WHAT IS A FOREST?

What springs immediately to mind when you think of a forest? Do you think of an area with lots of tall trees? If you were to walk through a forest would the ground be soft underneath your feet and the light be dim around you? Would you see and hear a variety of animals? Throughout the world there are many different types of forests, distributed according to several factors, such as climate, **precipitation*** and soil conditions, which influence vegetation patterns. Forests grow in areas with moist climates and at least one moderately warm season each year. In essence, forests are large, continuous stands of trees. Some forests are shorter or more open than other forests, but a common characteristic of forests is that trees are the dominant type of vegetation.

In many types of forests, the trees grow closely together such that the crowns (the top part of a tree formed by the leaves and branches above the main trunk of the tree) of each tree nearly touch or even overlap with the crowns of other trees, forming what is called a **canopy**. Many scientists define forests according to the percentage of land area covered by the canopies of the trees (percent canopy cover). According to many scientists, any wooded area with 10 percent or more canopy cover is considered a forest and wooded areas with a canopy cover of less than 10 percent are referred to as woodlands. However, other definitions of forests include only areas with 60 percent or more canopy cover. If you were walking through an area with very high percent canopy cover, you might get the sense of being under a closed roof created by the overlapping of the tree crowns. The diversity and density of the undergrowth in a forest can vary widely depending upon the type of forest.

**Throughout this packet, words that appear in bold are included in the glossary on page 65.*

How do scientists measure percent canopy cover?

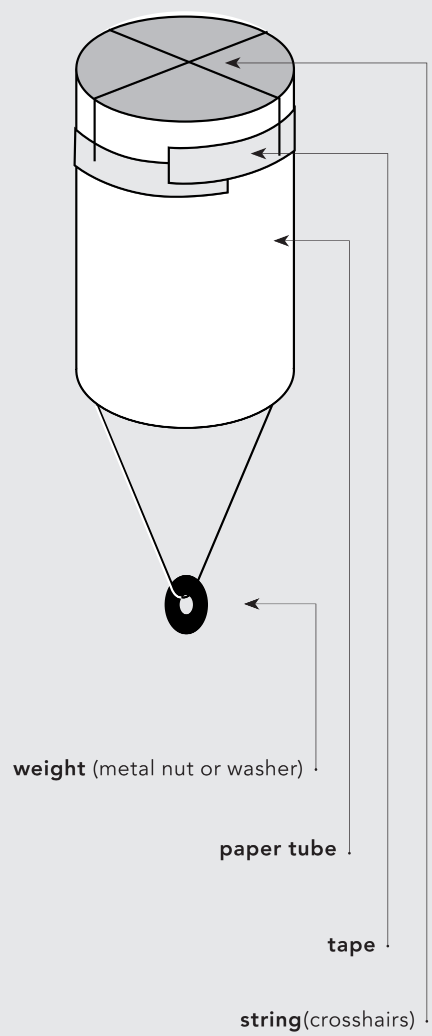
Scientists often calculate the percent canopy cover of trees in an area in order to determine whether the area is a forest. The percent canopy cover refers to the percentage of horizontal area covered by tree **foliage.** There are several different means scientists use to determine this percentage. A tool often used to measure canopy cover is a densiometer. There are two common types of densiometer, a spherical densiometer and a tube with crosshairs referred to simply as a densiometer.

A spherical densiometer is usually a convex mirror with a grid of 24 squares etched into it. While taking data in a forest, you would hold the densiometer at a point on your transect and look at the grid on the mirror. Imagine four uniformly spaced dots in each square of the grid. If there seems to be more canopy cover and less open sky, count the number of dots not covered by vegetation. If there seems to be more open sky and less canopy cover, count the number of dots covered by vegetation (this just gives you an easier job of counting). Then convert the dot numbers to percent canopy cover (or percent canopy not covered if you are counting sky) by dividing the number of dots covered by 96 times 100 (# dots covered/96*100).

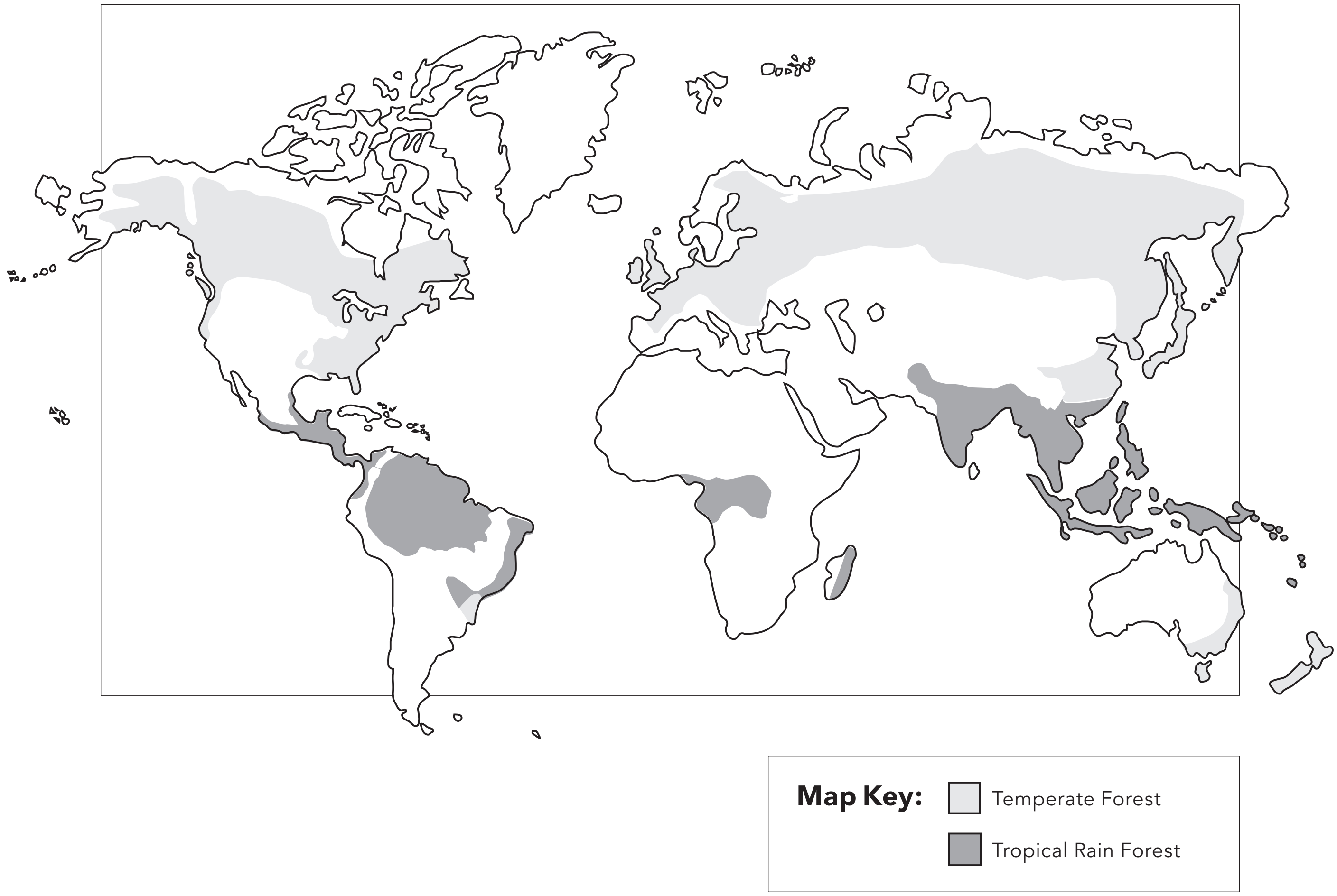
The simpler type of densiometer consists of a small, open tube with crosshairs that meet in the center of one end of the tube (see diagram). At a point on your transect, you look up through the tube. If you see vegetation touching the crosshairs you record a "+" or "yes" on your data sheet. If no vegetation, only open sky, touches the crosshairs, you record a "-" or "no" on your data sheet. You take measurements at several points along your transect and then record the number of +'s and –'s. To convert this to a percent canopy cover, add up all the +'s and divide by the sum of the +'s and –'s then multiply this fraction by 100 to obtain a percentage. (See "Estimating Canopy Cover Using a Densiometer" in the Activities section of this packet for instructions on how to make a simple densiometer and how to determine the percent canopy cover in a forest.)

How would estimates of global forest cover be different if forests were defined as areas with 60 percent canopy cover? With five percent canopy cover? Using a higher percent canopy cover as a definition would mean that estimates of global forest cover would be lower; using a lower percent canopy cover as a definition would mean that estimates of of global forest cover would be higher. (See "Forest of the World" on the following pages for estimates of global forest cover.)

Diagram of a simple densiometer:



FORESTS OF THE WORLD



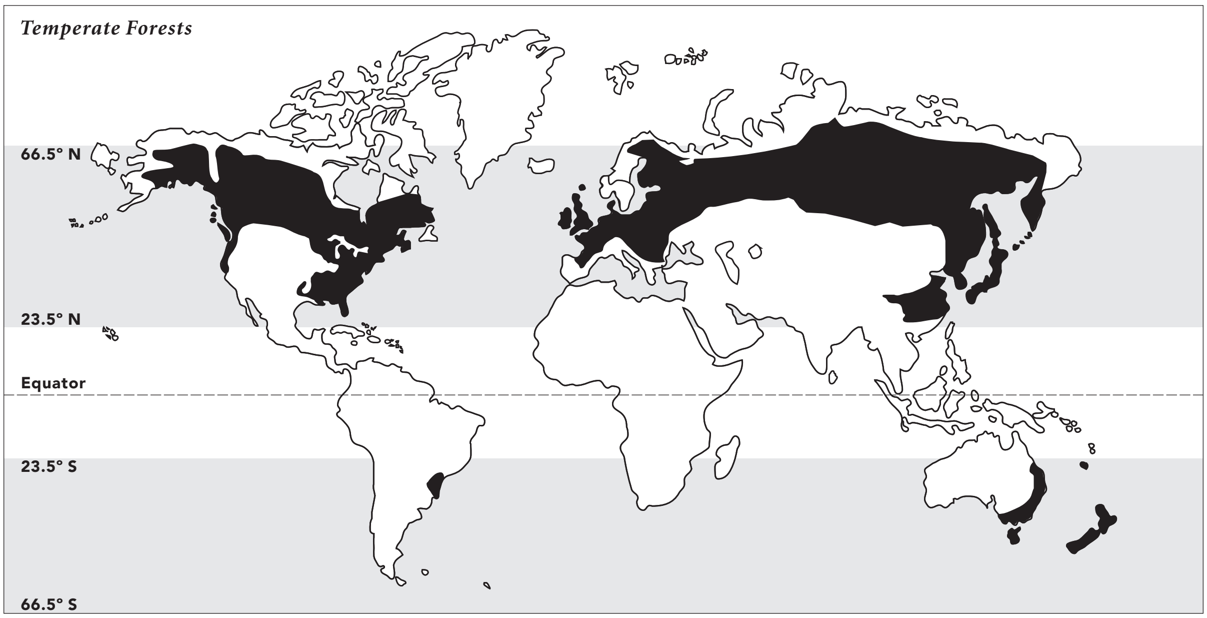
Eight thousand years ago, up to half of the earth's land surface may have been forested (Food and Agriculture Organization, 2000). Scientists estimate that global forest cover has decreased by anywhere from 20 to 50 percent over the last 8,000 years (Matthews et al, 2000). Currently, forests (defined as wooded areas with 10 percent or more canopy cover) cover approximately 25 to 30 percent of the earth's land surface (excluding Greenland and Antarctica) (Matthews, et. al., 2000). From cool mountain slopes to warm, humid coasts, areas of land with different precipitation and temperature patterns, different soils and other factors host very different types of forest. The world's forests can be divided into two main groups: temperate and tropical.

Forests cover approximately 25 to 30 percent of the earth's land area. Tropical and subtropical forests comprise 56 percent of the world's forests, while temperate and boreal forests account for 44 percent.

– Food and Agriculture Organization, 2001

Types of Temperate Forests

The word temperate refers to moderate annual climatic patterns characteristic of the regions of the world between latitudes 23.5° and 66.5° north of the equator and between latitudes 23.5° and 66.5° south of the equator (see map below). In these regions, temperatures cycle between cool to cold periods (winter) and warm to hot periods (summer). Within temperate zones, regional **biotic** (living) and **abiotic** (nonliving) factors have resulted in the presence of several types of forests. Scientists, conservationists, forest managers and other groups that study forests have categorized temperate forests in many different ways. We have chosen five main types of temperate forests to cover here, in accordance with the major forest types of the world as described by the World Resources Institute (www.wri.org). (See chart on page 13 for a summary of forest types and characteristics.)



Boreal Forests

Boreal refers to the northern lands of North America, Europe and Asia that ring the globe. Boreal forests are also referred to as "taiga," a Russian word that means "land of little sticks." Boreal forests, or taiga, lie between the temperate zone (forests of the Pacific Northwest for example) and the far northern tundra. The climate in boreal regions transitions between long, cold winters and short, cool summers. Precipitation is relatively low, with an annual average of 16 to 40 inches (400 to 1,000 mm) per year.

Boreal forests are made up of spruces and other **coniferous** trees as in the temperate **evergreen** forest, but boreal forests also have a great number of **deciduous** trees, primarily aspen. Coniferous trees are trees that bear their seeds in cones. Evergreen trees retain their leaves and are capable of carrying out **photosynthesis** year-round, as opposed to deciduous trees that shed their leaves all at once, usually in response to a seasonal change in climatic conditions, such as cold temperatures or lack of water.

In most forests, **decomposition** is the primary source of nutrients in the soil. However, in the far northern regions, soils tend to be nutrient-poor since the process of decomposition is restricted to only the few warm months of the year. Growth in these soils can also be affected by permafrost, permanently frozen soil, which prevents root penetration. Trees are not able to grow very tall if their root structures cannot reach far into the earth for stability. Lightning-caused fires are one of the greatest forces of change in this **ecosystem—**recycling nutrients, helping to melt permafrost and clearing areas for other plants to grow. In fact, cones of black spruce trees only open up and disperse seeds when heated by fire.

Boreal forests blend with temperate evergreen and temperate deciduous forests at the southern edges of their range and extend beyond latitude 66.5° north at the northern end of their range. Boreal forests and temperate evergreen forests are very similar, however temperate evergreen forests have milder winters and bigger trees than do boreal forests. Trees in the taiga are smaller in size compared to those in temperate forests due to a shorter growing season and nutrient-poor soils. On the far northern limits of the taiga, trees are often stunted due to the colder temperatures and harsh climate. Trees that are sheltered behind a ridge, in a valley or by other trees might grow to 20 feet (6 m) tall. But a tree exposed to the winds and snow may only grow to four feet (1.2 m) in as much as 100 years. The farther north you travel in the taiga, the more sparse trees become. Gradually the landscape changes into a gently rolling treeless plain called tundra. (*For more information on boreal forests, see Woodland Park Zoo's Northern Trail teacher packet.)*

Temperate Deciduous Forests

Temperate deciduous forests grow in the temperate zone where warm and cold air masses result in four distinct seasons: summer, fall, winter and spring. Winters are cold, with most precipitation falling as snow, and summers are hot and wet. Annual precipitation ranges from 30 to 60 inches (750 to 1,500 mm) and is spread fairly evenly throughout the year. These types of forests are found in eastern North America, western and central Europe and eastern Asia.

As the name implies, deciduous trees are characteristic of this type of temperate forest. In temperate deciduous forests, trees shed their leaves and become dormant before the onset of the cold winter season. This **adaptation** enables trees to survive through the winter without suffering the effects of cold and lack of water (most precipitation during this season falls as snow and is thus not available for plants to use). As the warmer and wetter spring season sets in, deciduous trees begin the process of developing new leaves to photosynthesize and make food through the summer growing season.

Temperate Evergreen Forests

Temperate evergreen forests grow in temperate regions where the majority of the annual precipitation falls between September and May and the summers are relatively dry. Annual precipitation in temperate evergreen forests ranges anywhere from 12 inches to 60 inches (300 mm to 1,500 mm). These forests are found in North America, Europe and Asia. Evergreen trees, trees that retain their leaves and photosynthesize year-round, are better adapted to survive this precipitation pattern (dry summers) because they can take advantage of fall, winter and spring rains, whereas deciduous trees have their leaves and are actively photosynthesizing during the summer when water is scarce. Evergreen trees are also adapted to survive and remain active (keep photosynthesizing) in cold winter weather. The majority of trees in temperate evergreen forests are not only evergreen, but they are also coniferous, meaning that they bear seeds in cones. These coniferous trees have needle-like leaves that also help them to remain active during the winter by retaining heat and to survive dry times during the summer by retaining water. Conifers maintain a conical shape that helps both to shed snow and to catch the sun's rays from all angles in the sky throughout the year.

Temperate Rain Forests

Temperate rain forests are a special type of temperate evergreen forest. These forests grow where seasons are very mild and annual precipitation is very high. Precipitation exceeds 60 inches (1,500 mm) per year. These conditions, along with the low frequency of fire, allow the evergreen, coniferous trees in temperate rain forests to grow very old and to reach great heights and girths. There are only a few places in the world where temperate rain forests grow: the Pacific Northwest coast of North America, the coast of Chile, the west coast of New Zealand's South Island and the southeastern coast of Australia. Temperate rain forests once grew on the west coasts of Ireland and Scotland and in Norway, but very few fragments of these forests remain. There are several defining characteristics of temperate rain forests, including:

- Several layers of overlapping vegetation (**forest floor, understory,** canopy)
- Trees that are long-lived and of great size
- Thick layer of organic debris on ground
- Cool, wet, acidic soils
- Abundance of **epiphytes**
- Dominated by coniferous trees
- Networks of flowing water
- Negligible **disturbance** by insect attack or fire
- Downed logs (nurse logs) and old stumps

Photo by Katie Remine

Temperate rain forest in southeastern Australia

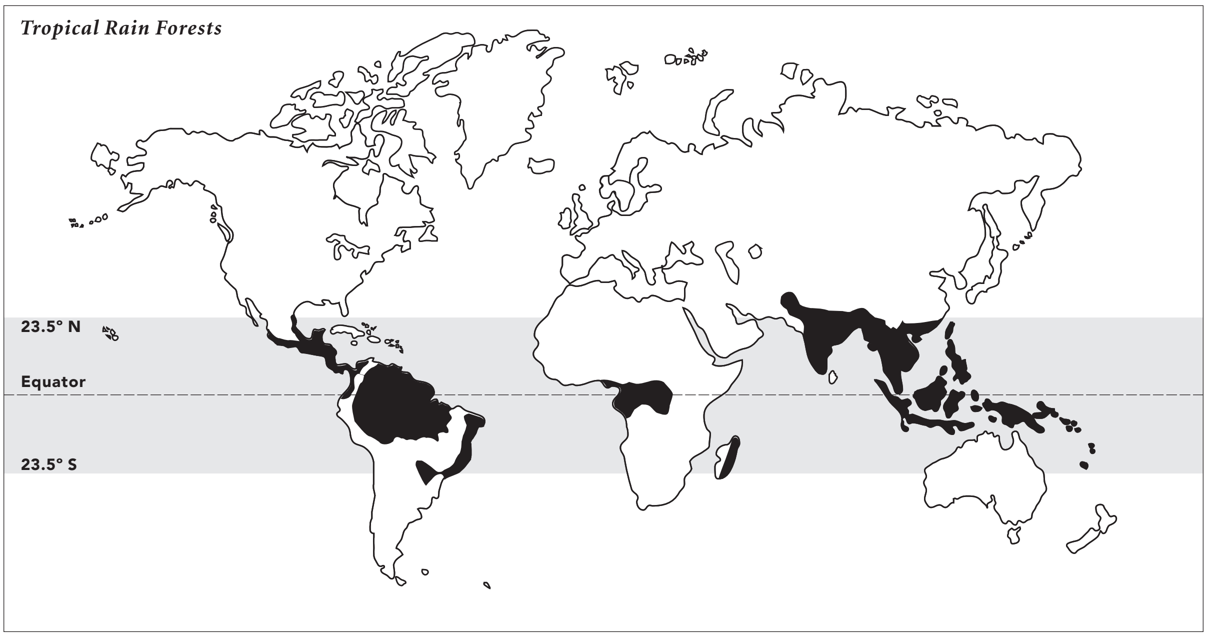
(For more information on temperate rain forests, see Woodland Park Zoo's Washington Wildlife teacher packet.)

