



ABANG

Orang Stone Toolmaker

Abang, a male orangutan in the Bristol zoo, mastered a skill once thought impossible for apes: he learned to make and use a stone knife.

Apes in the wild do not use stones to shape other stones, although they use rocks to smash hard nuts and fruits. Humans craft stone tools by chipping, shaping, or flaking them with other stones; one of the commonest of ancient blades is a long, sharp-edged flake struck off a larger flint core. In 1971, British anthropologist R. V. S. Wright worked with a five-year-old orang called Abang in the Bristol zoo. Wright repeatedly showed him how to use a flint blade to cut a nylon rope tied around a food box. After about an hour of demonstrations, the orang learned to use the knife to get the food. Soon after, he learned to make his own knife by striking off a flint flake with a hammerstone.

Eventually, whenever Abang was given a tied-up box of food, a flint nodule, and a hammerstone, he quickly made a stone knife and cut the rope.

See also APES, TOOL USE OF; KANZI; ORANGUTAN

ACTUALISM

Continuity of Causality

Actualism is the assumption that the Earth's past can be explained in terms of natural processes observable in the present. Many historians credit James Hutton (*Theory of the Earth*, 1788) with first applying it to geology.

Half a century later, the works of Sir Charles Lyell, a meticulous field geologist, solidly established actualism. Lyell made it the keystone in his cluster of ideas later known as uniformitarianism—the foundation of modern geology.

Lyell's subtitle for his *Principles of Geology* (1830–1833) is *An Attempt to Explain the Former Changes of the Earth's Surface by Reference to Causes Now in Operation*. His systematic observations of erosion, sedimentation, and volcanic formations enabled him to clarify many long-standing mysteries about the Earth's features. Unlike his predecessors, Lyell did not fall back on miracles or divine intervention to explain ancient events. (He was stymied, however, by the origin of the Earth, since no comparable processes appeared to be observable now.)

Catastrophist geologists believed that most of the Earth's history was a series of cataclysms or upheavals unlike anything known today, involving drastically different processes. Though actualism eventually led to the downfall of catastrophist geologists, some of them initially embraced Lyell's approach. If more ordinary geologic features had been produced by known causes, they reasoned, then those that defied explanation could safely be assigned to forces outside the range of human knowledge.

By 1840, Lyell's uniformitarian principles had exerted a huge influence. Not only did they set the tone for the next century of geological research, but they also directly influ-

enced Charles Darwin's view that species originated gradually through ordinary reproduction, rather than suddenly through supernatural agencies. Darwin had read Lyell during his voyage aboard H.M.S. *Beagle*, and later claimed his theories about geology came "half out of Lyell's brain."

But while Lyell had no problem in imagining that great canyons or mountain ranges had been shaped slowly by natural forces over eons, he balked at accepting a similar process for the human species. It was not until 1863, in *The Antiquity of Man*, that Lyell publicly supported Darwin's ideas about the continuity of life in the natural world, though he still skirted the issue of humans. Perhaps, he grudgingly conceded, "community of descent is the hidden bond which naturalists have been unconsciously seeking while they often imagined that they were looking for some unknown plan of creation."

See also CATASTROPHISM; GRADUALISM; LYELL, SIR CHARLES; PROGRESSIONISM; STEADY-STATE EARTH; UNIFORMITARIANISM

ADAM AND EVE

Biblical Primal Couple

In the Old Testament, the Lord creates the first man out of clay, breathes life into him, and calls him Adam, which means "from the dust of the Earth." When Adam becomes lonely in his Garden paradise, the Creator fashions the woman Eve from the man's rib, as "an help meet [suitable] for him"—commonly misread as "a help-mate." (Despite common belief, men do not have one fewer pair of ribs than women.)

Until the first couple violates the Lord's instruction not to eat the fruit of the forbidden Tree of the Knowledge of Good and Evil, they live in total harmony with nature, over which they are given "dominion." Before the Expulsion, they spend their days enjoying the benevolent works of the Creator and inventing names for all the plants and animals in the Garden.

Linnaeus, the great Swedish botanist who founded the system of biological classification, insisted Adam was "the first naturalist." To spend one's life studying, classifying, and giving names to plants and animals, Linnaeus wrote, was therefore sanctified in tradition as a manner of worshiping God (an excellent response, not incidentally, to bookish churchmen who scorned his practice of collecting dead plants and animals as vulgar).

Did Adam and Eve have navels? For painters and sculptors of religious subjects, this was a controversial question of great practical concern. During the Renaissance, the primal couple was sometimes represented without them, since neither was born of woman. Other artists avoided the question with strategically placed shrubbery. Some theologians argued the first man and woman were "finished" creations; they sported belly buttons though they never actually had an umbilicus—just as Eden's tree trunks were created complete with growth rings.

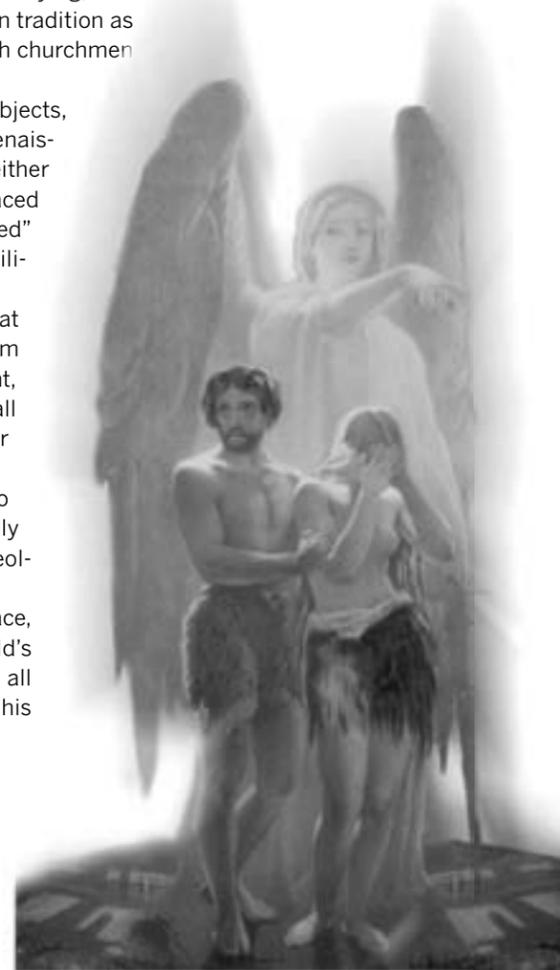
A popular 19th-century natural history writer, Philip Gosse, seized on that idea in an ill-conceived effort to finally reconcile scripture and science. If Adam and Eve's hair, fingernails, and navels were created complete in an instant, bypassing growth and development, he argued, then God must have created all the Earth's fossils and geologic strata as false remnants of a past that never actually happened.

Gosse's infamous 1857 book *Omphalos* (Greek for navel) was not credible to scientists and clerics alike. The Reverend Charles Kingsley, for instance, sadly confessed that if such mental contortions were really necessary to reconcile geology with the Bible, it shook his faith in scripture.

Mark Twain thought that Adam and Eve, the "founders" of the human race, deserve a memorial by their descendants. Twain campaigned for all the world's peoples to join in erecting a colossal statue of Adam and Eve—towering over all the divisive religious shrines—to be erected in the Holy Land. No one took his proposal seriously, but for once the celebrated humorist was not joking.

See also OMPHALOS; ORIGIN MYTHS

PRIMAL PAIR was often portrayed with navels by earlier church artists, but 19th-century illustrator John Tenniel avoided controversy by covering up the umbilical question.



ADAPTATION

Shaped for Survival

Fins and flukes evolved as swimming adaptations, wings for flight, and camouflage for defense. Structures and behaviors useful to an organism in a particular environment are adaptations, recognized as such long before Charles Darwin.

Woodpeckers (Darwin's favorite example) get their living by climbing tree trunks and extracting insects from bark. Adaptive features include a thick skull, "shock absorber" neck construction, chisel bill, long, barb-tipped tongue, claws like grappling hooks, and stiff tail feathers for stability. Admiring such adaptations—as narrators of television wildlife films often do—can lead to using them to "explain" evolution.

In fact, the concept of adaptation is one of the most troubling and puzzling in natural history. Since an animal is the product of a long history, its adaptation is relative at any given time. Feathers may now be adaptive for flight, yet they evolved before birds flew—possibly for retaining body heat. How could early wings have been adaptive? Or as paleontologist Stephen Jay Gould put it, "What good is forty percent of a wing?"

Many biologists believe the answer lies in a change or shift in function. A structure's eventual use may be quite different from its origin, a process known as "exaptation." Early flightless "wings" may have been used to stabilize swift-running birds or dinosaurs, as ostriches use them today, or they may have first functioned as heat regulators. Some living birds' wings are not adapted primarily for flying. Penguins use them to swim, and some wading birds curl them into glare shields while fishing in shallow water. For many structures, we cannot determine how they originated, nor what may be their future.

The explanation of the origin of adaptations is one of the most controversial areas in evolutionary biology. One persistent question is whether—as seems likely—new behaviors usually appear first and new structures subsequently evolve. Darwin thought behavior changed first, but rejected Lamarckian notions of organisms "willing" and "striving" in new directions.

Adaptation, which at first seems such an easy, commonsense concept, turns out to be slippery, sometimes even circular and paradoxical. A species is adapted if it survives in its environment, but how do we know it has not simply been dumb-lucky or neutral, while some calamity eliminated its competitors? Mass extinctions have several times wiped out 97 percent of species on Earth. If a species becomes extinct tomorrow, how well adapted was it? And how can one explain such seemingly maladaptive structures as the peacock's glorious tail, which gets in the way of efficient flight or food-getting? (This last question led Darwin to propose his theory of "sexual selection.")

