5

LEARNING ABOUT THE PAST

The Primates

CHAPTER CONTENTS

"What is man, that thou art mindful of him?" asks David in the biblical psalm. It is a question we must ask as well, but in a broader form: "What is a human being?" Before we embark on our journey through human evolution, we must understand modern humans, the species with which our journey ultimately ends.

Two problems are encountered in defining humanness. First, all modern human beings belong to a single species, and we lose perspective if we refer only to ourselves. Try describing any animal without referring to other organisms: "Well, a spider has body segments and jointed legs like an insect, only it has eight legs instead of six. . . ." Second, we are members of the very species we're describing. It's difficult to step back and see ourselves from an objective perspective. We have a tendency to focus on things that are important to us in a certain cultural setting at a certain time. For example, Carolus Linnaeus, the great eighteenth-century Swedish naturalist (see Chapter 2) listed as the distinguishing characteristics of *Homo sapiens* "diurnal [active during the day]; varying by education and situation." He then described five subspecies of humans using a combination of physical features and subjective European attitudes. Of the Native American, for instance, he said: "Hair black, straight, thick; nostrils wide, face harsh; beard scanty; obstinate, content free. Paints himself with fine red lines. Regulated by customs" (Kennedy 1976:25). (We will look at Linnaeus's classification of humans more fully in Chapter 10.)

Clearly, we need to look at ourselves not from cultural (and subjective) perspectives like Linnaeus's but in terms of how we compare objectively with other living organisms. Demosthenes, a fourth-century B.C. Greek orator, described us as "featherless bipeds"; twentieth-century biologist Desmond Morris dubbed us the "naked ape." These are better definitions because they are free from cultural values and recognize both our similarities to other organisms and our distinctive differences.

Taxonomy

We have already discussed the concept of the species, the natural unit of classification. Each organism belongs to a *specific species* (the words come from the same root), a group of potentially interbreeding individuals that are reproductively isolated from other groups.

The most cursory examination, however, shows clearly that there are larger units of classification of living things. Some species are more similar to one another than they are to other species. The book of Genesis, for example, does not name each species that God created, but it lists general categories: "the fish of the sea," "the fowl of the air," "every herb of the field," "every beast of the earth."

Linnaean Taxonomy

taxonomy A classification based on similarities and differences.

The idea that species share similarities so struck Linnaeus that he devised a taxonomic system to name and thus categorize all living creatures. A **taxonomy** is a system of classification, based on similarities and differences, that is organized into categories and increasingly specific subcategories.

TABLE 5.1 Linnaean Taxonomy of Five Familiar Species

	Human	Chimpanzee	Bonobo	Gorilla	Orangutan
Kingdom	Animalia	Animalia	Animalia	Animalia	Animalia
Phylum	Chordata	Chordata	Chordata	Chordata	Chordata
Class	Mammalia	Mammalia	Mammalia	Mammalia	Mammalia
Order	Primates	Primates	Primates	Primates	Primates
Family	Hominidae	Pongidae	Pongidae	Pongidae	Pongidae
Genus	Homo	Pan	Pan	Gorilla	Pongo
Species	sapiens	troglodytes	paniscus	gorilla	pygmaeus

Linnaeus (who used Latin names and, as mentioned earlier, even latinized his original name, Carl von Linné) devised a system, published in final form in 1758, that used four nested categories—*class, order, genus,* and *species.* Other scientists soon added *kingdom, phylum,* and *family,* giving us the seven Linnaean categories recognized by modern taxonomy (which uses additional categories when needed). Table 5.1 shows a traditional Linnaean taxonomy for five familiar species. We'll detail the taxonomy of our species to show what Linnaeus's system accomplishes.

It should be noted that a species is never referred to by just the species name, listed in the bottom row of the table. The species name is usually descriptive, and so there may be many species that share the same name. Many African animals have the species name *africanus,* for example. The chimpanzee shares its species name, *troglodytes,* with the winter wren, a small North American bird (the name conveying the erroneous assumption that these species are cave dwellers). It takes *both* the genus and species names to denote a particular species. We are, for instance, *Homo sapiens.*

Humans are members of the kingdom Animalia (Table 5.2). We share this grouping with the other four species in Table 5.1 by virtue of the fact that we all ingest our food, have sense organs and nervous systems, and are capable of intentional movement. We are not members of any of the other three kingdoms of eukaryotes (organisms whose cells have nuclei): complex single-celled organisms (amoebas and the like), fungi (mushrooms, mildews, molds), and plants (roses, ferns, broccoli, pine trees). There are, in addition, two main groups of prokaryotes, single-celled organisms that lack nuclei: bacteria and archaea. These are the microbes that make up the bulk of the earth's biomass.

TABLE 5.2 A Linnaean Taxonomy of Humans (with defining criteria)

Kingdom	*Phylum*	*Class*	*Order*	*Family*	*Genus*	*Species*
Animalia	*Chordata*	*Mammalia*	*Primates*	*Hominidae*	*Homo*	*sapiens*
Ingestion	Notochord	Hair	Arboreal	Habitual bipeds	Toolmaking	Brain size 1,000–2,000 ml*
Movement		Warm-blooded	Developed vision		Omnivore	
Sense organs		Live birth	Grasping hands			
		Mammary glands	Large brains			
		Active and intelligent				

**Note:* This definition is a matter of controversy and will be taken up in Chapter 10.

Within kingdom Animalia are about thirty *phyla* (singular, *phylum*), groups such as sponges, jellyfish, starfish, three types of worms, mollusks, arthropods (insects, spiders, crustaceans), and chordates. We are members of phylum Chordata because we have a bony spine, the evolutionary descendant of a **notochord,** a long cartilaginous rod running down the back to support the body and protect the spinal chord, the extension of the central nervous system (Figure 5.1). Chordates with a bony spine are grouped into a subphylum, Vertebrata. All five species in Table 5.1 are chordates and, more specifically, vertebrates.

There are seven classes within the vertebrates: the jawless fishes (an ancient group represented by only a few existing species), cartilaginous fishes (sharks and rays), bony fishes (guppies, tunas, and so on), amphibians (frogs and salamanders), reptiles (snakes, lizards, and alligators), birds, and mammals. All our sample species are members of class Mammalia because they maintain a constant body temperature (commonly called *warm-blooded*), have hair, give birth to live young, nourish the young with milk from mammary glands, and have relatively large, complex brains.

We need to stop here for an important point. You may have noticed that some of the traits listed for mammals are also possessed by other classes. Birds, for example, are also warm-blooded; so, according to many, were some of the dinosaurs, and so are a number of other creatures, including great white sharks. Some sharks, some bony fishes (such as guppies), and some snakes give birth to live young. By the same token, you might know two mammals that do not possess all the mammalian traits. The spiny anteater (or echidna) and the duckbill platypus, both from Australia, lay eggs. Obviously, though, birds, dinosaurs, and great white sharks are *not* mammals, while the spiny anteater and platypus *are*. What's the resolution to this seeming contradiction?

notochord The evolutionary precursor of the vertebral column.

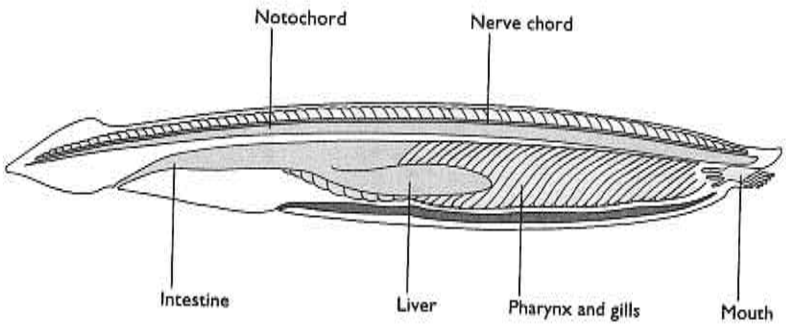


FIGURE 5.1 Shown here is an amphioxus, a chordate with a notochord but no bony spine (shown about four times life size).

The answer is that inclusion into a taxonomic category is more than simply a matter of possessing a list of traits. The traits of an organism make possible that organism's *adaptation*, and it is adaptation, measured by reproductive success, that is the criterion of natural selection. Thus, taxonomic categories become statements about adaptation, as well as biological relationships, with each taxonomic level becoming more specifically focused. Mammals, whether they lay eggs or not, are animals that are adapted through active lifestyles and a reliance on learned behavior facilitated by a set of shared traits. Mammalian young, therefore, require a great deal of direct care and nurturing. Mammals also require a constant body temperature to sustain their level of activity, and they require hair (or in the case of whales, a thick layer of fat) to maintain that temperature. That's not a very concise definition of a mammal, but the real world doesn't always make things easy for those of us who try to describe it.

Within class Mammalia are about nineteen existing orders—nineteen rather specific adaptive strategies and resulting sets of characteristics. There are, for example, the flying bats; the fully aquatic whales and dolphins; the partially aquatic seals, sea lions, and walruses; two orders of hoofed plant eaters (the difference being a skeletal feature of the feet); the rabbits and hares; the rodents; the meat eaters; the insect eaters; the pouched marsupials (kangaroos and opposums); and a group of large-brained tree-dwellers with three-dimensional vision and dexterous hands. These last mammals are the members of order Primates.

All the species in Table 5.1 are primates, but they differ at the level of family. Humans traditionally have been classified in family Hominidae, while the other four are members of family Pongidae, the great apes. Within the pongids we recognize three *genera* (singular, *genus*). The only Asian species, the orangutan is placed in genus *Pongo*. The African gorilla, although similar to the other African apes, is different enough to be placed in a separate genus, *Gorilla*. The chimp and bonobo are recognized as two species within the same genus, *Pan*. A Linnaean taxonomy thus indicates the relative relationships among named organisms.

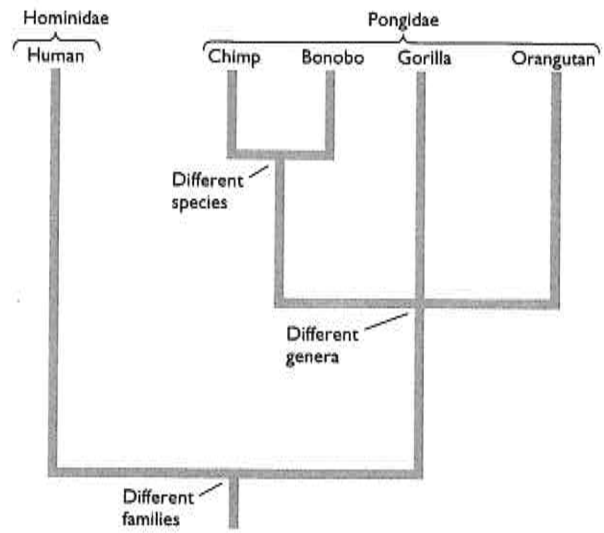


FIGURE 5.2 Evolutionary tree based on phenetic analysis. We infer the evolutionary relationships from the taxonomic classifications.

Linnaeus's goal was to describe the system that, as he believed, God had in mind when he created all the earth's living things. Linnaeus was a creationist, as were just about all scientists of his time. But as you can probably see, to modern scientists his taxonomy indicates not only present-day similarities and differences but evolutionary relationships as well. For example, the reason the chimp is more similar to the bonobo than to a human is that the chimp and bonobo diverged from each other more recently than they did from humans. The chimp and bonobo are thought to have had a common ancestor from which they split less than 1 mya. Humans and the chimp/bonobo line branched about 5 mya. Humans and chimps have had a longer time to evolve in different ways than have the bonobo and chimp, which is why they are more different and why they are placed in different taxonomic families.

So, a Linnaean taxonomy, or **phenetic taxonomy** (one based on existing phenotypic features and adaptations), can be translated into an evolutionary tree, showing the relative order of branching of the classified species and other **taxa** (categories; singular, *taxon*). Figure 5.2 shows an evolutionary tree derived from the classification of the five species in Table 5.1.

phenetic taxonomy A classification system based on existing phenotypic features and adaptations.

taxon A category within a taxonomic classification.