Sclerophyll Forests

Sclerophyll forests get their name from a common characteristic of leaves found in these forests. Sclerophyllous refers to hard leaves, which is due to extra **lignin**, an organic polymer that increases the rigidity of plant cell walls. This adaptation is a response to dry conditions and low levels of phosphorous in the soil. Sclerophyllous plants are generally evergreen. Examples of common sclerophyllous plants are oaks that grow in sclerophyll forests of North America and Europe, and eucalyptus **species** that grow in sclerophyll forests of Australia. Sclerophyll forests grow in what is often referred to as a "Mediterranean" climate where summers are long and hot and winters are mild. Precipitation is moderate, ranging from 12 to 40 inches (300 to 1,000 mm) per year and is evenly distributed from fall to spring, but summers are very dry. These forests grow in southern Australia, around the Mediterranean, and in the coastal ranges of southern Oregon to southern California. Sclerophyll forests merge into dry, open shrublands, such as the chaparral of coastal California.

Types of Tropical Forests

The word tropical refers to the constantly warm and humid climate characteristic of the regions of the world between latitudes 23.5° north and 23.5° south of the equator (see map below). In these regions, temperatures are relatively warm and constant and precipitation is high. Within the tropical zones, regional biotic (living) and abiotic (nonliving) factors, especially the annual patterns of precipitation, have resulted in the presence of several types of forests. As is true with temperate forests, scientists, conservationists, forest managers and other groups that study forests have grouped tropical forests in many different ways. Here too, we have chosen three main types of tropical forests to cover, in accordance with the major forest types of the world as described by the World Resources Institute (www.wri.org). (See chart on page 13 for a summary of forest types and characteristics.)



Subtropical Evergreen Forests

Subtropical evergreen forests in North America and in Asia are composed of evergreen trees, but with different types of evergreen trees in Asia as compared to North America. In southern China and southern Japan these forests are composed of **broadleaf** evergreen trees, such as chestnuts, magnolias and laurels; but in the southeastern United States, subtropical evergreen forests are composed of **needleleaf** evergreen trees, such as pines. In subtropical evergreen forests winters are mild, the spring season is warm and there is heavy precipitation during the summer. Annual precipitation ranges from 30 to 65 inches (750 to 1,625 mm).

Tropical Deciduous Forests

Tropical deciduous forests, also called tropical dry forests, are tropical forests where the temperature is consistently warm throughout the year and annual precipitation, which ranges from 30 to 80 inches (800 to 2,000 mm), is spread unevenly throughout the year. This precipitation pattern results in distinct wet and dry seasons. These forests grow in regions further from the equator than do tropical rain forests.

Plants, animals and other living things in tropical deciduous forests exhibit adaptations that aid in surviving both wet and dry times. Tropical dry forest canopies consist primarily of broadleaf, deciduous trees. In temperate regions, we often associate the annual leaf fall of deciduous trees with the onset of the cold winter. In tropical dry forests, however, annual leaf fall occurs in response to the onset of the dry season. In this way, trees and other plants can go dormant and conserve water during the dry season.

Fire is more common in tropical deciduous forests than in moister tropical forests. Many tropical dry forest trees have thick bark to protect them from fire. Some tropical dry forest trees, such as the large and stout baobab trees, are capable of storing large amounts of water in their trunks.

Baobab tree, *a common tropical deciduous tree species, in Tarangire National Park, Tanzania, East Africa.* Photo by Katie Remine

Tropical Rain Forests

Tropical rain forests are the warm, wet, lush forests that grow around the equatorial regions of the earth. These forests consist of broadleaf, evergreen trees and are consistently warm and wet throughout the year. Annual precipitation in tropical rain forests usually exceeds 80 inches (2,000 mm) per year, humidity hovers around 80 to 90 percent, while temperatures rarely range lower than 70 degrees Fahrenheit or higher than 85 degrees Fahrenheit (21 to 29 degrees Celsius). Some tropical rain forests receive extreme amounts of rainfall; the Choco region of Colombia can receive up to 324 inches (8,230 mm) of rain per year. Conditions in tropical rain forests are prime for life—constantly warm and humid—and these forests host a higher diversity of species than other terrestrial ecosystem in the world. Four layers of vegetation characterize tropical rain forests: the forest floor, understory, canopy and **emergent** layer. The rest of this teacher packet delves in more depth into the characteristics, plants, animals and cycles in tropical rain forests.

Tropical cloud forests are a unique type of tropical rain forest found in tropical regions at high elevations. Cloud forests are so called due to the frequent cloud cover, which contributes to the high humidity of these forests. Some of this moisture condenses from the air directly onto the plants. The plants may absorb this moisture or it may drip to the ground (this is called fog drip) and be taken up by the plants' roots. (Fog drip also contributes significantly to the annual precipitation in temperate rain forests.) Cloud forests are cooler and the canopy is more open than lower elevation tropical forests. The evergreen, broadleaf trees in cloud forests do not grow as tall as those in lower elevation tropical rain forests due in part to the cooler temperatures.

The chart on the opposite page illustrates some of the general characteristics of the world's main temperate and tropical forest types. For a further comparison of temperature and precipitation patterns in forests around the world, see the "Forest Climatographs" activity in the Activities section of this packet (page 103).

Forest Characteristics Chart

	Forest Type	Geographic Distribution	Annual Precipitation	Climatic Characteristics	Characteristic Trees	Characterisitic Wildlife
	Boreal Forest (taiga)	Northern latitudes of North America, Europe and Asia	Relatively low; 16″– 40″ (400 – 1,000mm) the majority as snow	Long, cold winters. Short, cool summers. Low evaporation rates, humid conditions.	Spruces, pines, firs and larches with scattered deciduous trees; willows, birches, aspens and alders.	Moose, bears, foxes, wolves, wolverines, caribou, hawks, ptarmigans
TEMPERATE	Temperate Deciduous Forest	Eastern North America, western and central Europe, eastern Asia	Ranges between 30″– 60″ (750 – 1,500mm)	Precipitation spread fairly evenly throughout the year. Distinct seasons: summer, fall, winter and spring. Cold winters. Hot, wet summers.	Deciduous trees; oaks, maples and beeches.	Foxes, squirrels, deer, songbirds, owls, salamanders
TEMPERATE	Temperate Evergreen Forest	North America, Europe, Asia	Ranges between 12″– 60″ (300 – 1,500mm)	Majority of precipitation occurs fall to spring; relatively dry summers. Distinct seasonal changes. Winters can be cold and snowy; summers can be hot.	Evergreen, coniferous trees with needle-like leaves; pines, firs, spruces, hemlocks and larches.	Wolves, deer, rabbits, eagles, owls
TEMPERATE	Temperate Rain Forest	Pacific Northwest coast of North America, coast of Chile, west coast of New Zealand's South Island, southeastern coast of Australia	Exceeds 60″ (> 1,500mm)	Precipitation falls mainly from fall to spring. Mild winters; less distinct seasons than in temperate evergreen forests.	Evergreen, coniferous trees, mainly spruces and hemlocks. Some deciduous trees, ie. maples and alders, along streams and rivers.	Black bears, elk, deer, otters and slugs in North America
TEMPERATE	Sclerophyll Forest	Coastal ranges of southern Oregon to southern California, around the Mediterranean and southern Australia	Ranges between 12″– 40″ (300 – 1,000mm)	Precipitation evenly distributed fall to spring. Long, dry summers. Mild winters.	Broadleaf evergreen trees, such as oaks and eucalyptus.	Kangaroos, wallabies, opossums and koalas in Australia; brown bears, wolves, lynx, ibex, chamois, and eagles in the Mediterranean; cougars, hawks, rabbits, foxes, and deer in North America.
TROPICAL	Subtropical Evergreen Forest	Southeastern United States, southern China and southern Japan	Ranges 30″– 65″ (750 – 1,625mm)	Mild winters, warm spring weather, heavy precipitation in summer.	Broadleaf evergreen trees such as chestnut, oak, magnolia and laurel in Asia; needleleaf evergreen trees, such as pines, in the United States.	Leaf monkeys, serows and giant salamanders in Asia; woodpeckers, songbirds, deer, hawks, and rat snakes in the southeastern United States.
TROPICAL	Tropical Deciduous Forest	India, Indochina, west and southern Africa, west Madagascar, South America (north and south of the Amazon), Central America and West Indies, northern Australia	Averages between 30″– 80″ (800 – 2,000mm)	Consistently warm temperatures. High annual precipitation spread unevenly resulting in distinct wet and dry seasons.	Broadleaf deciduous trees; species vary according to the region.	Lemurs in Madagascar; tigers and deer in Asia; elephants and rhinos in Africa and Asia; primates, bushpigs, antelopes and other ungulates in Africa; cougars, deer and hawks in the Americas.
TROPICAL	Tropical Rain Forest	Tropical (equatorial) zone: Amazon lowland, central Africa, southeast Asia	Exceeds 80″ (> 2,000mm)	Consistently warm; temperatures range between 70°F – 85°F (21°C – 29°C). Humidity ranges between 80 – 90 percent.	Broadleaf evergreen trees; species vary according to the region. Cloud forest: Broadleaf evergreen trees, but much shorter and more gnarled than those of tropical rain forests.	Monkeys and other primates; tigers, rhinos, tapirs, wild pigs in Asia; elephants, buffalo and antelopes in Africa; large rodents, anteaters, tapirs and sloths in South America.

EVOLUTION OF TROPICAL FOREST PLANTS AND ANIMALS

The remainder of this packet focuses mainly on the tropical rain forests of the world, with added concentrations on the similarities and differences between those forests and the temperate forests of the Pacific Northwest. References to temperate forests of the Pacific Northwest will be marked with the symbol shown left.

Late Paleozoic Era: 410 to 240 Million Years Ago

Many forests of the world, both temperate and tropical, have been evolving for the last 400 million years. Dominated by seedless **vascular** plants, these primitive forests were vastly different from modern-day temperate and tropical forests. For example, club mosses and horsetails, which today grow to heights of one to two feet (30 to 60 cm), grew to heights of 100 to 200 feet (30 to 60 m) in these ancient forests. Much of the plant material from these forests formed the coal deposits that fueled the Industrial Revolution in the United Kingdom in the 1800s.

Giant conifers, ancestors to those found in the Pacific Northwest's temperate forests, first appeared 300 million years ago. This proved a marked changed in plant reproduction because conifers are **gymnosperms**, which, literally translated, means "naked seeds" or seeds not enclosed by an ovary. Pollen grains of gymnosperms are carried by wind and, unlike the ferns and mosses, water is not required for the sperm to meet the eggs. This phenomenon helped gymnosperms, such as conifers and cycads, survive and dominate the forests during the many droughts that occurred over the next 100 million years.

Also during this time period, the giant landmass of Pangea formed and stretched from pole to pole. The formation of this "supercontinent," as scientists have termed it, allowed for the dispersal of terrestrial species. Plants and animals radiated, or spread out in all directions, to any suitable **habitat** on this giant landmass.

Following the formation of Pangea, the largest **extinction** known to date occurred. Nearly all animal and plant species on land and in the sea perished, including 90 to 95 percent of the marine species, 70 percent of terrestrial vertebrate families, and 33 percent of the insect orders. This period marks the only time that insects have suffered a mass extinction (WBGH Educational Foundation, 2001).

Mesozoic Era: 240 to 65 Million Years Ago

After this extinction came the recovery and dispersal of marine and land species. Species recovery was aided by the lush tropical conditions that occurred in Pangea's equatorial regions. Surviving reptiles thrived in this **environment** and quickly evolved to fill the **niches** of the now-extinct land animals. As a result, they diversified and grew in size. One group of reptiles was the archosaurs, which included the thecodont, a crocodile-like meat eater believed to be the ancestor of the dinosaur. Soon, dinosaurs dominated the landscape, effectively keeping the newly emerged mammal **populations** small in size and in number.

Approximately 150 million years ago, Pangea began to break up and **angiosperms**, or flowering plants, appeared. These two events were extremely significant with regards to their effect on forest **biodiversity**, which can be measured by the number of different species in a particular area. The appearance of angiosperms was a huge shift, not only in the way plants reproduced, but also in the evolution of animals. Unlike gymnosperms, the seeds of angiosperms are found in fruits and contain endosperm, which nourishes the embryo.

Over the next 150 million years, the flowers and fruits of the angiosperms **coevolved** with the animals that pollinated the flowers and the animals that carried the fruit. The relationships between these plants and their animal pollinators and seed dispersers are very specialized and mutually beneficial, and will be discussed in greater detail in the "Layers of Tropical Rain Forests: Canopy" section of this packet. Because of the **symbiotic relationships** with dispersing agents, angiosperms reproduce more rapidly and widely than gymnosperms, which rely on wind to disperse pollen. Soon, angiosperms dominated most of the world's forests, and do so to this day. Of the eight forest types described in this packet, only boreal, temperate evergreen and temperate rain forests are dominated by gymnosperms.

The breakup of Pangea aided forest diversity because it caused geographic isolation of the continents. As North America, Europe, and parts of Asia moved away from the equator, sections of forest were carried away and eventually evolved into modern-day temperate forests. As South America, Africa, and the rest of Asia ringed the equator, the existing tropical forests evolved.

Evolution took its own course within the tropical forests on each continent. The differences are particularly noticeable in the various mammal populations. For example, marsupials (pouched mammals), not monkeys, occupy the trees in the temperate and tropical forests of Australia. Approximately 120 million years ago, ancestors of modern-day marsupials crossed the land bridge from South America to the landmass that would eventually become Australia and Antarctica. By the time placental mammals, which are ancestors of monkeys, evolved and spread outward, the land bridge no longer existed. Those marsupials that made it to Australia thrived and diversified in the absence of competitors. Marsupials in the rest of the world were outcompeted by placental mammals and eventually died off, with the exception of the opossum. Eventually, Antarctica broke away from Australia and moved towards the South Pole. The cold temperatures and harsh climate that resulted were not conducive to the survival of marsupials.

Approximately 65 million years ago, dinosaurs disappeared in a mass extinction, which killed 60-80 percent of all living species. The cause of this extinction is greatly debated among experts. The absence of dinosaurs as dominant **predators** allowed mammals to diversify and increase in size and number.

Cenozoic Era: 65 Million Years Ago to Present Day

As the continents continued to drift away from each other and into their current positions, species differentiation among the different tropical forests continued. An excellent example of this is in the evolution of primates. The oldest primate ancestor is the prosimian, with "pro" meaning before and "simian" meaning ape. When Madagascar separated from Africa 150 million years ago, most of Madagascar's current mammal populations, including prosimians, hadn't yet evolved. It is believed that the ancestors of Madagascar's present-day mammal populations drifted over on floating logs or on mats of vegetation. Today, prosimians, including lemurs, are the only primates to inhabit Madagascar. Lemurs, which descended from the island's original prosimian inhabitants, are **endemic** to Madagascar, meaning they are only found on that island and nowhere else.

Ring-tailed lemurs

Golden lion tamarins

New World monkeys, found in South America, evolved independently from a common, but distantly related, ancestor. That ancestor was a single simian group that had appeared in Asia and Africa and migrated through North America to Central and South America. The North American group of monkeys eventually died out, but the southern populations adapted well to **arboreal** life; instead of opposable thumbs, they developed **prehensile** tails, with which to grasp tree limbs.

Apes developed from **Old World** (Africa, Asia and Australia) monkeys approximately 13 million years ago and spread throughout Europe, Africa and Asia. Apes couldn't reach Central and South America, however, because of the separation of the continents. These more primitive apes were the ancestors of lesser apes (gibbons and siamangs), the great apes (orangutans, gorillas, and chimpanzees) and hominids (humans and their early ancestors).

The Ice Ages

From approximately 2.5 million years ago to 10,000 years ago, a series of ice ages occurred. Currently, there is a debate on the effects the ice ages had on climatic conditions and biodiversity in the tropical rain forest. On a number of different occasions, ice caps may have moved towards the equator, causing tropical rain forests to become cooler and drier. Some rain forests may have become tropical dry forests or savannas. It is believed by some scientists that the tropical rain forests of the Amazon may have been fragmented into islands scientists call refugia. These refugia seem to correspond with areas that contain remarkably high numbers of species, leading researchers to believe that the fragmentation of the forest may have encouraged the evolution of a multitude of new species. Scientists with an opposing theory, however, believe that the ice ages decreased biodiversity by causing mass extinctions of species, and that the level of biodiversity in the refugia is merely representative of pre-Ice Age rain forest. Although tropical rain forests may have been affected by the ice ages, these forests were not completely covered over with ice, unlike most temperate regions of the world, allowing some species to survive through the ice ages and contribute to the biodiversity we find in tropical rain forests of the present day.

Modern-day Tropical Forests

Today, tropical forests contain a staggeringly high number of plant and animal species. To date, only a fraction of the forests have been studied, however some scientists estimate that, based on current research, 50 to 90 percent of the world's living species may occur in tropical forests. Furthermore, many scientists theorize that the over one million species identified and named worldwide is only a small fraction of the number of existing species and that millions of plant and animal species living in the tropical rain forests have yet to be discovered.

According to the U.S. National Academy of Scientists, a typical four square-mile (10.4 km²) patch of tropical rain forest contains:

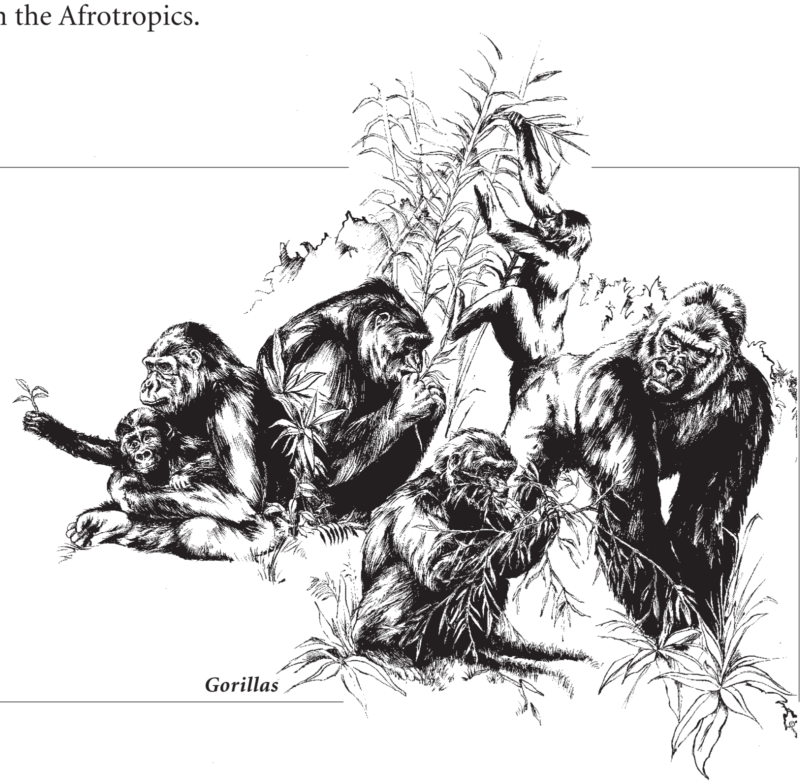
- 1,500 flowering plant species
- 750 tree species
- 125 mammal species
- 400 bird species
- 100 reptile species
- 60 amphibian species
- 150 butterfly species

(Rainforest Action Network, 2001)

Tropical regions support two-thirds of the world's approximately 250,000 identified flowering plant species, according to the World Resources Institute (WRI). Of these, the **Neotropics** (Central and South America) contain 86,000; tropical Asia (including Australia and New Guinea) contains 45,000; the **Afrotropics** contain 30,000; and Madagascar contains 8,200 plant species.

Due to a lack of research, it is uncertain how many **invertebrate** species are found in tropical forests. However, according to WRI, some scientists theorize that as many as 30 million **arthropod** species, up to 96 percent of the world's total, may exist in tropical forests.

WRI also estimates that approximately 2,600 bird species, which amounts to 30 percent of the world's bird species, live in tropical forests. Of these, 1,300 are found in the Neotropics; 900 are found in tropical Asia, and 400 are found in the Afrotropics.



Gorillas

WHY ARE TROPICAL RAIN FORESTS SO DIVERSE?

The factors contributing to the high level of biodiversity in tropical rain forests are many and varied:

- **Optimal growing conditions for plants:** Abundant precipitation, high humidity and year round warmth make tropical rain forests ideal places for plants to live. Temperate forests in Washington state, on the other hand, receive most of their precipitation during the cold winter months, when many plants are dormant. Also, much of this precipitation is in the form of snow, which plants can't use. During the warm summers, these temperate forest plants must endure drought.