To complicate matters, many species that don't seem adapted to certain environments have moved into them anyway. When Darwin visited the Galápagos, he was fascinated by the plentiful marine iguanas. When not basking on rocky beaches, these large lizards spend their days underwater, grazing on seagrass. Although excellent divers and swimmers, they never (or have not yet) evolved webbed feet or streamlined forms. Their bodies give no obvious indications that they get their living on the ocean floor.

Biologists studying wildlife in a South American rain forest in 1987 found fish that have recently become fruit eaters. When human activity caused regular flooding of the river banks, the fish learned to swim among submerged treetops, feeding on the fruit. In Oregon, a local population of deer (usually vegetarians) now patrol a river's banks, eating beached fish that jump out of the water while spawning. And Galápagos gannets are often found perched on tree branches—bizarre behavior for webbed-footed birds.

One of Darwin's enduring demonstrations was that adaptations are usually not marvels of perfection at all, but historical compromises. On closer examination, they usually turn out to be jerry-built contraptions, products of a unique, opportunistic history.

Darwin explains his views on how adaptations evolve from previously existing structures in this passage from *Orchids*:

Although an organ may not have been originally formed for some special purpose, if it now serves for this end, we are justified in saying that it is specially adapted for it. On the same prin-

ciple, if a man were to make a machine for some special purpose, but were to use old wheels, springs, and pulleys, only slightly altered, the whole machine, with all its parts, might be said to be specially contrived for its present purpose. Thus throughout nature almost every part of each living being has probably served in a slightly modified condition for diverse purposes, and has acted in the living machinery of many ancient and distinct specific forms.

With this approach, Darwin veered away from the natural theologian's concept of "perfect adaptation" by a "Designer." Adaptations are not perfect; they are often demonstrably makeshift. It was much more fruitful to focus on the "contrivances" and contraptions, evidence of made-over parts showing the pathways of an organism's specific, unique history.

Less sophisticated naturalists have, over the years, created fanciful "just-so" stories to explain the origins of particular adaptations. Appalled by these unbounded speculations, some biologists have suggested abandoning the concept of adaptation. They find it too vague to be useful and historically abused as a substitute for solid investigation.

See also CONVERGENT EVOLUTION; DARWIN'S FINCHES; DARWIN'S LIZARDS; EXAPTATION; "JUST-SO" STORIES; ORCHIDS, DARWIN'S STUDY OF; PALEY'S WATCHMATEK; PANDA'S THUMB.

ADAPTIVE RADIATION

See ADAPTATION; DARWIN'S FINCHES; HAWAIIAN RADIATION

AFAR HOMINIDS

Ethiopian Fossils

Charles Darwin had written in *The Descent of Man* (1871) that he thought Africa would be the place to seek a sequence of apelike creatures ancestral to humans. "But not even Darwin," wrote paleoanthropologist Tim White, "could have imagined that a single geological deposition in the Horn of Africa would by 2005 have yielded a record of human evolution stretching across the last 6 million years."

Ethiopia's Afar Depression, a vast arid triangle between the Blue Nile and the Red Sea ("Ophir" in the story of Solomon and the Queen of Sheba), has turned out to be the hottest fossil field of the past quarter-century. Three of the Earth's gigantic plates pull and rub against one another in the Afar, creating a junction of rifts where earth movements and erosion of exposed sedimentary deposits constantly bring fossils to the surface. A particularly rich locality, Hadar, is near the Awash River, about 185 miles northeast of Addis Ababa.

Maurice Taieb, a French geologist, began surveying the region in 1971, with American Jon Kalb. The following year this international research team added an American graduate student, Donald Johanson, who discovered a fossil knee joint of an erect-walking hominid, which would later be called *Australopithecus afarensis*, so named for the Afar region. Hoping to find more, he returned the following year and recovered parts of a pelvis, ribs, arm and hand bones, and skull and teeth. With almost 40 percent of the original skeleton represented (after mirror-imaging the 20 percent that was actually recovered), it was the most complete fossil of an early hominid (three million years old) ever found. This skeleton was nicknamed Lucy, after the Beatles' "Lucy in the Sky With Diamonds," a camp favorite.

When the Johanson-Taieb team returned the following season, they surpassed the previous year's success by unearthing the largest collection of hominid skeletal bones ever found at that time depth (3.2 million years ago). This extraordinary fossil trove, "The First Family," provided the first real glimpse of a population sample from that time. Thirteen individuals of various ages and both sexes are represented; the males appear to have been significantly larger than the females. All were relatively short (about four feet tall) with fully bipedal hips, legs and feet—fully upright walkers with chimp-sized brains.

Since the late 1990s, a succession of fossil discoveries by White and others has revealed a remarkable record of later human evolution in the Afar.

A CHILD'S SKULL was unearthed at Dikika, near the Awash River in Ethiopia, close to where "Lucy" was found in 1974. Dated at 3.2 million years, it had a chimp-sized brain.

Reconstruction by Viktor Deak
© Nevrumont Publishing.



Adaptation is relative at any given time. Feathers may now be adapted for flight, but they evolved before birds flew.



AFAR HOMINID FOSSILS from Don Johanson's early Ethiopian expeditions are spread out with chimpanzee skulls from the Cleveland Museum's collection. "First Family" fragments lie near the famous "Lucy" skeleton.

First, there was the Herto cranium, found with finely shaped implements of basalt and obsidian, a volcanic glass. It belonged to an ancient *Homo sapiens*, whose brain was slightly larger than our own, and is dated at 155,000 years ago. Near the Herto site, at Bodo, White found a 300,000-year-old cranium with a somewhat smaller brain capacity; however, it appears to be not fully human.

Nearby, in older sediments, his team found a heavy-browed *Homo erectus*, along with stone tools and remains of extinct animals about a million years old. Further south, at Bouri, in 2.5-million-year-old deposits, White, then with Berhane Asfaw's Ethiopian team, found a creature they called *Australopithecus garhi*. It had an apelike muzzle and a brain the size of a gorilla's, and it was found with cut-marked animal bones.

In 1992, while digging in 4.4.-million-year-old sediments at a place called Aramis, White's team found the even more primitive-looking *Ardipithecus*. Four years later, Yohannes Haile-Selassie of the Cleveland Natural History Museum, reported teeth and bones from a 5.7 million-year-old ape that he named *Ardipithecus kadabba*.

Most recently, in 2006, at a site called Dikika, six miles from where Lucy was found, Zereseny Alemseged of the Max Planck Institute discovered an excellent skull and partial skeleton of a 3.3-million-year-old juvenile female *Australopithecus afarensis*. More complete than Lucy, the three-year-old child was nicknamed Selam, the Ethiopian word for "peace." Over the past 25 years, according to White, the Afar has yielded the remains of 225 hominid individuals. Over several million years, they show a trend toward larger body size, larger brains, smaller teeth, and more sophisticated stone tools.

The importance of the Afar region has increased with each new discovery. Before the 1960s, no paleoanthropologists had ventured there. Taieb was the first to explore the Awash Valley area, with its sparse trees in the midst of Ethiopia's vast, arid desert region. He was interested in mapping its geological features but found himself in a remarkably rich fossil treasure trove. Steep ravines exposed sandstone layers, from which elephant bones, tusks, and extinct rhino remains stuck out as far as the eye could see. In 1964, he was joined by geologist Jon Kalb, who described a similar scene in Hadar, another locality in the Afar. Kalb wrote that he was awed by the sight of "an enormous, flat-lying encyclopedia of natural history with part of one page exposed on this hill, another in that ravine, another on the crest of a ridge. The formidable task ahead of us was to put together the pieces and see how much of any one page we could read."

See also AUSTRALOPITHECINES; JOHANSON, DONALD; "LUCY";

AGASSIZ, LOUIS (1807–1873)

Geologist, Zoologist

One of the most influential naturalists of the 19th century, Louis Agassiz (AGG-uh-see) was a comparative anatomist of the old school, who had studied with Georges Cuvier in Paris. His comprehensive, meticulous volumes on fossil fish practically

established the field, and his work on European glaciations provided the foundation for all future research on ice ages.

Raised in the Swiss Alps, he suspected their glaciers were remnants of vast continental ice sheets, which had left such telltale evidence as isolated boulders, deeply etched grooves in surface rock, and characteristic rubble heaped by the moving ice. Geological studies in Scotland and Ireland produced supporting evidence for his glacial hypothesis. The world's leading geologist, Sir Charles Lyell, rejected the idea as fanciful, but within a few years Agassiz's discovery of periodic ice ages became universally accepted.

After university stints in Europe, in 1848 Agassiz was wooed by Harvard, where he became the most influential zoologist and paleontologist in America. He founded the Agassiz Museum of Comparative Zoology there. Completed in 1860, it is preserved today as a Victorian-style natural history museum, just as he designed it—a three-dimensional textbook of the Plan of Creation as reflected in classification.

As an educator, he hoped he had "taught men to observe." He advised students to "read nature, not books. . . . If you study nature in books, when you go out-of-doors you cannot find her." One of the standard ordeals he imposed on new students was to leave them alone in a room for hours with a reeking preserved specimen of a fish or bird, telling them they must not leave until they made a detailed written description of everything they could observe about it. Frequently, he would send them back for additional hours—or even days—of communing with it until he was satisfied with their observations.

