be good. If the only organisms that can be found are those that tolerate low levels of dissolved oxygen, then the water can be considered poor quality and possibly polluted. A species which is normally present in an aquatic ecosystem under specific conditions is called an indicator organism.

Types of Living Freshwater Organisms

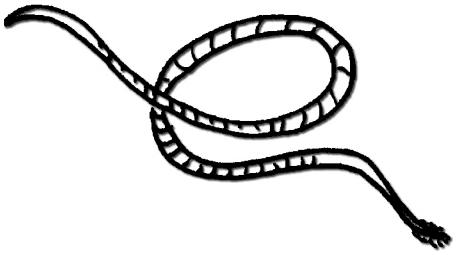
In a freshwater ecosystem, invertebrates and macroinvertebrates offer clues to show that the aquatic system is functioning. The diversity of macroinvertebrates can inform field biologists whether or not the ecosystem can support populations of amphibians, fish, birds, and other wildlife species.

Nematode

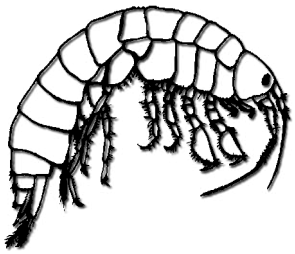
Dobsonfly

Stonefly

Damselfly



Earth Worm



Amphipod

Isopod

Soil Studies within Freshwater Ecosystems

Soils are made up of many materials, including organic matter, pieces of rock, and mineral deposits. The most common components of soil are sand and clay. The mixture of these materials, the size and shape of soil particles, and the amount of air space through which water can move determine how porous the soil is. Water will seep into certain soils faster than others. Permeability is the rate at which water percolates through the soil. The slower the percolation rate, the less permeable the ground. Permeability is the key factor in the formation of ecosystems. These conditions result in physical, chemical, and biological reactions that affect the ecosystem's plants and animals.

Topsoil (A Horizon)

Condition	Topsoil color		
	Dark (dark gray, brown, black)	**Moderately dark** (brown, yellow-brown)	**Light** (pale brown, yellow)
Amount of organic material	High	Medium	Low
Erosion factor	Low	Medium	High
Aeration	High	Medium	Low
Available Nitrogen	High	Medium	Low
Fertility	High	Medium	Low

Subsurface soil (B Horizon)

Subsurface soil color	Condition
Dull gray (if in low rainfall soils, 0-2 inches of rain)	Water-logged soils, poor aeration
Yellow, red-brown, black (if in forest soils)	Well-drained soils
Mottled gray (if in humid soils)	Somewhat poorly to poorly-drained soils

Common soil textures

Particle size	Feel	Air space	Water availability
Clay (.002 mm)	Sticky	Few, tiny	Slow movement of water; may result in low availability
Silt (.002 - .05 mm)	Smooth	Many, small	Good
Sand (.05 – 2.0 mm)	Gritty	Many, large	Low

Some effects of texture on soil conditions

Texture	Water-holding capacity	Looseness of soil
Sandy	Poor	Good
Loamy	Good to excellent	Good
Clayey	High (water held too tightly for plant use)	Poor

Physical Observation

Aquatic Landscape

Water site description:

Moving water:

❑ Stream ❑ River ❑ Other: _____ Width: _____ ft. (approximate)

Standing water:

❑ Pond ❑ Lake ❑ Reservoir ❑ Bay ❑ Ditch ❑ Other: _____

Is water bottom visible?

❑ Yes ❑ No Describe the bottom: _____

Describe what the bank of the water looks like:

❑ Boulders or stones around and in the water
❑ Fallen logs or branches in the water
❑ Sand bars or gravel bars
❑ Man-made structures
❑ Pools (streams only)
❑ Riffle areas (streams only)
❑ Other: _____

Erosion evidence:

❑ Bare soil unprotected by plants
❑ Exposed plant roots
❑ Cuts, ditches, or steep banks where soil is being washed away
❑ Trees, shrubs, or grasses preserved

Human influences:

❑ Drainage pipes ❑ Dams ❑ Litter
❑ Trails/bridges ❑ Swimming ❑ Boating ❑ Other: _____

Describe the habitats in shallow areas near the water's edge:

❑ Vegetation ❑ Boulders ❑ Gravel
❑ Rocks ❑ Logs ❑ Other: _____

Additional aquatic organisms observed:

❑ Fish ❑ Amphibians ❑ Birds ❑ Other: _____

Physical Observation

Air temperature: _____

Was there precipitation in the last 24 hours? ❑ Yes ❑ No

Description of weather conditions: ❑ Sunny ❑ Partly cloudy ❑ Overcast ❑ Rainy

Wind direction: _____

Relative humidity: _____

Soil Study

Soil color: ❑ Light brown ❑ Yellow/orange ❑ Green/gray ❑ Light gray ❑ Dark gray

Soil texture: ❑ Mostly clay ❑ Mostly sand ❑ Mixtures of clay and sand

Soil moisture: ❑ Soggy ❑ Moist ❑ Dry

Chemical Analysis

Use the table below to record your collected data

Date: _____

	Site #1 _____			Site #2 _____			Site #3 _____		
	Field Value			Field Value			Field Value		
H_2O Temperature (°C)	#1	#2	#3	#1	#2	#3	#1	#2	#3
	Average			Average			Average		
pH	#1	#2	#3	#1	#2	#3	#1	#2	#3
	Average			Average			Average		
Nitrate (NO_3) (mg/l)	#1	#2	#3	#1	#2	#3	#1	#2	#3
	Average			Average			Average		
Carbon Dioxide (CO_2) (mg/l)	#1	#2	#3	#1	#2	#3	#1	#2	#3
	Average			Average			Average		
Dissolved Oxygen (DO) (mg/l)	#1	#2	#3	#1	#2	#3	#1	#2	#3
	Average			Average			Average		
Hydrogen Sulfides (H_2S) (mg/l)	#1	#2	#3	#1	#2	#3	#1	#2	#3
	Average			Average			Average		
Phosphate (PO_4) (mg/l)	#1	#2	#3	#1	#2	#3	#1	#2	#3
	Average			Average			Average		
Turbidity (NTU)	#1	#2	#3	#1	#2	#3	#1	#2	#3
	Average			Average			Average		

Biological Analysis

Date: _____ Time: _____

Macroinvertebrates	Site 1 Tally	Site 2 Tally	Site 3 Tally	TOTAL
Ephemeroptera (mayflies)				
Odonata (dragonflies and damselflies)				
Plecoptera (stoneflies)				
Trichoptera (caddisflies)				
Diptera (flies)				
Megaloptera (fishflies and dobsonflies)				
Coleoptera (beetles)				
Amphipoda (shrimp and scuds)				
Isopoda (sowbugs)				
Decapoda (crayfish)				
Gastropoda (snails)				
Pelecypoda (mussels and clams)				
Oligochaeta (all segmented worms but leeches)				
Hirudinea (leeches)				
Other: _____				

Biological Analysis

Date: _____ Time: _____

	Column A	Column B	Column C
Macroinvertebrates	**# of Types**	**Tolerance Value**	**TOTAL**
Ephemeroptera (mayflies)		X 90	=
Odonata (dragonflies and damselflies)		X 60	=
Plecoptera (stoneflies)		X 100	=
Trichoptera (caddisflies)		X 80	=
Diptera (flies)		X 70	=
Megaloptera (fishflies and dobsonflies)		X 90	=
Coleoptera (beetles)		X 70	=
Amphipoda (shrimp and scuds)		X 40	=
Isopoda (sowbugs)		X 30	=
Decapoda (crayfish)		X 50	=
Gastropoda (snails)		X 40	=
Pelecypoda (mussels and clams)		X 20	=
Oligochaeta (all segmented worms but leeches)		X 20	=
Hirudinea (leeches)		X 10	=
Other: _____		X 90	=
SUM OF COLUMNS	**A**		**C**

Water Quality Index Number (sum of column A / sum of column C) = _____

Compare your water quality index number to the scale:
> 79 = Excellent
60-78 = Good
40-59 = Fair
< 40 = Poor

Health of the site: _____

Biological Analysis

Based on your collected data, what special adaptation would an organism need to make in order to live here? Why?

How would you best describe the water in this environment? What characteristics of this water determine the type of life found here?

As water temperature increases, what happens to the amount of dissolved oxygen in the water? How might this affect aquatic life?

If the number of stoneflies decreases, why should we be concerned?

Categorize each as acidic, neutral, or alkaline:

pH: 0-5 _____

pH: 5-9 _____

pH: 9-14 _____

Introduction

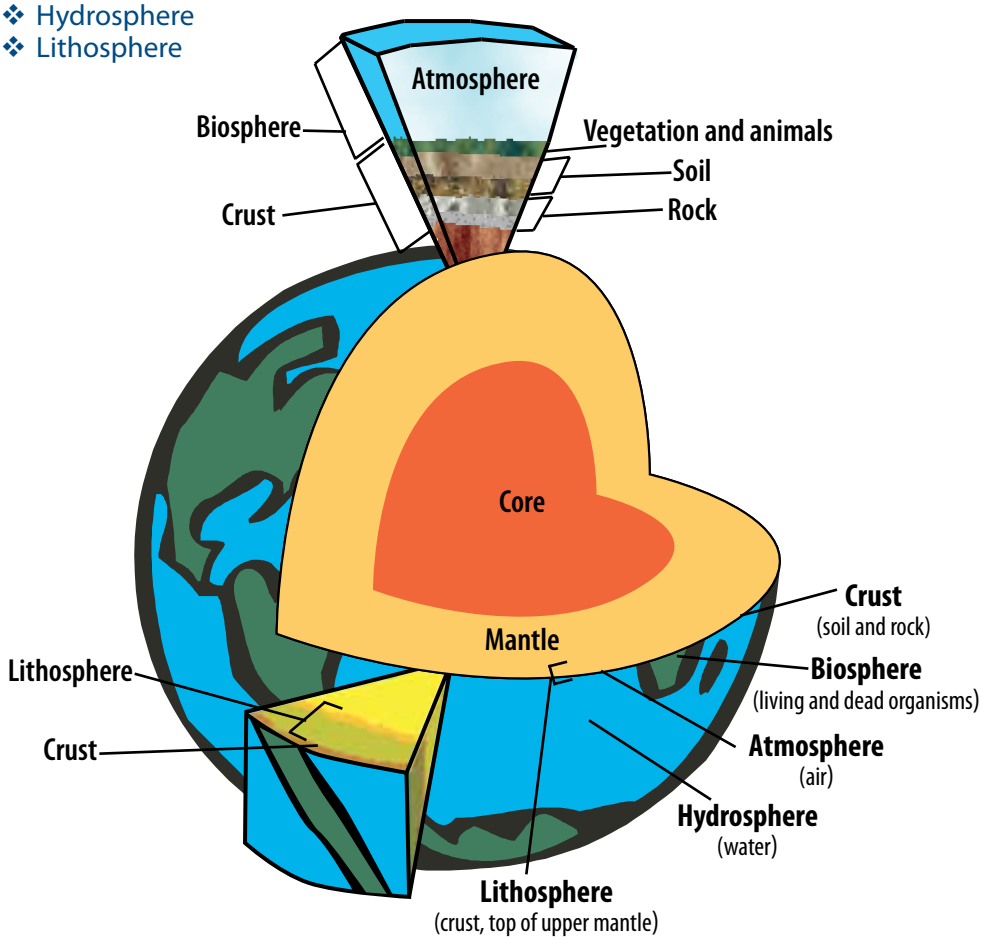
The Earth is active. As you are reading this:

- Volcanoes are erupting;
- Earthquakes are shaking;
- Mountains are being pushed up and are being ground down;
- Rivers are carrying sand and mud and laying them down;
- And all the time huge slabs of the Earth's surface are moving – about as fast as your fingernails grow.