- **A highly developed nutrient cycle:** Warm, moist conditions encourage rapid decomposition of dead plants and animals. The nutrients released by this process, which are essential to plant growth, are either immediately absorbed by plants or are leached out by the high amount of rainfall. This creates a patchy distribution of nutrients, to which plants have had to adapt to meet their nutrient needs. (See "Layers of Tropical Rain Forests: Forest Floor" in this packet for more information)

- **Plant and animal interactions:** As mentioned previously, tropical plants and animals coevolved, forming complex, specialized interconnections. These relationships have helped ensure survival for the participating plants and animals. (See "Layers of Tropical Rain Forests" in this packet for more information)

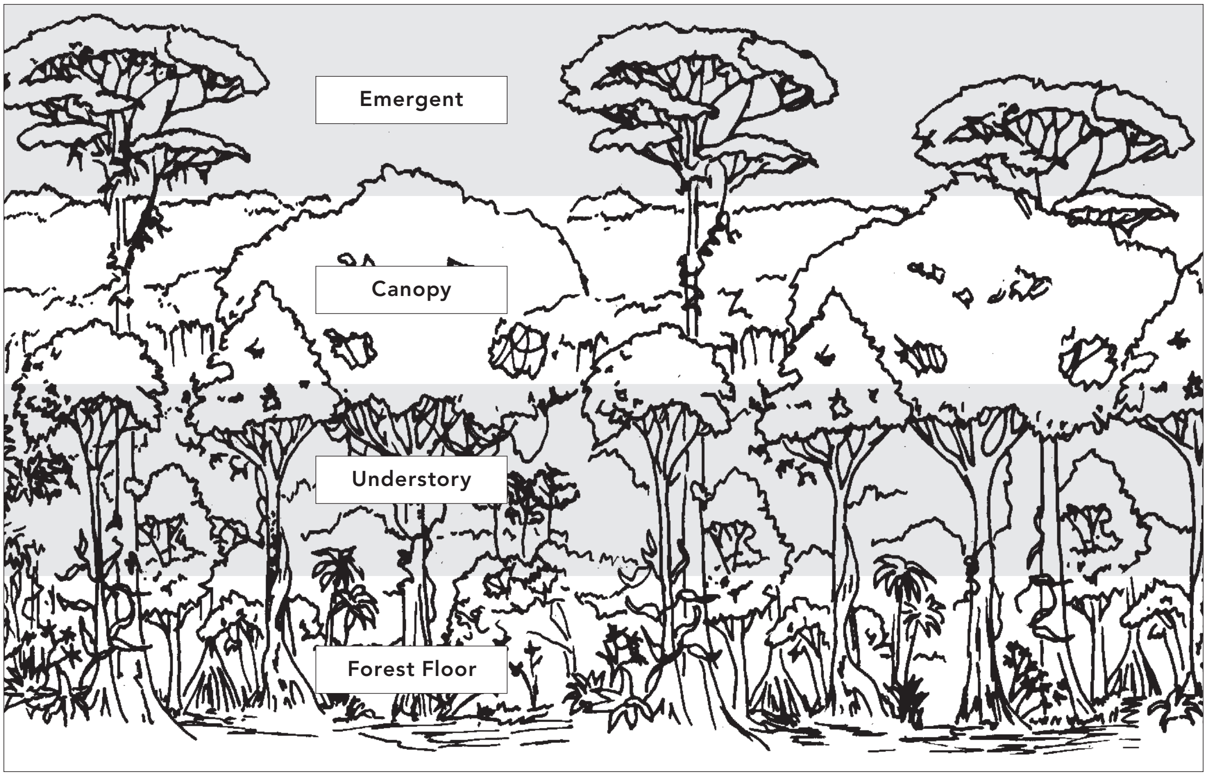
- **Forest structure:** The optimal growing conditions have created unique layering opportunities for plants. All forests can be described as consisting of three layers—forest floor, understory, and canopy—but the tropical rain forest is distinct in the vast numbers of different plants growing in each layer, especially the canopy, which is filled with vines and epiphytes, or plants that grow on other plants. The tropical rain forest is also unique in that it contains a fourth layer of tall trees, the emergent layer, that grow higher than the canopy layer. (See "Layers of Tropical Rain Forests" in this packet for more information.)

- **Light limitations and disturbance:** Despite year-round sunshine, light is a limiting factor in lower layers of tropical forests. Only one to 15 percent of available light reaches the understory and the forest floor. Therefore, plants have evolved a variety of ways to either reach light or adapt to low light conditions. The lower layers aren't always shrouded in darkness, however. When a canopy tree falls, due to old age, wind, lightning or other natural causes, a light gap is created. As with all ecosystems, a small-scale disturbance increases diversity by allowing new species to grow or fill a created niche. In this case, small trees suppressed by low light levels are able to move into the canopy layer, bringing along new vines and epiphytes, along with new food and shelter spaces for animals. (See "Layers of Tropical Rain Forests: Canopy" in this packet for more information)

- **Millions of years of stable conditions:** The majority of the world's tropical forests have not experienced dramatic climatic or geologic change since falling sea levels allowed for an exchange of species between North and South America five million years ago. Many plant and animal species persisted in tropical rain forests through the Ice Ages, and have contributed to the

present biodiversity in rain forests. Harvard biology professor, E.O. Wilson states that, "the historical circumstance of interest is that the [tropical rain] forests have persisted over broad parts of the continents since their origins as strongholds of the flowering plants 150 million years ago… The tropical rain forests, unlike large portions of the temperate forests and grasslands, were not obliterated by the continental glaciers of the Ice Age. They were never overridden by ice sheets or forced into new lands hundreds of kilometers from their original ranges." This relative period of stability allowed for the evolution of symbiotic relationships between plants and animals, as well as the formation of a complex nutrient cycling system.

LAYERS OF TROPICAL RAIN FORESTS



Multiple layers of vegetation occur in every type of forest. Tropical rain forests are characterized by four layers of overlapping vegetation, but the height of the layers and the inhabitants within each layer vary due to location, climate, altitude and geologic history, among other factors. Most animals use more than one layer for eating, drinking, sleeping, and finding shelter and many plants can be found in more than one layer as they strive to reach the sunlight in the canopy. The following sections describe general characteristics of tropical rain forest layers and provide some examples of what types of plants and animals inhabit each layer.

Forest Floor

The darkest layer of the tropical rain forest is the forest floor; in forests where the canopy above is very dense, the forest floor may receive less than one percent of available light. Because of the dense layers above it, the forest floor has a different microclimate than other layers; the temperature is 8 to 10 degrees Fahrenheit (4.4 to 5.6 degrees Celsius) lower than in the canopy and the humidity averages 90 percent, compared to 60 percent in the canopy.

The majority of soils on which tropical rain forests grow are extremely nutrient poor, due to a combination of factors:

- Soil is formed when the bedrock, or parent material, breaks down into clay, silt and sand particles and mixes with organic matter. Most tropical soils develop from an infertile clay layer called laterite, a general term for clay that has high levels of aluminum and iron.

- Millions of years of relatively stable conditions, with no recent geologic activity, translate into millions of years of soil weathering. As the parent material wears away, nutrients are taken up by plants or washed away. Only a small percentage of tropical forests were formed on younger soils created by volcanic activity or alluvial deposits, which are sand, silt or clay particles deposited by running water.

- The large amount of steady rainfall leaches, or washes away, nutrients from the soil. Due to leaching, infertile parent material, and weathering, tropical forest soils tend to be deficient in phosphorus, potassium, calcium, magnesium, sulfur, and nitrogen, all of which are macronutrients required by plants for growth and survival.

- The majority of nutrients in the tropical rain forest are held in the biomass, not in the soil (see chart). **Biomass** is the total dry weight of all organic matter (living and dead **organisms**) in a particular area. When tropical rain forests are cut and burned, some nutrients remain in the ash on the top of the soil, but most nutrients are either hauled away as timber or leached from the soil during the burning. Those nutrients that remain in the soil allow for short-term farming, but without the inflow of nutrients from decomposition, the soil is rendered infertile in a few years.

- The high rate of decomposition in the warm, moist tropical rain forest means that most soils are lacking in organic matter, which, in other forests, helps hold nutrients in the soil for plants to use.

A study in Brazil of the presence of nutrients in soil and biomass determined the following percentages:

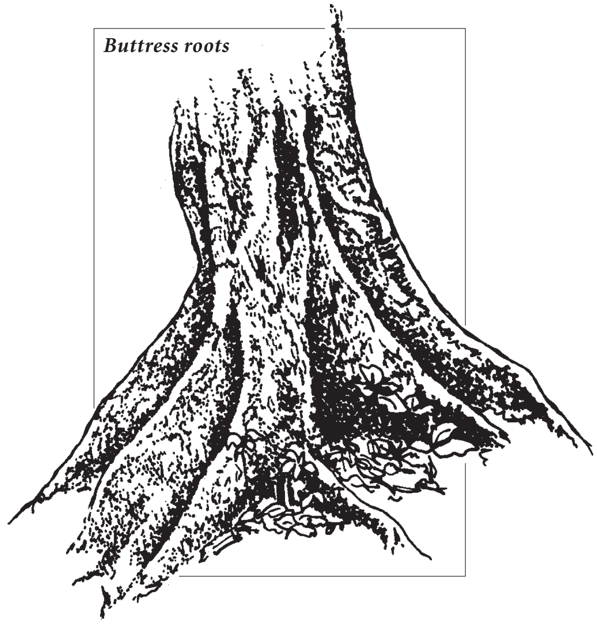
Element		Percent in Biomass	Percent in Soil
Potassium		89.6	10.3
Calcium		100.0	0.0
Magnesium		92.3	7.7
Phosphorus	**The majority of phosphorus in soil is immobilized by iron and aluminum and is unavailable for uptake by plants.*	31.9	68.1
Nitrogen	**The majority of nitrogen in soil is present as nitrites or ammonium, which can't be used by plants.*	26.9	73.1

(Brady and Weil, 1996)

To combat these nutrient limitations, tropical plants have evolved a highly complex nutrient cycle. Nutrients released from decomposing organic material—such as dead plants and animals, feces and skin sheds—are immediately taken up by plants through a thick tangled mat of roots at or near the surface of the soil. This rapid uptake helps prevent nutrients from being lost through leaching or volatilization (conversion to a gas or a vapor).

In temperate forests, roots may penetrate the soil three feet (one meter) or more in order to access water and nutrients deeper in the soil. These deep roots also help stabilize the tree during windstorms. In tropical rain forests, roots aren't able to grow deep because of the shallow soil, but instead spread out to form a wide net with which to catch nutrients. This often occurs in the form of **buttress roots**, which are woody flanges that extend from fifteen to twenty feet (4.5 to 6 m) up the trunk, down to the base. These roots then spread out great distances from the tree and send down fine rootlets, increasing a tree's nutrient-gathering capacity. These buttress roots also serve to support the tree during windstorms and hold soil in place, thereby preventing erosion. (See "Layers of the Tropical Rain Forest: Emergent" for more information on buttress roots.)

Buttress roots



Other roots that provide support are stilt roots and prop roots, which are found in areas such as flooded and mangrove forests. Stilt roots arch out from the trunk, divide into rootlets and form a scaffold of roots that stabilize the tree against floods and the movement of the tides. These above ground roots also help keep the root system aerated because they're above the water level part of the day. Prop roots are roots that grow down from branches to provide support. They do not branch into smaller rootlets and will not root upon contact with the soil.

Besides developing a thick mat of surface roots, many tropical rain forest trees also form symbiotic relationships with mycorrhizal fungi, which literally translates to "fungus roots." These fungi increase the roots' water and nutrient gathering capacity by expanding the surface area of roots and by penetrating into smaller pores than is possible for plant roots. Mycorrhizal fungi can provide as much as ten times the absorptive surface as plants without the association and is essential in absorbing phosphorus, zinc, copper and other nutrients. In return, the fungi receives sugars made during photosynthesis, sometimes as much as five to 10 percent of the plant's total production (Brady and Weil, 1996). Symbiotic relationships with mycorrhizal fungi are also important in temperate forests in gathering water during dry summers and in obtaining nutrients in areas where soils are heavily leached.

This complex nutrient cycle would not be possible without participation of animal **decomposers** known as saprotrophs, which means "putrid nourishment." Decomposition usually begins physically, with insects chewing into the decaying matter. This opens the organic matter up to fungi and bacteria, which begin the chemical decomposition process. Bacteria usually break down smaller pieces of organic matter, with fungi typically breaking down the larger pieces. Using special enzymes, fungi are able to break down cellulose, which is found in leaves and is difficult to decompose. Some fungi can also break down lignin, the fibrous element in wood, which is even more difficult to decompose.

Plants of the Forest Floor

The plants that live on the forest floor fall into three main categories: shade tolerant **herbaceous** plants, which are plants with soft, not woody, tissues; **heterotrophic** plants, which are plants that don't photosynthesize their own food; and saplings waiting to fill a light gap.

The shade tolerant plants of the forest floor typically have large leaves to capture as much sunlight as possible. These leaves often have narrow tips that point down, which allows water to run off the leaves. These **drip tips** prevent leaves from having a constant film of water on their surface. Constantly wet leaves would be vulnerable to colonization by algae, mosses and **lichens**, which would block necessary light for photosynthesis and interfere with the leaves' gas exchange abilities.

The heterotrophic plants exist in the form of **parasites** and **saprophytes**. Parasitic plants get their nutrients by invading the roots or stems of photosynthetic plants. One example is *Rafflesia arnoldii* found in Indonesia. This plant parastitizes vines and produces the world's largest flower. This flower, which can measure as much as 38 inches (1 m) in diameter, produces a smell similar to rotting flesh, which attracts the flies that pollinate it.

Saprophytes are plants that get their nutrients directly from decaying organic matter. Though most orchids are epiphytes, some are saprophytic. These orchids have no **chlorophyll** and are usually leafless. They get their nutrients through their roots, from a symbiotic relationship with fungi that helps break down organic matter. These saprophytic orchids occur in both temperate and tropical forests. One example in the temperate forests is the rare phantom orchid, which is a ground-dweller measuring 20 inches (50 cm) in height with creamy white flowers. It's found in low to middle elevation forests in North America.

In the tropical rain forest, some of the saprophytic orchids are also climbing plants. These climbing orchids can reach heights of 65 feet (20 m) on slender, leafless or tiny-leaved stems covered in small pale flowers. The roots of these orchids sometimes penetrate the bark as they climb. Some of these tropical climbing orchids are believed to have symbiotic relationships with *Armillaria*, an aggressive, wood-decomposing virus. Because *Armillaria* eventually kills its host plant, these saprophytic orchids may also be considered an indirect parasite.

The leaves of the saplings on the forest floor are different from those of full-grown trees in the canopy, even among the same species. Leaves in the canopy and emergent layers are smaller and more leathery in order to conserve water. In the shade of the forest floor, the leaves are larger and softer in order to catch as much light as possible. Sapling leaves also have drip tips similar to those on the other forest floor plants.

Examples of drip tip leaves

Invertebrates

Invertebrates, animals without backbones, dominate animal life in the tropical rain forest. It's estimated that of the total weight of the animal biomass in the forest, 50 percent comes from invertebrates in the top four inches (10 cm) of the soil (Myers, 1993).

In addition to sheer numbers, diversity of invertebrates on the rain forest floor is high as well. These animals range in size from microscopic to enormous. Centipedes, which average one to two inches (2.5 to 5 cm) in length in temperate zones, can reach eight inches (20 cm) long in tropical forests. Centipedes are susceptible to **desiccation**, or drying out, and thus live in rotting logs or moist leaf litter. They are **carnivorous** and kill their **prey**, usually insects and spider, with poison claws.

Millipedes are also extremely large in the tropical rain forest; giant millipedes can reach ten inches (25 cm) compared to one to two inches (2.5 to 5 cm) in the temperate forest. Millipedes are also sensitive to desiccation and live in rotting logs or in elaborate nests made of their feces. In addition to other plant material, millipedes feed on downed logs, thus helping to physically breakdown and decompose wood.

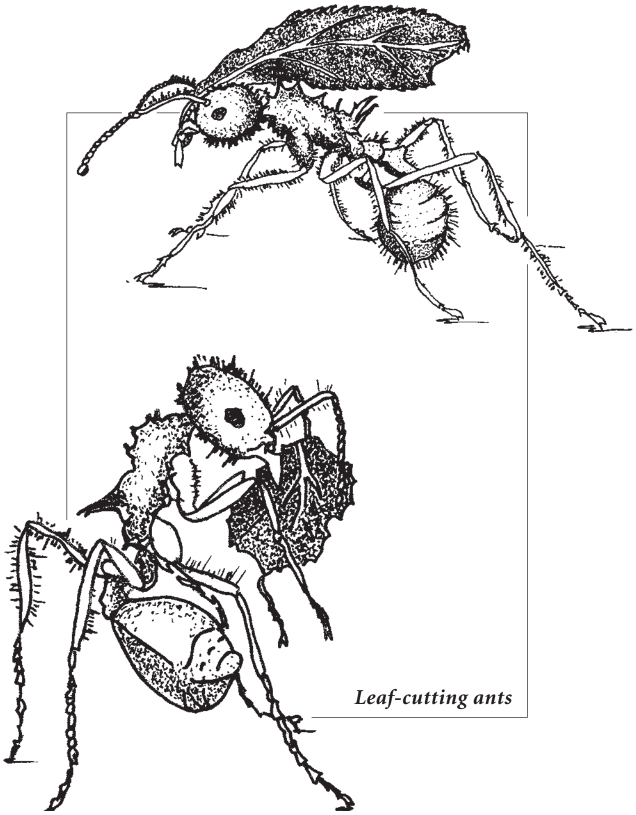
Another important group of decomposers is termites. Termites process huge amounts of organic matter, depending on location. In a region of Venezuela, termites consume three to five percent of the leaf litter; in parts of Malaysia, they break down 15 to 17 percent (Myers, 1993). Different species of termites decompose organic matter in different ways. Some have protozoa or bacteria living in their gut, which help with decomposition of cellulose and lignin. Others collect decaying plant material, feed it to an underground fungus garden, and then eat the fungus.

Termites live in different types of colonies, called termitaria. Some colonies are found in mounds built underground. Others are made of soil and/or termite droppings held together with termite saliva. The latter are either freestanding, are built in tree branches, or are built on the base of trees. Many are extremely elaborate with sloped roofs to allow rain to run off and the capacity to hold thousands or even millions of individual termites. Some even have towers that act as air conditioning systems, funneling cool air throughout the colony.

Termites and their termitaria are often important sources of food for many animals and plants. When threatened on the ground or in their colonies, termites will attack any predator and deliver painful bites. Many animals have adaptations that help them overcome these attacks, however. Tamanduas (New World tree anteaters) and pangolins (Old World scaly anteaters) have thick fur or scales, respectively, which protect them from bites. The thick fur of capuchin monkeys also helps protect them from bites after they break open the termitaria to eat termite eggs and **larvae**. Sometimes the physical structure of the colony is eaten by monkeys and other animals for its richness in mineral salts.

Termites are also susceptible to predation in the air. When a new termite colony is about to be formed, mass matings of thousands upon thousands of termites will occur mid-air. During this time, termites are easy prey for frogs, birds, spiders and other animals, but this mass predation usually doesn't make too significant of a dent in the huge population of that termite colony.

Termitaria are also very beneficial for plants. Abandoned termite colonies are extremely rich in nutrients and make excellent seedbeds for rain forest trees.

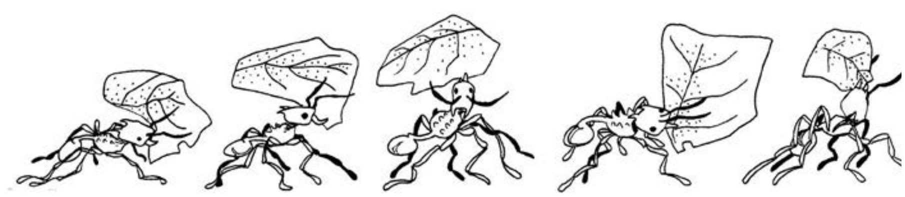


Leaf-cutting ants

Another group of invertebrates that make fungus gardens is the leaf-cutting ants, found in Central and South America. With their scissor-like mandibles, leaf-cutting ants clip sections of leaves from specific trees in the canopy and carry them down into their underground nests, which can be as much as 20 to 25 feet (6 to 7.5 m) below the surface. Then, they chew up the leaf, add fecal fluid, and apply the paste to the walls of the fungus garden. The ants then eat the fungus.

Leaf-cutting ants avoid defoliating whole trees by constantly varying which trees they visit, even traveling great distances to do so. These ants benefit their environment by mixing and aerating the soil with their tunnel-building activities. Abandoned colonies are also incredibly rich in nutrients, as all colonies have many large pits that collect plant **detritus** and waste.