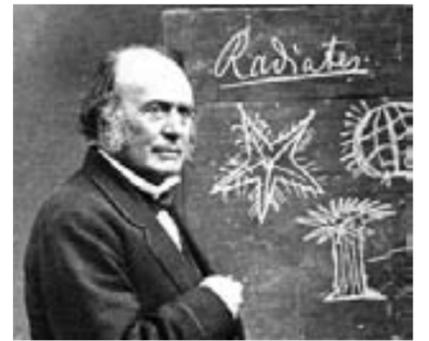
Despite his studies of fossil animals and ancient climatic changes, Agassiz remained a staunch antievolutionist. A believer in divine plans and ideal forms, he thought that later species must have had separate, successive creations, unrelated to what had gone before. Each time the ice sheets retreated, the Earth was repopulated by divine creation of new species.

In his *Methods of Study in Natural History* (1863), Agassiz compared the idea of continuous evolution—then known as the development hypothesis—to medieval alchemy. "The philosopher's stone is no more to be found in the organic than the inorganic world," he insisted, "and we shall seek as vainly to transform the lower animal types into the higher ones by any of our theories, as did the alchemists of old to change the baser metals into gold."

Standing on his reputation as the greatest naturalist in America, he ridiculed the Darwinian theory when it appeared in 1859 and refused to reconsider his position to the end of his life. Agassiz was stunned, however, when his best students, including his own son Alex, a marine biologist, abandoned his system of thought and adopted Darwinian theory. Because his own teacher Cuvier had appeared to prevail over Lamarck's earlier evolutionism, Agassiz had convinced himself that he would "outlive this mania." Instead, his influence gradually eroded until he slipped off his pedestal as a leader of biological thought.

Years after his death, during a California earthquake, a huge marble statue of Agassiz actually did topple from the Zoology Building of Stanford University. Though unbroken, it was found upside down, head firmly planted in the cement. Stanford's first president, David Starr Jordan, recorded in his memoirs that one professor declared that he had always thought that Agassiz was "better in the abstract than in the concrete."

See also ICE AGE; MILLER, HUGH; PROGRESSIONISM



TOPPLED FROM HIS PEDESTAL as leading zoologist of the 19th century, Professor Louis Agassiz refused to recognize the Darwinian revolution in biology. After the California earthquake in 1906, a large statue of Agassiz was found upended, with its head stuck firmly in the ground.

AGNOSTICISM

Seeking Evidence for Belief

Evolutionist Thomas Henry Huxley (1825–1895) may not have been the first agnostic, but he was the first to call himself one. Comparative physiologist, innovative educator, and “Darwin’s bulldog,” Huxley’s interests ranged widely over science, religion, and philosophy. He coined the term “agnostic” in 1869, when he joined London’s Metaphysical Society, a group of theologians, scientists, and writers who met to explore questions of belief.

When asked whether he was an atheist, a Christian, a theist, a materialist, an idealist, a freethinker, or a pantheist, Huxley was at a loss. He hadn’t “a rag of a label to cover [himself] with” and felt like the proverbial fox without a tail who was disowned by his fellows.

The one thing in which most of these good people were agreed was the one thing in which I differed from them. They were quite sure they had attained a certain “gnosis”—that is, a revealed knowledge of the truth about existence.

So I took thought, and invented what I conceived to be the appropriate title of “agnostic,” (meaning without revealed knowledge). It came into my head as suggestively antithetic to the “gnostic” of Church history, who professed to know so much about the very things of which I was ignorant; and I took the earliest opportunity of parading it at our Society, to show that I, too, had a tail, like the other foxes. To my great satisfaction, the term took.

Agnosticism, Huxley took pains to point out, “is not a creed but a method,” a skeptical, experimental approach to personal belief. “In matters of the intellect,” he advised, “follow your reason as far as it will take you [and] do not pretend that conclusions are certain which are not demonstrated or demonstrable.” Nevertheless, he had “a deep sense of responsibility” for his actions, and nurtured a profound religious feeling without relying on organized religion. When Huxley’s young son died in 1860, the Reverend Charles Kingsley asked if he now regretted his lack of belief in the soul’s immortality.

In an uncompromising and moving letter, Huxley replied:

If a jeering devil asked me what profit it was to have stripped myself of the hopes and consolations of the mass of mankind . . . [I should answer] truth is better than much profit. . . . [I] refuse to put faith in that which does not rest on sufficient evidence, I cannot believe that the great mysteries of existence will be laid open to me on other terms.

See also HUXLEY, THOMAS HENRY; METAPHYSICAL SOCIETY; SECULAR HUMANISM

AKELEY, CARL (1864–1926)

Artist Who Saved African Apes

Gorillas, one of our close evolutionary kin, have yielded important clues to the roots of human behavior. But without the impassioned concern of artist-taxidermist Carl Akeley, there might have been no gorillas left in the mountains of central Africa for anyone to study.

Akeley became interested in animals while still a boy in the farming town of Clarendon, New York. A self-taught taxidermist by age 13, he practiced on neighbors’ pets that had died, and then moved to Rochester to work at Ward’s Natural Science Establishment. There he helped mount P. T. Barnum’s famous Jumbo, when the elephant was killed in a circus train accident—a big step up from the neighbors’ canaries.

Hired by Chicago’s Field Museum to create a series of dioramas of North American mammals, he invented an entirely new method of taxidermy. After measuring muscles and bones when the animals were skinned, he sculpted clay models in realistic action poses. These were cast in plaster, and a light, hollow shell made from the mold. Finally, the skin was carefully fitted over the sculpture. So startlingly lifelike were the results of his art that the Akeley Method was adopted by all world-class museums.

Akeley went to Africa for the Field Museum in 1896 and again in 1905. He fell in love with its wildlife—though the animals did not always return his affection. On his first trip, he was

mauled by a leopard he wounded, which bit deeply into his left arm. Somehow, he managed to kill the enraged cat with his bare hands and escaped with his life.

After his African wildlife exhibits won fame and an invitation to dine at the White House with President Theodore Roosevelt, he was hired by the American Museum of Natural History in New York. In 1909, he joined Roosevelt’s hunting safari in Uganda, where the president shot an elephant for the museum’s mounted herd.

During the same field trip, Akeley had another close call when a bull elephant attacked. While recuperating, he conceived the museum’s great African Hall: a wide-ranging depiction of the continent’s ecology and wildlife. “My fondest dream,” he called it, “the unifying purpose of my work.”

Although it has endured as a world-class museum treasure, Akeley did not live to see his masterpiece completed. Delays and arguments among museum officials, and drawn-out quests for funding resulted in years of delay. Akeley’s assistants and colleagues, whom he had trained, completed all the dioramas after his death.

Inspired by the accounts of explorer Paul du Chaillu, Akeley became increasingly attracted by the gorillas of the Virunga volcano in the Belgian Congo. When he returned to Africa in 1921, he sought the elusive apes in their remote forest home, became completely fascinated, and was the first to take motion pictures of them in the wild. Although they were new to science, European “sportsmen” ruthlessly hunted them.

Despite intense feelings of affection and kinship for the great apes, Akeley shot five of various ages and sexes, took casts of their faces and hands and brought their skins back to New York for his African Hall. His mounted family group, frozen in time as they browse in their lush mountain forest, is a masterpiece that still excites millions of visitors. Even Dian Fossey, the most fanatic of gorilla conservationists, said when she saw them for the first



If Carl Akeley had not convinced the King of Belgium to protect mountain gorillas, the apes would be extinct today.

SEEING HIMSELF reflected in the gorillas he protected, naturalist-taxidermist-sculptor Carl Akeley contemplates an ape’s death mask, below. In the American Museum of Natural History’s African Hall he mounted an entire herd of elephants, setting a new standard of artistry.





MAN IN THE MIRROR
Carl Akeley in his field tent after tangling with a leopard, which he killed with his bare hands.

time in 1983 that she didn't begrudge Akeley the taking of those gorillas—so "respectful" had he been in creating the classic diorama.

Starting in about 1922, Akeley became an insistent, lone voice calling out for the conservation of gorillas as a world treasure, and his campaign impressed the Belgian ambassador. Finally, he took his case directly to King Albert, who convinced the Belgian government to create the Parc National Albert in 1925.

In 1926, Akeley returned there to work with photographers, artists, and botanists on the background for his gorilla habitat group. Although afflicted with dysentery, he led his party through the soaking, misty forests to the heart of the gorillas' homeland, which he considered "the most beautiful spot in the world." There Carl Akeley died and was buried by Mary, his third wife, and a small group of friends.

Concrete was brought to the remote site, and Akeley's forest grave was turned into a permanent memorial, later visited by such noted naturalists as George Schaller and Dian Fossey when they followed him in observing wild gorillas. However, in 1979, at the peak of hostilities between Fossey and local gorilla poachers, the grave was broken into and Carl Akeley's bones were stolen. In 1990, some bones and a skull, presumed to be Akeley's, were anonymously returned, and Akeley's biographer, Penelope Bodry-Sanders, repaired the memorial.

But "his greatest memorial," writes Bodry-Sanders, "is that the mountain gorillas still walk the earth today. They are endangered . . . and under constant pressure from poachers and human encroachment, but they still exist." If it had not been for Carl Akeley, the gorillas' evidentiary link to human beings might have been lost forever, within a century of their discovery.