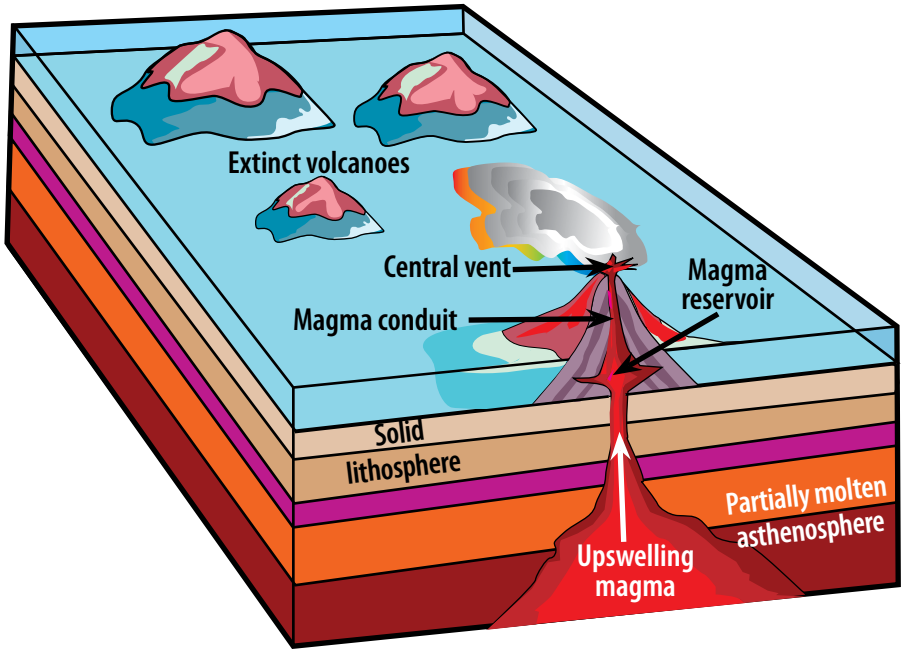
The Earth's surface is made up of tectonic plates which are in continuous motion. Some of these plates separate, allowing new material to come up from the mantle. Some collide at subduction zones, where one plate plunges beneath the other, returning material to the mantle. In Central America, we see the Cocos Plate colliding beneath the Caribbean Plate.

The Earth's life-support systems:

- Atmosphere
- Biosphere
- Hydrosphere
- Lithosphere

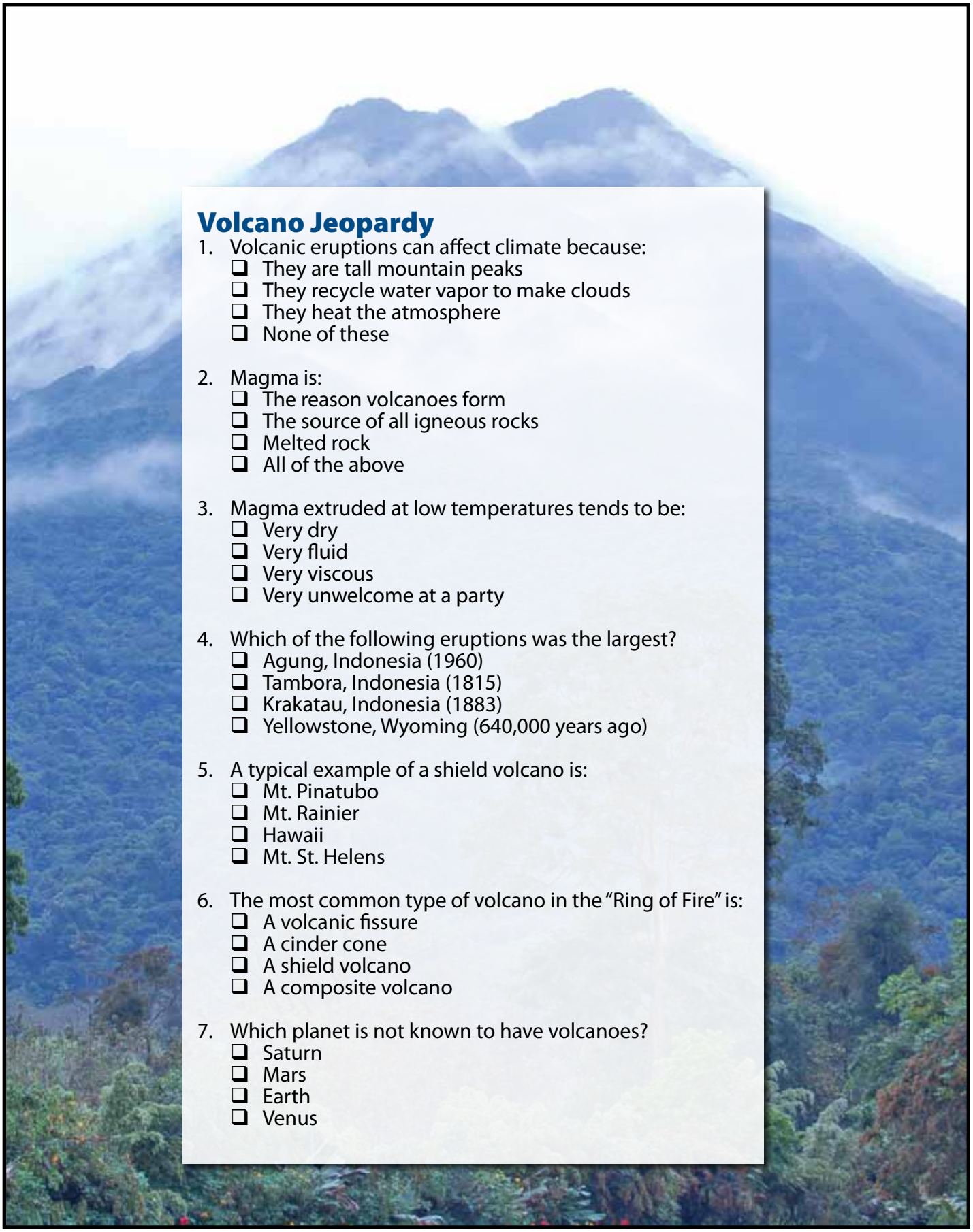


Natural Hazards: Volcanic eruptions



There are three main types of volcanoes.

Volcano type and shape	Composition	Eruption type
Stratovolcano 	Stratovolcanoes comprise the largest percentage (about 60%) of the Earth's individual volcanoes and most are characterized by eruptions of andesite and dacite, lavas that are cooler and more viscous than basalt. (Source: http://volcano.und.edu/vwdocs/vwlessons/volcano_types/strato.htm)	Plinian; explosive eruptions; generate large eruptive columns powered by expanding gas 
Shield volcano 	Shield volcanoes are almost exclusively basalt, a type of lava that is very fluid when erupted. (Source: http://volcano.und.edu/vwdocs/vwlessons/volcano_types/strato.htm)	Hawaiian; very calm eruptions; highly fluid with low gas content 
Scoria cone 	The cinder and scoria volcano, also called ash and cinder, is the most basic type of volcano, with a round crater at its summit. The cinder, or scoria, is the result of gas-charged lava cooling in the air during an eruption. Such volcanoes usually never surpass a height of 1,000 feet. (Source: http://library.thinkquest.org/03oct/00758/en/disaster/volcano/types.html)	Strombolian; pasty lava 



Volcano Jeopardy

1. Volcanic eruptions can affect climate because:
   - ❑ They are tall mountain peaks
   - ❑ They recycle water vapor to make clouds
   - ❑ They heat the atmosphere
   - ❑ None of these

2. Magma is:
   - ❑ The reason volcanoes form
   - ❑ The source of all igneous rocks
   - ❑ Melted rock
   - ❑ All of the above

3. Magma extruded at low temperatures tends to be:
   - ❑ Very dry
   - ❑ Very fluid
   - ❑ Very viscous
   - ❑ Very unwelcome at a party

4. Which of the following eruptions was the largest?
   - ❑ Agung, Indonesia (1960)
   - ❑ Tambora, Indonesia (1815)
   - ❑ Krakatau, Indonesia (1883)
   - ❑ Yellowstone, Wyoming (640,000 years ago)

5. A typical example of a shield volcano is:
   - ❑ Mt. Pinatubo
   - ❑ Mt. Rainier
   - ❑ Hawaii
   - ❑ Mt. St. Helens

6. The most common type of volcano in the "Ring of Fire" is:
   - ❑ A volcanic fissure
   - ❑ A cinder cone
   - ❑ A shield volcano
   - ❑ A composite volcano

7. Which planet is not known to have volcanoes?
   - ❑ Saturn
   - ❑ Mars
   - ❑ Earth
   - ❑ Venus

The Rock Cycle

Every type of rock can become every other type of rock (given enough time). The rock cycle shows how the three major rock types are formed.

IGNEOUS ROCKS – This type of rock comes from melted rock. It always starts as a liquid, formed deep below the ground but it can rise up and flow out on to the surface of the Earth (lava). This is the bright orange liquid that flows out of volcanoes. If the igneous rock is stuck below the ground, it cools very slowly, perhaps over millions of years, and the atoms in it have time to form into nice, organized mineral crystals. This is called an **intrusive** igneous rock, and you can see the wonderful minerals in any sample of it. If the magma comes out of the ground as lava, it cools very quickly and very few minerals have time to form. This is called **extrusive** igneous rock. The names of igneous rocks depend on **how the rock formed** and its **original composition**.

SEDIMENTARY ROCKS – These rocks are formed by the collection of pieces of rock that have been broken down from other rocks by weathering or erosion. On the Earth's surface, wind, water, and even plants can break rock into smaller pieces. Any kind of rock can be broken into pieces, called sediments, which can be piled together and become cemented to form a **clastic** sedimentary rock. Sedimentary rocks are also the kind of rock in which we find the most **fossils**.

METAMORPHIC ROCKS – This type of rock is probably the hardest to imagine. Sometimes rocks are pushed together so hard they fold and become mountains. This causes a lot of **heat and pressure**. This heats up the rocks that the land is made of, especially deep down in the core of the mountains, but it may not be enough heat to melt the rock. In that case, the rock is cooked and changed, although not melted.

There is often just enough heat for the elements that make up the rock to move around a little, and arrange themselves so that they take up as little space as possible between the pressures they are feeling. The rocks that are heated and pushed also change as the minerals change. These rocks are called metamorphic rocks because they change or metamorphose, the way a caterpillar metamorphoses into a butterfly. Since the metamorphic rock doesn't look the way it used to, we give it a new name. This name depends on the rock's new composition and appearance. These two criteria depend on what the rock was before it became metamorphosed (its parent rock) and how much pressure and heat it experienced.

Identifying Rocks at Arenal Volcano National Park – Identification Key

After determining the grain size, texture, color, and hardness of the rock on the previous page, use the key below to determine the name of the rock. Begin at the top of the key and based on the description of the rock, follow step by step through the key as directed until you identify the rock.

	ROCK DESCRIPTION	Go to...
1	Crystals can be seen without a lens.	2
	Crystals cannot be seen without a lens.	5
2	Made up of particles smaller than 2 mm.	3
	Made up of particles larger than 2 mm.	Conglomerate
3	Grains look like sand and can be easily scratched off.	Sandstone
	Grains not like sand and cannot be scratched off.	4
4	Crystals can be seen without a lens.	12
	Crystals cannot be seen without a lens.	Granite
5	Powder can be scratched off.	6
	Powder cannot be easily scratched off.	10
6	Soft and has many holes.	Pumice
	Does not have holes.	7
7	Dark, burns easily, and may be shiny.	8
	Dull and does not burn.	9
8	Can be scratched with a fingernail.	Peat
	Cannot be scratched with a fingernail.	Coal
9	Thin layers visible.	Shale
	Not layered.	Siltstone
10	Dull, very fine grains; splits in layers.	Slate
	Does not split in layers.	11
11	Large crystals.	Quartzite
	Small crystals.	13
12	Sedimentary rock may contain fossils.	Limestone
	Metamorphic rock made of calcite.	Marble
13	Dark, small crystals.	Basalt
	Small crystals.	Obsidian

Succession

Succession is the change of plant species in a given area through time. Succession begins when an area becomes devoid of vegetation, in this case by an erupting volcano. The trail in Arenal Volcano National Park is a perfect example of succession. We will see a few different stages of succession which occur after a volcanic eruption. The first groups of plants to arrive (pioneer species) are referred to as primary succession.

How do ecosystems respond to change?

Structures of ecosystems change in response to changing environmental conditions.

Ecological Succession – the gradual and fairly predictable change in species composition of a given area. Some species colonize and flourish, while others decline and even disappear.

Primary Succession – the gradual establishment of biotic communities in an area that has not been occupied by life before. Primary succession starts with a lifeless area (no soil).

