# HIST 9108
# Out of Eden: An Environmental History of Humanity

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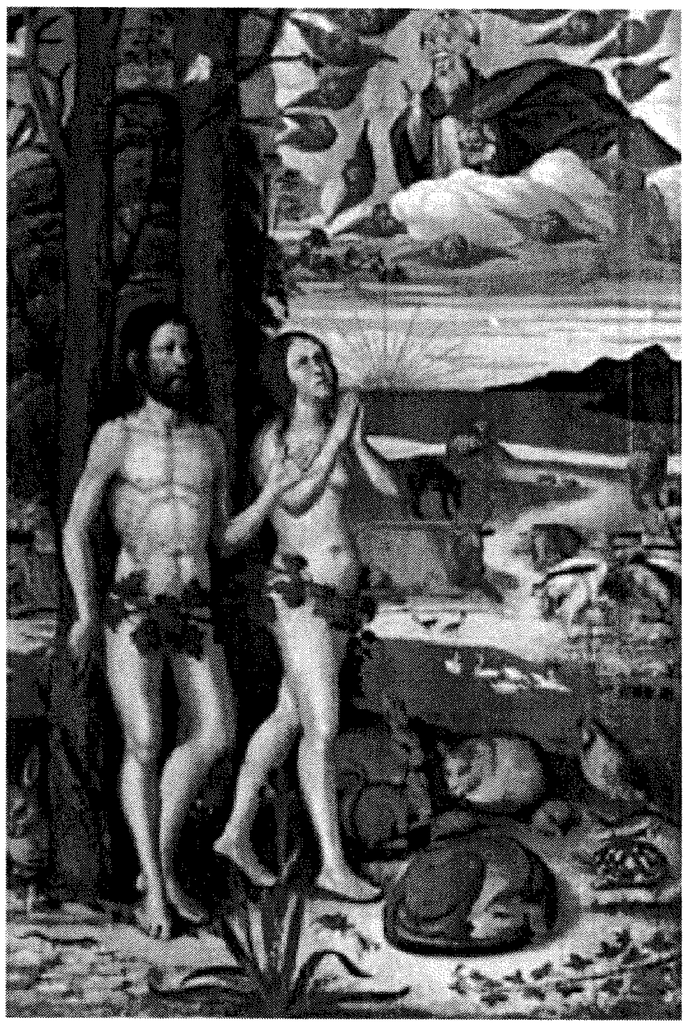

NIAGARA
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# Readings

## UNIT I - Introduction: What Is 'Environmental History' and Why Does It Matter?

Reading 1 Noel T. Boaz., 'Ecological Changes and Primate Evolution: The Prime Movers of Change' from Boaz, *Eco Homo: How the Human Being Emerged from the Cataclysmic History of the Earth* (1997).

## UNIT II – Prehistoric Environmental Themes, 2.5 Million to 5000 Years Ago

Reading 2 Nicholas Wade, 'Exodus,' from Wade, *Before the Dawn: Recovering the Lost History of Our Ancestors* (2006).

Reading 3 Brian Fagan, 'The Power of the Hunt,' from Fagan, *Cro-Magnon: How the Ice Age Gave Birth to the First Modern Humans* (2010).

Reading 4 Robert Wright, 'The Inevitability of Agriculture,' from Wright, *Nonzero: The Logic of Human Destiny* (2000); Cyril Aydon, 'Putting Down Roots,' from Aydon, *Humankind: 150,000 Years of Human History* (2007).

## UNIT III – The Environmental Impact of Civilization, 5000 to 100 Years Ago

Reading 5 J. Donald Hughes, 'Greek Attitudes toward Nature' and 'Roman Attitudes toward Nature,' from Hughes, *Ecology in Ancient Civilizations* (1975).

Reading 6 Brian Fagan, 'The Medieval Warm Period,' from Fagan, *The Little Ice Age: How Climate Made History, 1300-1850* (2000).

Reading 7 Jared Diamond, 'Lethal Gift of Livestock,' from Diamond, *Guns, Germs, and Steel: The Fates of Human Societies* (1997).

Reading 8 David Christian, 'Birth of the Modern World,' from Christian, *Maps of Time: An Introduction to Big History* (2004).

## UNIT IV – An Age Like No Other: Environmental Challenges of the 20th Century

Reading 9 Randall Fitzgerald, 'What Are We Doing to Ourselves?' & 'Reading the Signs,' from Fitzgerald, *The Hundred-Year Lie: How to Protect Yourself From the Chemicals That Are Destroying Your Health* (2006).

Reading 10 James Howard Kunstler, 'The Evil Empire,' from Kunstler, *The Geography of Nowhere: The Rise and Decline of America's Man-Made Landscape* (1993).

Reading 11 Jeffrey D. Sachs, 'Our Crowded Planet,' from Sachs, *Common Wealth: Economics for a Crowded Planet* (2008).

Reading 12 Paul Collier, 'The Natural Resource Trap,' from Collier, *The Bottom Billion: Why the Poorest Countries Are Failing and What Can Be Done About It* (2007).

**UNIT V – Eve of Destruction: An Environmental History of the Future**

Reading 13 James Lovelock, 'To the Next World,' from Lovelock, *The Vanishing Face of Gaia: A Final Warning* (2009); Jan Zalasiewicz, 'Meeting the People,' from Zalasiewicz, *The Earth After Us: What Legacy Will Humans Leave in the Rocks?* (2008).

# UNIT I

## Introduction

1. Noel T. Boaz., *Eco Homo: How the Human Being Emerged from the Cataclysmic History of the Earth* (New York: Basic Books, 1997). ISBN 0-465-01804-1. Chap. 1, 'Ecological Changes and Primate Evolution: The Prime Movers of Change' (pp. 23-50). 28 of 278



# 1

# Ecological Changes and Primate Evolution: The Prime Movers of Change

The long search for the ultimate causes of human emergence from the natural world has been a tortuous one. It has been difficult for self-important human beings to accept that they originated as small, inconspicuous animals in the shadow of the dinosaurs.

Contemplating the scene from my window looking onto the Oregon High Desert, it is easy to imagine this ancient time. I can see many small mammals much like our distant ancestors scurrying about in the juniper scrub and up in the trees. The large grazing ungulates like bison never made it this far west, and the scene that one sees today is a drier and colder version of the early primate North America of 50 to 60 million years ago, before the evolution of large mammalian herbivores. Evolutionary origins from little ratty tree-living animals are humble beginnings indeed for the cerebral giant primate that later came to dominate the earth. But there is an additional insult to human ego. All of the early primates that inhabited North America, our relatives and ancestors, went extinct. The primates themselves are missing from the indigenous small mammal faunas of North America and most of the rest of the Northern Hemisphere.

In the Mesozoic period, extending from some 230 to 70 million years ago, our ancestors were shrewlike small mammals that were nocturnal and tree-living. They were much like the living tree shrews of Southeast Asia but they probably lived throughout the northern half of the world (Laurasia) since climates were warm and there were no major barriers to their wide dispersal. The first primates were little-changed descendants of primitive insect-eating mammals such as these. We know about them primarily from sites in western North America. Long-snouted, whiskered, sharp-eyed, and hyperactive, these little creatures were understory denizens of worlds lorded over by huge reptiles.

When the reptilian ecological dominance of the earth ended, primates took part in the evolutionary diversification of nonreptile animals that followed. Primates, whose insectivore ancestors had lived on the forest floor among the trees, now took to the trees. The earliest primates, called plesiadapoids, evolved forearms that could be twisted around and hind limbs that could grasp, in order to climb trees and find food. A related group of archaic primates, the paromomyoids, experimented with another way of getting from tree to tree—flying. These early primates competed for air space with evolving birds, descended from the now extinct dinosaurs, and bats, their mammalian relatives. Perhaps the relative ease with which we humans learn to "fly"—airplanes, helicopters, and hang gliders—as well as our dreams of flying, a favorite of psychoanalysts, are mental attributes that we have inherited from our archaic primate relatives.