See also *CHRYSLIS*; *FOSSEY, DIAN*; *GORILLAS*

ALEX (1976–2007) Language-Learning Parrot

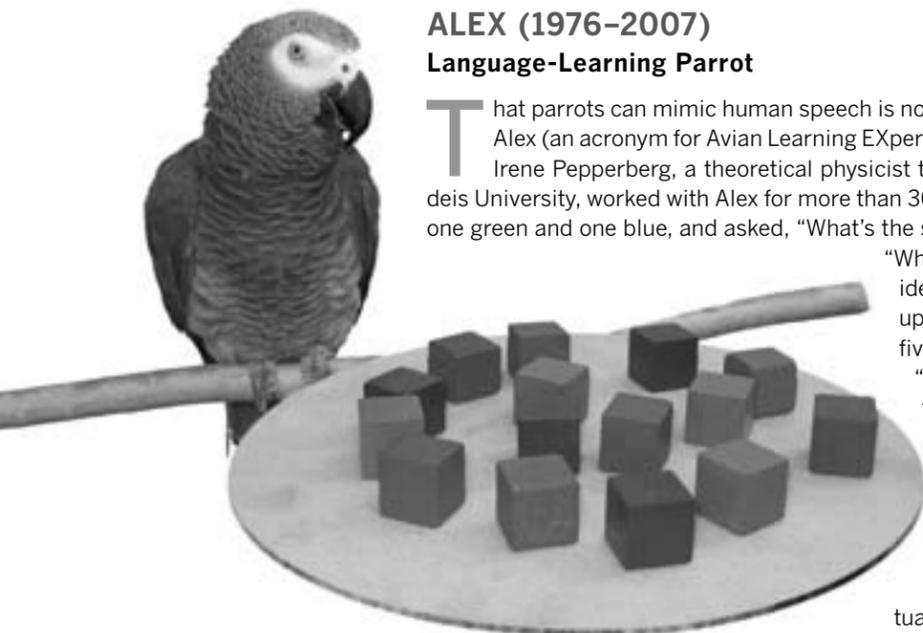
That parrots can mimic human speech is no surprise, but an African grey parrot named Alex (an acronym for Avian Learning EXperiment) seemed to know what he was saying. Irene Pepperberg, a theoretical physicist turned cognition researcher based at Brandeis University, worked with Alex for more than 30 years. When shown two wooden triangles, one green and one blue, and asked, "What's the same?" Alex would reply, "Shape." If asked,

"What's different?" he said, "Color." He could identify 50 different objects, count quantities up to six, distinguish seven different colors, five shapes, understand "bigger," "smaller," "same," and "different," and understand the concept of absence ("none"). More talented than Pepperberg's other two parrots, Alex analyzed hundreds of shape and color combinations he had never seen before.

Until Pepperberg's first publication in 1981, scientists considered conceptual use of symbols unique to primates. Alex asked for things by name ("I want cork" or "Want key"), then demonstrated he really wanted the items by clean-

ing his beak with the cork or scratching his head with the key. If given a key when he asked for cork, he would toss it back. He knew more than 100 words and used them appropriately in simple sentences. He said "No!" ("nuh") or "I'm gonna go away" when he didn't want to do something, and sometimes demanded rewards by saying "Want a nut" loud and clear.

AFRICAN GREY PARROT
Alex astounded scientists for 30 years with his analytical and communicative skills, surpassing those of many primates.



Alex's communicative abilities have yet to make anything like the popular impact of Jane Goodall's chimps "fishing" termite mounds with twigs—a possible example of our primate bias. Yet the bird's accomplishments, with a brain the size of a thimble, may well revolutionize our estimation of conceptual capacities among nonhuman beings.

According to Pepperberg, Alex's final words as she returned him to his cage for the last time were his customary "You be good. See you tomorrow. I love you."

See also *APE LANGUAGE CONTROVERSY*; *CLEVER HANS PHENOMENON*; *KOKO*; *NIM CHIMPSKY*; *WASHOE*.

ALLELOCHEMICALS Evolutionary Poisons

In the course of the evolutionary "struggle for existence," many animals and plants have evolved chemical defenses against predators. Such natural chemicals that affect the health, behavior, growth or population biology of members of other species are called allelochemicals.

Many plants produce substances that are toxic to the insects, bacteria, rodents and even viruses that try to feed on them. One of the most common allelochemicals, known as L-canavanine, has been identified in 1,200 legumes, including clover, wisteria, alfalfa, and some trees. When hookworm larva were fed L-canavanine in experiments at the University of Kentucky, it interfered with their protein metabolism, thereby disrupting development and producing defective adults.

Some creatures utilize allelochemicals even though they cannot produce them. Certain caterpillars, for instance, have evolved an immunity to the poison leaves on which they feed. When attacked by ants, they repel them by regurgitating a chemical derived from the leaves at their foes.

Research into allelochemicals is providing a new source of pesticides and other agricultural poisons; natural products without the harmful side effects of DDT and other artificial chemicals.

See also *NATURAL PRODUCTS CHEMISTRY*

ALLOPATRIC SPECIATION Evolution and Geographic Isolation

We enjoy a freedom of movement today that is new in the Earth's history. Until a century ago, most animals were often blocked in their travels by mountains, oceans, rivers, forests, or deserts, which created small, isolated breeding populations.

For instance, a river may divert and cut across a population's range, leaving breeding groups on either side. When populations are genetically isolated, they may diverge, first into geographic subspecies and, finally, species. These are known as "allopatric" ("different places") species. More rarely, new species may evolve from within a single, widely spread out population ("sympatric" or "same place" species).

Because individual subgroups encompass only part of the population's total variability, they take on different characteristics. As a result of sampling error (see *GENETIC DRIFT*), one cut-off group may have a higher proportion of the same genes or the presence or absence of particular alleles or mutations.

In small populations, such random differences can easily become established and passed on to a large number of descendants. Thus, the most common "origin of species" may occur on the very edge of species ranges, with very small subpopulations that have become isolated from the main population.

After a time apart, if the barriers are removed and two populations should remingle, they may have evolved differences in behavior, color, or vocalization ("isolating mechanisms") that still keep them from mating.



AMERICAN PALEOZOIC MUSEUM

Victorian Dinosaur Disaster

A VICTORIAN VISION of monsters appears in this drawing (left) by Benjamin Waterhouse Hawkins of the ill-fated Paleozoic Museum he planned for New York's Central Park. Hawkins's earlier statues (right) survive in a park in Sydenham, England.

Photo on right courtesy of Gryphon Films.

After Benjamin Waterhouse Hawkins (1807–1894), the first great dinosaur artist, created a successful prehistoric park in England, Americans wanted a bigger, better one. Under anatomist Richard Owen's direction, Hawkins had sculpted life-size models of the giant saurians at London's Crystal Palace—inventing the first dinosaur theme park. His monsters were so popular with the public that he was invited in 1869 “to undertake the resuscitation of a group of animals of the former periods of the American continents” in New York City's Central Park.

Working with the paleontologist Edward Drinker Cope in Philadelphia, Hawkins absorbed the fossil hunter's dramatic tooth-and-claw view of prehistoric life. He took molds of American dinosaur skeletons and a year later began work at a studio in Central Park.

Hawkins began to model huge hadrosaurs being attacked by smaller dinosaurs, while others fought over carcasses. Giant aquatic reptiles were to be half-submerged in real pools. Visitors would enter a huge, domed cavern, where mammoths and giant sloths awaited them—a “complete visual history of the American continent from the dawn of creation to the present time.”

Unfortunately, the project ran afoul of the infamous Tweed Ring, a nest of corrupt, powerful politicians who controlled most municipal projects. In 1870, their leader, “Boss” William Tweed, managed to wrest control of all construction in Central Park from the commission that had hired Hawkins. With the false claim that it was costing the city too much money, the Tweed Ring ordered work on the project stopped. Hawkins was ridiculed in the press as an impractical dreamer.

By the spring of 1871, Hawkins had finished the plaster casts of seven major figures and was battling to keep the project alive. Late one night, Tweed's hired vandals smashed the molds with sledgehammers, destroyed sketches and small models, and taunted Hawkins about his “alleged pre-Adamite animals.” To this day, Tweed's motives are unclear. Was it pure greed, because he couldn't make a huge profit from the project? An issue of control over turf? Or did religious zealotry fuel his implacable antagonism for the Paleozoic Museum?

Whatever Tweed's reasons, the result was a shattered studio and a Hawkins broken in spirit. He retreated to the Princeton Natural History Museum, where he spent a few years painting imaginative prehistoric landscapes, then returned to his native England in 1877. The smashed remnants of his work, his models, and his studio remain buried today near 63rd Street in the southwest corner of Central Park.

A few of his small models and sketches were rescued and give some inkling of what the magnificent exhibition might have looked like. His restorations were fanciful and inaccurate by present standards, but embody the unique style and viewpoint of their time. Hawkins's first prehistoric garden built for England's Crystal Palace survives at Sydenham

Park, in South London, where some of his splendid Victorian dinosaurs, still standing among streams and flower beds, remain to delight new generations.

See also HAWKINS, BEJAMIN WATERHOUSE.

ANIMAL RIGHTS

Inter-Species Morality

Humanity's absolute right to use animals as it sees fit—hunt them, eat them, wear their skins, experiment on them—was for many years justified by the passage in Genesis where God gives man “dominion over all the beasts.” Indeed, throughout the 19th century, many scientists maintained that the purpose of animals was to be used by man. Horses were made for human transport, foxes for fur, and sheep and cows for meat. Anatomist Richard Owen of the British Museum even noted that there was a convenient gap in horses' teeth where the metal bit was “meant” to be inserted to anchor the reins.

