WELCOME TO THE WORLD OF AKO THE AYE-AYE

The Ako the Aye-Aye Educator's Guide introduces you to the remarkable world of lemurs. This guide provides background information about the biological concepts conveyed through the 21 Ako lessons. These lessons were created to accompany the Ako books. The Ako book series were developed by renowned primatologist Dr. Alison Jolly to inspire understanding and appreciation for the unique primates of Madagascar. In addition to the books there is also a set of posters which showcase the habitat of each lemur species and their forest "neighbors."

GOALS OF THE AKO LESSONS:

- Inspire students to make a positive difference for lemurs and other wildlife.
- Promote environmental awareness, understanding and appreciation.
- Provide activities that connect students to nature and motivate conservation action.

HOW TO USE THIS GUIDE

Each lesson aligns with a specific grade level (Kindergarten-1st, 2nd-3rd and 4th-5th) and one or more of the seven environmental themes below. Before carrying out an activity, we recommend reading the corresponding section in this guide that matches the theme of the lesson. The themes are:

Lessons can be completed chronologically or independently. Each activity incorporates multiple learning styles and subject areas. Extensions provide additional learning opportunities to use in your classroom, your schoolyard or at your local zoo.

Every activity includes:

- A detailed lesson plan and list of required materials
- Content and background information specific to each activity
- Suggestions about ways to evaluate students after the activity
- Optional extensions that provide additional learning opportunities
- Correlations to National Science Standards, Next Generation National Science Standards, and Florida State Standards which are aligned with Common Core

WHY LEMURS?

Lemurs are primates like you and me. It's easy to see why people are fascinated by lemurs. In some ways, they remind us…of us! Both lemurs and humans are primates. That means we share certain characteristics like thumbs, forward facing eyes, and nails instead of claws. Like us, lemurs are social. Some live in small families, others live in larger communities. Lemurs are devoted parents that spend months, even years, raising and teaching their young. Like us, lemurs feel and express emotions like curiosity, excitement, affection and fear.

Lemurs provide clues about our earliest ancestors. The first primates to evolve were more like lemurs than monkeys, apes, or humans. This makes them important to the study of human evolution. Today lemurs are providing scientists with compelling clues about our earliest primate ancestors, the evolution of human intelligence, and how we came to differ from other species.

Lemurs are unique. From stink fights and sunbathing to side hopping across the sand, lemurs have developed astonishing adaptations that help them thrive on their island home. Tooth combs, grooming claws, reflective lenses and a super sense of smell are just some of their unusual features.

Lemurs are significant contributors to Earth's biodiversity. From the tiny 1.1 oz. Madame Berthe's mouse lemur (the world's smallest primate) to the 20 pound indri, lemurs come in a vast array of shapes, sizes, adaptations and social structures. Isolated on their island home, lemurs are found in virtually all of Madagascar's ecosystems and fill niches that would normally be occupied by monkeys, squirrels, woodpeckers and deer. Of the 17 primate families on Earth, five are lemurs.

Lemurs are the world's most endangered mammals. At least 17 species of lemur have already gone extinct in relatively recent times, including Archaeoindris, a lemur that was as heavy as an adult male gorilla. Today, the more than 100 living lemur species are threatened mainly by habitat loss and hunting. Over 90% of lemur species are considered threatened with extinction by the International Union for Conservation of Nature and conserving lemurs is the world's top primate conservation priority.

Lemurs keep Madagascar's forests growing. As pollinators and seed dispersers, they are critical to the health of Madagascar's forests. In fact, fruit-eating lemurs are some of the most important seed dispersers in Madagascar. Scientists have found entire groups of plant that depend on a single lemur species to disperse their seeds. Without them the plants and the animals that depend on them would eventually disappear.

Our actions can make a positive difference. Being mindful of what and how much we use is one of the most important ways our actions can help. Even simple things like making an effort to only purchase sustainably grown wood products or helping spread the word about the incredible biodiversity of Madagascar can create a more positive future for lemurs.

THEME 1: LOOKING AT LEMURS

BACKGROUND INFORMATION FOR THE FOLLOWING LESSONS:

AM I LIKE A LEMUR? | LEMURS, LITTLE AND LARGE

LEMURS HAVE CLASS! | MADAGASCAR THE MUSEUM

Taxonomy: The Science of Natural Order

Taxonomy is the science of categorizing and identifying living things based on their relationships. The Linnaean taxonomic system groups organisms into a specific kingdom, phylum, class, order, family, genus, and species based on similarities in ancestry, form and structure. Today most taxonomists also compare DNA to examine the genetic relationship between different species.

How Do Scientists Classify Lemurs?

Lemurs belong to the order Primata. This order includes prosimians, monkeys and apes. While diverse, all primates share some traits like color vision, increased brain development, hands that can grasp and forward facing eyes. As of 2017 there are over 600 described species of primates and more are discovered by scientists regularly.

Prosimians, Tarsiers, Monkeys and Apes… What's the Difference?

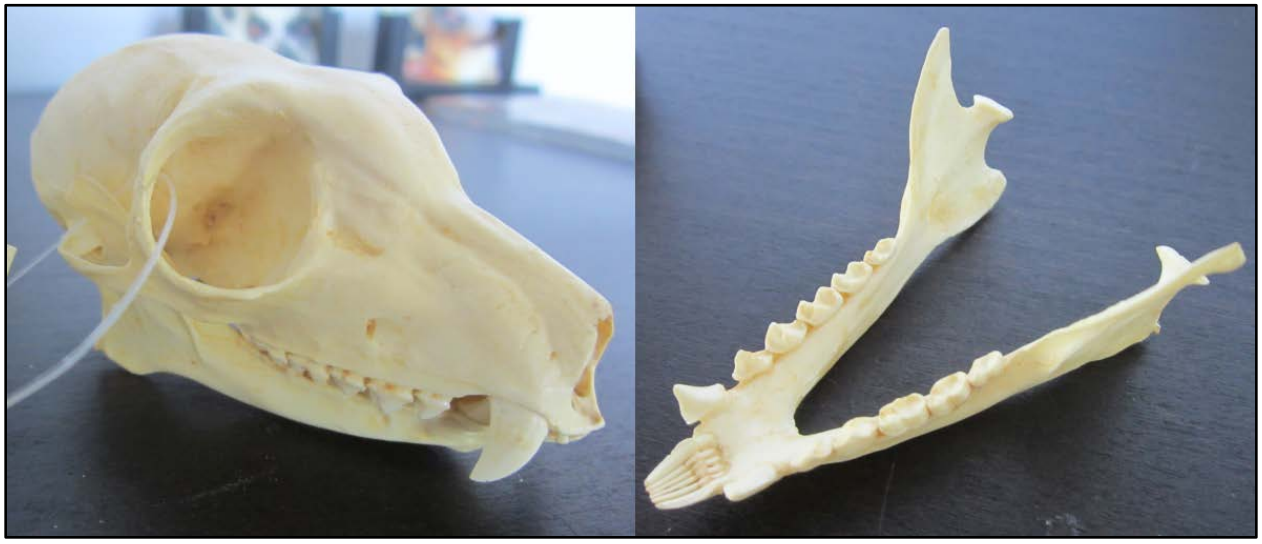
Prosimians are a subgroup of primates that evolved before monkeys and apes. The name "pro-simian" means "before monkeys." They include lemurs, lorises, pottos and bush babies. While today's prosimians are by no means primitive or unchanged, modern prosimians are physically, physiologically, and behaviorally more like early primates that existed fifty five million years ago than other primate groups.

The typical prosimian skull has large eye sockets, an elongated snout and a well-developed sense of hearing and smell. To enhance their sense of smell, prosimians have a moist surface surrounding their nostrils called a rhinarium. All prosimians are in the sub-order Strepsirhini to distinguish them from the Haplorhini or "dry-nosed primates." Species within Haplorhini lack a rhinarium. This sub-order includes monkeys, apes and tarsiers.

What Classifies a Prosimian?

All prosimians live in Africa and Asia. While the different prosimians vary in many ways (including location and physical appearance) prosimians share a similar ancestry and several physical traits. These shared prosimian physical traits include:

- **A tooth comb.** These comb-like projections on their lower front teeth are used for cleaning their own fur and the fur of others in their group.
- **A grooming claw.** Also known as a toilet claw, this is a specialized claw-like nail usually found on the second toe of each hind foot.
- **Tapetum lucidum**. This is a reflective layer behind the retina of the eye that captures stray light and enhances nighttime vision.
- **An elongated snout** and adaptations for well-developed senses of hearing and smell.



Left: Compared to other primates, prosimians have elongated snouts. **Right:** Lemurs have a "toothcomb," visible in the bottom left of the photo at the end of the jaw, which they use for grooming.

What about Lemurs?

Within the sub-order Strepsirhini there are five distinct families of lemurs: Cheirogaleidae (dwarf and mouse lemurs) Lemuridae (true lemurs), Indriidae (woolly lemurs), Lepilemuridae (sportive lemurs), and Daubentoniidae (aye-ayes). Each family has specific characteristics that distinguish it from the other. Lemurs that share similar physical and behavioral traits are classified together within a genus. Each genus is broken down into individual species. A species is most often described as "a set of individuals that can interbreed and produce viable offspring" although this definition of a species can pose some problems and often the relationship between species is more easily defined by examining their DNA and how similar or different it is to others.

The most common way to list the scientific or taxonomic name of an organism is to list the genus and species. For example, the scientific name of the ring-tailed lemur is *Lemur catta*. *Lemur* is the genus and *catta* is the species. The genus and species of an organism are italicized. As of 2017 there are over 100 described species of lemur, and new species are identified and described with some regularity so this number will undoubtedly increase in coming years.

How Are Humans and Lemurs Alike? How Are They Different?

While lemurs look different from humans, we are alike in many ways. Like humans, lemurs are mammals. That means that they are warm-blooded (they maintain a high and constant body temperature independent of their surroundings), have fur or hair, give birth to live young, breathe air, and drink milk when they're young. Like humans, lemurs are also vertebrates. This means they have a backbone to support their bodies. Both lemurs and humans share certain primate characteristics. Both have forward facing eyes, external ears and a mouth. Both humans and lemurs have a nose, however they look quite different. Because of specific adaptations, lemurs have a far greater sense of smell and use it for survival and daily life much more than humans. Like all primates, humans and lemurs both have 5 fingers on each hand and 5 toes on each foot. Like humans, lemurs have flattened nails rather than claws on their fingers and toes and opposable (or semi-opposable) thumbs.

What about Tarsiers, Apes and Monkeys?

