

Primates are the most advanced of the Order Mammalia. You, the species *Homo sapien*, are a primate. Primates are relative newcomers on our planet. The fossil record indicates that primates have been around for some 55 million years. The earliest primate diverged from a primitive arboreal form of insectivore at a time when many of the placental mammals were in their incipient stages of evolution. When dinosaurs became extinct (65 mya), new niches opened allowing mammals, including primates, to proliferate.

Many characteristics of modern primates drive from an early ancestor's practice of acquiring most of their food from the tropical canopy. The primates came to rely substantially on edible plant parts. Natural selection favored traits that enhanced their efficiency in foraging and agility in the trees. Primates use their limbs to climb in trees by grasping with hands and feet; they use their hands to bring food to their mouths for feeding.

Visual acuity with good depth perception and color vision were also favored, as both are important when looking for ripe fruits and young leaves. Cognitive skills were also enhanced as remembering the identity and location of food sources was a boost for survival rates. As brain size increases, instinctive behavior decreases and behavior is increasingly directed by experience and conscious decision. As a result, primate young, with their larger brains, have long periods of dependency during which they learn much of what they will need to know as adults. Primates depend on learning for survival more than any other group of animals.

Primates belong to complex social groupings, where they build and reinforce bonds between individuals and learn from their mothers and others of their species. They have prolonged childhoods with attentive parental care as well as relatively long lives.

Today there are three major types of non-human primates: **prosimians, monkeys, and apes.**

We will be referring to nonhuman apes in this section as apes and excluding talk of human apes, *Homo sapiens*.

Order Primates

Prosimians, Monkeys, and Apes

- Three types of primates: **prosimians**, **monkeys**, and **apes**
- Highly diverse **intelligent** group with more **complex social groupings**
- Primates have five digit hands, with various degrees of **opposable thumbs** and increased limb mobility
- **Binocular vision** and a decreased emphasis on olfaction
- **Nails** allow easier manipulation of objects
- Longer lives and longer periods of learning and dependency in infancy



What sets the primates apart from the other mammals? Primates are different from other mammals because they are a highly diverse, intelligent group with larger brains for their body size than are a lot of other mammals. Complex primate brains continue to develop after birth and into adulthood. Primates spend a lot of time learning skills and strategies for food gathering and survival from their mothers and others in their social groups. Primates trend toward longer lives with longer periods of infancy, childhood and adulthood, all of which promote brain growth. Primates also belong to more complex social groups than do other animals; being part of social group, building and reinforcing bonds between individuals, and learning from their mothers and others are all important in primate populations.

Primate brains have increased areas for vision and reduced areas for olfaction. Their eyes are forward facing with a reduced muzzle. The shortened muzzle prevents the nose getting in their visual field. They have **binocular vision** where both eyes are used together giving them a greater field of view. The vision from each eye overlaps (**stereoscopic vision**) resulting in **depth perception**. This is extremely useful for forest-dwelling primates, as it lets them judge how far away the next branch is as they are moving from tree to tree.

For the most part, nails replace claws; only primates have flat nails on toes and/or fingers; flat nails and accompanying sensitive finger pads are advantageous when climbing trees and grasping and manipulating objects. Primates have a very highly developed sense of touch, which includes the underside of many prehensile tails. The sensitive pads on the digits have friction ridges, which are important for grasping. These ridges, or finger prints are unique to the individual as they are in humans. All primates have essentially the same kinds of specialized mammalian teeth adapted to eating a wide variety of foods.

Primates have increased thumb mobility allowing them to manipulate objects but not all primates have similarly dexterous hands. As you move across the primate order from lemurs to great apes, including humans, the thumb becomes more and more mobile. Most Old World monkeys, apes, and humans have opposable thumbs. New World monkeys and prosimians have semi-opposable thumbs. Humans are the only animals on Earth with fully opposable thumbs; most primate thumbs will only oppose to their index fingers. Primates have good power grips, but lack the level of opposition that would give them a good pincher grip, or fine motor skills that humans have. With the exception of humans, primates all have grasping feet. *Homo sapiens* have lost the grasping ability in their feet because their feet are designed for bipedal walking with a more vertical posture than that of the other primates.