Secondary Succession – the reestablishment of a biotic community in an area where a biotic community was previously present. Secondary succession begins in an area where the natural community has been disturbed, removed, or destroyed, but the soil or sediment remains (abandoned farmlands, burned or cut forests, heavily polluted streams, etc.).

Draw an arrow representing the direction of time.

Describe the difference between the two stages of succession for each of the following.

	Early stage of succession	Late stage of succession
Plant biomass		
Plant longevity		
Seed dispersal strategies		
Plant diversity		
Efficiency of photosynthesis		

What is the Atmosphere?

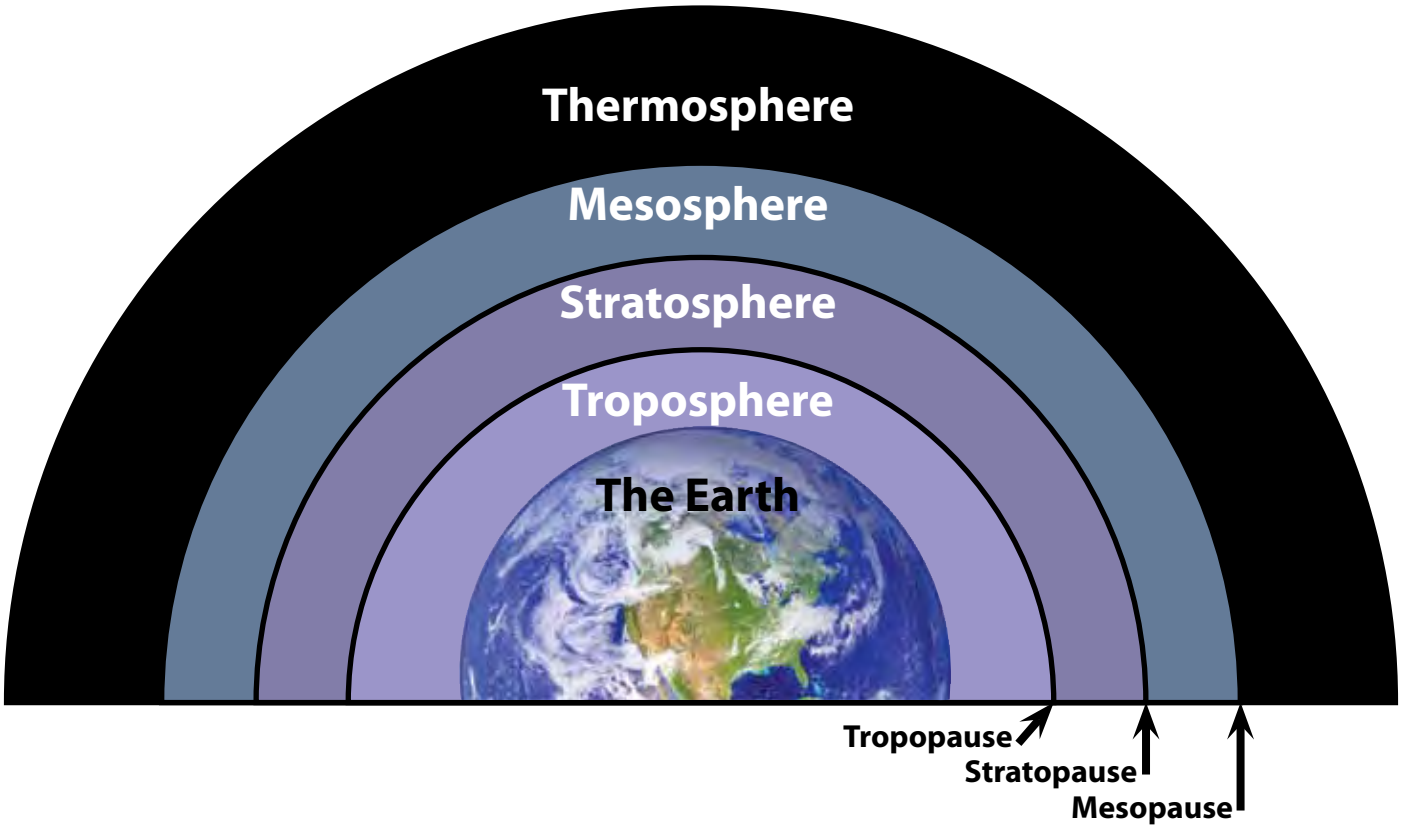
The atmosphere can be divided into four layers based on temperature variations. The layer closest to the Earth is called the troposphere. Above this layer is the stratosphere, followed by the mesosphere, then the thermosphere. The upper boundaries between these layers are known as the tropopause, the stratopause, and the mesopause, respectively.

Temperature variations in the four layers are due to the way solar energy is absorbed as it moves downward through the atmosphere. The Earth's surface is the primary absorber of solar energy. Some of this energy is reradiated by the Earth as heat, which warms the troposphere. The global average temperature in the troposphere rapidly decreases with altitude until reaching the tropopause, the boundary between the troposphere and the stratosphere.

The temperature begins to increase with altitude in the stratosphere. This warming is caused by a form of oxygen called ozone, which absorbs ultraviolet radiation from the sun. Ozone protects us from most of the sun's ultraviolet radiation, which can cause cancer, genetic mutations, and sunburn. Scientists are concerned that human activity is contributing to a decrease in stratospheric ozone. Nitric oxide, which is the exhaust of high-flying jets, and chlorofluorocarbons (CFCs), which are used as refrigerants, may contribute to ozone depletion.

At the stratopause, the temperature stops increasing with altitude. The overlying mesosphere does not absorb solar radiation, so the temperature decreases with altitude.

At the mesopause, the temperature begins to increase with altitude and this trend continues in the thermosphere. Here solar radiation first hits the Earth's atmosphere and heats it. Because the atmosphere is so thin, a thermometer cannot measure the temperature accurately and special instruments are needed.



Atmosphere Temperature Readings

1. The table below contains the average temperature readings at various altitudes in the Earth's atmosphere.

   Plot this data on the graph on the next page, and connect adjacent points with a smooth curve. Be careful to plot the negative temperature numbers correctly.

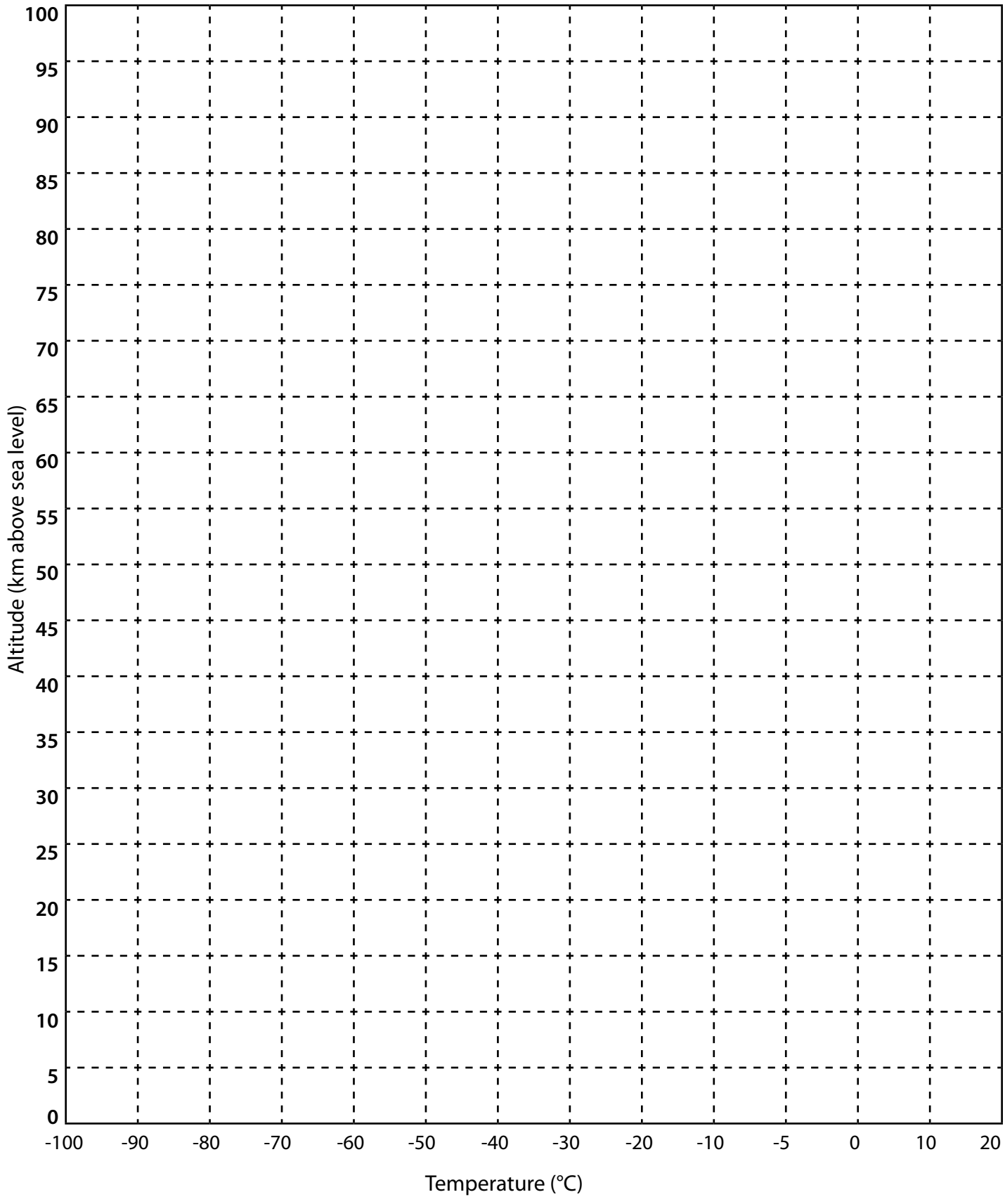
   This profile provides a general picture of temperature at any given time and place; however, the actual temperature may deviate from the average values, particularly in the lower atmosphere.

Average Temperature Readings at Various Altitudes

Altitude (km)	Temperature (°C)	Altitude (km)	Temperature (°C)
0	**15**	52	**-2**
5	**-18**	55	**-7**
10	**-49**	60	**-17**
12	**-56**	65	**-33**
20	**-56**	70	**-54**
25	**-51**	75	**-65**
30	**-46**	80	**-79**
35	**-37**	84	**-86**
40	**-22**	92	**-86**
45	**-8**	95	**-81**
48	**-2**	100	**-72**

2. Label the different layers of the atmosphere and the separating boundaries between each layer on the graph.
3. Mark the general location of the ozone layer. You should place eight terms on your graph in the correct locations: troposphere, tropopause, stratosphere, stratopause, mesosphere, mesopause, thermosphere, and ozone layer.

Graph of Temperatures at Various Altitudes



1. What is the basis for dividing the atmosphere into four layers?

2. Does the temperature increase or decrease with altitude in the:

Troposphere? _____ Stratosphere? _____

Mesosphere? _____ Thermosphere? _____

3. What is the approximate height and temperature of the:

Tropopause: _____ _____

Stratopause: _____ _____

Mesopause: _____ _____

4. What causes the temperature to increase with height through the stratosphere and decrease with height through the mesosphere?

5. What causes the temperature to decrease with height in the troposphere?

Butterflies

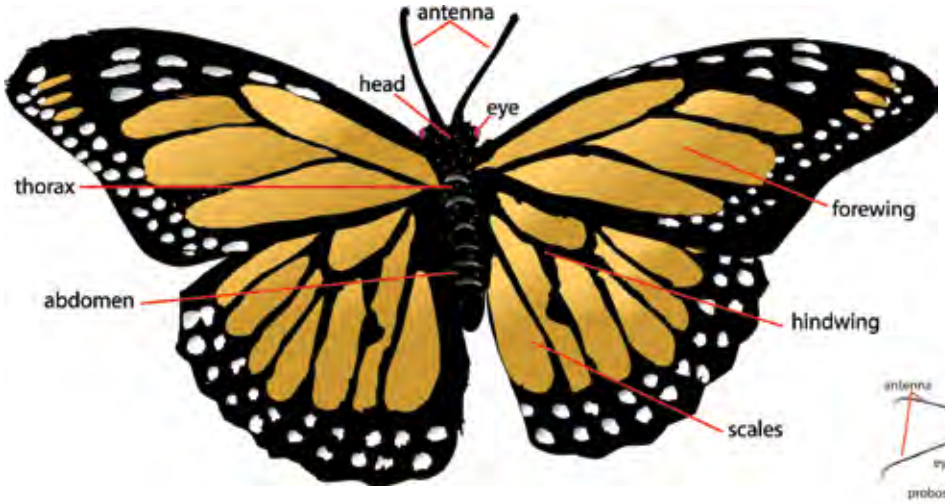
Butterflies are of the order Lepidoptera and characteristically have slender bodies, knobbed antennae, and four broad, usually colorful, wings. The word Lepidoptera comes from the Greek words "lepis" meaning scale and "pteron" meaning wing. Butterfly wings are made of hardened membrane, strengthened by veins and covered by tiny scales, each a single color. The intricate designs of butterfly wings are produced by thousands of scales, arrayed in complex patterns, and overlapping one another like shingles on a roof.