The remaining primates are classified in the suborder Haplorhini. This sub-order includes tarsiers, apes and monkeys. Humans also belong to this group. Apes and monkeys differ in several ways. Monkeys have tails, apes do not. Monkeys are usually smaller than apes, walk on all fours with palms down and have relatively smaller brains. Due to their different skeletal structure, apes

have a more upright posture. Since their arms are longer than their legs, apes walk on the knuckles of their hands. Apes also have larger and more developed brains than monkeys. Tarsiers are small nocturnal primates that move primarily by leaping. All tarsiers have claws on their second and third fingers and two grooming claws on their feet. These characteristics led to them being classified as prosimians at one time. Several bones of the heel (tarsals) are longer than those of any other primates—a trait that gave tarsiers their name.

A History of Prosimians

The first prosimian appears in the fossil record about 55 million years ago, which is about 10 million years before the first monkey and 20 million years before the first ape. Before monkeys and apes arrived on the scene, prosimians were common and widely distributed through Europe, Asia, and even in the US. However, once monkeys and apes appeared, prosimians were unable to compete. Diurnal prosimians (those that are active by day) disappeared in all areas except Madagascar. Nocturnal prosimians (those active at night) were able to avoid this direct competition and can still be found in Asia (lorises), Africa (galagos), and Madagascar. Due to their island isolation, the prosimians that ended up in Madagascar didn't have to compete with other primates and they evolved into today's lemurs.

How Did Lemurs Get to Madagascar?

Madagascar is an ancient island that split from the Gondwana super-continent approximately 165 million years ago. While some species were present when the island split, many (including lemurs) had to cross the Mozambique Channel, most likely by rafting on vegetation. It is believed that by the time monkeys and apes evolved, Madagascar had drifted too far from the African continent to make crossing probable. Island isolation and the lack of competition and predation allowed lemurs to evolve and diversify into the many species recognized today, and to expand into the large island's many niches including those that would normally be occupied by monkeys, squirrels, woodpeckers and deer.

The Big and Small of Island Species

From the tiny 1.1 oz Madame Berthe's mouse lemur (which is the world's smallest primate) to the extinct gorilla-sized 400 lb *Archaeoindris fontoynonti*, lemurs come in a vast variety of shapes and sizes. The tendency for island species to evolve into giant or dwarf versions of their mainland counterparts was first documented in 1964 by a young biologist named J. Bristol Foster. Today this theory is known as the "**island rule**" or "Foster's Rule." Foster observed that rodent species tended to grow larger toward gigantism, while meat-eating carnivores, lagomorphs (rabbits and

hares), and artiodactyls like deer and hippo were more likely to become smaller. He also noted that in general, large island mammals tend to shrink in size while small ones are more likely to grow larger.

Island Giants

Lacking predators, some island creatures become enormous. This is called island gigantism. Galapagos tortoise, Komodo dragon and the extinct dodo are some of the most famous examples. On Madagascar some examples include giant hissing cockroaches, giant millipedes, giant rats, as well as the extinct elephant bird and giant lemur species. Prior to the arrival of humans, ample resources and few competitors allowed these and many other island species to grow into giants. Being bigger has its advantages. Larger creatures can exploit a wider variety of foods and dominate others in territorial battles. The disadvantage? Their large size and lack of defensive adaptations make them easy targets for hunters and introduced species like pigs, dogs, cats and rats. Sadly, this has caused the recent extinction of many island giants.

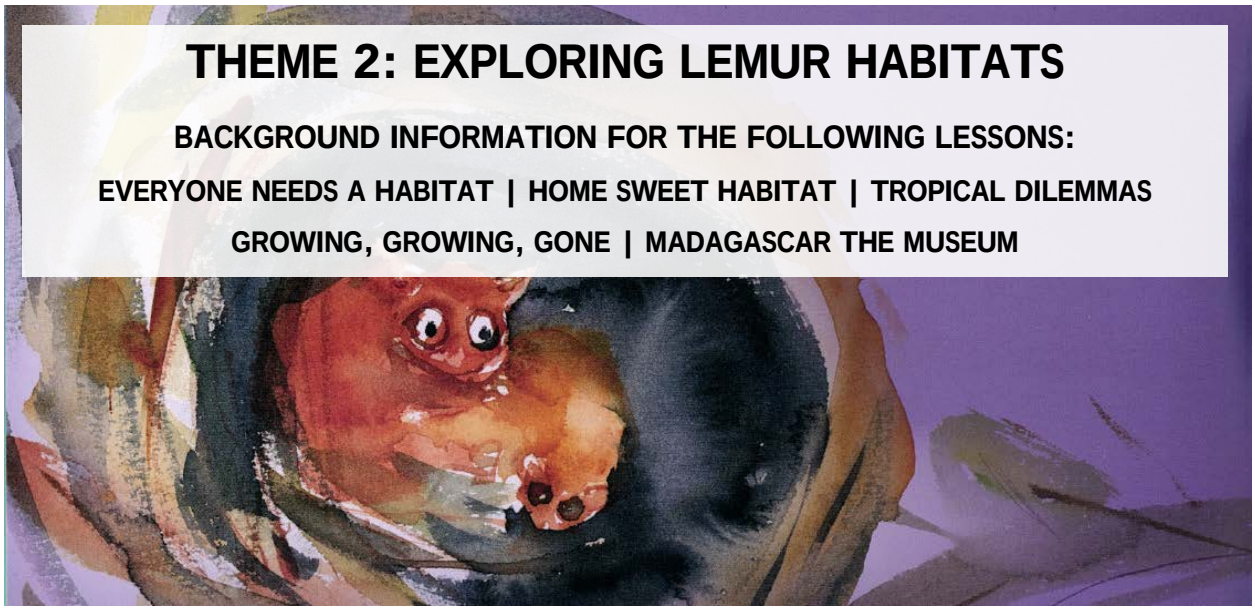
Island Dwarfs

Island isolation can also lead to "island dwarfism." Madagascar's Madame Berthe's mouse lemur (the world's smallest primate), leaf chameleons (the world's smallest chameleon) and the extinct Malagasy pygmy hippo (alive until only about 1,000 years ago) are just a few examples. Like gigantism, small size has advantages as well. Smaller animals need fewer resources to survive and reproduce. This can be an important advantage on smaller islands, where resources are limited. Smaller species are also more efficient at absorbing nutrients and energy and better able to hide from predators.

The Giant Sloth Lemur

At one time there were three genera of sloth lemur on Madagascar. One of these genera was *Palaeopropithecus*—a group with three known species; *Palaeopropithecus ingens, P. maximus,* and *P. kelyus*. Analysis of sub-fossil DNA shows that these lemurs were closely related to today's indri and sifaka. As the name implies, sloth lemurs were designed for treetop living, with long arms and legs, limber joints and hook-like hands and feet. These adaptations allowed them to be adept at both leaping and climbing. *Palaeopropithecus ingens*, the largest, was about the size of an adult chimpanzee. It was likely active by day and slower moving, like an orangutan. Radiocarbon dates indicate that these large sloth lemurs were still living when humans first arrived on the island about 2,000 years ago. *Palaeopropithecus ingens* is named in Malagasy

legends as the tretretretre or tratratratra, however more recent sub-fossils show scars from tools indicating that the species was hunted for food. It is believed that over-hunting and the burning of its forest habitat by these early human residents combined with a naturally slow reproductive rate gradually led to its extinction.



THEME 2: EXPLORING LEMUR HABITATS

BACKGROUND INFORMATION FOR THE FOLLOWING LESSONS:

EVERYONE NEEDS A HABITAT | HOME SWEET HABITAT | TROPICAL DILEMMAS

GROWING, GROWING, GONE | MADAGASCAR THE MUSEUM

Habitats for All

Like humans, every animal needs a habitat or home where they can find food, water, shelter, and space to raise their young. While the specific requirements may differ from species to species (for instance, depending on the species "shelter" could be a house, nest, den, burrow, or a small piece of coral in the ocean) all animals, plants, fungi and even microbes share these same four basic survival needs. For all animals (including humans), a habitat is much bigger than just their house, den or burrow. It includes the entire area or community where their basic needs are acquired. A human's habitat typically includes the entire city or region where they live.

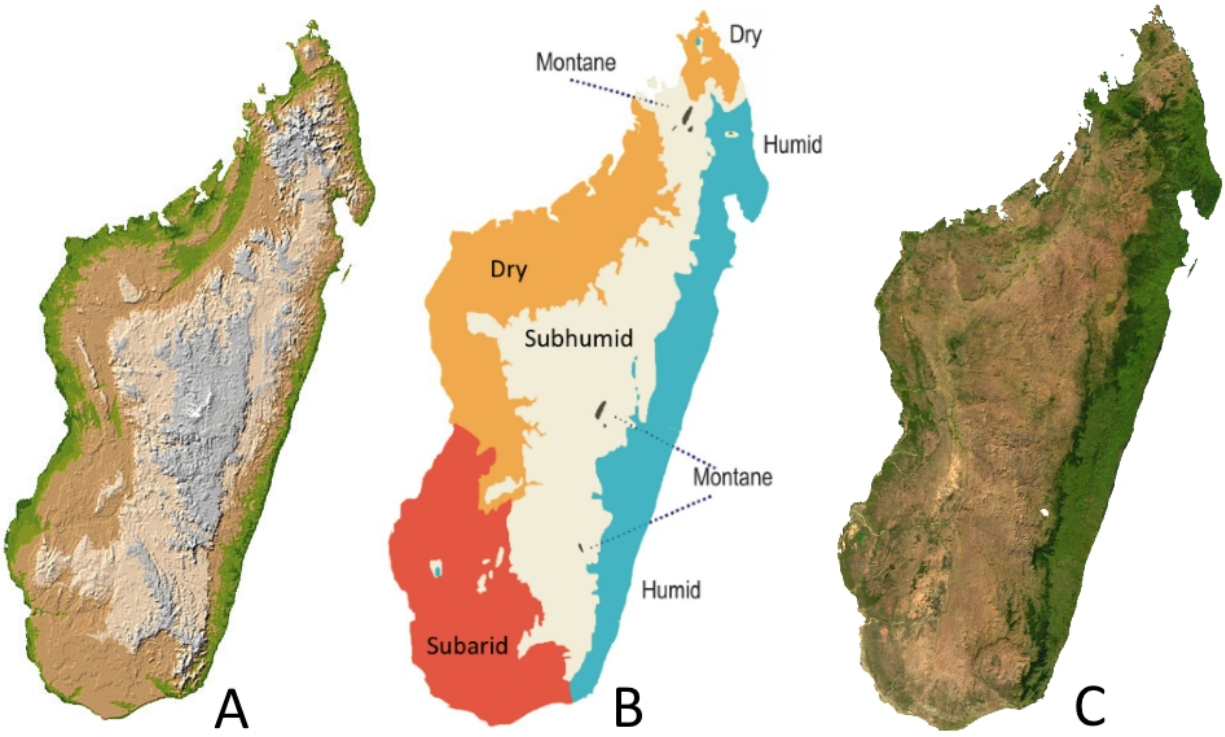
Lemurs: At Home in the Forest

In Madagascar, lemurs are adapted to a wide range of habitats—from rainforests to spiny deserts to tsingy rock formations and beyond. While each habitat looks very different, all provide lemurs with what they need to thrive and raise their young. To a lemur, a forest is a grocery store, house and freeway all in one! Trees and plants provide tasty fruits, flowers, buds, sap and pollen to eat. Leaves dripping with rain and dew provide treetop "water fountains." Rivers and streams provide water in the dry season. Insects and lizards roam among the branches ready to be captured and eaten. The network of branches creates an elevated "freeway," allowing lemurs to travel, forage and raise their young safe from predators. Some species will even "park" their young in a safe spot among the branches while they forage for food. When it's time to sleep, the treetops become the lemur's "bedroom." Some stretch out on branches, some sleep tucked into hollows and others curl up into nests safe from predators that prowl the forest floor.