All primates have ball and socket shoulder and hip joints. This type of joint allows increased rotation of the limbs, enabling primates to climb easily and quickly in the trees where they find food. Motion at the shoulder is further enhanced by the clavicle or collarbone.

Primate Evolution



- Trend toward enlarged brains with increased areas for vision and reduced areas for olfaction
- Trend toward more vertical posture
- Trend toward different use of forelimbs and hind limbs
- Trend toward longer lives with longer periods of infancy, childhood and adulthood

The first primate-like mammals were insectivores roughly similar to squirrels and tree shrews in size and appearance and were adapted to arboreal life and were probably nocturnal. Flowering plants had evolved and modern looking tropical forests contained a great variety of fruits. Primates became important arboreal seed dispersers and lemurs, with their longer snouts, were pollinators as well.

Early in primate evolution, prosimians drifted to Madagascar and were the only primates to ever successfully make this trip. Once established on this large island, they were free to evolve into a wide variety of ecological niches over the ensuing tens of millions of years. The great diversity of lemurs was probably a consequence of the fact that they did not have competition from monkeys and apes and few predators.

As monkeys evolved from prosimians, they became the dominant primates, and probably as a consequence, many of the prosimian species became extinct. Some early monkeys made their way to South America by island hopping and rafting, setting up the population of New World monkeys.

Eventually, apes evolved from Old World monkeys and displaced them from many environments. It is thought that the original ape group diverged from its monkey ancestors primarily because they came to exploit more intensively one particular forest food resource, fruit. Dietary changes led to changes in dentition. Using their arms to swing under the tree branches rather than walking on top with all four limbs became for the apes a very effective means of acquiring fruit on the outer 'reaches' of the tree; a mobile ball-and-socket shoulder joint permitted this.

As we progress from the less primitive prosimians to monkeys and into apes there are distinct evolutionary trends that differentiate them from other mammals. These include: 1) trend toward enlarged brains with increased areas for vision and reduced areas for olfaction 2) trend toward more vertical posture (primates tend to move with a more vertical posture, even if they are rarely upright) 3) trend toward different use of forelimbs and hind limbs (primates use their limbs for more than just locomotion) and 4) trend toward longer lives.

Prosimians



- Lemurs found only on Madagascar, pottos and bushbabies of Africa, and lorises and tarsiers of Asia
- Most primitive primates, with pointed muzzles and larger ears
- Semi-opposable thumb
- Stronger sense of smell than most primates
- Flat nails except for a claw for grooming on 2nd toe
- Mainly arboreal

Primates are additionally identified by their nose type and geographical location in two sub-orders, strepsirhini & haplorhini. All strepsirrhines are **prosimians** or “pre monkey or before the monkey”. Prosimians, identified by their wet noses, include lemurs found only on Madagascar, pottos and bushbabies of Africa, and lorises and tarsiers of Asia. The tarsiers recently have been placed on their own in some classifications and are a dry-nosed prosimian. Prosimians are more primitive primates, with pointed or dog-like muzzles and larger ears.

Lemurs tend to be diurnal and live in small social groups where the female is dominant in most lemurs and have their own hierarchy within the group. Most lemurs are arboreal, spending most of their time at the top of the rainforest canopy or in the forest midlevel. An exception is the ring-tailed lemur, which spends most of its time on the ground. Lemurs tend to eat fruits, leaves, and other edible plant materials.

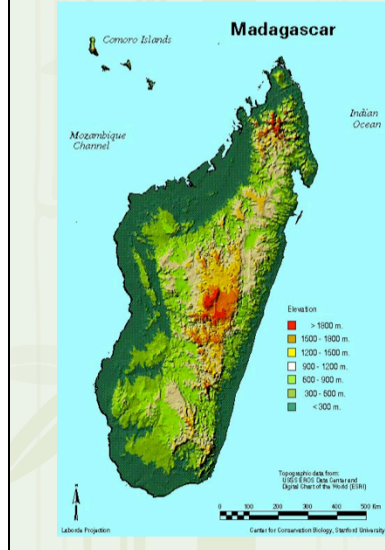
Prosimian olfactory brain lobes are larger than those found in monkeys and apes, indicating a greater reliance on a sense of smell. All lemurs have a wet, hairless nose with curved nostrils, and a **Jacobson's organ** (or VMO), which enhance their sense of smell. The wet nose is also useful for the perception of direction and for sensing pheromones; the sensitive cold receptors in the skin detect the place where the nose is cooled the most and this indicates the direction of a particular smell or odor. The moist nose is fused with the upper lip, which results in a face with a limited range of expression. The mobile, sensory whiskers on face enhance a lemur's tactile ability.