Cladistics

The tree in Figure 5.2 demonstrates the basis of a current debate within taxonomy. The tree was *inferred* from phenetic categories—physical comparisons of living species. Many such evolutionary trees prove quite accurate with regard to relative branching times and, thus, the overall pattern

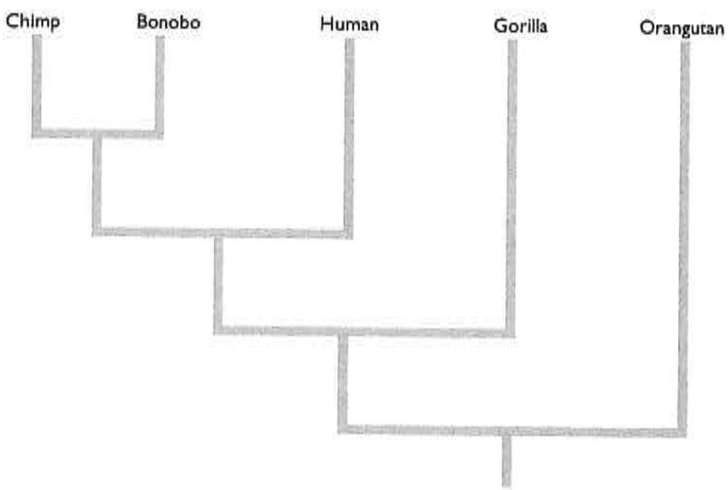


FIGURE 5.3 Accurate evolutionary tree based on cladistic analysis.

of branching. But as we learn more about the fossil ancestors of living species and as we improve our techniques of genetic comparison, we also learn more about the details of the evolutionary relationships among those species—particularly about the exact times and patterns of their evolutionary divergences.

Current knowledge from the fossil record and from genetic comparisons indicates that the orangutan line diverged earliest, the gorilla line next, and the human and chimp/bonobo lines most recently. In other words, the tree inferred from the phenetic taxonomy (see Figure 5.2) is inaccurate. The actual evolutionary tree should look like Figure 5.3. Thus, there is a contradiction between the traditional taxonomic names and categories for these species and their evolutionary relationships.

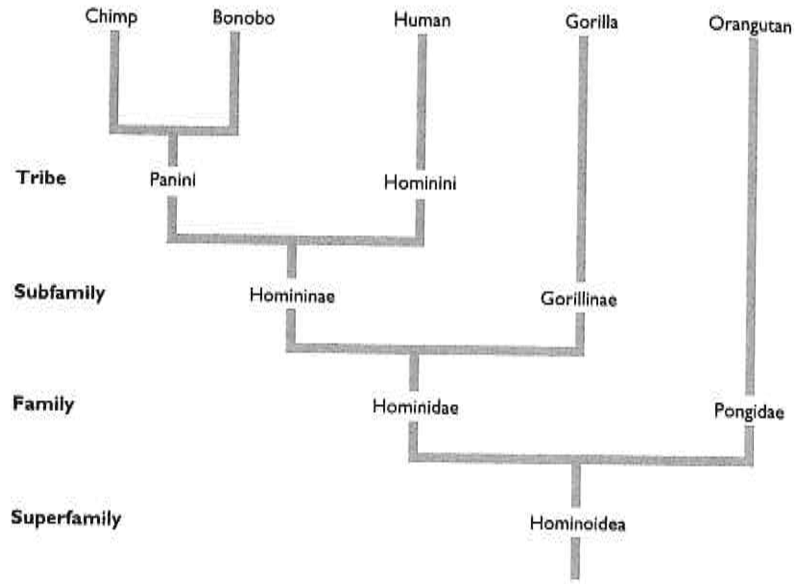
Cladistics (from *clade*, meaning "branch") works the opposite way from phenetics by starting with the evolutionary tree and placing organisms in taxonomic categories based on their order of branching, regardless of how their present-day appearances and adaptations might assort them into groups.

cladistics A classification system based on order of evolutionary branching rather than on present similarities and differences.

Branching order is determined in two ways. First, we use **shared derived characteristics.** If two groups share phenotypic features not found in other groups and if it can be supported that those features were derived from a common ancestor, the groups must be lumped into the same category at whatever taxonomic level is appropriate. For example, we could justify lumping birds with dinosaurs in the same taxon and placing reptiles in a different taxon because birds and dinosaurs share a feature of the pelvis not found in any other group, including reptiles. Second, branching order is determined by genetic comparison, now done at the level of the base sequence of the genetic code itself.

shared derived characteristics Phenotypic features shared by two or more taxonomic groups that are derived from a common ancestor and that are not found in other groups.

FIGURE 5.4 One possible taxonomic classification based on cladistic analysis. Note that new categories have had to be added.



What are the implications for the primates? Under a phenetic scheme (see Figure 5.2), there is a family division between hominids and pongids—in other words, between humans and apes. This is intuitively obvious since the four ape species resemble one another in some basic phenotypic features and adaptations more than they do us humans.

But in cladistics (Figure 5.4), there is no such thing as an "ape." There is no clade that *includes* the four great apes and *excludes* humans. Cladists have proposed a number of different taxonomies to reflect this. In one taxonomy, family Pongidae includes only the orangutan, and humans and the African apes are lumped into family Hominidae. Subfamily and tribe categories are then added to make further distinctions.

Is a phenetic or a cladistic system better? Phenetics captures obvious phenotypic and adaptive relationships but may fail to accurately reflect actual patterns of branching. Cladistics is evolutionarily accurate but requires redefinition of taxonomic categories that make sense in terms of obvious adaptive focuses. For instance, if we accept the preceding cladistic taxonomy, *hominid* is no longer restricted to "the **bipedal** primate" but now includes the **quadrupedal** chimps, bonobos, and gorillas. Its definition then becomes much more complex.

The debate continues, with no consensus in sight. Our own preference is to classifty taxa by branching order (that is, cladistically) and then, although it can get wordy, describe the phenotypic and adaptive differences that may have arisen within a taxon and figure out why they arose. Having said that, however, we will stick with the traditional phenetic classification for the primates in this text. Our focus is to show how primate

bipedal Walking on two legs.

quadrupedal Walking on all four limbs.

species, especially the so-called higher primates, look and behave and how those looks and behaviors have evolved. It is simpler to start with phenetic categories because they are based on looks and adaptive behaviors and *then* see how categories change under cladistic analysis. We will discuss some examples as we continue.

Now, let's focus on the adaptive strategy and the phenotypic traits that characterize the members of order Primates.

The Primates

The essential primate environment is the trees; primates are arboreal, or tree-dwelling. The fact that the human species is obviously built for locomotion on the ground—and clearly not for moving around in the trees—should not be misinterpreted. Although among the primates we humans are exceptional for our mode of locomotion, our bodies and behaviors still reflect that arboreal theme.

There are, of course, many other arboreal creatures. Squirrels, birds, many insects, and even a few snakes all have adaptations for a tree-dwelling way of life. Primates don't have a monopoly on that environment, but they do adapt to it in a way none of these others do. It has obviously been a successful adaptation. For even now, with all the changes and disruptions to the natural environment brought about by the human primate, there are still about 200 species of primates spread pretty much worldwide—in Central and South America, Africa, Asia (including northern Japan), and Europe (on Gibraltar).

To examine the characteristics that make possible this arboreal adaptation, we'll use categories that reflect an organism's relationship to its environment: the senses, locomotion, reproduction, intelligence, and behavior patterns. Keep in mind that these are generalizations. Because of the large number of primate species and their wide geographical range, this order displays a good deal of variation, which we'll detail later.

The Senses

The world in which an organism lives is to a great extent determined by its senses. All the information a creature takes in about its environment comes through the sense organs, which send signals to the brain for interpretation and (if possible) storage. The predominance of one sense over the others can make an enormous difference. Sound rules the sensory world of a dolphin or a bat; smell predominates for dogs. The primate's world is a visual one.

Most primates see in color. Although many mammals are not entirely colorblind (dogs and cats can see some pastel tints), full color vision is rare. Primate eyes face forward instead of out to the sides, so that each eye sees just about the same scene as the other eye but from a slightly different

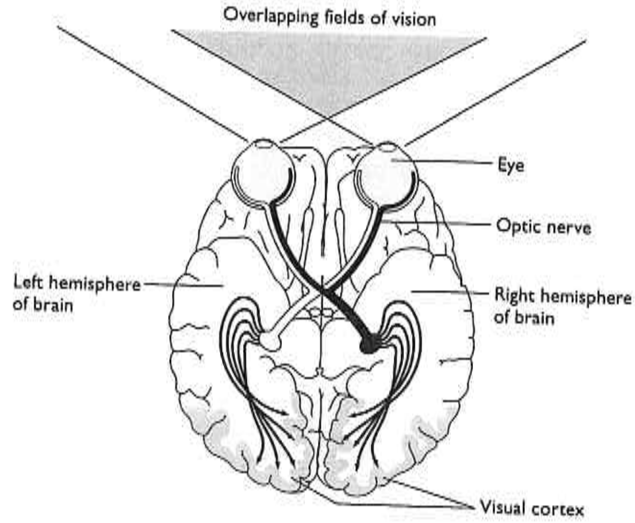


FIGURE 5.5 Stereoscopic vision. The fields of vision overlap, and the optic nerve from each eye travels to both hemispheres of the brain. The result is true depth perception.

angle. When the signals from such eyes are interpreted by the brain, the result is a world of three dimensions. Primates are said to have true depth perception, or **stereoscopic vision** (Figure 5.5). To protect their delicate muscles and nerves, primate eyes are enclosed in a bony socket.

This emphasis on the visual sense in primates seems connected to a reduction in the sensitivity of the other senses, at least as compared with many other mammals. Primates have neither the olfactory (smell) nor auditory (hearing) acuity of such familiar animals as dogs, cats, cattle, and horses. The areas of the primate brain that interpret these data are reduced in comparison with those of other mammals, and primates tend to have flat faces, reducing the olfactory receptor area within the nose. But no living creature, except possibly birds of prey, sees as well as we primates do.

Locomotion

stereoscopic vision Three-dimensional vision; depth perception.

prehensile The ability to grasp.

brachiate To swing through the trees using arms and hands.

Most mammals are quadrupedal; they walk on all fours. With the notable exception of humans, so do primates, but how they use their four limbs differs from other mammals. Whereas the limbs and feet of mammals in general are built for firm, solid contact with the ground (via hooves or paws with pads), primate limbs are highly flexible; the hands and, in many primates, the feet have the ability to grasp objects. Such hands and feet are said to be **prehensile** (Figure 5.6). Primates use this trait for several forms of locomotion. Some, called *vertical clingers and leapers,* jump from branch to branch or trunk to trunk, using the grasping ability of all four limbs. The apes are suspensory climbers with the ability to hang and climb by the arms. An extreme form of this mode of movement is **brachiation,**

FIGURE 5.6 The hands of a human and an orangutan show the prehensile ability of the primates. (© *Frans Lanting/Minden Pictures*)

swinging arm over arm through the trees (see Figure 5.15). When on the ground, most primates use all fours. Asia's orangutans walk on their fists. The African apes have a unique quadrupedalism, supporting themselves on the knuckles of their hands instead of the palms. Primate species may use one or more of these locomotor methods, depending on their anatomy and the situation.

Most primates also have some degree of **opposability**—the ability to touch the thumb to the tips of the other fingers on the same hand, enabling them to pick up small objects. And most primates have flat nails instead of claws on the ends of their fingers and toes. Nails lend support to the sensitive tactile receptors of the fingertips, and they don't get in the way as claws would when the hand is closed.

opposability The ability to touch the thumb to the tips of other digits on the same hand.

Reproduction

In contrast to many other mammals that bear litters or to fish and reptiles that may produce dozens of offspring at a time, nearly all primates have only a single offspring at a time. A small number of primate species normally give birth to twins or triplets. As mammals, the primates take direct care of their young, protecting, nursing, showing affection, and (even if indirectly) teaching. Particularly because of their large, complex brains, primates take a long time to mature. This time is related to size, so a mouse lemur (which you could hold in the palm of your hand) grows up faster than a gorilla or a human. Relative to size, however, the primates have the longest period of **postnatal dependency** of all mammals.