Madagascar: Island of Extreme Biodiversity

Madagascar is incredibly diverse both in species and habitats. While the discovery of even one new species of mammal is rare, according to the World Wildlife Fund, no fewer than 615 new species were discovered on the island between 1999 and 2010. This includes 42 species of invertebrates, 61 reptile species, 69 amphibian species, 17 fish, 385 species of plants and 41 species of mammals! Scientists believe the island's large size, geologic isolation and diverse topography are the reasons behind this extreme diversity.

A mountain range that runs north to south down the center of the island creates wet and dry regions. The land on the east side of the range is drenched with rain year-round. In contrast, the land to the west experiences a long annual dry season. In the extreme southwest portion of the island, drought can last as long as eighteen months. The result is habitats that range from deserts to lakes, stony caverns, arid grasslands, deciduous forests, and tropical rainforests. This mountain range also creates a natural barrier for wildlife which prevents interbreeding thus increasing the island's biodiversity.



Above: Maps showing the A) elevation and mountain range that runs down the center of the island B) major climatic regions based on rainfall and humidity and C) a recent satellite image of the island; the thin dark green line in the east is the remaining rainforest.

Lemurs: Adapted to a Variety of Habitats

Island isolation, few predators and a lack of competition have helped different lemur species thrive in almost every one of Madagascar's ecosystems, including rainforest, dry forests, spiny forest and scrubland. Some species, like red-ruffed lemurs, are adapted to live in just one habitat. Others, like the brown lemur, are able to thrive in several different habitats.

Living Life among the Layers

Seventy to ninety percent of life within rainforests lives among three leafy layers that grow above the forest floor. Each layer is home to a unique and closely connected plant and animal community.

The forest floor is humid and so shady that few plants grow. However, the rainforest floor teems with life. In Madagascar, insects like hissing cockroaches along with millipedes, frogs, turtles and tenrecs live among the leaf litter or hide among tree roots. Larger animals like fossa and mongoose prowl the forest floor in search of food.

The understory consists of shrubs and trees that grow about 10–30 meters (about 30–100 feet) above the ground. The dim light keeps trees from growing too thickly and flowers rarely bloom. Ferns and woody vines called lianas thrive here along with animals like red owls, chameleons and geckos.

The canopy layer rises like a giant leafy ceiling over the rainforest floor. On trees growing 30 meters (100 feet) in the air, leaves, fruit and seeds flourish thanks to plenty of sunlight. More animals live here than anywhere else in a rainforest. Drawn to the abundance of fruits, seeds, flowers, and leaves, lemurs, birds such as vangas, couas and rollers, geckos, chameleons and vast numbers of insects live among the dense network of branches and leaves. Many are so well suited to life above the rainforest floor that they never come down to the ground. As in human communities, each species within the canopy plays an important role. Lemurs keep the forest growing and healthy by pollinating flowers, and spreading seeds in their waste.

The overstory is the tallest. Within this layer, the crowns of emergent trees soar 20-100 feet above the canopy. With their small leaves, umbrella shaped crowns, tall, slender trunks and tremendous buttress roots they are well-adapted for sun and wind. Animals like eagles, insects, birds and butterflies climb to this level to find food and sun or to escape predators.

Madagascar Habitats

There are many different types of habitat in Madagascar. The following is information about each type occupied by the six lemurs in the Ako book series and used in the Ako lesson plan.

Rainforests—Hot, Humid and Humming with Life

At one time rainforests grew in a continuous band in Madagascar from Iharana (Vohemar) in the North to Tôlanaro in the South. Today this band has been severely fragmented as forests are harvested for timber or cut and burned to grow food. Scientists are racing to identify new types of rainforest plants and animals before they disappear forever.

Above. Lowland rainforest near Masoala National Park, northeast Madagascar.

There are two main types of rainforest on the island: Lowland and Mid-altitude. Let's examine them in more detail.

Lowland Rainforests: Home to Furry and Fuzzy as well as Ako the Aye-Aye

Lowland rainforests grow below 800m (2624 ft) above sea level. This is the wettest part of Madagascar. Here annual rainfall can exceed 5,000 mm (196 in) and there is no distinct dry season. The slopes are steep and shaped by fast flowing streams. These rainforests have a lush understory and lower canopy. Trees with buttress and aerial roots, palms, tree ferns, saplings, lianas, epiphytes (air plants) and orchids flourish within the canopy and understory.

Impatiens grow on the shady forest floor. Some of these lowland forests extend clear to the sea. Shaped by saltwater, sand, sun and seasonal cyclones, these unusual forests are home to unique plant and animal communities that are specially adapted to these conditions. The Masoala Peninsula has the largest remaining area of coastal lowland rainforest on Madagascar. Red-ruffed, black-and-white-ruffed, aye-aye, woolly and mouse lemurs, brown-tailed mongoose, fanaloka, fossa, tenrec, red owl, vanga, coua, rollers, chameleons, geckos and mantella frogs are just some of the species that make their home here. Masoala National Park is also home to the critically endangered Madagascar serpent eagle, which until recently was believed to be extinct. The park is so rich in biodiversity that many of its plants and animals have yet to be discovered.

Mid-Altitude Rainforests: Home to No-Song the Indri

Mid-Altitude rainforests are found between 800 m (2624 ft) and 1300 (4265 ft) m above sea level. Cooler than lowland forests, they feature a low canopy and thick understory dominated by tree ferns, bamboo, mosses and epiphytes. Kalanchoe thrive on the dark forest floor. Over sixty species of this flowering shrub (commonly used as a landscape plant here in the US) grow on the Island. While most grow less than three feet tall, the largest (*Kalanchoe beharensis*) can reach twenty feet tall. Many species of lemurs, chameleons and insects reside in mid-altitude rainforests, and they often support a unique diversity of fauna and flora with species from lowlands and higher elevations being found at the edge of their elevational range here.

The Dry Deciduous Forests: Home to Bitika the Mouse lemur

In contrast to the heavy rainfall on the eastern side of Madagascar, the dry forests that grow on the western side experience alternating periods of steady rainfall and droughts that can last up to eight months. These forests have an understory made up of very dense shrubs and saplings. While some of these plants keep their leaves during the dry months, many of the large trees lose their leaves in the dry season to reduce moisture loss. Some trees store water in their roots, or have the ability to dry up completely and revive themselves after it rains. The famous baobab trees of Madagascar hold water in their bulbous trunks to carry them through drought.

While not as biologically rich as the rainforests on the eastern side of the island, dry forests contain more endemic species (species found nowhere else) than any other region. They are also home to some of the island's most endangered species including flat-tailed tortoise, the giant jumping rat and Madame Berthe's mouse lemur. Six species of baobab tree grow here,

compared to only two species on the entire African continent. Alarmingly, ninety-seven percent of these dry forests have been destroyed by burning and clearing for grazing and agriculture. Those remaining are small fragments surrounded by fields, farmland, and sporadic settlements**.**

The Tsingy: Home to Bounce the White Sifaka

Within the dry deciduous forests of the west are "stone forests" comprised of limestone, gypsum and dolomite pinnacles. Known as *tsingy,* these pinnacles are made by heavy rains falling on highly porous limestone. Rivers of water flowing under the forest floor create underground passages and caves that become protected canyons for dry deciduous forests. These undisturbed forests provide habitat for rare lemurs, birds and other species. Like dry forests, the *tsingy* habitat is home to an exceptionally large number of endemic plants and animals. The summit, slope, and base of a *tsingy's* limestone needle form different ecosystems for different species. *Tsingy* residents include fossa, crowned lemurs, grey mouse lemurs, the northern ring-tailed mongoose, fanaloka, coua, vanga, crested ibis, pigmy kingfisher, scops owl, harrier hawk, dwarf chameleon, geckos, ground boa, plated lizards and several bat species.

Above. Tsingy de Bemaraha in western Madagascar. The unusual rock formations are made mainly of limestone and have a network of tunnels and caves beneath that lead to pockets of forest surrounded by tsingy.

Spiny and Gallery Forests: Home to Tik-Tik the Ring-Tailed Lemur

The dry southern end of the island is home to Berenty Reserve, a private wildlife refuge along the Mandrare River. The Reserve features gallery forests, dry open scrub, and spiny forests. It is home to six species of lemur, the south's largest colony of Madagascar fruit bats, and 103 bird species. The reserve has been the focus of lemur research for over fifty years. It is here where Alison Jolly, the author of the Ako book series, started her lemur research in the 1960's. Berenty Reserve features two habitats that are found only within Madagascar's arid southern tip - the spiny desert and gallery forest.

Spiny forests (also known as spiny deserts) are one of the most unusual and endangered of Madagascar's forests. These arid grasslands are characterized by flat sandy soils and thickets of thorny scrub dominated by large cactus-like trees from the *Didiereaceae* family. Like cacti, these plants have rows of formidable thorns and spines that grow directly out of the plant's branches. However, unlike cacti, *Didiereaceae* species also produce small deciduous leaves. Baobabs and species of "elephant foot" (named after their shape) survive here by storing water in their swollen trunks. Ninety-five percent of all the plant species here, including *Didiereaceae*, only grow within the spiny forest. Sadly, this unique ecosystem is rapidly being destroyed. While its arid nature makes it difficult for agriculture the slow growing plants are commonly harvested for cooking fuel and building materials.

