ART TO ZOO

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October 1988

Going . . . Going . . . Gone? Tropical Rainforests—How They Work, What They Do for Us, What's Being Done to Them. . . .

Jorge Orejuela, World Wildlife Fund—U.S.

Where there is a gap so the sun can get in, plants grow very thick, as in this rainforest in Colombia.

Teacher's Background

Diversity and Survival

Tropical rainforests—thought to be the oldest land-based ecosystem on earth . . . certainly the most diverse . . . the richest in species and in interdependencies! Rainforests are where you find flowers shaped like insects, vines as thick as a man's thigh, violets as big as apple trees, fish that eat fruit, snakes that "fly" by flattening out and gliding through the air, butterflies so brilliant they can be seen from airplanes. . . .

Yet all these astoundingly diverse forms and habits do one thing: *they help rainforest creatures survive.*

In temperate climates, plants and animals must spend a large proportion of their resources coping with freezes and droughts. But in tropical rainforests—where the average temperature is a balmy 75 degrees Fahrenheit and it never freezes, and where at least 60 inches of rain (and often much more) fall each year—the main obstacle to survival is competition from other species.

Resources are finite, even in an environment as lush as a rainforest. Other kinds of plants or animals are always competing for the food that an organism wants to eat . . . for the space it needs to occupy . . . for the water or sunlight that it must have to live.

In an overcrowded room where all the chairs are taken, you might make a seat for yourself by turning a wastebasket upside-down. Similarly, rainforest species find ways to get what they need by putting *every* resource to work.

Rainforest plants and animals have evolved digestive systems that can handle toxic foods; techniques to make uninhabitable places into homes; disguises that keep them safe among predators; tricks to lure prey and pollinators close; intimate relationships with other species that help both survive. . . .

Rainforest plants and animals also reduce competition by dividing up the available time and space and food. Some rainforest creatures are active by day, others by night. Some live high up, others near the ground. Some seek out dark crannies, some live out in the open. Some are adapted to life among the leaves, others to foraging along the ground. If everyone lived in the same part of the rainforest, or ate the same food, or hunted at the same time, more species would be competing for fewer resources.

Rainforests are ancient. They have probably been around for about 60 million years, plenty of time for a tremendous number of species to evolve to fit every available niche. Even though rainforests occupy less than 7 percent of the earth's surface, almost half of all species of living things are found here—perhaps five million kinds of plants and animals, perhaps far more.

Take trees, for example. A tropical rainforest contains an average of between 20 and 86 species of trees per acre—compared to about 4 species per acre in a temperate zone forest.

There are *more species,* but often *fewer individuals* of each species. In a rainforest, you might easily cross an acre and never see the same kind of tree twice. This is very different from a temperate zone forest, where you expect to keep passing the same kinds of trees.

Lush, but Fragile

These facts help explain why rainforest species are particularly vulnerable to extinction. When there are few individuals in a species, it doesn't take the destruction of very many to wipe out the whole population, or to scatter the population so thinly that individuals can no longer find each other to reproduce.

Moreover, many rainforest species are found in only one very small area. For example, over half of the kinds of mammals in the Philippines are found nowhere else in the world besides that country. If a plant or animal like this is wiped out—if, for example, the one rainforest in which the species lives is cut down—there are no other populations anywhere from which the species can re-establish itself.

Finally, many rainforest species are vulnerable to extinction because they depend on other species in extremely specific ways (the articles in the Special Supplement describe a number of such partnerships). For example, the approximately six hundred kinds of fig tree depend on different species of insect to pollinate them. Whenever this kind of partnership exists, the destruction of one species will also wipe out the other.

Another important factor in making rainforests fragile is that most are growing where the topsoil is thin and poor. How then can such luxuriant vegetation grow? Through frugality and efficient recycling. Almost nothing is wasted in a rainforest, even temporarily. The nutrients that plants and animals must have are recycled fast. A fallen leaf in a rainforest decomposes in about six weeks (compared to about one year for a fallen leaf in a temperate zone deciduous forest, and about seven years in a northern pine forest).

This means that, in a rainforest, most of the nutrients are stored in the plants rather than in the soil. When rainforest trees are cut down and hauled away, the nutrients they contain are also being permanently removed from the rainforest system. Even when the trees are burned after being cut down, their nutrient-rich ashes make the soil fertile for only a year or two before the rain washes them away.

These then are some general facts that help explain how rainforests can be simultaneously lush and fragile. With these facts in mind, let's now take a look at the rainforest itself—at the plants and animals that make it up and at its organization into several interconnected layers.

Rainforest Layers

The top of a rainforest is a different world from the bottom—primarily because the main layer of treetops forms a barrier that cuts off most of the light and wind, and a good deal of the water, from above.

We will be referring to four layers. From top to bottom, they are: the emergent layer, the canopy, the understory, and the forest floor. (The dotted lines on the Pull-Out Page diagram show where the breaks between

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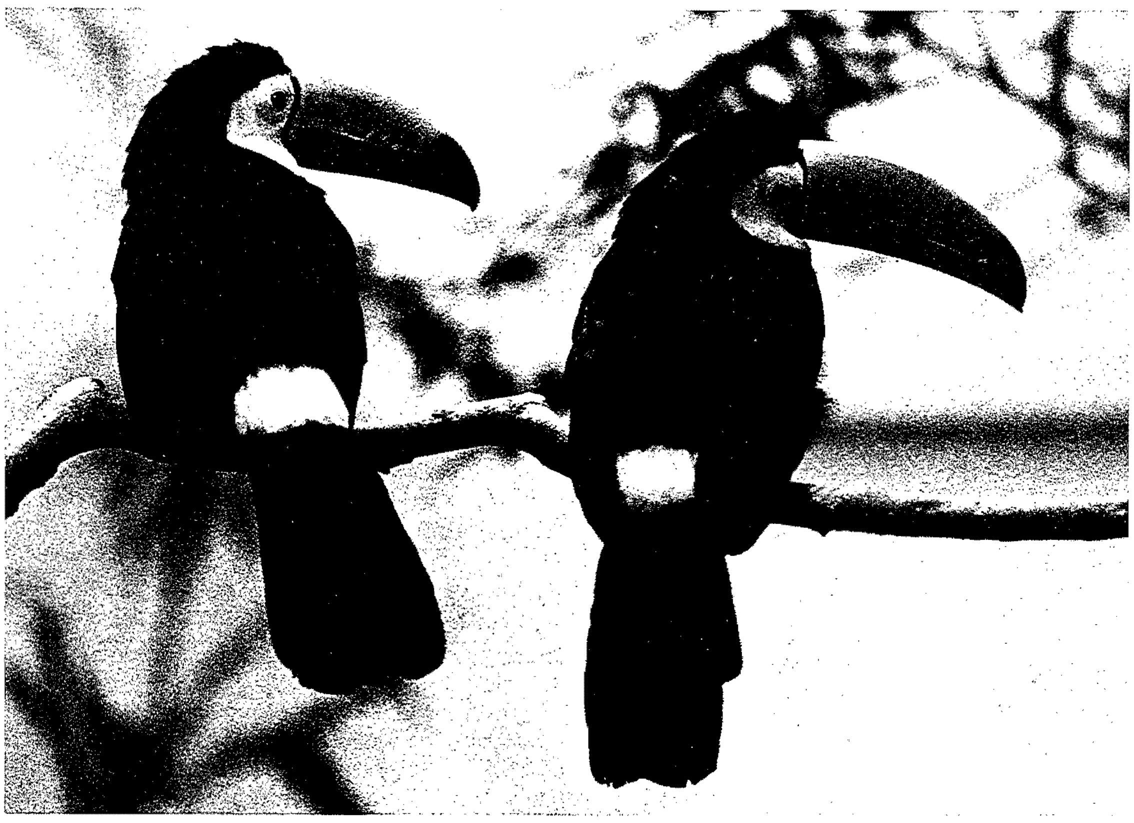
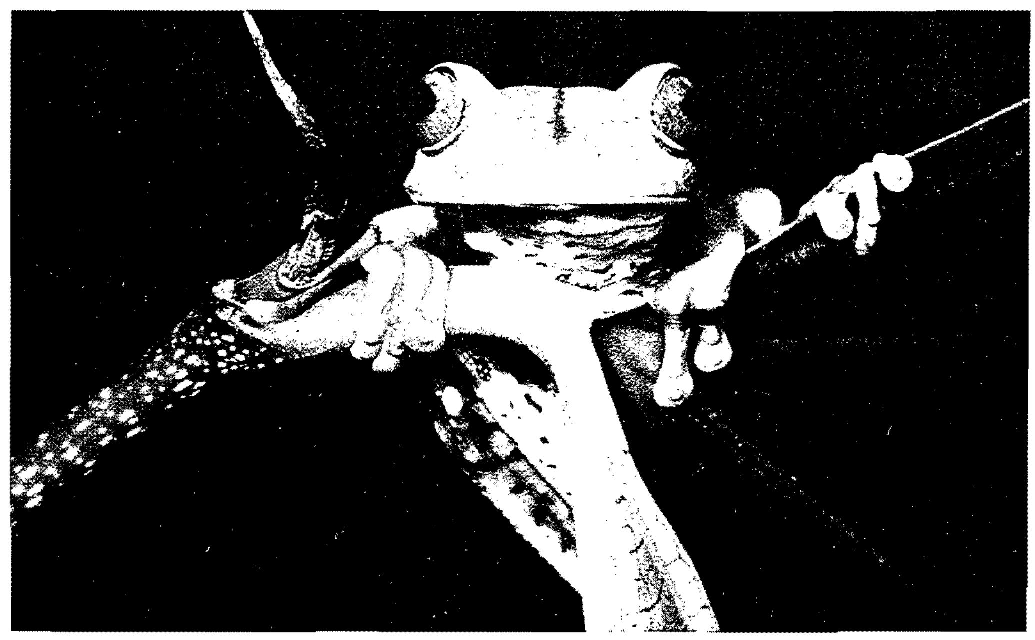


With its big, bright beak, a toucan is easy to recognize. Jessie Cohen, National Zoological Park, Smithsonian Institution

George Angehr, Smithsonian Tropical Research Institute

Bully, a hand-raised howler monkey whose dawn howls are the alarm clock for many scientists working at the Smithsonian Tropical Research Institute, in Panama.