Intelligence

Intelligence means the relative ability of an organism's brain to acquire, store, retrieve, and process information. To a great extent, these abilities are related to brain size. A bigger brain simply has more room for the neural connections that make it all work. (Brain-size variation *within* a species is another matter, which we'll mention later.) But intelligence is also related to the complexity of the brain—how many parts it has and the relative size of the parts—and to the brain's overall size relative to the organism's body. No primate has a brain the size of a whale's or an elephant's; when adjusted for body size, however, primates have the largest and most complex brains of all mammals.

The relatively large and absolutely more complex brains of primates allow them to take in, store, retrieve, and process more information in more complicated ways than other mammals. Primates are smart.

Behavior Patterns

Primates are social creatures. Most live in social groups, but even solitary primates interact with other species members in ways far more complex than would be found among, say, a herd of antelope. The difference is that primates (like some other mammals, especially social carnivores such as wolves and African lions) recognize individuals, and individuals each hold a certain status within a primate group. Some primates—baboons, for example—exhibit a form of **dominance hierarchy** in which individuals have differential social power and influence and, perhaps, access to mates. Nearly all primates recognize a special status for females with infants. Chimpanzees have varying attitudes about members of their group that can only be described by our human term *friendship*.

Much of the reason for this social structure stems from the long dependency period of the young. Born helpless and with much to learn about their world using large brains that take a long time to grow, primate babies need protection. With a close maternal bond to her infant—a bond common among all primates—the mother provides most of this protection. But especially in dangerous areas such as the open plains of Africa, the presence of a group adds greatly to the chance of successfully rearing offspring to become functioning members of the species' next generation.

postnatal dependency The period, after birth, of dependency on adults.

intelligence The relative ability to take in, store, access, and use information.

dominance hierarchy Individual differences in power, influence, and access to resources and mating.

FIGURE 5.7 Francois's langurs, monkeys from Southeast Asia, grooming. Grooming serves not only to rid the primates of parasites and dirt but also helps maintain group unity and harmony. *(© Noel Rowe)*

Care of offspring thus becomes another distinguishing feature of the primate behavior pattern.

Primate social systems are maintained through communication. Although only humans have a complex symbolic language, most primates have a large repertoire of signs and signals with specific meanings. These take the form of facial expressions, body movements, and vocalizations. Touch, usually through mutual **grooming** to remove dirt and parasites, is another form of communication common to most primates and seems to serve as a source of reassurance to maintain group harmony and unity (Figure 5.7).

Given this set of mutually reinforcing traits, the primates may be generally defined as arboreal mammals with a well-developed visual sense who, by virtue of a large, complex brain, complex social organization, and a long period of infant dependency with extensive and direct care of the young, adapt to life in the trees. They learn about, move with agility through, and manipulate this environment, with the last two abilities made possible by grasping and dexterous hands and feet.

A Primate Portfolio

For groups with numerous species and a variety of geographical locations and environmental niches, it is necessary to add to the basic seven Linnaean taxonomic categories (see Table 5.1).

Order **Primates** (Figure 5.8) is divided into two major groups, suborders **Prosimii** and **Anthropoidea.** Prosimians represent the most primitive

grooming Cleaning the fur of another animal, a behavior that promotes social cohesion.

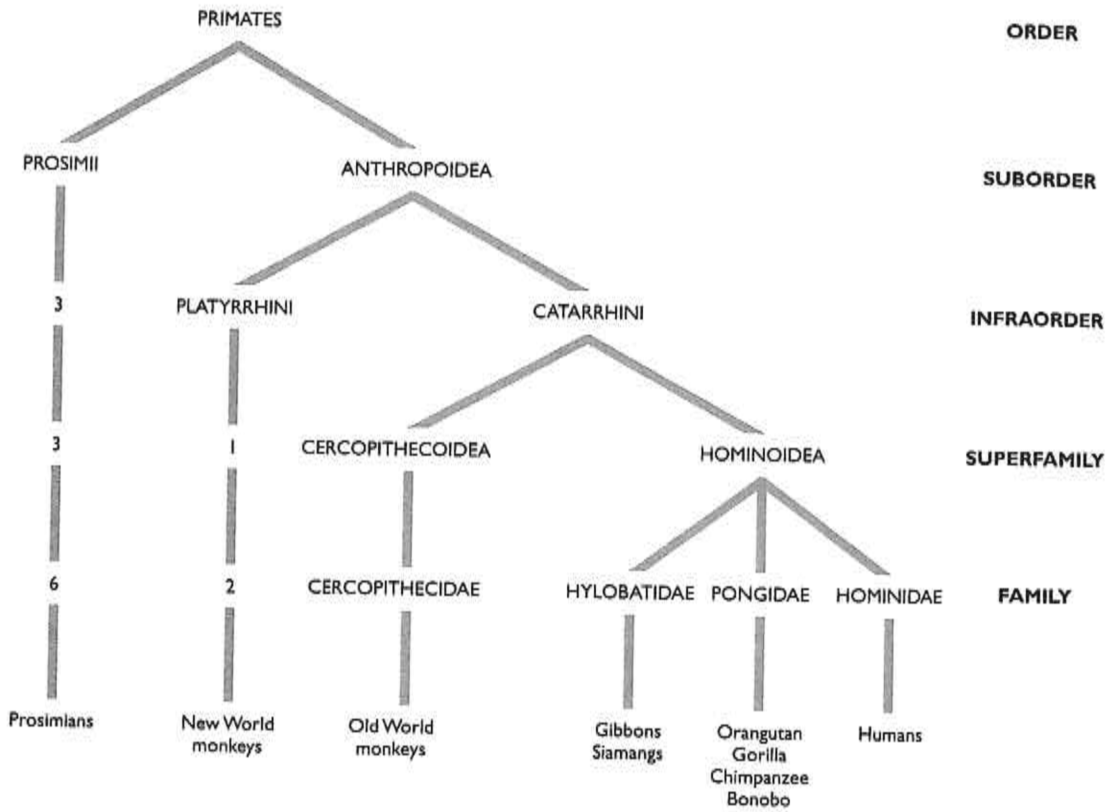


FIGURE 5.8 A traditional primate taxonomy. Numbers refer to living groups in that category. Alternative taxonomies exist.

primates. Biologically, the term *primitive* implies no value judgment but merely refers to age. Prosimians are said to be primitive because they most closely resemble the earliest primates as revealed by the fossil record discussed later in this chapter. As newer, more adaptively flexible primates evolved, the early prosimians were pushed into isolated, protected areas. Most prosimians now inhabit the island of Madagascar, which newer primates never reached, with other species on mainland Africa and India and on the isolated islands of Southeast Asia (Figure 5.9).

As a group, prosimians show some differences from the general primate pattern outlined in the last section (Figure 5.10, and see Figure 3.11). About half of the prosimians are **nocturnal**. These tend to live on mainland Africa and in Southeast Asia, where this adaptation helps them avoid competition with the **diurnal** anthropoid primates. As nocturnal creatures, prosimians have a better sense of smell than most primates. To aid this sense, they have a protruding snout with a large olfactory receptor area and a moist, naked nose (like a dog or cat) to help pick up molecules that provide olfactory signals.

nocturnal Active at night.

diurnal Active during the day.

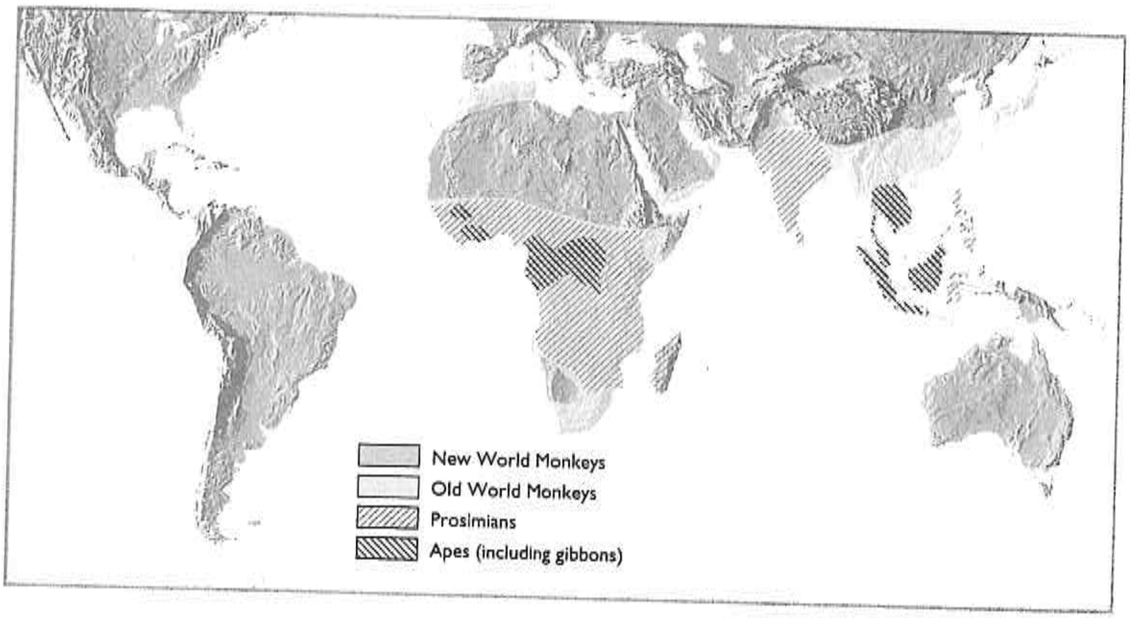


FIGURE 5.9 Distribution of the living primates.

Like nocturnal creatures everywhere, prosimians have large eyes to gather more light, but they have virtually no color vision because it's not useful at night. They do, however, have stereoscopic vision because, like all primates, they need to judge distances in bushes and trees. Many use this ability to catch insect prey.

Prosimians have prehensile hands and feet, but their opposability is different from the other primates. Rather than being able to touch the thumb to the other fingers on the same hand individually, the four other digits of prosimians (or three, as some prosimians lack an index finger) move together. In addition, some prosimians have claws on a couple of fingers or toes. These grooming claws are used for cleaning fur.

Prosimians spend most of their time in trees or, if they are small, in bushes. Their form of locomotion depends, of course, on their ability to grasp with their hands and feet the trunks and branches on which they are moving. The characteristic way many move about is vertical clinging and leaping—jumping from branch to branch in an upright position, pushing off with their legs and landing with both arms and legs. This trait differs from the behavior of other primates that "walk" one limb at a time through the trees, or brachiate, swinging arm over arm (see Figure 5.15).

A few of the Madagascar primates, the lemurs (see Figure 3.11), give birth to twins or even triplets on a regular basis. Transporting them seems to pose no problem because a male or older sibling often helps the mother take care of the babies. Some species also build nests in which offspring may be kept.

FIGURE 5.10 The slender loris, a prosimian from India and Sri Lanka. Note the large eyes and moist naked nose—adaptations to a nocturnal way of life. Note also the grooming claw, just visible on one toe in the foot at the top of the picture. Those typical primate prehensile hands and feet are easily seen. (© *Noel Rowe*)

A particularly interesting primate is the tarsier (Figure 5.11) of Southeast Asia, a small (4 or 5 ounces) primate noted for its powerful hindlimbs for leaping, enlarged fingertips and toetips for friction, ability to turn its head 180 degrees like an owl, and almost exclusively insect diet. Although traditionally classed as a prosimian, some authorities think it may be evolutionarily more closely related to members of the suborder Anthropoidea because, like all anthropoids, it lacks a moist, naked nose and has color vision.

The suborder Anthropoidea (meaning "humanlike") includes the monkeys, the apes, and the hominids (humans and human ancestors). It is divided into two infraorders, **Platyrrhini** and **Catarrhini**. This division is geographical, the platyrrhines (all monkeys) inhabiting the Western Hemisphere, or New World, and the catarrhines (monkeys, apes, and hominids) inhabiting the Eastern Hemisphere, or Old World.

