360 Virtual Rainforest Tour Outline

Introduction

Welcome to the *Costa Rican Rainforest*! In this tour, not only will you learn about the animals and plants in the rainforest, but also about important biological concepts that apply to all life on Earth. In addition, you'll learn about the current research and conservation happening in the rainforest by Milwaukee Public Museum scientists.

Alcove 1: The Cell

The Basic Unit of Life

Life as we know it is packaged as cells. Some living things are just one cell, other living things are made of many specialized cells. Whether from orchid, fungus, bacterium, or beetle, all cells can be categorized as either prokaryotic (PRO-kair-ee-ah-tic) or eukaryotic (U-kair-ee-ah-tic). Compare the differences between prokaryotic and eukaryotic cells below.

Eukaryotic Cell

1. Larger
2. Complex, with organelles.
3. Genetic material for nucleus

Prokaryotic Cell

1. Smaller
2. Lacks organelles
3. Genetic material loose

Being a prokaryote or eukaryote is one of the characteristics of living things.

Many Forms of Life

From the common denominator of a single living cell, life forms as different as the parrot and the palm tree have evolved. Millions of species currently exist and most are still unknown to us.

All of these diverse life forms are made up of either eukaryotic or prokaryotic cells.

Cells Specialize

In plants and animals that have more than one cell, cells specialize to perform certain tasks. Each

cell, however, still requires nutrition, gases for respiration, and mechanisms for waste removal and all other life processes that go on at the cellular level.

Look into Each Microscope to See Some Cells

Bone Cells: Bone and fibrous cells are called connective tissue cells.

Fibrous Cells: Fibrous and bone cells are called connective tissue cells.

Blood Cells

Epidermal Cells: They protect the inside of the plant from the outside environment. Stoma are small pores formed by guard cells which permit the exchange of gases.

Skin cells: Skin and gland cells are called epithelial cells.

Parenchyma Cells: They carry out photosynthesis and provide storage. They are the most abundant plant cell type.

Muscle Cells

Sieve-tube Cells and Companion Cell. They make up phloem tissue. Phloem conducts food materials throughout the plant.

Gland Cells: Gland and skin cells are called epithelial cells.

Tracheid Cells: They are one of several cell types that make up xylem tissue. Xylem conducts water and dissolved nutrients throughout the plant.

Nerve cells

Alcove 2: Cell Specializations

Cells Specialize and Organize

Every living thing has the same basic problems to solve in order to survive. As a many-celled organism increases in size, cells specialize to solve those problems. For example, some become support cells, others sex cells. Cells are organized into special tissues. Tissues form organs and organs form systems to deal with the problems common to all living things.

Whether plant or animal, one of the problems each living thing must solve is how to get, or transport, nourishment to all the cells in its body. How do you think a monkey and a tree solve the problem of transport?

How One Animal Solves the Problem of Transport

The circulatory system is one of the systems which solve the problem of transport for the monkey. Certain cells of the monkey specialize to form the tissue and organs of this system.

The circulatory system is made up of cells and fluids pumped primarily by heart muscles through a network of tubes called arteries, veins, and capillaries.

The circulatory system transports nutrients and oxygen to and waste from every part of the monkey's body. It is also involved in the immune defense against microbes and other foreign materials.

Cells Specialize and Organize

How One Plant Solves the Problem of Transport

The ceiba (SEE-bah) tree has two systems for carrying water and nutrients. One system is made up of xylem (ZYE-lem) cells. The other is made up of phloem (FLO-em) cells. In both systems, cells are stacked on top of each other to form "pipelines" running throughout the plant.

Xylem cells transport water and minerals from the roots to the stem and leaves. Phloem cells transport "food" in the form of sugars from the leaves to the rest of the plant.

But there are other problems plants and animals must solve in order to survive. They must find a way to separate their bodies from the external environment, a way to get water and nutrients and remove wastes, and a way to produce new individuals.

All animals and plants must also solve the problem of gas exchange, internal support, and the coordination of internal and external stimuli.

Prehensile Tail

A Helping "Hand"

This monkey's strong tail can be used much like an extra hand to curl around and hang onto a branch. It is called a prehensile (pre-HEN-sil) tail. Monkeys with prehensile tails can only be found in the American tropics.

Alcove 3: Diversity

These windows demonstrate a teeny-tiny fraction of the biodiversity found in the rainforest. But what is biodiversity, and why is it important? Watch the video below to find out! Then, download the PDF to fill out some of the connections you notice as you travel through the rainforest.

Biodiversity Bash
Web of Life Activity

Tropical Rainforest

The wealth of biological diversity is concentrated in the warm, moist forests of the tropics. In fact, most of the world's species of plants and animals occur on just six percent of the Earth's land. And nowhere on land is diversity greater than in the rainforests of Central and South America.

The walking stick, quetzal, hummingbird, and heliconia flower are all so different, yet each has so much in common.

Like humans, the walking stick, the quetzal, the hummingbird, and the flowering plant are all living things built of the common material of life.

And like all living things, they must meet the challenges of life. They must meet the challenge for living space, the challenge to get energy, and the challenge to survive and reproduce in a world of limited resources and ever-changing environments. This was true millions of years ago for the dinosaurs and tree ferns. It is true today for all creatures.

Butterflies and Moths

The wings of all butterflies and moths are covered with tiny overlapping scales. The scales create the different colors and patterns on the wings of these animals.

Scales can come loose and may allow a butterfly or moth to slip from the grasp of a predator.

Feisty Fish

Although most people think of the piranha as a ferocious and dangerous predator, they mistakenly accuse the creature of being a man-killer. Actually, the few reports of piranha attacks on living human beings are questionable.

The piranha is a carnivore, or a meat-eater, as are the other New World Tropical freshwater fish in this case.

Most fish are, in fact, carnivores.

Lancehead snake

Bothrops atrox

When people say that a cure for a disease might be in the rainforest, this lancehead viper is a perfect example. Two medical applications have come from studying the venom of this snake and other lancehead relatives:

Captopril
A lancehead snake's venom kills by catastrophically reducing blood pressure in its prey. Scientists were able to isolate the peptide in the venom that caused the blood pressure to lower and modify it to make it safe. The resulting medicine, captopril, is now commonly used to treat high blood pressure, potentially saving millions of lives!

Batroxobin
One of the compounds of a lancehead snake's venom has been derived into Batroxobin which induces blood clotting. Because of this unique feature, doctors and scientists can use it to gain better insights into the blood of a patient, particularly if there's something going wrong with how it

clots.

This amazing creature helped humans understand and treat two different medical issues. When we consider that only 1% of the rainforest's specimens have been studied, what other things might we discover if we take time to study the rainforest? Moreover, imagine what could be lost if the rainforest were to disappear.

Jaguar
Watch Jaguar Video

Alcove 4: Coloration

Camouflage

The color patterns of animals are essential to their survival. Some animals blend in with their surroundings to hide from predators and look like twigs, leaves, or even another predator. Can you find the noctuid moth caterpillar in the photo and other animals in the setting?

Sexual Dimorphism

Dimorphism (dy-MOR-fism) means occurring in two distinct forms. When males and females are of strikingly different colors or shapes, it is called "sexual dimorphism." The brilliant color of the male scarlet-rumped tanager helps him attract a mate and defend a territory. The drab color of the female makes her less conspicuous to predators.

Warning Coloration

Bold patterns, as shown by these brightly colored bug nymphs, warn that an animal is poisonous or tastes bad and should be left alone. Some animals that are not distasteful, but closely resemble animals that are, will also be avoided. An Automeris moth has forewings that blend in with its surroundings but flashes brightly patterned hindwings to startle a predator in order to escape.

Alcove 5: Rain Forest Exploration

Why Explore the Rainforest?

Nowhere on Earth is life more abundant than in the American tropical rainforest. This makes the tropical rainforest an ideal place for the study of living organisms. For this reason, the Milwaukee Public Museum chose an American tropical rainforest as the setting for its biology hall. Here we learn about the origin of life and its basic elements and processes.

In the surroundings of the American tropical rainforest, we discover how living things are similar, what makes them unique, and what living things must do in order to survive. Through the exhibits in this hall, we learn how all plants and animals, including humans, depend upon and interact with each other and their environment to meet the challenges of life.

Costa Rica: The Stage for Our Success

Much of what you will experience in this exhibit hall, *Rainforest: Exploring Life on Earth*, its plants and animals, the vibrant colors and sounds that symbolize the magnificence of tropical nature, was made possible by the cooperative bond that was forged between the people of Costa Rica and the Milwaukee Public Museum.

Milwaukee Public Museum curators and exhibits staff worked closely with people in Costa Rica to gather information and materials necessary to make *Rainforest* a reality for the Milwaukee community.

Such collaborative international efforts help bring the rest of the world to Milwaukee, and provide the opportunity for a mutual exchange of knowledge and skills.

Central American Bridge

As Earth's crustal plates collided, separated, and slid by one another, the planet's surface changed. About 3 million years ago, this plate movement along with volcanic activity resulted in a continuous land bridge between North and South America. This land bridge allowed a great interchange of plants and animals to occur between the two continents.

Mountains and the Ice Age

During the latter part of the Pliocene Epoch, about 2 million years ago, the mountainous backbone of Central American reached its present altitude, creating a variety of new habitats. Plants and animals that live in the mountains were able to cross the land bridge at this time.

As the ice sheets advanced in north American during the Pleistocene Epoch some 1 to 2 million years ago, there were periods of very dry and cool conditions and much of Central American became grassland. Grazing animals such as horses, ground sloths, and camels moved over the bridge.

Tropical Rainforest

As temperatures gradually became warmer and moisture increased, the tropical rainforests became widespread in Central America. This blocked the movement of organisms adapted to drier or cooler conditions and led to the development of the rich diversity of life forms we find there today.

Alcove 6: Biomes

What's in a Biome?

Tundra, desert, temperate forest, and tropical forest. You've heard each of those terms before. But did you know that they represent large geographical land areas called biomes? Every living thing on land can be found in one or another of the world's major biomes.

Communities of plants and animals can be grouped according to their similarities in form and structure. These similarities come about as a result of adaptations to rainfall and sunlight. Each of

these land communities can be called a biome. A biome, while including both plants and animals, is named according to the type of dominant vegetation found in it.

Major Terrestrial Biomes

- Ice (Polar)
- Tundra (and Alpine Tundra)
- Northern Evergreen (Boreal) Forest
- Temperate Forest (Rain and Deciduous)
- Tropical Forest (Rain and Deciduous)
- Grasslands and Savanna
- Scrub and Chaparral
- Desert and Semi-Desert

The Ocean Has Zones, Too

This coral reef shows the most diverse maritime community. The coral reef is the "tropical rainforest" of the sea. A steady rock flow of minerals and organic matter in runoff from the land, rapid nutrient cycling by corals, and shallow warm waters allow a tremendous variety of life forms to develop.

Mountains Make a Difference

Temperature is affected by more than distance from the equator. Regardless of what major biome mountains might be found in, temperature tends to decrease the higher up in the mountain you go. This, along with differences in light intensity and variations in moisture, affects the vegetation so that, in a sense, you find biomes within a biome.

Mountains have another important effect on vegetation around them as well. As wind rises on the windward side of mountains, moisture drops in the form of rainfall. Land on the other side, the leeward side, gets little rainfall.

Alcove 7: Seasonality

What's in the Tropics?

If you answered lush vegetation and a tangle of jungle vines, you're partly right. But there's much more. Within the tropics, there are many biomes, or areas of land characterized by their vegetation. These are the product of rainfall, temperature, altitude and soil.

Alpine

This is a high altitude cold area where the moisture is locked up in ice and snow for much of the year. The cold temperature and lack of water for much of the year limits plant growth.