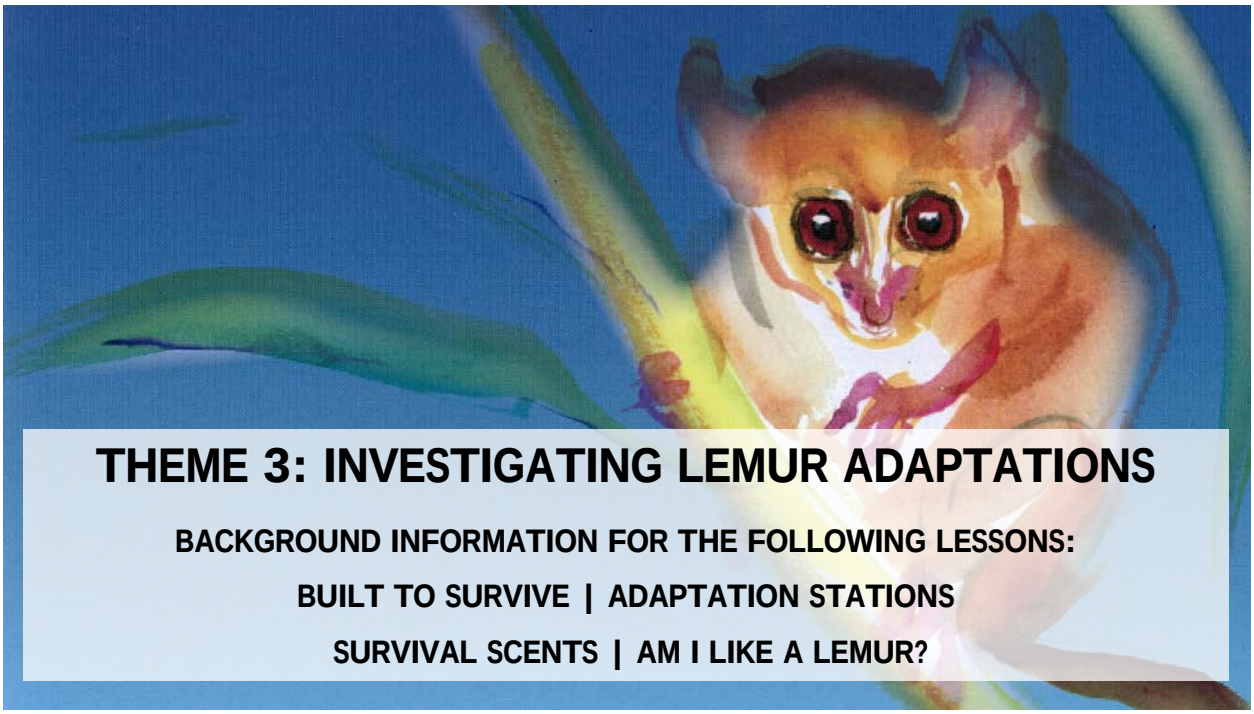
Above. Spiny forest (also known as spiny desert) is a very unique habitat found only in southern Madagascar. It is characterized by cactus-like trees and patches of scrub. Even in this unusual habitat there are lemurs.

Gallery forests are another habitat found in the arid south. Also known as riverine or tamarind forests, they grow along rivers in the south where the water table is high enough to support tamarind trees. These forests look similar to the dry deciduous forests further north, but are dominated by towering tamarinds and banyan trees. Gallery forests are preferred by ring-tailed lemurs. They are also home to Verreaux's sifaka, the grey mouse lemur, the white-footed sportive lemur, tenrec, flying fox, giant coua, hook-billed vanga, magpie-robin, Paradise flycatcher, sparrowhawk, vasa parrot, radiated tortoise, spider tortoise, Dumeril's boa, chameleon, geckos and plated lizard. Due to expanded population growth, gallery

forests are rapidly being converted to farmland, over-grazed by livestock and harvested for charcoal.

The Need for Trees

Whether the forests are tropical, dry deciduous or spiny, all lemurs depend on trees for their survival. Alarmingly, since the 1950's at least half of Madagascar's primary forests have been harvested for timber or charcoal, mined for precious metals, or cut and burned to create space for farmland. Today, virtually all lemur species are threatened by habitat destruction.



THEME 3: INVESTIGATING LEMUR ADAPTATIONS

BACKGROUND INFORMATION FOR THE FOLLOWING LESSONS:

BUILT TO SURVIVE | ADAPTATION STATIONS

SURVIVAL SCENTS | AM I LIKE A LEMUR?

Adaptations for Extreme Living

All animals have adaptations (physical and behavioral traits) that help them survive within their specific habitat. Streamlined body shapes, camouflaged colors, prehensile tails, claws, opposable thumbs and toes, webbed feet, hooked beaks and canine teeth are all examples of physical adaptations.

While we require special clothes and equipment to survive harsh environments, animals are able to thrive in extreme conditions thanks to their unique adaptations, such as:

- Marine Adaptations: Gills, blowholes, fins, streamlined body shapes, scales, specialized eyes, blubber, camouflage colors and echolocation are just a few ways that fish, shark, and marine mammals like dolphin are adapted for life in the sea.

- Desert Adaptations: Camouflage colors for hiding, large feet that stay on top of the sand, long eyelashes to protect eyes from blowing sun and large ears that release heat are physical adaptations that help animals such as camels and fennec foxes survive hot arid desert conditions.

- Arctic Adaptations: Short ears and short round bodies that reduce heat loss, thick warm fur, large feet that act like snowshoes and white colors, for hiding from predators or prey are just some of the adaptations that help arctic animals like polar bear, arctic fox and snowshoe hare survive extreme Arctic conditions.

- Rainforest Adaptations: Camouflage colors, toxins, mimicry, bright warning colors, prehensile tails, specialized hands, feet and beaks for climbing and dense waterproof fur are examples of adaptations for species from rainforests.

Lemurs: Built to Thrive in Madagascar

Finding food, avoiding predators and surviving Madagascar's diverse environments isn't easy. All lemurs possess certain features—for instance strong back legs, opposable or semi-opposable thumbs and a superb sense of smell to help them survive. In addition, variations in body size and shape, coloration and tail structure help different lemur species thrive in habitats that range from warm humid rain forests to dry rugged tsingy.

Adapting to a Changing World

Animals constantly adapt to the changing world around them. Sudden changes in weather temperatures, food supplies, or physical environment can cause significant decreases in animal or plant populations. Some species are able to adapt to a variety of environments. Other species like the bamboo lemur are more specialized and depend on specific food sources or living conditions. Some animals can change homes or food sources while others can't. Island species, like lemurs, are particularly vulnerable to changes in their habitat since many are highly specialized and are unable to move if their habitat disappears.

Surviving through Scents

Scents play an important role in lemur life. Smells are a primary form of communication among troop mates. Territories, foraging routes, mates, competitors and predators are all identified via scents. Lemurs have pointy, moist noses and like dogs have "super sniffing" abilities. All lemurs have scent glands that are located (depending on the species and sex) around the feet, chest, wrists, arms and genitalia. Scents from these glands are rubbed on plants, rocks, trees and other lemurs to mark territory and foraging routes. These sensory "fences" notify other groups to stay away, reducing physical conflicts. Male ring-tailed lemurs use spurs on each wrist to pierce tree branches before marking them. Male ring-tails also use scent during "stink fights" with other males. When battling over a female they will rub scents from their wrist glands onto their tail and

wave it at their opponent. The lemur with the strongest scent wins! These stink fights allow males to battle without injury. It is thought that ring-tailed lemurs may have the most complex scent language of all primates. Studies show that ring-tails use scents to identify who they are (the way we use our written signature), dominance status, breeding potential, social attachments, health, and stress levels.

Seeing in Stereo

Fish, insects, reptiles, most birds and many mammals such as rabbits and horses have eyes located on either side of their head. This allows their eyes to point in different directions as well as in front and behind. This "panoramic vision" helps them spot and escape predators. Lemurs, along with humans, other primates and most predatory animals have eyes that face forward and point in the same direction. The view from each eye overlaps giving them stereoscopic (3-D) vision and the ability to judge depth as they climb through the trees. How does this work? When our brain tells us what we are seeing, it needs information from both eyes. For depth perception, the brain uses the differences between the picture from the left eye and the right eye to figure out how far away something is. If only one eye sends information, the picture is not complete and depth perception is lost. The ability to judge distances is extremely important for animals that leap from branch to branch since even the tiniest mistake could lead to a fatal fall. Some scientists believe that forward-facing eyes may also help lemurs and other arboreal (tree-dwelling) species see through "cluttered" environments like leafy forests. Lemurs also have color vision which, along with their super sense of smell, help lemurs find favorite foods like fruits and flowers.

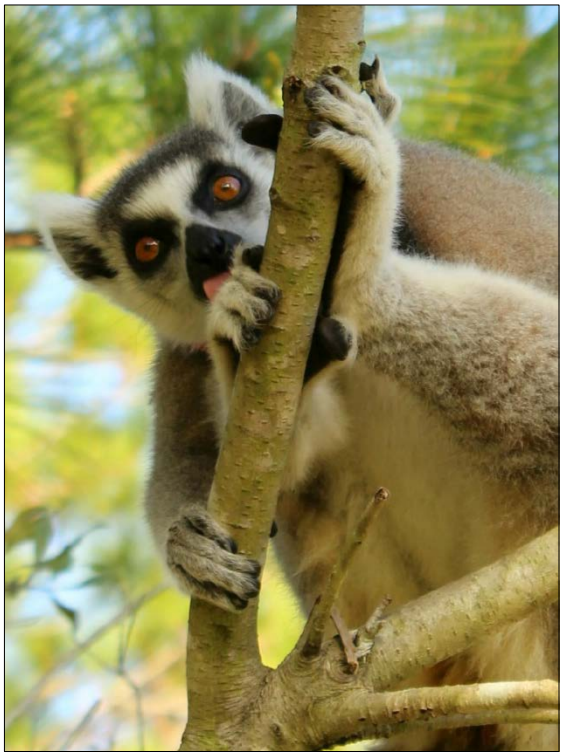
Night Vision

Many lemurs have enhanced nighttime vision thanks to a layer of cells called the *tapetum lucidum* located along the back of their eyeball. Acting like a mirror, this reflective lining bounces light back through the retina. It's the reason why lemur eyes shine so brightly at night when light is shown on them. Dogs, cats and deer also have a reflective *tapetum lucidum*, but humans do not.

Teeth for Feeding, Fighting and Cleaning Fur

Like a Swiss army knife, lemur teeth are shaped for a variety of uses. Sharp front teeth are designed to snip buds, fruits and flowers from branches. They also can crunch through an insect's hard exoskeleton. The aye-aye's continuously growing, chisel–like incisors can gnaw through nuts, coconut husks and even wood. But lemur teeth are used for more than just eating.

Male lemurs use their long razor sharp canines to slash competitors when battling for females or protecting territory. A lemur's teeth are also used for grooming. The tiny gaps between a lemur's bottom teeth (incisors) form a natural comb. Lemurs use this "tooth comb" to groom their own fur and the fur of others in their group. Mutual grooming keeps parasites away, maintains everyone's coat in top condition, reinforces social hierarchy and bonds individuals within the group, helping them stay calm and connected.



Left: All but one lemur, the indri, have long tails which they use for balance. Unlike some monkeys, lemur tails are not prehensile. **Right.** Lemur feet resemble hands and are adapted to grip and hold onto features in their habitat.

Tails for Climbing, Leaping and More!