The platyrrhines have several physical characteristics that distinguish them from the catarrhines (Figure 5.12). One distinguishing feature is the nose. *Platyrrhine* means "flat nose," and the noses of the New World mon-

FIGURE 5.11 The tarsier of Southeast Asia. Note the huge eyes (each eye is as big as the entire brain) for nocturnal vision, the powerfully built legs for jumping, and the enlarged finger and toe tips for friction. Grooming claws are also visible on some of the toes. *(© Noel Rowe)*

keys have widely spaced nostrils separated by a broad septum. Compare this with your own catarrhine nose, with its closely spaced nostrils that face downward. (We are considered Old World primates because that is where humans first evolved.) In addition, platyrrhine primates have more teeth than the catarrhines—twelve premolars or bicuspids compared to eight for the Old World primates (including humans). Because most New World monkeys are almost completely arboreal, they have evolved long limbs and long, curved clawlike nails; a few even have prehensile tails capable of grasping things and supporting their weight. No Old World primate has this kind of tail. Finally, one group of platyrrhines, the marmosets, normally gives birth to twins.

Referring to Figure 5.8, we see that the Old World primates are divided into two superfamilies. The monkeys of Europe, Africa, and Asia make up superfamily **Cercopithecoidea** and family **Cercopithecidae.** The apes and humans comprise superfamily **Hominoidea.**

Within the cercopithecids are two subfamilies and about a dozen genera with numerous individual species. These monkeys have the nasal

FIGURE 5.12 The northern woolly spider monkey, a platyrrhine primate from Brazil. Note the prehensile tail with the bare strip of skin on the inner surface to enhance grasping ability. (© *Noel Rowe*)

shape and tooth number of Old World primates, and most have tails, though none are prehensile. Males tend to be larger than females, unlike the New World species, which show little sexual dimorphism. The cercopithecids have fully opposable thumbs (also unlike the platyrrhines). In general, the monkeys of the Eastern Hemisphere seem more adaptively flexible. One large genus, ***Macaca***, has representative species all the way from North Africa to India to the mountains of northern Japan, where they are called "snow monkeys" (Figure 5.13).

Another genus, ***Papio***, is of particular interest to us because it contains most of the baboons, the large, long-snouted monkeys of the African savannas (Figure 5.14; see also Figures 6.2 and 6.3). This is an important environment for the early evolution of our lineage. The savannas are nearly the same today as when early hominids lived on them. By observing the adaptations of another primate to the same environment, we may get some idea of how our ancestors survived. We'll discuss this topic in detail in Chapter 6.

Superfamily Hominoidea, the large, tailless primates, is made up of three families. Family **Hylobatidae** includes the gibbons and siamangs of Southeast Asia and Malaysia, sometimes referred to as the "lesser apes" because they are smaller than the African apes. These species are especially

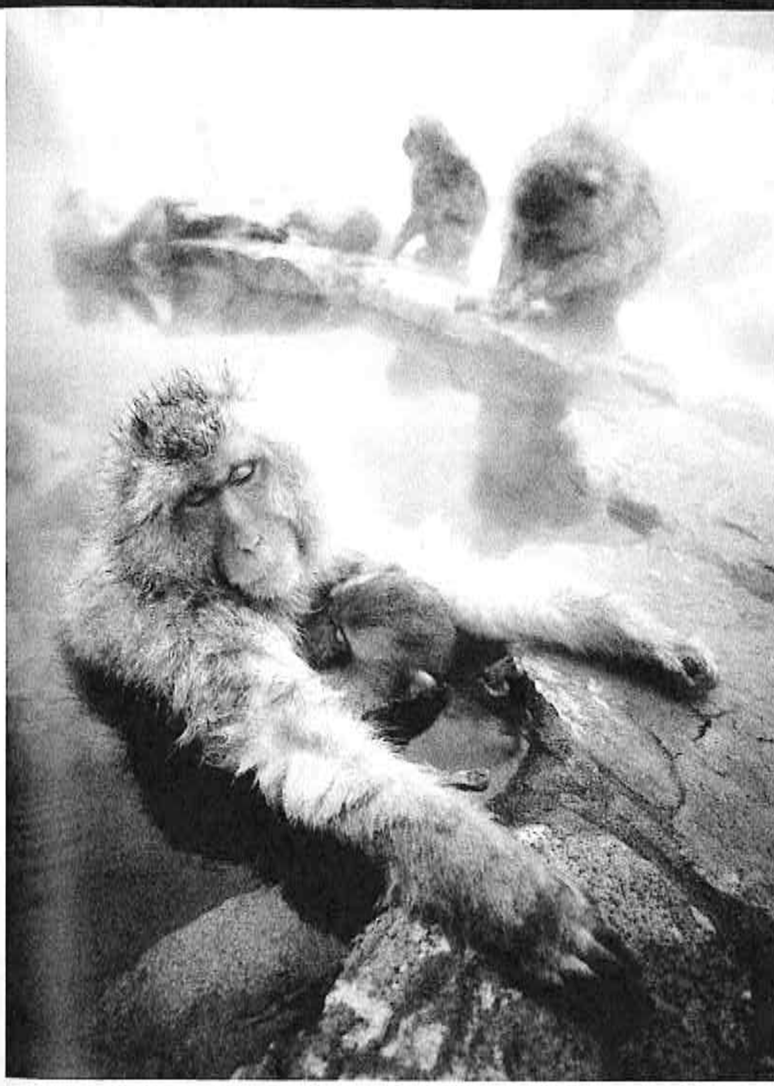


FIGURE 5.13 Japanese macaques, or "snow monkeys," are well adapted to life in cold, mountainous areas, even to the point of warming themselves in volcanic hot springs. *(© Steven Kaufman/Peter Arnold, Inc.)*

noted for their brachiating form of locomotion (Figure 5.15). To aid in this movement, the arms of gibbons and siamangs are much longer and more powerful than their legs and end in hands with short thumbs and long, hooklike fingers. The hylobatids have, for the primates, an unusual social group: male and female are monogamous, establish and defend a territory, and may even help their offspring set up a territory.

Family **Pongidae** comprises the "great apes," of which there are four living species: the orangutan of Southeast Asia (genus ***Pongo***) and three African species—the chimpanzee and the bonobo (genus ***Pan***), and the gorilla (genus ***Gorilla***) (Figure 5.16). These are the most robust primates, heavy-boned with large, powerful jaws and chewing muscles used for eating a wide range of fruits and vegetables and, in the case of the genus *Pan*,

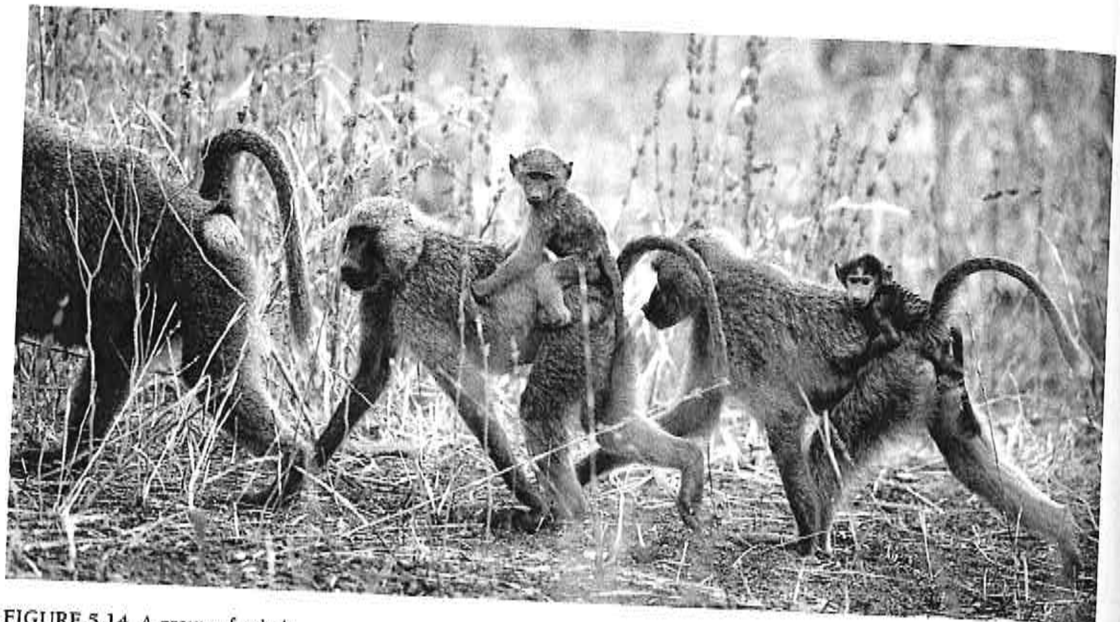
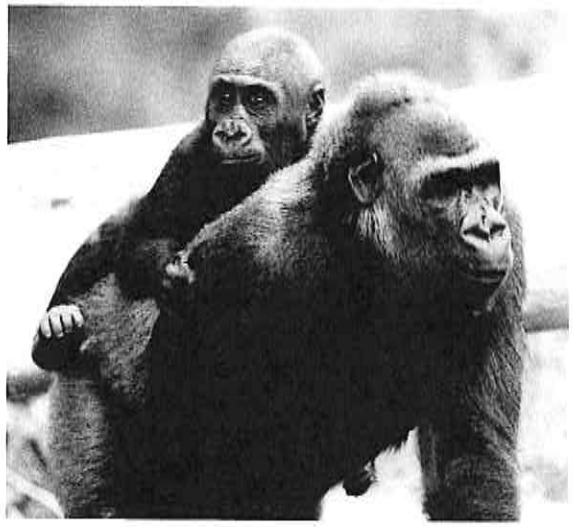


FIGURE 5.14 A group of gelada baboons on the grasslands of Ethiopia. *(© Brand X Pictures/ PunchStock)*

FIGURE 5.15 White-handed gibbon from Southeast Asia suspended by one arm. Notice the long, hooklike fingers and that it is also grasping with its feet. *(© Noel Rowe)*



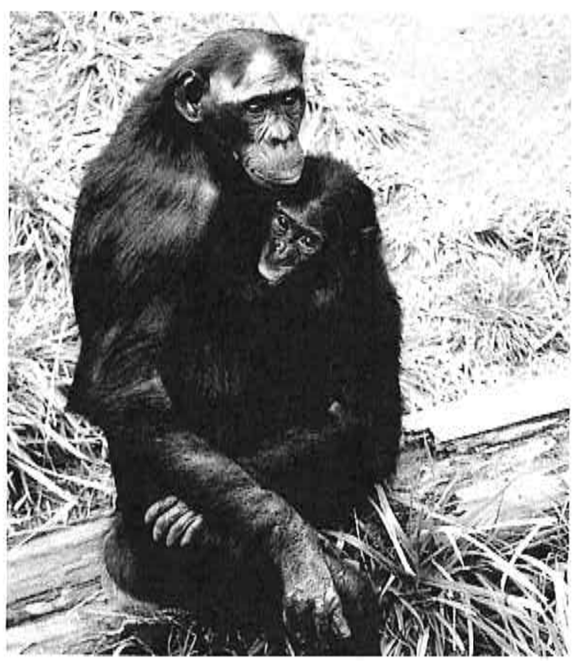


FIGURE 5.16 The great apes (*clockwise from top left*): the orangutan of Southeast Asia and the gorilla, bonobo, and chimpanzee of Africa. *(Orangutan: © Noel Rowe; Bonobo: © Ron Garrison/The Zoological Society of San Diego; Gorilla: M. A. Park; Chimpanzee: © Steve Turner/Animals Animals/Earth Scenes)*

meat. The apes are essentially quadrupeds. Chimps and gorillas spend a large portion of their time on the ground, whereas the orangutan spends almost all of its time in the trees. In fact, the orangutan is so well adapted to arboreal locomotion that its feet look and function like two additional hands. All the great apes are built like brachiators, with large and powerful shoulders and arms, but they are too large to do much traveling in this fashion. Though predominantly quadrupedal, the apes can and do walk upright on occasion, usually when they want to look around or carry something. These two specific benefits made possible by the ability to stand upright may have been crucial in the evolution of a primate that could stand—and move about—habitually, as we will discuss in Chapter 8.