The archaic primates were very successful. At one site in western North America they comprise 39 percent of all animal fossils recovered—by far the largest single group. They dominated the



forests and they proliferated into a number of different species with a wide variety of adaptations. Evolutionary biologists call this an *adaptive radiation*—an evolutionary fanning out of species from one original ancestral population into a number of different species with many different ways of life. Some species became large, the size of a large cat. Others evolved specialized teeth for eating, losing some teeth or adding cusps to the back teeth for grinding. Others evolved specializations of their limbs for moving about, mostly involving the ability to grasp tree branches with the hands and feet. Others became gliders or flyers. Some scientists believe that the living dermopterans, or "flying lemurs," as well as the megabats, or "flying foxes," are remnants of this "flying primate" radiation. The bulk of the archaic primate radiation was, however, confined to earthbound small-mammal niches in the trees.

Our ancestors among these earliest primates were the plesiadapiforms—generalized, small-bodied, and arboreal. As successful as they were in their time, their numbers began to wane in the Eocene, and by the end of this epoch, some 35 million years ago, they were extinct. The oxygen isotope record shows that global temperatures began a long slide downward beginning about 58 million years ago. The tropical forests of the archaic primates, particularly in those parts of their range farthest from the equator (North America and Eurasia), were affected. We know few of the details, but whatever changes in food resources and competitive interactions with other species occurred, they resulted in a major change of trajectory of primate evolution. By the beginning of the Eocene epoch some of the plesiadapiforms had evolved into prosimians—"primates of modern aspect" and the most primitive members of the order still alive today.

## The Emergence of Prosimians

The earliest primates of modern aspect that we know of are set apart from their more primitive ancestors by several important traits. Some of these we know about because of fossil discoveries, and some we deduce from the comparative anatomy of modern primates. The eyes move close together on the front of the face, giving prosimians overlapping fields of vision that allow very accurate depth perception. The ends of the digits of the hands become flattened into sensitive fingertip pads supported by fingernails instead of claws. The brain enlarges in overall size. Particularly, the visual cortex, that part of the cerebrum located at the back (occipital) pole of the brain, enlarges, and the ancient smell-brain (olfactory cortex) decreases in relative size and importance. The jaw becomes heavier and connected by fused bone in the chin region in order to anchor teeth that are exerting more force in chewing harder foods. And fossil limb bones indicate that some species made a transition from the typical mammalian four-footed, head-down stance in climbing to one in which the hind limbs supported most of the weight of the trunk and body, which were held vertically. The prosimians thus evolved the ability to hold onto large vertical tree trunks in feeding, and some became extremely adept jumpers.

Why these changes occurred and in what exact sequence they appeared have been debated for nigh on a century. Early researchers thought that somehow there was an inexorable "trend" toward larger brain size in primates, culminating in the greatly enlarged cerebrum of humans. They tended therefore to posit brain size as the "prime mover" of primate evolution. But there is nothing intrinsic to brain size increase that would have driven primate evolution. Rather, the brain responds to natural selection as do all other structures in the body, and it is to those selective forces that we must look if we are to understand the emergence of the modern primates.

## An Order of Omnivores

Anthropologists Robert Harding and Geza Teleki, in an exhaustive compilation of primate dietary patterns, concluded that primates



were, across the board, omnivorous. Only in isolated cases did some species, such as colobus monkeys, become obligate herbivores, or other species, such as the needle-clawed galago, become dedicated gum-eaters. The primates as a whole have retained their generalized dietary preferences.

But primates are omnivores with a difference. They probably had origins as predator species, unlike such other familiar omnivores as pigs or rodents. This idea comes from Matt Cartmill of Duke University. Cartmill points out that somewhere along the line leading from the tree shrew–like ancestors of primates to the first true prosimian primates, the eyes moved from the sides of the head to the front. The old idea was that this forward position of the eyes served an important adaptive function in depth perception of tree-living animals. The visual fields of the two eyes overlap and thus slightly different angles of view are transmitted to the brain. This stereoscopic adaptation allows an accurate estimate of distance and depth of an object, such as a tree limb, to be judged before the animal leaps into thin air.

Cartmill believes that there was more to this story. He emphasizes the similarity between primates' eyes and those of such nocturnal predators as cats and owls, while he points out that many small mammals live in trees and do not *per force* have to evolve stereoscopic vision to do so. To catch small prey at night or at least in reduced light conditions in a potentially dangerous three-dimensional environment requires close-in focusing on prey and great accuracy in attack. Cartmill thought that the first true primates retained their insectivore ancestors' taste for bugs and small animals (and their spiky teeth betray this dietary preference), but that they became much more adept hunters than their walleyed predecessors.

The primates, however, have a unique way of dispatching their prey, and this aspect of basic primate adaptation does not fit Cartmill's scenario so well. Since time immemorial the mouth has been the organ of feeding, and most predator species have evolved specializations of the mouth region, such as a long, sticky tongue as in chameleons, frogs, or anteaters, or sharp, piercing teeth and strong jaws as in lions, crocodiles, or sharks. The primates lack such specializations and their hunting technique is remarkably primitive—they simply grab their prey, stick it in their mouth, chew it up a little bit, and swallow it. The primates even lack claws, which many other carnivorous species have so they can utilize their forelimbs in feeding. What is most telling for Cartmills's hypothesis is that claws are primitive for the mammals. If primates had first evolved as obligatory predators, claws would have been retained as very useful in helping to catch, pierce, and hold onto small prey. It follows that the flattened fingernailed digits of primates had to have evolved for specific adaptive uses probably unrelated to predation.

Robert Sussman and Peter Raven, in a unique collaboration between an anthropologist and a botanist, put forward an ecological argument for the evolutionary origins of the early primates. Noting that these species were forest-living and arboreal, they made the now obvious connection between the appearance of diverse flowering trees (angiosperms) and the opening up of new niches for evolving primates. In their scenario, primates became important dispersal agents for the new plants, eating their fruits and spreading the seeds via their droppings. The new plants in turn became important new food resources for primates. This hypothesis helps to explain the evolution of a tactilely sensitive organ like the primate hand, with its fleshy and ridged fingertips, designed for careful selection and deliberate removal of ripe fruit from branches rather than rapid dispatch of a moving prey target. A feeding adaptation including fruit also helps to explain why primates all have color vision, not an important adaptation in a nocturnal predator.

Cartmill's and Sussmann and Raven's hypotheses both explain important aspects of primate adaptations, and although they have been considered competing hypotheses, it is also possible that they are both partially right. Since primates are not now and probably never were either exclusively predatory or frugivorous, their



anatomical specializations may well reflect selective forces for omnivory. Indeed some primate field researchers have pointed out that climbing onto the ends of branches for the best fruit and, while there, picking off a few tasty bits of protein on the wing constitutes a very effective adaptation in a tropical forest environment. The fossil record is still too fragmentary to reconstruct whether predaceousness or fruit-eating came first in prosimian evolution, but they both must be ancient components in an overall omnivorous dietary adaptation.

## Prosimian Paradise

There is only one place on earth where a fauna has survived with primates of analogous evolutionary grade to the prosimian world of Paleocene North America. That is the large, equatorial island of Madagascar off the east coast of Africa. Here a variety of species of lemurs—strangely intelligent catlike and rodentlike animals—occupy habitats all over the island, mostly in the forests. Some are nocturnal, but many are active in the daytime as well, for here the rodents failed to colonize. Continental drift pushed Madagascar out to sea, far enough away from the African mainland to keep the primates' voracious and rapidly reproducing bucktoothed relatives off the island. Even more importantly from a standpoint of lemur ecological competition, because many prosimian lineages had increased in size to be much larger than most rodents, no advanced primates—monkeys or apes—made it to Madagascar either.