Lemur tails come in a variety of lengths, shapes, sizes and uses. Lemurs lack the prehensile or grasping tail that some monkeys possess. Instead, their tails act like a trapeze artist's pole, helping them balance as they run, leap and climb among the branches. But lemur tails are for more than just climbing. Ring-tailed lemurs use their long brightly striped tails to communicate with each other while traveling. Males wave them during "stink fights" over territory and females. Mongoose lemurs also use their tails to communicate. They "swish" their tail back and forth like a cat when they see a predator or unfamiliar lemur. If two mongoose lemurs are looking to challenge one another, they will curl their tail into a tight coil as a warning to the other lemur. During the first few days after birth, lemurs whose infants cling to them use their tails to shield and

hide their infants. Fat-tailed dwarf lemurs store fat in their tails (up to 35 percent of their body weight!) and burn it during Madagascar's dry season when food is scarce.

Unique Hands and Feet

All lemurs have specialized hands and feet that help them move through the trees. Adaptations include padded palms and soles for traction and protection, nails instead of claws and opposable (or semi-opposable) thumbs and toes. Having opposable thumbs means that lemurs can press their thumbs against their fingers like humans can. This allows lemurs to grasp branches as they climb and leap from tree to tree. Lemurs have nails on their fingers instead of claws. This helps them pick up and grab fruit, insects and branches with greater delicacy. Aye-ayes have a specialized skeletal finger used for locating and digging insects from trees. They also use it to extract meat from hard-shelled nuts and fruits and even use it to drink water by quickly moving their finger between the liquid and their mouth.

Most lemurs have feet that are shaped more like elongated hands with an opposable big toe that acts like a thumb. This allows them to grip branches with both their hands and feet as they run and leap from tree to tree. A special "grooming claw" located on their second toe is used for grooming, scratching and getting those hard to reach places.

Fur to Protect from Predators and the Elements

Lemurs have short dense fur that protects them from insects, thorns, rain, nighttime cold, and daytime heat. Nocturnal forest-dwelling species like mouse lemurs and aye-aye are typically camouflaged in browns and black to help them hide from predators and sneak up on small animals like insects and lizards. Diurnal (daytime) dwellers like ring-tailed lemurs, indri and sifaka are often lightly colored. This may help them keep track of each other as they forage for food and reflect daytime heat. Some lemurs have the ability to "drop their fur" during conflict or direct fighting. Similar to the lizard that can drop a section of their tail if caught by a predator, lemurs have the ability to do the same with their fur when in a tussle with another lemur. This is a common strategy used by ring-tailed lemurs and numerous tufts of hair can be found surrounding, and missing from, two fighting males.

THEME 4: DISCOVERING LEMUR COMMUNITIES

BACKGROUND INFORMATION FOR THE FOLLOWING LESSONS:

WHAT'S FOR DINNER? |CREATE A TSINGY FOOD WEB

YOU CAN'T GROW HOME AGAIN | MADAGASCAR THE MUSEUM

A Fragile Balance

The living and non-living things within a habitat, including the plants, animals, rocks and soil, make up an ecosystem. An ecosystem can be as small as a single tree or as big as an entire forest. Everything within an ecosystem is dependent on one another.

Sharing the Sun's Energy

Animals within an ecosystem are linked together by what they eat. Within these food chains, energy from the sun is passed from one living thing to another. Food provides nutrients (substances living things need to stay healthy) and energy. Plants use energy to grow, move and reproduce. Energy is transferred when plants (called producers because they produce their own foods) change sunlight and nutrients from the soil into food for herbivores (animals that eat plants). Herbivores become prey for carnivores (meat eaters) and omnivores (animals that eat both plants and animals). Together these animals are called consumers. When animals die, their bodies decompose and replenish the soil so new plants can grow. When food chains are combined, they create a food web.

Every Organism Plays a Part

Like a human community, every plant and animal within Madagascar's ecosystem has a niche (role) that keeps it in balance. Decomposers like hissing cockroaches and giant millipedes break down dead plants and animals. This nourishes the soil and keeps the forest floor clean. Butterflies, birds and some lemurs spread the pollen needed to help plants grow. Plant-eating herbivores, including some lemurs, the Malagasy giant rat, tortoises, and fruit bats, keep sun-filled clearings open, spread seeds and fertilize the plants with their waste. They, along with insects, also become prey (food) for predators (animals that hunt other animals) like fossa, mongoose, tenrecs, crocodiles, turtles, snakes, frogs, owls and eagles. Predators keep animal populations from growing too large and exceeding the ecosystems carrying capacity—the maximum number of animals an ecosystem can support.

Lemurs and Madagascar's Forests: Working Together to Survive

Within the forests of Madagascar, lemurs fill many niches typically filled by other species. For instance, physical adaptations like long, chiseled incisors and a skeletal third finger help the aye-aye feed on tree-boring grubs, a role filled by woodpeckers in North America. Some lemurs help Malagasy forests grow by serving as key pollinators and by dispersing seeds in their feces as they travel through the forest. This ensures a constant food supply for themselves and other plant-eating species. Without them, these plants and animals and ultimately the forest itself would disappear.

Black-and-White Ruffed Lemurs and Traveler's Palm: Partners in Pollination

Lemurs probably aren't the first animals that come to mind when you think of pollination, but many lemur species, such as the mongoose, dwarf, mouse and red-ruffed lemurs pollinate flowers. Black-and-white ruffed lemurs are the largest pollinators on Earth and a main pollinator of the Traveler's Palm. Using their nimble hands to pull open the tough flower bracts, they stick their long snouts and tongues deep inside the palm's flowers. In the process they collect pollen on their muzzle and fur and transport it to the next flower. The fruits of the Traveler's Palm are a major source of food for lemurs and other animals. Scientists believe that Black-and-White lemurs are the only animals on Madagascar that are strong and nimble enough to pollinate these forty-foot tall palms. Without them the Traveler's Palm, as well as the animals that depend on them, would eventually vanish.

Seeding Forests for Survival

As fruit-eating, highly mobile animals, lemurs play a critical role in dispersing seeds. Studies show that in some forests, large groups of plants are so dependent on a single species of lemur for seed dispersal that its loss could threaten the survival of the entire group. In some cases, lemurs are the only animals big enough to move large seeds. In one study conducted at Lokobe Reserve, scientists found that fifty-four percent of the tree species and sixty-seven percent of individual trees within the reserve had grown from seeds dispersed only by the black lemur. In the dry forests of western Madagascar, studies show that ten percent of tree species rely on lemurs to distribute their seeds. Scientist fear that as lemur populations dwindle the trees that rely on lemurs will disappear as well.

Why are lemurs so good at dispersing seeds?

According to biologists, it's because some lemurs are one of the only fruit-eating species that can swallow large seeds (up to 1.6 inches) and many seeds (up to ten) in one sitting. Many of these seeds are shaped like a capsule or tablet and contained in soft fruits making them easy (and tasty) for lemurs to swallow. Plant species that attract lemurs typically have fruit and flowers that have strong highly attractive scents. As the lemurs digest the fleshy fruit and travel through the forest, the seed passes through their system well away from the parent tree. Once on the ground, the seeds take root. Moving seeds away from the parent trees improves the seeds survival by ensuring the seed has adequate resources to grow. It also reduces the chance of plant disease and parasites spreading to the young trees.

THEME 5: LEARNING ABOUT LEMUR LIFE

BACKGROUND INFORMATION FOR THE FOLLOWING LESSONS:

GROWING UP LEMUR | A DAY IN THE LIFE OF A LEMUR

LEMUR ETHOGRAM | SURVIVAL SCENTS

Survival through Behavioral Adaptations

Like physical adaptations, animals use behavioral adaptations to survive. A behavior is any action that an animal performs. Blinking, eating, running, playing and communicating are all examples of behaviors. Because lemur species and habitats vary so dramatically, their behaviors do too. Some live in pairs or groups. Others tend to be solitary. Some are active by day (diurnal) others at night (nocturnal). While most lemurs spend much of their lives in the trees some, like ring-tailed lemurs, spend time on the ground. Even vocalizations vary dramatically—from the chirps of the mouse lemurs to the loud wailing call of the indri.

Learning About Lemur Life through Scientific Study

The study of animal behavior is called ethology. Those who study it are called ethologists. Much of what we know about lemur behavior, including their female dominated social structures, is thanks to ethologist Dr. Alison Jolly, author of the Ako the Aye-Aye series.

Ethologists often use a chart called an ethogram to record behavioral data. An ethogram consists of a list or catalog of behaviors that are specific to a particular species. After developing

an ethogram, a scientist can use it to record data and figure out how often and under what circumstances certain behaviors occur.

Observing animals in the wild helps us to better understand their world. By observing, we can also understand the differences between individual animals within animal social groups. Studying the behavior of animals has helped us provide better care for animals in zoos and protect them in the wild. Scientists use animal behavior studies to assess environmental damage, to learn how to preserve habitats, to understand habitat ecology, to develop effective conservation policies, and to improve captive care and breeding.

Growing Up Lemur: A Look at Lemur Life Cycles

The diversity of lemur adaptations and habitats extends into their life cycles. Let's take a look at the life cycles of two very different lemur species: the tiny, nocturnal, semi-solitary Madame Berthe's mouse lemur and the larger, diurnal and highly social, ring-tailed lemur.

Above: Madame Berthe's Mouse Lemur is the smallest primate in the world and is a solitary forager. Photo by Daniel Austin.

Madame Berthe's Mouse Lemur—Small and Solitary

Madame Berthe's mouse lemurs are born in December or January. After a gestation period of 2 months, females give birth to one to three infants. Infants are born, eyes closed, in the security of their nest. Compared to larger lemur species, baby mouse lemurs grow up fast. Their eyes open after just a few days. By the time they are thirteen days old, developing youngsters begin to play alongside their mothers. For young mouse lemurs, games like chasing and jumping over their mother's feet help develop their agility and locomotion skills. They will need these skills to

survive once they venture from the nest. At three weeks they begin to explore the forest with their mother at night. During their travels the mother leaves scents marks along her network of foraging paths and home range. When the offspring are six weeks old, they begin to sample solid foods like "honeydew" (a sugary substance secreted by insect larva), fruit, flower nectar, buds and insects. By the time they are eight weeks old, offspring stop nursing completely and feed only on solid foods. When winter arrives, male mouse lemurs leave to seek out their own territory. By the time they are one-year- old the mouse lemurs are old enough to have offspring of their own. If they can avoid predators like owls, mongoose and fossa, mouse lemurs can live for 8 years in the wild.