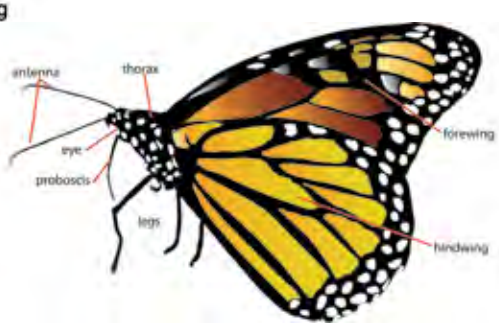
Insect Anatomy

- All insects have certain identifying features that scientists use to classify them as insects.
- All insects have three body parts: a head, a thorax, and an abdomen.
- Insects have exoskeletons (the skeleton on the outside that can be shed and regrown as the insect grows in size).
- Generally, insects have three pairs of legs attached to the thorax. Spiders have four pairs of legs and are not insects.
- Most insects have two or more pairs of eyes (compound eyes) located on their head, which allows them to see ultraviolet waves, which humans cannot see.
- Insects have antennae, which are used for smelling and analyzing odors and tastes.

Butterfly Characteristics

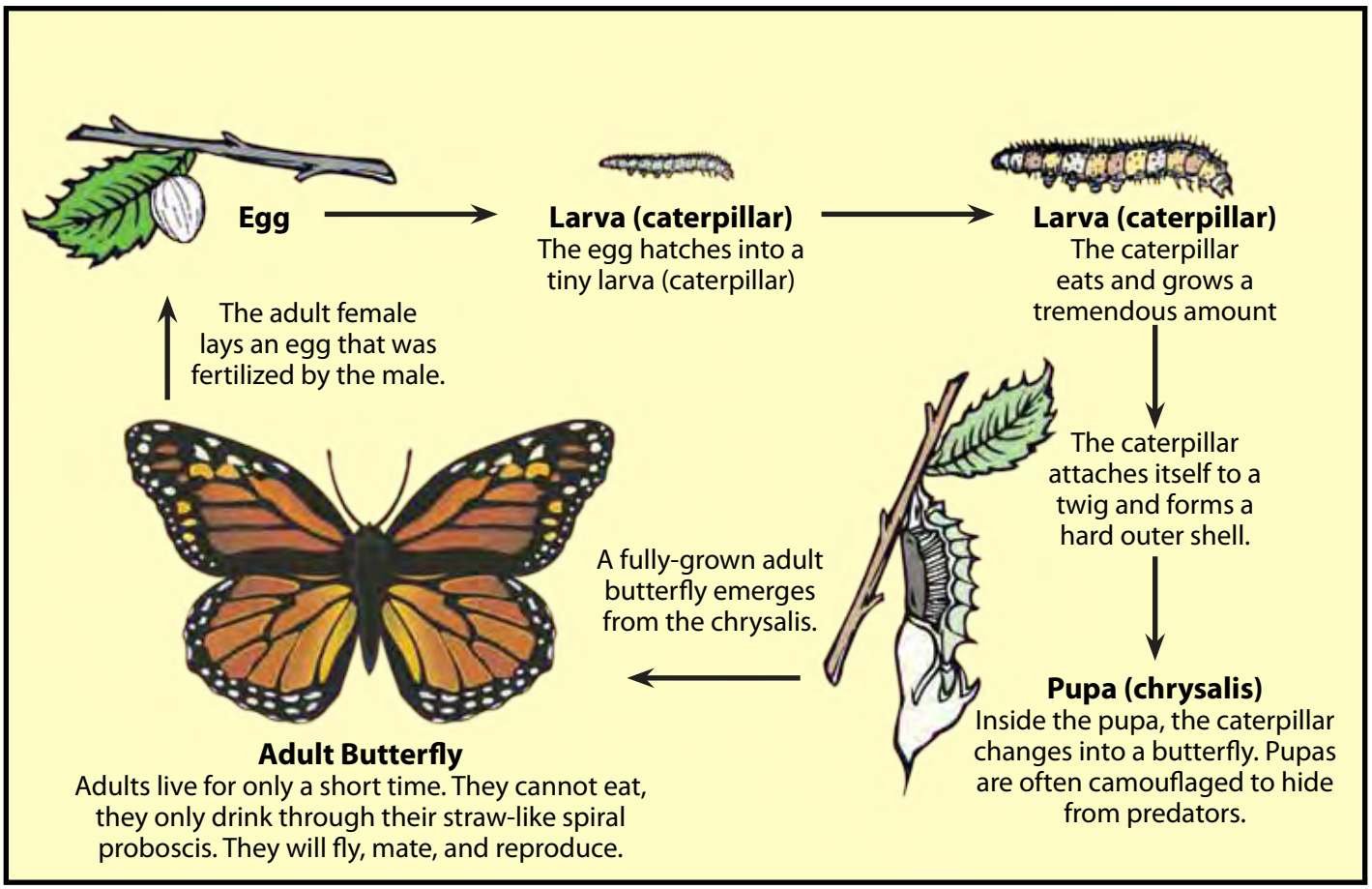
- Butterflies sip nectar and other liquids using a spiral proboscis, located on their head, like a straw.
- They also use their feet to taste!
- Butterflies have two upper forewings and two lower hindwings all located on the thorax, along with their six legs.
- Their wings are made up of many tiny scales, and wings are symmetrical, meaning each side looks exactly the same.
- Butterflies have two antennae with clubs located at the ends.





Butterfly Life Cycle

Metamorphosis of a Monarch Butterfly



Egg	Butterflies will lay 200-500 eggs on leaves and stems of host plant. Caterpillars hatch from the eggs in about five days.
Caterpillar	Some caterpillars may eat as much as 25,000 times their body weight. Since they grow so fast they molt up to five times in a few weeks.
Chrysalis (pupa)	The caterpillar will shed its skin for the last time and become a pupa. Inside the chrysalis the pupa is reorganizing cells to become an adult.
Adult	The adult butterfly will emerge in a few weeks and look for a mate. After mating, the females will lay eggs. In most cases butterflies live for only two weeks.

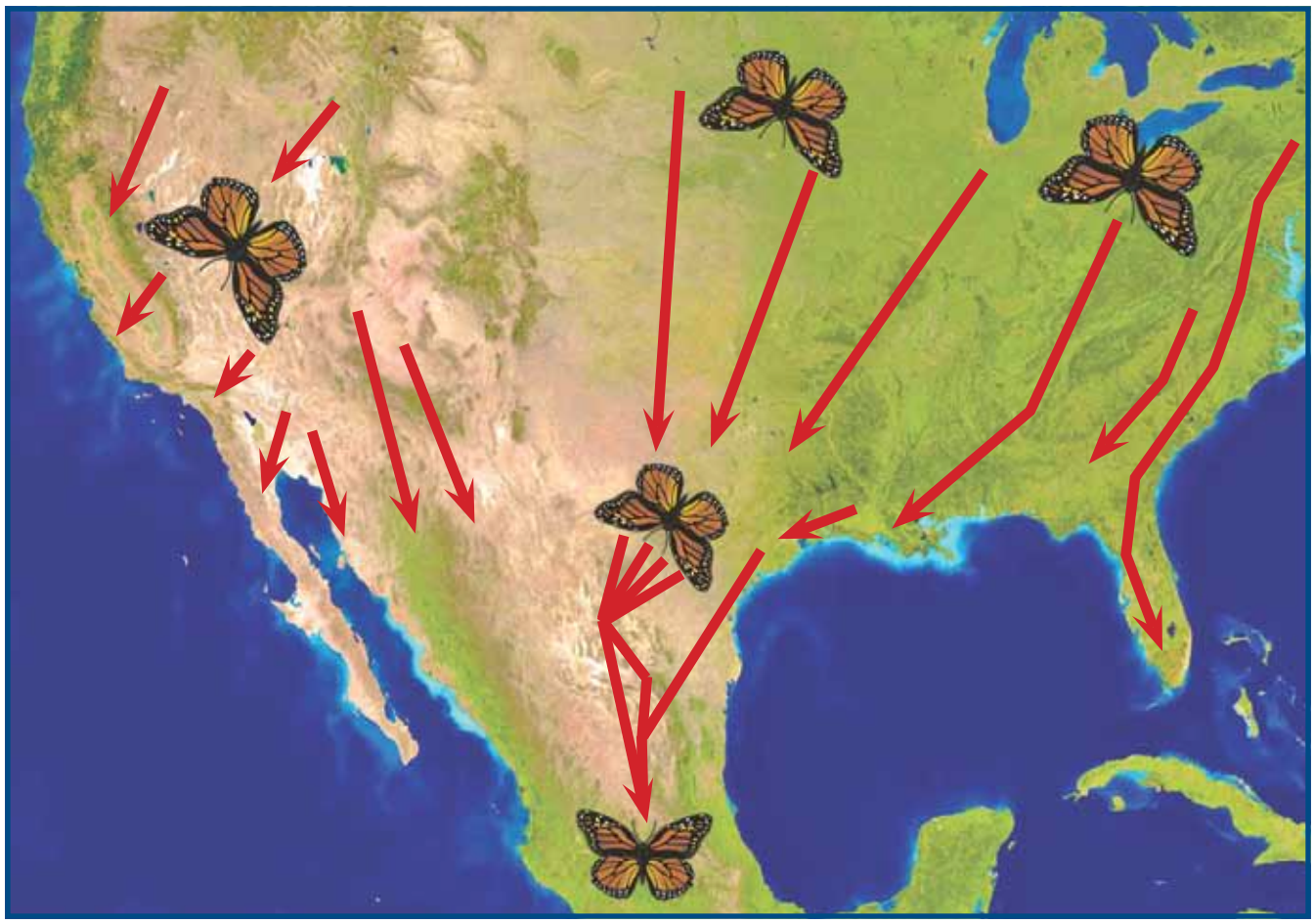
Butterflies and Conservation

Many species of butterflies are endangered because their living spaces — swamps or forests, for example — are being destroyed. Some kinds of butterflies only feed on one particular species of plant. If this plant disappears, the butterfly disappears too. People sometimes use pesticides to get rid of the harmful insects in their gardens and on their farms, but the pesticides also harm the butterflies.

What is special about the monarch butterfly?