Desert

Because there is little moisture throughout most or all of the year, vegetation is sparse and has adapted to the arid conditions by conserving or storing water. Rainfall is less than six inches annually.

Grassland-Savannah

Rain is sparse and unevenly distributed throughout the year; occasional drought years occur. Annual rainfall is 20-30 inches. The trees and shrubs may be scattered among the dominant grasses.

Dry Forest

This is a warm region with seasonal rainfall. During a drier season very little rain falls. Some trees are deciduous, shedding their leaves during the dry period.

Rainforest

It rains throughout the year in this warm region, although there is a season when it rains less. Annual rainfall exceeds 80 inches. Temperatures are high and very constant. Most of the trees remain green all year long, shedding their leaves continuously, a few at a time.

Floodplain (Swamp) Forest

Much of the South American rainforest is for several months each year as rivers overflow their banks. This flooding results in little understory vegetation. There is, however, a rich variety of epiphytes covering the branches. Epiphytes are plants that grow on other plants.

What Happens When Seasons Change?

An ecosystem is a community of organisms and the physical environment with which they interact. Changing conditions within an ecosystem can have a great impact on the living orgamsrns there. Seasonality is a dramatic example of conditions within an ecosystem. Organisms can respond to seasonality in different ways. Do you know how?

Escape in Space

Some living things, like these butterflies and birds, can respond to seasonality by escaping an area which has become unfavorable. For example, they leave a colder climate for a warmer one. This is called migration. This allows them to avoid freezing and to follow their food supply.

Escape in Time

Other living things, like certain plants, respond to seasonality when they stop growth and become dormant. Some species of plants delay development of flower buds, and when conditions are right they burst into flower.

Picture captions:

Tabebuia tree, Photography by Allen Young

Canopy view of synchronous flowering, Photograph by Loren McIntyre

Alcove 8: Comparisons

Effects of Climate

An acre of tropical rainforest has a greater diversity of lifeforms than an acre of temperate deciduous (dee-SID-you-us) forest. (Wisconsin is in the temperate zone. Deciduous trees, such as sugar maples, shed their leaves each year.)

A Temperate Deciduous Forest in Wisconsin

In temperate regions such as Wisconsin, organisms must be adapted to handle climatic extremes. In Wisconsin, temperatures may span more than 100 degrees Fahrenheit over the course of a year. Moisture may be locked up as snow or ice for many months and day length varies. The harsh environment presents the greatest challenge for survival.

A Tropical Rainforest in Central America

In the tropical rainforest, the warm, moist environment and relatively constant levels of light throughout the year are favorable for life. The resulting abundance of lifeforms means high levels of competition, parasitism, and predation. In the climatically mild environment of the tropical rainforest, competition and predation are the greatest challenges for survival. Meeting these challenges has led to a greater diversity of life there.

Rainforest Gradient

In the rainforest, the environment is moist year-round. The dense canopy of the tropical rainforest acts as a giant sieve filtering rainfall, wind, and sunlight. Below the canopy, temperatures are cooler and humidity is higher. The canopy also acts as a trap, accumulating debris such as dead plants and animals which are rapidly recycled into the system.

A Matter of Degree

The warm moist environment and relatively constant levels of light throughout the year are favorable for life in the tropical rainforest.

Temperature Forest (Aerial View)

The temperate deciduous forest has many individuals of a relatively few species of trees.

Temperate Flowers

The temperate deciduous forest has many individuals of a fewer species of flowering plants.

Tropical Rainforest (Aerial View)

An area of equal size in a tropical rainforest has fewer individuals of any one tree species, but many more species are present. In the tropical rainforest, the nearest tree of the same species may be as far as a mile away. This spacing presents a special challenge in efforts to preserve the rainforest. Large tracts of land are often needed to maintain a population of widely spaced individuals successfully.

Tropical Flowers

An area of equal size in a tropical rainforest has fewer individuals of any one flowering plant species, but many more species are present.

Layers of the Forest

There are different layers in forests and each has its own resident plants. Compare each layer of the tropical rainforest and the temperate deciduous forest and find the differences.

Temperate Deciduous Forest

Temperate deciduous forests can be found in temperate areas like Wisconsin

- The Canopy (100 feet): The canopy of a temperate deciduous forest is relatively uniform in height over large areas. This is because the first is made up of comparatively few species of canopy trees.
- Shrub and Herb Layer (15 feet): Below the canopy in both forests, light levels are low and the vegetation is sparse. In the temperate deciduous forest, there is a distinct layer of shrubs (woody plants with many stems and herbs [non-woody plants]).
- Ground Litter and Soil (Ground Level): All plants need nutrients like nitrogen and potassium to live and they generally get them through their roots. The root systems of the temperate deciduous forest is much deeper than those of the tropical rainforest. That is because the soil of the temperate forest is much richer and the nutrient later is much deeper.

Tropical Rainforest

Tropical rainforests can be found in tropical areas like Central America where the climate is more favorable to life. Temperatures and sunlight in the tropics are more constant.

- The Canopy (150 feet): The canopy of a tropical rainforest is dramatically different from the canopy of a temperate deciduous forest. There are many more species of canopy trees. The trees are much taller and of varying heights and shapes. Epiphytes, plants that grow on plants, blanket the tree branches. Vines grow intertwined among the branches as well. In fact, most of the plants and animals of the tropical rainforest can be found in the canopy.
- Shrub and Herb Layer (15 feet): In the tropical rainforest, it is often difficult to distinguish between the herb and shrub layers since many of the herbs grow to large sizes.
- Ground Litter and Soil (Ground Level): In the tropical rainforest, most of the nutrients are above ground, in the vegetation, and perched soil of the forest. Many nutrients are

recycled through the plants and animals of the forest itself. The soil alone, without the forest, is very poor in nutrients.

A Wealth of Diversity

Not only does the tropical rainforest have a greater diversity of tree species than the temperate deciduous forest, but there is a greater diversity of other life forms as well.

While Wisconsin is not all temperate deciduous forest and Costa Rica is not all tropical rainforest, a comparison of the two demonstrates the differences in the variety of life that can be found in each place. This difference becomes even more dramatic when remembering that Costa Rica is just a little more than one-third the size of Wisconsin.

The Ferns

About 100 species of ferns are found in Wisconsin. Costa Rica has about 800 species of ferns.

The Frogs

About 12 species of frogs can be found in Wisconsin while Costa Rica has more than 120 species of frogs.

An Abundance of Species

Butterflies and Birds

The Butterflies: There are about 150 species of butterflies in Wisconsin. Costa Rica has more than 1,000 species of butterflies.

The Birds: About 308 species of birds can be found in Wisconsin. In contrast, Costa Rica has 827 species of birds, including 200 species of hummingbirds alone. Wisconsin has only one species of hummingbird.

Alcove 8A: Decomposers

Decomposers are organisms of decay. Various bacteria, fungi and protists live on dead or dying plants, animals, and their wastes. They speed up nutrient release by breaking down these organic substances into smaller inorganic molecules. The molecules are then available for uptake by plants or other organisms.

Light Gap - A Natural Disturbance

Life is a dynamic process, and life in the tropical rainforest is no exception. Conditions change. A tree falls pulling down surrounding trees and vines with it. A gap in the canopy occurs. And plants which could not grow under the rainforest's dense canopy of vegetation suddenly get their chance in the sun.

Disturbance plays an important role in developing and maintaining natural systems. The make-up

of the tropical rainforest is always changing as organisms are removed by either natural or human disturbances. As long as these disturbances are not too severe, they can initiate change which occurs in different stages. The series of different stages is called succession.

Underground Connections

Mycorrhizal (my-ko-RYE-zal) soil fungi are found in association with the roots of trees. This association may allow mineral nutrients released by the fungi to be transferred directly to the tree roots. This allows the tree to obtain nutrients that might otherwise be washed out of the soil litter layer by heavy rains.

This diorama shows several types of decomposers. Decomposers, such as bacteria, fungi, and protists, live everywhere: in the soil, water, on dead or dying plants and animals, and their waste. These creatures turn these waste materials back into nutrients that plants can absorb from the soil, and start the cycle of life again. For example, the orchid on the dead tree relies on fungi breaking down the wood for water and minerals.

If decomposers didn't exist, everything that has ever died would pile up, and the nutrients inside wouldn't return to the soil for plants to use. If all plants died, then what would happen to the herbivores? What would happen to animals that consume herbivores?

Alcove 9: Disturbance

Six Months After a Disturbance

Six months ago, a tree fell, creating a gap in the forest. The gap has been filled by pioneer plants and animals, the first to occupy an opening. This tree was blown over by the wind. There are many other disturbances such as landslides, fires, or floods.

Before the tree fell, little wind or sunlight filtered down to the forest floor. Now, many forces can come into play such as pollination, seed dispersal, and colonization strategies. This stage of succession is called early secondary growth.

Seed Dispersal

Birds, like insects, are attracted to colorful fruits. After a bird eats the fruit, the seed is dropped, or, if it is small enough, it passes through the bird's body to be eliminated with its waste on the ground. Bats and other mammals also move seeds, as do insects, wind, and water.

Avocado Strategy

The avocado and the wild nutmeg produce firm but large seeds with a lot of stored food to nourish the seedlings as they become established.

Pollination

The butterflies shown here inhabit small, sunny, disturbed areas. As larvae, they feed on plants and

tend to have large populations. As adults, they feed on the nectar of certain flowers, and incidentally transport pollen between flowers helping these plants reproduce.

Piper's Strategy

The piper's strategy is to populate an area with large numbers, with the goal of having at least some of their number survive and eventually reproduce. At the same time, they provide cover which allows other plants to grow.

Seeds of these pipers were dropped in the feces of bats flying over the gap. These pipers, which prefer open disturbed areas, are now able to grow here. They have multiplied rapidly, competing with each other for their place in the sun.

Disturbance Brings Change to the Tropical Rainforest: 10 Years After a Disturbance

Life is a dynamic process and life in the tropical rain forest is no exception. Conditions change. A tree falls, pulling down surrounding trees and vines with it. A gap in the canopy occurs. And plants which could not grow under the rainforest's dense canopy of vegetation, suddenly get their chance in the sun.

Disturbance plays an important role in developing and maintaining natural systems. The make-up of the tropical rainforest is always changing as organisms are removed by either natural or human disturbance. As long as these are not too severe, they can initiate change which occurs in different stages. The series of different stages is called succession.

10 Years After a Disturbance

The greatest number of plants and animals are present in this mid-stage of succession. Plants and animals from both early and late succession are present. The plants and animals that first occupied the tree fall opening have changed physical conditions from what they were. Some of the early colonizers have lost out in their struggle and now plants which need less sun have a chance. This scene is generally what is thought of as a "jungle." This stage of succession is called late secondary growth.

The Struggle for Survival

There is a continual struggle for survival among all living things. Plants compete against plants, and animals compete against animals for vital resources.

Since all living things are potential food, each must also defend itself against being eaten. Plants and animals have evolved many different chemical and physical defenses to deter predators.

Partnerships

The struggle to survive has also led to the evolution of partnerships between certain plants and their animal pollinators. Plants with flowers that use color, fragrance, nectar, or shape to attract pollinators have evolved over time.

Bats, bees, hummingbirds, butterflies, and hosts of other creatures may be used by plants to transport pollen to other members of their species. Some plant and pollinator relationships are very specialized, but others are more general.

100 Years After a Disturbance

More than 100 years have passed since the last major disturbance in this area of forest. The canopy opening is filled with plants that have survived to reach their place in the sun. Once again the upper canopy story of the trees gets the most sun and wind. Many plants and animals will spend their entire lives in the canopy.