Another group of ants having a large impact on their surroundings are army ants of the Neotropics. These ants live in colonies with as many as one million individuals. By night, the ants form camps up to 35 cubic feet (1 m^3) in volume around the queen and her brood. By day, they march through the forest floor, raiding the nests of termites, wasps or other ants. They'll even capture and eat larger insects, scorpions, small snakes and lizards. Many birds benefit by catching insects fleeing from advancing army ants. Attacks by army ants leave areas of the forest floor devoid of activity for weeks, contributing to the army ants' nomadic lifestyle. The Old World counterpart of the army ant is the driver ant. These ants are blind and live under the leaf litter in colonies that can have twenty million or more individuals.



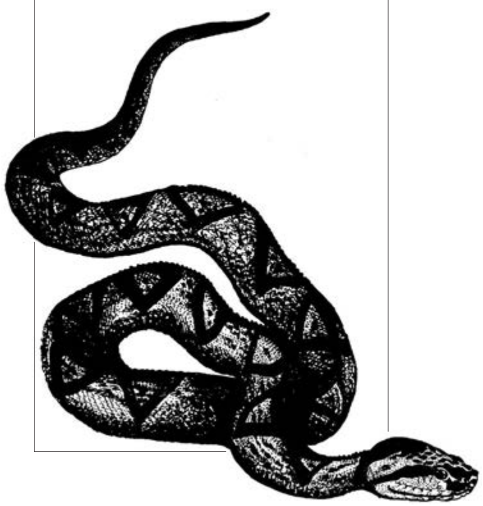
When scaled to the size of a human, each leaf-cutting ant that carries a clipped leaf from the rain forest canopy down into her underground nest is running the equivalent of a four-minute mile for 30 miles carrying 500 pounds.

– Moffett, 1995

Reptiles and Amphibians

Snakes are common forest floor predators, eating a wide range of food, from frogs to terrestrial birds to small mammals. Most of these snakes use camouflage and lie-in-wait strategies to catch their prey. The green anaconda, the largest snake in the world, is found in South America in swamps and in and along streams. This snake, also called a water boa, kills with constriction and can reach lengths of more than 30 feet (9 m).

Bushmaster



At lengths of eight to twelve feet (2.5 to 3.5 m), the bushmaster is the largest venomous snake in the New World and the longest viper in the world. This **nocturnal** snake is a pit viper meaning it has heat sensitive pits on each side of its head, which help it locate prey. The bushmaster is also called *cascabella muta*, which means "mute rattlesnake," because of its resemblance to the rattlesnake. The venom of a bushmaster is not as toxic as other venomous snakes, but is produced in enormous quantities and kills by causing internal bleeding. Despite this, however, and because of their elusive nature, there have been very few human fatalities from bushmasters.

The snake that is considered much more of a threat than the bushmaster is the fer-de-lance. The fer-de-lance is responsible for more human fatalities than any other South American snake. Also called *barba amarilla*, or "yellow beard," the fer-de-lance lies in wait to attack prey such as small mammals and ground-dwelling birds. If startled or provoked by larger animals, including humans, the snake will attack aggressively with repeated bites.

Other inhabitants of the forest floor include frogs. Some forest floor frogs are dull in color, which helps them camouflage against the soil and leaf litter. Others, such as the poison dart frogs of South America, are brightly colored to warn predators of their toxicity. Poison dart frogs secrete poisons through their skin, which affects the nervous system and muscles of predators such as birds and snakes. Some native people of the tropical rain forest put this poison on the tip of their darts when hunting. (See "Layers of Tropical Rain Forests: Understory" in this packet for more information about poison dart frogs.)

Poison dart frog

Birds

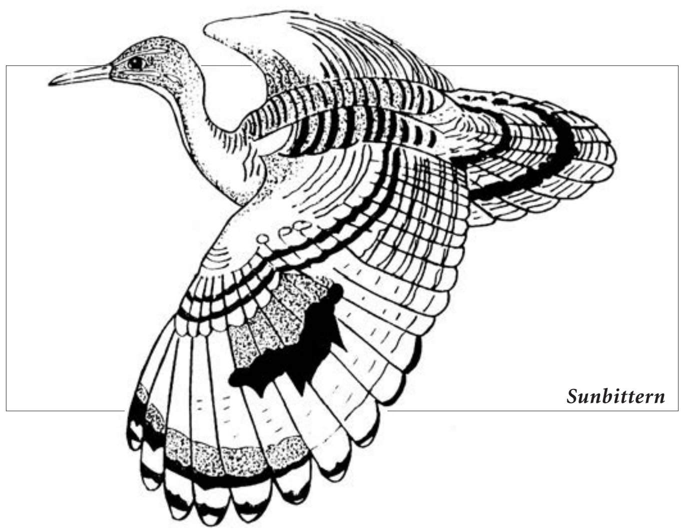
The birds of the forest floor tend to fall into two categories: larger, heavier birds that are primarily foraging on the forest floor, and those that nest on the forest floor, but which may venture into the upper layers to find food or to make communication calls.

Members of the first group include pheasants, sunbitterns, curassows and cassowaries. Pheasants are mostly found in Asia with one species, the Congo peacock, occurring in Africa. Most male pheasants have elaborate, colorful plumage to attract females, which are usually dull in color. Many pheasants also perform complicated courtship rituals to attract a mate. Some scientists believe that these rituals appear in areas such as the tropical rain forest more than in temperate regions because of the abundance of food. Energy and time can be spent on competition for mates instead of competition for food.

The argus pheasant clears a small area in the dense forest to perform his courtship ritual. After strutting about the clearing for a short period of time, he will suddenly fan his ornate tail feathers, which resemble hundreds of eyes. Researchers theorize that in addition to being attracted to the most flamboyant display, the female may be momentarily stunned by the display of eyes, and will thus allow the male to mate with her. It's also believed that this same startling display may also startle predators, allowing the pheasant time to escape.

Sunbitterns are New World forest floor dwellers. Both male and female birds use coloration for camouflage and defense. Sunbitterns have stripes of dark brown and chestnut-orange that blend in well with the sun-flecked forest floor. When spread out, the tail feathers resemble eyes, which can scare off potential predators. Sunbitterns are often found along rivers and streams, hunting fish, amphibians, crustaceans and insects with their long, heron-like necks and spear-like bills.

Curassows are also large birds found on South American forest floors. Due to their size and heavy weight, these birds tend to be poor fliers. Some curassows have evolved adaptations allowing them to eat the hard nuts and tough seeds produced by some tropical rain forest trees. These nuts and seeds are often too tough for many animals to eat. However, to help in digestion, some species of curassow will swallow stones along with their food. The stones help to grind up the nuts and seeds in the bird's crop, which is the extended area of the foregut that stores food.



Sunbittern

At nearly six feet tall, the cassowary is the largest land animal in New Guinea. Cassowaries are related to emus and kiwis and have drooping dark plumage, wattles, and a casque on the top of the head. A casque is a bony extension of the bird's upper mandible and is thought to be used to push through thick vegetation or to turn over leaf litter while foraging for small animals, fruit and fungi. Cassowaries have massive claws on their three-toed feet and have supposedly disemboweled predators with a ferocious kick. These birds primarily rely on a diet of fallen fruit; however, they will eat other food including small animals. To fill their need for a steady supply of fruit year-round, cassowaries rely on large tracts of diverse forests in which trees are on different fruiting cycles. Second-growth or plantation forests are most often not diverse enough to support cassowaries.

Pittas rummage through the leaf litter of Old World forests for worms, insects and snails, but these songbirds will travel up into the canopy at dusk or dawn to sing. Pittas are brightly colored, with the most brilliant colors occurring on their underside. When alarmed, pittas stand motionless, waiting for the threat to leave.

Tropical rain forest birds that can be found in many layers, but which make their nests on the ground include motmots and megapodes. Motmots make their nests in existing holes in riverbanks or in burrows that they dig themselves. They hunt insects and lizards and crush their prey with their large, powerful, serrated bills. Motmots are found throughout Central and South American rain forests.

Megapodes, found in tropical Asia and Australia, are one of many mound-building birds that build huge compost heaps to incubate their eggs. A pair will work for as long as eleven months to build their nest, which can be as tall as five feet (1.5 m) and as wide as twenty feet (6 m). When the vegetation begins to decompose and give off heat, the male digs a hole in the mound and the female deposits one egg. This process continues each day until the female has laid five to eight eggs. Then, the parents cover the eggs with leaf litter and the chicks will hatch 50 to 90 days later. Megapodes can have an enormous impact on their surroundings; in some areas, one pair can clear thousands of square feet (hundreds of square meters) of forest floor litter.

Bowerbirds also build intricate structures on the forest floor, with a purpose of attracting a mate instead of incubating eggs. Male bowerbirds use twigs to build different bowers, depending on the species, on which to perform a courtship dance. These bowers are often decorated with feathers, snail shells, bones, berries and flowers. Competition is fierce not only for a mate, but also for decorations; males will often steal trinkets from other males' bowers. Bowerbirds are found in New Guinea and Australia.

Mammals

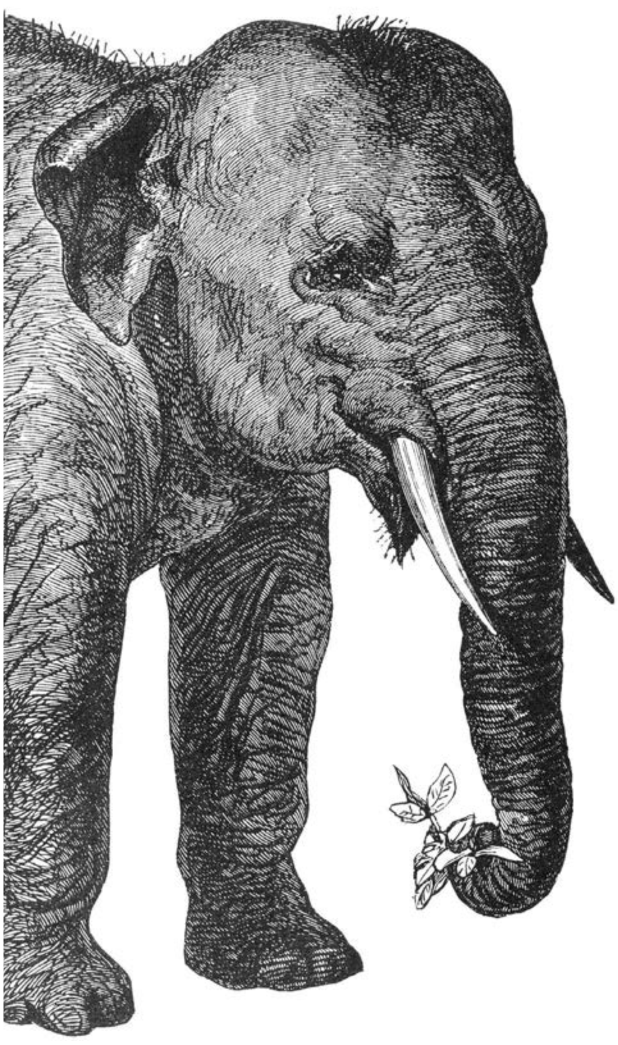
The tropical rain forest floor is also home to a diverse number of mammals, most of which are much larger than similar animals in other habitats. This is particularly evident with the rodent populations. In the tropical rain forest, rodents can weigh as much as 100 pounds (45 kg). Most, such as tropical America's agoutis and pacas, have a huge impact on their environment, from their importance as seed distributors to their availability as prey for forest floor predators.

One tropical forest tree that often falls victim to seed predators is the black palm, which guards its fruit using needle-like spines on its trunk and leaves and protects its seeds in hard seed casings. When ripe, the fruit drops to the ground. Many animals, including pacas and opossums, then eat the fruit and discard the seeds. This disperses the seed, but doesn't insure germination. The hard seed coat doesn't protect the seed from peccaries, seedeaters that can crush the seed with their large flat molars, or from pocket mice and squirrels, which can gnaw their way through to the seed. Those seeds that aren't gnawed or crushed often fall victim to bruchid beetles, which lay their eggs on the skin of the fruit or on the seed itself. The larvae then bore through the hard seed coat and devour the seed of the black palm.

The agouti has an important mutually beneficial association with the black palm. It eats some of the seeds and buries the rest for later. Burial protects the seed from further attack. The key to the symbiotic relationship is that before burying the seed, the agouti strips it of its fruit, thus removing any bruchid beetle eggs already present. It's unknown why it does this, however, because the agouti usually doesn't eat the fruit that it strips away.

Wild pigs offer further examples of adaptations to forest inhabitation. As mentioned earlier, the evolutionary response of peccaries, seed eaters found in the tropical Americas, to the rock-like seed coats on the seeds of some tropical trees is a set of large, flat molars, which crush the hard seeds. The body shape of peccaries also helps them push through the undergrowth. Bearded pigs of Borneo have adapted to a diverse diet to ensure survival. They eat roots, fungi, soil, insects, rotting wood, small vertebrates, **carrion** and fallen fruit. This varied diet decreases the need for competition for food.

While the rodents of the tropical rain forest are unusually large, other mammals on the tropical rain forest floor represent the smallest members of their families. For example, elephants can be found in three places: the African savanna *(Loxodonta africana africana)*, the African tropical forests *(Loxodonta africana cyclotis)*, and the Asian tropical forests *(Elephas maximus)*. The Asian and African elephants that live in forests are significantly smaller than their savanna counterparts. Scientists are debating whether the African forest elephant is its own species.

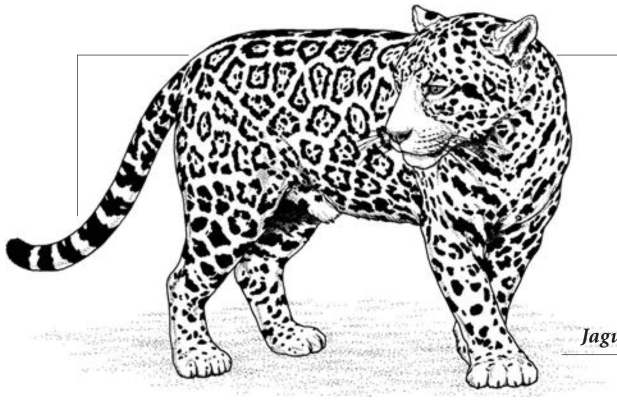


Asian elephant

Some scientists explain the size differentials with the fact that animals typically smaller in size, such as rodents and frogs, will evolve into larger individuals over time in the rain forest due to the large amount of food available. Those animals that are normally larger, such as the elephant and the hippopotamus, will have smaller forest counterparts to help facilitate movement through the dense forest.

Other adaptations to dense forest include visual cues, such as the bright facial coloration of the mandrill. Many primates use facial gestures, along with auditory vocalizations, to communicate. In order to facilitate communication in the dark forest floors in the Congo and Cameroon, where they forage in groups, mandrills evolved the elaborate facial ornamentation they have today.

Other adaptations to life on the forest floor are the long neck and legs of the okapi, the only other member of the giraffe family besides the giraffe. Like its savanna relative, the okapi uses its height and reach to access the leaves of saplings and small trees in the African tropical forests.



Jaguar

Jaguars

Jaguars play a significant role in the ecosystem and culture of the tropical rain forests of the Americas. These mysterious cats were once found from the southwestern United States through southern Argentina. Due to deforestation, hunting and human development of their habitat, the range of jaguars has been cut in half since 1900, according to the Wildlife Conservation Society (2003). Most of the **habitat loss** occurred in the United States, Mexico, Brazil and Argentina.

Though their spotted coats give them a similar appearance to the leopards of Asia and Africa, jaguars generally are larger and heavier, with broader heads and shorter, thicker legs and tails. In fact, jaguars are the largest cats in the Western Hemisphere and the third largest cats in the world, after lions and tigers.

Jaguars are excellent hunters, employing their sharp teeth and claws as well as their stealthy and powerful bodies. Jaguars tend to be solitary, nocturnal hunters that feed on a wide variety of prey. In fact, as many as 85 different species have been linked to the diets of jaguars, everything from larger forest floor mammals such as tapirs and peccaries to lizards, frogs, caimans and fish. Jaguars are excellent swimmers and will pursue prey into the water.

Their spotted coats help jaguars to blend in with the dappled light on the forest floor, allowing them to stalk their prey. They kill by pouncing on the backs of their larger prey and delivering a strong bite through the skull. In fact, the jaguar's name is derived from an American Indian word meaning "killer that takes its prey in a single bound." Smaller prey are sometimes killed with a fierce swat of the jaguar's mighty paw.

In addition to eating a wide range of food, jaguars can also be found in many different habitats. Though mostly found in tropical rain forests, jaguars can also range from **montane** tropical forests to wet savanna areas.

Perhaps due to their wide range, jaguars became important figures in many disparate native populations throughout Central and South America. According to a Mayan myth, the sun is embodied by a jaguar that rises each day in the east, prowls across the sky all day and finally plunges into darkness in the west, where it fights the lord of the underworld for the right to rise the next day. Through strength and cunning, the jaguar always wins. The Tucano Indians in the Amazon also associated the jaguar with the sun. According to their tribe, the sun created the jaguar as its representative on earth.

Many native peoples—including the Chavins, one of the earliest cultures in Peru—worshipped the jaguar as a deity. The Olmecs of Mexico also deified jaguar monuments in their honor. Jaguar imagery is also found among the ruins on the Yucatan Peninsula.

Understory

Plants of the Understory

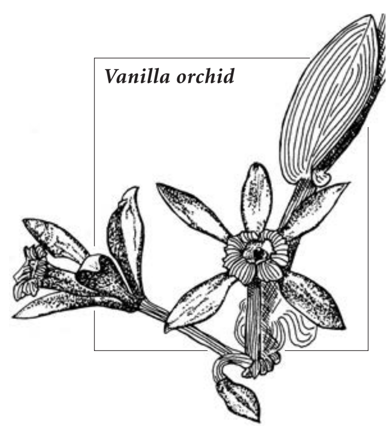
The understory of the tropical rain forest receives two to 15 percent of the sunlight reaching the forest and is characterized by small trees and shrubs. Many of these small trees are saplings of canopy and emergent trees that are living in a state of arrested development until a gap in the canopy occurs. When this happens, these saplings experience a rapid surge of growth, allowing some to move into the canopy and close the gap.

Many of these small trees and shrubs are covered in vines and epiphytes. Some of these vines, which, when woody, are called **lianas**, began life as small shrubs and later, using curling tendrils or hooks, climbed up into the understory in search of light. Most end up winding around the treetops of the canopy, but many, such as some species of pitcher plants, remain in the understory. Tropical pitcher plants, found in southeast Asia, have leaves shaped like pitchers, which trap and digest mostly insects, but occasionally small mammals and reptiles. These plants extract nutrients, proteins and amino acids from their prey, which allows these plants to grow in areas of nutrient poor soils such as tropical rain forests. Pitcher plants climb by using barbed, whip-like extensions on new leaves. Pitcher plants often use nectar, aromas or visual signals to attract insects.

Epiphytes are plants that grow on other plants instead of in the soil of the forest floor. Often called "air plants," epiphytes exist in temperate forests in the form of mosses, liverworts, lichens and some ferns. In the tropical rain forest, however, they explode in number, size and diversity. It's estimated that a quarter of all plant species that live in lowland rain forests are epiphytes. They can be as small as the algae, lichens and moss epiphylls that colonize the surface of a leaf or as large as full-grown trees.

Epiphytes grow on branches of trees and shrubs in the understory and canopy. They generally have two different root systems—one that clasps onto the host and one that collects moisture either from the air or by tapping into debris collected on limbs and tree crotches.

One successful example is the orchid, of which almost 30,000 species have been identified worldwide, the majority of which are located in the tropics. These tropical orchids are primarily epiphytic and are found in the understory and canopy layers. Their roots are contained in loose spongy 'skin' that increases the surface area and thus the roots' abilities to absorb water. Many have associations with threadlike fungi that extend the orchid's nutrient-gathering capacity. Most epiphytic orchids have pseudo-bulbs that hold water for the orchids to use during dry times.



Vanilla orchid

Bromeliad

Many orchids have complex relationships with specific insect pollinators. Some bear flowers that resemble female insects in appearance and smell. Others produce tiny flowers that smell of rot and mildew, which attracts tiny flies. The seeds produced by orchids are some of the smallest seeds of any flowering plant. As fine as powder, they are wind dispersed and have no food reserves. To germinate, seeds form a relationship with nutrient-providing fungi. Once germinated, orchids grow slowly and take years to flower.

Tropical rain forests are also home to various species of epiphytic cacti. Desert cacti conserve water by being deep-rooted in the ground and having barrel-shaped stems. Most are covered in hairs or spines, which reflect sunlight, decrease water loss from wind, and diminish grazing. In the tropics, however, cacti are epiphytic and spineless, with leaves that are smooth and flat in order to absorb light.