Ring-Tailed Lemurs: Power in Numbers

Unlike the solitary mouse lemur, the social ring-tailed lemur lives in groups or "troops." These can number from as few as three to more than 25 individuals. When it comes to ring-tailed lemurs, females rule! Troops revolve around related adult females (mothers, daughters and sisters) and their offspring and are led by a top-ranking female. This dominant female decides where the troop eats, sleeps and travels. Wild ring-tailed lemurs in Madagascar typically mate in April. While competing for females, males participate in a variety of behaviors including:

- Cuffing: Swatting their hands at the other's face. This can escalate into scratching, grabbing and pulling out tufts of fur.
- Jump-fighting: Intimidating each other by standing on their hind legs and grabbing each other from above. This often includes slashing each other with their canine teeth, which sometimes results in injuries.
- Stink-fighting. This involves rubbing their tails with a strong scent secreted from glands on their wrist and waving them at each other. These "stink fights" are a way to avoid actual fights that could lead to injury. A winner is determined when the less aggressive male retreats.

In the wild, females give birth between August and October. In Madagascar, this is right before the start of the rainy season when food is readily available. Typically one infant is born, however twins sometimes occur when food is plentiful. Newborns are about 10 cm (3.9 inches) long and weigh less than 3 ounces. They are born with their eyes open and with adult markings including the striped tail. For the first two weeks, youngsters cling to their mother's stomach. As they grow they graduate to riding on her back. Like human children, young lemurs spend much of their day playing, and since births within the troop take place at the same time, they have plenty of

playmates! For young lemurs, chasing, play- biting, jumping, and wrestling are opportunities to learn and practice important life skills and behaviors. Through play, young lemurs become strong and agile and learn how to get along with others.

While a young ring-tailed lemur's mother provides most of the parental care, other members of the troop (both male and female) help too. This strategy (called alloparenting) gives the mother a well-earned break, enhances the infant's social skills and provides young female lemurs the chance to practice their parenting skills before they have infants of their own. Young lemurs begin to eat solid food after two months and are fully weaned after six months. They reach full adult size at around 1.5 years of age and are able to have offspring of their own at 2.5 to 3 years. While females stay in the same troop, males may travel to other troops when they are three to five years old. Ring-tailed lemurs can live up to twenty years in the wild and more than thirty-five years in managed captive populations.

Above: Ring-tailed Lemurs live in groups of up to 25 individuals and are female dominant.

A Day in the Life of a Ring–Tailed Lemur

A ring-tailed lemur's day starts at dawn. After a night spent huddling together in their sleeping trees to stay warm, lemurs move into the sun to warm up. This is done by sunbathing—sitting upright on their haunches and resting their forearms on their knees "yoga-style" to expose their undersides to the sun. Around noon the group settles into the shade. On particularly hot afternoons they often take a second rest in the mid-afternoon. Grooming and playing are popular activities during these "down times." Grooming keeps fur clean and healthy and strengthens troop bonds. Status is very important in ring-tailed society and every member has its own rank. The hours spent playing, grooming and networking help bolster alliances and reinforce social hierarchies.

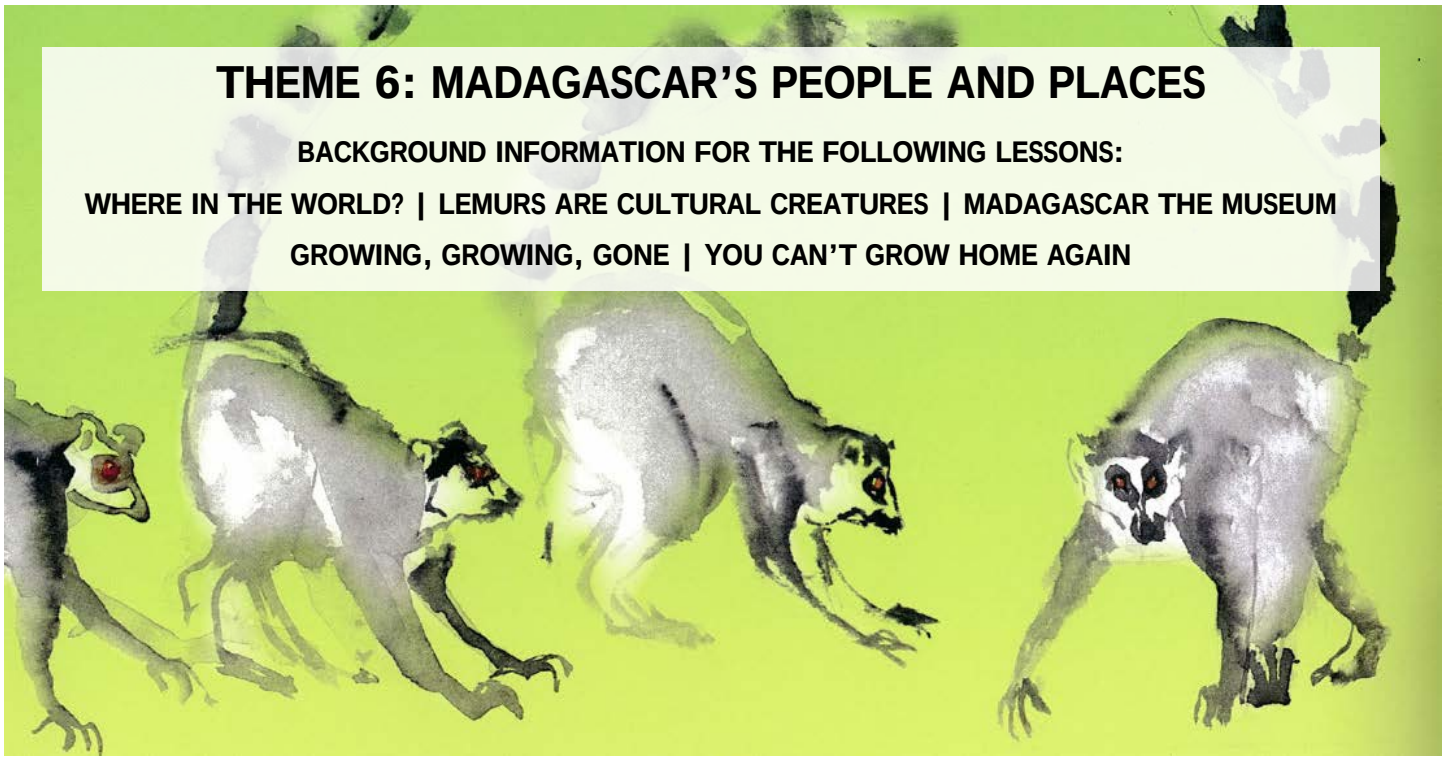
In between these morning and afternoon siestas, ring-tailed lemurs travel and forage for food. While most lemurs spend their days in the trees, ring-tailed lemurs spend 30-40 percent of their day on the ground. Troops travel with their striped tails held high to communicate. Travel and foraging typically take place within their home range which can cover fifty acres. Each troop defends its home range from other troops.

As the sun sets, troops return to the safety of their sleeping trees for the night. Here they remain as a group for a night of sleeping, grooming and interacting. Scientists recently discovered that some ring-tailed lemurs sleep in caves instead of trees. While this has likely been going on for millennia, it is just now being recognized as a regular behavior. Scientists believe sleeping in caves protects the lemurs from potential predators and extreme temperatures. The caves may also provide sources of water and minerals.

Survival through Sound, Scent and Sight

With large social groups and a home range to patrol, it is no wonder lemurs have so many ways to communicate. In addition to communicating through scent, lemurs communicate through vocalizations and facial expressions.

Lemurs are one of the most vocal primates and their vocalizations include barks, howls, screams, clicks and purrs. Common calls include separate alarm calls for land predators and aerial predators, a meow-like cohesion call that signals troop members to gather for travel and a territorial howl that can be heard for over half a mile. Ring-tailed lemurs also communicate through facial expressions. They may stare open-mouthed, bare-teeth, pout and hoot to convey different information.



THEME 6: MADAGASCAR'S PEOPLE AND PLACES

BACKGROUND INFORMATION FOR THE FOLLOWING LESSONS:

WHERE IN THE WORLD? | LEMURS ARE CULTURAL CREATURES | MADAGASCAR THE MUSEUM

GROWING, GROWING, GONE | YOU CAN'T GROW HOME AGAIN

Welcome to Madagascar

Imagine an island, filled with strange looking creatures roaming an even stranger landscape. Imagine a place where giant bottle-shaped trees mark the skyline and both lush rainforests and arid deserts flourish. Imagine a place where most of the plants and animals are found nowhere else in the world. Welcome to Madagascar—a land like no other. Located in the Indian Ocean, 250 miles from Africa's eastern coast, Madagascar is about as distant from the United States as you can get.

Geologic History

Before becoming an island Madagascar was part of the Gondwana supercontinent. When Africa broke away 165 million years ago it formed Madagascar's western edge. It became an island around 80 million years ago when the land broke away from what today is India. 226,627 square miles in size (about the size of Texas or France) Madagascar is the fourth largest island in the world. Only Greenland, New Guinea, and Borneo are larger.

Human History

While there is some debate as to the origin of Madagascar's first settlers, most archaeologists agree that humans settled the island between 1,500 and 2000 years ago. Most believe the first

people sailed from Borneo, with later immigrations from mainland Africa. Others suggest that the first arrivals were of both Indonesian and African descent. While there is still much to be learned, elements of the Malagasy language and culture indicate both strong Indonesian and East African roots. Like many of today's island residents, these earliest inhabitants hunted and grew crops from forest that was cleared using *tavy* (slash and burn agriculture). These practices ultimately led to the extinction of Madagascar's largest wildlife species, including the giant lemurs, elephant bird and Malagasy hippo.

In the 7th century, merchants from the Middle East established trading posts along Madagascar's northwest coast and there was active trade from Madagascar abroad. Madagascar was discovered by Europeans in the early 1500's when a Portuguese ship explored the island's northern coast. The island was a popular haven for pirates from the 16th to 18th century thanks to its proximity to Indian Ocean trade routes and its abundance of hidden coves. Today, tales of buried treasure and buccaneers continue to be a colorful part of the nation's folklore.

The Sakalava Kingdom in the west traded with Europeans throughout the 17th and 18th century, but it wasn't until later that the island was unified together under Merina rule and more established relations developed between Madagascar and Europe. In 1794, King Andrianampoinimerina united many of Madagascar's different tribes and formed the Merina Kingdom. In 1810, his son and successor King Radama I continued extending the Kingdom over much of the island. During his reign, King Radama also introduced industry and established relationships with many European countries. He also opened the island to English missionaries who introduced Christianity, the Roman alphabet and transcribed Malagasy into a written language. After King Radama I's death in 1828, his wife Queen Ranavalona took over the throne. She expelled the missionaries and re-instituted a focus on traditional beliefs.

In 1883 the island was invaded by France. By 1896 it was made a French colony and a valued source of timber and spices, including vanilla. During World War II, Malagasy troops fought alongside Vichy forces in France until the British invaded the island and, for a brief period, overtook Madagascar. After World War II there were major uprisings against the French by Malagasy and the island nation finally regained independence in 1960 under the newly-elected French president Charles De Gaulle. The new country was given the name the Independent Malagasy Republic. Today the country is officially known as the Republic of Madagascar.