There is little understory left. On the forest floor, only shade-tolerant species have survived. This stage of succession is called climax forest. It will persist until another disturbance such as the toppling of a large tree by the wind occurs. The process will then begin again.

Life in the Shade

The lifeforms here are adapted to live in the deep shade of the mature forest. Unlike the butterflies of a tree fall opening which feed primarily on nectar, those shown here feed on carrion and bird droppings, fungi-covered sap flows, and the sugary juices of fallen fruit.

Unlike the piper, which requires the high light levels of the tree fall opening to survive, the palm seedling is adapted to the climax forest. It grows slowly under the low light levels found here. When an opening in the canopy occurs the seedling begins to grow rapidly. Only under these high light conditions is it able to mature. If the canopy closes before the palm reaches maturity, its growth once again slows until there is another gap in the canopy.

Alcove 10: Deforestation - The Vanishing Rainforest

A Fragile Ecosystem

During the time it takes you to read this label, 25-30 acres of tropical rainforest will be cleared. This means that in one year an area the size of Pennsylvania will have been drastically altered.

The tropical rainforests are a result of hundreds of millions of years of evolution. They contain the greatest diversity of species anywhere on land. The interrelationships of these forest species with one another and their environment are complex and extremely fragile. The loss of tropical rain forests through massive man-made disturbance may have global consequences.

Ironically, by clearing away the lush vegetation for cattle and cropland, the real wealth of the forest is being destroyed. Gone will be the rich treasure of lifeforms, many never having been seen or recorded, and their potential never known. Also gone will be most of the nutrients that are stored primarily within the forest's vegetation.

Why is the Rainforest Vanishing?

Consumer demand at home and abroad for bananas, lumber, beef, coffee, and other products

results in the cutting of the tropical rainforests, as does a need to make a living.

The naturally diverse rainforest, left untouched, can sustain itself. There is a rich source of seeds and there are plenty of animals to disperse those seeds. The forest's nutrients are tied up in and recycled through its own plants and animals.

When the rainforest is cut down, seed sources and dispersers are removed. The soil quickly loses its fertility and the ability to support the lush life that was found there before. An ecosystem which takes care of itself is replaced by one dependent on humans to maintain it.

Picture label: A banana plantation is a monoculture, a place where only one crop is grown without using the land for other purposes. The commercial banana plants grown here are dependent on humans for the fertilizer, pesticides, and fungicides which allow them to survive. Picture by Allen Young

What Do We Lose?

Creatures like the *Morpho* butterflies. They can survive only in the rainforest habitat.

Protection for the area drained by a river. Without vegetative ground cover, water causes the soil to run off into the river, clogging it, spoiling the drinking water, and killing fish. The soil is now also exposed to wind and can be blown away.

Plants like these orchids. More than beauty is lost. We lose the potential for many new foods, medicines, and products.

What Do We Lose?

The stability of the world's atmosphere. The plants of the tropical rainforests recycle carbon dioxide by taking it out of the air for use in photosynthesis. Loss of trees could mean an increase of carbon dioxide in the atmosphere, creating a gradual rise in temperature that would melt polar ice caps, causing a tremendous rise in sea water levels throughout the world.

Winter homes and feeding stations for migrating birds like our warblers, grosbeaks, and orioles.

Rainfall. About 50% of the rainfall in and around the tropical rainforest is recycled by the trees back into the air.

Destruction of the Rainforest

What's the Alternative?

New approaches to farming the tropical rainforest can help to prevent its total destruction. Some of these approaches are:

- Agricultural practices designed for tropical areas
- Lumbering that does minimal damage to the forest
- A program to reforest areas cleared of trees

- A way to raise cattle without using large tracts of land
- A way for people to make a living from the land while a wide variety of plants and animals can exist in reserves and buffer zones.

At the time this exhibit hall was being built, some of these practices were being applied at La Tirimbina, the Hunter farm in Costa Rica which is pictured here. Much of the fieldwork for this exhibit hall was done at La Tirimbina.

Will It Survive?

Will the pressures on the tropical rainforests result in their disappearance before their potential riches are known? If the present rate of destruction continues there will be no more tropical rainforests by the year 2100.

Cacao Flower

"A tiny fly no bigger than the head of a pin is responsible for the world's supply of chocolate."

—Dr. Allen M. Young (Milwaukee Public Museum research and expert on cacao pollination)

This model of the cacao flower and a cacao midge, a fly that pollinates it, is 1,850 times actual size. Cacao midges average only 3 to 4 millimeters long. Although some are members of the same family as the “no-see-ums” that plague us with their bites, cacao midges breed in the humus layer of the rainforest and feed on nectar from the cacao flowers.

Dr. Allen Young is a scientist at the Milwaukee Public Museum and was part of the group which discovered that this midge fly, no bigger than the size of a pinhead, is the only creature that will pollinate a cacao tree. The chocolate midge, no bigger than the size of a pinhead, is the only creature that can pollinate a cacao flower.

Cacao trees naturally grow in the shady areas of the rainforest. When grown commercially, they are usually grown in sunnier areas where other trees have been cleared out to plant more cacao. However, the midge fly prefers shade, and, because of this, typically only three of every 1,000 flowers get pollinated in a commercial crop.

Biotechnology

Today’s scientist in the lab

Today, some scientists work in up-to-date biotechnology laboratories like the one here. The techniques of biotechnology may help them unlock secrets of the rain forest so that new cures for diseases may be found and riddles of plant and animal life histories may be solved.

Costa Rica: The Model for Milwaukee’s Rainforest
Much of what you will experience in this exhibit hall, *Rainforest: Exploring Life on Earth*, its plants and animals, the vibrant colors and sounds that symbolize the magnificence of tropical nature, was made possible by the cooperative bond that was forged between the people of Costa Rica and the

Milwaukee Public Museum.

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Such collaborative international efforts help bring the world to Milwaukee, and provide the opportunity for a mutual exchange of knowledge and skills.

Alcove 11: Classification - What's in a Name?

Organisms are identified or classified to species by the scientific process called systematics. Each species is given a unique, two-part name following an international code of rules. This allows scientists around the world to communicate about the same organism. Only 1.7 million of the estimated 30 million species living on Earth today have been studied and named.

The scientist follows a series of steps which compare an unknown organism with known species in increasingly specific ways until the proper identification can be made. Publications and museum collections are used as references. Without the proper name, valuable information may be lost or the wrong information may be given about an organism.

Can you identify this beetle?

Follow the steps in this simple key to see how a scientist would attack the problem. In each step you must choose between two characteristics. Only three steps of the key are shown here.

Step 1: What Family?

Are the antennae clubbed, that is, with the last segments expanded into lobes? Or are the antennae not clubbed?

The antennae are clubbed. This means the beetle belongs to the family Scarabaeidae, commonly called scarab beetles. If the antennae had not been clubbed, you would have been referred to a later step in the key.

Step 2: What Genus?

Is the body length less than three centimeters or more than three centimeters? Does the body segment behind the head lack horns or have horns?

The body length is more than five centimeters and the head and the body segment behind it have horns. This means the beetle belongs to the genus Megasoma.

If the body length had been less than three centimeters, or if there had been no horns, you would have been referred to a later step in this key.

Step 3: What species?

Is the top of the body shining black? Or is the top of the body golden to reddish brown?

The top of the body is golden to reddish brown. The species is *Megasoma elephas.*

If the top of the body had been shining black, you would have been referred to a later step in the key.

Classification: Kingdom: Animalia (animal), Phylum: Arthropoda (arthropod), Class: Insecta (insect), Order: Coleoptera (beetle), Family: Scarabaeidae (scarab beetle), Genus: *Megasoma*, Species: elephas

Alcove 12: Scientist at Work - Museum

Today's Scientist in the Museum

Once data and specimens are gathered in the field, they must be analysed, classified, and cataloged. The curator here is identifying the specimens he has brought back from the rainforest. The scientific process of systematics allows specimens to be identified so that information about them can be shared and used in scientific study worldwide.

Scientists are working year-round at the Milwaukee Public Museum to better understand our natural and cultural worlds. Dr. Chris Tyrrell, an adjunct curator at MPM, has researched American bamboos for years and discovered many plants that are completely new to science. Click the links below to learn more.
American Bamboo
Bamboo Untold

How Many Kingdoms?

Because there are so many kinds of living things, we group or classify them by common characteristics. Today, most scientists group living things into five kingdoms.

Animal Kingdom, The Consumers

Animals eat plants or other animals to obtain food energy. This kingdom contains the greatest diversity of life forms.

Protist Kingdom, Producers, Consumers, Decomposers

Protists, or Protoctista, are all eukaryotic cells, cells in which the genetic material is gathered in a nucleus. Most are single-celled organisms.

Plant Kingdom, The Producers

Plants contain chlorophyll, a green pigment through which they are able to trap the energy of the sun and use it to make food.

Fungus Kingdom, The Decomposers

Fungi obtain food energy by breaking down plant and animal tissues in the process of decay. Lichens are a special partnership between fungi and algae.

Monera Kingdom: Producers, Consumers, Decomposers

Monera, or Bacteria, are all prokaryotic cells, cells in which the genetic material is loose. All monera are single celled.

Scientists used to group everything into only two kingdoms, plant or animal. But increasingly specialized instruments and techniques have allowed us to learn much more about the complexities of life. Today, most scientists group living things into five kingdoms shown above. This classification may also change as our knowledge continues to grow.

Alcove 14: Products from the Rainforest

Abundant Forest

When the tropical rainforest is destroyed so land can be used to raise cash crops, thousands, or perhaps millions, of possibilities are destroyed as well. Potential cures for cancer and other diseases, sources of food, and much more may be locked up in the organisms of the American tropical rainforest.

Only a small fraction of the plants and animals that are known to exist in the tropics have been screened for potential use. Already scientists have found possible treatments for Hodgkin's disease, certain forms of leukemia, hypertension, and rheumatoid arthritis.

Products from the Rainforest

The American tropical rainforest has provided people with many familiar products such as cocoa, Brazil nuts, and lima beans. Many other products are shown below. But the majority of plants and animals in the rainforest have yet to be discovered.

Food

Manioc or cassava (sources of several starchy products such as cassava flour and tapioca)
Cashew Nuts
Brazil Nuts
Palm Hearts
Lima Beans
Cacao (source of chocolate and cocoa)

Medicine

Curare
Rotenone
Quinine

Ipecac
Cocaine
Poison Frogs
(Dendrobates and Phyllobates produce compounds that show promise for uses in medicine)

Industrial Products

Natural Rubber (still in demand for certain industrial and laboratory applications)

Spices

Cayenne Peppers
Allspice

Rainforests in Costa Rica and all over the world provide many products we use every day. Download our Rainforest Scavenger Hunt activity to learn which products in your home originated in the rainforest.
rainforest Scavenger Hunt PDF

Learn more about some common beverages derived from plants in the tropical rain forest in our Botany of Beverages Lecture below
Botany of Beverages

An Example of Biotechnology

The techniques of biotechnology have been applied to rainforest plants such as cayenne pepper, several kinds of palms, rubber, and cacao.

For example, scientists have isolated the gene which controls formation of cocoa butter. Cocoa butter is the primary storage product of cacao seeds. This gene may influence the melting point of cocoa butter, which is of critical importance in manufacturing chocolate.

Modification of this gene through laboratory techniques, and its insertion into cultivated varieties of cacao, could improve the handling qualities of cocoa butter and greatly benefit the chocolate industry.

New and Improved Products Through Biotechnology

Biotechnology holds a key to the farming of the future. By using laboratory techniques of gene modification and selective breeding, production and disease resistance can be improved more rapidly than by using traditional breeding programs. Also, large quantities of useful substances can be treated for industrial and pharmaceutical uses.