In general, plants of the understory endure less stressful conditions than those in the canopy due to many factors: less intense solar radiation, less drying and damaging winds, higher humidity, more moderate temperature fluctuations, and less damage by torrential rainfall. Because of these factors, epiphytes that live in the canopy are very different from those found in the understory. Canopy epiphytes have small, tough, waxy leaves to prevent water loss and scorching. In the understory, however, most epiphytes have larger, thinner leaves with drip tips and corrugated or velvety surfaces. These adaptations help rid the leaves of excess water while increasing the light gathering surface area.

Because the roots of epiphytes don't penetrate the tissues of the host plant, they're not considered parasites. They do, however, compete with the host plant for light and nutrients, and often cause branches of the host plant to collapse under their combined weight. Some trees have adapted to these problems by periodically shedding their bark and ridding themselves of the load of epiphytes. Others have smooth bark, which is difficult for epiphytes to colonize.

Epiphytes do sometimes benefit their host species, however. Moisture laden, nutrient rich debris collects in and around the leaves and roots of epiphytes. Some trees sprout **adventitious roots,** which are roots that sprout from unexpected places, in this case, from the trunk or branches. These roots tap into this debris to collect nutrients. This phenomenon also occurs in temperate forests.

Other species benefit from the presence of epiphytes as well. Many frogs, insects and earthworms live in or feed on the debris collected around the epiphytes. Some epiphytes are colonized by ants, which pack organic matter around the plant to make their nests. As the debris decomposes, it nourishes both the ants and the epiphyte.

Bromeliads, which are a type of epiphyte, are especially beneficial to the animals around them. The leaves of the bromeliad form a cup at the base of the plant. This cup collects water and serves as a watering hole, feeding area, and breeding ground for many animals.

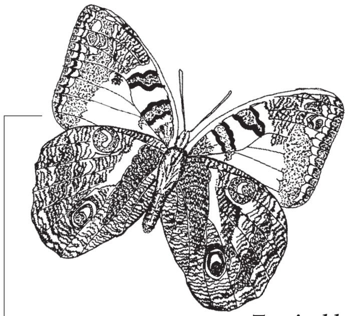
The poison dart frog lays its eggs on leaves on the forest floor. Most frogs around the world require pools of water in which to lay their eggs, but in the tropical rain forest, the high humidity of the forest floor provides enough moisture for the developing eggs.

In some species of poison dart frogs, the male tends to the eggs and newly hatched tadpoles; in other species, the female plays this role. When the eggs hatch, the attending parent climbs high into the understory or canopy and deposits each tadpole into a different bromeliad. This ensures that all are not lost if a bromeliad is attacked by predators such as the giant damselfly larvae, which hatch in bromeliad pools and feed on tadpoles.

Besides damselfly larvae, tadpoles also face predation by other tadpoles. If a parent approaches a bromeliad already occupied by a tadpole, the tadpole makes its presence known by rapidly shaking the leaves with its tail. If the parent doesn't heed this warning and deposits the tadpole into the already occupied pool, the original larger tadpole will eat the younger one.

Tadpoles primarily feed on algae and mosquito larvae, but in some species, the mother returns each day and deposits a single, nutrient-rich, unfertilized egg for the tadpole to feed on. The tadpole stays in the bromeliad during its entire metamorphosis to adult frog.

Tropical epiphytes



Tropical butterfly

Animals of the Understory

Like the poison dart frog, many animals use the understory on a temporary basis, while others use it as their primary habitat.

Invertebrates

Many invertebrates have close associations with specific understory plants. Along with damselflies, invertebrates such as mosquitoes, beetles and cockroaches utilize bromeliad pools as breeding areas. Others, such as one species of crab, make the bromeliad watering cups their permanent home. Some species find food and shelter in the litter that collects in and around bromeliads. These include spiders, snails, ants, scorpions, crickets and millipedes. Velvet worms, which are primarily terrestrial, have also been found hunting among the leaves of the bromeliad. A velvet worm shares characteristics with worms and arthropods, but is a peripatus, which has 14 to 43 pairs of unjointed legs. Taxonomically, velvet worms are considered either as a class in the arthropod phylum or as a separate phylum. These animals feed by squirting a sticky fluid onto small arthropods and other invertebrates. This fluid immobilizes the prey, allowing the velvet worm to bite into its victim and suck the soft insides out.

Another close relationship between understory plants and insects occurs between scarab beetles and *Philodendron bipinnatifidum*. This plant, found in South America, has an upright **inflorescence** (cluster of flowers) called a spadix, which is a floral spike enclosed in a sheathing bract called a spathe. The spadix is covered by zones of male and female flowers, separated by zones of sterile flowers. For a period of 24 hours, these sterile flowers heat up the spadix, giving off pungent odors that attract hordes of scarab beetles. During that period, the scarab beetles feed on the sterile flowers and mate on the warm, odorous spadix. In the process, the beetles are coated by a sticky resin that is exuded by the spathe. At the end of the 24 hours, the male flowers release pollen, which easily sticks to the resin-coated bodies of the beetles. After 24 hours, the spathe closes and the pollen-covered beetles fly off to the next newly opened inflorescence.

Some invertebrates, such as the euglossine bee, are the sole pollinators for many orchid species. The bucket orchid lures the bee with a pool of perfumed oil that the bee uses to attract a mate. The bee falls into an enclosed pool of the perfume and must squeeze through a small side door to escape. When he does, two pods of pollen stick onto the bee's back. When the bee repeats the procedure in another orchid's bucket, the pollen pods are transferred, thus causing pollination to occur.

Many rain forest plants are pollinated at night by moths. These plants usually have white flowers with an intense scent. One example, the *Angraecum* orchid of Madagascar, is pollinated by a specific moth due to the fact that its tubular nectary, the place that nectar is secreted, is 14 inches (35 cm) long. The Madagascan hawk moth is the only moth in Madagascar with a long enough proboscis, the sucking mouthpart of butterflies and moths, to access the nectar and pollinate the orchid.

Butterflies are closely tied to understory plants. One example is the birdwing butterflies. One species, found only in a small area of Papua New Guinea, is the Queen Alexandra's birdwing butterfly. With a wingspan of 11 inches (28 cm), it's considered the largest butterfly in the world. The caterpillars of several species of birdwing butterflies feed on the highly poisonous leaves of particular liana species. These caterpillars store the toxins in their tissues and then go through metamorphosis. The striking colors of the adult butterflies warn predators of their toxicity.

Heliconia and its Animal Connections

The pendulous, bright red and yellow flowers of the *Heliconia* species, found in the Neotropics, are a common sight in light gaps in the tropical rain forest understory. The numerous upturned bracts of each flower hold water, which provides a breeding pool for flies and mosquitoes. Many insects, including katydids, beetles, and spiders, find shelter in the furled *Heliconia* leaves. The tawny owl butterfly lays its eggs on the leaves of the *Heliconia*, which is then a food source for the hatching larvae. This butterfly is known for the large eyespots on the underside of its wings, which are thought to help deter predators.


Heliconia *Photo by David Selk*

As the primary pollinators of *Heliconia* species, hummingbirds are often seen in the understory of tropical America. They hover over flowers and use their long bills to feed on nectar. Because of their small size and almost constant movement, hummingbirds need large amounts of high-calorie nectar, supplemented with protein-packed insects, to survive. They can get both from *Heliconia* flowers.

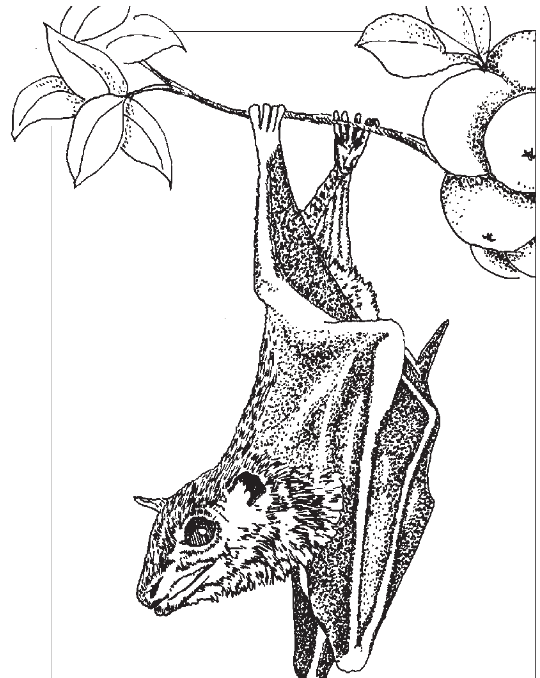
Some hummingbirds have longer, more specialized bills that fit specific flowers. Many different species of hummingbirds feed on the nectar of the *Heliconia*, in part because it produces copious amounts of nectar, but it's the sicklebill's long, curved bill that perfectly fits the flower bracts of the *Heliconia*. Passionflowers are well adapted for pollination by most hummingbirds. To sip nectar, the hummingbird has to wedge its head into a tight fit below the flower's stamens. While the bird is feeding, pollen is deposited on the back of its head. When it visits the next passionflower, the pollen is transferred.

Bats can also be found around the versatile *Heliconia*. Tent-building bats, found in New and Old World tropical forests, collapse leaves of the *Heliconia* to form "tents" by biting through the midribs of the leaves. These tents then protect the bats from predators, harsh rain and glaring sun.

Mammals

Bats are incredibly diverse forest-dwelling species. With almost 1,000 species worldwide, bats have adapted to numerous niches and feed on a wide variety of food sources. Bats pollinate many understory plants. The flowers of these plants, such as the calabash tree found in tropical America, are often pale and have strong odors to attract bats. These flowers open at dusk and have sticky nectar, which is easier for the bat to lick. Many bat-pollinated trees have **cauliflorous** flowers that bud from the trunk of the tree instead of the branches. These flowers are easier for bats to access, since many larger bats fly below the dense canopy rather than through it.

Tropical rain forest bats are not only important pollinators, but many species are also vital seed dispersers as well. These fruit eating bats, found in Old and New World tropical forests, are attracted to fruits with strong scents, such as ripe bananas. Some fruit bats reside near oceans as some supplement their diets with mineral salts from seawater.



Fruit bat

Other tropical bat species are insect eaters, preying on night-flying insects such as moths. Like their temperate forest counterparts, these bats use sonic echolocation to find their prey. The bats emit high frequency beams of sound from their mouths or noses. These beams bounce off nearby insects and return to the bats, allowing the bats to gauge the direction and speed of their prey. Insect-eating bats also fly low through the less dense understory in order to have less interference with their echolocation systems.

The fabled vampire bats are only found in tropical Americas and, unlike popular legend, do not suck blood. Instead, the vampire bats remove small pieces of skin from their hosts, which are primarily domestic animals such as horses, cattle, goats and pigs. The bats' saliva contains anticoagulants that prevent the hosts' blood from clotting and the bats are then able to lap up the blood. This process is so quick and painless that a sleeping animal may not even wake when bitten by a vampire bat. When the bats return to their roosting sites, they will regurgitate blood for individuals that were unable to feed. The feeding by vampire bats generally amounts to an insignificant amount of blood loss by the host, which is rarely a human. If the same host is used several times, however, that host can be severely weakened. Some bats also transmit diseases such as rabies, although the percentage of bats with rabies is incredibly low.

Although bats are the only true flying mammals, other mammals have different adaptations that allow them to leap from tree to tree with the appearance of flight. Flying squirrels and Australian sugar gliders have extra skin between their limbs that act as parachutes when they jump. Tropical flying squirrels are found in southeast Asia, India and Sri Lanka. Sugar gliders are found in the tropical rain forests of New Guinea and Australia, as well as the temperate forests of Australia.

Some small primates—such as the tarsiers of southeast Asia, galagos (bush babies) of Africa, and marmosets, Goeldi's monkeys and golden lion tamarins of Central and South America—have strong hind legs that allow them to leap from tree to tree. They also have claws, instead of nails, in order to grasp tree trunks. Many of these small primates occasionally include sap in their diet, but pygmy marmosets—the smallest monkeys in the world—are primarily sap eaters. With their large front teeth, they chew holes in a number of trees in their range. Then, they periodically visit each tree to lap up the flowing sap.

Many primates use **brachiation**, in which they swing hand over hand underneath branches, to travel through the trees of the understory and canopy. Orangutans, which primarily occupy understory and canopy trees in Sumatra and Borneo, are ideally suited for brachiation with their long arms, curved hands and mobile shoulder joints. These solitary apes eat leaves, fruit, flowers, bark and the occasional bird's egg or insect.

Ocelots, found in the tropical Americas, are well adapted for both life in the understory and life on the forest floor. Small cats with black spots on yellowish fur, ocelots blend in well with the dappled light conditions in these layers. On the forest floor, they hunt peccaries, small deer, rabbits and small rodents. Ocelots are also excellent swimmers and include plenty of fish in their diet. In the understory, ocelots can use their exceptional climbing skills in hunting birds, reptiles and monkeys. Ocelots are also versatile in their habitat choice and inhabit several different kinds of habitats, from tropical rain forests to dry scrub and chaparral zones.

Canopy

The canopy layer of the tropical rain forest has the largest amount of biomass and the greatest number of plant and animal species due to abundant light, moisture, food and shelter.

Plants of the Canopy

This layer is composed of the crowns of the canopy trees and is the primary region of photosynthesis for the tropical rain forest. Within these crowns are countless epiphytes, vines and lianas. In fact, the leaves of lianas comprise as much as 20 to 40 percent of all leaves in the canopy (Myers, 1993). The plants in the canopy receive the full glare of the sun, and experience temperatures of 90 degrees Fahrenheit and higher and 60 percent humidity.

The trees of the canopy can be between 100 and 200 feet (30 to 60 m) in height, depending on location, and often branches don't occur until 65 feet (20 m) up. The crowns of these trees usually don't interlock, but maintain a distance of approximately three feet (one meter). This phenomenon is called crown shyness. It's unknown why it occurs, but researchers theorize that crown shyness might prevent damage to other trees in high winds or stop the spread of leaf-eating insect larvae.

The plants in rain forests around the world have many similarities, such as the presence of buttress roots, lianas and epiphytes, but have very few plant species in common. For example, bromeliads (discussed in the "Plants of the Understory" section of this packet) are extremely common in Central and South America, but only one species of bromeliad occurs in tropical Africa and no bromeliad species occur in tropical Asia.

The same holds true for rain forest trees. For example, dipterocarp trees dominate the forests of southeast Asia, but are hardly found in Africa and the Americas. These huge trees are commercially valuable to the timber industry and, as a light-loving species that readily colonize large light gaps, can regenerate rapidly after logging. Dipterocarp trees flower irregularly at intervals of five to nine years, possibly triggered by drought. At this time, the entire canopy of dipterocarp forests becomes a mass of floral color.

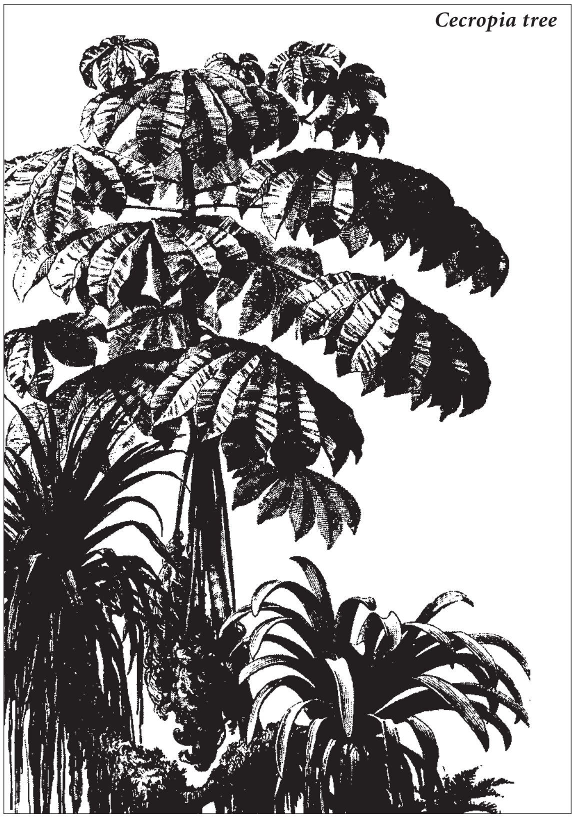
Unlike the majority of trees in the tropical rain forest, the seeds of which are dispersed by animals, the winged seeds of dipterocarp trees are wind-dispersed. Unless picked up by an extremely strong wind or caught in the fur of a passing animal, most dipterocarp seeds germinate near their parent plant. Because of this, dipterocarp trees spread slowly through intact rain forests.

Trees that colonize light gaps are called **pioneer species**. These plants typically flower and fruit quickly and profusely. Energy is put towards rapid growth, thus leaves are less well defended than long-lived canopy trees and are magnets for **herbivores**. Fruits are typically small-seeded and sweet in order to attract an abundance and variety of seed dispersers.

Cecropia is one example of a New World pioneer species. *Cecropia* trees rapidly colonize large light gaps, providing invaluable services such as offering shelter for animals, and quickly shading the forest floor, which provides suitable conditions for slower growing canopy seedlings and protects the vulnerable root mat from desiccation. The fruits of *Cecropia* trees are reportedly eaten by eight monkey species, 12 bat species and 76 bird species (Myers, 1993). *Cecropia* trees also have an intricate symbiotic relationship with Aztec ants, which will be discussed in the "Animals of the Canopy" section of this packet.

Most canopy trees rely on animals as pollinators and seed dispersers. These trees have coevolved with specific pollinators to ensure pollination. Many canopy species are pollinated by bees and have evolved plant parts that deposit pollen in specific places on a bee's body. Each bee in the tropical rain forest might be carrying pollen from four or five different tree species, deposited on a particular part of the head, thorax, abdomen or legs. This ensures that a receiving flower only obtains the pollen from its own species.

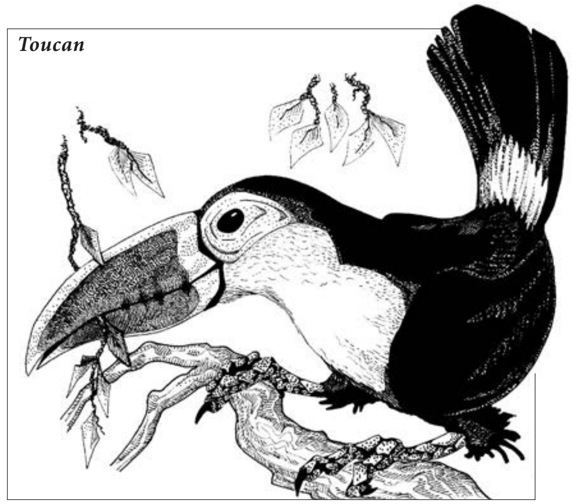
Cecropia tree



Flowers from tropical rain forest trees are also adapted to the specific needs of their animal pollinators. Moth-pollinated flowers are generally white in order to be more visible for night-flying moths. Bat-pollinated flowers are usually large and tough in order to provide a landing stage for the bats. These flowers are also often white and produce copious amounts of nectar and pollen to suit the bat's large appetite.

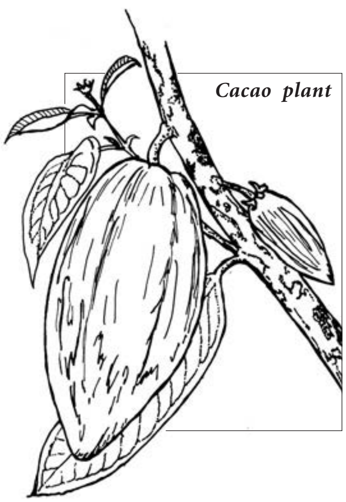
Canopy trees employ different strategies for seed dispersal. Some, such as many fig species, produce large volumes of small seeds packaged in easily consumed fruit. These fruits attract a large variety of **frugivores**, which are animals that primarily eat fruit. The seeds are most often swallowed whole and, if they survive digestion, are deposited in feces far from their parent plant. Once deposited, these small seeds need to germinate quickly because their size does not allow for a large food reserve. The majority of seeds do not germinate, but because the seeds are produced in such a large volume and are spread so far, figs are common in tropical rain forests.

Another seed dispersal strategy is attracting more specialized dispersers with larger fruits and seeds, such as the example of the relationship between the agouti and the black palm, which was discussed in the "Animals of the Forest Floor" section of this packet. In the canopy, many birds, such as hornbills and pigeons in the Old World and toucans, quetzals and bellbirds in the New World, are large-seed dispersers. These birds are able to swallow large-seeded fruits whole. Their reduced gizzards, the top part of the stomach in which food is ground up, remove the flesh of the fruit without damaging the seed, which is then either regurgitated and spit out or passed through the digestive system unharmed.