Left: A photo taken in 1863 while the Malagasy embassy visited Europe. Before the French colonized the island in 1896, Madagascar was an independent nation recognized internationally. **Right**: Ambohimanga, one of the best preserved settlements from pre-colonial Madagascar. Located near today's capital Antananarivo, this site was home to Merina royalty for centuries.

An Island Rich with Culture

Malagasy culture is uniquely its own, but draws from Southeast Asia, India, Africa, and the Middle East. Indonesian roots are evident in the Malagasy language, which is a member of the Austronesian language family. Malagasy is more closely related to the East Barito languages of Borneo than to those spoken in mainland Africa. Indian influences can be seen in food (samosas are a popular street food) as well as in the significant population of Malagasy from recent Indian descent. The zebu cattle commonly raised on the island reflect African influences. Veneration of the dead is another aspect of Malagasy culture that is often compared to belief systems in some East African cultures.

Today's Madagascar is home to over twenty different ethnic groups. The largest group by population are the Merina, the people of the highlands. The Betsimisaraka of the east are the second largest. Differences between peoples in Madagascar are reflected in clothing and hairstyles but are most easily heard in the language. While everybody speaks one language, Malagasy, there are many regional dialects and words for certain things used in one part of the island may be unknown in another.

Above: Madagascar is home to more than 21 million people who belong to regional ethnic groups. They share one common language, Malagasy, but each group has their own distinct dialect and traditions. Photos by Daniel Austin.

Traditional Beliefs and Religion

Traditional Malagasy beliefs are centered on a supreme God (*Zanahary* or *Andriamanitra*) and close ties between the living and deceased. *Razana* (ancestors) are considered the most important members of the family and are closely involved in the daily lives and customs of the living. Hardship results if the dead are offended or neglected.

The burial tomb is the primary link between the living and dead. It is often built with great care and expense and in some areas may be more substantial than the family home. Laws ensure that the land it is constructed on, *tanindrazana* or "land of the ancestors," forever remains with the family. A tomb's structure and construction reflects their ethnic group as well as the family's wealth and status.

The custom of *famadihana* reaffirms the link between the living and the ancestors. *Famadihana* occurs when someone has a vision or vivid dream where an ancestor visits them. The tomb and remains must then be cared for and the bones of the ancestor moved and wrapped in new shrouds. This is a festive occasion with food, music, and dancing. Hundreds of family members may come to participate.

Fady (taboos) are also an important part of the Malagasy belief system and govern daily life. Taboos vary widely among different ethnic groups, and from village to village within the same

ethnic group. These traditional beliefs are augmented by imported organized religions. Around half of Madagascar's population adhere to traditional beliefs, forty-percent identify as Christian (evenly divided between Roman Catholics and Protestants) and around five percent are Muslim.

Language

While many Malagasy traditions and customs are regional, the island's population is bonded by a common language. Both French and Malagasy are official languages. Malagasy is the language you will hear if you walk through town or market and French is typically left for preparing official paperwork and conducting business. French is also taught in school along with an official version of the Malagasy language which is meant to be understood by all.

The Malagasy alphabet includes the same letters as the English alphabet except C, Q, U, W, and X. The letter "A" is always short (as in "watch"). The letter "E" sounds like a long "A" (as in "pace"). The letter "I" is pronounced like a long "E" (as in "bean"). The letter "J" sounds like "dz" and the letter "O" sounds like "oo." Want to try some Malagasy phrases? Visit the National Museum of African Art's online exhibit to hear how the following are pronounced.

"Hello" Manahoana
"What's your name?" Iza no anaranao?
"What's new?" Inona ny vaovao?
"It's very hot!" Mafana be!
"It's very cold!" Mangatsika be!
"Thank you very much" Misaotra betsaka
"Goodbye" Veloma

Economy

Madagascar's economy is highly dependent on agriculture, fishing, and forestry. The island is the world's largest producer of vanilla and accounts for nearly fifty-percent of the global market. Other key exports include coffee, sugarcane, cloves, rice, cocoa, cassava, and beans. Increasingly large-scale mining projects are being developed and the country is home to a substantial nickel and cobalt mine and refinery as well as a large titanium mining operation. The country's unique wildlife and picturesque beaches make Madagascar a popular tourist destination as well, especially with the French, and tourism makes up a significant component of the economy.

Despite its rich resources, Madagascar is one of the world's poorest countries. Contributing factors include its colonial roots, modern day government corruption, political instability, severe environmental damage, a lack of roads and infrastructure, and the island's geographic isolation that makes transporting goods difficult and expensive.

Left: Madagascar is the largest producer of vanilla in the world. Here vanilla beans are being dried in the sun on the street in Maroantsetra. **Right:** A group of women sort cloves in northeast Madagascar. Photo by Daniel Austin

National Parks

There are more than 50 parks and reserves managed by Madagascar National Parks, a branch of the Malagasy government. Some of the most popular parks with tourists include Andasibe-Mantadia National Park in the central-east, Isalo National Park in the south, and Ranomafana National Park in the southeast. These parks can receive tens of thousands of tourists each year. Other protected areas, such as Anjanaharibe-Sud Special Reserve, where the Lemur Conservation Foundation works, may only receive a few dozen tourists annually and there is great potential to further develop nature-based tourism in Madagascar.

Madagascar: Home to Strange and Wonderful Wildlife

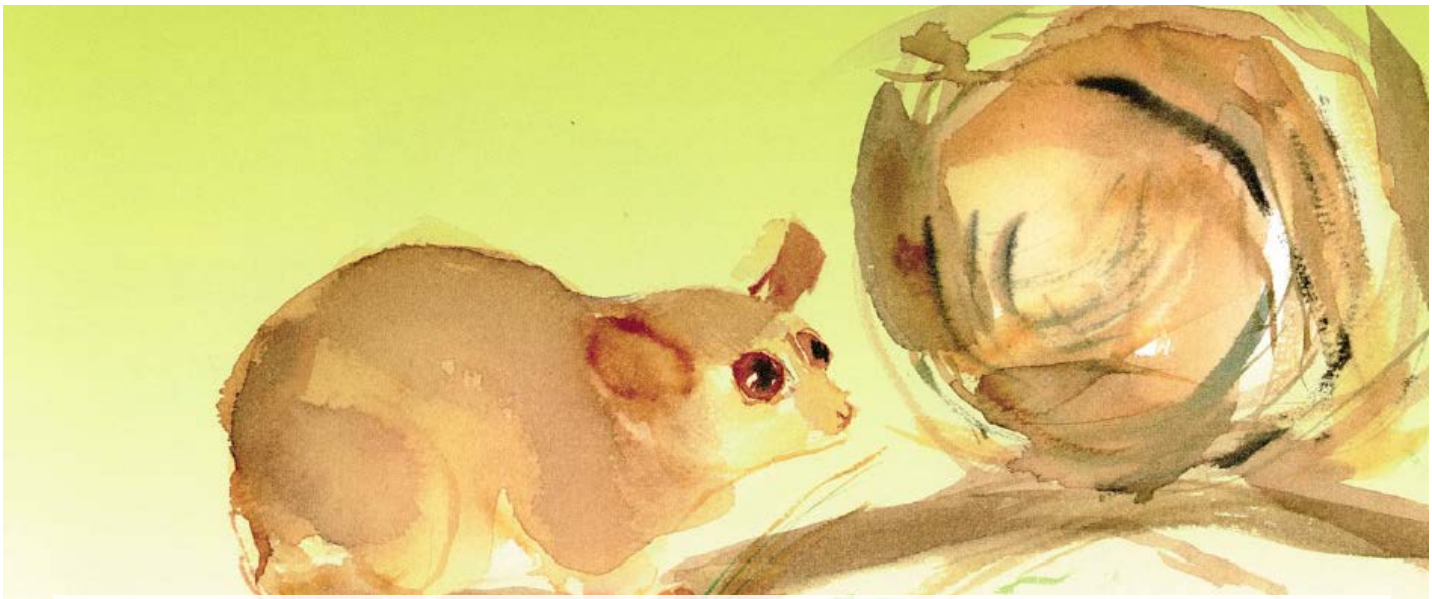
Home to approximately two-percent of the Earth's biodiversity, about ninety- percent of the island's 250,000 species are found nowhere else in the world. These endemic species include lemurs, fossa and an amazing array of birds, chameleon, tortoises, snakes, frogs and insects. Madagascar is home to more species of orchid, chameleon and tenrec (a group of small, spiny mammal species) than can be found on the entire African mainland. And while the African continent is home to two of the world's eight species of baobab trees, Madagascar is home to

six. Due to its high number of endemic species, biologists have referred to Madagascar as the "eighth continent" and agree that saving the island's extreme biodiversity is the planet's top conservation priority.

Human and Wildlife Challenges

Madagascar is one of the world's poorest nations. Its 24 million residents (as of 2016) continue to rely heavily on farming for their livelihood and most get by on less than a dollar a day. Half of its population is under the age of 15 and a majority suffer from chronic malnutrition. The extreme poverty most of the population lives in and its fast growth drives the country's environmental problems. As Madagascar's population increases, the little natural habitat that remains is being used for fuel, farmland and settlements, and extinction will continue to occur for many of the island's unique endemic species should nothing change. Efforts to protect Madagascar's wildlife must therefore address the needs of the people. Despite national and international conservation efforts, very little of Madagascar is currently protected. Established parks and reserves rarely have the resources needed for management and their borders are often left open and unenforced. To preserve this fragile land, conservation efforts will need to continue in ways that support wildlife as well as Madagascar's human population.

Above: The Lemur Conservation Foundation (LCF) works with Madagascar National Parks (MNP) to manage Anjanaharibe-Sud Special Reserve in northeast Madagascar. Here field agents are installing a sign to demarcate the western boundary of the reserve which formerly was not posted.



THEME 7: MAKING A DIFFERENCE FOR LEMURS

BACKGROUND INFORMATION FOR THE FOLLOWING LESSONS:

WE MAY BE SMALL BUT TOGETHER WE ARE BIG | BUYER BEWARE | TROPICAL DILEMMAS

GROWING, GROWING, GONE | YOU CAN'T GROW HOME AGAIN | MADAGASCAR THE MUSEUM

Lemurs Are Up Against a Lot

If we want to make a difference for lemurs we first need to examine the threats they face. Since the settlement of Madagascar around 2000 years ago, at least 17 species of lemur have already gone extinct. Almost all of the species that remain are threatened by habitat loss due to extensive deforestation. Other threats include hunting, invasive species and the pet trade.

Habitat Destruction: Losing ground (and trees) to farming

Madagascar's primary forest cover has been halved since the 1950's and habitat destruction continues at a rapid pace today. One of the main causes is forest clearance for agriculture. Forests are cut and burned as a way to grow food. In October and November, when the island is driest and the farmers are in the fields, smoke fills the air and ash rains down as land is cleared. By burning the forest, nutrients are quickly released into the soil and people can easily grow food for one or two seasons, but afterwards they must cut down a new stand of trees and burn again to grow more. Once there are no trees left to hold soil in place, the earth is washed into rivers during the rainy season and the landscape is irreversibly damaged.