Several important aspects about the setting of Madagascar, other than its isolation by continental drift, can tell us about the ecological adaptations of the early prosimians. First of all, it is and has been for all the time that prosimians have occupied it, near the equator. Although some latter-day prosimian species have spread to some of the drier parts of the Madagascan forests, the seasonal and temperature variations on Madagascar are quite mild compared to higher latititudes. Rainfall varies with the monsoons blowing in from the Indian Ocean but temperatures are relatively constant. Not only do oceanic currents buffer the island from major temperature change but insolation (the amount of incident sunlight) and day length stay relatively constant throughout the year. This is because the effect of the earth's tilt is least felt near the equator. Constancy of environment is the key to understanding why a prosimian world has been able to persist on Madagascar and nowhere else in the world. And Madagascar is large enough to have preserved some of the diversity of the prosimian evolutionary radiation, from tiny dwarf lemurs to the dog-sized and terrestrial ring-tailed lemurs. Some species, such as *Megaladapis,* became huge before their gorilla-sized bulk and unsuspecting temperaments made them easy targets for extinction by early human colonizers of the island.

The constancy of their environment and their lack of ecological competitors has allowed a degree of dietary specialization among the Madagascan prosimians that is reflective of the kinds of dietary specializations of the ancient prosimians. The lemurs as a group are picky eaters. For example, in the largest captive colony of lemurs in the world, at the Duke University Primate Center in North Carolina, lemur food stores of fresh mango leaves have to be flown in every day from Florida. It is very important that the leaves are still *on the branches*. Otherwise, the largest of the lemurs, the indris, will turn up their noses at them. The founder of the Duke facility, John Buettner-Janusch, discovered that all the previous attempts to breed the endangered indris in captivity had failed because they simply could not pick and then eat their favorite food leaves. When he took single mango leaves and tied them onto an artificial tree so that the indris could actually pluck them off, as they do in the wild, they ate! If most North American Paleogene (Paleocene and Eocene) prosimians were such prima donnas when it came to food, it is not hard to see how any change in their environment and food source would have caused a problem.



## The Ascendancy of the Rodents and Demise of the High-Latitude Primates

All of the North American small mammals with primatelike adaptations are rodents of one sort or another—gophers, squirrels, marmots, pack rats, chipmunks, and field mice. Rodents are a remarkably successful group of mammals. In North America they replaced the primates, who died out some 45 million years ago, not to be represented again until huge, bipedal primates called humans made the trek from Asia into the New World, only a few thousand years ago. What do the rodents have that the primates lack? The primates are a lot smarter, although people who have only barely been able to wrest control of their house away from a family of mice or rats might question that assumption. Usually another species, a domesticated small carnivore (a cat), has to be brought in by the humans to finish the job. Rodent–primate competition over resources is an ancient one, and humans usually win only because they are much bigger and are able with their superior intellectual capabilities to devise new and innovative ways to do in the rodents. This is why "building a better mousetrap" will cause the world to beat a path to your door. But despite the accolades of our fellow humans and the success of some of our inventions, the rodents continue to thrive. We primates have to be content with keeping them at bay, out of our immediate sight, and out of our food supply.

Earlier primates did not have at their disposal either the advantages of great size or of vast intelligence in their ecological competition with rodents. Many lineages lost that competition, which explains why the view from my window does not reveal a riot of primate diversity. Compared to rodents, primates put a lot more parental effort into raising their offspring, helping them to survive, and because of this they have fewer offspring per litter. Rodents, in contrast, generally produce many more offspring, and they are willing, evolutionarily speaking, to sacrifice a large number of them to the forces of natural selection. Untold millions of owls, hawks, and small carnivores have gorged themselves on billions of young rodents over the past 50 million years in the Oregon outback, but still their population numbers are high and they are successful species. The reproductive potential of rodents is phenomenal, allowing rodents to not only sustain tremendous predation but also to outcompete other species in the ecosystem by outbreeding them.

Evolutionary biologists have referred to the modes of natural selection that rodent and primate evolution exemplify as *r selection* and *K selection,* respectively. The terms come from population genetic equations describing the interactions of birth rates, predation rates, and other ecological parameters. Generally speaking, r-selected species are those with great reproductive potential, capable of producing several large litters over a period of a year's time, usually in seasonal peaks correlated with the abundant food supply. They suffer high predation pressure and high death rates. But r-selected species such as rodents shed no tears for their lost offspring. They just produce more.

K-selected species are very different. They have small litters. All primate females, for example, have only two nipples for suckling one or two offspring at a time, indicating that large litters have not been a part of the primate adaptation for tens of millions of years. K-selected species keep their unborn offspring developing longer inside the mother's body before birth, accounting for lower reproductive rates but a higher chance for individual survival after birth. The primates even enhance the quality of life for their unborn offspring. The primate placenta—the flat, blood-filled connection plate of the fetus's umbilical cord to the mother's uterus—has a thinner lining than other mammals, thus allowing better delivery of maternal oxygen and nutrients to the fetus and better removal of fetal waste products. Primate parents, usually mothers, continue this coddling of their infants after birth, ensuring that they have sufficient food, warmth, and protection for their survival. When offspring of a K-selected species die, all of that invested energy is lost, entailing a high cost to the species. But



if the parental investment is effective, many fewer K-selected offspring die and their species thrive. If this were always the case, the early primates would not have died out in North America. What happened?

## A Collision of Reproductive Strategies and Environmental Change

Why species went extinct in the past has always been more than a little mysterious. We know so little critical detail about the past—the organisms and their adaptations, the terrain and its habitats, the climate and its perturbations. And our experience with extinction has been strongly colored by the rapid elimination of numerous species by the combined human effect of "civilization." It is easy for us to imagine a catastrophe, analogous to human slaughter of Steller's sea cow or widespread despoliation of the riverine environments of the snail darter, as responsible for wiping out species in the past. Some scientists subscribe to this "catastrophic" view of evolutionary history and posit such events as meteoritic collisions with earth, viral epidemics, and explosive evolutionary changes as responsible for species extinctions in the past.

Most of these "unitary cause" arguments for extinction are unconvincing. First of all, natural events drastic enough to wipe out species, that is, killing *all* breeding members of a population, must be extremely rare. Consequently, they require a feat of imaginative reconstruction that, without strong empirical evidence, is difficult to make. True, certain cataclysms, such as the drying up of the Mediterranean Sea, did occur. But even in this case, as we shall see, accompanying massive species extinctions do not seem to have occurred at this same time. Second, whatever catastrophe is invoked to explain extinction must have been selective—it must have killed off one species or one group of species but not others. The meteorite that theoretically hit earth at the end of the

Mesozoic era, for example, had to have killed off giant carnosaurs, tiny dinosaurs, and sea-living plesiosaurs, but not have harmed any of the other species living in these same environments.

Extinctions in the past, one may reasonably surmise, are usually results of combinations of species and environmental interactions. The environment changes, shifting food resources around, and these changes create stresses on some species while opening up opportunities for others. Species may compete in many ways—for space, for nesting or sleeping sites, for shade, for warmth, for water, for anything that they need that may be in short supply—but the most common arena of competition is likely what they eat. Dietary competition between species happens day in and day out, and observations on living species show that it can be exacerbated during certain annual seasons of scarcity. Animals with similar dietary adaptations are most likely to have competed, and both primates and rodents, as a general rule, are omnivores. It is thus reasonable to expect that they would have been ecological competitors.