Toucan

To combat seed predators that crush or digest seeds, trees develop specific defense strategies. Many seeds have hard seed coats to allow passage through the digestive tract. Others are defended with a mix of toxic chemicals. An example of this is nutmeg. Humans grind the seeds and use them in small amounts as a spice. If a person ate whole nutmeg seeds, however, he or she would have strong hallucinations and could fall into a coma. Another example is cashew nuts, which are found on the ends of fleshy, sweet stems. Animals such as spider monkeys eat the stem, but discard the nut, which has a toxic seed coat.



Cacao plant

Cacao seeds, from which humans make chocolate, are also chemically defended. The seeds of the cacao are found in caulifourous pods, which are broken open by monkeys. The seeds are surrounded by a sweet, white pulp, which is sucked off by the monkeys. The seeds are then spit out by the animals that find them inedible. Many animals have adapted to these chemical defenses, however, and continue to be seed predators. Colobus monkeys of Africa are able to digest a wide range of toxins that would be fatal to many animals.

Vines and lianas reach the canopy through a variety of means. In addition to the barbed hooks and curling tendrils discussed in the "Plants of the Understory" section of this packet, some vines are twiners that coil their entire stems around the trunks of smaller trees. Others have different forms in the understory than in the canopy layer. One example is the *Monstera* species in Central America. Seedlings on the forest floor reach a tree trunk and begin the climb up, laying their leaves flat like shingles against the trunk. Upon reaching the canopy, the leaves change to large leaves held horizontally away from the trunk.

While vines and lianas start on the forest floor and grow up towards the canopy, other canopy plants, such as the strangler fig, start life in the canopy and grow towards the forest floor. These plants are known as hemiepiphytes because they live as an epiphyte until their roots reach the ground and penetrate the soil.

There are over 900 species of fig in tropical forests around the world and each species of strangler fig is pollinated by a specific wasp species. The sweet fruits of strangler figs are numerous and are dispersed


Strangler fig

by a large number of primates, small mammals and birds. The seeds germinate when deposited on a branch with enough debris to support the nutrient needs of a seedling.

As an epiphyte, the strangler figs depend on air and debris for water and nutrients, and have to contend with the hot glare of the sun. To counter these conditions, the strangler figs have thick, water-storing tissues and closed **stomata** to prevent water loss. When the roots reach the ground, the strangler figs are able to tap into water and nutrient supplies and grow rapidly. Eventually, the host trees are shaded out by the foliage of the figs and the host trees die.

Animals of the Canopy

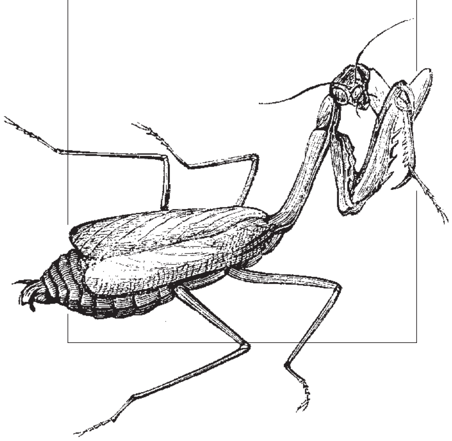
Invertebrates

The canopy layer supports a large number of invertebrate species. In Peru, one 17,500-cubic-foot (500 m^3) area of foliage, which is roughly equal to a two-car garage, may contain as many as 100,000 individual insects, including 50 species of ants and 1,000 species of beetles (Myers, 1993).

Leaves are the most abundant and constant food source in the canopy and are good sources of nutrients and protein. Many invertebrates, such as caterpillars and katydids, are primarily leaf eaters. To protect leaves from these and other herbivores, trees evolved complex defenses.

One line of defense is that cellulose in leaves is too hard for most animals' digestive systems to break down. Some bacteria and a few beetle species can digest it, but most animals can't. Caterpillars combat cellulose by chewing the leaves thoroughly enough to release the nutrients. Other plant defenses include thorns, spikes and toxic chemicals. For every adaptation a plant develops to protect itself, there is one or more animal that adapts to get around the plant's defenses. And so the cycle of adaptation continues.

Praying mantis



The abundance of insects in the canopy attracts many animals in search of food, including predatory insects. These insects, such as praying mantises and assassin bugs, are found in an array of colors, sizes and shapes. Praying mantises use their front legs, which are equipped with sharp spines to grab their prey.

To combat these and other predators, many insects, such as the aforementioned birdwing butterflies, accumulate toxins and are then themselves poisonous. Other insects attempt to fool predators by employing mimicry, in which they resemble poisonous individuals in appearance, but are not themselves toxic. Insects also use camouflage to blend in with parts of plants or have false eyespots on their wings to scare off predators.

Some insects use more aggressive strategies to deter predators. Bombadier beetles store chemicals in their glands and will blast attackers with a hot jet of irritating chemicals. These beetles are less than an inch (20 mm) in size, but can deter mice, praying mantises, wolf spiders and frogs.

Aztec ants live in the hollow chambers in the trunk of *Cecropia* trees and feed on Mullerian bodies, which are glandular nodules found at the base of each leaf's petiole or stem. These Mullerian bodies are made up of 50 percent glycogen, an energy-rich compound typically of animal origin. As Aztec ants are a predatory species, they require glycogen in their diet. *Cecropia* trees are the only known plants to produce glycogen. When *Cecropia* grows without Aztec ants present, no Mullerian bodies are produced.

Aztec ants also keep mealybugs in the hollow chambers of *Cecropia* trees. These bugs are "milked" for the sugary nectar they produce; in return, the ants protect the defenseless mealybugs. In exchange for food and shelter, Aztec ants also protect the *Cecropia* trees from attack by leaf and fruit eaters. They will cover an intruder within moments, delivering vicious bites in the process. Even encroaching vegetation is attacked and ripped to shreds, giving *Cecropia* a competitive advantage that allows it to grow eight feet (2.5 m) a year (Collins, 1990).

One of the few animals able to dine on *Cecropia* leaves is the sloth, which is protected from ant bites by its thick, coarse fur. This New World leaf eater has a large, multi-chambered stomach containing bacteria, which digest the cellulose in leaves. Sloths move extremely slowly. Their main defense from predators is the green algae that grows in their fur and helps them blend in with their surroundings.

Birds

The main predator of sloths, as well as monkeys, is the harpy eagle. Harpy eagles sit on the tops of emergent trees searching for sloths and other prey. Upon locating a sloth, a harpy eagle will dive below the sloth and roll in-flight to grab it from below (Grambo, 2002).

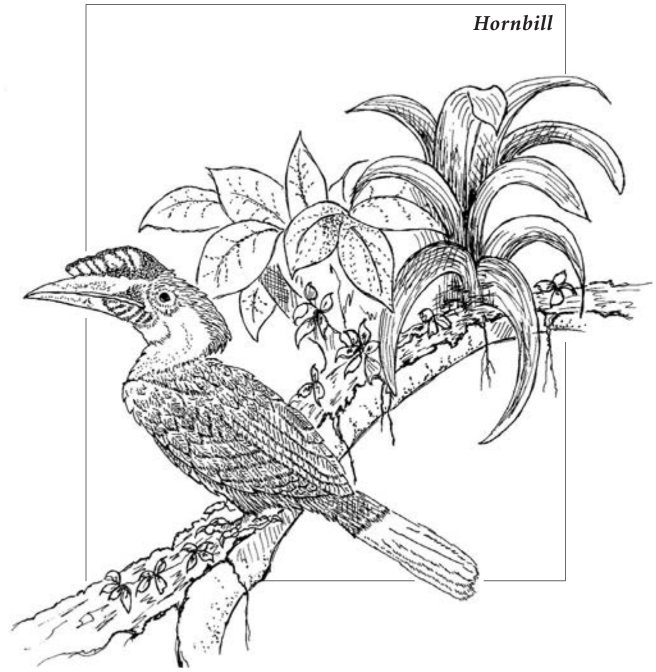
Many of the birds in the canopy are insect eaters that will often form mixed species groups for foraging. In the Old World, minivets, flycatchers, warblers and babblers are some of the insect eaters that may forage together. Minivets are brightly colored, gregarious birds commonly found in southeast Asia. Warblers are predominantly **insectivores**. Some species of Old World warblers are also found in the New World. Babblers eat insects and other invertebrates and are found in a range of habitats from desert scrub to tropical forests. Most babbler species occur in tropical Asia, but one species is found in western North America.

Mixed species groups of foraging insect eaters also occur in the New World. Many birds, including the gray-headed tanager, form groups that follow army ants as they march through the forest. Many tanagers are mostly fruit eating and don't digest the seeds they swallow, making them important seed dispersers. Most supplement their diet with insects.

Two of the most important seed dispersers in the canopies of the tropical rain forests are the New World toucans and Old World hornbills. Toucans are well known for their large colorful bills. These bills are surprisingly light as the insides are full of a spongy web of tissues. The long bills help toucans reach berries and other fruits on branches that are too thin to support their weight. It's unknown why their bills are so colorful. Some theories include use in courtship rituals, intimidation of predators or camouflage with the bright flowers and fruits of the tropical rain forests.

The diets of toucans consist mainly of fruits, but may also include insects, small lizards, snakes, bird eggs and nestlings. The Toco toucan of Brazil has the largest bill, which is slightly serrated to aid in grabbing fruit and prey.

Hornbills are found throughout the Old World. Half of the hornbill species occur in Africa, with the rest occurring in Asia and one species in New Guinea. Like the toucans, these large birds are also known for their long bills, which are often topped with a large casque. Not all hornbills are primarily fruit eaters. Many of the smaller hornbills are insectivorous and the two species of ground hornbills are predators, feeding on hares, tortoises, snakes and squirrels. Most of the larger, fruit-eating hornbills live in Asia. These hornbills must range widely through the forest because tropical trees are often on irregular fruiting cycles.

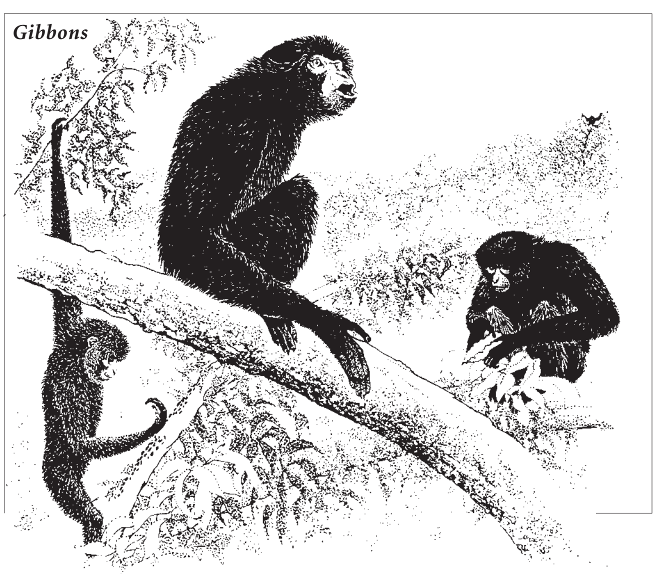


Hornbill

Hornbills are also important culturally. In parts of Africa, hornbills are sacred and thrive undisturbed in locations with high human populations. Some West African tribes use the heads of hornbills as camouflage when stalking prey. In southeast Asia, the rhinoceros hornbill was thought of as a god of war and is the emblem of the Malaysian state of Sarawak. In other parts of Asia, the casques of hornbills are carved into ear ornaments and other jewelry. These casques were also an important trade item with the Chinese.

Mammals

The canopy is also home to many primates such as the gibbons of Asia. These lesser apes are canopy specialists and important seed dispersers. Their arms are twice as long as those of humans compared to body length. These long arms and strong hands make them excellent at brachiation.



Gibbons

Gibbons live in small family groups, not large troops like some other apes. Each group remains in a large, but fixed, **territory** of fruit trees. Every morning, a pair of gibbons will sing together. The male starts before dawn and is later joined by the females. This singing serves not only as a means of pair bonding, but also as a way of delineating their whereabouts for the day.

Howler monkeys also produce large calls to delineate their territory and to avoid confrontation with other troops of howler monkeys. These leaf eaters are found in the

New World and have special adaptations to eating leaves. Unlike the colobus monkeys of Africa, which have stomachs similar to cows to aid in digesting leaves, howler monkeys have cellulose-digesting bacteria in their hindgut. To aid in the efficiency of their digestion, howler monkeys tend to select younger leaves, which are easier to digest. They will also eat fruits and flowers when available.

Another adaptation of some animals to the canopy layer is the prehensile tail, which acts like a fifth limb for canopy animals. Prehensile tails are tails that are able to grasp tree limbs. They are found in the pangolins (spiny anteaters) of Africa and southeast Asia as well as the porcupine, tree possums, kinkajou and tamanduas of Central and South America.

New World monkeys are the only primates with prehensile tails. These monkeys, including howler monkeys and spider monkeys, are able to use these prehensile tails to hang from branches to gain access to leaves and fruit.

Emergent Layer

Plants of the Emergent Layer

The emergent layer is comprised of the crowns of trees that grow up through and emerge above the canopy layer. These trees can be more than 200 feet (60 m) tall and 120 feet (37 m) around. In some trees, branching begins 130 to 165 feet (40 to 50 m) up the trunk. Like the branches of the trees in the understory and canopy, many epiphytes and lianas grow on the branches of these emergent trees.

Falling emergent trees can clear large areas by taking down a multitude of plants as they fall. This occurrence provides light for the forest floor, light gaps for pioneer plants and dead plant material, which will decompose and release nutrients for plants to use.

Due to their extreme height, both canopy and emergent trees have large buttress roots for support. Emergent trees need additional support due to the fact that they stand so high above the canopy trees with no buffer from strong winds and storms. As discussed in the “Plants of the Forest Floor” section of this packet, buttress roots are woody flanges that extend far up the trunk and outward from the base. These buttress roots not only stabilize the soil and increase the trees’ water and nutrient-gathering capacity, which helps the trees combat climatic stress, but also stabilize the trees against high wind and stormy conditions. If the buttresses were removed, the tree would be easily knocked over due to the fact that most tropical soils are too shallow for a deep taproot to grow and secure the tree.

The leaves of emergent trees are also often small and tough to counteract the drying winds. Many emergent tree species, which vary from forest to forest, drop their leaves during drought.

Kapok
One extremely important emergent layer tree is *Ceiba pentandra*, commonly called the kapok or silk-cotton tree. These trees occur naturally in tropical rain forests or moist areas of drier forests in West Africa and in Central and South America. In the Americas, the kapok grows from southern Mexico to the southern boundary of the Amazon basin. Kapok trees are also grown on plantations in southeast Asia.

Ceiba pentandra can reach heights of 200 feet (60 m). They have wide buttresses at their base and large, flat crowns on top. The flowers of the kapok tree have a pungent odor, which attract their bat-pollinators. One to two flowers on each tree open each night, helping to ensure cross-pollination. In addition to bats, hummingbirds, bees, wasps and beetles have been seen visiting the flowers.

Each tree may produce 500 to 4,000 fruits each fruiting season. The fruits are thick, woody seedpods containing approximately 200 small, brown seeds (Janzen, 1983). The pod-like fruits open on the tree, releasing the seeds to the wind. Each seed is covered in white tufts of silky hair called kapok fiber. These hairs act as parachutes, helping the wind-dispersed seeds spread away from their parent plant.

"Kapok" around the world

French: kapokier, capoc, bois coton
Spanish: ceibo
American Samoa, Tonga: vavae
Chuuk: koton
Guam: algodon de Manila
Cook Islands and French Polynesia: vavai, vavai mama'u, vavai maori
Fiji: vauvau ni vavalangi, semar
Marshall Islands: koatoa, atagodon, bulik, kotin
Palau: kalngebard, kalngebárd, kerrekar ngebard
Pohnpei: cottin, koatun, koatoa
Saipan: arughuschel

(Pacific Island Ecosystems at Risk, 2003)

These kapok fibers were, and in some places still are, commonly used as insulation and stuffing material for furniture and upholstered automobile seats. Because they're lightweight and waterproof, lifejackets were exclusively filled with kapok fibers until the middle of the 20th century.

Oil is made from the seeds of kapoks and is then made into soap. The seeds are also eaten by people and livestock in many parts of the world. In traditional medicine practiced in Surinam, the seeds, leaves, bark and resin from kapok trees are used to treat dysentery, fevers, venereal diseases, asthma, menstrual bleeding and kidney diseases (Tropilab Inc., 2003). In Colombia, the bark is made into a liquid and applied to hair to stimulate growth. The same concoction is also given to cows after delivery to help shed the placenta.

Native tribes also put bits of kapok fiber on the base of their poison darts to make the darts fly better. Other tribes wrapped the fibers around the trunks of fruit trees to discourage leaf-cutting ants from clipping the leaves of the trees. The trunks of kapok trees were also made into carvings, canoes and coffins.

In addition to the use of the products, the kapok tree is culturally important to different groups of native people in tropical forests. To the Maya and other Hispanic cultures in Central and South America, the kapok is a holy tree that connects the terrestrial world to the heavens above. Some cultures believe that the dead climbed the kapok to reach heaven.

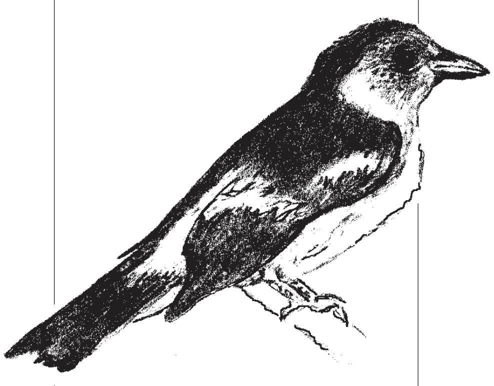
Kapok trees are also culturally significant in Africa and are sacred in West Africa because they're associated with burial and ancestors. It's also thought that the bark and leaves of kapoks have the power to expel evil spirits. In a region in Senegal, healing villages were founded at the base of large kapok trees because it was believed that these trees heal and protect people.

Many non-healing villages are also centered under the shade of kapok trees. If a kapok tree is not present at a village site, one will usually be planted. Often, when a forest is cleared, a great kapok tree will be left, providing shade for crops and serving as a reminder of the forest that once stood there.

Animals of the Emergent Layer

Many epiphytes and vines are found in the crowns of emergent trees. These plants provide permanent homes to many invertebrates and other small mammals, many of which never travel to the forest floor, much less to the layers below.

As with all layers of the forest, many animals use the emergent layer on a temporary basis. Due to immense heights of emergent trees, many animals will use these trees as lookouts while searching for prey or predators. Emergent trees can also provide vantage points for animals looking for flowering or fruiting plants. Crimson topaz hummingbirds and blue morpho butterflies will visit the flowers in the tall tree crowns looking for nectar. Cockatoos, macaws and toucans will forage for fruit in the emergent layer. Howler monkeys may venture into these tall trees to make their territorial calls at dusk. And harpy eagles will perch in the emergent trees looking for prey such as sloths, monkeys and other large birds.



Western tanager

Forest Connections

Migrating birds, such as western tanagers and rufous hummingbirds, are examples of an ecological interconnection between temperate and tropical forests. Western tanagers spend the spring and summer in temperate forests breeding and raising their young, taking advantage of the abundant food supply (insects, fruits and seeds) available in temperate forests during these seasons. In fall, western tanagers migrate south to tropical forests of Central America, thus avoiding the cold and lack of food during the fall and winter season in temperate regions. This ecological connection demonstrates the importance of both temperate and tropical forest ecosystems to western tanagers and other migratory species.

Strangler fig Photo by Katie Remine

IMPORTANCE OF FORESTS

Forest Ecosystem Services

Ecosystem services are important processes carried out by healthy, functioning ecosystems. People, and other living things, would be unable to survive on Earth if it weren't for the services that ecosystems provide. Forest ecosystems carry out many processes that benefit life on Earth including:

- Absorbing and storing carbon from the atmosphere
- Maintaining the balance of oxygen in the air
- Regulating stream flow and water quality by absorbing and slowly releasing precipitation
- Preventing soil compaction and creating air spaces in soil
- Maintaining moisture levels in the atmosphere through transpiration
- Providing habitat for animals
- Creating soil and protecting it from erosion

The absorbing and storing of carbon from the atmosphere is a critical service of forest ecosystems. Tropical and boreal forest trees store great amounts of carbon in their vegetation, more than the vegetation of any other terrestrial ecosystem. Due to land use changes and the combustion of fossil fuels, humans have been releasing more and more carbon into the atmosphere over the last 200 years. The earth's atmosphere takes up and stores some of this carbon, as do the oceans. However, the vegetation in terrestrial ecosystems, especially in tropical and boreal forests, is the most important carbon store ("sink"). This carbon storage is a vital function — when carbon levels in the atmosphere rise, in conjunction with higher concentrations of other emitted gases, global temperatures may also rise. By storing carbon in plant tissues, forest ecosystems help to buffer the effects of carbon emissions on global climate.