Orangutans are solitary, but chimps, bonobos, and gorillas live in social units marked by a changing group membership, loose organization, and some degree of dominance recognition. Because the apes don't live in areas that present the dangers faced by savanna primates, dominance and its recognition may be even looser and more flexible than among baboons.

Apes have large brains, some measuring about half the size of the smallest modern human brains. Many features of the anatomy of pongid brains are also similar to those of humans. Apes are intelligent. They have, for example, a vast knowledge of a great number of food sources. Because many of these foods are fruits, they need to be aware of seasonal changes so they can be at the right place when the fruits ripen, a cognitive behavior found also in some monkeys.

Chimpanzees can even make simple tools. Their most well-known tools are the "termite fishing sticks" they make from twigs and blades of grass. They stick these down termite holes, wiggle them around, and draw out a meal of termites that have attacked the "invader" by clinging to it with their powerful pinchers (Figure 5.17). This is a cultural behavior: it is learned. It also involves abstract concepts; the chimps must visualize the tool within the bush or grass as well as the behavior of the unseen termites. It involves an **artifact**—a natural object consciously modified for a specific purpose. This tool-using behavior also differs from individual to individual and from group to group, with each chimp having a raw material that is her favorite (usually only females perform this activity). Most chimp troops don't do it at all, a sure sign that the behavior is learned rather than genetic. And among chimps that do make tools, different groups have different styles. Humans are clearly not the sole possessors of cultural behaviors.

Chimps are also known to hunt small mammals, including young baboons, which they capture with their hands, kill by biting through the back of the skull or neck, and then tear apart with their hands and teeth. In some groups, just one chimp—nearly always a male—does the hunting and killing, but in other groups it is a cooperative venture that appears to have some sort of group strategy. The meat acquired is the one food that chimps share with one another. Bonobos also hunt and eat meat, although less often.

artifact A natural object consciously modified for a specific purpose.

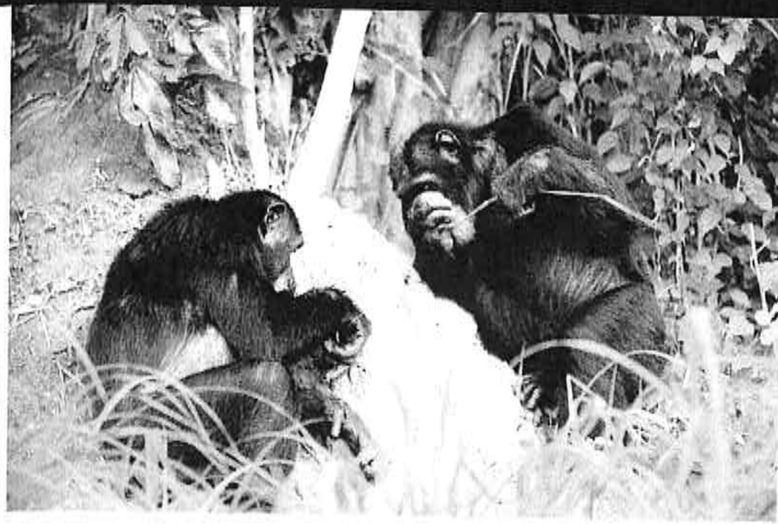


FIGURE 5.17 Chimps using tools they have made to extract termites from a mound. *(Jane Goodall/ National Geographic Society)*

Like all primates, apes use vocalizations, facial expressions, and body language to communicate. They have nothing like a human language, but, because of their complex ecological niches and rich social lives—not to mention the large, complex brains they have correspondingly evolved—they are capable of learning the rudiments of human language. Chimps, gorillas, and orangutans have been taught to use various symbolic representations of language, most notably American Sign Language for the hearing impaired (Ameslan), because these species lack the vocal apparatus to make the full range of human sounds. Some researchers claim that these apes can communicate at about the level of a 4- or 5-year-old human, linking words in grammatically correct ways. Others refute this, saying the apes are only mimicking their trainers. This research remains controversial, although most evidence seems to point to some elementary linguistic ability on the part of our closest relatives.

The other family within the hominoids, **Hominidae**, includes living humans, all of whom belong to the same genus and species, *Homo sapiens*. Humans of the past, when at times several genera and species existed, also belong to family Hominidae, the hominids.

The Human Primate

It should now be clear that humans are primates. We share with some 200 other living species a common set of basic physical and behavioral traits. Each primate species, though, has its own unique expression of the primate adaptation. Humans are no exception; our expression of the primate adaptation involves not being arboreal at all. Let's review the five categories discussed earlier and see how we compare.

1. ***The senses.*** Our sensory organs are basically the same as those of the anthropoid monkeys and apes. Sense of smell seems exactly the same. Monkeys can hear higher sound frequencies than we can, but we are more sensitive to changes in pitch and intensity. Color vision is the same in humans, apes, and monkeys, except that humans may be more sensitive to slight differences in colors than monkeys. It is possible, though, that this may be because we have assigned cultural names to slightly different shades of color and so recognize them because we have learned them. It has also been suggested that we can distinguish many colors because we can concentrate harder on such tasks (Passingham 1982). In general, in terms of the five senses, humans, apes, and monkeys perceive the same world.

2. ***Locomotion.*** The most striking physical difference between us and the other primates is the way we move about. We are the only primate that is habitually bipedal, walking on two feet. The bones of our back, pelvis, legs, and feet are all structured to balance us and hold us erect (see Figure 8.12). Our musculature has evolved to serve the same purpose. Even the rather spherical shape of our head, as opposed to the more elongated heads of other primates, may have evolved in part to be more balanced atop a vertical spine. Because our legs are the limbs of locomotion, they are longer and more muscular than our arms—just the opposite of apes. Completely freed from locomotor functions, our hands have become organs of manipulation. We have the most precise opposability of the primates, facilitated by the longest and relatively strongest primate thumb.

3. ***Reproduction.*** Like nearly all primates, we normally have one offspring at a time. Though we are not the largest primate (gorillas are), we have the longest period of dependency and maturation. Chimps, for example, reach sexual maturity in about nine years and physical maturity in about twelve years. For us, the averages are thirteen years and twenty-one years. Not only do we grow up more slowly, we are born relatively more immature and helpless than other primates, so we get off to a late start.

4. ***Intelligence.*** We are clearly the most intelligent primate because we can store and process more information in more complex ways than the others. Our cultural behavior—our languages, societies, abstract belief systems, scientific knowledge—attests to these abilities. Our intellect is made possible by our big brain, the result of and reason for the extended period of growth after our immature births. Although some primates, such as squirrel monkeys from South America, have larger brains relative to body size than ours, our brains are still three times the size expected for a primate of our body mass. In absolute terms, our brains are larger and more complex than any primate's. Especially large is our **neocortex**, the outer layer of the brain where abstract thought, problem solving, and attentiveness take place (Figure 5.18).

neocortex The part of the brain responsible for memory and thought.

5. ***Behavior patterns.*** Like most primates, humans live in social groups that are made up of individuals with differential identities and statuses.

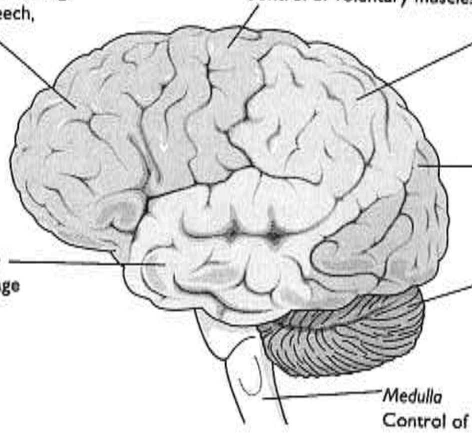


FIGURE 5.18 The human brain, with major parts and their functions. The lobes and motor cortex are all part of the neocortex.

The difference is that human groups are structured and maintained by cultural values—ideas, rules, and behavioral norms we have created and share through complex communication systems.

Our big brains have allowed us to move well beyond purely biological evolutionary processes. Certainly, natural selection brought about the evolution of our big brains in the first place, but the way in which this organ functioned permitted us to think up answers to the problems of our survival. As human societies moved around and encountered varying environmental situations and other human groups, these answers became so complex that strikingly different social systems evolved. In a sense, culture became our environment, to which we responded with still newer cultural ideas, systems, and artifacts.

Chimps may exhibit some cultural behaviors, may be able to learn to use the basic features of human language, and may differ from us genetically by approximately 2 percent of their genes, but our behavior—the extent to which we use and indeed rely on culture—is very different from that of the other primates.

Genetics and Primate Relationships

Physical features are controlled by a complex interaction of genetic loci, evolutionary processes, and environmental factors. Therefore, trying to examine evolutionary relationships based solely on physical traits can be misleading. A trait may look the same in two organisms, but the expressions of the trait may be based on very different genetic and developmental processes, and the traits themselves may differ in their adaptive significance.

A famous example (Gould 1980) is the "thumb" of the panda, a bear. It looks very much like the thumb of many primates, but its use is specialized: it enables the panda to handle and strip the leaves off bamboo stalks. And it's not a finger at all but an elongated wrist bone.

Some investigators asked, then, would it not be more informative to look at the genes themselves—or at least at the immediate products of the genes? Two organisms with similar genes must certainly be closely related evolutionarily.

In the 1960s, Vincent Sarich and Allan Wilson of the University of California at Berkeley pioneered research along just such lines (Sarich 1971). They compared the blood proteins of a number of organisms, with the goal of quantifying similarities and differences. Blood proteins such as albumin are large, easy to work with, and made up of amino acids—the immediate products of the genes. Sarich and Wilson's research indicated that the blood proteins of humans and chimpanzees are almost identical.

But there was an even more startling inference from this research. Sarich and Wilson wondered if their figures might provide a relative idea not only of evolutionary distance but also of the timing of the evolutionary split. Because evolution involves the accumulation of mutations, the differences between two species in a genetic product such as albumin might act as a "clock" if the mutations causing those differences take place at a fairly constant rate and if we can then figure out how many of those mutations take place over a certain period of time.

Comparing species whose time of divergence was well established from the fossil record, Sarich and Wilson concluded that the small difference in blood proteins between chimps and humans corresponded to an evolutionary separation of only 5 million years. At the time, the accepted date for the divergence of our two lineages stood at between 12 and 15 million years. Based on the "protein clock," Sarich said that no primate that old could be a hominid no matter what it looked like. He was right.

Other types of genetic comparisons yielded the same basic results. Comparisons of the amino acid sequence of certain blood proteins such as hemoglobin among primates showed a difference of 2.8 percent between humans and orangutans, and the amazingly low figures of 0.6 percent for humans compared with gorillas and 0.3 percent for humans compared with chimpanzees. Another method that compares the bonding reaction between DNA of different species showed humans and chimpanzees to have nearly the same DNA.

Yet another method, one that gives visible results, involves comparing patterns of bands appearing on chromosomes treated with certain dyes that show areas of active genes (Figure 5.19). Eighteen of the twenty-three pairs of human chromosomes are virtually identical to chromosomes of chimpanzees. Moreover, although chimps have twenty-four pairs of chromosomes, it appears as if one of our chromosomes may have been derived from two of theirs (the far left comparison in Figure 5.19).

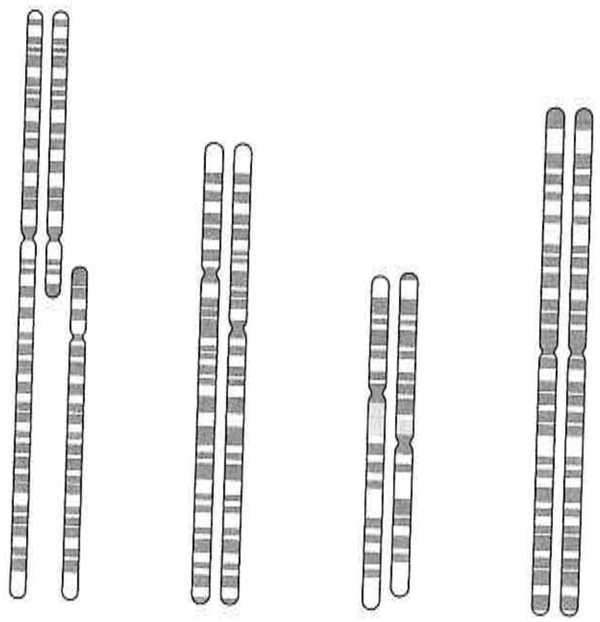


FIGURE 5.19 Human chromosomes, on the left in each pair, compared to those of chimpanzees. The similarities in banding pattern are clear. In the far lefthand pair, the pattern of human chromosome 2 is similar to that of two chimp chromosomes. The far righthand pair are virtually identical. This is one piece of evidence for the 98 percent genetic similarity between our two species.