When Darwin established an evolutionary kinship between species, he saw at once it might imply a moral obligation not to abuse animals. In one of his early private notebooks, he had jotted that “animals our fellow brethren in pain, disease & death & suffering & famine; our slaves in the most laborious work, our companions in our amusement, they may partake, from our origin in one common ancestor we may be all netted together.”

His disciple in America, the Harvard botanist Asa Gray, pursued the point: “It seems to me that there is a sort of meanness in the wish to ignore that tie. I fancy that human beings may be more humane when they realize that, as their dependent associates live a life in which man has a share, so they have rights which man is bound to respect.” The philosopher Bertrand Russell snorted that “such a philosophy could logically end with the demand of Votes for Oysters.”

Yet many religions—including the Jewish and Christian—have a tradition that grants animals the status of independent beings, created without reference to human wants, as in this rarely quoted passage:

For the fate of the sons of men and the fate of the beasts is the same; as one dies, so the other. They all have the same breath, and man has no advantage over the beast for all his vanity. All go to one place; all are from the dust, and all turn to dust again. Who knows whether the spirit of man goes upward and the spirit of the beast goes down to earth? (Ecclesiastes 3:18)

Naturalist Henry Beston put it another way in his classic 1928 book, *The Outermost House*: “Animals,” he wrote, “are not brethren. They are not underlings. They are other nations—caught with ourselves in the net of life and time, fellow prisoners of the splendor and travail of the earth.”

The modern movement for animal rights, which was spearheaded by Princeton University philosopher Peter Singer, has made an impact. Through the efforts of activists, including Jane Goodall and the Great Ape Project, captive primates have been granted some protection from abuses. However, apes are better protected in Europe than in the U.S., where there are 3,000 chimpanzees in captivity—half of which are used in medical research. Such use of apes has been banned in the UK, Sweden, Spain, and the Netherlands.

Geneticist Steve Jones of University College London, however, has expressed concern that all animal experimentation could be banned. Taking a page from Russell, he told a BBC journalist, “Mice share around 90 percent of human DNA: should they get 90 percent of human rights?”

ANNING, MARY (1799–1847)

Discoverer of “Sea Dragons”

Mary Anning, a self-taught geologist, became world-famous for finding ancient “sea dragon” remains near her native Lyme Regis, a seaside village in southern England. At a time when virtually all geologists were wealthy gentlemen, Anning became expert at spotting fossils, extracting them from the rocks, identifying species, and analyzing

Mallorca was first to guarantee apes legal rights, such as freedom from mistreatment or death at the hands of humans.



ONCE A FAMILIAR FIGURE combing the cliffs and beaches of Lyme Regis, England, Mary Anning, a self-taught paleontologist, remains a popular local hero.

“I worshipped [the sea dragon] for hours in my mad intoxication of spirit.”

—Thomas Hawkins, *Book of the Great Sea-Dragons*, 1840

their anatomy. Her 200-million-year-old plesiosaurs, ichthyosaurs, and pterodactyls (flying reptiles) became famous, and helped to popularize the infant science of paleontology.

In the early nineteenth century, Lyme Regis was a poor little village, inhabited by rough fishermen and smugglers. Anning’s father, a carpenter, supplemented his meager income by selling curious objects he had found at the water’s edge to tourists. Young Mary assisted him, and seems to have been the inspiration for the famous tongue-twister: “She sells sea-shells by the seashore.” (A popular rejoinder went: “Sam sells clam shells for a lot more.”)

After her father’s death in 1810, Mary and her brother Joseph made fossils their full-time business. Joseph discovered the head of a “crocodile” in 1811, and he and Mary found and restored its skeleton a year later. One of the first ichthyosaurs known to science, it still occupies an honored place in London’s Natural History Museum.

A gentleman geologist, Thomas James Birch, bought many fossils from the Annings, but became appalled at the family’s poverty. When he visited them in 1819, Birch found the Annings “selling their furniture to pay their rent—in consequence of their not having found one good fossil for near a twelve month.” Eventually, Birch sold off his entire fossil collection and donated the proceeds to the Annings, “who have in truth found almost all the fine things which have been submitted to scientific investigation.”

Birch was not alone in his admiration of Mary across the class divide. Famous gentlemen called on her seeking fossils and her analyses of them—which they published under their own names. A female acquaintance wrote in her journal that Mary “says the world has used her ill and she does not care for it. According to her account these men of learning have sucked her brains, and made a great deal by publishing works, of which she furnishes the contents, while she derived none of the advantages.”

Dr. Gideon Mantell, the premier discoverer of dinosaur fossils, visited Anning’s “dirty shop, with hundreds of specimens piled around.” He described her as “the presiding Deity, a prim, pedantic vinegar looking, thin female, shrewd and rather satirical in her conversation.” Every day, in all kinds of weather, Mary could be seen combing the shores and cliffs of Lyme Regis with her collecting bag and geological hammer.

Another wealthy amateur geologist, Thomas Hawkins, related how Mary led him to discover a large plesiosaur skeleton (*Chiropolyostinus*) embedded at the base of a cliff, covered by seawater. He fell in love with the fossil, but Anning advised him against pursuing it, warning, “you will never get that animal, [because] the marl, full of pyrites, falls to pieces as soon as dry.” Undaunted, Hawkins devised a chemical treatment that would preserve it. For days he “lay upon a thorny pillow listening the livelong night to the rumbling gale” and hoping against hope that his plesiosaur would not be destroyed. “The angry waters of the channel,” he wrote, “are pent up by contrary winds and the relic of an incalculably remote generation sleeps on in his oozy bed secure beneath the main.”

At Mary’s urging, Hawkins positioned six workmen to be ready the moment the tide retreated. Within an hour, racing against the return of high tide, the men freed the fossil skeleton and got it into a horse cart. Hawkins gazed lovingly at his dragon as he secured it in a tight wooden case, encased in a shell of plaster of Paris. “I worshipped it for hours,” he wrote, “in my mad intoxication of spirit.” Such was the romance and excitement that Mary Anning had fostered in the quest for her “sea dragons,” which are still the pride of London’s and Oxford’s Natural History Museums. At her death she was honored by London’s Geological Society, a “gentlemen only club” from which she had been excluded in life by the very men who had built their reputations on her achievements.

APE LANGUAGE CONTROVERSY

Capacity for Symbolic Communication

Can animals learn human language? Dyak tribesman told anthropologists that they thought wild orangutans could speak but pretended to be dumb when humans were around, because they were afraid men would put them to work. Charles Darwin’s neighbor, Sir John Lubbock, tried in 1882 to teach his dogs the Sign Language for the Deaf, prompting Samuel Butler’s remark: “If I was his dog and he taught me, the first thing I should

tell him would be that he is a damned fool.” A century later—with Lubbock’s dogs long forgotten—attempts to teach chimps human sign language became fashionable in research.

Robert Yerkes, the pioneering psychologist who began to study captive chimps around 1900, noticed they were more apt to mimic movements and facial expressions than the sounds of human speech. Early on, he suggested trying a visual language, but no one did until the 1960s, when a few psychologists began teaching chimpanzees American Sign Language (Amslan).

Sarah, one of the first famous language-learning chimps, was taught by psychologist David Premack to communicate with standardized plastic chips on a magnetic board. Another researcher taught a chimp called Lana to use a system of geometric symbols on a specially designed computer keyboard. By 1971, a husband and wife team of psychologists had taught Washoe, a young female chimp, 150 hand gestures in simplified Amslan. Next, Herbert Terrace’s Nim Chimpsky mastered a vocabulary of 132 signs.

There were two basic questions. Could chimps learn to associate a given sign, symbol, or word with its referent? And were they capable of combining them into “sentences” according to some kind of rules (grammar)?

Herbert Terrace knew psychologists had been impressed before by “remarkable animals” in flawed experiments. In the nineteenth century, a horse named Clever Hans had amazed scientists when he tapped out answers to mathematical problems—until his trainer was completely removed from view.

In 1979, Professor Terrace publicly challenged his own methods and accomplishments. Reviewing the videotapes, Terrace could not honestly establish that his chimp had really used the symbols conceptually or mastered any of the grammatical rules that structure human language. Yes, Nim had learned scores of gestures, but he was often haphazard about their sequence. (He didn’t seem to know the difference between “Nim eat banana” and “Banana eat Nim.”) And he often produced a lot of irrelevant signs, which the experimenters had ignored.

Apes were playing a game all right, Terrace concluded, but not the language game; they were just running off various signs until they got what they wanted. No one had really demonstrated that chimps understood that signs carry definite meanings.

Those who wanted to preserve human uniqueness in the natural world were delighted, echoing Samuel Butler’s sentiments: Researchers were deluded fools. Grant funding dried up and no new chimp language programs were begun. But the story was far from over; in fact, some surprises lay just ahead.

Duane Rumbaugh and Sue Savage-Rumbaugh, at the Language Research Center of Yerkes and Georgia State University, never doubted their apes had learned to use symbols. The challenge was to convince everyone else, so they redesigned their experiments.

The chimps were now given tasks that were impossible without real symbol use. Sherman and Austin would see a symbol flashed on a screen. The chimps then left the room, entered another room containing many objects, and were to bring back only the object named (symbolized) on the screen. To do this, they had to remember what the symbol stood for. Not only did the chimps retrieve the correct objects, but they came back empty-handed if the named object was not in the other room.



AN OLD QUESTION about men and apes is expressed in this B.C. cartoon by Johnny Hart. Humans did not “come from” any existing ape. Chimps, gorillas, and humans share common ancestors.