The Cenozoic era began with a series of global cooling events that had widespread environmental effects. There are many who consider that these changes were the very ones that slowly did in the dinosaurs. The warm-blooded birds and mammals took over an increasingly changeable world. Forests became cooler and less swampy, and the numbers and kinds of fruiting trees increased. The primates probably developed both as predaceous small animal-eaters and fruit-eaters. But as climates became progressively cooler and drier, fruit trees became sparser. They, along with other plants, evolved in response to the changing climate. Lush tropical fruits gave way to thick-coated fruits and nuts, more impervious to drying out. Hard-covered seeds, nuts, and grains became more the norm, and primate adaptations were less up to the challenge. Still today we can easily eat soft fruits such as bananas, oranges, apples, dates, and peaches with only our hands, but we require tools, such as a nutcracker, to eat hazelnuts, brazil nuts, and walnuts, and a millstone or fire to eat grains such as wheat, barley, and

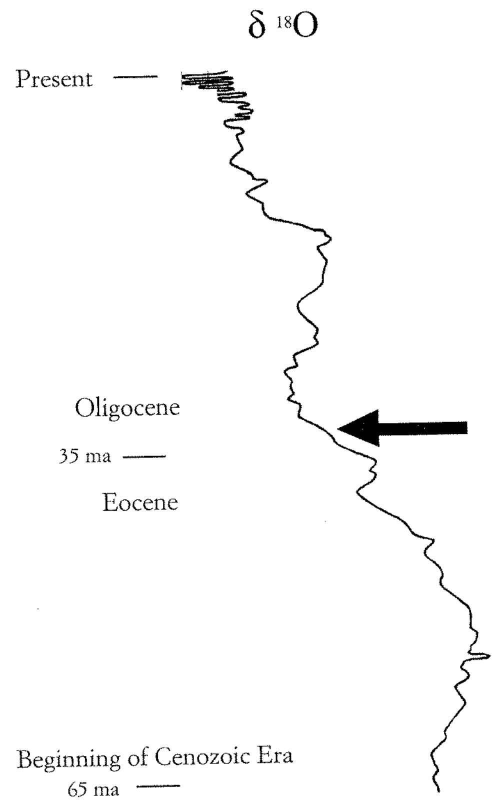


rice. The rodents with their formidable, ever-growing front incisors could eat through the toughest nut and grain seed coats and successfully ingest foods that non-tool-using primates could only dream about. And they could outbreed primates by a wide margin. It is no wonder that at high latitudes where climatic changes would have been greatest, primates went extinct by the end of the Eocene epoch. The rodents were very likely one of the prime biotic agents responsible.

In North America, Europe, and northern Eurasia, the rodents took over many of the primate niches. They themselves underwent an adaptive radiation, their species spreading and differentiating into many patterns of adaptation, but they did not *become* primates. Squirrels, for example, became denizens of the trees, like the early primates. But their eyes stayed on the sides of their heads, their sense of smell remained an important part of their adaptation, they retained their claws, and their brains stayed relatively small. Because squirrels do not have accurate stereoscopic vision, they have a parachute-like tail that breaks their relatively frequent falls out of the trees. Because they do not have grasping hands with an independently moving, "opposable" thumb, they must use both hands in eating their food. And they do not supplement their nut, seed, and fruit diet with any animal protein.

Nonhuman primates were gone from North America by the beginning of the Oligocene epoch, some 34 million years ago, never to return except by the hand of man. We can surmise that they were done in by a combination of the marked climatic shift toward cooler and drier conditions that occurred at this time (see Figure 2), associated changes in vegetation that altered their multistoried forest habitats, and ecological competition from the advancing and differentiating rodents. Perhaps the distances between trees just became too far to leap. Or the fruits and insects that they fed on became too rare to sustain them. The rodents perhaps beat them to the best fruiting trees and were able to eat the fruits before they were quite ripe, gnawing through the still tough

**Figure 2**




*The arrow indicates the major downturn in global temperatures that accompanied the beginning of the Oligocene epoch. The important primate fossil site of the Fayum, Egypt, records this time period.*



rinds before the primates could. Whatever the exact combination of factors that wrought the extinction of North American prosimians, the same underlying paleoenvironmental changes effected the emergence of true higher primates, the anthropoids, in other parts of the world.

## The Oligocene and the First Large Primates

In the Tropics, the climatic changes that occurred at the beginning of the Oligocene epoch, 34 million years ago, were not so markedly felt as they were at higher latitudes. Forest environments changed in the composition of their species in response to climatic cooling, lower humidity, and lower precipitation, but they nevertheless retained their multistoried complexity. The forest-tied primates with their K-selected adaptations continued to thrive.

Much of our knowledge of this time in primate evolution comes from Africa—from one remarkable site in the Sahara Desert of northern Egypt. Despite this solitary ray of light, we are able to make some deductions about general primate distributions from other data. Because continental drift cut off the archaic primates of North America and Eurasia from the ancient southern continent of Gondwanaland, prosimians never reached South America, Australia, and Antarctica, the modern continents formed from this old supercontinent. Here primitive pouched marsupial mammals continued to hold sway over the small-animal niches in the trees. The original Antarctic fauna was frozen into extinction as that continent separated from Australia. Australia stayed isolated by its deep and wide South Pacific moat and thus retained its diverse marsupial mammal diversity. South America also was a marsupial stronghold, lacking primates, until it drifted northward and modern placental mammals flooded across the Isthmus of Panama. Prior to contact, there was even an Argentinean platypus, an egg-laying mammal even more primitive than marsupials. Primates were to make it to the lush South American rain forests, but they were late immigrants.

Thus, by the Oligocene, the scene of primate evolution shifts to what we rather incongruously call the "Old World"—that part of the Northern Hemisphere consisting of the contiguous landmass of Eurasia and a major piece of Gondwanaland—Africa—that drifted northward to meet it. Of course there is nothing intrinsically "old" about it. It just happens to be what our intellectual forebears had imperfectly known about and put on maps before 1492.

Evidence now indicates that the earliest "higher primates," anthropoids, appeared as early as the middle Eocene epoch. Sites in China, Burma, and Morocco now show that primates with such humanlike characteristics as forward-facing eye sockets totally enclosed by bone, well-developed jaws with fused bone in the chin region, and single frontal bones in the forehead had evolved by 40 million years ago. Since no primate like this is known from North America, we can presume that faunal interchange had been cut by this point between Eurasia and North America. Contact with Africa, which we may probably assume had a marsupial-dominated fauna, allowed Eurasian prosimians to extend their range into the tropical forests of Africa for the first time. Because of the tropical conditions, there was continuous forest from Africa to Eurasia, and thus Morocco, Burma, and China would have been much more ecologically similar than they are today. The primate faunas thus could be expected to have been similar throughout this region of the Old World.

The site of the Fayum, in Egypt, is situated within this ancient Old World forest zone, and it is replete with primates. Elwyn Simons, the world's senior paleoprimatologist, has worked at the Fayum for two decades, and has succeeded in uncovering a primate radiation of impressive diversity. It has been for several decades the primary window onto this period of florescence of the higher primates, but recent discoveries by Simons and his team from Duke University continue to provide new insights.

At the time that the Fayum deposits were laid down by ancient channels of the Nile, Egypt lay several degrees south of where it is now. This more southerly location, as well as the proximity of moisture-bearing winds from the large Tethys Sea, the much larger ancestor of the Mediterranean Sea to the north, made the Fayum an area of dense tropical forest. The lowest strata of the Fayum are Eocene in age, about 36 million years old, but most of the deposits are Oligocene in age, some 31 million years old. The Fayum preserves both prosimians and the first well-preserved anthropoids.