Lemurs have flat nails except for a **grooming claw** on second toe; the big toe is widely separated from other toes, allowing for a secure grip during locomotion. Their lower incisors form a **dental comb** used in grooming and for scraping bark for those lemurs whose diet includes barks and gums such as the ring-tailed lemur. In primates, grooming promotes social cohesion. Lemurs have grasping ability with their semi-opposable thumbs. Their legs tend to be longer than their arms. Legs are strong for leaping and clinging to branches and tree trunks.

Lemurs are mainly arboreal and use their long tails for balance. They have a distinct breeding period that lasts less than three weeks rather than individual cycles. Lemurs typically give birth to a single lemur, but ruffed lemurs have litters, usually consisting of 2-4 offspring.

The Zoo has eight species of lemurs: ring-tailed lemurs, blue-eyed black lemurs, crowned lemurs, red-fronted brown lemurs, red-bellied lemurs, red ruffed lemurs, black and white ruffed lemurs and Coquerel's sifaka. The Sculpture Learning Plaza features a nocturnal lemur, the aye-aye.

Importance of Madagascar



- 90% of Madagascar's plants and animals are **endemic** to Madagascar; including lemurs
- Lemurs have thrived on Madagascar because no other primates inhabit the island.
- Deforestation, hunting for **bushmeat**, and pet trade threaten native species
- Promotion of sustainable agriculture including the native crops: vanilla beans, cloves, and orchids

Madagascar lies about 425 km (266 miles) off the east coast of Southern Africa. It is the oldest geological island on the Earth and the fourth largest. Generally, Madagascar has two seasons: a hot, rainy season and a cooler, dry season and hosts a variety of ecosystems. The east coast is the wettest part of the country and thus home to the island's rainforests. The central highlands are considerably cooler and drier. The west coast is home to dry deciduous forests; the deciduous trees lose all their leaves during the dry season. The southwest of Madagascar has the island's driest climate; parts of this area can be considered desert because so little rain falls.

Why is it so important for the SF Zoo to have the Lipman Lemur Forest exhibit and educate people about Madagascar? Madagascar has been isolated for over 165 million years, which accounts for the island's unique biodiversity. Approximately 90 percent of all plant and animal species found in Madagascar are endemic. Madagascar's early lemurs radiated into the large island's many niches without much competition or predation, especially from other primates. There are now over 90 lemur species. Lemur populations have suffered extensively from deforestation and habitat fragmentation. Nearly 25% of all species are either Endangered or Critically Endangered, and nearly all populations are in decline.

Madagascar is among the world's poorest countries. As such, the day-to-day survival of its people is dependent upon natural resource use. Each year as much as a third of the country burns and one percent of its remaining forests are leveled. Madagascar's native species have been aggressively hunted and collected by people desperately seeking to provide for their families. While it has been illegal to kill or keep lemurs as pets since 1964, lemurs are hunted today in areas where they are not protected by local taboos.

Rapid deforestation in Madagascar has numerous causes. Tropical rainforests are being converted into rice fields. Logging for timber is a problem especially in the eastern rainforests. The high value of Malagasy hardwoods (mostly ebony and rosewood, which may fetch \$2,000 a ton in international markets) makes illegal logging a significant problem in some protected areas. The endemic spiny forests of Madagascar are being cut at an alarming rate using slash and burn techniques for charcoal production. This deforestation has resulted in a significant soil erosion problem. Conservation efforts in Madagascar must address the needs of local people, and must focus on poverty alleviation and economic development as well as protecting wildlife and ecosystems. Madagascar must promote sustainable agriculture for its native crops such as the orchids which produce vanilla beans, a lucrative, but eco-friendly crop for many farmers in northeastern Madagascar, where the canopies of trees provide the shade the orchids need. Orchids, cloves, coffee and raffia are also exports of Madagascar that can be grown sustainably.