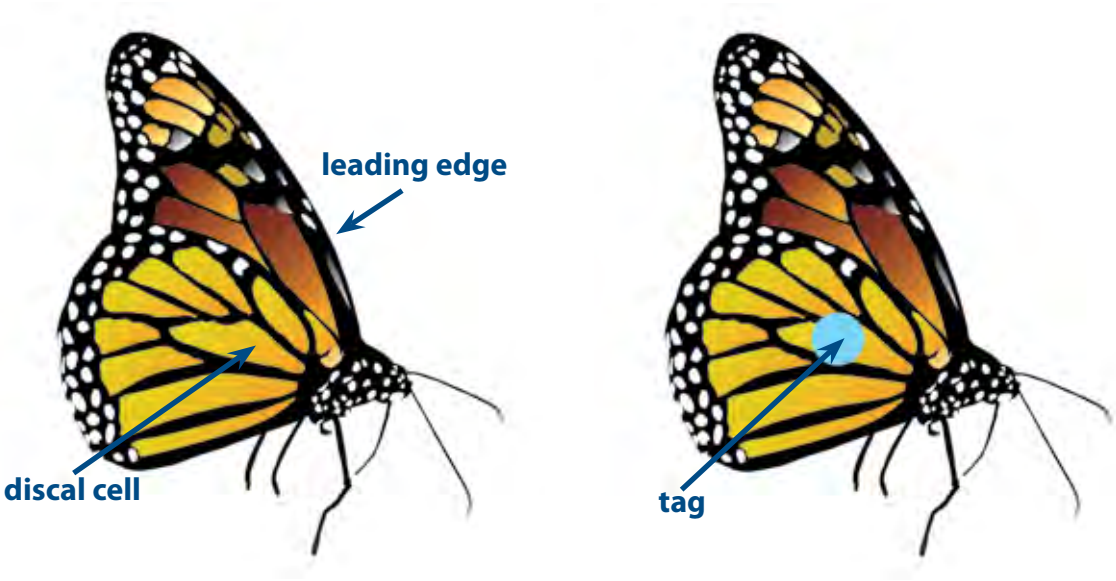
Packed into this animal weighing in at .3 grams is one of nature's greatest mysteries. Each autumn, hundreds of millions of these creatures head south, from the Eastern United States and Canada, on a migration of 4,000 miles to the interior of Mexico. Even more amazing, the return migration of this species covers four generations. That means that a monarch seen in Vermont, in August, will have returned to the same area from which its great-grandparents departed south the previous year.

Butterfly Migration



Monarch butterflies are just one type of 24,000 species of butterflies in the world. They are unique because scientists recently discovered that two-thirds of the world's population of monarchs (that is, all the monarchs east of the Rocky Mountain range) migrate each winter to a small town in the mountains of Michoacan, Mexico. The remaining third of the monarchs migrate along the West Coast of the United States during the winter months. Monarchs may travel as far as 4,000 miles to reach their wintering sites! The butterflies travel to Mexico in the fall, and return to their homes all over the United States, Mexico, and Canada in early spring.

Tagging Basics
Butterflies are tagged so the scientists who study the monarchs will be able to track them and find out more information about their migration. Many questions about monarch migration still remain. Each fall, classroom teachers, scientists, and concerned community members catch the butterflies with slow movements, so as not to damage them. Each tag is a small, round (9 mm in diameter) adhesive that is placed on the underside of the hindwing of the monarch. The tag displays a certain number that is recorded before releasing the butterfly. Once recaptured, scientists studying the monarchs can determine where the tagged monarchs came from, if they move along "paths," how weather might play a role, and other mysteries of monarchs.



How do species, such as the Monarch Butterfly, become extinct?
When environmental conditions change, a species may cease to exist if it cannot adapt. Several major factors affecting speciation:

- Large-scale movements of the continents
- Gradual climate changes
- Rapid climate changes (catastrophic events)

Background extinction is the disappearance of a species at a low, gradual rate. **Mass extinction** is the abrupt rise in extinction rate above the background level. People are a major force in the premature extinction of species.

Amphibians

The word "amphibian" refers to an organism that can live both in water and on land. Most stay in or around water, but many will spend portions of their lives on land. In addition to lungs, amphibians have thin skin to aid in respiration (breathing). Costa Rica is at the center of interest to biologists because of the great diversity in habitats and the rich number of amphibian species.

Amphibians in Costa Rica need the same respect we give to snakes. Many of them may be dangerous to handle due to their toxic skin. Since their skin is so thin, we can harm them by holding them.

Why might biologists keep amphibians in terrariums?

Toads and frogs belong to the group of anurans. What are some differences between toads and frogs?

How do predator and prey species interact?

- Predators feed on prey, but they do not live in or on the prey.
- This is a positive feedback system for the predator.
- Prey organisms may or may not be killed by their predators. Predation can benefit the prey by eliminating the sick, weak, and aged members.

How do predators increase their chances of getting a meal?

- Pursuit – run fast to catch their prey; have keen eyesight; hunt in packs; humans have invented tools (weapons and traps.)
- Ambush – camouflage helps conceal them while they lie in hiding waiting for their prey.

How do prey defend themselves against predators?

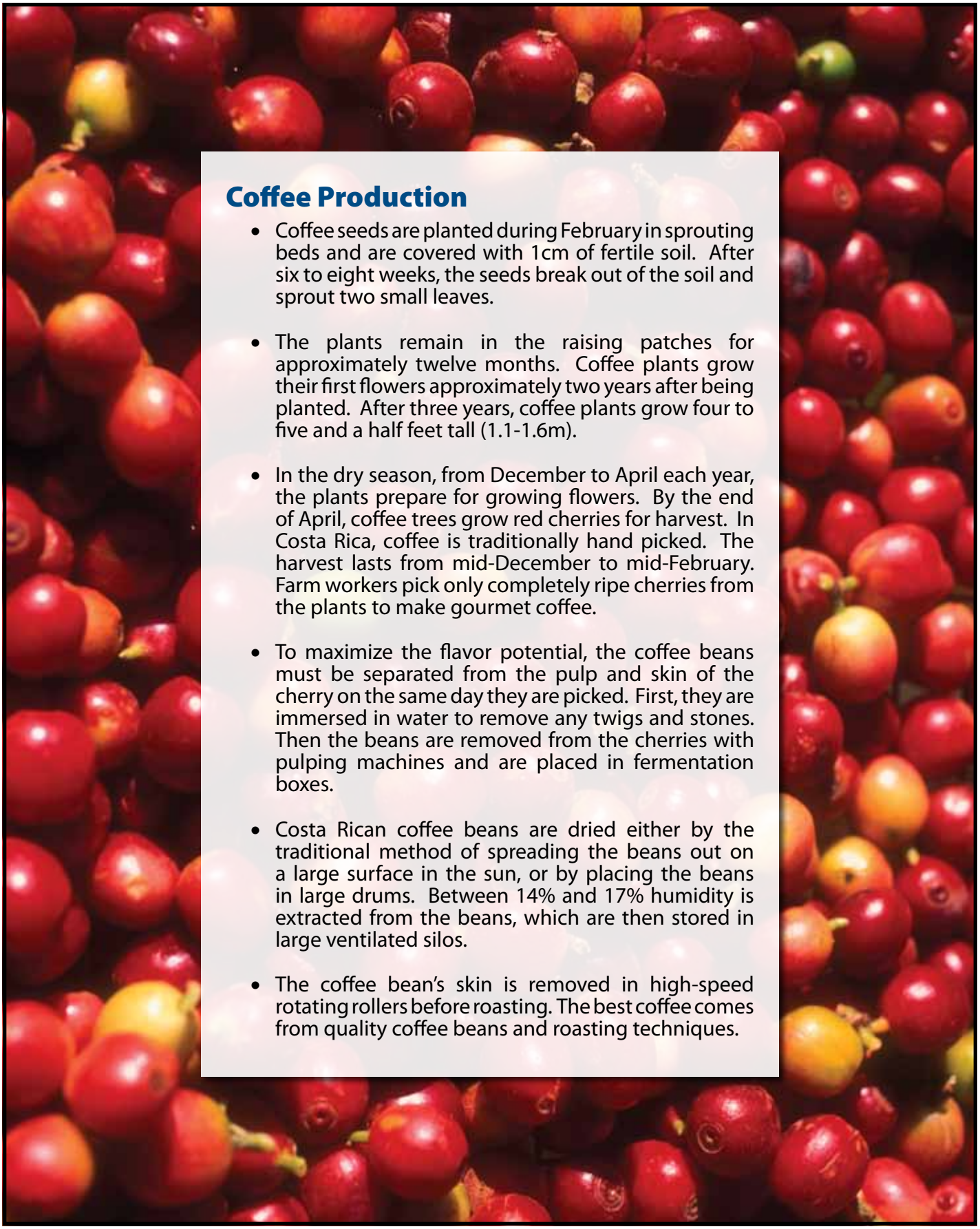
- Run, swim or fly fast; keen sight or sense of smell to alert them to the presence of predators; protective shells; thick bark; spines; thorns; camouflage to hide from predators.
- Chemical warfare – chemicals that are poisonous, irritating, foul-smelling, bad-tasting.
- Warning coloration so predators know that this animal is bad-tasting.
- Mimicry – species take on the appearance of another animal that may be very poisonous.

Coffee Production

It is unlikely that the people responsible for introducing coffee (café) to Costa Rica in the early 1800s knew what a perfect choice they'd made. Costa Rica was the first Central American country to develop a coffee industry, and certainly the environmental conditions were a key factor in its development. The combination of a highlands region and a chain of volcanoes created terrain in which the coffee plant could thrive.

Costa Rica is composed of a number of volcanic chains, starting in the northwest part of the country and crossing to the southeastern region. As a result of the volcanic activity, the soil in these areas is rich in organic materials which benefit the growing coffee plant. The volcanic soil's composition encourages the roots of the plant to distribute evenly, invigorating growth by promoting retention of moisture and facilitating proper oxygenation. In addition, the plant thrives in the shade of the country's dense forests and favorable altitude. A moderate to high altitude is important to maturing coffee plants. Most Costa Rican coffee is grown 1,300 feet (396 meters) to 5,700 feet (1,737 meters) above sea level.

Unfortunately, human impact has altered some of the original conditions that enabled Costa Rica's easy embrace of coffee. Farmers created massive coffee plantations, clearing large areas of trees in the process. While increased sunlight on the coffee plants produces more fruit, the loss of trees (and falling leaves) leads to a decrease of nitrates being returned to the soil. In turn, much more chemical fertilizer is needed, drastically changing Costa Rica's soil composition over time. A new era of farmers, however, are striving to recreate the original conditions of the land. An example of the new efforts is the replanting of trees. These trees provide the preferred shade and allow nutrients to return to the soil. With a continued focus on rebuilding and preserving the ideal harvesting conditions, Costa Rica's history as one of the top coffee producers in the world is far from over.



Coffee Production

- Coffee seeds are planted during February in sprouting beds and are covered with 1cm of fertile soil. After six to eight weeks, the seeds break out of the soil and sprout two small leaves.

- The plants remain in the raising patches for approximately twelve months. Coffee plants grow their first flowers approximately two years after being planted. After three years, coffee plants grow four to five and a half feet tall (1.1-1.6m).

- In the dry season, from December to April each year, the plants prepare for growing flowers. By the end of April, coffee trees grow red cherries for harvest. In Costa Rica, coffee is traditionally hand picked. The harvest lasts from mid-December to mid-February. Farm workers pick only completely ripe cherries from the plants to make gourmet coffee.

- To maximize the flavor potential, the coffee beans must be separated from the pulp and skin of the cherry on the same day they are picked. First, they are immersed in water to remove any twigs and stones. Then the beans are removed from the cherries with pulping machines and are placed in fermentation boxes.

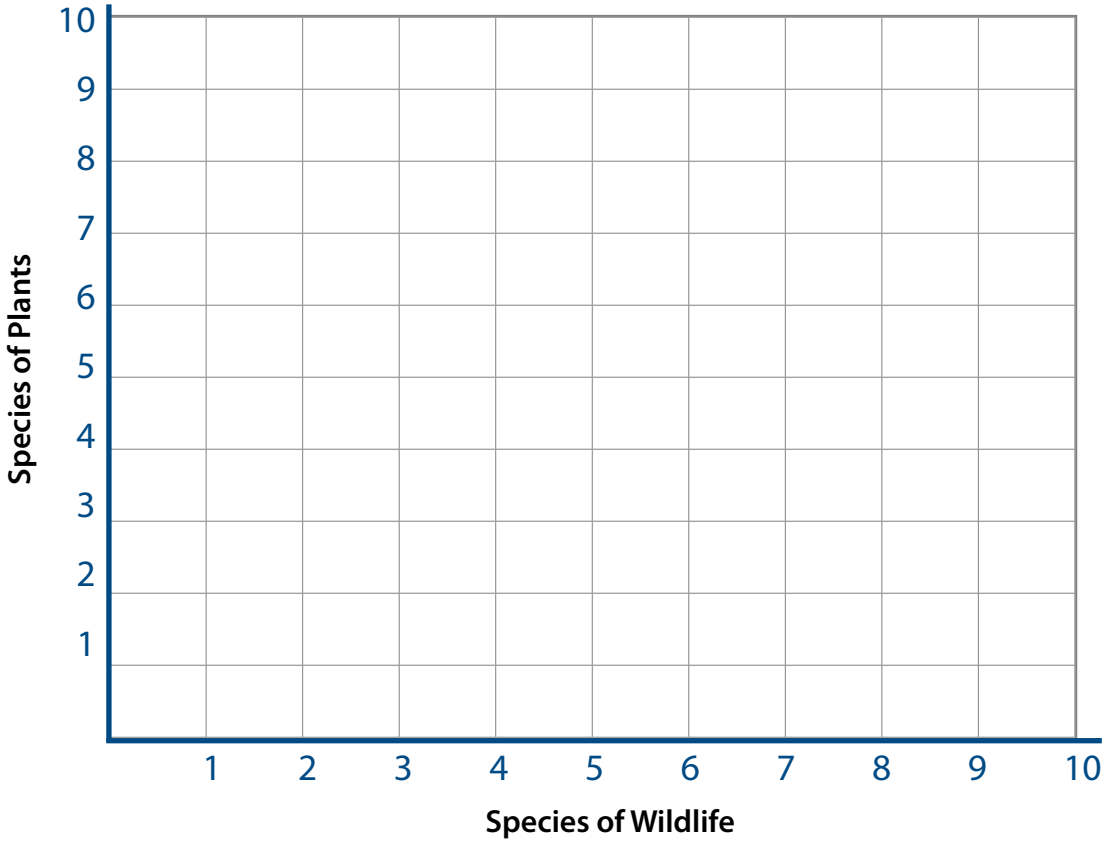
- Costa Rican coffee beans are dried either by the traditional method of spreading the beans out on a large surface in the sun, or by placing the beans in large drums. Between 14% and 17% humidity is extracted from the beans, which are then stored in large ventilated silos.