The striking aspect of the primate fauna that Simons has discovered is that all of the species are small. Among the prosimians, a recent discovery is the small lemurlike species *Plesiopithecus,* which had incisor teeth elongated to form a "tooth comb" for grooming, and which may provide a mainland African link with the Madagascan lemurs. Small, tarsier-like prosimians show that the Fayum primates shared close ties with the Asian rain forests, where tarsiers survive to this day.

Most interesting from the standpoint of human evolution is the appearance of two groups of diminutive higher primates, anthropoids, in the fossil record of the Fayum. One of these groups has the three premolars characteristic of the New World monkeys, a trait that is today no longer found among the primates of the Old World. This group, known as the parapithecids, probably accounts for the origin of the New World monkeys. As unlikely as it sounds, some of these tiny primates apparently dispersed to South America along with African hedgehog rodents, probably on floating rafts of vegetation that broke off from westerly flowing rivers, perhaps the Niger or the Zaire. Hurricane winds, which today originate off the West African coast and buffet the Caribbean and northern South America, could transport such a raft across a then-narrower Atlantic in a couple of weeks. When these small primates reached the tropical forests of South America they underwent a rapid radiation, the details of which primate paleontologists are just beginning to unravel.

The second anthropoid group at the Fayum is the propliopithecids, a group that includes our probable ancestor at such a distant time. The most well-known of this group is *Aegyptopithecus,* but Simons's recent discoveries have shown that, like the other primates at the Fayum, the earliest members of this family were tiny. A new species from the Eocene of the Fayum that Simons named *Arsinoea* in 1994 was no larger than a small chick!

The paleontologist Alfred Romer made the observation that in many evolving lineages of vertebrates there is a clear tendency to increase in body size over time. This generalization has become known as Romer's Law, and it accurately describes what happened to the propliopithecid lineage from the Eocene to the Oligocene. *Aegyptopithecus* evolved to become about the size of a large house cat, with males about twice as big as females. This was indeed a significant increase in size, and it represents the first time that anthropoids made the transition from "small animals" to "medium-sized" animals. Why this transition occurred in these particular primates involves a consideration of the general applicability of Romer's Law.

## Climate Change and the Origins of the Anthropoids

As conditions get colder, animals get bigger. A German naturalist noticed this back in 1837 and the generalization still bears his name—Bergmann's Principle. Bergmann compared body sizes of related animals, bears for example, from the equator to the poles. He found that as one progressed from sun bears to black bears to grizzly bears to polar bears, size increased. One explanation for Romer's Law then is that it is a special application of Bergmann's Principle through time—as conditions become colder over time, species evolve to be bigger. There is a simple principle of physics that explains body size increase with decreasing temperature. As mass of a body increases, its relative surface area decreases. Thus, with warm-blooded mammals, the bigger the animal the smaller the relative body surface that would be exposed to the cold.



The oxygen isotope curve shows that there was a significant period of global cooling at the beginning of the Oligocene epoch. It is tempting to jump to the conclusion that this decrease in temperature prompted the evolution of larger body size among the anthropoids. While it is not yet possible to rule this out as an explanation, there are other possibilities.

Interspecies competition can also lead to an increase in body size. This can happen as a result of "scramble competition," when individuals of one species directly compete for some environmental resource in limited supply—for example, meat from a kill or fruit from a tree. The larger animals usually displace the smaller, thus winning a competitive advantage in access to food resources. In the case of the early anthropoids, the rodents are again a prime candidate for the competitors. One species of Fayum primate, *Serapia eocaena,* for example, is the spitting image of a squirrel, if you do not look too closely at its teeth or hands.

Larger body size can evolve as a defense against predation. Rather than develop fleetness of foot, bony body armor, an offensive smell, or an especially effective way of hiding, animals can just grow too large for predators to handle. Imagine for a moment that you were one-sixth the size you are, say less than one foot tall. The number of potential predators in your everyday environment would be tremendously increased, beginning with your pet cat and dog. The early anthropoid's arboreal environment would have placed a limit on how large they could have become (as well as limiting the size of their potential arboreal predators). Up in the branches, the bigger you are the harder you fall. So the list of predators for the Fayum primates would have included animals whose means of locomotion included access to the trees—snakes, particularly booid constrictors, raptorial birds such as eagles, hawks, and owls, and any small carnivorous mammals that could climb.

Finally, evolutionary forces within the species can make for larger body size. Charles Darwin first noted that some changes in species could not be easily explained by adaptation to the reasonable than regarding the history of life as long periods of stasis automatically punctuated by periods of rapid change, a model called "punctuated equilibrium" by Stephen Jay Gould and Niles Eldredge. Punctuated equilibrium was an attempted description of paleontological history, mainly of invertebrates, based on Gould and Eldredge's reading of the fossil record and their comparison of their understanding to sociopolitical history. Most evolutionary biologists did not care for the rather mysterious vitalistic wonder of it all, and found it too much to ponder what underlying cosmic laws might account for both the fall of the ancient Egyptian empire and the demise of the ammonites. Some good paleobiology was, however, accomplished in the effort to test the model, and for this we can be grateful. But punctuated equilibrium as a predictive model is useless since it lacks any clear causative association in nature.

## A Riot of Apes in the Miocene

With the increase in body size and dominion established over the tropical forests, the primates emerged from the Oligocene, some 20 million years ago, with an abundant and wide range of species (see Figure 3). We know most about these species from sites in western and central Kenya, and from sites in eastern Uganda. They are called apes—proconsulid apes.

The early apes were in general smaller and much more monkeylike than what we now think of as apes. Their skeletons show that they were quadrupeds, capable of climbing, rather than the specialized arm swingers and branch hangers that modern apes are. They came in all sizes and shapes, from the gorilla-sized *Proconsul major* and *Turkanapithecus heseloni* to the diminutive *Micropithecus clarki.* Some of the smaller varieties, such as *Dendropithecus macinnesi,* were beginning to specialize in arm swinging and were akin to the adaptation seen today in the South American spider monkey. Somewhere in the small-to-middle-size



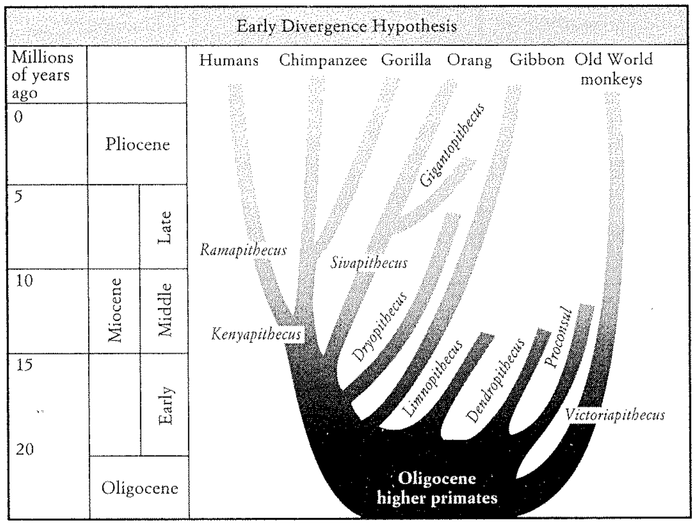
range of the proconsulid apes lies our ancestor—actually the common ancestor of the living apes and humans. It may be a species close to the relatively well-known species *Proconsul africanus,* a tailless climber the size of a small dog.

The forests in which the proconsulids lived was dense but far different from the rain forests of the Oligocene and preceding epochs. The early Miocene proconsulid site of Koru in western Kenya preserves the remains of a mature forest but one that was adapted to periodic dry conditions. The site of Napak in eastern Uganda is perhaps the driest of these early Miocene sites, and although a forest, it probably had open patches within it. Most of the fossils here were covered by an ash that erupted from a nearby volcano.