Monkeys



- Monkeys are divided into the **Old World monkeys** and the **New World monkeys**;
- All monkeys have binocular vision, most have **opposable thumbs** and **nails** instead of claws, are **intelligent**, and have **large canines**
- Quadrupedal with limbs roughly the same length
- All monkeys have tails
- All live in stable social groups

The **Haplorhini** are dry-nosed primates and include the monkeys and apes. All monkeys have tails. They have flat nails on their digits, although in the marmosets and tamarins, the nails are claw-like. Opposition of thumbs and big toes is of varied degrees, but generally they are better graspers than prosimians and not quite as good as apes. Their limbs are of roughly equal length. The true leaf eaters (i.e. langurs and colobus) have shortened thumbs.

Monkeys are mostly diurnal, have single births, and eat mostly a mixed diet. Monkeys have eyes that face forward and are adapted to diurnal vision; all monkeys have binocular vision for good depth perception. Most have opposable thumbs and five digits on each limb, are intelligent, and have large canines. Virtually all live in social communities. Groups are stable over generations, regardless of the deaths of individuals, while ape groups may break up upon a leader's death, or change composition at times. Generally, male monkeys must leave the group upon adulthood.

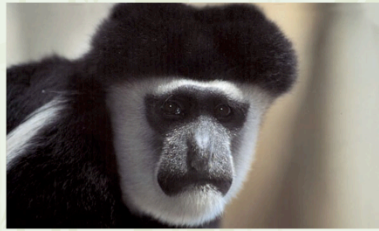
Compared to the early prosimians, early monkeys had fewer teeth, less fox-like snouts, larger brains, and increasingly more forward-looking eyes. These and other anatomical features suggest that the early monkeys were becoming mostly diurnal fruit and seed eating forest tree-dwellers.

The monkeys are further divided into the **Old World monkeys** (Catarrhini) and the **New World monkeys** (Platyrrhini). These two groups evolved some distinguishing differences including the number of teeth, shape of the nose, and the configuration of the bones of the skull. **Note:** Old World refers to Africa, Europe and Asia whereas New World refers to North and South America.

One main difference between monkeys and apes is in their locomotion. Although monkeys and apes both live in trees, they move about them very differently. Monkeys move about like other **quadrupeds**. They have a long muscular body and use their tails for balance. Some New World monkeys have prehensile tails, which they use to help move about and support their body weight in trees. Monkey forelimbs are more mobile than those of a ground dwelling quadruped, e.g. a dog, but they do not swing on them like some nonhuman apes. Their shoulders are small and narrow. They cannot straighten their elbows completely and have restricted movement of the forearm and wrist.

Apes move around by **brachiation** or **knuckle walking**, which we will discuss under ape characteristics.

Old World Monkeys



- Found in Asia and Africa
- Narrow nosed monkeys; nostrils are close together and face forward or down
- Non-prehensile tails
- **Ischial callosities**
- Many are ground dwellers
- Most are larger than New World species
- Thumbs are rotated and more opposable than New World monkeys
- True **color vision**

The Old World monkeys live in a wider range of climatic conditions than do any other primate except humans. Old World monkeys have non-prehensile tails, many are ground-dwellers, and their nostrils are closer together and face forward or down. Old World monkeys and lesser apes have **ischial callosities**, which are specialized tissue pads on their rumps, an adaptation to sitting. These “sitting pads” enable the monkeys to sleep sitting upright on thin branches, beyond reach of predators, without falling. Old World monkeys sleep sitting up whereas great apes and New World monkeys assume a horizontal sleeping posture.

Old World monkeys include baboons, macaques, langurs, and colobus, which are found in Asia and Africa. Most are larger than New World species and tolerate a wider range of habitats. Many are ground dwellers, including the mandrill and patas monkey. The other Old World monkeys are more generalized omnivores. Many of them have **cheek pouches** like those of hamsters that accommodate the secure temporary storage of food.

The colobus and langurs are often referred to as leaf-eating monkeys. They have evolved a specialized diet of high cellulose leaves and associated traits such as high-crowned molars, a sacculated and elongated intestinal tract to process the food as well as having a small nub for a thumb. With extra long fingers, they are able to wrap around branches as they leap; a normal thumb would hinder this activity.