- The coffee bean's skin is removed in high-speed rotating rollers before roasting. The best coffee comes from quality coffee beans and roasting techniques.

"Shade Grown Coffee" is coffee grown under a canopy of native species. In the table below, name three positive and three negative effects this growing technique may have.

Shade Grown Coffee Technique	
Positive effects	**Negative effects**

On the following graph, draw a line representing the diversity of wildlife species in relation to the diversity of plant species found in a forest or a coffee plantation.



Human Interaction with the Environment

Case Study

Humans, like all other life forms, depend on the unique relationships between the biosphere, hydrosphere, atmosphere, and lithosphere. We need air to breathe, water to drink, and land to grow the food we eat. But the balance between people and place is fragile. When humans interact with the natural environment, there are always consequences. Some of these are intended; some are not. Some consequences are positive and beneficial; some are negative and costly.

For the inhabitants of Country X, the beautiful and tempting blue expanse of the Blue Sea, with its lazy curving beaches, is no longer pure. Into this sea flows the urban and chemical waste from the Baltic States and beyond.

Marine life has suffered as a direct result of Country X's fishing policies. The natural balance has been destroyed by overfishing, and during the 1980s spawning fish levels in the entire Blue Sea fell by more than 50 percent. In the past 20 years, the concentration of nitrate from improperly treated waste water quadrupled during the winter months. This has increased organic material on the sea bottom, which has reduced oxygen levels and led to a decline in numbers of fish. Stocks of whitefish and smelt have dropped and cod reproduction has been seriously affected.

Naturalists say that some of the country's mismanagement of coastal areas has actually protected the whole coast from development. For nearly two generations, most coastal land remained unused. For the first time in 50 years, people are rediscovering beautiful beaches. Country X's control also saved large tracts of woodland and wildlife, sustaining habitats that have completely disappeared elsewhere in the world. Fortunately, Country X has several natural parks and special areas set aside for the study of plants, animals, and geological sites.

Energy is a crucial question, and the search for it has been a major contributor to the pollution of Country X. Two nuclear reactors are now up and running, but plans for another two at the same site were halted following the demonstrations organized by an environmental group.

Country X has no natural fuel resources and consumes twice as much energy as it produces at the nuclear station and at a thermoelectric power plant. Officials do not plan to close down the electric plant, which produces more than half the electricity generated in Country X, but they are trying to increase the reactor's safety. Little has been done to promote heat and light conservation at home. Windows are badly-fitted and buildings are poorly-insulated. Government attempts to control fuel use during energy shortages have not been successful. Country X's forests are already threatened by a burgeoning black market for timber exports, and with the fuel crisis, they will increasingly be used for fuel to heat homes during the long, dark days of winter. Wood and peat currently supply about four percent of Country X's energy needs.

Out of Balance

The ecological changes described on the previous page all have human (or "anthropogenic") rather than natural causes. Complete the chart below indicating the environmental problem related to the aspect of the environment listed. Note the probable human causes of each problem, as well as the effect this problem has on the ecology of the area. Finally, note the effect of this ecological change on humans and their culture.

Aspect of Environment	Problem	Human Cause(s)	Effect(s) on Ecology	Consequences for Humans
AIR				
LAND				
VEGETATION AND WILDLIFE				
WATER				

Out of Balance

Discuss these questions in small groups and come to agreement. Record your answers to share with the class. Answers between groups may vary, so be prepared to defend your responses. Consult your chart on the previous page.

1. Of the environmental problems noted on your chart:

Which are primarily the result of local causes?

Which are primarily the result of regional causes?

Which are primarily the result of international causes?

2. Of the human causes noted on your chart:

Which are related to meeting basic needs for food and water? How?

Which are related to industrial development? How?

Which would be the easiest for people to change? Why?

Which would be the most difficult? Why?

3. Of the effects on ecology noted on your chart:

Which of these effects would be easiest to reverse? Why?

Which would be the most difficult to reverse? Why?

Which do you believe is the most urgent problem? Why?

4. Discuss the solutions to this problem.

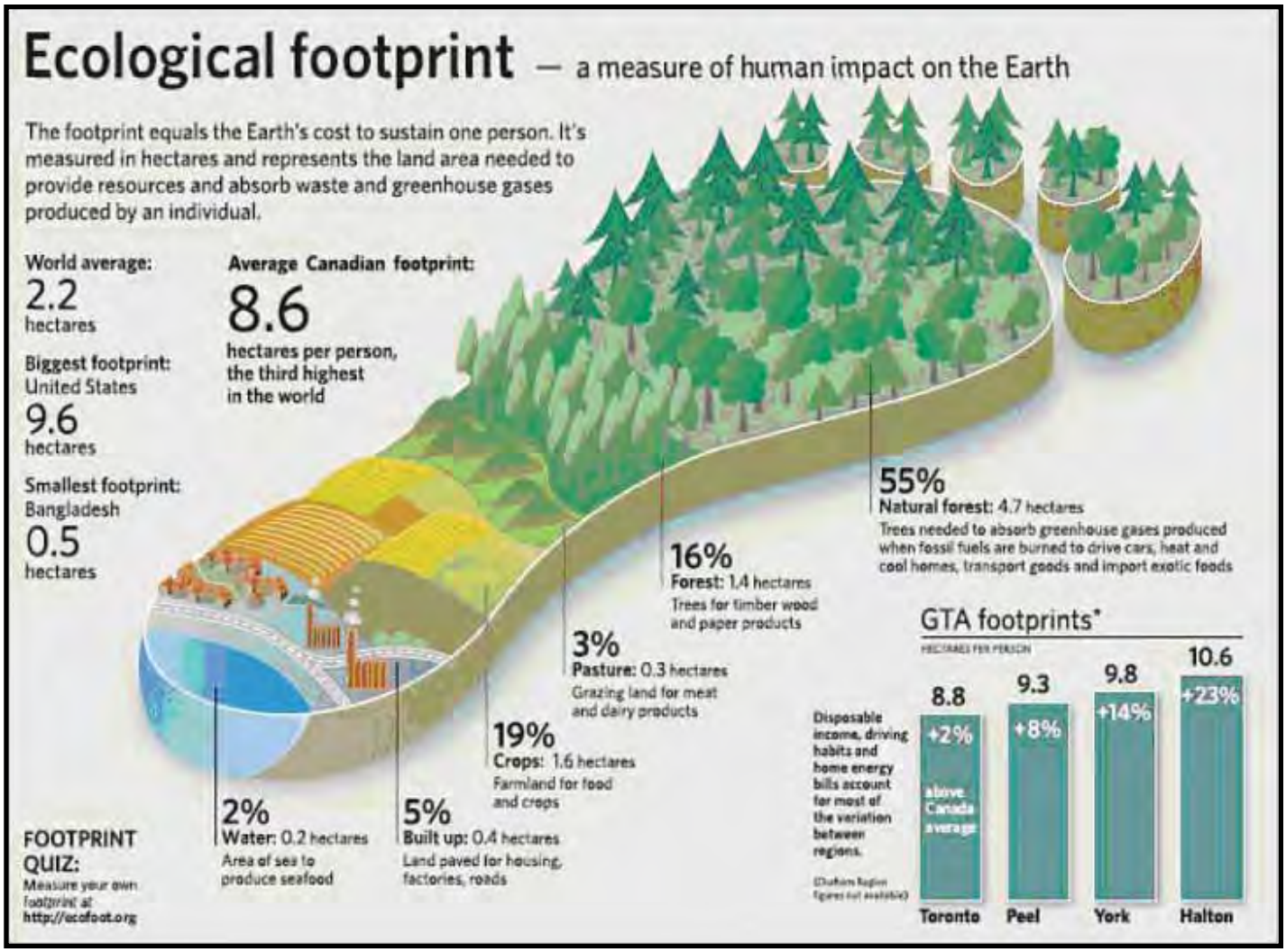
What is the best way to solve this environmental dilemma?

Costa Rica's Environmental Problems

Whether you're an environmental scientist or just a tourist, you should do a little research on pollution in the country you are going to visit. Is the air in the city OK to breath? How about the city water? Can I drink it? Let's take a look at pollution in Costa Rica, both to gain a better understanding of environmental science and to ensure that we have a safe and healthy traveling experience abroad.

Ecological Footprint

In order to get started, we need to introduce the concept of an ecological footprint. Do you ever think about what happens when you throw away a plastic bottle? What happens to the trash you throw away each week? Where does wastewater from your house flow? This section is about answering these questions and understanding one's impact on the environment.



San José:

Understanding the Urban Organism and Population Dynamics

When you arrive in San José, you might be surprised by the hustle and bustle of the city. San José is the capital of Costa Rica at 3,800 feet above sea level (wow, that's high!), and is the largest city in the country with a metro population of roughly 1.6 million people (roughly a third of the entire Costa Rican population), up from just 70,000 people in the 1940s—an incredible increase. Many Ticos (the name given to native Costa Ricans) migrated from the countryside into San José in the latter-half of the 20th century looking for better jobs. Recently, the massive influx of people into the city has created considerable problems for the metropolis. To understand how population increases affects human's viability in a cosmopolitan setting, we must discuss some of the basics of population dynamics.

You've just arrived in the urban core of Costa Rica, San José. One thing you should always do when you arrive in a new place is take a walk outside and take in the atmosphere of a new city. As you walk around San José your first day in Costa Rica, use your five senses to describe the urban environment of San José. Do you find it dirty? Smelly? Loud? Does it seem crowded? How does it compare to your hometown? Use the space below to write down some initial thoughts about San José.

Population Dynamics

According to the Population Institute, an international nonprofit organization dedicated to world population studies, it was not until 1830 that the world population reached 1 billion people, but in less than two centuries, the world population has increased by more than 6 times the 1830 figure, and in 2008, the world population was approximately 6.6 billion people. Can our earth sustain this kind of dramatic population growth? What kinds of natural resources are most jeopardized by rapid population growth? These are the types of questions that environmental scholars interested in population dynamics ask.

Perhaps the greatest scholar to deal with issues pertaining to population and sustainability was Thomas Malthus who wrote *Essay on Population* in 1798. Malthus provided the following **demographic** model in order to calculate population change:

$$\frac{\text{CHANGE IN POPULATION}}{\text{POPULATION}} = \frac{\text{BIRTHS}}{\text{POPULATION}} - \frac{\text{DEATHS}}{\text{POPULATION}}$$

(Rate of Change of Population) (Crude Birth Rate (CBR)) (Crude Death Rate (CDR))

Let's offer an example of how we might use this equation. If there are 60 births per 1,000 people in a city in a given year and 30 deaths per 1,000 people in a given year, the population will increase by 30 per thousand, or 3%. According to Malthus' calculations, the natural rate of population change is 2%. Malthus believed that population would increase at a rate that exceeded the rate at which food could be produced, and that two types of checks controlled population growth. The first of these he termed **positive checks**, that is famine, natural disasters, war, and catastrophic events which would limit human's ability to sustain population growth. The second he termed **preventive checks**, or decisions about birth control, etc., which societies could adopt in order to control growth.