Louis Leakey believed that women would be better suited than men to study groups of wild apes without threatening them.

Going even further, Sherman and Austin began to communicate with each other using the signs. After being taught they must share food, the chimps used the symbols to ask each other for specific items. The Rumbaugh's work finally convinced many scientists that apes can use signs to convey meaning, though their ability to form grammatical combinations is extremely limited.

Sue Savage-Rumbaugh and Rose Sevik made a major breakthrough working with pygmy chimps, or bonobos, during the 1980s. While trying with little success to teach language behavior to a wild-born female, they inadvertently discovered that her captive-born son, Kanzi, "had learned everything we'd been trying to teach the mother." Extensive work with Kanzi resulted in his learning and demonstrating more sophisticated vocabulary and communication than in any previous experiments with apes.

During the 1980s, a growing body of research established that language-like abilities (conceptualizing and symbolizing) belong to some very diverse creatures: sea lions, dolphins, pigeons, parrots.

At the University of Hawaii, psychologist Lou Herman's dolphins not only associated hand signs with particular objects ("ball," "disk"), but responded correctly to sentence-like instructions. Without having seen the sequence before, they can tell the difference between "Take the disk to the ball" and "Take the ball to the disk."

But perhaps the most astounding language learner of all is not a primate, but an African grey parrot named Alex. He could identify seven colors, five shapes, and quantities of up to six. And he needed no plastic chips, computers, or signing gestures—he did it in English! With a brain the size of a thimble, he appeared to have some language capabilities that rivaled or even surpassed those of the vastly larger-brained monkeys and apes.

See also ALEX; CLEVER HANS PHENOMENON; KANZI; NIM CHIMPESKY

"APE WOMEN," LEAKEY'S Primate Field Observers

Famous for his discoveries of early hominid fossils in East Africa, Dr. Louis Leakey wanted more than dry bones to help reconstruct early man—he wanted behavior. During the 1960s, he sought a few exceptional individuals to study our closest living relatives, the African apes.

His recruits would face dangerous, difficult years in the wilderness, trying to approach unpredictable animals capable of tearing a human apart—and they would not carry guns. From the first, Leakey believed that women were better suited for the job than men. Women, he thought, were more perceptive about social bonds and maternal behavior, more patient and capable of long-term dedication, and would perhaps appear less of a threat to the male apes.

Jane Goodall, a young Englishwoman, was the first of Leakey's three "ape women," whom he sometimes referred to as his "trimates." She came to visit him when he was curator of the National Museum in Nairobi, and was hired as assistant-secretary on the spot. "He must have sensed," she later wrote, "that my interest in animals was not just a passing phase." She accompanied Louis and Mary Leakey on their next paleontological expedition to Olduvai Gorge, where she absorbed their enthusiasm for understanding the roots of human behavior and evolution. Leakey asked her to study a group of wild chimpanzees he had seen near Lake Tanganyika.

Leakey was particularly interested in the lakeshore habitat because early hominid remains showed evidence of lakeside living. When Goodall protested that she was inadequately trained to undertake such a study, "Louis [told me he felt] a university training was unnecessary, [and] even that in some ways it might have been disadvantageous," she later recalled. "He wanted someone with a mind uncluttered and unbiased by theory who would make the study for no other reason than a real desire for knowledge; and, in addition, someone with a sympathetic understanding of animals."

Next, Leakey wanted to find a "gorilla girl." Like Goodall, Dian Fossey had no university background in animal behavior, but had loved animals since childhood. She was working

as an occupational therapist in Louisville, Kentucky, and had traveled to Africa on vacation to see wildlife. She met Leakey—who spoke of his search to find a woman to study wild gorillas.

In 1966, when Leakey gave a lecture in her home city, Fossey spoke with him about her continuing interest in studying gorillas. "After a brief interview," she wrote in *Gorillas in the Mist* (1983), "he suggested I become the 'gorilla girl' he had been seeking. . . . Our conversation ended with his assertion that it was mandatory I should have my appendix removed before venturing into the remote wilderness" of the Zaire volcanoes. She promised she would have the operation.

Six weeks later, on returning home from the hospital minus her appendix, Fossey found a letter from Leakey. It began, "Actually, there really isn't any dire need for you to have your appendix removed. That is only my way of testing an applicant's determination!" Was he kidding about having the operation, or about not having it? "This was my first introduction," she wrote, "to Dr. Leakey's unique sense of humor."

A few years later, inspired by the efforts of Goodall and Fossey, another young woman, Birute Galdikas, undertook a prolonged field study of the orangutan in Indonesia.

Leakey had found and inspired three "unqualified" amateurs, who, though working outside of academia conspicuously outperformed every established university department of anthropology in the world!

See also APES; FOSSEY, DIAN; LEAKEY, LOUIS

APES

See APES, TOOL USE OF; BONOBOB; CHIMPANZEES; GORILLAS, KANZI; NIM CHIMPESKY; ORANGUTANS

APES, TOOL USE OF A Puzzling Pattern

In an early series of experiments by the German psychologist Wolfgang Köhler published in 1917, a captive chimp named Sultan piled up several boxes, climbed atop this construction, and used a stick to knock down a banana dangling from the ceiling. When given a short stick, he used it to snag a much longer stick just outside his cage, then used the new one to reach up and knock down the prized fruit.

Over fifty years later, in 1971, British Anthropologist R.V.S. Wright decided to settle the question of whether apes were capable of making stone tools. Working with Abang, a five-and-a-half-year-old orangutan in the Bristol zoo, Wright repeatedly demonstrated how to use a flint blade to cut a nylon rope tied around a food box. Abang learned to use the knife to get at the food. Next, he mastered the skill of making his own knife by striking off a sharp flint flake with a hammerstone, and used it to cut the rope.

In 1994, Carel van Schaik of Duke University documented the use of sticks and branches as tools among wild orangutans. In the swamps of the northwest corner of Sumatra, he watched the red apes prepare sticks to use for getting termites, breaking into ants' and bees' nests, and remove sharp spines from wild fruits.

Gorillas, though closely related to chimps and humans, had never been observed to use tools in the wild for getting or preparing food, though they do build night-nests out of sticks and leafy branches. In 2007, however, primatologists studying lowland gorillas in a Congo swamp, where they waded into the water seeking succulent plants, observed the apes using straight sticks or staffs to test the depth of the water and firmness of the mud to hold their weight, much as humans would do.

As is well known, chimpanzees strip the leaves from twigs to prepare them for poking into termite mounds to capture insects. After applying saliva to a thin twig, they push it into a termite burrow, where thirsty insects grab onto it. The apes then withdraw the probe and eat the termites. In 2004, Crickette Sanz of Washington University (St. Louis) and her col-



JANE GOODALL'S CURIOSITY led her to seek out fossil-hunter Louis Leakey in Kenya, never dreaming he would steer her toward studies of wild chimpanzees that would eventually bring her international acclaim. Photo © by Kenneth Love.

leagues videotaped Congo chimps using various kinds of specially prepared twigs—a veritable “tool kit”—to perform different tasks in gathering termites. They may prepare a heavy puncturing stick, a lighter perforating stick, or a light, flexible fishing stick.

Chimpanzees also chew leaves and use them as sponges for gathering water from tree hollows in the dry season, and have been observed using an anvil stone and a bashing stone to smash open nuts.

In 2007, archeologists in Africa discovered a series of stone tools (simple bashing stones and anvils, like those chimps use today) that were made and used by the apes thousands of years ago. Some stones—the first stone artifacts known from chimp prehistory—still contained protein residues of the nuts that were smashed open.

Kanzi, a bonobo at the Georgia State University Language Research Center, has been spectacular at solving problems associated with making tools, including redefining the nature of the experiments. He acquired much of his advanced symbol-using abilities by observing other “educated” chimps, especially his adopted mother.

One primatologist tried to find a pattern. Was evolutionary closeness to humans correlated with proficiency of tool use? No such pattern could be discerned. To confuse matters further, in 2004 Cambridge anthropologists Antonio Moura of Darwin College and Virginia Lee of Cambridge University reported that they observed capuchin monkeys using stones to dig for insects, roots, and tubers, and crack open seeds, and twigs to probe for insects—although the monkey’s brain is the size of a domestic cat’s.

See also CHIMPANZEE, KANZI

ARCHAEOPTERYX

Transitional Fossil

Charles Darwin, in a letter to Charles Lyell, predicted the discovery of an *Archaeopteryx*-like fossil more than two years before it was described. When the fossil was discovered in 1863, his friend Hugh Falconer excitedly informed him:

Had the Solenhofen quarries [in Germany] been commissioned by august command to turn out a strange being à la Darwin—it could not have executed the behest more handsomely—than with the *Archaeopteryx*.

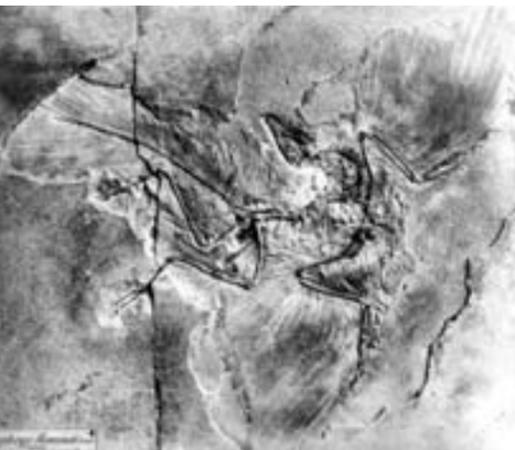
At Solenhofen, a fine-grained stone had been quarried for centuries because it is smooth, porous, and particularly suitable for lithography, such as in printing the famous Toulouse-Lautrec posters. Within these 150-million-year-old Jurassic stones, a beautifully detailed imprint of a single feather was found in 1861, and two years later a complete skeleton of the remarkable creature was discovered. It was named *Archaeopteryx lithographica*—ancient winged creature from the printing stone.