Deforestation

Ironically, by clearing away the lush vegetation for cattle and crops, the real wealth of the forest is being destroyed. Massive inroads by the chain saw and bulldozer could result in the disappearance

of the tropical forest by 2100.

Cacao Tree
The cacao tree grows in the shade of the rainforest. Notice the unusual pods growing from its trunk instead of the branches. The cacao pods are necessary to make one of the most popular ingredients in the world: chocolate! How does it go from a funny-looking plant to a chocolate bar?

- First, cacao pods are harvested, then split open to dry.
- Next, the seeds are fermented in large heaps, often covered in leaves or cloth. Fermentation causes chemical changes that develop chocolate's distinct flavor and color.
- After fermentation, the beans are dried in the open sun.
- Once dry, beans are roasted and separated from the shells, which creates a product called cocoa nibs.
- Cocoa nibs are ground into a paste-like "cocoa liquor" (not actually alcoholic) which is mixed with other ingredients like milk and sugar to create many of the chocolate products we enjoy today.

Cauliflory

You've heard of Cauliflower, but this is Cauliflory

Some rainforest trees and shrubs produce flowers and fruits directly from the trunk or main branches. This feature is called cauliflory (CALL-i-floor-ee). It appears to increase the flowers' chances of being pollinated by insects. An example of cauliflory can be seen in this cacao tree.

Rubber Tree
This is a rubber tree, native to the Amazon rainforest. This tree's milky sap, called latex, is a natural defense that seeps out of wounds to heal the tree. Latex can be used to make natural rubber for things like tires, rubber balls, rubber bands, and the soles of shoes. However, artificial rubber is now more commonly used in the United States.

Rubber trees can grow up to 4 feet each year and can reach between 100-130 feet high.

Strangler Fig
Strangler figs start as sticky seeds dropped by birds or bats at an elevated portion of another tree. The fig grows downward around the trunk of the host tree until it reaches the ground. The strangler fig's leaves deprive the original tree of light and therefore the ability to sustain itself. The fig's roots also deplete the tree of nutrients. Eventually, the fig "strangles" the original tree, causing it to rot away. The fig remains after the original tree rots, leaving a hollow interior. Many creatures benefit from the hollow strangler fig as a home, breeding ground, and source of food.

Strangler figs are one of the rainforest's **keystone** species, meaning they provide critical sustenance to a wide variety of species within the rainforest, and if they were to go extinct, would cause the extinction of many other species.

4WD Vehicle
Nowadays, a four-wheel-drive vehicle is often the best means for scientists to get to hard-to-reach spots in the field. Terrain can be rough, roads narrow or non-existent, and bridges can be flooded or washed away. Airplanes, helicopters, motor boats, and four-wheel-drive vehicles have all sped

up the process of getting scientists into remote areas for research studies.

The Strangler Strikes Again

The hollow in the tree to your right provides a home to many rain forest creatures. This strangler fig tree began many years ago as a seed dropped by a bird or bat high up on a host tree branch. When the seed sprouted, the roots grew downward along the host's trunk towards the soil far below.

When the strangler fig roots tapped into the nutrients and water in soil, the plant began to grow even more rapidly. The leaves of the strangled fig intermingled with the leaves of the host tree and prevented the host tree from getting as much sun as it needed to be healthy. Gradually, the host tree rotted away; it provided a place for abundant new life to flourish.

Energy Links for Life

In the hollow tree to your left, you can see a food chain at work. At each step in the food chain, some energy is lost. Energy from the fruit in the bat guano is used by the cricket when it breathes, mates, and escapes from predators. Only a small part of that energy is available for the tailless whip scorpion that eats the cricket, so it must eat many crickets to have enough energy to sustain life. It takes a lot of crickets and whip-scorpions to keep one toad going. In fact, there are fewer creatures that can be supported the further away you get from the original producer.

Today's Scientist: In the Field

Biologists from the Milwaukee Public Museum work in a variety of habitats, from steaming tropical rainforests to frigid mountain tops. Here is one of the biologists at work in the tropical rainforest gathering data and specimens. The work in this forest is hot, the hours long, and the insects formidable. But the opportunity to gather data and specimens is great and the possibility of gaining new insight and understanding about life on this planet is exciting. Can you find all the equipment the curators use in their work?

Scientists are as diverse as the rainforest! Some scientists work in the field, gathering data. Others work in a lab, creating experiments, analyzing data, and caring for scientific materials. Many scientists work to share information with the public.

Learn more about the Milwaukee Public Museum's scientists in the video below.
What is a Scientist?

Lichens

Lichens are a permanent association of an algae and a fungus, two very different organisms. Their relationship is mutually beneficial. The fungus creates shelter for the alga, and the photosynthetic alga provides carbohydrates (food) for the fungus. Lichens live in or on places like tree trunks, tropical leaves, and rocks, where it is difficult for many plants to live.

Alcove 15: Insects

Research Methods

Research isn't always as easy as it looks. It can be a challenge to come up with successful ways to get information. Orchid bees, for example, are difficult to observe as they can swiftly fly through the rain forest. But the bees can be lured to orchid fragrances and collected in special traps. Rotted fruit baits attract some of the forest butterflies.

Defensive Sounds Against Bats

Bats have been major predators of night-flying insects for over 50 million years. Bats hunt their prey using echolocation by producing high-pitched chirps and using their sensitive ears to listen for echoes from objects in their environment. Some insects, such as tiger moths, have evolved unique sound-based defenses to protect themselves against predators.

Tiger moths have ears that are sensitive to bat echolocation. These ears allow them to hear incoming bats and take evasive action. If this fails, these moths can also produce their own sounds when bats get close. In the same way that bright colors of poison dart frogs or venomous snakes tell predators to stay away, these sounds can serve as "aposematic warnings" which signal to bats that the moths are toxic. However, some tiger moth species produce so much sound that can "jam," or interfere with a bat's ability to use echolocation, making it difficult for the bat to capture the moths. These sound-based defenses give tiger moths an effective way of escaping bat predation.

Watch Bat vs. Moth Video

Termites
There is a termite nest hanging from the tree branch above. The termites reach their nest by crawling up the tree through covered termite walkways. Termites are social insects that feed on wood.

But a termite will starve to death without the aid of special bacteria or protists that can digest cellulose, a main component of wood. These microorganisms live in the termite gut and are passed on in a liquid exchanged between termites. Both the termite and its microorganisms benefit by this partnership.

Alcove 16: At the River's Edge

Although we often imagine the rainforest as a dense, unbroken jungle, there are thousands of rivers, tributaries, small lakes, and swamps that are created by the tremendous amount of precipitation the rainforest receives.

One family of fish, found in Costa Rica and all over the world, is the cichlid family. A MPM scientist researched cichlids in Africa and discovered two new species!
Learn more here

A Story of Life and Death

No creature lives forever. Organisms are born. They grow and develop, and then they die. But life

itself continues through the process of reproduction. We can explore reproduction, growth, and development by looking at some creatures at the river's edge.

New Life Begins

Life Goes On With Sex….

Can you find the juvenile frog that looks just like either parent?

If you're feeling frustrated because you can't find the matching frog, don't. You're actually very observant. In the wild, there is probably no baby frog which exactly matches either of its parents.

When a male and female mate, their offspring are somewhat different from either parent. This is one of the advantages of sexual reproduction. Half of the genetic material comes from one parent, half from the other. The resulting genetic variation allows a species to adapt to changes in its environment.

This is true of plants and animals.

...Or Without It

What sex do you think the offspring of this female lizard will be?

Female, of course. Because in asexual reproduction, the offspring are always genetically identical to the parent. This is true of plants and animals. Although most lizards reproduce sexually, this whiptail lizard is an example of a vertebrate that can reproduce itself through asexual reproduction. Reproduction occurs from an unfertilized egg. Asexual reproduction happens when one organism divides and creates a new organism genetically identical to itself.

A Frog Is Born

This ranid frog's eggs are often fertilized in water. The female releases her eggs into the water. Males cover the eggs with their sperm. A different sperm cell has to penetrate each egg cell to fertilize it. Eggs and sperm that don't unite die.

Once an egg cell has been fertilized, the new organism will begin to grow and develop. Growth, in living organisms, is a change in overall size and body proportions. Development is a change in form. In most mammals the egg is fertilized and the new organism will begin to grow and develop within the body of the mother.

Life Changes Through Growth and Development

Growth and Development

What is the Difference?

While growth in living organisms is a change in overall size and proportions, development is change in form. Some animals, like the frog and the Morpho butterfly, have one form when they

are young and a very different form when they are adults. This often allows the immature form and the adult form to occupy different habitats and use different resources. This phenomenon is called metamorphosis.

The Frog's Story

Take a look at the development of the fertilized frog egg.

1. After a sperm cell penetrates the egg cell, the egg begins to divide. First, there are two cells, then four, then eight, and so on. The egg becomes a hollow ball with a single layer of small cells. This is called a blastula.
2. Then, some of the cells are forced to move inwardly, change shape, and grow as the blastula becomes a gastrula. The gastrula is a three-layered embryo, made of ectodermal, mesodermal and endodermal layers.
3. Organs begin to develop. The ectoderm gives rise to skin and its derivatives, the sense organs and the brain and spinal cord. The mesoderm gives rise to muscle, connective tissue, the circulatory system and most of the excretory and reproductive systems. The endoderm gives rise to the lining of most of the digestive tract, most of the respiratory tract, the urinary bladder, liver, pancreas and some endocrine glands.
4. In about five days, this fertilized frog egg develops into a tadpole. Tadpoles have gills for breathing underwater but they also breathe through their skin. After a few weeks or months, the tadpole loses its tail and gills. It grows lungs and legs as it transforms into a frog.

The Butterfly and the Grasshopper

Compare the growth and development of this butterfly with that of the grasshopper. What differences can you find?

Do you know what process this insect needs to go through in order to grow?

There are four growth stages, or instars, in the development of the butterfly. In the butterfly, the immature form, called the larva, is specialized for feeding and growth. The pupal stage is a time of change. The adult that comes out of the pupa is very different from the larva. The adult is specialized for dispersal and reproduction. This type of development is called complete metamorphosis.

There are three stages in the development of a grasshopper. As the grasshopper grows, it changes in size and proportion but there is no pupa stage. The young nymphs resemble the adult and often occupy the same niche, but full development of the wings and reproductive organs is not completed until the adult stage. This is called gradual metamorphosis.

The Sundown Cicada

This sundown cicada is molting. Like other insects, crabs, lobsters, and spiders belonging to the animal group called the arthropods, it has a jointed covering called an exoskeleton. In order for

these animals to grow, they must first shed their old exoskeletons and then produce larger ones. This process is called molting.

The Anaconda, the Arapaima, and the Kingfisher

Can you guess which ones has limited growth?

Most reptiles, such as the anaconda to your right, and fish, such as the arapaima in front of you, will continue to grow throughout their lives. As they get older, however, they will grow more slowly.

Creatures such as birds, mammals, and most insects do not continue to grow larger throughout their lives. The kingfisher, for example, has grown about as much as it can. Although it might gain an ounce or two, its frame will grow no longer, nor its wingspread any wider.

Life Ends

The caiman's life is about to come to an end as it becomes nourishment for the hungry anaconda. No creature lives forever. Organisms are born. They grow and develop and then they die.

Arapaima (Air-a-PIE-ma)

The Arapaima, a tropical fish, can grow to nine feet in length, or more. It is one of the world's largest freshwater fishes. It matures in four to five years, but can live as much as eighteen. During the breeding season, it keeps to shallow water where the female can lay up to 180,000 eggs.