Bat preparing to eat fruit. George Angehr, Smithsonian Tropical Research Institute



A tree frog's feet help it grip the branches. Andy Young, World Wildlife Fund—U.S. [illegible]

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these layers are.)

Though the layers are related, each is a distinct world. And the plants and animals that live in each* will need characteristics that suit them to the unique conditions of their particular surroundings.

• ***Emergent layer.*** At the very top of the rainforest, a few trees considerably taller than all the rest stick up out of the greenery like giants looking over the heads of a crowd. These scattered tallest trees form what is called the emergent layer.

These emergent trees, protruding as they do each at some distance from neighboring emergents, bear the full brunt of all extremes of weather. Winds toss and churn them. The tropical sun beats down on them, drying them out. Rainstorms pummel them. Up here, temperatures drop from hot noons to cool nights, and rise again.

To thrive above the canopy, plants and animals must be adapted to a bright, open, changeable world. Between rainstorms, the climate here is often dry, because of the bright sun and strong winds.

Emergent trees cope with this dryness by producing tough little leaves whose small surface area and waxy coating keep evaporation to a minimum.

These emergent trees also use to full advantage the resources that these heights offer. They make the most of the open space that surrounds them by spreading their foliage out wide so their leaves catch as much sunlight as possible.

They make use of the wind to disperse their pollen and seeds. Many emergent trees produce seeds with wings, so the wind can carry them away from the ground directly below, where they would be competing with the parent tree for food and water.

For emergent-level animals, sheer size is an important factor. Many of these topmost branches could not bear the weight of a large animal, so none make their home in the tallest treetops.

Not surprisingly, many of the creatures that live up here move around by flying or gliding. The top predator up here is a flier: the harpy eagle, a fierce hunter perfectly adapted to life lived from a home base in these tallest rainforest trees.

A few powerful wingbeats carry it from one treetop to another as it seeks its prey, its mottled coloration blending in perfectly with bark and leaves.

Since much of its view downward is obscured by branches, it relies on excellent hearing, as well as vision, to locate prey—a capuchin monkey, perhaps, or a sloth, a macaw, or a snake.

The harpy eagle's long tail and short, broad, rounded wings suit it to treetop hunting. It can drop almost vertically. It dives and twists through the leaves in pursuit of its prey, seizing it finally in its powerful talons. Though the harpy eagle weighs only about 20 pounds, its feet are almost as large as a man's, armed with claws that stab inward as it squeezes its victim . . . which it then carries back to its nest to eat at leisure.

Pygmy gliders, from New Guinea, have a completely different approach to getting what they need at the top of the rainforest. This tiny mammal (no bigger than a shrew) is protected from predators by the secretiveness of its life. Under cover of darkness, it feeds on insects, sap, and buds in the emergent treetops. By day it rests packed together with others of its kind in a leaf-lined hole in a tree.

Though it has no wings, a pygmy glider can move around easily up here. It has flaps of skin between its front and rear legs. When it extends its limbs, it can glide forward and downward, steering with its hind legs and its tail (which looks very much like a feather).

Its feet give it a safe grip when it lands on a branch. Each finger and toe ends in a short, sharp claw. And, to increase traction, its paw pads have grooves, a little like the treads on a running shoe's sole.

The pygmy glider is far from the smallest creature up here. The intensely colored flowers on the tall treetops glow and beckon. Butterflies flutter among them, around 200 feet above the ground, the way temperate zone butterflies visit wildflower after wildflower in a ground-level meadow. Male Morpho butterflies gather up here to attract females. They are so brilliant a blue that low-flying pilots have caught sight of them from airplanes.

• ***Canopy.*** The canopy—where more species live than anyplace else in the rainforest—is the dense layer of greenery about 20 feet thick formed by the next tallest trees. It acts like a roof over the rest of the rainforest.

This roof is not, however, solid like the roof of a house. It is partially permeable. Its leaves and branches absorb and deflect much of the sunlight pouring downward, letting only a little through. Result: the lower parts of the rainforest are dim and greenish, with only scattered flecks of direct sun.

In much the same way, the canopy shuts out most wind and breaks up falling raindrops. A heavy downpour beating onto the top of the canopy roof has, by the time it reaches the lower levels of the rainforest, been turned into a fine rain accompanied by sheets of water streaming down the tree trunks.

When you enter the canopy you leave behind the open changeable emergent world, and enter a very different place: much darker and more unvarying, a place of dense enclosing greenery and high humidity.

Canopy trees are adapted to this humidity. Their leaves are remarkably similar from species to species, with pointed "drip tips" like tiny spouts and glossy hairless surfaces that help water roll off easily. Drying off fast is important because doing so discourages the growth of the tiny lichens, algae, and mosses that, in this warm moist environment, are prone to spread over leaves' surfaces, stealing their light and blocking the openings through which they breathe.

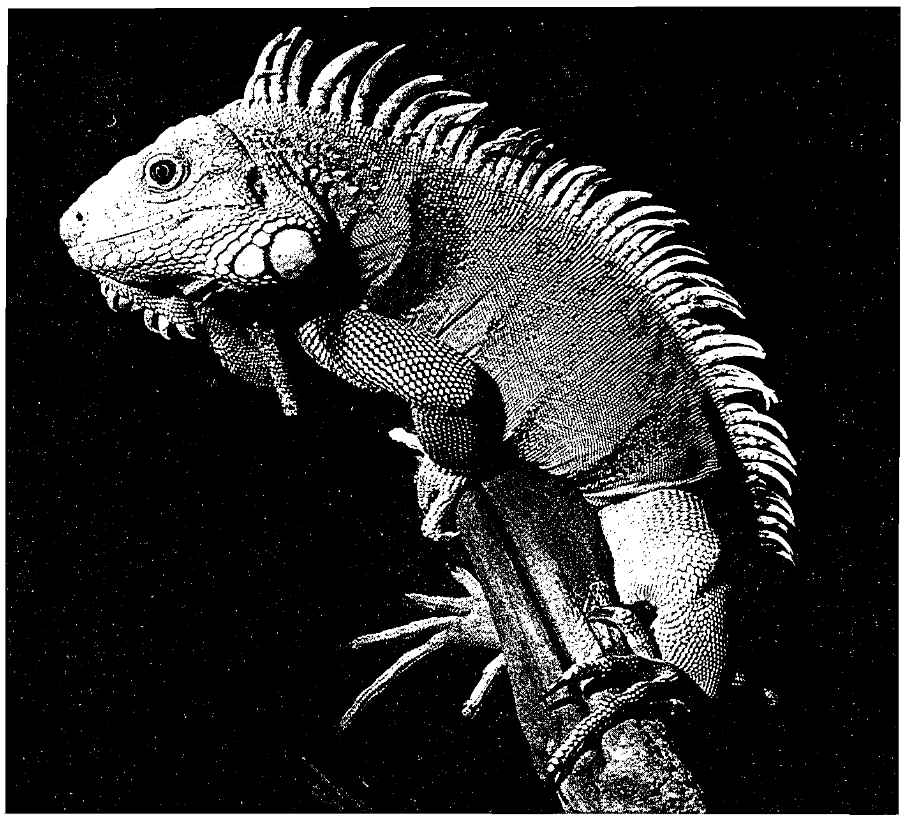
The air is very still inside the canopy, so most plants here rely on animals, not wind, to disperse their seeds. To get animals to perform this essential service, plants often encase their seeds in succulent fruit. A large fruit with a large seed inside falls to the ground and the fleshy fruit is eaten—with luck after being carried off to a different place. Smaller fruits containing many tiny seeds may be eaten on the spot. But these seeds too are likely to end up in a different part of the forest, because they have tough coverings that allow them to pass unharmed through the animals' digestive systems. When you see a supermarket display of tropical fruits like mangoes and papayas, what you are looking at are the rewards that tropical trees offer to animals for helping them to reproduce.

At any time, some of the canopy trees are likely to be in blossom or in fruit. Crowds of birds, monkeys, and other animals that eat nectar, fruit, seeds, or leaves have only to follow this moveable feast.

If you were up here you might catch sight of a parrot hanging by one foot as it used its other to hold a piece of fruit it was gnawing. Or you might hear the croaking calls of some toucans hopping around in the branches.

Large and strong enough to be safe from most predators, a toucan can advertise its presence with gaudy feathers and a beak so bright it looks painted. It can use this huge beak, almost as long as its body, to signal a mate. A toucan picks fruits and berries with the tip of

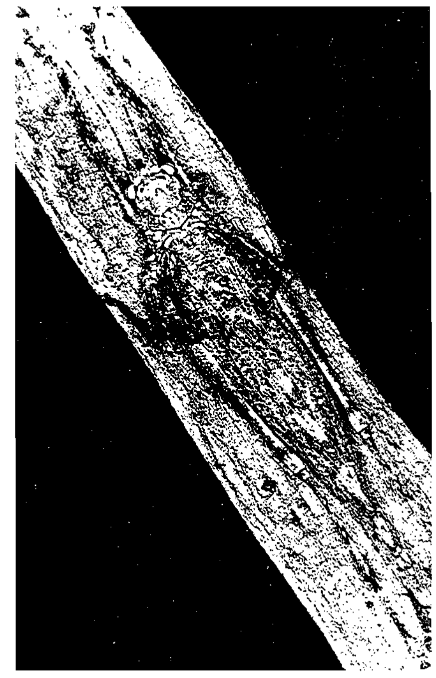
*The animals described in what follows do not necessarily spend *all* their time in one layer of rainforest. But even those that move up and down regularly must be equipped for survival wherever they are. Note also that the animals described here are found in *New World* rainforests unless otherwise indicated.