Coming just two years after the publication of *Origin of Species*, it was hailed as a “missing link” between reptiles and birds, a proof of the theory of evolution written in stone. *Archaeopteryx* appeared to be a truly transitional creature, combining attributes of two classes of vertebrate animal. Its feet were suitable for perching, its pelvis seemed birdlike, yet it did not have the keeled breastbone to which flight muscles attach in modern birds nor their light, hollow bones. Feathers were completely birdlike, but the skeleton showed digits on the bifurcated wings, claws, teeth, and long vertebral tail. Darwin called it “the wondrous Bird . . . by far the greatest recent fossil.”

Anatomist Richard Owen, a bitter enemy of the evolutionists, described it as an aberrant bird. But a sharp-eyed paleontologist, John Evans, noticed that Owen had overlooked the fine, perfectly formed teeth within the beak. Congratulating Evans on that crucial observation, Hugh Falconer joked that perhaps he would next find the creature’s “fossil song.”

Attempts have been made over the years, including one in the 1980s by astronomer Fred Hoyle, to prove that the fossil is a fake, cooked up by paleontologists to support their theories. But the microscopic structure of the feath-

THE THROWN-BACK HEAD in this classic *Archaeopteryx* fossil is consistent with death by trauma to the nervous system and can be seen in modern animals that die of brain injury or toxic bacterial infections.



ers, preserved in fine-grained stone, is much too intricate to copy; subsequent discoveries of other specimens have passed every conceivable test for authenticity.

During the 1990s, hundreds of fossil discoveries from China established the existence of many kinds of early birds and “feathered dinosaurs.” Many represent closer and much earlier affinities between dromaeosaurs—upright, meat-eating dinosaurs—and birds. *Archaeopteryx* is now thought to be a very early “bird,” but only one of many transitional species that are now known from the late Jurassic and early Cretaceous.

See also BRANCHING BUSH; BRIDGEWATER TREATISES; CLADISTICS; DINOSAURS, FEATHERED; “MISSING LINK”; TRANSITIONAL FORMS

ARGUMENT FROM DESIGN

See also BRIDGEWATER TREATISES; INTELLIGENT DESIGN; PALEY’S WATCHMAKER; PANDA’S THUMB

ARISTOGENESIS

Evolution by the “Superior Few”

Paleontologist Henry Fairfield Osborn, the influential director of the American Museum of Natural History in its formative years, fancied himself an aristocrat. Upper crust in manners, education, and social standing, he believed evolutionary progress was driven by the “superior few”—his theory of aristogenesis.

Osborn extended his notion of superior and inferior to ethnic groups, never doubting that he and his circle were the highest products of evolution. To the lasting embarrassment of his admirers, he wrote enthusiastic introductions for his friend Madison Grant’s notorious books *The Passing of the Great Race* (1916) and *The Conquest of a Continent* (1933). Grant warned of “Nordic debasement” by a flood of “alien” Italians, Jews, Asians, and Africans unless America maintained strict immigration quotas and laws against “racial intermarriage.”

His theory of aristogenesis also led Osborn to disavow the “apish ancestry” of man—a strange position for America’s leading evolutionist. Instead of Darwin’s ape-man, he imagined a separate, superior line of “dawn-men,” who never lived in forests (*Man Rises to Parnassus*, 1927). “We have all borne with the monkey and ape hypothesis long enough,” he told an audience, “and are glad to welcome this new idea of the aristocracy of man back to . . . a remote period.” Anatomist William K. Gregory claimed Osborn was “afflicted with pithecophobia—the dread of apes as relatives or ancestors.”

See also EUGENICS

ARTIFICIAL SELECTION

Breeding Domestic Varieties

Natural selection is a familiar concept from Charles Darwin’s *Origin of Species* (1859), but he also wrote several volumes on what he called artificial selection—the creation of domestic varieties by breeders.

In *Origin*, Darwin contrasts natural and artificial selection. He makes it clear that natural selection does not create variability—it merely acts on “the individual differences given by nature.” Man selects the variations he can see, while Nature “can act on every internal organ . . . on the whole machinery of life.”



AUTOCRATIC PRESIDENT of the American Museum of Natural History and paleontologist, Henry Fairfield Osborn startled colleagues by disavowing an ape ancestry for humans. In this 1930 newspaper cartoon, a chimpanzee is greatly relieved at the news.



MICKEY MOO, a Holstein cow, was born on a farm in Whitefield, Maine. She was bought by Disneyland in 1988 and bore a calf there—which did not inherit the Mickey shape that made its mother famous.

Humans breed animals for what they find beneficial to themselves, while Nature selects for the benefit of the plant or animal species. Since artificial selection has produced the fastest horses, the most succulent fruits, and the most ornate pigeons, Darwin asked, “What may not natural selection effect?”

Characteristically, Darwin was not content to draw the comparison and rest; he methodically found out everything he could about plant and animal breeding. He built a dovecote behind his house, bred pigeons, and attended meetings of the local pigeon enthusiasts. He bombarded horse breeders, gardeners and agricultural experts with his questions, and performed thousands of botanical experiments in his garden and greenhouse.

In 1868, he published a two-volume work on the subject: *The Variation of Animals and Plants under Domestication*. Here Darwin covers virtually everything that was then known about the breeding of dogs and cats, horses and asses,

pigs, cattle, and other barnyard animals, pigeons, canaries, fowl, bees, fruit, flowers and vegetables. Though little read today, its wealth of detail was invaluable to contemporary gardeners and breeders.

In fact, Darwin had gathered so much material on pigeons that the bird figured prominently in several of his books. When his publisher submitted *Origin of Species* to an independent evaluator for an opinion, the critic wrote back suggesting he cut the theoretical parts and turn it entirely into a book on pigeon breeding! “Everybody is interested in pigeons,” he enthused. “The book would be reviewed in every journal in the kingdom, and would soon be on every library table.”

See also NATURAL SELECTION

“ARYAN RACE,” MYTH OF Racial Supremacist Theory

One of the most infamous and disastrous attempts to trace the racial ancestry of Europe was born as a minor issue in comparative linguistics, developed into a pseudo-Darwinian theory of history, and became a cornerstone of Nazi ideology.

Originally, the term “Aryan” was applied to a language group also known as Indo-European. In the 1780s, Sir William Jones, an English Orientalist, compared languages and grammars and concluded that ancient Indian Sanskrit was related to Persian, Greek, Latin, Celtic and Germanic languages. He thought that they all must have branched off from a lost mother tongue, which he called “Aryan” after the “Aryas,” an ancient people who had supposedly invaded India and Persia. By the mid-19th century, German linguists and anthropologists developed “Aryan” studies into a major branch of inquiry.

It was but a short, illogical step from the notion of a single mother tongue to conjectures about a single original race that civilized Europe.

Count Arthur de Gobineau, a French journalist and historian who claimed aristocratic descent, believed that humankind was divided into three races, differing in degrees of superiority: black at the bottom, yellow in the middle, and white at the top. In his *Essays on the Inequality of the Races* (1850s), he asserted that within the white race, the Aryan branch was the highest of the high. Aryans originated in central Asia, he believed, and were tall, blond, alert, honorable, and powerful.

Gobineau wrote that he was “sure that everything great, noble and fruitful that man has

created on earth . . . issues from a single root, results from a single idea, and belongs to a single family—the Aryan race.” In England, Max Müller, a professor of comparative philology at Oxford, championed the Aryan source of European civilization.

As Müller gathered more evidence, however, his belief that European culture was founded by a pure Aryan race evaporated. In *Biographies of Words and the Home of the Aryas* (1888), he about-faced, arguing that language has nothing to do with race and that a person of any race can learn to speak any language. “An ethnologist who speaks of Aryan race, Aryan blood, Aryan eyes and hair,” he wrote, “is as great a sinner as a linguist who speaks of a dolichocephalic (long-headed) dictionary or a brachycephalic (broad-headed) grammar.” But Müller’s earlier teachings had been enormously influential and had already done their harm.

With the spread of European colonial empires and the inequities of economic domination came the rise of Social Darwinism as a convenient justification for conquest. If evolutionists had taught that it is “natural selection” for the “fittest” to survive, then it was only right that the “superior” white race should dominate and subjugate people with yellow or brown skin. And blond, blue-eyed people should rule over brown-eyed people, Germans over Jews and so on. Darwin would have been appalled. Many times he had emphasized that he was not a Social Darwinist, that he detested slavery, and that his theories about the natural world were misapplied to commerce and politics.

In America, the most famous advocates of “Aryan” supremacy were Madison Grant, who in 1916 wrote *The Passing of the Great Race*, and Lothrop Stoddard, whose *Rising Tide of Color Against White World Supremacy* appeared in 1920. American racists propagandized against “mixing” with people of color, and also tried to bar immigration of “inferior” European types such as gypsies and Jews. Englishman Houston Stewart Chamberlain (*The Foundations of the Nineteenth Century*, 1899) and the German composer Richard Wagner (who published his anti-Semitic diatribe *Judaism in Music* in 1850) directed their venom at European Jews. In their popular writings, everything that was good, true, and pure was Aryan; everything that was low and degraded was Jewish.