## The Apes Leave Africa

As Africa drifted northward at the beginning of the Miocene, a broader land connection was established between the Arabian Peninsula, primitively part of Africa, and the mainland part of Southwest Asia. From some newly discovered faunas in Saudi Arabia we know that this part of the world was densely forested in the Miocene, and that apes inhabited what now is the totally treeless Empty Quarter. The Sahara was still largely a forest, although the first plant fossils indicative of aridity come from this time in southern Algeria. Forest stretched from Africa eastward to southeastern Asia and westward to Europe. With the newly established land connection, elephants, originating from Africa, spread into Eurasia for the first time. Apes came with them.

Exactly how many and what kinds of apes made it out of Africa are still questions to be answered. The ancestor of the gibbon, the living Southeast Asia long-armed tree-swinger, may have already split from the line leading to the larger apes before the African ape diaspora. Or the split may have occurred just after the spread of apes to Eurasia. In any event, by the middle Miocene, an ape in



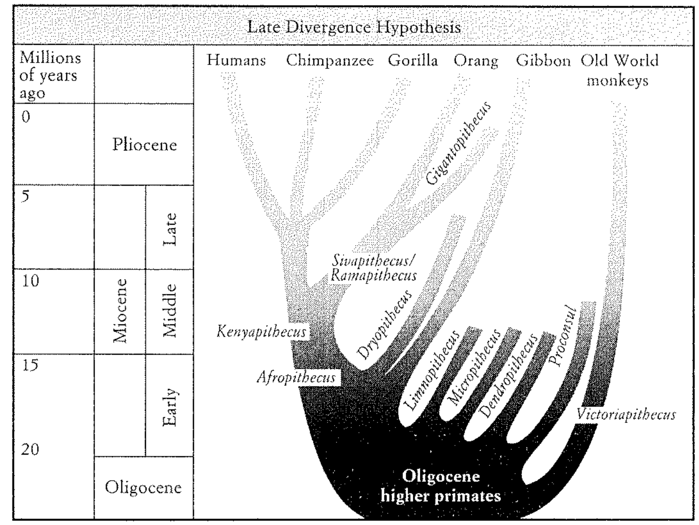




**Figure 3:** *Theories of hominid evolution. The older paleontological view that placed humans far outside the context of primate evolution, exemplified by the "Early Divergence Hypothesis," has now been replaced with a view that emphasizes how close human ancestry is to that of our living African ape relatives, the "Late Divergence Hypothesis."*

China, *Dionysiopithecus,* records what most primate paleontologists consider a good fossil ancestor for the living gibbons.

A very strange ape named *Oreopithecus*—one with the body of an orangutan but the teeth of an overgrown prosimian—dispersed into Europe from an early Miocene ancestor known from Kenya. It lived on into the late Miocene in the coal forests of central Italy, where it eventually died out as its habitats disappeared. Most of the apes of Europe were dryopithecids, small to medium-sized species that resembled their proconsulid ancestors. They were also forest dwellers, and like *Oreopithecus,* they went extinct in the late Miocene by the time the European forests thinned out too much to support them.

## The Rise of the Monkeys

In addition to habitat change, there is another explanation for the passing of the great diversity of apes seen in the early and middle Miocene. It is the evolutionary diversification of a related group of primates, the monkeys. Monkeys are in general smaller than living apes, they usually have tails, their molar teeth are pushed up into transverse crests called lophs, and their brains are relatively smaller than apes' brains. The distinction between monkeys and apes is still muddled in the popular mind: Chimpanzees, gorillas, and orangutans are still frequently called "monkeys," and very good monkeys, such as Barbary "apes" and Celebes black "apes," continue to carry their misnomers.

The evolutionary distinction between apes and monkeys is razor-sharp, however. The earliest monkeys are singular species with lophed molar teeth that appear in the early Miocene. They must have lived surrounded by trees teeming with different species of early apes. The apes had dominated the primate ecological spectrum since the Oligocene, when they and the monkeys had last shared a common ancestor. The apes had won the first round, but by the middle to late Miocene it was the monkeys' turn.



Although we would like to have more sites to more fully document the transition, the available evidence shows a clear inverse relationship between number of species of apes and monkeys through time. As monkeys increase in diversity, apes decline. The similarities in their adaptations, as indicated by skeletal form, make it likely that the decline of the apes can be directly attributed to the rise of the more r-selected, less intelligent monkeys. The monkeys could perhaps subsist on diets of less high-quality fruit and protein, which became sparser and sparser as the Miocene progressed. They successfully radiated into a number of niches, taking over ape habitats and spreading throughout the Old World. The even more impressive radiation of monkeys in South America happened in the absence of apes, who were perhaps already too big in the Oligocene to have made the trans-Atlantic journey with them and their rodent companions to colonize the New World.

## The Evolutionary Origin of the Orangutan

The middle Miocene in both Africa and Eurasia first records the presence of grassland and open wooded savanna in the middle Miocene, 13 to 15 million years ago. This is the time that protein and DNA (deoxyribonucleic acid) analyses of living apes and humans indicate that the orangutan, the only extant Asian great ape, split off from its African cousins, the chimpanzee, gorilla, and humans. The timing corresponds well with the cutting of forest connections between Africa and Eurasia.

The European apes, the dryopithecids and *Oreopithecus,* continued to live in their forested cul-de-sac. They were cut off from further contact with ape populations to the east and to the south. The spread of open woodlands in southernmost Europe and southwestern Asia through the middle to late Miocene heralded the appearance of faunas in which primates played almost no part. Sites such as Maragheh in Iran and Samos and Pikermi in Greece preserve beautifully diverse animal communities, but there are no primates, except for some very fragmentary remains of monkeys. The Mediterranean crossroads of faunal migration became essentially closed to apes.

In the rainier and more well-wooded parts of Asia, to the east, some apes persisted. The woodlands surrounding the mountain massifs of the Zagros in Turkey and the Himalayas allowed a group of apes known as sivapithecids to survive. One of this group persisted as the orangutan, up until only a few thousand years ago still inhabiting the Chinese and Vietnamese mainland, but now limited to only relictual island populations in Indonesia (Borneo and Sumatra). Pressed into this same Southeast Asian forest isolate are the only other extra-African group of surviving apes, the gibbons and related siamangs.

Our realization, born of molecular and fossil discoveries over the past twenty years, that the orangutan bears no intimate relationship to human or African great ape ancestry allows us to concentrate the search for earliest hominid origins on the African continent. Eurasia in fact has a much better fossil record of the late Miocene than does Africa, a fact fostered no doubt by a century-and-a-half-old belief among many paleontologists that human origins lay in the Northern Hemisphere. They did not. Africa, the part of Gondwanaland that broke off early from the other southern continents and first docked with Eurasia, provided a haven for primates that had originally arisen in the north. Climatic change and interspecific competition drove North American primates to extinction and pushed Eurasian primates southward. It was Africa that shaped anthropoid evolution for the next 40 million years, and it is to a consideration of this continent's latter ecological history and ape evolution that we will turn next.

# 2

## HYPOTHESIS 1

# The Earth Cools and the Gorilla Evolves in Montane Isolation

There are a few national parks in the high lake country of northwest Rwanda, southwest Uganda, and eastern Zaire where one can trek into the montane forest habitat of the mountain gorilla, its last natural refuge. There it is possible to visit, after a strenuous hike of several hours, gorilla family groups living in the wild and habituated to the presence of humans. There are no bars, no glass enclosures, no water barriers—just you, the gorillas, and a few dozen feet of space in between. It is an unforgettable experience.