Iguana. Researchers at the Smithsonian Tropical Research Institute have found that iguanas return to the same nest site on a sandy beach each time they breed. The rest of the time they live in the canopy treetops, where they feed on leaves. Jessie Cohen, National Zoological Park, Smithsonian Institution

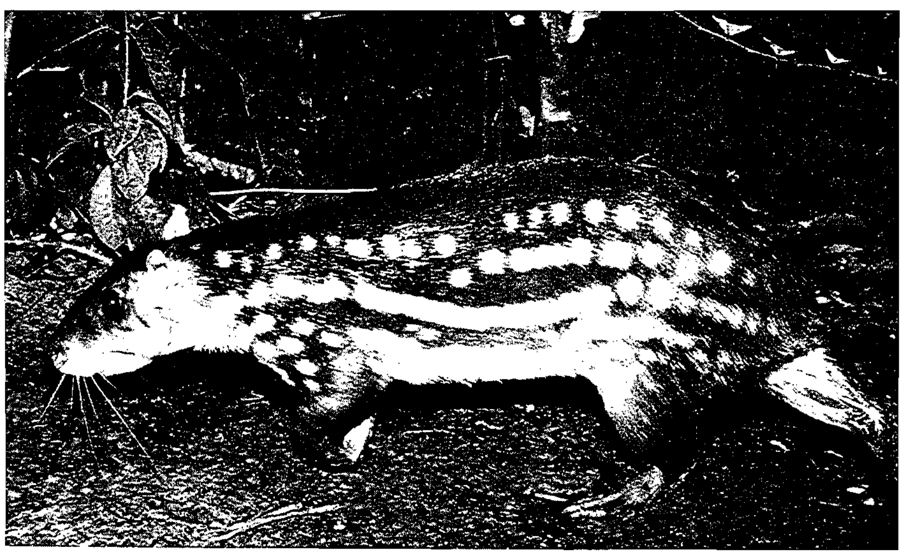
Kerry Dressler

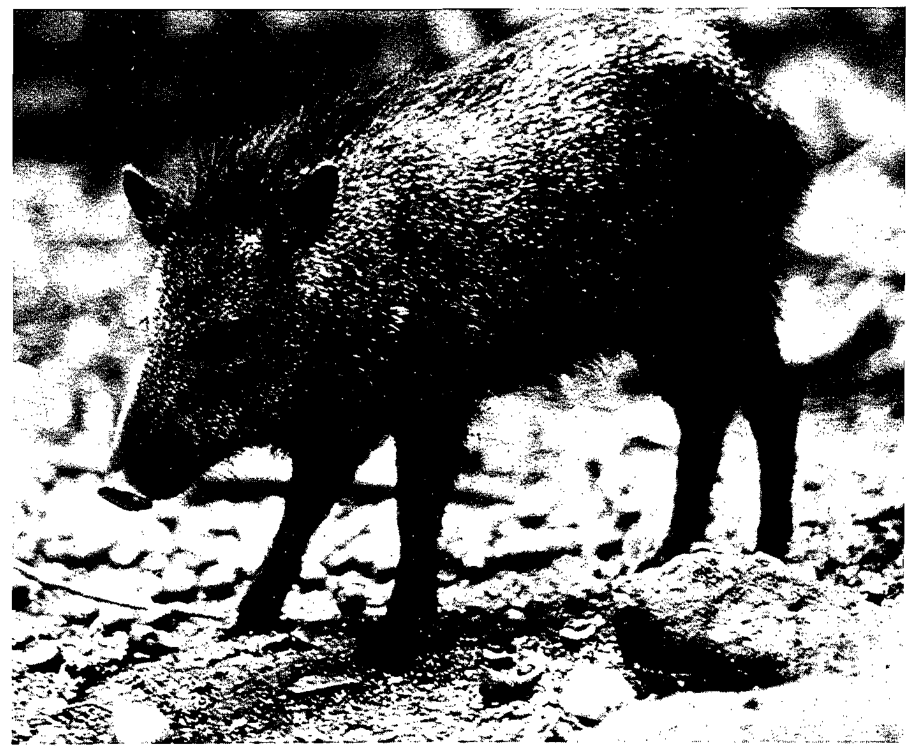
They come big in a tropical rainforest! A giant earthworm from Panama.



Michael H. Robinson, National Zoological Park, Smithsonian Institution

Can you find the katydid on this branch?





Nicholas Smythe, Smithsonian Tropical Research Institute

Two ways to keep safe on the forest floor: Pacas (left) forage at night, secretively and alone. Peccaries (right) forage in bands by day, while individuals stand guard.

this beak . . . then tosses the tidbit back into its throat, like a person throwing grapes into the air and catching them in her mouth.

Many species of monkeys live up here too—spider monkeys, howler monkeys, and sakis. . . . They move through the canopy foliage, using their long, prehensile tails to free their hands to pick fruit and other edibles.

Canopy animals like these often follow regular routes through the thick greenery. They have paths that lead to places they visit regularly: to food sources, or safe hiding places, or jumpable gaps. A "highway branch" tends to be barer than its neighbors, very likely coated with only a thin layer of moss, while all around epiphytes* grow thickly. Even tiny leaf-cutter ants will prune away vegetation that threatens to overgrow their regular paths along branches.

At sunrise and sunset, the howler monkeys troops call from the treetops, asserting their canopy territories. They have an extra large larynx that allows them to produce calls that can be heard over a kilometer away. Since the dense foliage up here screens visual signals and muffles sound, communication among canopy animals can be difficult. A loud voice is an asset—particularly a voice in the low frequency range (like a foghorn), which carries far better than higher frequencies through the thick leaves and branches.

But vertebrates like the howler monkeys constitute only a tiny minority of canopy creatures. Insects form the vast majority. Considering that scientists have found over 950 species of beetle *on one tree* alone (in Panama), you can imagine how crowded the canopy is with tiny invertebrates, many of which are tropical varieties of insects you are familiar with, like bees, ants, wasps, and butterflies.

Of course, these insects attract animals that eat them—like the dwarf anteater, for example. This creature, about the size of a squirrel, is toothless but has a long sticky tongue to suck up ants and termites. It is well equipped for life in the trees. Its prehensile tail is strong enough to hang its whole body from, and its feet are adapted to climbing.

And if you were in the canopy of a Malaysian rainforest, you might come across one of the most surprising creatures of all—the paradise tree snake, which appears to fly through the air. Actually it is gliding, not flying. It launches itself from a high branch, flattens out its body, and sails through space, making swimming motions to steer. . . a handy way to get around in a world over 100 feet above the ground.

• ***Understory.*** Some way below the bottom of the canopy is the understory, a layer made up of young trees, shorter species of trees, shrubs, and soft-stemmed plants. The understory varies a lot from rainforest to rainforest. But everywhere it is even darker and stiller and more humid than the canopy above it.

Many familiar houseplants are native to this part of the rainforest (philodendrons, zebra plants, and prayer plants, for example). These plants can thrive in your living room as well as in the understory because both places are low-light environments.

Understory plants have to find ways to advertise their flowers, so that the animals and insects that carry their pollen can find them in the dim light. Often these flowers are large and pale so they can be easily seen. Frequently, flowers grow directly on the trunks of trees, making them easier to find than if they were tucked away among the leaves. Understory blossoms also often advertise themselves by producing a strong smell suited to the particular tastes of the pollinator the plant depends on. Flowers pollinated by hawkmoths, for example, have a heavy, sweet fragrance, while those pollinated by bats have a meaty, sweaty odor.

In this dim, leafy world with its poor visibility, disguises can be very effective—and are much used. An insect may look like a stick or a leaf, a poisonous animal or a bird dropping. . . . As long as it is unnoticed or is considered dangerous or inedible, it will probably be safe.

Most reptiles living in the rainforest understory are camouflaged to some degree, as protection from predators like coatis or eagles. Many tree snakes, like the emerald tree boa, are bright green to blend in with the foliage (while their ground-level relatives are brownish to match the dead leaves on the forest floor).

This helps a snake avoid being eaten. It also helps it catch the food it eats. A camouflaged snake is almost invisible as it lurks—until its prey passes by, and in a flash it strikes.

Mammals too often have markings that blend into the understory foliage. A jaguar is hard to see as it waits high on a branch to drop onto the back of passing prey: its spots make it look like just one more variation in the dappled leaf light.

But the understory space is not completely filled with leaves and branches. Bats, birds, and insects can frequently fly more freely over longer distances down here than they can in the canopy above . . . so animals that eat these fliers are attracted to this part of the rainforest. Spiders, for example, stretch their webs across flight paths, catching insects and sometimes even bats and birds.

The humidity of the understory suits amphibians like salamanders and frogs. They cannot survive if their skin dries out, and most species must lay their eggs in or over water. Tree frogs have evolved feet with tiny suction pads covered with a sticky mucus that helps them hold onto branches. They move easily up and down rainforest treetrunks, usually under cover of darkness, to escape their predators.

• ***Forest floor.*** At ground level, the rainforest is very dark. No more than a fiftieth of the light from above penetrates this far down. The humid air is almost completely still.

It's easy to walk down here. Your path isn't blocked by flowering plants, because it's too dark down here for most to grow.