One of the problems with Malthusian thinking is that it does not take into account innovative advancements in technology. So how do environmental scientists discuss the **ecological costs** of population growth and technological change? One useful equation that can be used to determine the impacts of population growth on the global environment is:

Impact of any human group on the environment = Number of people x Average person's consumption of resources x Environmental disruptiveness of the technologies that provide the goods that people consume.

As you can see above, when population is high, even a small amount of technological disruptiveness can greatly increase the impacts on the environment. For example, two cities both with populations of 300,000 people have vastly different impacts on the environment if urbanites primary mode of transportation in one city is automobiles, while in the other residents typically ride bikes. Nonetheless, increased technology is not always a bad thing. Innovative engineering may allow for a way to create cheap and efficient energy, reducing the use of fossil fuels and limiting pollution.

OK, enough equations for the moment! Let's see how we might apply the concepts discussed above to real life situations.

Pollution and Conservation

While Costa Rica may not suffer from overpopulation (the current population is app. 4.1 million), other polities have struggled to deal with population issues. Mexico City, alone, for example, was home to over 8.7 million people in 2005, with the greater metropolitan area featuring a population of over 19 million people. China faces serious population issues with a population that reached 1.3 billion in 2008. The Chinese government has attempted to abate population growth by imposing certain restrictions on how many kids a family can have (this might be called a preventive check in Malthusian terms).

Pretend you are the leader of a third world country facing overpopulation concerns. What would you do in order to ensure sustainability? What are the cultural considerations that would drive your decision? What are the political implications of intervening?

Can I Drink the Water?

Understanding Costa Rica's Sewerage Systems and Waterworks

According to a report put out in 2005, roughly 99% of all Costa Ricans living in urban areas are connected to public water systems, but only 70% have access to **potable** (suitable for drinking) water. Nonetheless, Costa Rican officials encourage tourists to drink from the tap, arguing that the water is just fine for drinking. Let's find out more about how Ticos get their water and decide for ourselves whether we should drink the water or not.

For years, the major metropolitan centers in the heart of Costa Rica (Cartago, Alajuela, Heredia, and San José) tapped surrounding springs and aquifers to slake the thirst of city residents. The water supply for this area, known as the Gran Area Metropolitana, still comes from some of these groundwater sources, but new reservoirs have helped to increase the area's water supply.

The most troubling problem concerning drinking water in Costa Rican towns is not so much where the water is coming from but that the water can become easily contaminated, as few cities have developed effective sewerage systems. Amazingly, roughly 96% of all wastewater in the country is funneled into watercourses without being treated. According to one scholar writing in 1993, approximately 60% of Costa Rican urbanites were not connected to adequate sanitation facilities at the end of the last century.

One way to determine the purity of the city's drinking water would be to use the skills we've learned for testing water quality and apply them in an urban setting. Let's grab a sample of tap water from the hotel room and carry out some water quality tests. We'll follow the same steps we outlined earlier. Remember, these tests can't tell us everything (we will not test for viruses, for example), so we still have to be careful, but we can gain some valuable information from our field tests.

ASSESSMENT

World Conservation Organizations:

How to get involved in Civic Environmentalism

Throughout this journal we've talked broadly about conservation and the ways we can adjust our life habits to help keep our earth clean and beautiful. Now let's talk about some of the major world organizations– many of which are active in Costa Rica– that have remained at the forefront of civic environmentalism. As you peruse the organizations below, consider which one might best fit your interests and talents and consider getting involved.

The Red List

The International Union for Conservation of Nature (IUCN) puts out a **red list** of threatened species every year, providing statistical data about animals that are suffering from loss of habitat, over-hunting, or other major problems. The IUCN assesses the conservation status of species throughout the world. You may be familiar with the IUCN Red List. It is a system designed to determine the relative risk of a species extinction. The categories recognized by the IUCN are Critically Endangered, Endangered and Vulnerable.

Currently, the IUCN has listed the Costa Rican *Atelopus Varius*,

Atelopus Varius

a harlequin toad, on their critically endangered list. The Union believes that the major issue is loss of habitat caused by drought (harlequin toads are amphibious, like most toads, and thus require a wet habitat). It is estimated that the *Atelopus Varius* population has declined by roughly 80% over the last three generations.

IUCN Red List

Status	Definition	Examples
EXTINCT	Last remaining individual of the species has died	Dinosaurs, dodo bird, passenger pigeon, Barbary lion, Bali tiger
EXTINCT IN THE WILD	Only survives in captivity, reintroduced populations, or outside its native habitat	Przewalski's horse, Sahara oryx, black-footed ferret, Mexican gray wolf
CRITICALLY ENDANGERED	Faces an extremely high risk of extinction in the wild	Red wolf, golden lemur, black rhinoceros, angle shark, California condor
ENDANGERED	Faces a very high risk of extinction in the wild	Giant panda, orangutan, Grevy's zebra, gorilla, blue whale, brown kiwi
VULNERABLE	Faces a high risk of extinction in the wild	African lion, wolverine, hippopotamus, polar bear, American crocodile
NEAR THREATENED	Does not face a high risk of extinction, but is likely to be threatened in the near future	Black-tailed prairie dog, cougar, striped hyena, giant anteater, jaguar
LEAST CONCERN	Species is thriving, widespread, and abundant	Gray seal, naked mole-rat, American beaver, giraffe, bald eagle

Humpback Whale

Pollution and Conservation

Another of Costa Rica's endangered species is the **humpback whale**. Perhaps one of the most well-loved sea creatures of the Pacific Ocean, the humpback whale is a gigantic mammal, often weighing in at over 30 tons (at full maturity, they can reach a length of 40 feet). Like all whales, humpbacks belong to the Cetacean family: marine mammals that have hair, breath air, and nurse their young. To break it down even more, humpback whales are also members of the baleen family, which means they are whales that run food through huge filters in their jaw (as opposed to toothed whales that have teeth and, thus, chew their prey). A humpback can eat 9,000 pounds of food in a day! They roam from Hawaii (where they breed) to Alaska, cruising up and down the Pacific Coast of Central and North America.

Whaling Boat, 2007

Between the 19th and 20th centuries, commercial whalers decimated humpback populations, killing off by the mid-1900s roughly 90% of the worldwide population, all in an avaricious pursuit to secure boatloads of the whale's valuable blubber (used to create flammable oil). Conservation efforts, however, have helped to revitalize the species, and humpback numbers are currently estimated to be around 20,000 across the globe.

Today, humpback whales are on the rise because of the concerted efforts of conservationists who worked hard to end the destructive whaling industry that targeted humpback whales. In 1966, the International Whaling Commission placed a moratorium (stop order) on the whaling of humpbacks.

Today the biggest concerns are actually less focused on whalers and more on preserving the oceanic habitats of these marvelous creatures. Organizations like the Whale Conservation Institute and the American Cetacean Society continue to work hard to preserve the oceanic habitat of humpback whales.

Despite conservationists' effort, however, recently Japan lifted its ban on hunting humpback whales, this despite the fact that the IUCN still lists the species as vulnerable on its endangered list. Many international bodies condemned these actions as despicable and dangerous. Whale meat in Japan sells for top-dollar in local markets, sometimes bringing in over $100 a pound.

BECOME AN ACTIVE CONSERVATIONIST:

How do you convince people that the Atelopus Varius needs to be saved? It's not always easy to make people realize the importance of a small animal that seems to have very little impact on most people's everyday lives. Your job today is to become an active civic environmentalist and create a poster that teaches the public of your conservation effort. You will need to execute a campaign to get the word out that includes:

- *Natural history information about one of Costa Rica's endangered species (where it lives, what it eats, when it is active, etc.)*
- *Why is the species in trouble*
- *What are people doing to help this species*
- *What this species looks like (draw it)*
- *Where your species lives (range map)*

Note: The posters should be designed to help attract attention and share information in a creative easy-to-read way.

GET STARTED SAVING A SPECIES!

Conservation Organizations:

The World Wildlife Fund (WWF)

Founded in 1961, the WWF is the largest privately-funded international environmental organization in the world today. Its declared mission is to "stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by: conserving the world's biological diversity, ensuring that the use of renewable resources is sustainable, [and] promoting the reduction of pollution and wasteful consumption." Wow, no small feat, but why start small when there is so much to be done! A nonprofit organization supported by over 5 million activists worldwide, the WWF has considerable resources that smaller non-governmental organizations (NGOs) and nonprofit organizations cannot marshal. The organization is truly international with affiliates in over 30 countries.

In its over 45-year-old history, the WWF has been responsible for a number of major conservation hallmarks. In 1990, the organization helped bring about the cessation of the international ivory trade – a global industry that had decimated elephant populations throughout Africa and elsewhere. In that same year, they also secured a moratorium (stop of activity) on commercial whaling.

Greenpeace

In 1971, a group of environmental activists set out on a journey from Vancouver to protest U.S. testing of nuclear weapons in Alaska. This cohort formed Greenpeace. From that date to today, Greenpeace has grown into one of the most important environmental groups in the world. Like the WWF, Greenpeace relies on the generous support of people like you, receiving no money from the federal government (they also do not solicit donations from corporations).

Greenpeace is particularly interested in reaching out to the next generation of environmental activists, and as such has created a Greenpeace Student Network– a youth-based branch of the organization designed to get young people involved in environmental protection programs. Most recently, the network has executed a series of effective campus campaigns to boycott paper products produced by Kimberley-Clark, a corporation known for its **clear-cutting** operations (clear-cutting is when a timber company cuts down vast acreage of land, rather than selectively cutting down trees in ways that ensures the sustainability of the harvesting fields).

The Sierra Club

In his *The Yosemite* (1921), John Muir, perhaps America's most renowned conservationist, exclaimed, "Everybody needs beauty as well as bread, places to play in and pray in, where nature may heal and give strength to body and soul alike." Muir's words speak to the mission of the Sierra Club. Founded in 1892 by John Muir and a cohort of western environmentalists opposed to a plan to reduce the size of Yosemite National Park in California, the Sierra Club was the first conservationist organization established in the United States for the express purposes of preserving the country's wondrous natural spaces.

Originally an organization focused on the American West, it quickly spread across the nation. Today, in an effort to bring more people into the organization, the Sierra Club sponsors local outings across the country. You can visit the Sierra Club website (http://www.sierraclub.org/) when you get back to the states and link up with a trip near your home community.

The Earthwatch Institute

Founded in the same year as Greenpeace, Earthwatch has a slightly different message than the other world organizations we have discussed. Their primary focus is to link volunteer researchers with naturalists and conservationists working in the field. The Institute has two programs operating in Costa Rica currently, one focused on studying sustainable coffee cultivation just south of the Monteverde cloud forest. The other program focuses on leatherback turtles' breeding grounds on the western coast of Costa Rica.

The Rich and Famous:

Popular Icons in Civic Environmentalism

The Dave Matthews Band has become a fixture of the American pop music scene in the past two decades, transforming from an obscure band from Charlottesville, Virginia, to a national megaband. But their rise to fame seems to have little effect on their humanitarian convictions. Dave Matthews and his band have made significant efforts to support conservation projects. They have participated in eco-friendly festivals, including the 2007 "Green Concert" in Atlanta's Piedmont Park, which took place in 2007. Over 50,000 fans attended the event. Proceeds from the event went to help expand Atlanta's largest inner-city park. Through their foundation **Bama Works**, the band helped launch a Ben & Jerry's ice cream called One Sweet Whirled, setting aside a portion of the profits to go towards global warming research and education.

Speaking of ***Ben & Jerry's***, the Vermont-based ice cream company has become a leader among corporations looking for creative ways to help protect the environment. Every year the company publishes a very

candid report on the company's impact on the environment. Some of the facts they mention are flattering, but they also include things they need to improve. For example, in 2006, they regretted to inform their customers that they had to switch from an eco-pint packaging that featured unbleached paperboard because of increasing production costs. However, in their 2006 report, they happily announced that they had far exceeded their carbon dioxide emission goals for the period 2002-2006, reducing normalized emissions by over 30%! Ben & Jerry's is truly a model of how a company can pursue profits while looking out for the environment.