One is acutely aware that this is not a human environment. It is cold—a kind of wet, cloud-shrouded chill that settles deep into your bones early in the morning and stays there. Your muscles ache from the constant shivering. It is also an environment in which it is impossible to walk. In most places you cannot see the actual surface of the ground—it is covered in a mass of tangled roots, branches, moss, and leaves. You slip, crash, stumble, and

# UNIT II

# Prehistoric Environmental Themes, 2.5 Million to 5000 Years Ago

# 5

# Exodus

*Let us suppose the members of a tribe, practising some form of marriage, to spread over an unoccupied continent, they would soon split up into distinct hordes, separated from each other by various barriers, and still more effectually by the incessant wars between all barbarous nations. The hordes would thus be exposed to slightly different conditions and habits of life, and would sooner or later come to differ in some small degree. As soon as this occurred, each isolated tribe would form for itself a slightly different standard of beauty; and then unconscious selection would come into action through the more powerful and leading men preferring certain women to others. Thus the differences between the tribes, at first very slight, would gradually and inevitably be more or less increased.*

CHARLES DARWIN, *THE DESCENT OF MAN*

OUT OF AFRICA there are two routes. One is to travel above the northern tip of the Red Sea and through the Sinai desert into the Levant, the lands of the eastern Mediterranean. The other is to cross the Red Sea at its southernmost point, the Bab al-Mandab or Gate of Grief.

For the ancestral people in their East African homeland, the vast desert to their north may have been a serious barrier. But the Gate of Grief was almost on their doorstep.

Today these straits are some 12 miles wide. But 50,000 years ago much of the world's ocean water was locked up in the glaciers of the Pleistocene ice age, and the straits would have been much narrower. At that date the water level of the Red Sea was some 230 feet lower than at present.[86] The straits were never completely closed but at low sea-stands they would have been dotted with islands, an inviting chain of stepping-stones to the southern Arabian peninsula.

"With the blast of thy nostrils the waters were gathered together, the floods stood upright as an heap, and the depths were congealed in the heart



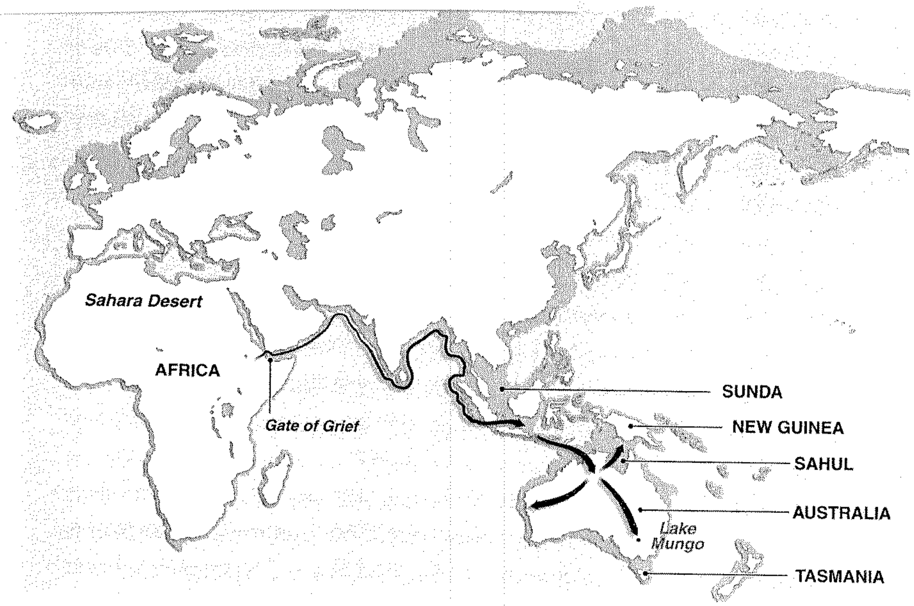



FIGURE 5.1. THE ROUTE FROM AFRICA TO THE FORMER CONTINENT OF SAHUL. Humans left Africa at a time when ice sheets covered northern latitudes of Europe and Asia, and sea levels were some 200 feet lower than now. They probably crossed the Red Sea at its southern entrance and reached India. Generation by generation, people expanded along the coastlines of southern Asia until by 40,000 years ago they had reached the foundered continent of Sahul (now Australia, New Guinea and Tasmania).

This eastward route taken by the first modern humans to leave Africa may reflect a preference for staying within the tropical climates to which they were adapted, or the occupation of the mainland by *Homo erectus*, or both.

of the sea." Those were Moses' words of appreciation for the divine wind that parted the waters of the Red Sea, just in time for the Israelites to escape from Egypt and the pharaoh's pursuing chariot forces.[87] Too bad that the epic, if less miraculous, crossing of the first modern humans into the world beyond Africa cannot be reconstructed in equal detail. Still, some essential features of this ancient exodus are clear enough.

The first, based on genetic analysis, is that there seems to have been just a single emigration of modern humans from Africa. A second genetic inference is that the number of those who left was probably quite small. Indeed it could have been as few as some 150 people, raising the puzzle of why, if one group of people managed to escape from Africa, many more did not do so.

After some differences of opinion, geneticists now seem to agree that the trees drawn on the basis of the Y chromosome and of mitochondrial DNA both point to a single exodus from Africa. "Analysis of mtDNA and Y chromosome diversity support a single East African source of migration out of Africa," say two geneticists in a recent review.[88] If there were many migrations, they add, "they would have had to originate from the same source population in Africa."

It's reasonably likely, then, that the first modern humans left Africa in a single group, that they crossed the southern end of the Red Sea and slowly spread, generation by generation, around the coasts of Arabia and Iran until they reached India. Because of the lower sea levels during the Pleistocene ice age, the archaeological evidence of this coastal passage would now lie underwater.

But this version of events is not yet generally accepted. Another possibility, favored by some experts, is that people traveled from Africa to India by a northern route, across the top of the Red Sea and through the Levant and Iran.

A third possibility is that there were at least two migrations, one to the north and the Levant, the other to the south and India. This theory is favored by archaeologists who have reservations about the reliability of genetic inferences. But if the geneticists are right that there was only one migration, a choice must be made between the northern route, across the top of the Red Sea, and the southern route, across the sea's southern end; and the present weight of evidence, at least in the geneticists' eyes, favors a single exodus via the southern route.

In tracing the movements of the first modern humans across the globe, geneticists' maps show neat arrows stretching from eastern Africa to India, Australia or Japan, and the arrows unavoidably give the impression that the emigrants were purposefully traveling to these distant endpoints. But of course they were not—they had no maps and no idea of what lay at the end of their journey. In fact, it's doubtful they they were on a journey at all.

For foraging people, short journeys may be routine but long distance travel, carrying their infants and all necessities, is arduous. Rather than trek determinedly into the unknown, or expose their families to the hazards of exploration for its own sake, it's more likely that the first modern humans to leave Africa behaved as foragers usually do—they moved a short distance



and stayed put. After a number of years, as new births swelled the group's size, it would have divided so as to prevent the usual discord that wells up in large foraging populations.

Following such splits, one group would stay put while the other moved on into unclaimed territory. Foragers need a lot of space to support themselves, so in a century—five generations—a hunter-gatherer society might spread over a considerable distance, especially if its members had learned the art of coastal fishing and preferred to stay near the water's edge. Those long distance migrations, in other words, were not made by a single group on a long trek, but were the slow expansion of human populations who took a generation to travel each leg of the journey.

Crossing from Africa to the Arabian peninsula via the Gate of Grief would have required boats. Though archaeologists have found no water craft from this period, people who lived at African sites of the Later Stone Age, which began shortly after 50,000 years ago, could certainly fish, so boat building techniques may well have been familiar to the ancestral human population. If the emigrants left Africa by boat, their descendants may thereafter have moved along coastlines until they reached India.