As the Aryan hysteria continued to froth, any serious examination of language stocks or ethnic histories was now completely overwhelmed by polemics, hatred and politics. Chamberlain wrote this prophetic statement in his *Foundations*: “Though it were proved that there never was an Aryan race in the past, yet we desire that in the future there may be one. That is the decisive standpoint for men of action.” When asked to define an Aryan during the height of the Nazi madness, Josef Goebbels proclaimed, “I decide who is Jewish and who is Aryan!”

During the German Third Reich (1933–1945), the ideal of Aryan purity and supremacy became national policy. Adolph Hitler’s program of herding “inferior” races into concentration camps and gas chambers was rationalized as making way for the new order of superior humanity. Meanwhile, S.S. officers were encouraged to impregnate selected women under government sponsorship to produce a new “master race”—an experiment that produced a generation of ordinary, confused orphans.

Hitler was furious when the black American Jesse Owens outraced “Aryan” athletes at the 1936 Berlin Olympics, contradicting his theories of racial supremacy. And when the “Brown Bomber” Joe Louis knocked out boxer Max Schmeling in 1938, German propaganda became even more vehement that white superiority would be vindicated. However, when Hitler needed the Japanese as allies in World War II, he promptly redefined the Asians as Aryans.

Historian Michael Biddiss has commented that “the history of the Aryan myth demonstrates the power of belief over the power of knowledge. . . . We may now hear more often of Caucasians than of Aryans, but the substance and errors of the belief in white supremacy linger.”

See also LEBENSBOHN MOVEMENT



ARYAN SUPREMACY POSTER, issued by the Nazi government in Germany (1932), shows a steely Nordic knight battling the many-headed reptile of “inferior races” within the Fatherland. It reads, “Fight the danger! Damage prevention is your duty! This concerns you!”

Heinrich Himmler, head of Hitler’s Stormtroopers, believed the “Aryan race” originated separately from the rest of humankind, preserved as “living shoots” in ice crusts from outer space.



ATAPUERCA “Pre-Neanderthal” Death Pit

The gently rolling hills known as the Sierra de Atapuerca in northern Spain hide a complex system of limestone caves where archeologists have uncovered abundant—if enigmatic—evidence of western Europe’s earliest inhabitants.

Hundreds of bones and artifacts have been recovered from two principal Atapuercan sites over the past quarter-century. Although the caves are quite close to one another, their contents are believed to date from very different time periods—and apparently represent different species of hominids.

Railroad workers uncovered the first site, Gran Dolina, when they blasted a hillside to make way for train tracks in the 1890s, exposing an enormous sequence of prehistoric deposits. Archeologists, alerted by the railroad company, immediately recognized it as an “early man” site. Excavations in the 1990s revealed eleven stratigraphic levels. With an influx of government funding and the help of hundreds of student volunteers during that period, the pace of excavation and discovery dramatically accelerated.

The site has yielded hominid fossils, 200 stone tools, and more than a thousand fossils of horses, deer, rhinoceros, bison, wolves, wild cats, elephants, and other animals. Most exciting for Spanish paleontologists José María Bermúdez de Castro, Juan Luis Arsuaga, and Eudald Carbonell, in 1994 their team unearthed a partial skull, jaw, and skeletal fragments of a new species of human, which they named *Homo antecessor*, “the man who came before.” Because the layers were rich in marker pollens, small mammal fossils, and rocks amenable to dating by measuring their ancient magnetic fields (a technique first developed in the 1960s and 1970s for determining the age of tectonic plates), the team was able to date the skull at 800,000 years old. It appears to have belonged to an 11-year-old male, nicknamed the “Gran Dolina Boy.” Bermudez de Castro and his colleagues believe *H. antecessor* represents the last common ancestor of modern humans and pre-Neanderthals; many of the latter’s remains were found together at the other, later Atapuercan site.

Also at Gran Dolina, the scientists discovered many bones of animals with telltale marks caused by cutting, scraping, and chopping with stone tools. Since the associated human bones show identical cuts and scrapes to those of the butchered animals, these hominids may have practiced cannibalism.

In 1976, half a mile away from Gran Dolina in a cave known as Cueva Mayor, spelunkers discovered the Sima de los Huesos (the Pit of Bones), a 42-foot-deep shaft filled with hundreds of pre-Neanderthal bones, dated at from 400,000 to 600,000 years old and belonging to almost thirty individuals. Skeletons and skulls of cave bears were mingled with them, along with a well-formed quartzite hand axe. While there appears to be no direct connection between the two sites, they do demonstrate that these wooded hills, with their labyrinth of caves, have attracted hominid occupation during widely different time periods.

Ian Tattersall, curator of anthropology at the American Museum of Natural History, told *Natural History* magazine that the Sima de los Huesos is “the most astonishing concentration of human fossils that has been found anywhere in the world . . . but you have to descend down a vertical pit in a pitch dark cave to get to them.” How these remains, belonging to various ages and both sexes, ended up in the “Pit of Bones” is a complete mystery—perhaps even a murder mystery. Were they sick or dying or already dead, or perhaps victims of a plague? Were they enemies or relatives of those who dumped them there so unceremoniously? Or is there some completely different explanation that we will never know? If humans did indeed deposit the bodies there, it would be the earliest known example of human funerary activity.

Atapuerca proves that Europe has been home to a variety of hominid species over the last million years. The earliest hominids in Europe whose bones are preserved lived 1.7 million years ago at what is now Dmanisi, in the Republic of Georgia. Atapuerca shows that early *Homo* species such as the proposed *H. antecessor* were also living in Europe 800,000 years ago. The hominids from the Pit of Bones were related to *Homo neanderthalensis*,



EXCAVATIONS AT ATAPUERCA since the 1990s have yielded scores of pre-Neanderthals (top) and the much earlier skull of a young boy (middle), called *Homo antecessor*, dated at 800,000 years ago.

which, beginning some 200,000 years ago, dominated Europe as well as parts of western Asia, and persisted for over 150,000 years—longer than our own species has existed. Then, around 40,000 years ago, a new species arrived in Europe, presumably from Africa: *Homo sapiens*. These modern humans were sophisticated artists, hunters, and toolmakers; by 30,000 years ago they had replaced Neanderthals throughout Europe.

See also *HOMO ERECTUS*; NEANDERTHAL MAN

AUSTRALOPITHECINES Man-Apes of Africa

As African fossil hominids came to light over the past 80 years, one of the very surprising discoveries was that the early hominids were upright walkers, even though they had brains the size of a chimp’s. Before these fossils were discovered, anthropologists assumed that upright walking had developed after the expansion of brain size. Australopithecines were bipedal apes. They had upright posture and walked bipedally on the ground, but they certainly lacked language and human cultural capacities.

Difficult to pronounce and misleading in meaning, *Australopithecus* refers to a genus of early hominids that were the closest evolutionary relatives to the genus *Homo* and our possible ancestors. Coined by South African anatomist Raymond Dart in 1924 to describe his famous “Taung child” skull, it means “southern ape.” But subsequent discoveries showed they were neither southern nor close to modern apes. They ranged over the length of the African continent, from south and east to the northern areas of Ethiopia.

Raymond Dart and Robert Broom, two physicians with a passion for paleontology and anatomy, effectively began modern paleoanthropology with their discoveries of the australopithecine fossils in South Africa during the 1920s and 1930s. *Australopithecus africanus*, the first one found by Dart, is the smaller, more lightly built hominid. A larger, more robust genus, known as *Paranthropus*, was discovered by Broom a few years later.

Several species of “australopith” are currently recognized. Some are more lightly built (*gracile*), such as *Australopithecus africanus*, from South and East Africa, and *A. afarensis* and *A. anamensis*, from East Africa and Ethiopia. They were about three to four feet tall, with arms longer than in humans but shorter than in modern apes, and were probably still good climbers. Their legs, and pelvises, however, indicate that they walked upright. Some of their faces were flatter than in modern apes, but jut out farther than in *Homo*. *Australopithecus anamensis* is the oldest of the australopiths, dated at around four million years, and *A. africanus* is somewhat younger at two to three million. Paleoanthropologists believe *A. afarensis* may be ancestral to *Homo* as well as to other australopithecines.

Two larger, heavy-boned australopithecines are recognized: *Paranthropus robustus* and *P. boisei*, and a slightly earlier form called *Australopithecus aethiopicus*. Formerly known as *Zinjanthropus*, *Paranthropus boisei*, or “Nutcracker Man,” had heavy grinding molar teeth and bony crests that supported strong jaw muscles. The heavy, large-toothed forms were at first thought to be a later side branch of the hominid family, but it now appears that these presumed “descendants” coexisted in the same times and places in Africa with some of the smaller, more lightly built “ancestral” species.

The long-standing tradition about the uniqueness of bipedalism in humans goes back to the ancient Greek philosophers. They knew that birds walked on two legs, but observed that man seemed to be the only other creature that did. Consequently, when one of Plato’s students defined man as a “featherless biped,” no one was able to offer a logical refutation. The next day, however, another student showed up for class waving a plucked chicken.

See also *AFAR HOMINIDS*; DART, RAYMOND ARTHUR; TAUNG CHILD.



“MRS. PLES” was Dr. Robert Broom’s nickname for the South African fossils he named *Plesianthropus* (top) but later lumped with *Australopithecus africanus*. “ZINJ” OR “NUTCRACKER MAN” refers to the heavy-boned *Paranthropus boisei* found by Mary Leakey in East Africa’s Olduvai Gorge. It had huge grinding molars and powerful jaw muscles. Photos by Margot Crabtree.