Nevertheless, if you were walking through a Southeast Asian rainforest, you might come across the world's largest flower. It is called *Rafflesia,* and can be up to three feet across. The *Rafflesia* plant is a parasite that lives inside the roots of vines. The only part that shows outside is the flower itself, which you would not be tempted to pick: it smells of rotting meat, to attract the flies that pollinate it.

Most of the vegetation down here consists of fungi and other plants that live off the thin layer of decaying leaves and other matter that has fallen from the trees onto the ground.

This decomposing litter is a source of food for all kinds of small invertebrates like termites and millipedes. Countless centipedes, cockroaches, scorpions, slugs, earthworms, and beetles live here under stones and leaves and logs.

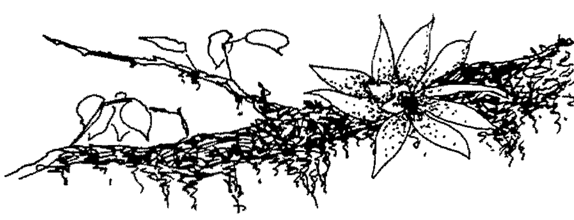
These creatures, along with the edible roots and tubers underground, make the forest floor a rewarding habitat for animals that forage for their food . . . the giant armadillo, for example; whose front feet are equipped with huge curved claws for digging beetles, worms, and larvae out of the ground . . . or peccaries (wild relatives of pigs), with snouts that sniff out underground shoots and bulbs.

It takes time to dig food out of the ground, so foragers are vulnerable to surprise attack. Peccaries protect themselves by feeding in groups, while one or two individuals stand guard. Smaller animals are more likely to hide under roots until the threat is past.

*See definition in "Piggyback in the Rainforest," on page 4.

Special Supplement

Many thanks to the Smithsonian Tropical Research Institute (STRI), whose generous contribution made this Special Supplement possible. STRI scientists made many of the research discoveries on which the materials in this issue are based.



Piggyback in the Rainforest

A rainforest looks like a rainforest partly because of all the plants growing on other plants there. A great many of these are *epiphytes,* plants that use other plants as support . . . but that don't use them as food (the way a *parasite* would).

In rainforests, tiny epiphytes like algae, mosses, and lichens grow on the surface of leaves. Larger epiphytes like ferns, bromeliads, and orchids often make their homes on tree branches or trunks.

The Epiphytes' Point of View

One main reason they do this is to get sunlight. How much easier it is to begin life in a tiny bit of soil where two branches meet in the sunshine of the upper canopy . . . than to have to struggle all the way up from the darkness at the bottom of the forest.

There are other advantages to living up here: wind to disperse the epiphytes' seeds, for example, and canopy animals like bats, birds, and bees to carry the epiphytes' pollen.

But treetop life has drawbacks too. The main one is lack of water. Rain pours down and is gone. Epiphytes have no roots in the ground to suck up water lingering there.

Epiphytes have a variety of ways of dealing with this water problem. Some epiphytes have fat stems or thick leaves to store water in. Others have pores they can close to keep water from evaporating. Some are even shaped to be living water storage tanks.

Tank Bromeliads

The thick leaves of these epiphytes form a hollow that can hold water—one kind can store as much as 12 gallons!

These tanks increase the plant's supply of nutrients as well as of water. They do so by providing a place where water-loving creatures can live. These creatures in turn supply the nutrients.

Dust, animal droppings, dead flowers, and leaves fall into the bromeliad pool and sink to the bottom. They are the basis of a whole miniature ecosystem. Bacteria and tiny one-celled animals feed on the decaying matter, and in turn are food for slightly larger animals. Mosquito larvae, dragonfly larvae, meat-eating beetles . . . all feed in the pool and leave their wastes there.

These creatures are prey to vertebrates like birds, mouse opossums, salamanders, and frogs. They come to the pool to eat and the salamanders and frogs also lay their eggs there.

The wastes produced by all these creatures are full of minerals that dissolve into the pool, where they are a rich source of nutrients for the bromeliad. Tank bromeliads are another example of the trade-offs between species that are so common in rainforests.

The Trees' Point of View

But what about the trade-off between epiphytes and the trees they grow on? We've seen the advantages the tree offers the epiphytes—a good berth in life, a sun-drenched platform. But what do the epiphytes offer the tree?

Much less. They may contribute nutrients: sometimes a tree will produce roots that grow through the air, high up, and reach into the litter in which the epiphyte is growing.

But in general epiphytes are a disadvantage from a tree's point of view.

As rain falls through the canopy, epiphytes remove from it nutrients that the tree could have used. Moreover, small epiphytes like mosses and lichens cut down the amount of light available to the leaves they are growing on. Large epiphytes block out the sun.

And the sheer weight of thousands of epiphytes (especially after a rainstorm) is a tremendous load for a tree. To hold up this burden, a tree must use its resources to grow thicker. If it isn't massive enough, it will be torn down by the extra weight.

So the trees fight back, in this struggle for survival. They grow leaves whose shape and surface texture help them to shed water fast. They produce smooth bark for the same purpose. Some can even shed their bark off in flakes to get rid of epiphytes. And some trees have bark that contains chemicals that keep lichen and algae from growing.

Kjell Sandved, National Museum of Natural History, Smithsonian Institution

Epiphytes grow on tree branches wherever they can find a spot.

Ant Snapshots

Ants are little, but there are a lot of them! If you could put all the ants in a tropical rainforest onto a giant scale, they would weigh more than all the animals with backbones there.

Because there are so many of them, and because they are often partners with other plants and animals, they are very important in rainforests. Here is some information about how two kinds of ants live.

Army Ants

Here come the army ants. If you are an insect, look out! Millions of ants may be in the column of raiders that is advancing through the rainforest, pinning down and cutting up every small creature that cannot get away. The swarm changes shape as it advances, but it may fan out as it moves until it is as wide as 100 feet at the front.

Army ants don't spend all their time on raids like this. They will stay in one place for almost three weeks. Eggs are laid there.

It is after these eggs hatch, producing larvae, that the raid begins—to feed the hungry young.

These raids may last a couple of weeks. When the ants are on a raid, the column advances by day. At night, they create a temporary nest with their bodies. The ants hook their claws together so their bodies form a living shield. Inside, the larvae and queen are kept safe. The army ants spend each night that way, and then in the morning they move on.

This is how the army ants make sure that they can successfully raise their young. But as is typical in rainforests, the lives of other species are connected with those of the ants.

For example, there are beetles, wasps, and millipedes that imitate the smell of the army ants. Ants don't see well. They communicate with each other mostly by smell. So when these other insects imitate the army ant smell, the ants think these strangers are part of the swarm and do not attack them. That way these other insects can safely do the eating without doing the hunting.

The best known camp followers are the antbirds. Sometimes as many as ten different kinds will follow a column of army ants, flying along above the front of it. These birds do not eat the ants, but feed on insects the ants have caught and on insects that are trying to escape from the ants.

The chain of connections goes even further. There are butterflies that flutter around army ant columns. What they are interested in is the antbirds' droppings.

Even rainforest people have found ways to use the army ants, some of which have huge pincerlike jaws. These jaws are so big and strong that Indians in South American rainforests sometimes use them to clamp wounds shut, the way our doctors use stitches. (The ant is killed after it has bitten the wound closed.)

Leaf-cutter ants

Leaf-cutter ants live in colonies that can be huge, up to three or four million individuals, occupying as many as three thousand underground rooms.

These ants live in a partnership with a fungus that grows nowhere else in the world except in leaf-cutter ant colonies. The ants depend on the fungus and the fungus depends on the ants.

The ants grow the fungus, feeding it pieces of leaves and flowers that they bring back, often from high up on rainforest trees. They destroy more leaves than any other insect in the rainforest.

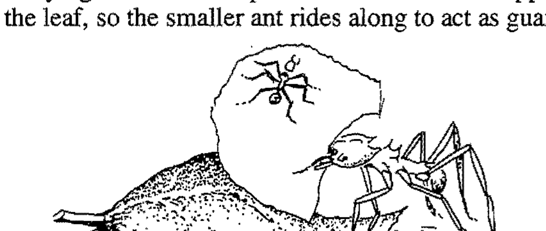
The ants chew up the leaves for the fungus, and fertilize it, and weed out any other plants that start growing in the fungus garden.

It is also the ants that start new gardens (the fungus has lost the ability to do so by itself). When a young leaf-cutter ant queen flies off to start a new ant colony, she takes with her in her mouth a small piece of the fungus to begin a new garden.

The ants in turn depend on parts of the fungus to digest their food, and the leaf-cutter ant larvae eat nothing but the fungus.

Remember the ants you saw carrying pieces of leaf down a tree when your classroom was "transported" into a rainforest? Those were leaf-cutter ants, many carrying pieces so large that it would be as if you were carrying a dining room table down a tree.

And on many of these leaves, if you recall, a smaller ant was perched. Why? It was acting as a guard, protecting the larger ant against a parasitic fly. This kind of fly tries to lay its eggs on an ant's head. The larvae that hatch from these eggs would kill the ant. The ant carrying the leaf can't protect itself without dropping the leaf, so the smaller ant rides along to act as guard.




Kjell Sandved, National Museum of Natural History, Smithsonian Institution

A three-toed sloth looks around.

A Rainforest Arms Race

High in the canopy of a Latin American rainforest, a bright yellow, orange, and black butterfly flutters along. It is a Heliconid butterfly, looking for a passion flower vine to lay her eggs on.

She is one soldier in a war for survival between Heliconid butterflies and passion flower vines. For the butterflies, the goal is to lay their eggs; for the vines, to keep from being eaten.

When the eggs hatch, the Heliconid caterpillars will feed on the vine's leaves. Most insects can't do this, because passion flower vines are poisonous.