They have color vision. There is considerable variation among primates in terms of the ability to see colors. The best color vision exists in diurnal species. Humans, apes, and most, if not all, of the Old World monkeys are **trichromatic** (literally "three colors") meaning they have normal color vision. By contrast, prosimians and many New World monkeys have relatively poor color vision being dichromatic (“two colors”).

Old World monkeys at the Zoo include: Francois langur, black and white colobus, patas monkey and the mandrill.

New World Monkeys



- Restricted to Central and South America
- Broad-nosed monkeys; nostrils pointing out, facing sideways
- Some species have prehensile tails
- Strictly arboreal
- Generally smaller than Old World species
- Thought to be more primitive than Old World species
- **Semi-opposable** thumbs

New World monkeys appeared for the first time about 30 million years ago. It is generally thought that they began as isolated groups of Old World monkeys that somehow drifted to South America from Africa most likely on large clumps of vegetation and soil. They are more primitive in features than the Old World monkeys. New World species include tamarins, squirrel monkeys, and howlers. They are generally smaller and thought to be more primitive than Old World species.

New World species are restricted to Central and South America, are strictly **arboreal**, and are broad-nosed or flat-nosed monkeys with their nostrils pointing out, facing sideways. Thumbs are semi-opposable and are capable of a power grip. Most move quadrupedally on the branches, while some have a **prehensile tail**, which they use as an extra appendage in support.

New World monkeys rely more on scent to mark territories and have scent glands. New World monkeys form more monogamous pair bonds. The social groupings vary from species to species, but overall the intensity of social organization, maternal care, peer-group play by the young, and group cohesiveness are all more significant than in most prosimian primates.

Color vision among New World primate species is variable- some are dichromatic and others are trichromatic. Most females in some species have good color vision but males may not. This is the case with marmosets, tamarins, squirrel monkeys, and spider monkeys. All males of these species are dichromatic. In the howler monkey, both the male and female have color vision.

New World monkey's at the Zoo include: pied tamarin, squirrel monkey, and black howler.

Apes

- Large, tailless primates in two families, the gibbons, and the great apes
- Extremely intelligent, large brained mammals, can recognize themselves in mirrors, and can learn sign language
- Form complex social groups
- Forelimbs are longer than rear limbs
- Found in Africa and Asia, except for humans, which are worldwide



Apes are large, tailless primates. Apes include the gibbons or lesser apes and the greater apes (gorillas, orangutans, chimpanzees, bonobos and humans). The ancestors of today's nonhuman apes and humans diverged about 7 million years ago. Humans are characterized by their larger brain cases and their bipedalism.

Gibbons have **ischial callosities**, while greater apes do not. Apes have no claws, only flat nails, on their digits. Thumbs and big toes are opposable. Forelimbs are longer than rear limbs. Noses are flat and they have no muzzle, although the jaw protrudes. Their jaws are rectangular and have large prominent canines. In general, nonhuman apes are vegetarian, living on fruit, leaves and young shoots. Apes are mostly diurnal, have single births, and eat mostly a mixed diet.

Locomotion for apes is different from that of the monkeys. **Brachiation** is the primary form of arboreal locomotion for the smaller apes such as the gibbon and siamang, as well as occasionally the orangutan; brachiators swing from branch to branch, easily supporting their body weight on their strong arms. Apes have flexible shoulders (ball and socket joint) with broad chests, elbows that can fully straighten and a large range of movement in the wrists and forearms; the clavicle provides the extensive shoulder motion because it is the only bony link between the upper limb and the trunk. The thumb tends to be short to accommodate brachiation and thus cannot completely oppose all the fingers. One unique aspect of gibbon anatomy is that the wrist is composed of a ball and socket joint, allowing for biaxial movement. In other words, apes can pitch a baseball, but monkeys cannot. Modern humans retain many physical characteristics that suggest a brachiating ancestor, including flexible shoulder joints and fingers well suited for grasping.

On the ground chimpanzees and gorillas are **knuckle walkers** - supporting their weight on the backs of their long, curled fingers. Ape hands are quite good at manipulating objects but must share the load in locomotion. This posture allowed these tree climbers to use their hands for terrestrial locomotion while retaining long fingers for gripping and climbing.

Humans differ from other primates in having a relatively longer and more distally placed thumb and in having larger thumb muscles, giving humans greater mobility of the thumb, and an enhanced ability to manipulate small objects with thumb tip-to-finger tip precision grips. This could be an adaptation to the use of tools.