A Struggle to Death

Even though the caiman, a close relative of alligators, is a good fighter, it is about to lose its struggle for survival. The large anaconda is constricting the life from its prey. Each time the caiman exhales, the anaconda tightens its hold. Eventually the snake will strangle its victim.

A special jaw attachment is one of the features that allows the anaconda to swallow creature as large as the caiman. After a meal of this size, the anaconda may rest for weeks to digest its meal.

Even though the caimen will die, it will become nourishment to sustain the life of the anaconda. You can find out more about the life cycle from the exhibits to your left

.Alcove 16A: Plants and Peccary

Plant Growth and Development

Primary Growth

As a seedling grows, its shoot emerges from the soil and leaves are formed. In addition, its roots continue to push further down into the soil. For the seedling to grow and develop, shoot and root tips must continue to produce new cells cell division. These areas of active cell division in the shoot and root tips are called apical meristems (AP-i-kall MER-i-stems). All cells produced by these apical meristems form primary growth.

As new cells continue to form at apical meristems, previously formed cells become repositioned, elongated, and modified into cells that can transport minerals and water and help to the seedling as it grows taller. Eventually, long pipelines of cells are created, running throughout the plant. These pipelines form two principal transport systems: xylem (ZYE-lem) and phloem (FLO-em). The xylem carries water and dissolved minerals taken from the soil. The phloem moves sugar and other organic materials by photosynthesis.

Many plants go through their lives with only primary growth. They grow in width only by enlargement of the cells produced by the apical meristems. The interior of their stems remains soft and they are called herbaceous plants. Examples of these plants are beans, corns, and bananas.

Secondary Growth

Another kind of growth, characteristic of trees and other woody plants, is known as secondary growth. The center of a tree is solid dead wood. The tree cannot grow thicker from the inside out. The bark on the outside also looks dead. So how does a tree grow thicker?

Between the wood and the bark is a thin layer of dividing cells called the vascular cambium. Only a few cells thick, the vascular cambium is responsible for the tree's growth in diameter, whereas the apical meristem initiates growth in height. All cells produced by the vascular cambium form secondary growth. The vascular cambium secondary phloem cells to its outside and secondary xylem to its inside. The secondary xylem is wood and it gives strength to stems. The secondary xylem is the part of the tree we use for lumber.

The Function of Flowers

Flowers are more than just beautiful. They are the reproductive organs of a plant.

Pollination

Before a flower can be fertilized, pollination must occur. Pollination, the transfer of pollen from the anthers to the stigma, is one of the most important features in the sexual reproduction of the flowering plant.

This hawk moth is attracted by the color and smell of this morning glory flower. As it feeds on the nectar in the flower, it touches the anthers, and grains are brushed onto the moth. When the moth visits another flower, some of this pollen will be transferred when it touches the sticky stigma.

Fertilization

The grain grows after it lands on a stigma. From the pollen grain, a tiny pollen tube grows down the style, into the ovary. Two male cells are released. One of the male cells, a sperm cell, unites with an egg cell to form a zygote which grows into an embryo, a tiny new plant.

The other male cell unites with nuclei and together they grow to form the endosperm, stored food for embryo. With the development of a protective coat around the embryo and endosperm, a seed

has been formed.

Seed Dispersal

Since most plants cannot move their seeds, they must depend on animals, wind, or water to disperse their seeds. The fruit, the ovary wall surrounding the seeds, protects the seeds and often aids in the dispersal of those seeds. Animals are attracted by the fruit's scent or color. They eat the fruits and by the time the seeds are eliminated through the digestive system or regurgitated, the animal has ranged far and wide.

Germination

Wherever a seed ultimately lands, it is usually dormant for a time, until moisture, temperature, and sunlight are right for germination and growth.

Puddling Butterflies

The butterflies gathered here are collecting the salts and minerals they need to survive. Hundreds of butterflies may jostle each other to gain a spot on the damp mud surrounding rain puddles. They imbibe a lot of water to secure small amounts of dissolved sodium. This behavior is called "puddling."

Plant Defense

Since all living things are potentially food, each must defend itself against being eaten. Plants and animals have evolved many different chemical and physical defenses to deter predators.

The Sura keeps other plants from growing on it and overwhelming it by periodically sloughing, or shedding, its bark. The Aristolochia vine produces toxins which make it distasteful to most insects and other animals that might eat it. The sharp spines of the ceiba tree and the palm discourage climbing animals from feeding on their leaves. The cecropia tree has formed a partnership with ants that attack would-be predators.

Alcove 17: Nocturnal Animals

Watch Nocturnal Adaptations Video

The Forest Doesn't Sleep at Night

Night in the tropical rainforest brings on a different set of players and events. The daytime creatures become inactive as the creatures of the night play out their roles in the struggle for survival.

Butterfly Roost

These creatures are not active at night. They heliconius butterflies gather together in a roost to sleep.

Kinkajou

These tree dwellers search their arboreal home for fruit at night.

Small Creatures

All of these animals are active at night.

Paca

The paca searches for food on the forest floor under the protection of night.

Pollinators

The white color and strong fragrance of night-blooming *Bombacopsis* flowers attract bat and hawk moth pollinators.

Alcove 18: Animals of Canopy

Above the Forest Floor - Into the Canopy

There is much more to the tropical rainforest than meets the eye. High above the forest floor, in the forest layer called the canopy, many plants and animals live out their entire lives. Monkeys swing from tree to tree. Tiny shrimp live in the pools of tank bromeliads, plants whose roots never touch the forest floor. Iguanas defend their territories, mate and reproduce rarely leaving their arboreal homes.

Eighty percent of the rainforest's food is produced here. And two-thirds of the rainforest's plant and animal life can be found in the canopy, rarely seen by the human eye.

But that is beginning to change. Scientists are finding ways to study the canopy. They are beginning to discover what parts the canopy plants and animals play in the intricate web of rainforest life.

Iguana

The iguana eats tender shoots and other vegetation. When it stands still it can be easily overlooked among the green leaves of the canopy.

Spider Monkey

The spider monkey is active during the day and can move rapidly through the trees. Its prehensile tail can wrap around branches and hold the entire weight of the monkey.

Great Potoo

The potoo is a large rare nocturnal bird. It eats insects and sometimes perches on branch stubs where it blends in with lichen-covered bark.

Fiery-billed Aracari

Groups of aracari are often seen straggling single file through the foliage, leaping from branch to branch through their canopy domain. They eat mainly fruits and berries, but dine on small reptiles, insects, and the eggs and young of other birds as well.

Two-toed Sloth

Sloths live, feed and reproduce in the canopy spending most of their lives hanging upside down. The sloth's long, coarse hair is covered with green algae for camouflage. Its body provides a living hotel for beetles, moths, ticks and mites.

Watch Two-Toed Sloth Video

Tree Boa
The tree boa climbs well and may eat small iguanas. It spears its prey with sharp teeth and suffocates it by constriction (in its coils) and then swallows the animal whole. By day, the nocturnal tree boa coils on a shaded tree branch and rests.

Small Creatures
Many small creatures live in the canopy, barely visible to the eye. Some are “hidden” by their small size, others by protective coloration. Many of these animals are active during the day, others at night.

Cutaway A

Many-a-Macaw
The scarlet and green-winged macaws on the waterfall are flocking. There is greater safety in numbers and they have a better chance of finding food. These birds are eating clay that contains minerals and salts, which may aid in absorbing or detoxifying poisons ingested in the many bitter, toxin-rich seeds and fruits they eat. During nesting season pairs of macaws leave the flock to raise their young.

Macaws group together in large flocks of 10-30 birds to protect each other from snakes and other large predators. Although they may seem flashy, their bright colors are actually camouflage, as they blend in with the leaves and bright fruits of the rainforest.

Click below to hear their call.

Acrobatic Birds

Do you know why the birds in front of you are hanging from the tree branches? They are male oropendolas who are courting the females with unusual displays of bows, branch hanging, wing flapping and strange gurgle-like calls. The male oropendola is larger than the female and, like many other animals, the oropendola needs a mate to reproduce.

Hanging Nests

Oropendolas nest in colonies ranging in size from four to 150 nests. The average is usually 30 to 40 nests. These large bag-like nests are well over three feet in length and can most often be found in

the tallest rainforest trees in a clearing or at the edge of the forest. The nests are similar to, but much larger than, northern oriole nests in Wisconsin.

The smaller females usually outnumber males in most colonies. And the females alone weave the large nests and incubate the eggs as well as care for the young.

Cutaway B

Something in Common

Every living thing must solve the same basic problems in order to survive. Both the ocelot on the tree branch and the jaguar below are good swimmers and excellent climbers. These abilities help both big cats catch the prey they need for survival.

Alcove 19: Natural Selection

Watch Natural Selection Video

Natural Selection: Who Will Survive?

These frogs are struggling for survival in a portion of the rainforest. Those which blend in best with their surroundings are more likely to survive.

Predators like the snake or coati (koh-AT-ee) are most likely to catch the frogs that stand out. Can you identify the frogs that are most likely to be eaten? Do you know why?

The process of natural selection is at work. In nature, there are many factors, called selection pressures, which determine whether individuals will or will not survive long enough to produce offspring. Predation is one example of a selection pressure.

Do You Know How Natural Selection Works?

1. Organisms produce many offspring, and these offspring vary in traits such as color, behavior, structure, or chemical processes.
2. Only part of the offspring survive. Natural selection determines which offspring survive.
3. Those offspring which survive to become adults pass on their traits to yet more offspring.
4. In time, selection, together with other environmental factors, result in new species which are adapted to new conditions

Natural selection can act as an influence on characteristics at the same time that it encourages population and species diversification.

Who Will Survive?

The circled frogs have a better chance of surviving. The process of natural selection favors the frogs that blend in with their surroundings and that have the formed structures for carrying on their day-to-day activities. More of these frogs will survive to reproduce.

Predation is only one type of natural selection. Heat, cold, lack of moisture, too much moisture, parasitism, and competition for nesting and feeding territories are some others.

Who Will Perish?

The red frog in the illustration above is less likely to survive. Do you know what type of selection is at work?

Heat - Sorry! Heat is a type of natural selection but not the one at work here.

Predation - Right! The frog's color made it possible for the predator to see it and catch it.

Charles Darwin (1809-1882)

The Theory of Evolution

Natural selection is an important driving force in the production of new species, that is, in evolution. Charles Darwin was the first person to publish on the theory of evolution, the theory that existing living things are the modified descendants of other species that lived in former geological times.

A species is a group of organisms with a similar evolutionary history and an ability to interbreed and produce fertile offspring. The members of a species generally resemble one another in form and other traits.

Use It or Lose It

This is a tamandua, or lesser anteater. What is missing? The anteater has no teeth. The anteater doesn't need teeth to eat ants. It takes energy to develop structures and natural selection does not favor individuals with structures that are unnecessary. Members of a species which do not have the unnecessary structure, may have an equal or better chance of surviving and reproducing.

Alcove 20: Evidence for Evolution

Fossil Evidence

Each exhibit below offers some interesting evidence for evolution. Can you identify the evidence in each?

Scientists examine fossils. Fossils are hardened remains or traces of former animal or plant life preserved in rock formations.

Can you find the similarities between the fossil Archaeopteryx (are-key-OP-ter-iks), the basilisk lizard, and the hoatzin bird? The hoatzin bird and the basilisk lizard are found in the American tropical rainforest today.

Some fossil records contain forms intermediate between major groups of animals or plants. Scientists believe birds evolved from a group of reptiles. The fossil Archaeopteryx is intermediate

between birds and reptiles. Archaeopteryx has reptilian features such as a small brain, long tail, and free fingers. It also has features found in birds such as feathers, wings, and a wishbone.