Poison as Protection

Heliconid caterpillars can eat these leaves safely. In fact, for them, the poison is an advantage: it stays in the caterpillars, making them poisonous . . . so birds that would otherwise eat them leave them alone.

And when these Heliconid caterpillars grow up and turn into butterflies, the chemicals still remain. Heliconid butterflies too are poisonous.

Sometimes, a passion flower vine start producing a new poison that works even on Heliconids . . . but in a while, new types of Heliconid develop that are immune to the new poison. The struggle for survival between plants and plant-eaters goes on and on.

Advertising and False Advertising

Of course, being poisonous is no protection unless animals that might eat you *know* you're poisonous . . . so a Heliconid butterfly advertises. It wears bright colors that are easy to recognize.

Like a security alarm sticker on a house, the Heliconid's coloring gives a warning: "Don't mess with me. I'm dangerous!"


Kjell Sandved, Smithsonian Institution


Kerry Dressler

Other kinds of poisonous butterfly imitate the way the Heliconids look, to show that they too are dangerous to eat.

But imitation goes further. Butterflies don't own copyrights on their colors . . . so some butterflies that are *not* poisonous also look like Heliconids. They are trying to trick predators into leaving them alone—by *pretending* they are dangerous to eat.

Caterpillars, Keep Off!

In this war, the passion flower vines fight back. Poison is just the beginning. Here are some other means that passion flower vines use to get rid of Heliconid caterpillars.

- *Disguises.* Some passion flower vines produce leaves that look like the leaves of other kinds of plants. If the butterflies think they aren't passion flower vines, they won't try to lay their eggs here.
- *Guards.* On occasion, passion flower vines get ants to guard them. The vines supply a special nectar that the ants like to eat. In exchange, the ants pick off any young Heliconids that develop on the vines' leaves.
- *Fake eggs.* A passion flower vine may grow imitation eggs. When the butterfly comes to lay *her* eggs, she thinks that the leaf is already occupied . . . and goes off to look for an empty vine.
- *Weapons.* Some passion flower species grow hooked hairs on the surface of their leaves. These hairs kill the caterpillars.
- *Dumpers.* Since Heliconids like to lay their eggs on the tendrils of the vine, some vines grow special, extra weak tendrils. When an egg laid on one begins to develop and becomes heavier, the dumper tendril can't hold its weight anymore, and the egg falls off.

Life in Slow Motion

Can hanging upside down from a branch, hardly moving for up to 18 hours a day, help an animal survive? In the case of a three-toed sloth—yes!

This strange and appealing animal, one of the most common larger mammals in New World rainforests, has a lifestyle that is unusual but that suits it perfectly for life in the canopy. Its way of surviving is based on using as little energy as possible. That means it doesn't need to eat as much, and it can live on leaves, which are not very nutritious.

Sloths spend most of their time upside-down, hanging from branches by their three-inch-long claws. They even sleep and have babies in this position. Sloths eat the leaves of around fifteen to thirty different kinds of trees. But they spend most of their time in the branches of a few favorites.

Leaves are hard to digest, so sloths have special, large stomachs. Their digestion takes place at the same pace as the rest of their lives—very slowly. Food can take up to a month to pass through a sloth's digestive system.

This is a long time, and leaves don't supply much energy. So sloths live in ways that use up as little energy as possible. Moving little and slowly is one way to save energy. They also burn their food at a very slow rate. And they don't keep their body temperature as constant as most other mammals (to do so takes a lot of energy). Sloths use their surroundings to adjust their body temperature.

Because of this, a sloth that needs to warm up after a chilly night must climb to a patch of sunlight in the upper canopy.

This warms up, but also puts it in danger. Out in the open, a sloth has no protection. If a hungry eagle spots it, it cannot run.


Kerry Dressler

The rest of the time though, down in its usual spots among the leaves, the sloth is pretty safe. It has tiny plants growing in the grooves of its hairs. These plants make its hairs look greenish. This color, and its very slow movements, make the sloth very hard to spot among the leaves. It tends to look more like a bunch of epiphytes than like an animal.

And in fact, for many insects, a sloth is home. Over 900 beetles have been found on a single sloth . . . and other creatures like mites and other insects also live in its fur.

A few years ago, scientists at the Smithsonian Tropical Research Institute in Panama found that one of these insects, a kind of moth, not only lives on the sloth but depends on it to feed its developing young. Here is how this happens.

About once every two weeks, a three-toed sloth makes a very, very slow trip all the way down to the ground. Here it digs a hole and deposits its droppings in the hole.

At this point these moths that live in the sloth's fur fly out and lay their eggs in the droppings. The droppings will be food for the moth's developing offspring.

Hummingbirds—High-Energy Pollen-Carriers

Shimmering in the sunlight, hummingbirds dart from flower to flower among the tall rainforest treetops, drinking nectar and eating insects.

These tiny birds survive by using tremendous amounts of energy. They burn energy so fast that they have to feed every 10 or 15 minutes when they are active. And when they wake up after a night's sleep, they are often near starvation.

A man who burned as much energy as a hummingbird does would have to eat 370 pounds of potatoes a day, just to keep going.

Why does a hummingbird use so much energy? For one thing, it flies fast—up to 40 miles an hour. This high speed helps keep it safe, so it can go about its business, in full daylight and looking flashy, without much fear of being eaten.

Another reason hummingbirds use a lot of energy is the way they move their wings. When a hummingbird takes nectar from a flower, it doesn't *stand* in front of the flower. It hovers in the air in front of it, holding its body upright, its wings beating in a figure-eight motion as much as a hundred times a *second.*

While a hummingbird is hovering in the air in front of a flower this way, it sticks its long tongue into where the nectar is. Its tongue is divided into two tubes at the tip—so the hummingbird sucks up the nectar through a built-in double straw.

Different kinds of hummingbirds are suited to different types of flowers. A hummingbird that feeds at tube-shaped flowers, for example, will have a very long, stick-shaped bill, while one that feeds at shallower flowers will have a bill that is shorter.

From the hummingbird's point of view, it is visiting the flower to drink nectar. From the plant's point of view, the hummingbird is there to help it reproduce.

For a flowering plant to reproduce, pollen must be carried from the male part of one flower to the female part of another . . . often on different plants.

As the hummingbird sticks its bill deep into the flower to get at the nectar, its head and body rub against the pollen inside. Then, as the hummingbird flies off to visit other trees, the pollen that has stuck to its feathers will be rubbed off onto other flowers . . . and the tree will be able to reproduce.

Flowers that need hummingbirds attract them by providing the kind of high-energy nectar they require.

These flowers also dress the way hummingbirds like—in red. In fact, if *you* wore a red shirt into a rainforest, it probably wouldn't be too long before a hummingbird flew up to check you out.

Lesson Plan

Step 1: Headlines of Destruction

Give each of your students a copy of the following "headlines of the 21st century":

- Floods cause landslides on former rainforest area. Hundreds killed, thousands homeless.
- More dry days. Rainforest clearing blamed for lack of rain. Farmers seek help.
- Bye-bye brazil nut! Species becomes extinct as plantations fail.
- Donations pour in for Iowa dust bowl refugees as drought gets worse.
- Wheat hit by new disease. Crop 90% destroyed. High prices, widespread hunger expected.
- Thousands of farms on cleared rainforest lands fail. Soil changes blamed.
- Government reports one million species now extinct. Most never studied by scientists.
- Birds' spring songs silent. Hooded warbler fails to return from tropical wintering place. Believed extinct.
- Manhattan under water. Central Park evacuated as Atlantic continues to rise.
- Dirt continues to fill reservoir near felled rainforest area. Water rationing expected.
- World temperatures climb: 5° Fahrenheit higher than century ago. Poles especially hard hit.

First have your students read through the headlines. Tell them that all these events can be traced back to one common cause, and ask them to guess what it might be. (This opening is just to get the kids thinking, and should be *very* brief.)

Then tell the children that all these imaginary headlines describe events that could happen *if tropical rainforests continue to be cut down* at the current rate.*

Tell them that some of these events are much more probable than others. Rainforest destruction can definitely cause local erosion and flooding (such problems are already occurring in deforested areas). Large-scale changes in global weather patterns are *much* more doubtful. Scientists don't agree about what is going to happen.

You will, of course, want to define what a tropical rainforest is. Tell the children that tropical rainforests are what they have probably been calling *jungles*. Draw on the third paragraph of the Teacher's Background to describe the weather conditions there. On a wall map, point out the main areas of rainforest worldwide (see map on this page).

How can just cutting down trees lead to such far-reaching consequences? Tell the children that this is the question that they will be answering as they do the Lesson Plan. Also tell them that, as they find answers for themselves, they will be preparing a show for other students in their school to look at so they too can learn about rainforests and what is happening to them. Explain that, as they go along, they will be getting instructions on how to do this.

Step 2: Welcome to the Rainforest

Introduce the children to what rainforests are like by having them take an imaginary trip to one. Describe what they see at ground level by using the script "A Rainforest in Your Classroom," in the box on this page. (Or you may want to give the gist of the script in your own words, perhaps adding detail from the "Understory" and "Forest Floor" sections of the Teacher's Background.)

When the children have finished this imaginary trip, tell them that way up far above their classroom, above the whole rainforest, the weather is very different: the sunshine is bright, the air often dry, the wind blows, and frequently, heavy tropical rainstorms beat down on the treetops.

Ask the children why, if it is so bright and windy up there, is the forest floor so different.

Then draw on the "Rainforest Layers" section of the Teacher's Background to describe how the rainforest greenery filters out most of the light and wind, and changes the character of the rain. Describe the rainforest from top to bottom, explaining that these layers are not rigid or clearly separated, but are the rainforest's overall structure. If the children walked into a real rainforest, they would very likely not be able to tell where one layer ended and another began. Yet the overall sequence of changes from top to bottom would hold true.