Commonly called “slash and burn agriculture” (*tavy* in Malagasy), this farming practice can work well when there is a small human population and a lot of forest, but in Madagascar where the human population is rapidly increasing and there is little forest left *tavy* is not sustainable.

Above: *Tavy* or slash and burn agriculture is one of the main contributors to lemur habitat loss. This is a typical view of the countryside after forest has been cleared. Although the cleared land is now fertile, the soil will soon be washed into the rivers below and new forest will need to be burned to create arable land next year. Photo by Jean Noel Ndriamiary.

As their forest homes disappear, lemurs are forced to live in smaller areas that no longer provide the space and food they need to survive. The forests that remain become islands of trees surrounded by empty grasslands, villages, and fields. This fragmentation of forests brings lemurs into closer proximity to humans and domestic animals. This introduces lemurs to new diseases, alters natural behavior and makes them easy targets for hunters. It also disrupts natural processes like breeding, pollination and foraging patterns.

Madagascar’s human population is growing quickly and as the number of people increase, the competition between humans and lemurs for living space and resources continues to grow.

Habitat Destruction: Selling the forest for timber

Certain trees native to Madagascar, such as rosewood and ebony, are desired worldwide for use in furniture, guitars, and other products. These trees are found in key lemur habitats including

protected areas that contain endangered species. Commercial logging opens up the forest, eroding soil and disrupting biological processes like pollination and seed dispersal.

Although logging is illegal in many protected areas, in Madagascar it is difficult to enforce. A military coup in 2009 resulted in a surge of illegal logging, as the government was either unwilling or unable to enforce protective environmental regulations. In 2013, numerous Malagasy species of rosewood and ebony trees were added to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) making it illegal to import or trade timber from these rare trees. Still, the illegal sale of Malagasy rosewood and ebony continues and so long as there is demand it will be difficult to stop.

Habitat Destruction: A warming world

Today's atmosphere is made up of more carbon dioxide than at any other time in the last 10 million years. This greenhouse gas traps heat and has caused the average temperature of the earth to warm, which in turn is affecting weather patterns and the climate as a whole. In Madagascar, the effects of climate change are projected to continue to be worse than average. Most alarming is the threat this poses when lemurs are already confined to small forest fragments. While in times past lemur populations may have easily moved to higher or lower elevation forests and adapted to climatic changes, with so little forest currently left on the island it is now impossible to move and migrate as they may have been able to do before.

Bushmeat: Hunting lemurs to feed a growing population

Lemurs are hunted and trapped for food. Although it is not as great of a threat as habitat loss, hunting is of great concern in many areas and especially in those forests which are close to human settlements. One species, the Verreaux's sifaka, is even known as "*ifaka-bilany*" or "sifaka of the cooking pot" in certain areas. Hunters kill lemurs using slingshots and snares and either eat them themselves or sell at market. Even lemurs living in protected areas are not safe and today lemurs are being hunted at an unsustainable rate. Lemurs are particularly vulnerable to over-hunting because some species do not mature for many years and produce offspring only once every two to three years. This means the loss of even a few lemurs in a forest can have a very big impact on the population.

Alien Invaders: Losing to invasive species

When humans migrated to Madagascar they brought domestic dogs to guard livestock and domestic cats to fend off rodents and other pests. Today their modern ancestors as well as non-

native rats and feral pigs roam the island destroying resources and preying on lemurs. Another recent arrival is a poisonous Asian toad. Although Madagascar has hundreds of different kinds of frogs, its lemurs and other endemic wildlife evolved without the presence of toads and there is growing concern that this new invasive amphibian will cause severe problems for the island's unique wildlife.

Above: The poisonous Asian toad was introduced to Madagascar around 2010. The toad population is now estimated to be in the millions. It is expected to spread over much of the island and impact lemur habitat. Photo by James Reardon.

The Pet Trade: Madagascar for sale

Every year thousands of reptiles, amphibians, invertebrates and even some mammals like tenrecs are exported from Madagascar, purchased abroad and kept as pets. These wild-caught creatures often adjust poorly to captivity and during transport there is usually alarmingly high mortality. The impact this legal trade has on wild populations is not fully understood, but it certainly is not helping. The pet trade also threatens lemurs, though, because in Madagascar lemurs are often illegally caught and kept as pets. There are thousands of lemurs in captivity in the country and this has impacted wild populations.

Although lemurs are not among the animals legally captured in the wild and sold internationally, many lemurs are still bred in captivity and sold as pets online or at pet stores that specialize in exotic animals. Lemurs and other primates are not designed to live in a human home. Quick moving, and with strong nails and sharp teeth, they frequently injure their owners. Their space, diet and habitat needs exceed the finances, time and knowledge of all but the most dedicated

individuals. Usually purchased as babies, when captive lemurs grow to adulthood without a family group of other lemurs, they suffer psychologically and inevitably end up a problem for their owner.

Solutions: Working together to create a better future for lemurs

Like all conservation issues, those surrounding lemurs are complex. They require scientific study, creative problem solving, education and, most importantly, local community involvement.

To be effective, Madagascar's conservation programs must be implemented by Malagasy. They must also support the needs of local communities in a way that protects wildlife. Fortunately, a global network of scientists, universities, conservation organizations, accredited zoological parks, reserves, private citizens, and Malagasy communities are working to save lemurs and their habitats. The Lemur Conservation Network is a global group of more than 50 organizations dedicated to protecting Madagascar's primates. As one of its many members, the Lemur Conservation Foundation works with Madagascar National Parks and local communities to protect Anjanaharibe-Sud Special Reserve in the northeast of the island.

Positive Conservation Action in Madagascar

Through cooperative efforts between Malagasy communities, government, and conservation organizations, Madagascar is finding alternative and sustainable means to support its people, its wildlife and its wild places. None of these actions are standalone solutions that instantly and immediately protect lemurs from extinction, but together they help make a difference. Some ongoing and encouraging solutions include:

Replanting forests: Native tree planting and rainforest restoration efforts are taking place throughout Madagascar. These range in scale from small local operations to massive country-wide efforts. While the success of reforestation programs also depends on the long-term ability of an organization to manage the reforested land afterwards, at this point millions of trees have been planted and the outlook is encouraging.

Planting forest corridors: Planting native trees to reconnect forests allows natural processes like pollination, foraging, seed dispersal and breeding to continue. Expanding the forest allows lemurs to live further from humans. This makes them less vulnerable to disease, hunters and introduced species. Planting and protection of these forest corridors is being carried out at a number of sites throughout the country.

Reducing the need for fuel with rocket stoves: In Madagascar, families traditionally cook over a fire with a pot placed on top of three stones or on a small metal charcoal grill. In some parts of the country, a family can spend more than two hours of each day collecting fuel wood from nearby forests. If wood is not collected it must be bought. Purchasing charcoal or wood can consume half of a family's already small income, leaving little money for food, health expenses or school fees. The introduction of affordable, fuel efficient "rocket stoves" reduces the amount of wood needed and helps alleviate some of the pressure on forests.

Spreading sustainable agriculture: With one of the main causes of habitat destruction slash and burn agriculture, many organizations are working in Madagascar to promote other more sustainable means to produce food. Agro-forestry projects, the introduction of permaculture techniques, and the development of agricultural training centers are some of the activities being carried out.

Developing community-run reserves: In the early 2000's it became possible for local communities to legally gain management rights of natural areas near where they live. This process of transferring habitat management from the State to the people who live near the forest has helped expand Madagascar's protected area network and, in many areas, has improved the way in which forests are conserved.

Creating value through nature-based tourism: Poverty, especially in rural areas, is a primary cause for the widespread environmental destruction seen in Madagascar today. Ecotourism helps the economy of Madagascar by providing work opportunities for local people while providing money for conservation efforts. Income from sustainable tourism provides a financial incentive to protect wildlife, and can help local communities become actively involved in conservation efforts.

How to be a wildlife hero

It may seem difficult to help lemurs when they live so far away, but the good news is that every day each of us can take small simple actions that together make a big difference. Here are just some of the ways that you and your students can help the lemurs of Madagascar, as well as the plants and animals that live near you.

1. **Provide a home for wildlife**

   With students, plant a butterfly garden, hang a bird house, construct a pond, or plant native trees in your backyard, schoolyard or community. Creating a school flower or native plant garden is another way to improve habitat for local wildlife and provides a great opportunity to connect students to nature. Gardens also are a way for teachers to illustrate complex ecological concepts (such as pollination, food webs, and decomposition) in a fun and easy-to-understand setting.

2. **Share what you have learned**

   Raising awareness about what you and your class have learned about lemurs can inspire others to take steps in their own life to bring about positive change. Lemurs are fascinating animals that do amazing things, and spreading the word about the remarkable lives they live helps get people involved in learning more about Madagascar and conservation efforts they can support.

3. **Reduce your impact**

   Perhaps the best way to help lemurs from afar is by reducing your own and your classroom's impact on the environment. Some solutions include:

   - Walk, ride a bike, or use public transportation rather than a private vehicle.
   - Turn off lights when you leave a room. Turn off appliances when not in use.
   - Switch to energy efficient sources of light, such as LED lightbulbs.
   - Turn off the water while brushing your teeth; only run the dishwasher when full.
   - Use both sides of a piece of paper; find new uses for items before discarding them.
   - Bring reusable containers or sacs to the store instead of using paper or plastic bags.
   - Use cloth napkins instead of paper ones, and rags instead of paper towels.
   - Recycle glass, plastic, metals, and electronics as appropriate for your area.
   - Spend, use, and consume less. Monitor what you need vs. what you want.
   - When making a purchase, choose products made from renewable resources.

4. **Be careful what you buy**

   Research the products that you buy to ensure they do not harm lemurs or their habitats. Do not buy furniture or products made from tropical hardwoods like rosewood and ebony. When buying a guitar ask if the neck is made of rosewood. Choose Forest Stewardship

Council (FSC) certified paper and wood products to protect forests and their wildlife residents.

Read the labels. Understand the impact that popular ingredients have on wildlife and their habitats. If you do not recognize an ingredient on a label, learn what it is and where it comes from. Is there an alternative that is better for the environment?

Never choose a lemur as a pet. Like monkeys and apes, lemurs are not safe or responsible choices as pets. Few people have the financial resources, knowledge, time or space to provide the high quality care they need.

5. **Support conservation organizations that protect lemurs**

Lastly, finding ways to raise funds for ongoing conservation programs in Madagascar is always helpful**.** Organize a bake sale, raffle or environmental festival to raise money for conservation issues facing lemurs. You or your class can also **adopt a lemur** at the Lemur Conservation Foundation's reserves in Florida and Madagascar.