Trees in forests play a major role in most of these ecosystem services, but small invertebrate animals are the major players when it comes to the creation of soil. Bacteria, fungi, worms and arthropods all help to decompose organic matter, creating rich soil and providing nutrients for plants in the process.

Biodiversity in Forests

Tropical forests host an awe-inspiring diversity of living things. Closed (high percent canopy cover) tropical forests cover approximately seven percent of the earth's land surface, yet it is estimated that these forests host half the world's species of living things. For example, approximately 70 percent of the world's vascular plant species occur in tropical regions (approximately 45 percent occur in closed tropical forests) and approximately 30 percent of the world's bird species are dependent upon tropical forests for survival (World Resources Institute, 2001).

Although less diverse overall than tropical forests, temperate forests, too, host a diversity of organisms. In fact, the forests of the southern Appalachian mountains in the eastern United States are home to a greater diversity of salamanders than anywhere else on earth (World Wildlife Fund, 2001). A Pacific Northwest temperate forest region of high biodiversity is the Klamath-Siskiyou region of southwestern Oregon and northwestern California. A recent review of the **conservation** importance and status of the Klamath-Siskiyou region compared this region to other temperate coniferous forests regions in North America and to other diverse forest regions throughout the world.

The scientists stated that "based on comparisons of species richness, endemism, unique evolutionary and ecological phenomena (e.g., species migrations, adaptive radiations), and global rarity of habitat types, we ranked the biodiversity of the Klamath-Siskiyou **ecoregion** among the world's most outstanding temperate coniferous forests" (DellaSala et. al., 1999).

"Tropical forests have a special role in the conservation of biodiversity…The tropical forests contain 70% of the world's vascular plants, 30 percent of all bird species, and 90 percent of invertebrates."

– Roper and Roberts, 1999

Products of the Forest

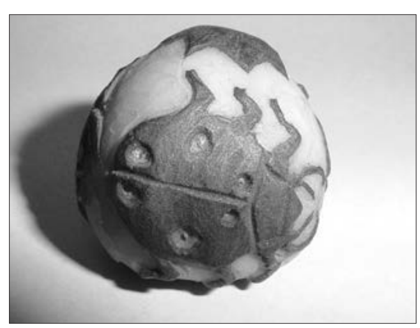
Look around you right now. How many things around you are products of trees or forests? What about the foods you ate today? What about the recycled paper this packet was printed on? Forests provide necessary products, including foods and medicines, that we all use everyday (see "Products of the Forest" on the following pages).

Many forest products are harvested in ways that leave the forest intact. These types of products, referred to as non-wood forest products, can help to save forests by providing income to local people without damaging the forest ecosystem. Non-wood forest products provide communities with economic incentive to maintain healthy forest ecosystems. One example of a sustainable non-wood forest product is the tagua nut. Tagua nuts, dried seed pods of the tagua palm, are harvested in the rain forests from Panama to Peru. Tagua nuts are a sustainable forest product and are an excellent substitute for ivory—carved tagua nuts closely resemble carved ivory. So the production and sale of tagua nuts not only benefits tropical forests in South America and the economy of local communities there, but also may reduce the demand for ivory from elephants and other ivory-bearing mammals.

Non-wood forest products that are produced and harvested in a sustainable manner can provide benefits for both biodiversity and local economies. The Food and Agriculture Organization (FAO) of the United Nations estimated that the total value of world trade in non-wood forest products, such as fruits, nuts, mushrooms, gums, resins, aromatic plants and honey, was approximately $11 billion dollars as of 1993. Medicinal plants top the list for their value in the world market, followed by nuts, ginseng roots, cork and cork products and essential oils (Walter, 2002).

Tagua nut *Photo by Jenny Mears*

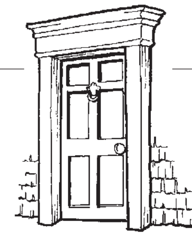
As described in the "Canopy" section of this packet, many plants produce chemical compounds to protect their leaves and seeds from being eaten by animals or to ward off diseases. In some cases, these compounds can act as effective treatments for human ailments. Medicinal compounds used by people have come from plants all over the world. Tropical rain forests, with their incredible biodiversity, house numerous resources, both discovered and undiscovered, that can benefit human health.



Carved tagua nut *Photo by Jenny Mears*

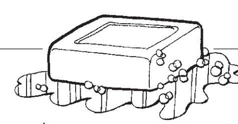
Products of the Forest

The following is a list of a few products originating in temperate (*) and tropical forests.
(Note: Products without stars originate in tropical forests but some may also be found in temperate regions.)



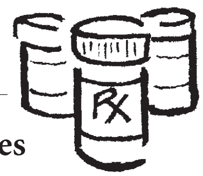
Wood	Common Uses
teak	furniture, doors, door frames
mahogany	garden furiture
rosewood	packing cases
balsa	cases, window sills
sandalwood	insulation, flooring, general construction, subflooring, railroad ties, paneling, pilings, boats, cabinetry, salad bowls, buoyancy material, toys
bigleaf maple*	firewood, veneer, furniture
Douglas fir*	timber for house construction, Christmas trees
western red cedar*	shingles, siding, outdoor decks and furniture
western hemlock*	paper, gymnasium flooring, cellulose for rayon, cellophane and plastic products
red alder*	firewood, furniture, paper, veneer
Stika spruce*	lumber, veneer, paper, WWI aircraft (Spruce Goose)

Fibers	Common Uses
bamboo	furniture, baskets, house construction
hemp	rope, cord
jute/kenaf	rope, burlap, paper
kapok	insulation, soundproofing, life jackets
raffia	rope, cord, baskets
ramie	fabric, fishing line
rattan	furniture, wickerwork, baskets, seats



Oils	Common Uses
camphor oil	perfume, soap, disinfectant, detergent
cascarilla oil	confections, beverages
coconut oil	suntan lotion, candles
eucalyptus oil	perfume, cough drops
oil of star anise	scenting, beverages
rosewood oil	perfume, cosmetics
ylang-ylang	perfume

Gums & Resins	Common Uses
chicle latex	chewing gum
gutta percha	golf ball covers
rubber latex	rubber products
tung oil	wood finishing



Medicines	Common Uses
Taxol*	cancer medication
Atropine	dilates pupils for eye exam, dries up saliva in oral surgery
Desperpidine	antihypertensive, tranquilizer
L-Dopa	Parkinson's disease
Ouabain	heart tonic
Papain	papaya derivative, better digestion, meat tenderizer
Physostigmine	used for glaucoma
Quinine	malaria
Reserpine	antihypertensive, tranquilizer
Tubocurarine	skeletal muscle relaxant
Vinblastine	Hodgkin's disease; cancer treatment
Vincristine	acute childhood leukemia

Fruits	Spices	Vegetables, Nuts & Other Foods
avocado	allspice	Brazil nuts
banana	black pepper	walnuts*
coconut	cayenne	hazelnuts*
grapefruit	chili	cane sugar
guava	cinnamon	cashew nuts
lemon	cloves	chocolate (cacao beans)
lime	ginger	coffee
mango	nutmeg	macadamia nuts
orange	paprika	mayonnaise (coconut oil)
papaya	vanilla	peppers
passionfruit		soft drinks (cola nuts)
		tea
		sauces (tamarinds)

Medicines from the Rain Forest

Although many drugs can be synthesized in laboratories, the original formulas for these compounds may only exist, yet to be discovered, in rain forest plants and other organisms. The story of a recent example began in a peat swamp forest near Lundu in Sarawak, Borneo. In the mid-1980s, researchers funded by the National Cancer Institute (NCI) took samples of a number of trees in a peat swamp forest in Sarawak. Back at the NCI labs, one tree, a species of *Calophyllum*, showed no anti-cancer properties, but several years later was found to have strong effect against the replication of the AIDS virus. When researchers went to get more samples from that tree, they couldn't find that individual tree. It had probably been cut down during the original collection or by local people for **fuelwood**. No other trees of that species were found in the area. Other trees of related species were collected in the same area, but none showed the same properties. A *Calophyllum* of the same species as the original sample was located in the Singapore Botanical Garden and the compound again showed activity against the AIDS virus. The compound, calanolide A, was synthetically developed by Sarawak MediChem Pharmaceuticals, a public-private partnership that was formed between a pharmaceutical development company and the government of Sarawak. Calanolide A is in final testing stages and is showing positive results. This is the first naturally occurring compound to be developed as an AIDS treatment. This instance provides a strong argument for the value of protecting intact rain forest from logging or other impacts on the biodiversity of the rain forest.

(American Museum of Natural History, 1998)

Forests and Cultural Survival

We all depend in one way or another on forests—for food, for medicines, for household objects and for other materials as described on the "Products of the Forest" page in this packet. There are many **indigenous** cultures across the globe whose livelihoods and cultural integrity depend directly upon the health of the forests in which they live. When forests are destroyed, traditions of cultures can be lost because these traditions are so closely tied to the forests and the plants and animals that inhabit them.

One program aimed at protecting rain forests and the cultures associated with them is the Shaman's Apprentice Program. This program, which is active mainly in the Amazon River basin forests of Colombia, was started in response to the recognition of the important link between traditional healers and protection of land in the Colombian Amazon. Areas in which shamans, or traditional healers, had passed on their knowledge to the next generation had better protection and preservation of forest lands and the natural resources within the forests than areas where this knowledge was not shared. To this end, the Shaman's Apprentice Program provides financial support, necessary in modernizing communities in the developing world, to young people who apprentice with shamans in their local communities. Conservation funds from Woodland Park Zoo and other donors provide support for these shaman's apprentices, thus contributing to the conservation of habitat and species in the rain forests of Colombia.

"Some 500 million people live in or at the edge of the tropical forests…Included in this population of forest-dependent peoples are the world's 150 million native or indigenous peoples who rely on the forests for their way of life. They not only meet their economic needs for food and shelter but also form an integral part of their culture and spiritual traditions."

– Roper and Roberts, 1999

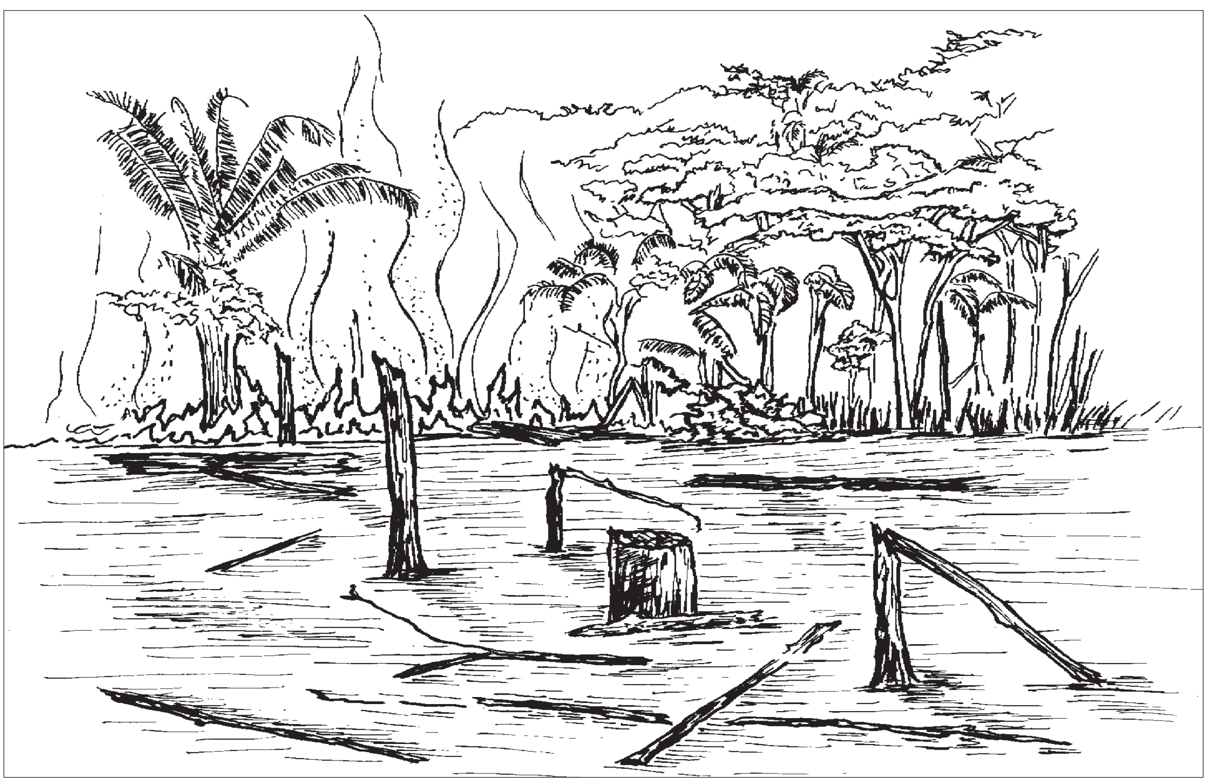
FOREST CONSERVATION

Threats to Forests

As we have seen, tropical forests and other forests of the world harbor an incredible diversity of organisms, play an important role in many crucial ecosystem services, and provide people with a long list of essential products. Forests face both natural and human disturbances on a daily basis. Natural disturbances include forest fires, insect damage, disease, drought, and storm damage from floods or high winds. These natural threats are usually localized within a forest, allowing the forest as a whole to recover over time. Natural occurrences, such as trees being blown down, can provide forest floor and understory plants the opportunity to grow up into the ensuing light gap and can help to sustain biodiversity within a forest by maintaining the structural diversity of the forest.

However, natural disturbances, such as fires, can be exacerbated by the effects of human activities and forest management practices. In addition, over the course of human history, people have used forests and their products in an increasingly unsustainable manner to such a degree that over the last 8,000 years scientists estimate that anywhere from 20 to 50 percent of land that was once forested no longer hosts forests (Matthews, et. al., 2000). The current major threats to forests include logging, agriculture, forest fires, **introduced species** and road building through forests.

It is important when considering threats to forest ecosystems to distinguish between the agents and the causes of deforestation. Agents are the people or organizations that are involved in clearing forests, such as farmers, loggers and logging companies, ranchers, etc. Causes are the forces that motivate the agents, which can be economic situations, government policies and land use or land tenure systems. Solutions to curtailing deforestation lie in changes that affect the causes of deforestation.



Logging/Wood Harvesting

When considering the current factors contributing to the decrease in forest cover across the globe, large-scale commercial logging rates among the top threats to forests. Commercial logging, carried out by multinational corporations, is often conducted in an unsustainable manner. Furthermore, logging companies, along with mining and oil extraction companies, open the way for other impacts by building roads through forests (see "Roads" in this section). Logging, and its infrastructure of roads, impacts the ability of forests to carry out the ecosystem services described on page 47 ("Forest Ecosystem Services" in this packet), particularly the storing and absorbing of carbon, the maintenance of healthy watersheds and soils, contributions to atmospheric moisture levels, and providing habitat for animals. Depending on local conditions, the removal of forest cover can contribute to increased soil erosion, major fluctuations in annual water flow (i.e. droughts and/or floods), and decreased ability to purify water (Matthews et. al., 2000). Logged forest areas are also more prone to damaging forest fires (see "Fires" in this section). In arid wooded areas, such as at the transition zones between deserts and woodlands, deforested areas are subject to desertification, in which formerly wooded land gradually becomes desert.

Unfortunately, the most devastating logging is logging that occurs illegally, often under the auspices of commercial logging companies. Illegal logging is the procurement, processing and trading of timber that is not in accordance with local or international forest management and/or trade laws. It is estimated that illegal logging is responsible for well over half of the total log production in the three top tropical timber-producing countries, Brazil, Indonesia and Cameroon.

Corruption within the logging industry and in governments contributes to illegal logging. Although most illegal logging involves Asian logging companies exporting to Asian nations, the illegal timber is sometimes re-exported to other countries, including the United States. In August of 2001, international trade in a southeast Asian species of tree called ramin (a species of *Gonystylus*) was banned due to the high incidence of illegal harvest and export of these trees and the economic and environmental impacts of these illegal activities. The United States was a major importer of ramin, used in products such as wood dowels, moldings and handles. Trade restrictions such as this one play an important role in ensuring the sustainability of forest ecosystems.

A major demand for wood, especially in developing countries, is the need for fuel in the forms of fuelwood and charcoal. In most developing countries, wood provides the major source of energy for cooking and for heating. For example, in Africa, approximately 40 percent of the total energy requirement is supplied by fuelwood, as compared to 1.4 percent for North America (World Energy Council, 2003). The majority of wood harvested for fuel does not come from closed canopy forests but from other types of woodlands. Wood is a renewable resource, unlike the fossil fuels that provide for most energy needs in developed countries, however, in many parts of the developing world current demands for fuelwood and charcoal are not sustainable. One reason for this is that many uses of wood for energy, such as open cooking fires, are inefficient. More efficient and cleaner burning of wood for fuel could help to alleviate some of the pressures on woodlands and forests. A number of organizations, such as the Forestry division of the Food and Agriculture Organization of the United Nations, are working to address issues of sustainable forestry for fuelwood production and more efficient use of fuelwood. In Colombia, a **wildlife** conservation project, Proyecto Tití, has helped to incorporate the use of fuel-efficient stoves in place of open cooking fires in an effort to protect local forests that harbor **endangered** cotton-top tamarins.

Pacific Northwest Forest Issues – Northwest Forest Plan

In the early 1990s in the Pacific Northwest, significant conflicts erupted over forest management when declining employment in the timber industry, a result of increased automation and decreased supply, coincided with the addition of the northern spotted owl to the endangered species list. The conflict rose between people who were impacted by declining employment and people who felt that logging of ancient forests had had drastic impacts on watersheds and plant and animal species, including the northern spotted owl. The conflict was so intense that logging of old growth forests was halted by court order until a new management plan could be put into effect.

In 1994, a new forest management plan for federal lands in western Washington, Oregon and northern California (the area concerned was defined by the range of the northern spotted owl) was adopted. This plan, the Northwest Forest Plan (NWFP), is based on an ecosystem management approach aimed at fulfilling economic, social and ecological objectives. In order to maintain diversity in northwest forests, the NWFP aims to establish a patchwork of reserves of old growth forests within a matrix of logged land. This land use pattern is based on the theory that viable populations of species within the old growth reserves can disperse across the matrix of logged land to other old growth forests, ensuring the survival of healthy populations of these species. Other species that are less likely to survive the effects of logging and are less able to disperse are protected under the Survey and Manage strategy of the NWFP. This strategy calls for the surveying of lands designated for logging, to determine the presence of certain species of mosses, lichens, mollusks, salamanders and other sensitive species. If these species are located, measures must be taken to protect them.

There are those that would argue that the NWFP has been unsuccessful in fulfilling its ecological aims because studies have indicated that the population of northern spotted owls has continued to decline despite the protective measures of the NWFP. And there are those that would say that the NWFP has failed to meet its economic objectives because the timber harvests of the Bureau of Land Management and the Forest Service (the agencies responsible for the implementation of the plan) have not yet reached the levels called for in the original plan. But the NWFP has also seen successes in the sense that the plan represents a significant compromise between ecological, social and economic interests in forests. In addition, the plan has facilitated the close cooperation among numerous federal agencies and better communication between these agencies and state agencies, tribes and the general public. The NWFP "established a common vision for the management of federal lands within the range of the northern spotted owl. It delineated a set of objectives covering ecological protection as well as commodity production and committed all the agencies to work toward all those objectives. Even more importantly, it required them to work together, on an interagency basis, to implement the Plan" (James, 1998).

Agriculture

The clearing of forests for agriculture is another major factor contributing to the loss of forests around the world. Agriculture at both the commercial level, such as the clearing of natural forests to make way for monoculture plantations, and the **subsistence** level has had significant impacts on forests. Commercial, large-scale agriculture, including the clearing of land for cattle ranching, can have more extensive impacts than subsistence farming. In tropical areas, soils that are exposed by the clearing of trees are subject to the extremes of tropical sun and rain, which can lead to soil compaction, leaching of nutrients and the reduction of organic matter in the soil. The fertility of the soil is exhausted after a number of years of cultivation or ranching. Due to this unsustainable use, plantations and ranches are continually expanded by the further clearing of forest. Furthermore, on the previously cultivated or ranched lands forests are no longer able to regenerate, mainly due to the invasion of aggressive, **non-native** species of plants.