Include examples of how the plants and animals in each part of the rainforest are adapted to their surroundings. Wherever possible, use pictures to make what you are describing more real to the children.

The children can then apply what they have been learning by doing the Pull-Out Page activity. Be sure to keep their finished Pull-Out Pages. They will be the basis of a large group painting of a rainforest that will be the backdrop for the Rainforest Show.

Step 3: Diversity and Survival

Now that the children have an overall grasp of how a rainforest is put together, they are going to add detail to their understanding by working with some specific examples—first by reading one of the articles in the Special Supplement; then, if possible, by doing some outside research on the same subject*; and finally, by creating a display about the particular topic.

This display can be a poster with text and pictures, and can also include whatever models, real objects, dioramas, etc., help put the content across. The finished displays will be part of the class's Rainforest Show.

The children will be carrying out these activities in small groups, each group working on one of the Special Supplement topics.

Tell the children that, as they do their research and prepare their displays, they should focus on the unity that underlies the rainforest's diversity: *all the forms and behaviors they are learning about help rainforest plants and animals survive.*

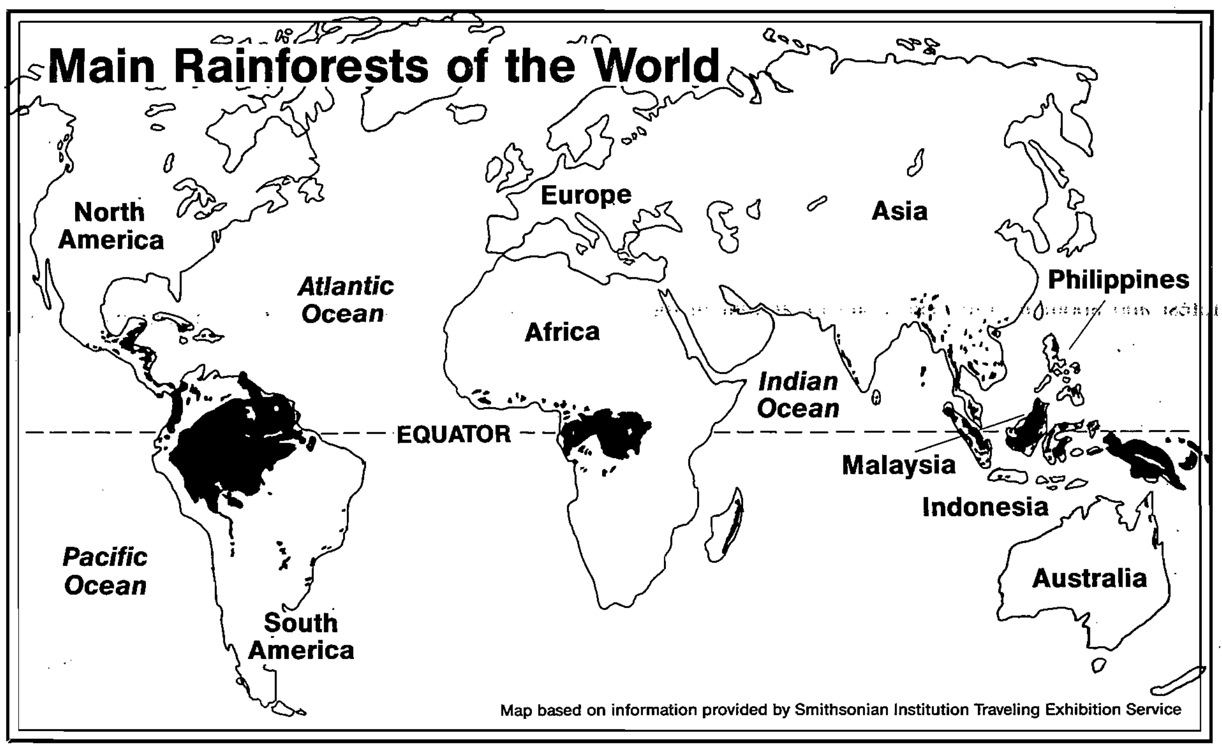
And remind the children of what *surviving* involves: **to survive, a plant or animal has to find a way to**

- **take in the things it needs from its environment** (food, water, sunlight, etc.);
- **avoid being eaten;** and
- **reproduce.**

To highlight this underlying unity, each display should include at least three *survival points*—boxed sentences printed in red. Each survival point is simply a sentence describing how one particular feature or behavior helps a plant or animal survive. For example, the description of how algae growing in a sloth's fur give it a greenish tinge might elicit a survival point that reads: "Being green like the leaves where it lives helps the sloth **avoid being eaten,** by making it hard for predators to see." Or the description of frogs laying their eggs in bromeliad pools might call for a survival point that reads, "Laying their eggs in bromeliad pools helps these frogs **reproduce.**"

*See box "How Fast Are Tropical Rainforests Disappearing?" on page 8.

*Finding outside pictures is particularly strongly recommended. Many magnificent color photographs of rainforests are in print. They will add immeasurably to the children's involvement in the topic . . . and to the vividness of the show they are creating. The Bibliography on page 8 will give them a start in finding such pictures.



A Rainforest in Your Classroom (script)

By magic, the space within your classroom has been carried into the middle of a tropical rainforest. The desks and chairs and books have vanished. Only the block of space inside your classroom walls is left . . . and it is now filled with rainforest.

Go there now, with your eyes closed.

What is it like standing on the ground in the middle of a rainforest?

The first thing you notice is how muggy it is—hot and damp and still. No breezes at all.

It smells damp too. You shift your feet and dead leaves scrunch and squelch. You sniff their earthy smell.

All around you, the forest is loud with insect sounds: the rising buzz of cicadas and the chirping of crickets and other calls you don't recognize.

Open your eyes. How dark it is . . . very dim and greenish—like evening, except that a few flecks of bright sunlight are scattered here and there on the leaves.

Look around. There's no wall of vegetation to hack your way through, like explorers in movies do. You can walk in just about any direction you want . . . as long as you're careful not to trip over tree roots running along the ground and not slip on damp decaying leaves underfoot.

What's this in front of you? It looks like a tree trunk, but the most weirdly shaped tree trunk you've ever seen. And there's another. They're like giant skirts sitting on the ground. *(Show the children the picture of the buttress on page 7.)*

Many rainforest trees broaden out this way at their base. This broad base is often much taller than a person. The ones you see now almost reach the ceiling of your classroom. Then they narrow and become straight like regular treetrunks. Rainforests usually have shallow soil, so tree roots don't go deep. These broad bases help hold the trees up.

Touch the base of the nearest tree. It's damp. See the mosses and little ferns growing all over it? And the ants . . . can you see the ants going up and down this tree in a line? The ants going up are not carrying anything. But almost every ant coming down is carrying a piece of leaf—often bigger than the ant itself. And look, there is a smaller ant riding on many of the pieces of leaf.*

There is a sudden chattering and rustling in the branches overhead, and a few leaves and twigs rain down. You look up and see half a dozen furry faces peering at you—a troop of spider monkeys. One has a baby on its back. For a moment, it looks to you as if they have five legs. Then you realize that one of the legs is actually a tail that they use for grabbing. There is a swing and swish of branches, and the monkeys move upward out of sight.

You walk forward, through what looks like thick, stiff ropes hanging down here and there. They are vines, woody vines. Rainforests are full of them. Sometimes they tie trees together so thoroughly that they can hold a tree upright even after its base has been cut through.

Between two plants along your path, a spider has spun her web. . . . Something is caught in it—what? You can't believe your eyes—a bat, wrapped round and round in the spider's silk!

A band of about 20 little animals comes into sight: coatis. They look a bit like raccoons, but they have short legs and tapered noses. Each coati has a long, striped tail that it holds straight up in the air. Together they march along the forest floor, poking their noses into cracks, searching for insects. They pay little attention to you.

And now it's time to end your short visit to the rainforest.

As you take a last few steps here, a cloud of wonderful fragrance surrounds you—the best smell you've ever smelled. Where is it coming from?

You look around for a flowering bush, but see none.

Then you catch sight of a scattering of pink blossoms on the ground . . . and you realize that they are messengers from another world—a world far, far above you, where a tree is in blossom.

That is where the fragrance is coming from . . . from that hidden *upper* world, where most rainforest plants and animals pass their lives.

*These are leaf-cutter ants. You will be learning more about them in "Ant Snapshots" in the Special Supplement.

George Angehr, Smithsonian Tropical Research Institute

How tall do you think these buttresses are?

Kjell Sandved, National Museum of Natural History, Smithsonian Institution

Erosion in area in Brazil where rainforest has been cleared. The rain beats straight down, washing away the soil. See the stone on top of each peak? Only the dirt protected by these stones remains.

These survival points can take many forms. The important thing is that they be constant reminders that the rainforest's diversity results from its species' struggle to survive.

Step 4: Rainforests—lush, but fragile

Now your students are ready to look at the other side of rainforests—their fragility.

Tell the children that a rainforest is very vulnerable to breaking down as a system, and rainforest species are very vulnerable to becoming extinct.

The children can guess one reason from what they have learned. They have seen how common it is for rainforest species to depend on other species. Remind them of the leaf-cutter ants and their fungus, for example, or of the moths and the sloth.

What would happen if the partner species was wiped out? The other, which depends on it, would also be wiped out. Rainforests are full of these kinds of special partnerships. It is common for whole chains of dependencies to exist: a plant may depend on one kind of animal to pollinate it, and on another to disperse its seeds. Each of these animals may, in turn, depend on other plants and animals for their own survival. Result: *the extinction of one rainforest species often leads to the extinction of other species*. Write this on the board.

Ask the children to draw on what they have learned to give other examples of plants and animals that depend on another species.