Now, recent technology has allowed us to look at and compare the most basic genetic components—the sequence of base pairs that make up the codons, which in turn make up the genes. This is the same technology that is applied to the investigation of criminal and missing-person cases. For example, blood samples from crime scenes can be genetically compared with samples from suspects, virtually assuring accurate identifications. DNA sequencing also helps in locating genes involved in various diseases. And, relative to our topic here, we can now precisely compare the genetic makeup of primate species, establishing just how genetically similar or different they are and, using the logic described above, estimate how long ago their evolutionary lines diverged. There has even been an attempt to reconstruct the ancestral genome of all living primates (O'Brien and Stanyon 1999).

To be sure, until we can compare *all* the base pairs of the species in which we're interested, there will be some differences in the estimated relationships. Comparisons of different sections of the genomes may yield slightly different results. But this new technology is accurate enough that we are, for example, confident in the 2 percent genetic difference identified between humans and chimpanzees and of the evolutionary branching pattern that has been genetically determined for the hominoids.

An interesting new question that has resulted from these studies is the matter of just *which* genes differ between humans and chimpanzees and *what* those genes do. In other words, what genetic differences make chimps chimps and humans humans? Recent studies suggest that the difference may be as few as 50 coding genes (out of an estimated 100,000) (Wade 1998) and that one of those differences—a 92-base pair section of a single gene—leads to humans' lack of a certain chemical on the surface of all body cells that all other mammals, including the apes, possess (Gibbons 1998b; Muchmore et al. 1998; Normile 2001). The results of this difference are still being investigated, but it is known that the chemical acts as a receptor for messages from other cells, is used by pathogens to attach to a cell, and, importantly, may be involved in cellular communication during brain development and function, something that could influence the timing and extent of brain growth. This last function has obvious implications for the story of human evolution.

Another specific difference is in some genes for enzymes called *proteases*, which are important to the immune system. This could explain why chimps are less severely affected by some diseases such as AIDS and Alzheimer's. And most recently, a difference between nonhuman primates and humans has been located on a gene for a protein important in the building of some jaw muscles. Because of a mutation, the human version of the gene is inactivated, resulting in reduced muscle fibers and even a reduced size of some jaw muscles (Stedman et al. 2004). Moreover, the origin of this mutation has been placed at about 2.4 mya, a date, as we shall see, that is about the time of the first fossils identified as belonging to our genus, *Homo*.

In addition to these specific differences, it has also been established that five chromosomes in our two species show significant differences in the arrangement of the same genes. Some sequences, for example, have been flipped (or inverted) in one species as compared to the other. These changes could lead to different roles for those genes. Identifying their functions is a current goal, as is the establishment of a primate genome project to provide a complete sequence of the genomes of our closest relatives (Gibbons 1998b).

The Evolution of the Primates

To say that the fossil record of the early primates is confusing is to understate the case. There are a large number of fossil specimens of primates, but, as one authority notes, 65 percent of extinct primate species are based on fossils that are "extremely fragmentary," mostly pieces of jaw or sometimes just teeth (Martin 1990:39). Although one extinct species may be represented by many specimens, fossils of its contemporaries are lacking, giving us little basis for comparison. For certain periods of primate evolution, all fossils are found in one or two locations. Still, we have been able to piece together the basic picture of the primate evolutionary story (Figure 5.20).

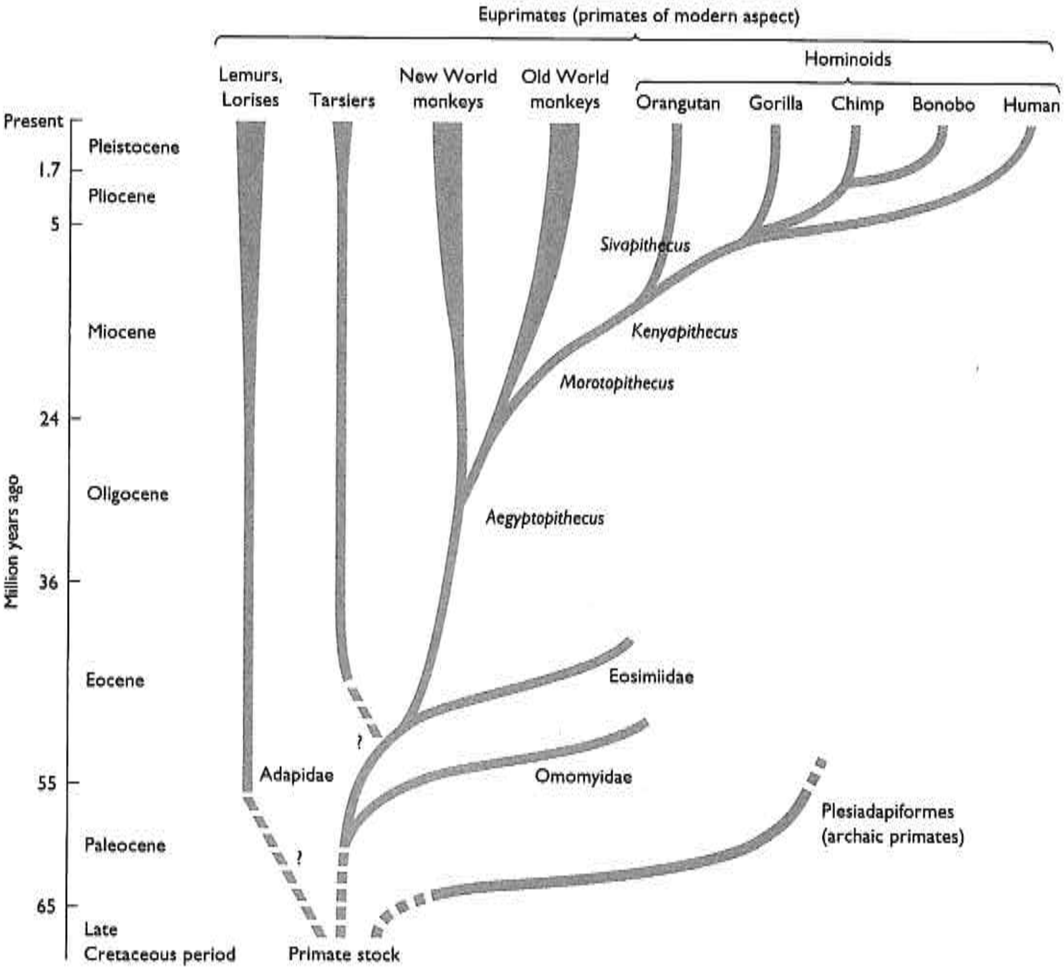


FIGURE 5.20 Simplified evolutionary tree for the primates, with major geological epochs and dates. Question marks and dashed lines indicate insufficient data to establish evolutionary relationships. This tree represents one of several possible interpretations.

Very little exists to tell us about the beginnings of the primates. Some genetic comparisons, such as those described in the last section, point to the origin of the primates at 90 to 80 mya, well back into the time of the dinosaurs (Gibbons 1998a; Tavaré et al. 2002). In terms of hard evidence, a few primatelike teeth from Montana dated at 65 mya and some bones from Wyoming from 60 mya show primatelike anatomical features related to climbing. Remember that at that time, North America and Europe were still very close together and possibly still connected in some locations (see Figure 3.6), so the primates probably originated on the large northern

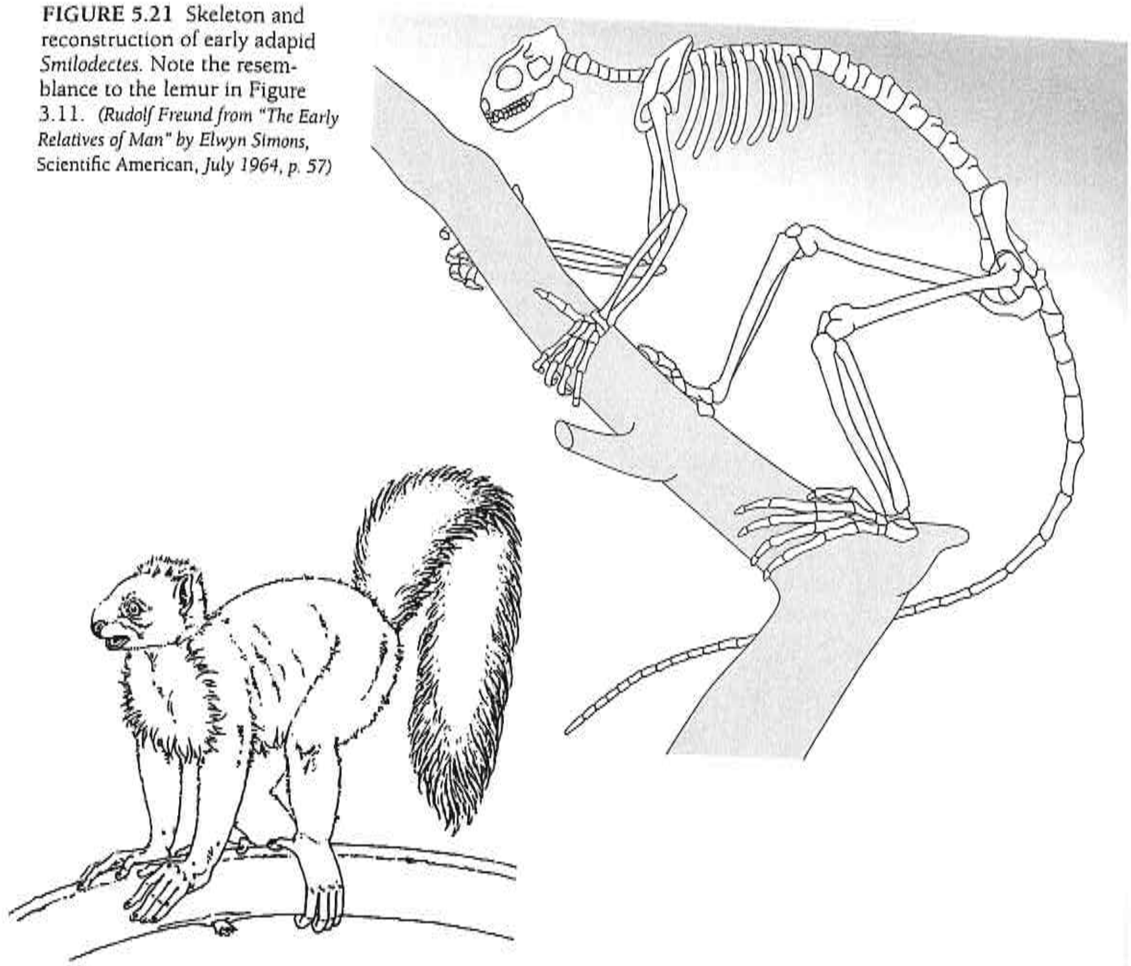


FIGURE 5.21 Skeleton and reconstruction of early adapid *Smilodectes*. Note the resemblance to the lemur in Figure 3.11. *(Rudolf Freund from "The Early Relatives of Man" by Elwyn Simons,* Scientific American, *July 1964, p. 57)*

landmass called Laurasia. It is not until about 55 mya that fossils of undisputed primates are found.

The traits of modern primates that we associate with an arboreal adaptation may not have first evolved specifically to facilitate that adaptation. Anthropologist Matt Cartmill (1992) suggests that prehensile extremities and stereoscopic vision may have evolved to aid leaping as a means of locomotion in the forest canopy or the shrub-layer undergrowth and to promote fruit eating and "visually directed predation" on insects. Some modern primates such as the tarsier (see Figure 5.11) track insects by sight and seize them by hand. As the early primates evolved, then, these basic traits also proved a useful adaptive theme for life in the trees in general.