Skeletal Evidence

Birds, ocelots, monkeys, seals, and humans look very different from the outside. But their skeletal limbs are similar. The bird wing, ocelot leg, monkey and human arm, and seal flipper are called homologous (ho-MOLL-a-gus) organs. That means they correspond in basic type of structure and are derived from a common primitive origin.

Can you find the humerus, radius, and ulna bones and the phalanges in each skeleton? The bones may be longer or shorter in each, but the basic structure is the same.

Evidence in Remnants

Can you find the evidence that the snake's ancestors walked on land? The arrow points to a vestigial pelvic girdle which indicates that in former times, the ancestors of the snake had legs which would have required a pelvic structure. Natural selection must have favored the loss of legs and now only a trace of the former structure survives. A vestige is an atrophied or rudimentary organ or part which was more fully developed or functional in an ancestral form of species.

Genetic Evidence

The embryo illustrations to the left look similar to each other yet, as adults, they will look different. Why is that? Human and other animal bodies develop along similar pathways because they all share nearly identical genes. These genes contain the blueprint for building body parts such as the limbs, heads, and eyes. These body parts look different among species because of how and when their underlying genes become active as an individual grows.

Basic Biochemical Similarities

Even though the cotton-top tamarin and the morning glory look very different, they, like all living things, are made of cells. But like all living things, they have something else in common as well. Do you know what that might be?

At a nuclear level, the tamarin and the morning glory encode their genetic information by use of the chemical DNA. All animals and plants, regardless of how different they might look, also use DNA to encode their genetic information.

Alcove 21: Patterns of Evolution

The Making of a Species

Many different species of *Morpho* butterflies are shown here. A species is a group of organisms which have a similar evolutionary history and can interbreed and produce fertile offspring. The members of a species generally resemble one another in form and other traits.

How Does a New Species Come into Being?

Scientists believe geographical isolation encourages the development of new species. Changes in climate or other environmental factors, like a mountain range rising or a river becoming established, can result in some members of a species being isolated from others.

When members of a species are not geographically isolated, they can exchange genes. This exchange of genes prevents the formation of new species.

When environmental factors isolate members of the same species in different areas, the organisms in each area can interbreed with each other but not with those in different areas. The organisms isolated in the different areas may vie with different competitors for food, territory, shelter, mates, nesting sites, and sunlight. The lack of genetic interchange between the organisms in isolated areas allows different selection pressures to cause the accumulation of new traits. Eventually new species are formed.

Some causes of geographical isolation for American tropical rainforest organisms are rivers, mountains, and grasslands.

Taking Advantage of the Possibilities

Here are organisms that have a great deal in common. The beetles, grasshoppers, etc. are all insects. The flowers are all orchids. But there are many variations from orchid to orchid. Each type of insect has specialized adaptations too. Can you guess why?

Some groups of animals and plants have evolved adaptations which allow them to occupy or make use of a whole range of previously unavailable environments or resources. This is called adaptive radiation.

The Orchids

Orchid adaptations include minute seeds, high seed number, and wide seed dispersal. Some are epiphytic, living on other plants. Others are terrestrial, growing in soil. They may be adapted to dry or moist conditions.

The Insects

One adaptation of insects is small body size which permits life in habitats not suitable for larger animals. The ability of most insects to fly (to find mates and food and to escape enemies) is another important adaptation. Other important insect adaptations are the tough waterproof outer skeleton which protects internal organs and prevents loss of moisture, a system of air tubes which takes oxygen directly to cells within the body, and short life cycles and numerous eggs which enable insects to multiply rapidly when conditions become favorable.

Making the Most of a Good Thing

Birds, bats, and insects are very different creatures in many ways. But they have evolved similar

adaptations to the pressures of their environment. Can you tell what adaptation they share?

If you guessed “flight,” you are right. When very different types of organisms evolve similar appearing adaptations to environmental pressures, the phenomenon is called convergent evolution.

Another Example of Convergent Evolution

Can you tell what example of convergent evolution these plants demonstrate? They all have evolved drip-tip leaves to manage rainfall. This drip-tip acts like a funnel, speeding surface runoff and drying. Without the drip-tips, the leaf surface remains moist, and liverworts, lichens, and algae cover the leaf, reducing its ability to capture the sun's energy. The longest drip-tips occur on the leaves of plants in the understory and subcanopy layers. The drip-tips of canopy trees and vines are shorter or absent because wind and sunlight dry the leaves.

Extinction: The Price of Failure

Long ago, dinosaurs like these and the ones you saw in the geology hall roamed the Earth. The dinosaurs were large and successful. But species do not last forever and these dinosaurs no longer exist. Competition for limited resources can be fierce. A species that cannot adapt may lose the struggle for food, mates, or sunlight.

On the other hand, a species that becomes too over-specialized may find itself unable to respond to change and may reach an evolutionary dead end. Change in the environment or predation may also bring about the demise of a species. When a species dies out, it becomes extinct. It no longer exists.

Scientists are currently trying to discover what caused the dinosaurs to become extinct. Many researchers believe there was a single massive extinction event, like a large meteor hitting the earth, bringing about a climatic change that caused plants and animals to die out.

Alcove 22: Struggle for Survival

Spacing

Living things need space so much that they’re willing to fight, or at least threaten to fight for it. They need space to ensure an adequate food supply and mates. Many animals defend their territories by using behavior such as prancing, posturing, scent marking, and singing and using other types of calls.

Lizards on Patrol

Look at the two anole lizards on the branch below. Can you tell what the lizard on the right is doing to defend its territory? If you noticed the anole's out-stretched dewlap (or loose fold of skin), its raised crest, and its wide open mouth, you are very observant. And if you were an intruding lizard,

the territorial warning conveyed by the outstretched dewlap might inhibit you from coming any closer.

The lizard defends its territory to insure that it has an adequate food supply and mates. A male may allow females and young or subordinate males to enter his territory, but vigorously defends its territory against intruding competitive males.

Warning: Territorial Defense

If you're close enough to read this sign, you've invaded the territory of the howler monkey on the branch behind you.

Press the button to find out how the howler monkey defends its territory.

Play Territorial Defense

Here are six forest canopy creatures. How do you think each creature will defend its territory?

Poison Frog: Males use vocalization to inhibit an intruder from entering their territory. An intruding male can expect to have a wrestling match.

Iguana: A male will warn intruders to stay away by bobbing its head. A persistent intruder will face combat.

Marmoset: First a vocal warning, then a fight.

Harpy Eagle: If the sharp cry of the harpy male doesn't keep an intruder at bay, antagonists wil language in ritualistic combat and swoop at each other.

Kinkajou: First vocal warning, then a fight

Macaw: The macaw defends his territory from a distance with a raucous call. At closer range, posturing warns an intruder not to enter.

Solve This Territorial Riddle

Pictured here are the same lizards as on the branches above. But they aren't actually fighting. Why? Neither lizard is in his own territory, the area which would typically be most strongly defended. Both are moving near the boundary of their activity range. The activity range is the widest area an animal frequents.

Activity Range: Area in which an animal lives, but which is generally not exclusive or actively defended.

Territory: Area which is usually defended by an individual or group. It is the favorite spot for courtship, basking, and getting prey.

The Howler Monkey

The howler monkey's loud call frightens away predators and other animals invading their foraging range. Male howler monkeys have large throats and shell-like vocal chambers to amplify and project their sound, sometimes up to three miles. If howling doesn't work, these monkeys play dirty! When their territory is encroached upon, howlers will defecate on the offender with marksmanship-like accuracy.

Courtship

Many animals need mates to reproduce. Each species has unique courtship displays that help males attract mates.

- Ornamentation: The Amazonian umbrella bird attracts females with its crown of glossy black feathers.
- Color: The brilliant color of the Festae cichlid fish attracts the female.
- Motion: The male praying mantis performs an elaborate dance and then leaps onto the female who, contrary to myth, does not normally devour her mate.
- Vocalization: The male hylid's (tree frog) distinctive call draws the female to him.
- Visual: This male Guianan cock-of-the-rock's courtship devices are ornate plumage and a crest extended to cover his bill.
- Scent: The male tayra lays down a scent which attracts the female.
- Touch: The male bold snake scratches the female's body with his spurs to stimulate her to mate.

Mating Calls

When it comes to mating, female frogs are fussy. Females will respond only to males of the same species, attracted by unique mating calls.

Energy is in limited supply, so most creatures avoid wasting it. Species-specific courtship displays help females know which males are their own species. Mating with a male of a different species will rarely result in offspring being produced. Why waste the energy?

Click here to hear the mating calls of four different species of male frogs.

Danger

But there are dangers to courtship. Advertising for a male can also attract predators as this unwary frog discovered. Predators, like some bats, cut into the frog's call.

Foraging and Feeding

These birds demonstrate how animals have evolved structures and behaviors to get specific kinds of food. Birds have evolved specialized beaks and associated foraging strategies. Other animals, like the bushmaster snake, have evolved fangs and venom. And still others, like the lesser anteater, long sticky tongues.

All of these special structures and behaviors are adaptations which help the organism survive its

own environment.

Rummager

The pale-billed woodpecker forages on trunks, branches and branchlets to feed on insects like ants and beetles, but also eats seeds and fruit. It excavates, taps, pecks, and gleans the bark with its large chisel-like beak. It also debarks dead trees by probing to find insects.

Seed Eater

The blue-and-yellow macaw cracks nuts, seeds, and fruit with its strong beak.

Nectar Feeder

Although the rufous-breasted hermit hummingbird also eats insects, its long, narrow beak is just right for getting the nectar from bell-shaped flowers while its rapid rotating wing movements help it to hover in the air.

Sentinel

The roadside hawk sits and watches for prey to pass by. Insects, birds, and small animals are easy prey for its powerful talons.

Diver

The belted kingfisher dives into streams and pools and catches fish with its long beak.

Insect Eater

The rufous motmot sits on the edge of a branch and flies out and back to the same perch catching insects on the wing.

Omnivore

With its versatile beak, the brown jay eats fruits, nuts, eggs, small mammals, reptiles, and carrion.

Fruit eater

The keel-billed toucan's long, thick, colorful bill can push foliage aside to reach tasty fruit. But it will eat insects, frogs, and young birds as well.

Watch Bird Beaks Video

Match the Beaks and Birds

The birds' beaks shown here provide an example of structural modifications evolved by animals to help them locate and secure food. Which beak is built to let the bird get food from the flower? Which beak is built to let the bird catch flies in mid-air?

Brown Jay: Sorry, try again. This beak belongs to an omnivore. It will eat almost anything.

Pale-billed Woodpecker: Sorry, try again. This beak belongs to a rummager. It searches for insects in crevices and other places, but also eats seeds and fruits.

Keel-billed Toucan: Sorry, try again. This beak belongs to a fruit eater. It eats fruits and seeds.

Rufous-breasted Hermit Hummingbird: Right! This beak belongs to a nectar-eater. It gets nectar from flowers.

Rufous Motmot: Right! This beak belongs to an insect-eater. It catches insects in mid-air.

Ringed Kingfisher: Sorry, try again. This beak belongs to a fish-eater. It catches what others leave behind.

Blue-and-Yellow Macaw: Sorry, try again. This beak belongs to a seed-eater. It cracks hard nuts, seeds, and fruits with its beak.

Roadside Hawk: Sorry, try again. This beak belongs to a sentinel. It sits and waits, then swiftly strikes.

A Moveable Feast

Birds in the rainforest don't just forage and feed in the canopy. This silhouette shows which birds and other animals dine where.

Defenses

As animals forage for food, mate, and go about their daily lives, most of them are in constant danger from predators who seek them as food. Consequently, animals have evolved a wide variety of defensive behaviors and structures to protect themselves.