Then draw on the "Lush, but fragile" section of the Teacher's Background to explain further reasons for the vulnerability of the rainforest and its inhabitants:

- the small number of individuals for most species:
- the fact that many species are found in only one small geographical area; and
- the fact that the nutrients plants must have are stored in the trees rather than in the soil, which is usually poor. If the trees go, so do most of the nutrients. Write these reasons on the board.

Step 5: Good-bye, rainforests?

Now show your students the picture of cleared rainforest area on page 8.

Have them discuss what they see. What happened to the trees? to the other plants? to the animals that lived there? Will the forest grow back?

The trees here will probably never grow back, or only very few kinds will grow back. . . .

But this is not the only result. If the land stands bare, a number of other changes may take place. Your students now know enough to come up with some of them on their own. Others you can introduce in the course of the discussion, gradually creating on the chalkboard a list similar to the one on this page.

To conclude this step, ask each of the children to choose one of the rainforest plants or animals they have learned about, and write an autobiography of an individual of that species ("The Autiobiography of a Tank Bromeliad," for example).

This autobiography should be based on factually accurate information about how the plant or animal lives. But it should also be written as imaginatively as possible, in the first person, and should tell how the author thinks the plant or animal would feel about the forest and about its life. The plant or animal in the autobiography should spend part of its life in a rainforest area that is destroyed, or about to be destroyed, or near an area that is destroyed.

These autobiographies can take the form of stories, diaries, poems, or skits. They will form a section of the Rainforest Show.

Step 6: Completing the Rainforest Show

Now your students are ready to finish creating the Rainforest Show. They have already completed displays (in Step 3) and autobiographies (in Step 5). They have also done individual versions of the Pull-Out Page picture.

Before proceeding, the children should discuss what the show needs to include—bearing in mind that its audience will consist of viewers who don't know anything at all about rainforests.

Here are a few of the exhibits they may want to include:

continued on page 8

What Is Likely to Happen?	Why?
Local Effects (very probable)	
Loss of fertility	Most of the nutrients have been removed with the trees. Soil and weather changes result from destruction of trees.
Soil changes	Without the protection of plants, the cleared soil is compacted by force of rain beating directly down on it, and by overheating in direct sunlight. Chemical changes take place. Soil organisms essential to plants die off.
Flooding	Plants no longer act as sponges, soaking up rain and releasing water slowly. Heavy rains pound soil's surface.
Erosion	No plant roots to hold soil. Rain beating directly on ground carries soil away.
Less rain, or droughts	Much of rain that falls on tropical rainforests comes from moisture trees have released. In Amazon rainforests for example, about half the rain probably comes from trees.
More extreme temperatures	Vegetation made temperature changes more moderate. When land is cleared, days become hotter, nights colder.
Loss of plant and animal species, extinction of many	Conditions to which they were adapted have changed completely: they have lost food, shelter, partner species. . . .
Displacement of human beings. Loss of homes, ways of life, entire cultures.	Homeland destroyed. Way of life made impossible. Other groups often move in, take over land, introduce disease, etc.
Larger-scale Effects (possible, harder to predict)	
Rise in global temperatures. This rise would probably not be the same around world. Very likely would be greatest at poles, causing polar ice to melt.	Burning of rainforest trees on large scale would add carbon dioxide to atmosphere, increasing greenhouse effect—which causes heat to be held in, making atmosphere warmer.
Ocean levels rise.	Polar ice melting.
Change in rainfall patterns worldwide.	Changes in temperature.
No one is sure how likely these larger-scale effects are. But one large-scale effect is sure:	
Loss of genetic variety	Species of plants and animals that might have been sources of life-saving drugs and disease- and pest-resistant strains of crops have disappeared forever.

continued from page 7

- Certainly, a large color *mural* based on the Pull-Out Page rainforest cross-section. Since the children now know more than when they carried out this activity on an individual basis, they will probably want to add more animals. They should certainly also add fairly detailed explanatory labels, to help visitors to the show understand what they are looking at.
- A *map* of the main areas of rainforest worldwide.
- A *list of familiar products of rainforest origin.* The books in the Bibliography provide many examples, and the free resource materials from SITES include a list of such products (the address from which these materials may be ordered is given at the end of the Bibliography). A good way to start is for the children to figure out how many foods from rainforest plants they have eaten in the past 24 hours.
- *Information about what happens to a rainforest area when the trees are cut down.* The list developed in Step 5 is one way of presenting this information.
- *Information about why rainforests are being destroyed.* Who wants to do what to them, and why? What does this destruction mean to us? The books by Caufield, Myers, and Gradwohl and Greenberg in the Bibliography are excellent sources. These books also describe ways that people are trying to help save rainforests.
- *Headlines of Hope.* To conclude the show and their study of rainforests, the children should write a set of headlines that correspond (in a general way) to the Headlines of Destruction with which they began. These Headlines of Hope should refer to positive events that might happen if people learn to manage tropical rainforests more wisely. ("New cancer treatment found" . . . "Tropical fruit boom hits U.S. market" . . . "Indian tribe returns to homeland," and so on.)

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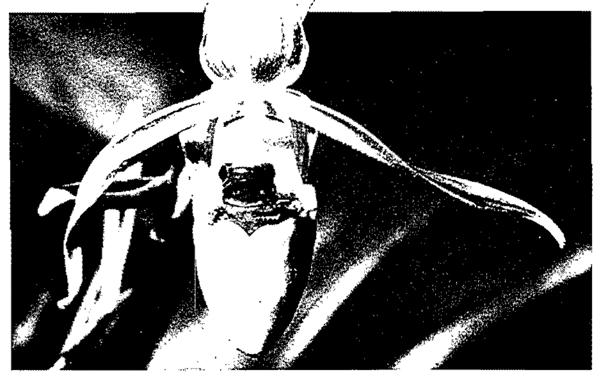

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Resource materials and activity sheets on tropical rainforests will be available, free of charge, from October 1988, by writing: Smithsonian Institution Traveling Exhibition Service (SITES), 1100 Jefferson Drive, S.W., Room 3146, Washington, DC 20560.

These materials were designed to accompany the exhibition *Tropical Rainforests: A Disappearing Treasure,* but you will find them a useful classroom resource even if you cannot visit the show.

Chopped-down rainforest in Brazil. Russell A. Mittermeier, World Wildlife Fund—U.S.

How Fast Are Tropical Rainforests Disappearing?*

Every SECOND we lose an area the size of 4/5 OF A FOOTBALL FIELD
Every MINUTE we lose an area the size of TEN CITY BLOCKS
Every DAY we lose an area the size of THE CITY OF PHILADELPHIA
Every YEAR we lose an area the size of PENNSYLVANIA
Every 10 YEARS we lose an area the size of the NORTHEASTERN U.S.
Every 50 YEARS we lose an area the size of the U.S. EAST OF THE ROCKY MOUNTAINS

Smithsonian Institution Traveling Exhibition Service

*These figures are based on a constant rate of 54 acres cleared per minute.

Yanomamo

Your students would be interested in hearing what one school has done to tell people in other communities about rainforests. The children at St. Augustine School in Billington, Blackburn, United Kingdom have traveled all over England—and even to the United States—performing *Yanomamo,* a musical about rainforests.

A tape of the musical is available. For information, write: Boosey and Hawkes, Inc., Promotion Department, 24 West 57th Street, New York, NY 10019.

See For Yourself!

Tropical Rainforests: A Disappearing Treasure, an exhibition organized by the Smithsonian Institution Traveling Exhibition Service (SITES) in cooperation with the World Wildlife Fund, is open in Washington, D.C. You can see it in the International Gallery of the S. Dillon Ripley Center, on the Mall, through January 2, 1989.

Tropical Rainforests is about the ecology of the rainforest; the people of the rainforests; and the destruction of the rainforest—its causes, consequences, and possible solutions.

Included in the exhibition are a life-sized model of a fig tree with buttresses, a multiscreen slide show about rainforest life, a U.S. living room filled with rainforest products, and an interactive video that involves visitors in making management decisions about tropical rainforests.

If you can't come to *Tropical Rainforests,* the show may come to you. During the next five years, it will be traveling to Portland, Charlotte, Indianapolis, Los Angeles, St. Louis, Boston, New York City, Denver, New Orleans, Houston, Atlanta, Chicago, St. Paul, and Toronto. For more information, contact the Office of Public Affairs, Smithsonian Institution, Washington, DC 20560. Tel. (202) 357-2627.

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Smithsonian Institution Press

Designer: Joan Wolbier

ART TO ZOO brings news from the Smithsonian Institution to teachers of grades three through eight. The purpose is to help you use museums, parks, libraries, zoos, and many other resources within your community to open up learning opportunities for your students.

Our reason for producing a publication dedicated to *promoting the use of community resources among students and teachers nationally* stems from a fundamental belief, shared by all of us here at the Smithsonian, in the *power of objects.* Working as we do with a vast collection of national treasures that literally contain the spectrum from "art" to "zoo," we believe that objects (be they works of art, natural history specimens, historical artifacts, or live animals) have a tremendous power to educate. We maintain that it is equally important for students to learn to use objects as research tools as it is for them to learn to use words and numbers—and you can find objects close at hand, by drawing on the resources of your own community.

Our idea, then, in producing ART TO ZOO is to share with you—and you with us—methods of working with students and objects that Smithsonian staff members have found successful.