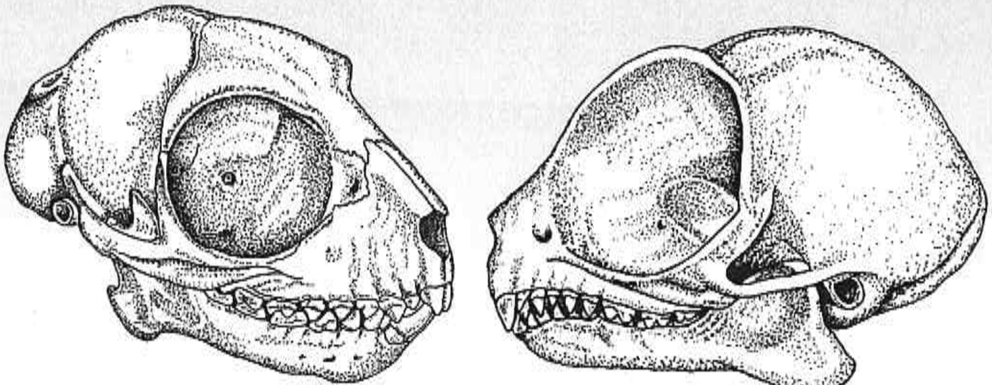


FIGURE 5.22 Comparison of fossil omomyid *Necrolemur (left)* with modern tarsier. *(From R. D. Martin,* Primate Origins, *p. 61 © 1989. Reproduced with permission of Kluwer Academic Publishers)*

Some new fossil finds from Wyoming (Bloch and Boyer 2002; Sargis 2002)—representing several families of **Plesiadapiformes,** an extinct branch of archaic primates (as opposed to the euprimates, or primates of modern aspect)—clearly show features related to grasping, indicating that that adaptation evolved early in primate evolution.

The early primate fossils come in two groups, and both have been found in North America, Europe, Asia, and Africa. One group, the lemurlike **Adapidae** (Figure 5.21), is thought to be ancestral to modern lemurs and lorises. The other group, the tarsierlike **Omomyidae** (Figure 5.22), which may date back to 60 mya, may be ancestral to both tarsiers and anthropoids. A recently discovered group, the **Eosimiidae** from Asia, appears to represent the more direct ancestors of monkeys, apes, and hominids (Gebo et al. 2000; Jaeger et al. 1999; Kay et al. 1997). Important evolutionary shifts that mark the origin of the anthropoids were changes from a nocturnal lifestyle to a diurnal one, from less leaping to more climbing through the trees with all fours, and from an insect-based diet to a more herbivorous diet. (How we can discern such changes among often fragmentary fossils is a topic we'll discuss in Chapter 7.)

By the time the omomyids were moving into Asia, the Eastern and Western Hemispheres were separate. The New World has so far offered virtually no fossil evidence to tell us what happened next. It may be that the prosimian forms that ended up in the New World moved into South America once it joined North America and evolved into the present-day platyrrhine monkeys. A second view is that prosimian evolution got no farther in the Western Hemisphere and that early monkeys from the Old World "rafted" over to South America, floating on logs and branches, or crossed over on a chain of volcanic islands when South America and Africa were still fairly close together. The degree of physical similarity among all modern anthropoids suggests a single origin and so argues for the second scenario, as does a recent find of a 25- to 27-million-year-old monkey from Bolivia (Takai et al. 2000) whose teeth are very similar to an older

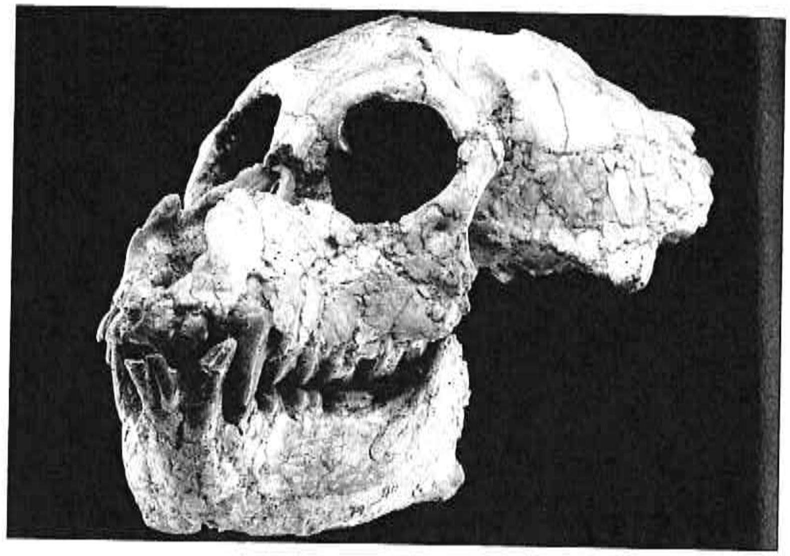


FIGURE 5.23 Skull of *Aegyptopithecus* from the Fayum in Egypt, considered an early monkeylike form that may be ancestral to later Old World monkeys and apes. *(© David L. Brill 1985/Brill Atlanta)*

fossil form from Egypt, suggesting that the New World monkeys originated and diversified first in Africa. That this scenario is plausible is demonstrated by a report (Yoon 1998) of fifteen iguanas (large lizards) floating on a huge raft of trees 200 miles from the Caribbean island of Guadeloupe, where this particular species was native, to the island of Anguilla, where they had not previously been found. They are established and reproducing in their new habitat.

Much of the early evolutionary history of the Old World monkeys themselves is known from a single site, though it has yielded a large number of fossils. This is a desert depression, the remains of an ancient lake southwest of Cairo, Egypt, called the Fayum. New evidence has recently come from other sites in Africa and Southwest Asia. For more detail on this complex period of primate evolution, see Benefit 1999 and Simons and Rasmussen 1994.

From the Fayum come a number of monkeylike forms dated 40 to 25 mya, perhaps the best known of which is ***Aegyptopithecus*** (Figure 5.23) dated at 34 mya. From its postcranial skeletal remains, this anthropoid of about 10 pounds seems to have been an arboreal quadruped. It shows a number of features of the teeth, brain, and skull that resemble those of the later hominoids, the apes and humans. *Aegyptopithecus* may be an early ancestor of the hominoids, although it is still primitive enough to be ancestral to the modern Old World monkeys as well.

Definite apes appeared beginning about 23 mya and became more numerous over the next 10 to 15 million years. We refer to these as "dental apes" because their teeth have the characteristics of modern apes. Their bodies, though, are distinctly different. Do not get the impression that modern-looking chimpanzees were running around in these very ancient times. The classification of these primates as apes is based on a number of physical features, the most important of which is a trait of the molar teeth found only in modern hominoids and no other primate—the Y-5 cusp pattern (Figure 5.24).

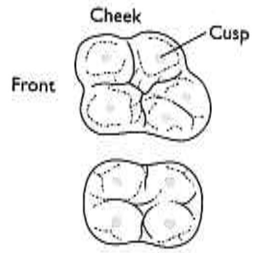


FIGURE 5.24 Y-5 cusp pattern found only in hominoids *(top)*, and the four-cusp pattern found in all anthropoids. The chewing surface is shown. A look in the mirror will probably give you a firsthand glimpse of a Y-5 tooth, but not all molars of all hominoids show this feature.

Between 23 and 5 mya, there were an estimated thirty or more different types of apes—larger-bodied, tailless, larger-brained primates. Only one lineage, however, gave rise to modern apes and hominids. Evidence is scanty, but new fossil finds point to two African forms as candidates for the earliest hominoid. ***Kenyapithecus,*** from around 15 mya, has some modern ape features of the jaw, face, and teeth. Newer fossils, placed by some into a new genus, ***Equatorius*** (Ward et al. 1999), indicate similarities in the arm and ankle bones that are related to the modern chimpanzee's abilities to hang in trees and to rotate the foot, which permits walking flat-footed on the ground and grasping (McCrossin 1997).

A more ancient and more arboreal form, ***Morotopithecus*** from Uganda, dated at 20 mya, also shows similarities. It has a mobile shoulder joint that would have aided in hanging from trees by the arms, as chimps and orangs do, and vertebrae that suggest a short, stiff spine, a feature of modern apes that allows them occasional upright posture (Gebo et al. 1997).

Starting about 12 mya, we find fossils of more ground-dwelling, open-country apes, whose larger back teeth with thicker enamel point to a more mixed vegetable diet that included harder foods such as nuts. Fossils of these apes have been found in Africa, India, Pakistan, China, Turkey, Hungary, and Greece. One group from India and Pakistan, ***Sivapithecus,*** shares features with the modern orangutan and so is most likely an ancestor of that species or closely related to it (Figure 5.25). A new form from Turkey, ***Ankarapithecus,*** dated at 9.8 mya, also shows similarities to this group.

Another form, however, ***Ouranopithecus,*** so far only found in Greece and dated at 10 to 9 mya, shares some features with hominids. Though clearly an ape, about the size of a female gorilla, it is thought by some to be a member of the ape line that eventually led to the hominids (DeBonis and Koufos 1994).

Yet another interesting fossil form in this general group is a giant ape from China, Vietnam, and northern India called ***Gigantopithecus.*** So far, only its massive jaws and teeth have been found, but estimates from these indicate that it may have been 10 to 12 feet tall when standing upright and weighed from 700 to 1,200 pounds. It lived from 7 mya to perhaps as recently as 300,000 ya. Evidence from its teeth indicates that, like the gorilla, it was a vegetarian. Certain features of the teeth link it to the sivapithecid group.

Current evidence indicates, then, that the apes evolved in Africa and diverged into a number of evolutionary lines all over the Old World. Gradually, these lines decreased, leaving relatively few forms to evolve into the

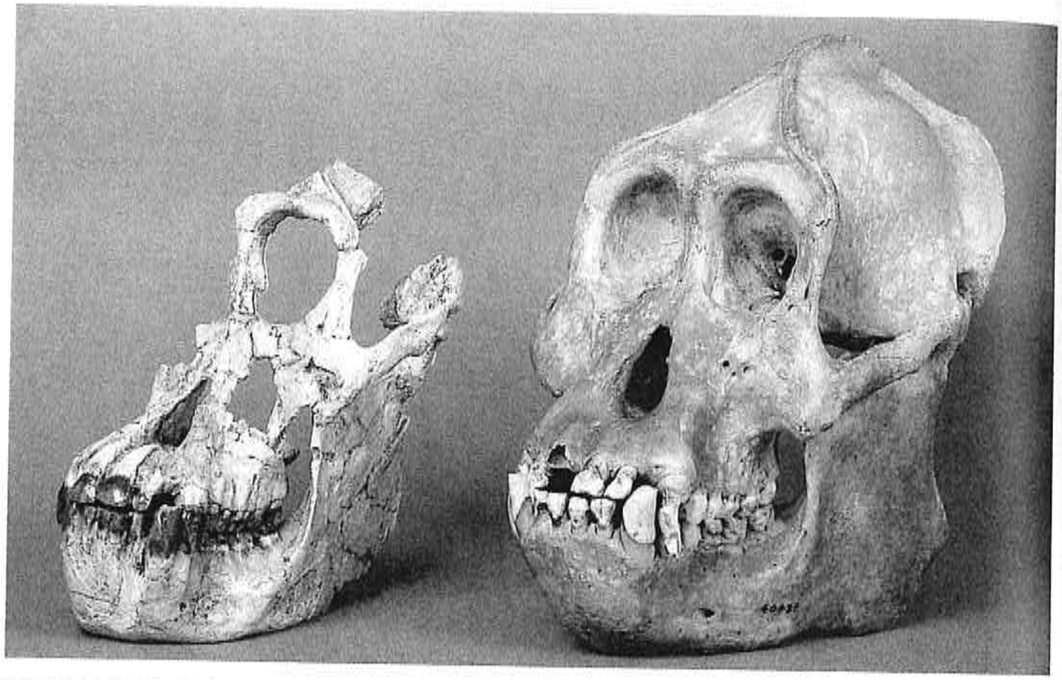


FIGURE 5.25 Skull of *Sivapithecus* (*left*) compared to modern orangutan. They are essentially identical. (*From Dr. Ian Tattersall, American Museum of Natural History,* The Human Odyssey, *1993*)

modern hominoids. One line that we are fairly certain of is that from *Sivapithecus* to modern orangutans. Some African form—or an African population of that form—gave rise to the line leading to modern African apes and the hominids. This is the subject of Chapter 8.