Leonardo DiCaprio

Leonardo DiCaprio has become a major civic environmentalist in Hollywood, helping to promote awareness about global warming and linking up with other prominent activists and politicians like Al Gore to educate the public about global climate change issues. A strong believer in the motto that you should practice what you preach, DiCaprio has even had a special compost toilet installed in his home and is working closely with the Four Seasons to construct an eco-friendly, "green" hotel on property he owns in Belize. He has also produced the film, *The 11th Hour*, which speaks of the growing problems associated with global warming.

André Benjamin (André 3000)

While the hip-hop industry is perhaps best known for harsh lyrics and bling-bling studded rappers, many hip-hop artists have become activists in the crusade to save the planet. André Benjamin of the Atlanta-based duo Outkast is one such crusader. Known for his flamboyant dress and bizarre lyrical style, Benjamin is also a dedicated vegan (does not eat meat or products produced by animals, such as milk). He also writes songs that speak directly to humans' devastating effects on the environment.

Pollution and Conservation

Craft an eco-JAM!

Touring Costa Rica can be a truly breathtaking experience. When Dave Matthews crafted his smash hit "Don't Drink the Water" he was camping up near Lake Superior and was moved to write a song about Americans' lack of respect for sacred lands. Now you have a chance to craft a tune that speaks to your experience in Costa Rica. Put down some lyrics that you think will help increase awareness about environmental issues in Costa Rica that concerns you.

Conclusion:

Leaving on a Jet Plane

You've learned a great deal about the ecology of Costa Rica; now it's time to return home. But as you sit and wait for your plane to arrive at the airport in San José, let's take a moment to widen the aperture of our investigative lens, and return once again to a global perspective.

While it may be comforting to think that what you've done in Costa Rica only had localized repercussions, the fact of the matter is that what happens in Costa Rica affects the health of our global ecology. To best illustrate this, look out on the tarmac for a second.

You'll remember that we talked about the fact that Costa Rica's ecotourism industry brings in roughly 1.9 billion dollars in revenue each year, but let's consider what this means in terms of the annual number of visitors to the country. The U.S. Department of State estimates that roughly 700,000 Americans travel to Costa Rica each year. Wow, that's a lot of tourists! Now, for the most part – except for some adventurous sailors and roadtrip warriors – the majority of these folks fly on commercial jets to get to Costa Rica.

OK, so what are the ecological costs associated with all these flights? Let's start by talking about the fuel expended. According to a corporate fact sheet on Boeing aircraft, a 747-400 traveling 3, 500 miles will carry 126,000 pounds (!) of fuel and consume its supply at a rate of roughly 5 gallons per mile.

Now let's do some calculations. A Boeing 747-400 can seat roughly 300 passengers at full capacity. So, let's assume that the flight is half full (seating 150 people). For a flight from Washington, D.C. to San José, Costa Rica – which totals a distance of approximately 2,040 miles – fuel consumption per passenger for the flight is roughly 68 gallons (2,040 miles x 5 gallons/mile / 150 passengers = 68 gallons/passenger).

That's a lot of fuel per person when you consider the ecological costs of burning that fuel. Most commercial jets use Jet A fuel, which is made up of hydrocarbons (remember our discussion about how carbon is cycled through our environment!) and which gives off greenhouses gases when burned. It has been estimated that inflight commercial jet emissions make-up roughly 2% of the world's total carbon dioxide emissions.

But greenhouse gas emissions are not the only negative repercussions of commercial flights. We must consider other factors, like noise pollution. While it may seem a bit silly to consider noise pollution an environmental problem, the fact of the matter is that noise pollution can reshape the wildlife composition of particular habitats. Animals, for example, that used to call the woodlands around the San José airport home may have migrated once the booming and swooshing of commercial flights became unbearable.

And what about those strange patterns in the sky left by planes? If you've every looked up at a commercial airliner on a clear day, you know about this phenomenon. It looks like the plane has left a white puffy cloud in the sky. Well, in fact, it has. Commercial jet engines give off water vapors that, at certain altitudes, turn immediately to ice crystals (thus the cloud-like streams). These cloud-like formations are technically called contrails. Some experts believe that these seemingly innocuous contrails actually contribute to global warming. Interestingly enough, the strongest evidence for this came on September 11th, 2001,

Conclusion

when all the airlines were grounded for three days because of the terrorist attacks in New York and Washington, D.C .and temperature tests were conducted to reveal that over the three-day period when planes could not fly, the average temperature range increased (presumably because the earth's ability to cool and warm was not hindered by contrail layers).

Wow. So there are real ecological costs to flying, costs that, before now, you would probably admit you never knew. What about the broader public? Do you think they are aware of the statistics we outlined in this journal?

As we argued at the beginning of this journal, there is a real need for people to become aware of the environmental costs associated with daily life activities. But to know the truth is not enough. We have to act on what we know. We don't have to grow our hair out and eat granola everyday to make a difference; as we have seen, we can make a difference by making small decisions that affect the health of our global community.

So what should you do? Not get on the plane? That probably would not be a good idea (your friends back home probably would not like you very much if you did that). No, head home, but do so with a new appreciation for the real costs that must be met in order for you to do what you do. No longer should you think about the cost of living in terms of dollars and cents; now you know there are other things to consider. Realize that the power to change the future is in your hands. As an eco-conscious civic environmentalist, return home as an ambassador for a new cause. The earth will thank you!

Unit Conversion Chart

The following conversion chart may be helpful as you work through the activities in your Discovery Journal.

If you know →	Multiply by →	To get
To get ←	**Divide by ←**	**If you know**

Length

inches (in)	2.5	centimeters (cm)
feet (ft)	30.0	centimeters (cm)
yards (yd)	0.9	meters (m)
miles (mi)	1.6	kilometers (km)

Area

square inches (in^2)	6.5	square centimeters
square feet (ft^2)	0.093	square meters (m^2)
square yards (yd^2)	0.84	square meters (m^2)
square mile (mi^2)	640.0	acres (acre)
acre (acre)	43,560	square feet (ft^2)
acre (acre)	4,047	square meters (m^2)
acre (acre)	0.405	hectares (ha)

Volume

fluid ounces (fl oz)	30.0	milliliters (ml)
cups (c)	0.24	liters (l)
pints (pt)	0.47	liters (l)
quarts (qt)	0.95	liters (l)
gallon (gal)	0.134	cubic feet (ft^3)
gallon (gal)	3.79	liters (l)
cubic feet (ft^3)	0.03	cubic meters (m^3)
cubic feet (ft^3)	28.32	liters (l)

Flow

cubic feet per second (cfs)	0.03	cubic meters per sec (m^3/s)
cubic feet per second (cfs)	448.8	gallons per minute (gpm)
cubic feet per second (cfs)	646,320	gallons per day (gpd)

Temperature

degrees Celsius (C°)	(9/5 x °C) + 32	degrees Fahrenheit (°F)
degrees Fahrenheit (°F)	5/9 x (°F – 32)	degrees Celsius (°C)

Expert Scientist Checklist

Mammals

English name	Common Spanish name	Scientific name
Mantled howler monkey	Mono congo	alouatta palliata
Spider monkey	Mono araña	ateles geoffroyi
White-faced capuchin monkey	Mono cara blanca	cebus capucinus
White-nosed coati	Pizote	nasua narica
Three-toed sloth	Perezoso de tres dedos	bradypus variegatus
Two-toed sloth	Perezoso de dos dedos	choloepus hoffmanni
Variegated squirrel	Ardilla, chiza	sciurus variegatoides
White-tailed deer	Venado cola blanca	odocoileus virginianus
Collared anteater	Tamandua, oso hormiguero	tamandua mexicana
Agouti	Guatusa	dasyprocta punctata
Nine-banded armadillo	Armadillo, cusuco	dasypus novemcinctus
Common opossum	Zorro pelón	didelphis marsupialis
Long-nosed bat	Murciélago de nariz larga	rhynchonycteris naso

Reptiles

English name	Common Spanish name	Scientific name
Green iguana	Iguana verde	iguana iguana
Jesus Christ lizard	Lagartija jesucristo	basiliscus sp.
Central American whip-tailed lizard	Chisbala	ameiva festiva
Ctentosaur	Garrobo	ctentosaura similis
Spectacled caiman	Caimán	caiman crocodilus
Orange-eared slider	Tortuga resbaladora	trachemys scripta venusta
Boa constrictor	Boa; béquer	boa constrictor
Fer-de-lance viper	Terciopelo	bothrops asper
Coral snake	Coralillo, corál	micrurus nigrocinetus
Eyelash viper	Bocaracä, oropel	bothriechis schlegelii

Amphibians

English name	Common Spanish name	Scientific name
Blue jeans poison-dart frog	Ranita roja venenosa	dendrobates pumilio
Black and green poison-dart frog	Ranita verde venenosa	dendrobates auratus
Cane toad	Sapo gigante; sapo marino	bufo marinus
Red-eyed tree frog	Rana calzonuda	agalychnis callidryas

Insects

English name	Common Spanish name	Scientific name
Bullet ant	Hormiga bala	paraponera clavata
Leafcutter ant	Zompopas	atta cephalotes
Army ant	Hormiga arriera	eciton burchelli
Hercules beetle	Cornizuelo	dynastes hercules
Golden orb spider	Araña de oro	nephila clavipes

Birds

English name	Common Spanish name	Scientific name
Montezuma oropendola	Oropendola	psarocolius montezuma
Great-tailed grackle	Zanate	quiscalus mexicanus
Groove-billed ani	Tijo, zopilotillo	crotophaga sulcirostris
Turkey vulture	Zopilote cabeza roja	cathartes aura
Black vulture	Zopilote negro	coragyps atratus
Cattle egret	Garza ganadera	bubulcus ibis
Snowy egret	Garza de las nieves	egretta thula
Great egret	Garza real	casmerodius albus
Great blue heron	Garzón azul	ardea herodias
Little blue heron	Garceta azul	egretta caerulea
Green heron	Garceta verde	butorides virescens
Tiger heron	Garza tigre	tigrisoma sp.
Neotropic cormorant	Cormorán	phalacrocorax brasilianus
Anhinga	Aninga, pato aguja	anhinga anhinga
Sunbittern	Pájaro sol	eurypyga helias
Tropical kingbird	Tirano tropical	tyrannus melancholicus
Great kiskadee	Pecho amarillo	pitangus sulphuratus
Social flycatcher	Mosquero cejiblanco	myiozetetes similis
House wren	Soterrey cucarachero	troglodytes aedon
Squirrel cuckoo	Cuco ardilla	piaya cayana
Chesnut-mandibled toucan	Quioro, tucán	ramphastos swainsonii
Keel-billed toucan	Curré, tucán	ramphastos sulfuratus
Emerald toucanet	Tucancillo verde	aulacorhynchus prasinus
Black-faced grosbeak	Picogrueso carinegro	caryothraustes poliogaster
Clay-colored robin	Yigüirro	turdus grayi
Crested guan	Pava crestada	penelope purpurascens
Ringed kingfisher	Martín pescador collarejo	ceryle torquata
Amazon kingfisher	Martín pescador amazónico	chloroceryle amazona
Green kingfisher	Martín pescador verde	chloroceryle americana
Rufous motmot	Bobo, momoto	baryphthengus martii
Turquoise-browed motmot	Momoto cejiceleste	eumomota superciliosa
White-tipped dove	Paloma coliblanca	leptotila verreauxi
Ruddy ground-dove	Tortolita rojiza	columbina talpacoti
Red-billed pigeon	Paloma morada	columba flavirostris
Neotropical swallow-tailed kite	Gavilán tijereta	elanoides forficatus
Osprey	Águila pescadora	pandion haliaetus
White-throated magpie-jay	Urraca	calocitta formosa
Northern jacana	Gallito de agua, jacana	jacana spinosa
Spotted sandpiper	Alzacolita	actitis macularia
Rufous-tailed hummingbird	Colibrí rabirufo	amazilia tzacatl
Violet sabrewing	Colibrí ala de sable	campylopterus hemileucurus
Blue-gray tanager	Viudita	thraupis episcopus
Passerini´s tanager	Sargento	ramphocelus passerinii

Notes

WORLD STRIDES®

DISCOVER YOUR WORLD

www.worldstrides.org