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Binney Levine, Resident Associates Program, Smithsonian Institution

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Georgina de Alba, George Angehr, James Karr, Ira Rubinoff, Neal Smith, and Nicholas Smythe, Smithsonian Tropical Research Institute, Smithsonian Institution

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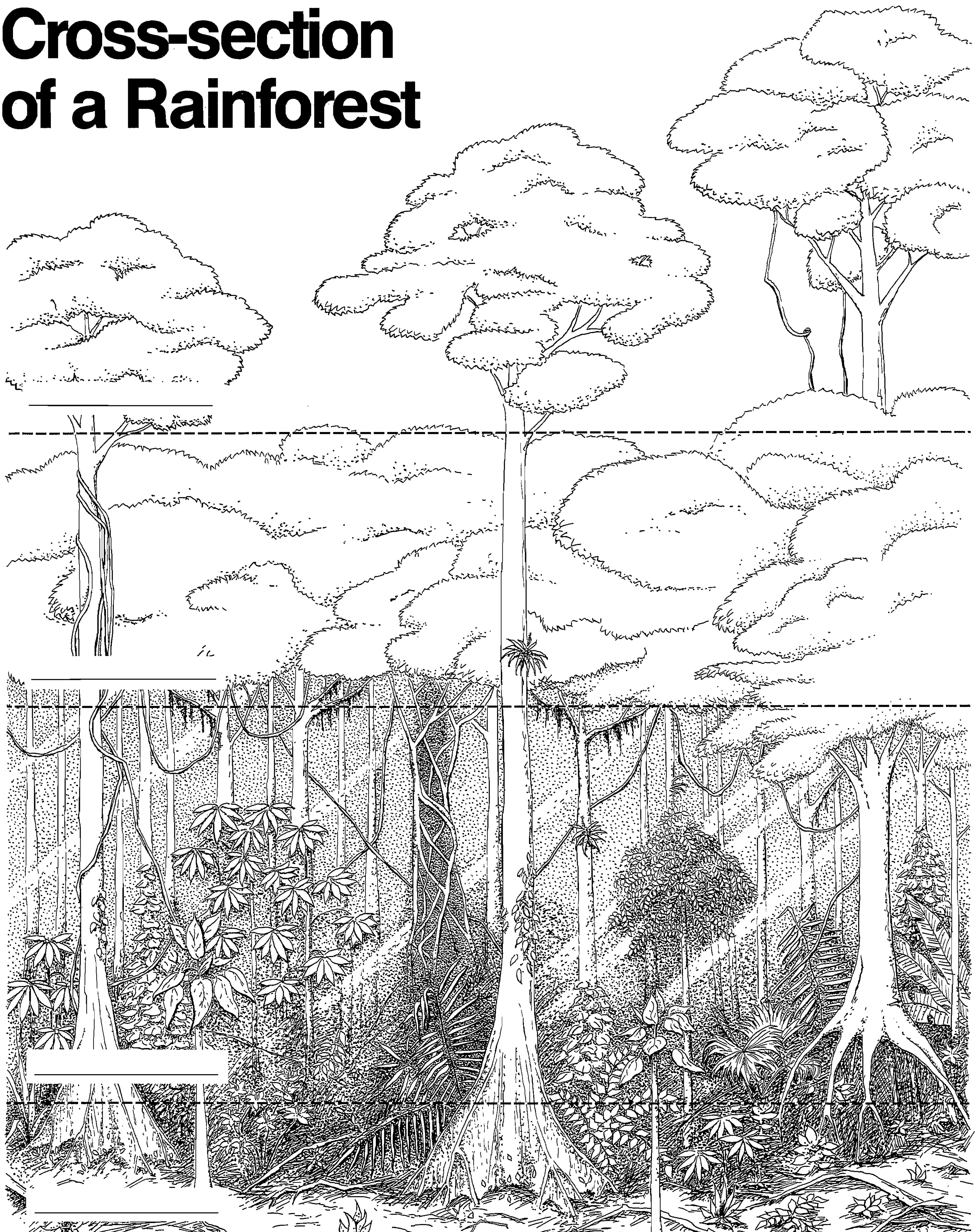
Cross-section of a Rainforest



Complete the labels, here and in the illustration:

E ____________________ layer

C ____________________ layer

U ______________________

F ____________ F ____________

Match the description to the layer.

Darkest part of the rainforest.

Weather here varies a lot.

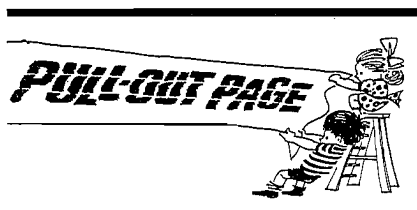
Layer that contains the most plant and animal species.

Small trees and shrubs grow here, in dim light.

Choose five of these animals. Look each one up and learn something about it. Look at a picture of each animal.

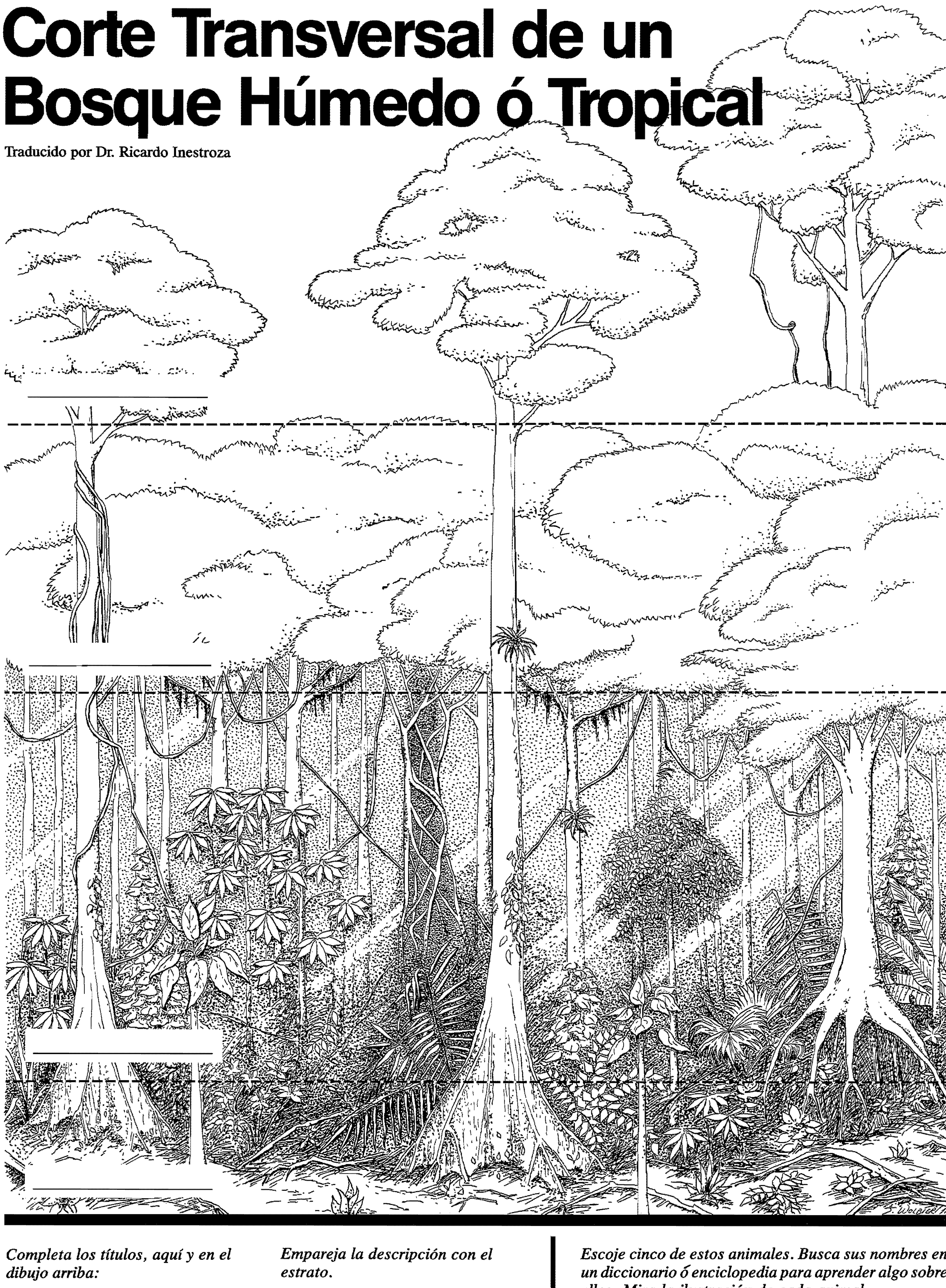
When you have finished, draw each animal you have chosen in the right part of the rainforest. For example, you might draw the sloth hanging upside down in the canopy. (Your teacher will help if you aren't sure where an animal goes.)

coati, giant armadillo, harpy eagle, hummingbird, jaguar, peccary, sloth, spider monkey, toucan, tree frog



Corte Transversal de un Bosque Húmedo ó Tropical

Traducido por Dr. Ricardo Inestroza



Completa los títulos, aquí y en el dibujo arriba:

Estrato E ____________________

Estrato S ____________________

S ____________________________

P ____________ del B __________

Empareja la descripción con el estrato.

La parte mas obscura de un bosque húmedo ó tropical.

El clima aquí varía mucho.

El estrato que contiene mas especies de animales y plantas.

Árboles pequeños y arbustos crecen aquí, en luz tenue.

Escoje cinco de estos animales. Busca sus nombres en un diccionario ó enciclopedia para aprender algo sobre ellos. Mira la ilustración de cada animal.

Cuando termines, dibuja los animales escogidos en la sección correcta del bosque húmedo ó tropical. Por ejemplo, puedes dibujar al perezozo patas arriba en el estrato superior. (tu maestro te ayudará si no estás seguro de donde vive un animal.)

coatis, pecarí, armadillo gigante, águila harpía, colibrí, jaguar, perezozo, mono araña, tucán, sapo de árbol

Las respuestas en la sección de „Completa los títulos„ son:
Estrato emergente, Estrato superior, Sotobosque, Piso del bosque