Summary

One important tool for learning about the past is an understanding of the results of the events that made up the past. By determining our place in nature and our relationships with other primates, we can see what the present-day products are of the 65 million years (or more) of primate evolution. This gives us a road map for journeying into the past and looking at our other tool, the fossil record.

Humans are among some 200 species of living primates. In many ways, we are typical of this group—with three-dimensional color vision; prehensile, opposable hands; emphasis on social groups; a long period of dependency shown by single-birth offspring; and the intelligence and flexibility of our brains for dealing with our world.

In other ways, however, we are atypical primates. We are not arboreal. Our feet are not prehensile but are built to support the entire weight of our upright locomotion. We have especially dexterous hands with long, strong opposable thumbs. We take the longest time of any primate to mature, and we have the largest, most complex brains. Finally, we rely for our very survival on one of the products of those brains: our culture.

The primate fossil record is a complex one that may stretch back to the time of the dinosaurs. Much remains to be explained, especially about the early stages of primate evolution. Clearly, though, our group, the hominids, is a late arrival on the primate scene, splitting off from the African apes a mere 6 to 5 mya.

Study Questions

1. What is our place in nature; that is, where do we humans fit—from a scientific point of view—in the world of living things? How does taxonomy help us describe our place in nature?
2. What are the characteristics of the members of the primate order?
3. What are the different groups of primates? What are their characteristics, basic behaviors, and geographical distribution?
4. In what ways are humans like the other primates? In what ways are we unique?
5. What is the genetic evidence for our relationship with the other primates?
6. What is the basic story of primate evolution?

Key Terms

taxonomy	bipedal	intelligence
notochord	quadrupedal	dominance hierarchy
phenetic taxonomy	stereoscopic vision	grooming
taxon	prehensile	nocturnal
cladistics	brachiate	diurnal
shared derived characteristics	opposability	artifact
	postnatal dependency	neocortex

For More Information

An excellent book that examines humans as an animal species is Richard Passingham's *The Human Primate*. Perhaps the major reference work on the nonhuman primates is *The Natural History of the Primates* by J. R. and P. H. Napier. The National Geographic Society's *The Great Apes: Between Two Worlds*, by M. J. Nichols and colleagues, discusses not only the four species of apes but also talks about the scientific studies conducted on

CONTEMPORARY ISSUE

What Is the Status of Our Closest Relatives?

In a nutshell, the answer is, not good. The International Union for Conservation of Nature and Natural Resources (www.redlist.org) recognizes 296 species of primates.* Of these, 20 are listed as "critically endangered," 48 as "endangered," 46 as "vulnerable," and 47 as "near threatened." The rest are "lower risk/ conservation dependent," "least concern," or "data deficient" (none of which are necessarily good signs).

And it's getting progressively worse, especially in Africa and especially among the great apes. An estimated 80 percent of the world's gorillas and most chimpanzees live in the West African countries of Gabon and the Republic of Congo. In Gabon, the populations of those species have decreased by more than half over the last twenty years. Two-thirds of the gorillas in a sanctuary in Congo died in 2003. At its present rate of decline, the bonobo will be extinct in the wild in a decade. In the mountains east of those countries, the population of the rare mountain gorilla (made famous by the book and film *Gorillas in the Mist*) is thought to be down to fewer than 650 individuals.

What is causing this disastrous decline? Worldwide, we humans threaten the primates, as well as other endangered species, through our overpopulation, depletion of resources, warfare, habitat destruction, pollution, hunting, and other direct exploitation of innumerable species, both plant and animal. In the case of the African apes, the effects of hunting have been recently exacerbated by the "bushmeat" trade, targeting any number of large native animals, including chimpanzees, bonobos, and gorillas. The encroachment of logging and mining into these animals' habitats (particularly in Congo, which is rich in coltan, an ore used in the production of cell phones and laptops) has brought an influx of workers who subsist on the meat of whatever animals are available to hunt, whether endangered or not. Elsewhere, local peoples in need of food in their poverty-stricken countries are also turning to hunting. And most egregiously, and the main motivation for hunting, there is a lucrative commercial market for bushmeat in African cities and towns as well as abroad. Some believe that hunting caused the first recorded primate

*There are not that many acknowledged species, so some of these are certainly named subspecies.

them in the wild and the dangers they now face from their closest primate relative. For an informative and beautifully illustrated book on the primate order, see Noel Rowe's *The Pictorial Guide to the Living Primates*. Most of the primate photos in this chapter were taken from that book.

More on the linguistic abilities of the apes can be found in "Chimpanzee Sign Language Research" in *The Nonhuman Primates*, by Phyllis Dolhinow and Agustín Fuentes.

On the importance of brain size, see the interesting article in the December 1999–January 2000 issue of *Natural History* by Göran E. Nilsson, "The Cost of a Brain."

For the evolution of the primates up to the hominids, see John G. Fleagle's *Primate Adaptation and Evolution*. The story of *Gigantopithecus* is extinction—of the wonderfully named Miss Waldron's red colobus, an African monkey.

Related to the bushmeat trade is a serious threat to humans—the virus that causes Ebola, the hemorrhagic fever whose origin is still unknown (Walsh et al. 2003). Ebola decimated the gorillas at the sanctuary in Congo and is now spreading toward a national park that has one of the largest, densest ape populations in the world. Outbreaks of the disease in apes coincide with outbreaks in human populations, so it is likely that humans are contracting Ebola from apes, largely as a result of hunting and eating them. It's unclear whether the apes are transmitting the disease to one another or are, because there are more and more humans in the forests, being forced into closer contact with the source of the virus (hypothesized to be bats, mice, or birds). But we do know that outbreaks have occurred among apes in regions remote from human habitation as well.

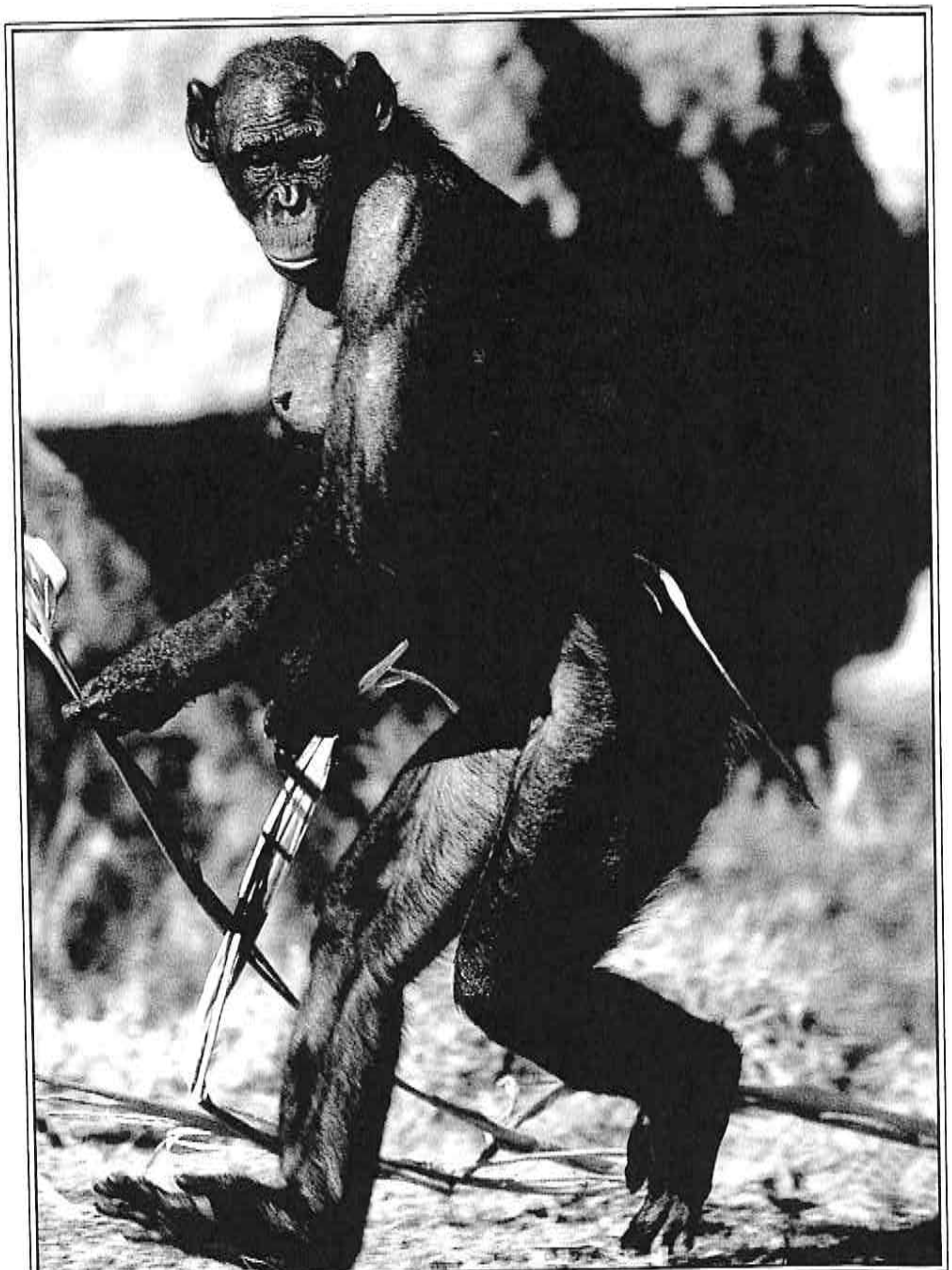
The debate now centers on what action to take. Walsh and his colleagues (2003) recommend that the apes' status be changed from "endangered" to "critically endangered." They also suggest that only a "massive investment" in law enforcement to prevent hunting will stem the bushmeat trade. As for Ebola, some have suggested transporting apes to a safe area or otherwise dividing infected groups from noninfected groups. If, however, the apes are continually contracting the disease from its still-unknown source, these measures won't do much. There is an experimental vaccine that works on monkeys, but it still requires testing, and administering it to wild animals would be a difficult task.

The prospects, in other words, don't look good—either for the apes of West Africa or, in the long run, for the world's other primates and all the other endangered species of life. At times, the situation seems hopeless, but various organizations are working tirelessly to prevent the local zoo from ultimately being the *only* place to see the apes and other species. For more information on the crisis, what is being done, and how we can help, see http://pin.primate.wisc.edu and click on "Conservation" under the heading "About the Primates." Also see www.unep.org/grasp for information on the United Nations Great Apes Survival Project. To paraphrase Gandhi, whatever we do might be insignificant, but it is very important that we do it.

told in *Other Origins: The Search for the Giant Ape in Human Prehistory,* by Russell Ciochon et al. For a more technical piece on early primate evolution, see R. D. Martin's "Primate Origins: Plugging the Gaps" in the May 20, 1993, issue of *Nature.*

The status of the mountain gorilla is discussed in "Gorilla Warfare" by Craig B. Stanford in the July–August 1999 issue of *The Sciences,* and for a consideration of the endangered status of many of the primates from the perspective of a primatologist, see "A View on the Science: Physical Anthropology at the Millennium," by Richard Wrangham, in the April 2000 issue of the *American Journal of Physical Anthropology.*

For conservation information, try the Web sites listed in this chapter's "Contemporary Issue" box, as well as http://primatecenter.duke.edu.



It is no accident that this bonobo, or pygmy chimpanzee, strikes us as so humanlike; our behaviors, including upright walking, have the same evolutionary origin. What can we learn about the evolution of human behavior by examing our close relatives? *(© Frans Lanting, Minden Pictures)*