- Autonomy: The gecko's tail breaks off, allowing it to escape its predator.
- Startle: The automeris moth flashes the bright colors and eyespots on its wings to startle and confuse predators.
- Spines: The freshwater stingray deters would-be predators with its prickly spines.
- Mimicry: Although harmless, this false coral snake looks like a creature that can cause pain or death.
- Crypsis: The vine snake looks like the branch on which it lies.
- Jump: When bothered, the purple-winged grasshopper takes off.
- Venom: The scorpion's sting is poison.
- Armor: The nine-banded armadillo's tough coat provides a moveable fortress.
- Flight: This black-cowled oriole escapes through the air.

Defense strategies:

Can you tell how each creature is defending itself?

Cooperation

These busy leaf-cutter ants are collecting leaves to use in their underground "farms." They are social insects living in colonies and cooperating to survive. Each member of the colony has a specialized task and would perish on its own. All members cooperating together function as a superorganism, that is, the colony as a whole behaves in many ways like a single organism. Each member does not carry out all the functions of courtship, defense, and foraging for food, etc. Instead, each member carries out some of those functions so that the colony, as a whole, can survive.

- The Queen: In the colony, the queen lays the eggs. There are males who mate with new queens during nuptial flights. And there are workers and soldiers, sterile females who usually do not mate or lay eggs, but do most of the work.
- Soldiers: Soldiers guard the queen and brood.
- Large Workers: Large workers cut leaves and protect the colony.
- Medium-sized Workers: Medium-sized workers collect the leaves, tend garden, and care for the brood.
- Small Workers: Small workers tend and cultivate the fungus beds and care for the brood. They also accompany the medium-sized workers riding "shotgun" to protect them from attacks of a certain kind of small fly. This fly lays an egg on the back of the medium-sized worker's neck while the ant has its jaws full of leaf, and can only protect itself with its legs. The fly's egg hatches into a parasitic larva which eats out the ant's brain. The small-worker bodyguard can ward off fly attacks by running back and forth on the piece of leaf carried by the medium-sized worker and snapping its jaws at the flies.

Underground Garden

Leaf-cutter ants live underground. They cover their nests with the earth they've excavated. There can be three to four million ants in one nest!

In their nests, the leaf-cutters energetically farm a certain species of fungus. They chew the leaves they collect to form a compost upon which the fungus can grow. The fungi produce masses of threads called hyphae which the leaf-cutter ants feed to their larvae. They never actually eat the leaves.

Social Insects

Honey Bees

The queen bee is the largest individual in the honey-bee hive and the only one who produces eggs. Surrounding her are workers who perform the many other tasks which are necessary for the colony's survival.

Army Ants

During their long marches, army ants sometimes create living suspension bridges with their own

bodies. The workers of the colony link their legs and form chains by hooking their tarsal claws together.

Wasps

Members of a paper-wasp colony construct a nest that shelters the queen and the offspring she produces. The tough, paperlike nest is made of the workers' saliva and wood pulp they have gathered. It consists of combs of symmetrical cells.

Termites

Termite workers use pellets of wood they have digested to cover an opening to their next in a tree trunk. The soldiers, with their large jaws, form a protective ring of guards around the workers.

Alcove 23: Partnerships for Survival

Partnerships for Survival

Just as the leaf-cutter ants and fungi to your left have formed a partnership, evolving behaviors and structures to each other's mutual benefit, all of life is interdependent. Each leaf-cutter ant has many interactions with other ants, with other animals, and with many plants each day. Some of those interactions are mutually beneficial. Some of them are one-sided. The leaf-cutter ant does not help the tree whose leaves it strips. The fly who lays eggs on the ant's nest does not help the ant. But the leaf-cutter ants and fungi could not exist without each other.

As it is with the ants, so it is with all of nature, including humankind. Animals and animals, animals and plants, plants and plants all interact in myriad ways within the web of life.

Here are a few of the more dramatic interactions within the tropical rainforest setting. It is important, though, to remember that each of the plants and animals here has many other interactions with many other organisms as it goes about its daily life. These represent only some highlights.

Moving the Seeds

Just as many plants can't pollinate themselves, most seeds can't move themselves either. But animals like this monkey can move seeds to new areas where they can germinate and grow. If the new plants can compete successfully with other plants for nutrients, water, and light, they will survive to reproduce.

The Pollinators

Pollen transferred from the stamen (male) to the pistil (female) of flowers is important in the reproduction of flowering plants. In some plants, this transfer occurs within the same flower. Many plants, however, need to move the pollen from their own flower to the flower of another plant of the same kind. And since plants can't move from one place to another themselves, bees, birds, bats, and other creatures move the pollen for them. The plants get to reproduce and the pollinators often get the food they need to power their flight and fuel their other life processes. Wind or

water can be a partner in this pollination process, too.

Many plants have evolved special features to attract animals. Color and scent are used to guide the pollinators to the flower. Nectar often serves as a reward and ensures the return of the animal to the flower. The promise of pollen can lure an animal as well. Often, the form or structure of the flower will discourage animals who will not pollinate the flower.

Ant Guards

This is a *Cecropia* tree. Without its colony of *Azteca* ants, it might be covered with vines and epiphytes, which are plants that grow upon plants. The weight of this mass of plants could eventually topple the tree. The ants patrol the trees that prune away vines and epiphytes. The ants will even drop down from the tree to attack a large animal that disturbs it, including a human trying to cut the tree down.

To maintain ant colonies, *Cecropia* trees have evolved structures called “Mullerian bodies” that provide the ants with fats, protein, and sugars which are their main source of food. The trees also provide homes for the ants in the large hollow stem lengths between the nodes where leaves are attached. These hollow internodes have regular thin spots through which ants can easily cut entrances.

Bee Trap

These male bees are busy collecting an oily perfume from the waxy surface of the bucket orchids. They store it in a pouch on their hind legs and later deposit it on a spot where a female will be attracted. They gather the orchid substance with great excitement and occasionally engage in aerial combat. Sooner or later, one of the bees is bound to fall into the flower's liquid-filled bucket. The bee will then be trapped. His only escape route is through a narrow tunnel in which pollen sacs will be attached to the bee's back.

If the bee falls into another orchid flower of the same species later, a pick-up hook on the ceiling of the escape tunnel will pluck the pollen sacs from the bee's back as it struggles to exit, and the flower will be pollinated. This partnership is mutually beneficial. The bees and the orchids help each other successfully reproduce.

A Day in the Life of a Butterfly

As with most living things, the passion-flower butterfly has many interactions with others of its species, with other animals and with other plants each day.

Butterfly Roost

This passion flower butterfly spends its night at a roost, resting on a dead twig or vine with others of its species. By selecting dead twigs, the butterflies may avoid both ants that patrol the green parts of the plant and larger predators that would not be supported on the fragile twigs.

The bright "warning" colors of the butterflies may also protect them by reminding certain predators that these butterflies taste terrible and should be left alone. The butterflies are distasteful because of chemicals in the passion vines that they fed on as larvae.

In the morning, the butterfly will fly off to look for passion-flower vines with tender new growth on which to lay eggs. It will also seek food plants. Passion-flower butterflies learn where resource plants are located in the tropical rainforest and visit these sites daily. This behavior is called traplining.

The Butterfly Connection

Passion-flower butterflies live a long time (for butterflies), often several months. They are the only butterflies able to feed on pollen as well as nectar. Pollen provides a rich source of amino acid to help sustain them and is important for egg production.

These wild cucumber vines are the source of nectar and pollen favored by the passion flower butterflies. The butterflies get food from the vines. But the vines get something, too.

The male vines occur singly and are widely scattered in the tropical rainforest. They generally produce only one flower at a time, and each flower lasts only one day. But one male vine may produce hundreds of flowers over its three year lifespan. Female cucumber vines are extremely rare and their flowers contain no pollen. So the female vines "mimic" the appearance of male flowers to attract the butterflies. If traplining butterflies who are carrying pollen from a male flower see the female flower and are attracted to it, pollination of the female flower can occur.

Beware, the Butterfly

It is time for the butterfly to lay its eggs. These tiny passion-flower butterfly eggs look harmless. But what hatches from the eggs can be harmful to the passion-flower vines on which they have been laid. The eggs will hatch into larvae which feed exclusively on passion flower vines.

To protect itself, the passion-flower vine has evolved some incredible strategies.

The Vine Defense

This vine has developed small, sharp, hooked hairs that kill the young larvae.

This vine has nectar-secreting glands outside its flowers which will attract ants, wasps, and flies that will feed upon the eggs and larvae.

You may have thought that this vine has butterfly eggs on it. But these are not eggs. They are nectar glands which have evolved to resemble eggs! This discourages the females from laying real eggs on the plants because there would not be enough food for more larvae.

These passion-flower leaves have come to resemble other more common rainforest plants that are inedible to the passion-flower butterfly.

An Uninvited Guest

When oropendola females are busy making their unusual hanging nests from palm fibers, the males stand guard, serenading all the while. But they let out a warning cry if danger threatens.

Sometimes, though, the males miss the cowbirds who come to lay their eggs in the oropendola nests. The baby cowbirds hatch before the oropendolas and keep away life-threatening botflies by eating the larvae on themselves and the young of their host birds. The cowbird gets a babysitter and the oropendola gets a bodyguard for its babies.

Biological Hitchhikers

The survival of some plants depends upon others in the American tropical rainforest. Many, like the epiphytes here, could not exist in the forest if they did not have other plants to grow upon.

Orchids, ferns, mosses, and tank bromeliads are epiphytes, or plants which use the surfaces of trees, shrubs, and lianas to hold them up where there is more light. They do not use the tree, though, as the source of their nutrition. Epiphytes play an important part in the forest by providing habitat for many small animals.

Parasites

Some plants growing on other plants are parasites. Parasites get nutrition from the plant they grow upon. Mistletoe is a parasite that grows on high canopy plants where there is plenty of light. While they are capable of making some of their own food from sunlight, they are still dependent on their host tree for much of their nutrition.

Alcove 24: Organisms and Environment

Living Things…

The Pattern of Life

Like all living things, an *Anolis* lizard's behavior has a purpose. Its action is not random. Every living thing is well integrated, or organized, within itself and within its environment. It must be or it cannot survive. There is coordination of many complex processes, all part of the pattern of life. This *Anolis* lizard spends a good deal of its time in the trees, high above the rainforest floor. Here, it may hunt for food, take a drink from the pool of water in the center of the bromeliad, or lay its eggs among the leaves of the bromeliad or other rainforest plant.

This male lizard is climbing up the tree trunk into the canopy, where it will encounter a female lizard of the same species.

Environment, hormones, and the sensory and nervous system interact to cause a coordinated sequence of behaviors.

Environment

1. Rainfall initiates a release of hormones in the male reproductive organs (a hormone is an organic molecule secreted in one part of an organism that regulates the function of another tissue or organ).

Hormones

2. Hormones produced by the male reproductive organs stimulate the brain to secrete hormones and activate sexual behavior.

Sensory and Nervous System

3. The presence of a female anole triggers courtship by the male.
4. The female responds to the visual cues given by the male, produced mainly by the dewlap which radically changes the shape of the male's body.
5. Male courtship is necessary to stimulate hormone secretion in the female to promote ovarian growth. If courtship is successful, it will result in mating and production of a fertilized egg.
6. Anoles lay one egg per clutch but females lay eggs more frequently with increased rainfall.

Environment, Hormones, and Sensory-Nervous System Interact

The tightly integrated series of events in the reproductive process has its basic beginnings on the cellular level. Cells are organized into tissues, tissues into organs, and organs into well-integrated systems within each organism. Each organism is integrated with others of its own species and the species population, as a whole, is integrated within its community or ecosystem. There is coordination of many complex processes, all underlying life. This is all managed through a close association between hormonal and nervous control systems.