Slash-and-burn agriculture is a method of subsistence farming, in which plots are cleared and burned before planting, that has taken its toll on forests. Traditionally, when population pressures were less severe, small-scale farmers would clear, burn and cultivate small plots of land, shifting among the plots and leaving plots to regenerate over a relatively long period of time before recultivation. Under increased population pressures coupled with government land use policies, farmers can no longer leave plots fallow for long periods of time. Thus, forest soils do not have enough time to regenerate before recultivation. In addition to the loss of forest plants and wildlife, slash and burn agriculture releases carbon dioxide stored in forests into the atmosphere and causes local smoke **pollution** in the air. A number of agencies and organizations are exploring more sustainable alternatives to this type of slash-and-burn agriculture that can preserve some elements of a healthy, functioning ecosystem while still providing for the agricultural needs of people.

Fires

Natural forest fires can maintain the diversity of forest plant species by initiating natural cycles of **succession**. Natural forest fires also provide food for animals by encouraging the growth of forest floor plants. However, forest fires can become agents of destruction when they occur in the wrong place and at the wrong time, such as those started inadvertently by people.

In forests today, human-induced fires far outweigh naturally occurring forest fires. Forest management practices have called for fire suppression in many forest ecosystems that are adapted to regular forest fires. Fire suppression, in addition to grazing and logging, have altered the natural conditions of these forests, causing changes in the natural species composition of the forests and leaving them more susceptible to insects and diseases and prone to catastrophic fires. Catastrophic fires can alter forest composition and structure, threaten human habitations, release large amounts of carbon dioxide into the atmosphere, and impact human health. There is no consensus among natural resource managers about the best way to manage forests that will allow for healthy, natural fires while completely preventing catastrophic fires. It is agreed, however, that in areas where human life or property are at risk, protection of human life and property is of the highest priority. Management regimes in these areas might be significantly different from those in more remote areas in order to fulfill different objectives.

Introduced Species

Wildlife habitats have been severely altered by introduced, or non-native, species. Species of plants, animals and even disease pathogens have been, and continue to be, introduced from one region to another by humans, both accidentally and intentionally. Some plant species first became established as garden ornamentals before they “escaped” into the wild and spread. Pest species, such as the Asian longhorned wood-boring beetle, may be transported from Asia to North America in raw logs. Other species travel along with shipments of fruits and flowers or even in the wheel wells of planes!

Once introduced, species may not survive due to differences between their natural habitat and the new habitat. Some species, however, thrive and proliferate in their new environments. These **invasive** species, whether plants or animals, can severely reduce the numbers of **native** species in the area. Without the natural predators or disease controls found in their native regions, introduced species can proliferate at fantastic rates. Introduced species may prey on native species, alter the natural habitats of the native species, or they may out-compete native species for basic needs. Either way, the spread of an introduced species leads to the loss of biodiversity.

The state of Queensland, in northern Australia, hosts Australia’s only tropical rain forest with a high diversity of plants and animals, many of them endemic to the region. The edges of the rain forest are prone to the spread of invasive **weeds**. In Queensland, trees such as African tulip and privet, shrubs such as lantana, and vines such as cat’s claw and Madeira are all invading the edges of tropical rain forest, impacting native forest plant species (Latch, 1999).

Introduced species of plants and animals have had great impacts on many native species of Washington state. Some non-native plant species aggressively invade forests and shade or choke out native plant species. Many temperate forests understories of western Washington have been invaded by the weedy geranium, herb robert *(Geranium robertianum)*. Originating from Europe, Asia and North Africa, herb robert was introduced to Washington, most likely as a garden ornamental, in the early 1900s. This plant spreads readily in the shady forest floor of forests, often outcompeting native forest floor and understory plants, eventually covering up to 50 to 100 percent of the ground (Simon, 2003). There are many community groups in western Washington that are actively engaged in the removal of invasive plant species in order to protect the diversity of our temperate forests.

Herb robert ***(Geranium robertianum)*** *Photo by Katie Remine*

A road through Mt. Rainier National Park, Washington Photo by Shane Farnor

Roads

Road building through forests, often for the purpose of logging or mining, has myriad impacts on forest ecosystems. Roads open up previously inaccessible forests to other threats such as clearing for agriculture, settlement, logging (legal and illegal), forest fires and hunting (legal and illegal). Furthermore, roads themselves impact ecosystems and species through increased mortality from construction and collision with vehicles, changes in animal behavior (such as declines in reproductive success), changes in the physical environment (such as soil compaction and the flow of surface water), the introduction of chemicals (such as heavy metals and salt), and the facilitation of the dispersal of invasive species of plants and animals (Trombulak and Frissell, 2000). Some animals try to cross roads and are prone to being hit by vehicles. Other animals, particularly invertebrates, amphibians and small mammals, will not cross wide gaps, such as roads, and can therefore be stranded in fragments of forests bordered by roads. In the United States, a number of organizations have supported the protection of current roadless areas in national forests in order to prevent the recognized impacts of roads on forest ecosystems and wildlife.

Rates of Tropical Forest Loss

These numbers are provided to give you some idea of the current rates of tropical forest loss. Forests are large, complex ecosystems found throughout the world, so these statistics will vary depending on definitions, data collection methods, when the data were collected and other factors. A recent assessment of forest cover change between 1990 and 2000 estimated that natural tropical forests (not including forest plantations) were decreasing at an average rate of 35 million acres (14.2 million hectares) per year (Food and Agriculture Organization, 2001).

Rates of Tropical Forest Loss	Number of Acres	Hectares (one hectare = 2.47 acres)
per year	35 million	14.2 million
per month	2.92 million	1.18 million
per day	97,333	39,333
per hour	4,056	1,639
per minute	67.59	27.31
per second	1.13	0.45

(Food and Agriculture Organization, 2001)

What is Being Done to Help Conserve Forests?

The conservation of biodiversity, in forests and in other ecosystems, is a complex endeavor that encompasses social, political and economic factors as well as ecological considerations. With proper protection, scientific research, education, community involvement and forest management policies, forests can continue to provide people with necessary products, provide healthy habitat for a diversity of species, support traditional cultures, and carry out important ecosystem services. The following paragraphs illustrate just a few ways that people around the world are striving to conserve forest ecosystems, wildlife and resources.

Forest Research


photo by Jenny Mears

Scientific research is an important part of forest conservation. Forest canopy research has grown by leaps and bounds since the mid 1970s when scientists began to explore forests canopies in earnest. Over the years, new methods of exploring the forest canopy, such as towers, walkways, construction cranes and rope climbing, have been developed, facilitating our understanding of canopy ecosystems.

In 1995, a temperate forest canopy crane was established in Washington state, giving researchers new insights into this hard-to-reach forest level. As of 2003, there are a total of eleven canopy cranes around the world in both temperate and tropical forests (Basset et. al., 2003). Washington's crane is located in stands of old growth at the Wind River Experimental Forest, between Mt. St. Helens and the Columbia River. The crane, which is 285 feet (86 m) tall and is similar to those used for city construction, is owned by the University of Washington and jointly managed by the university and the U.S. Forest Service. The crane is used by a myriad of researchers exploring such topics as the use of different forest levels by bats, life cycles of insects that breed in the canopy, the important role of invertebrate animals living on conifer needles in the food chain, the role of lichens in fixing nitrogen and improving air quality, canopy photosynthetic rates under varying environmental conditions, and weekly counts of songbirds inhabiting this layer of the forest. These studies, as well as similar studies in tropical forest canopies, have turned up large amounts of new information, adding to our knowledge of the complexity of forest canopies and aiding in designing new forest management and conservation practices.

Protection

In some areas of the world, people have chosen to set aside forests where no logging or other extraction is allowed to occur and forests are designated to remain in their wild state. These lands may be publicly owned, privately owned or a patchwork of the two.

In Washington state, supporters of the Loomis Forest Fund have achieved permanent protection for 25,000 roadless acres in the Loomis State Forest located in Okanagan County, Washington. The forest encompasses a vast expanse of old growth temperate forest wilderness, habitat for some of the world's most majestic and, in many cases, endangered wildlife. Grizzly bear, wolverine and the healthiest remaining populations of lynx left in the lower 48 states inhabit this great wilderness. In the fight to save this area, a 1998 agreement with the state placed a moratorium on logging in key old growth forest habitats while obligating conservationists organized by the Northwest Ecosystem Alliance to raise enough money to compensate the Common School Construction Trust Fund for permanent land protection. Woodland Park Zoo's Jungle Party Conservation Fund and the Puget Sound Chapter of the American Association of Zoo Keepers contributed funds to this effort. The Cascade Conservation Partnership, administered by the Northwest Ecosystem Alliance, continues to work toward purchasing and protecting more than 75,000 acres in the North and Central Cascades.

In many parts of the world small forests have been protected from human disturbance for their spiritual, religious and culture importance. These sacred groves also protect watersheds and provide habitat for plants and animals. Sacred groves are still important in India. In India, fig trees (*Ficus* species) were offered special protection both in sacred groves and in villages. Due to the importance of fig fruits for a wide diversity of tropical forest species, the protection of these fig trees has provided great benefit for forest wildlife in India.

Community Forestry

Local communities are increasingly involved in implementing sustainable forest practices when government capacity to properly manage forests falls short. In some cases, governments have passed forestry laws that turn over forest management to communities, recognizing that management at the grassroots level can be more successful. Community forestry efforts often benefit from the support and experience of organizations, such as the Forest, Trees and People Program of the Food and Agriculture Organization of the United Nations, in the management of their forests to achieve ecological, economic and social objectives.

Communities can benefit from the sustainable production of non-wood forest products. The harvest and sale of these products can provide economic incentive to local communities to protect their forests. See "Products of the Forest," page 48, in this packet for more information on non-wood forests products.

Forest Certification

Forest Stewardship Council (FSC)
As consumers, there is a lot that we can do to protect forests in our region and around the world. One thing we can do when buying wood products is to look for products certified by the Forest Stewardship Council (FSC). The FSC is a private group consisting of environmentalists, community groups and professionals in the timber industry whose aim is to "encourage environmentally appropriate, socially beneficial and economically viable management of the world's forests" (Forest Stewardship Council, 2001). FSC accomplishes these goals by implementing a rigorous set of standards that certified forests must meet. Consumers who purchase FSC certified wood products are assured that the forests from which the wood came meet the principles and criteria as set forth by the FSC. In order to be certified, companies must:

- Meet all applicable laws
- Have legally established rights to harvest
- Respect indigenous rights
- Maintain community well-being
- Conserve economic resources
- Protect biological diversity
- Have a written management plan
- Engage in regular monitoring
- Maintain high conservation value forests, and
- Manage plantations to alleviate pressures on natural forests.

(Forest Stewardship Council, 2001)

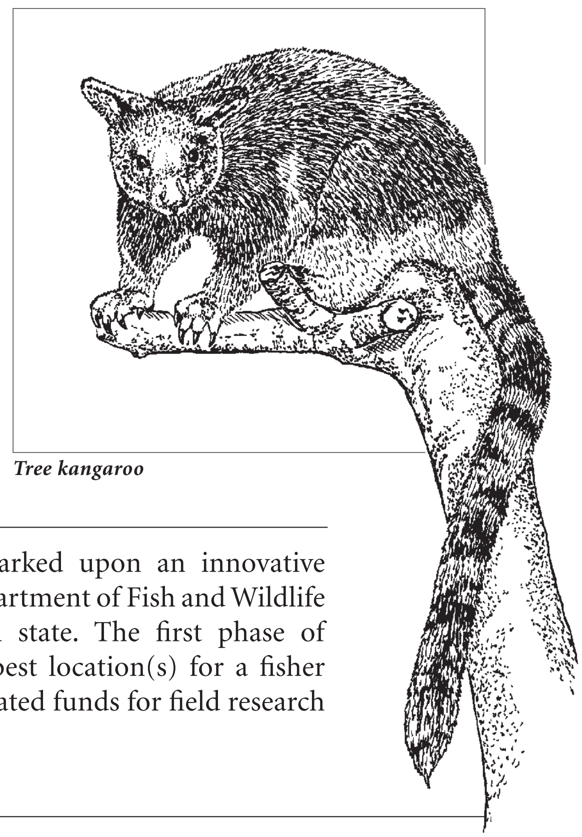
The certification efforts of the FSC help to ensure that forest product consumers contribute to maintaining environmentally, socially and economically sustainable forests around the world.

Woodland Park Zoo's Support for Conservation

Zoos can play a key role in the conservation of biodiversity in forests. In North America, zoos are accredited through the **American Zoo and Aquarium Association (AZA)**. In order to achieve accreditation, AZA zoos must participate actively in conservation and in educating the public about wildlife conservation issues. Zoos help people to understand local and global conservation issues by providing people with the opportunity to experience and learn about animals and plants. Zoos support the conservation of forest habitats and species in the wild by providing funds and other resources to field conservation projects. The following are a few examples of how Woodland Park Zoo is involved in the conservation of forest habitats and species around the world and in our own backyards.

Tree Kangaroo Conservation Program

In Papua New Guinea, nearly all land is owned by private landowners. This means that in order to conserve forests, and species such as tree kangaroos, conservation biologists must work closely with local communities. Through the efforts of the Tree Kangaroo Conservation Program (TKCP), local landowners have taken significant steps to conserve their forests. One step towards ecologically sustainable forests is the establishment of Wildlife Management Areas, in which landowners designate community lands as conservation zones and petition to obtain legal recognition of these zones by the government. The TKCP was the result of efforts by several Woodland Park Zoo staff members and has been supported in part by funds from Woodland Park Zoo over the years.



Tree kangaroo

Fisher Reintroduction in Washington

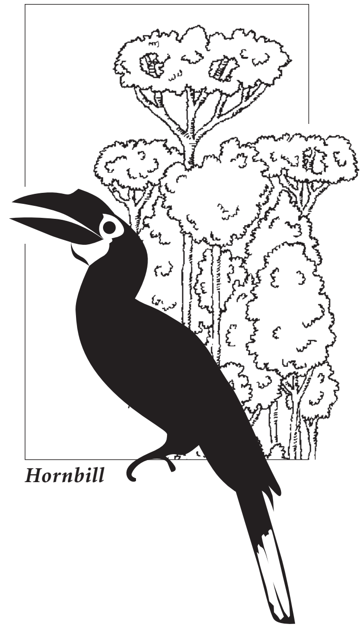
Northwest Ecosystem Alliance (NWEA) has embarked upon an innovative public/private partnership with the Washington Department of Fish and Wildlife (WDFW) to reintroduce fishers into Washington state. The first phase of this project is a series of feasibility studies to determine best location(s) for a fisher reintroduction in Washington. Woodland Park Zoo has donated funds for field research that is an important first step in this process.

Hornbill Nest Adoption and Conservation and Education Center

Through funding and field work by zoo staff, Woodland Park Zoo supports the Hornbill Nest Adoption Project through Thailand's Hornbill Research Foundation (HRF), which is led by Dr. Pilai Poonswad. Since 1978, the Hornbill Project has actively conducted research on the biological and ecological aspects of the birds, including their important role of dispersing seeds throughout forests by way of regurgitation. It has been said that forests need the hornbills as much as the hornbills need forests!

The adoption project, which began in 1998 in Budo-Sungai Padi National Park, pays nearby villagers to watch over the nests. This not only provides a financial incentive for protecting the hornbills, but also instills a spirit of stewardship of the local forest and its wildlife. This is a win-win situation. The hornbills are protected, villagers receive much needed income, and researchers receive valuable reproductive information about the hornbills.

Since the spring of 1999, the Puget Sound Chapter of the American Association of Zoo Keepers and the WPZ Jungle Party Conservation Fund have adopted 58 nests. In addition, the zoo has been supporting the development of an education center near Budo Mountain in Tapoh village, Ruso District, Narathiwat province, southern Thailand, which will provide educational opportunities to schools in the surrounding area. If you would like to support either of these projects, you can go to the AZA Taxon Advisory Group Web site for hornbills at www.coraciiformestag.com/Hornbill/asia.html.


Hornbill

Jaguar Conservation

As a part of the opening of a new jaguar exhibit in June 2003, Woodland Park Zoo committed conservation support and funds to four field conservation projects that help to conserve jaguars and their habitats:

The Conservation Status of Jaguar, Pumas and Tapirs and Their Potential as Landscape Detectives for the Brazilian Atlantic Forest
This project aims to protect one of the last remaining Atlantic Forest populations of jaguars, pumas and lowland tapirs. Specific objectives include: 1) estimating the population size of jaguars, pumas and tapirs in the Morro do Diabo State Park and neighboring Atlantic Forest fragments, 2) assessing the genetic status of these fragmented and isolated populations, and 3) investigating these species as potential "landscape detectives" (i.e. can the animals' dispersal and travel routes reveal what lands should be protected as wildlife **corridors**?).

Status of Jaguar in Southern Brazil
Jaguars are thought to be extinct in the southern region of Brazil, with the last known individuals having been shot in the 1970s. However, there has been no survey in the general area and there are still many remote, forested areas where the puma has made a remarkable recovery due to a decrease of hunting in the area. Some of the reports from local people are inconclusive as to the species of large cat, with descriptions being more indicative of jaguar than of puma. This study will investigate more thoroughly the possibility of the presence of jaguar in the area, which, if confirmed, would represent the southern limit of the species in South America.

Camera-Trapping Jaguars in Madidi, Bolivia
Camera-trapping is a tactic whereby remote cameras are place in areas that animals use as "through-ways" on their hunting and foraging routes. The animals trip sensors, thereby recording their existence. This helps to build a picture of jaguar densities and habitat use across the range and therefore assess overall jaguar population size, as well as the viability of various subpopulations and the efficiency of protecting areas for these animals. This methodology will also allow the monitoring of jaguar populations over time, both at sites with few direct jaguar threats and in areas where persecution, habitat loss and/or prey density reduction are major issues.

Shaman's Apprentice Program (Colombia)
The Shaman's Apprentice Program was developed in 1994 by **ethnobotanist** Dr. Mark Plotkin in order to protect the health and knowledge of shamans, or native healers, among indigenous cultures of South America. Funds from Woodland Park Zoo are supporting the shaman of the Kofan people of Colombia. The support also helps the healers to pass along their knowledge of the medicinal properties of rain

forest plants to future generations and to establish "chagras," or medicinal plant gardens, and health brigades to help remote villages that have lost their shamans. (See "Forests and Cultural Survival" page 62 in this packet for more information.)

What You and Your Students Can Do to Help Conserve Forests

It's true that many factors affecting forests are dependent on economic policies put in place by governments in areas of the world from which we may be far removed. However, there are powerful things that every person can do to contribute to the protection of forests around the world and in our own backyards. Here are a few ideas for what teachers and other adults can do and a handout to help your students understand their roles in forest conservation. (Please note that this handout may not be suitable for all grade levels—you may wish to modify these suggestions depending on the level of your students.)

If you are purchasing wood products, either for home or school use, be sure to look for certified forest products, from building materials to charcoal (see "Forest Certification" in this packet). Look for the Forest Stewardship Council label that indicates that the wood comes from a certified forest. If you are unable to find certified wood, ask your local home and hardware stores to stock it.

One way you can help to protect tropical forest ecosystems, if you are a consumer of coffee, is to look for shade-grown, organic coffee when you're purchasing coffee for yourself or for an event. Coffee plants are naturally adapted to grow in the shady understory of tropical forest canopies. In order to increase production, many large-scale coffee growers have converted to "sun" coffee plantations, in which new varieties of coffee plants are grown in full sun. Sun coffee plantations substantially increased the yields of coffee, however, this technique requires the application of fertilizers and **pesticides** (insecticides, herbicides and fungicides). Shade coffee, on the other hand, is grown under the canopy of tropical forest trees, reducing the need for fertilizers and pesticides and enhancing soil stability and health. The canopy trees provide necessary food and shelter for many birds, including hummingbirds, swallows, warblers and tanagers. You can find out more from the Seattle Audubon Shade Coffee Campaign at 206-523-8243 ext.13 or on the Web at www.seattleaudubon.org/shadecoffee/.

You and your school community can have a big impact by making more environmentally sustainable choices. Become an environmental leader in your school—bring students and teachers together to restore forest habitat on your school grounds or in the community, help your students to conduct a recycling or energy assessment of your school building and find ways to increase your reuse and recycling and to reduce your use of energy. Teachers are in a unique position to model environmentally conscious behaviors—teach by example through your actions, both for your students and for your colleagues.

The following page is a handout for your students about their roles in forest conservation.