Apes are extremely intelligent, large brained mammals that can recognize themselves in mirrors and can learn sign language. They have been known to solve simple problems and use tools. Nonhuman apes are found in Africa and Asia, and of course humans are found worldwide. They form complex social groups which may not be stable over generations.

The Zoo has one species of lesser ape, the siamang, and two greater apes, the chimpanzee and western lowland gorilla.

Primate Conservation

- Nonhuman primates constitute the mammal species most threatened with extinction
- Exploitation and habitat destruction have led to the Endangered or Critically Endangered status of over 1/3 of primates.
- Due to the close genetic relationship between nonhuman primates and humans, disease causing organisms are easily exchanged between them.
- The chimpanzee shares 98.5% of our DNA as humans; the study of primates has played a vital role in many of the medical and scientific advances of the past century; primates offer insights into human evolution, biology, and behavior and play roles in cultures of many societies
- Low reproductive potential of primates; primates tend to have a single offspring and have a long period of maternal dependence.
- Blue-eyed black lemur SSP

The future for many primate species is not very secure. One-third of all primates are endangered or critically endangered. The main problem primates face is one that's affecting many kinds of animals: large-scale destruction of habitat. The tropical forests where most primates live are disappearing at an alarming rate, and poaching is a major problem for most of these species. Poachers kill these animals not only for their meat but also for their skins, skulls and hands.

Firearms have greatly increased the success of hunters and have led to elimination of large populations of primates. New roads built to support mining, logging and agriculture, as well as improved methods of transportation have also increased the success of hunters/poachers. Earlier methods of hunting did not have as much impact.

Other threats to primates are medical research (the close relationship of humans to other primate species assures the validity of experimental results) and capture for the pet trade. Due to the close genetic relationship between nonhuman primates and humans, disease causing organisms are easily exchanged between them. Scientists believe that HIV was transmitted from the chimpanzee to humans when the chimp was being hunted for meat. Primates are also natural Ebola virus hosts and are able to spread the virus to humans.

Primates have low reproductive potentials. Chimpanzees produce a baby only every 5-6 years, and there's a very high infant mortality- 50% die in their first two years. This means that populations can't bounce back very quickly.

Blue-eyed black lemurs are among the most threatened primates in the world. Efforts are underway in AZA Zoos through a SSP to increase their population to a self-sustaining level.

Key Primate Concepts

- Primates that eat a diet that consists of a high proportion of fruits play an important role in the forests as seed dispersers.
- Many primate characteristics represent adaptations to life in an arboreal environment. These include: a decline in use of the sense of smell and a shift to a reliance on vision, an increase in size of cerebral cortex compared to other mammals and an increase in both mobility and the ability to grab and manipulate objects.
- Social organization is extremely important in primate evolution.

Corresponds with the Primata Study Guide in the Docent Notebook. For specifics on the Zoo's primate collection read the Primata Fact Sheets in the Docent Notebook and go to the SF Zoo's website (sfzoo.org)

Key Primate Vocabulary

- Opposable thumbs
- Binocular vision, stereoscopic vision, depth perception
- Quadrapedal, bipedal, knuckle-walk, brachiation
- Prehensile
- Ischial callosities
- Endemic
- Biodiversity, species diversity

Definitions:

Binocular vision: vision in which both eyes are used together; this gives a wider field of view.

Biodiversity: the degree of variation of life.

Bipedal: having two feet

Brachiation: using the forelimbs to swing from branch to branch.

Depth perception: visual ability to perceive the world in three dimensions and the distance of an object.

Endemic: native or restricted to a certain country or area.

Ischial callosities: a thickened piece of skin found on the buttocks of animals, especially the baboon; a 'sitting pad'.

Knuckle-walk: a form of quadrupedal walking in which the forelimbs hold the fingers in a partially flexed posture that allows body weight to press down on the ground through the knuckles

Opposable thumb: the thumb can bring its tip into opposition with the tips of any of the other digits.

Prehensile: adapted for seizing or grasping, especially by wrapping around.

Quadrapedal: having four feet.

Species diversity: the effective number of different species that are represented in a collection of individuals.

Stereoscopic vision: the single perception of a slightly different image from each eye, resulting in depth perception.