Position is Important

Since plants cannot move about once rooted, response is primarily reflected in positioning of parts following growth pattern changes. Among the more obvious plant environment responses are those that relate directly to the direction and intensity of a stimulus. These responses are called tropisms (TROW-piz-ems). Some animals also respond to these stimuli. An animal response is called taxis (TAK-sis). Examples of stimuli which affect living things also are gravity, light, and neighboring objects.

Which stimuli affect the living things below?

The vine is responding to the neighboring object -- in this case, a tree. This response is called thigmo-tropism. It is a positive response involving the adhesion to or curling around by a plant shoot structure, such as a pad or tendril, to a contacted object. Scientists are still trying to figure out exactly how this tropism works.

The worm responds to light. This response is called photo-taxis. It is a total body movement of certain animals whose “nervous system” is tied to temperature, light, or chemical stimuli. The

response can be positive (toward the light) or negative (away from the light).

The stem responds to light. This response is called photo-tropism. Shoots show a positive response to light by bending towards the source. The lit side of the stem tip is activated to transfer its natural auxin (a hormone) content to the dark side causing the latter to grow faster and bending the plant towards the light.

The roots are responding to gravity. This response is called geo-tropism. Roots show a positive response to gravity (they grow toward the stimulus). This appears to involve a hormone called abscisic acid which restricts elongation growth on the lower side. Normal growth on the upper surfaces causes the root to bend downward.

...And Their Environment

Adapting to Extremes

Just as living things have partnerships with other living things, they also, in a sense, have a partnership with their environment, the place in which they live. If the place in which an organism lives is very cold, dry, or hot, the species must evolve adaptations to the extreme conditions surrounding it. And that takes energy. Each of the creatures below is well adapted for its environment.

Ermine (Polar Region)

The ermine needs its abundant coat of thick white fur, bushy tail, fur-protected feet and ears, and its black heat-absorbing nose to adapt to the extreme snow and cold of the polar region.

Mouse Opossum (Tropical Forest)

The tropical rainforest with its relatively constant levels of light, humidity, and temperature allows creatures like the mouse opossum to live without expending a lot of energy on specialized adaptations of form or function. The opossum does quite well with a bare tail, long bare ears, a pink nose and bare feet.

At least in part because living things have not had to put energy into adapting to extremes, there is an abundance of life in the relatively constant environment of the tropical rainforest.

Living Air-Conditioning Systems

Here are four creatures who are frequent visitors to the tank bromeliad in the plexiglass case to your right. Can you tell…

1. Which two bromeliad visitors have a temperature control system most similar to ours and maintain a high uniform body temperature?

2. Which two bromeliad visitors must take in a great deal of food to provide the energy to run their own self-contained "central air-conditioning" systems?

3. Which two bromeliad visitors can be as active in cool weather as in warm because their body temperatures stay the same?

4. Which two bromeliad visitors can maintain a high and uniform metabolic rate? (Metabolism is the sum of all chemical reactions occurring within a cell or an organism to keep it alive.)

If you answered hummingbird and bat for each question, you are correct. Birds and mammals can regulate their internal body temperature within a narrow range through their bodily functions and processes and are called warm-blooded or endotherms. A physiological process which helps us is perspiration.

Other creatures are cold-blooded, or ectotherms. Their temperatures can fluctuate in response to the temperatures of their surroundings. Many ectotherms regulate their temperatures behaviorally. For example, a butterfly may sit in the sun with its wings spread to get warm. To avoid overheating, it will fold its wings.

Many modern buildings have air-conditioning and heating systems to provide temperatures comfortable for us. The rainforest provides a similar service by giving shade and shelter to the creatures who live there. In addition, the rainforest affects weather formation and rainfall in its own biome and perhaps even globally. Still, living things must find a way to regulate their own internal body temperature. If that temperature becomes either too hot or too cold, the organism will die.

Tank Bromeliad
Watch Tank Bromeliad Video

This is a tank bromeliad. It is an epiphyte, or a plant that grows upon other plants. Tank bromeliads can be found clinging to trees high above the forest floor and they provide the stage for many dramatic happenings in the tropical rainforest. Can you find all the players in this bromeliad? Look for the poison frog, hummingbird, tree boa, spider, and mouse opossum.

There's More to the Bromeliad Than Meets the Eye
There are many bromeliad inhabitants you cannot easily see. They are very tiny, some so small you can only see them with a microscope. Who do you think they might be?

The Tank Bromeliad's Inhabitants

1. Rufous-breasted Hermit Hummingbird (*Glancis hirsuta*)
2. Cuban Anole (*Anolis equestris*)
3. Tree Frogs (*Agalychnis sp.*)
4. Poison Frog (*Dendrobates sp.*)
5. Damselfly Larva
6. Worms (*Turbellaria*)
7. Slugs (*Veronicellidae*)
8. Snail (*Drymaeus sp.*)
9. Land Crab (*Gecarcinus lateralis*)

10. Common Mouse Opossum (*Marmosa murina*)
11. Scorpions (*Scorpiones*)
12. Damselfly (*Zygoptera)*
13. Spider (*Selenops sp,)*
14. Tree Boa (*Corallus enydrus*)
15. Red Bat (Lasiurus borealis)

The Small Inhabitants

Here are some bromeliad inhabitants that are very small. Dragonfly larva, midge larva, rat-tailed maggot.

The Microscopic Inhabitants

Here are some bromeliad inhabitants that are microscopic. They can be found in a drop of water. Daphnia, diatom, algae.

A Micro-Environment High Above the Forest Floor

Perched in the tropical rainforest canopy, the bromeliad lifts to the sunlight not only its own leaves and flowers, but also a series of tiny bonds within the bases of those leaves. These ponds provide a mini-water environment high above the forest floor. It is a protected environment, relatively stable and predictable and crucial to the organisms who live within it. In fact, we can find here a microcosm of life processes that are occurring throughout the rainforest.

Creatures like hummingbirds can find some of the great quantity of food they need to maintain their body temperature. The water which provides the home for the poison frog's tadpole inspires the long climb of the parent up the tree. And conditions are so favorable throughout the tropics that more than 340 species of organisms have been found to call this tiny niche of the rainforest home.

An Intricate Ecosystem

Energy originally trapped by the bromeliad and other green plants is passed along to other organisms, especially animals, which feed on the leaves, or get nectar from the flowers, and so forth. Such animals themselves are also preyed upon by others, thus transferring the energy along another step. Decaying plant material is eventually broken down into its organic and mineral components by still other organisms, the decomposers, who thus fill their own energy needs. These breakdown products are available once more to the primary producers, the plants. The cycle can start again.

Harvesting the Sun
Bromeliads are important as homes to many rainforest creatures, but they are important for another reason. If it were not for bromeliads and all other green plants on this planet, we would not exist! Do you know why?

Our existence depends upon energy. Every life process our bodies carry out, whether we are awake and active or asleep and dreaming, requires energy. We even need energy to breathe. And all of our energy comes from the sun.

But we cannot process the sun's energy directly. Only green plants can harvest the sun's energy and, through a chemical process, turn it into food from which we, and all other animals, can get energy. We get energy from the sun by eating green plants or by eating animals that eat green plants.

Nutrients for All

The roots of plants are also for getting nutrients. They tap into the minerals of soil to do this. The process is called nutrient procurement. Nutrients are the building materials cells need to grow, and minerals are one kind of nutrient.

In the bromeliad, nutrient procurement includes a specialized ability to absorb nutrients from rainwater directly as well as from the mat of vegetation the branch. In a sense, the whole carpet of epiphytes and the debris it collects becomes the “perched soil” of the canopy.

The branches of trees hosting bromeliads can tap into the cushiony mat of live and decaying epiphytes to get nutrients by means of their adventitious roots, roots that you would not expect to find so high above the ground. This supplements the nutrients the trees get from the soil of the forest floor in the conventional manner. Animals get nutrients by eating plants and/or other animals.

How Do Green Plants Harvest the Sun?

Steps in the process called photosynthesis:

1. Sunlight strikes the green leaf.
2. Within each leaf cell are hundreds of chloroplasts which absorb light energy.
3. In the chloroplast, chlorophyll uses the light energy to split water molecules into hydrogen and oxygen.
4. Chemical energy is released when the water molecules are split. This energy is stored in phosphorous compounds called ATP molecules.
5. The energy in the ATP molecules is used to combine carbon dioxide and hydrogen to form simple sugars.
6. The simple sugars become the stored plant food from which we, and all other animals, get energy.

How is the Energy Used?

How do the bromeliad and other green plants use the energy they harvest from the sun? If you answered to put out roots, to produce flowers, to grow taller, or to reproduce, you are right on all counts. In fact, every life process requires energy, the very energy that is produced by photosynthesis and stored by the cell in its carbohydrate, protein, or lipid molecules.

Energy Breakdown and Release

The energy trapped as stored food is of no use unless some of it is released so that each plant cell can carry out its daily activities. This breakdown and release of energy from food molecules by an organism is called cellular respiration. It is most efficient if it takes place in the presence of oxygen, one of the products produced by plants in the process of photosynthesis.

Every living thing depends upon cellular respiration. Our cells are carrying out this process right now, and so is the hummingbird who has visited the bromeliad flower to sip the nectar and get the energy it needs for life. Floral nectars are rich in carbohydrates, fats, and other nutrients.

The hummingbird will use some of the energy to power its flight, to gather food, and reproduce. Some of its activities, like flight, require a lot of energy. Other activities, like sleeping, require less.

The Waters of Life

Life begins in water and water must be present for life's continued existence. Every living thing faces the challenge of maintaining an internal balance between water uptake and output. The roots are responsible for water uptake in green plants. A path of the arrows in the bromeliad show the directional flow of the water through the body of the plant. Follow the water's path from the roots to its final loss through the surface of the leaves.

The process by which water moves up through the plant to exit the leaf surface in the form of water vapor is called evapo-transpiration. This constant water loss maintains a suction force that continuously lifts more water. The process cools the plant as well.

Alcove 25 - Scientist in the Canopy

Scientist in the Canopy

There is much more to the tropical rainforest than meets the eye. High above the forest floor, in the forest layer called the canopy, many plants and animals live out their entire lives. Monkeys swing from tree to tree. Tiny shrimp live in the pools of tank bromeliads, plants whose roots never touch the forest floor. Iguanas defend their territories, mate, and reproduce, rarely leaving their arboreal homes.

In order to understand more about the world, scientists observe nature in the field and collect specimens for identification, study, and cataloging. This canopy field station allows scientists to study the tropical rainforest high above the first floor. This biologist is observing a colony of Montezuma oropendolas, where the male birds are courting the smaller females.

This scientist is collecting specimens for the Museum. But who takes care of them once they arrive? Watch the video below to learn what it takes to be a Collections Manager.
Collections Manager Video

Slow Sloth

The three-toed sloth uses a strategy of slowness to survive in the rainforest. Vegetarians who dine almost exclusively on leaves, sloths need to conserve energy whenever they can. The leaves of many tropical trees are hard to digest, low in protein, and do not provide an animal with much energy. But the sloth doesn't use much energy.

In addition to moving slowly, the sloth conserves energy in other ways. Its coat is a good insulator and helps in conserving body heat. And the three-toed sloth has nine neck vertebrae rather than the seven found in most mammals. This lets it feed by swinging its head around instead of its body.

Thank you for visiting the *Costa Rican Rainforest*! Don't forget toTest your rainforest knowledge with this downloadable trivia game.
MPM Trivia PDF

Video Scripts *for reference only*