The coastlines could well have been safer than the interior. Southern Arabia is for the most part an inhospitable desert and would have presented a formidable obstacle to foragers. But from time to time on the geological time scale it enjoys rainy periods. Even within the Pleistocene ice age that gripped the world until 10,000 years ago, there were periods of relative warmth. One, known as oxygen isotope stage 3, peaked around 50,000 years ago. During this warm phase, as well as two earlier ones, southern Arabia was wetter and would have been habitable by hunter-gatherer populations.[89]

But these spells of favorable climate may also have drawn down Neanderthals from the north. The Neanderthals may have thwarted previous attempts by humans in Africa to cross into Arabia, just as they crushed the attempt by anatomically modern humans to penetrate the Levant. By 50,000 years ago, however, the Neanderthals would have faced a different adversary. The ancestral people, with their new gift of language, would have enjoyed better organization and superior weaponry. Though physically weaker than the Neanderthals, the new model of humans may at last have gained an edge over their fierce archaic relatives.

Still, having their families with them, they may well have preferred to keep out of the archaics' way. So instead of striking out across the interior, they may have expanded along the coastline of southern Arabia, using their boats both as transport and to fish from.

So why was there only one migration of modern humans out of Africa? Could it have been that there was only one way out—the Gate of Grief—and the first people to cross it stayed put on the other side and prevented others from invading their territory? Perhaps more likely is that the odds of survival were small, and only one group of people was fortunate enough to surmount all the daunting obstacles in their path.

## Passage to India

How can the long ago journey of those first emigrants be traced? Because of the territorial behavior of the first modern humans, rigorously maintained as they invaded the world outside Africa, everyone essentially stayed in place in their new home, except for those at the head of the wave of advance. The world would thus fill up in a rather orderly way. For thousands of years thereafter, people lived and died in the place where they were born. Populations did not mix, except at a local level under the patrilocal system of hunter-gatherer societies.

This conclusion emerges directly from the genealogies of the Y chromosome and the mitochondrial DNA. Men of each branch of the Y chromosome tree are mostly found in a particular geographic region. The same is true for mitochondrial DNA lineages. Some branches of the two trees are confined to a single continent. Others spread over several land masses, but in a way that tracks an orderly movement of population. If the world's population were highly mixed, each of these branches would be found all over the place.

Even today, most people in the world still belong to Y chromosome and mitochondrial DNA lineages that accurately reflect their continent of origin. Africans south of the Sahara belong to mitochondrial lineages L1, L2 and L3. All the rest of the world belongs to the two daughter lineages of L3 known as M and N.

Lineage M is of particular interest in tracking the exodus from Africa. Silvana Santachiara-Benerecetti of the University of Pavia in Italy has found that M is quite common in people of the southern Arabian peninsula, but is not seen in the Levant.[90] This is interesting evidence that the route out of Africa may have led through southern Arabia to India. It is not conclusive, however, because a vigorous Arab slave trade flourished between AD 650 and 1900 and brought many Africans to Arabia. The female slaves, who became integrated into Arab populations, could be the source of the M lineage.[91]



Since men and women had to spread through the world together, the story told by the Y chromosome's genealogy should match that of the mitochondrial DNA genealogy. The two stories do agree well in general outline, though not yet in every detail. The mutations that generate the Y chromosome's genealogy were discovered more recently and are still under study. Mitochondrial DNA mutates at a faster rate than the Y chromosome and the dates derived for the branch points in its genealogical tree are generally older than those for the Y chromosome's tree. It will take much more work to get dates of the two trees into correct alignment.

Besides helping to track the movement of the first modern human emigrants around the globe, the two trees also record that only a small sample of the African population emigrated to the rest of the world, a conclusion also implicit in the fact of a single migration. On the female side, lineages L1 and L2 of the mitochondrial DNA tree remained confined to Africa, at least until modern times; only the M and N daughters of L3 left for the world beyond. On the Y chromosome genealogy, sons A and B of the Y tree never left Africa. Only the group of sons carrying a mutation known as M168 are found outside Africa. Presumably men of the M168 lineage accompanied the M and N lineage women as they and their descendants migrated from Africa to India.

The emigration of modern humans from Africa was not only a watershed in history but also a significant demographic event. The few who left Africa carried only a small subset of the genetic diversity present in the ancestral human population. Genetic diversity refers to the number of alternative versions of each gene—known as alleles to geneticists—that exist in a population; each individual can carry up to two of these alleles, one inherited from each parent. For instance, a region of DNA associated with the insulin gene exists in 22 different versions in African populations, but only three of these occur outside Africa.[92] The small size of the departing population would have increased the chances of its following a different evolutionary path from the host population in Africa because it created the conditions for the important kind of evolutionary change known as genetic drift.

Natural selection is the better known agent of evolutionary change but drift is also powerful, and the smaller the population, the more quickly drift acts. The mechanism of drift is the purely random way in which about half of a parent's genes get passed on to a child and half are discarded.* Depending on the luck of the draw, some versions of a gene become more common in a population as one generation succeeds another, while others grow rarer. Eventually one version of a gene may become universal while all the alternative versions are lost. This is what has happened in the cases of the Y chromosome and mitochondrial DNA. In terms of evolution's overall process, drift is the counterpart to mutation. Mutation constantly injects novelty into the genome, and in each generation drift sweeps novelty away. Natural selection draws on this flux, using it to keep each species adapted to the changing environment.

Since drift is random, the versions of a gene that it makes universal may be good or bad. For the most part, though, they are neutral, in geneticists' parlance, because they make no difference to an organism's survival. The smaller a population, the fewer generations it takes for a particular version of a gene to become universal. So drift would have been enhanced among the small group that left Africa and in its far-flung descendants as they spread out across the world. The human population as a whole probably existed for many millennia as small, largely separate groups, because distance and territoriality would have deterred any substantial mixing of peoples.

Those who left Africa carried only a slice of the full genetic diversity of the human population, and the size of the slice allows an estimate to be made of the emigrants' numbers. Sarah Tishkoff, a geneticist at the University of Maryland, has calculated that the number of modern humans who left Africa could have been as few as 160.[93] Another estimate, made by geneticists working with mitochondrial DNA, is that the source population in Africa from whom all humans outside Africa are descended numbered at most 550 women of childbearing age, and probably considerably fewer.[94]

*Everyone carries about half of their father's genes and half of their mother's; so what happened to the half you didn't inherit? It gets discarded, along with all the genes it contains. Each gene comes in a variety of different versions, known as alleles. By sheer chance, proportionately more of some alleles may get into the next generation, just by the luck of the draw, while fewer fall into the discard pile. The frequency of a given allele in the population may thus change considerably from one generation to the next, from 5%, say, to 33%, to 13%, to 55%, and so forth in a random fashion. But this random walk cannot go on forever. Sooner or later the frequency of the allele in the population will hit one of two numbers, 0% or 100%. At 0%, the allele is lost forever from the population. At 100% it becomes universal, i.e., the only version of that gene in the population since all other alleles are lost. When an allele becomes universal, geneticists say it is "fixed." The time it takes for any allele to become fixed depends on the number of generations and the size of the population, being faster when the population is smaller. When an allele becomes fixed, the population is then set on a different path through evolutionary space than if the other alleles of that gene had remained available to it.



Despite the appearance of precision, these numbers have wide ranges of error and are very approximate. The basic inference that can be drawn from them is that the ancestral group in Africa from which the first emigrants derived was very small, probably just a single band of hunter-gatherers. Such a band would number about 150 people if modern hunter-gatherer groups are typical of ancient ones. The group that left Africa would presumably have been this one band or a part of it.

## Peopling the Lost Continents of Sunda and Sahul

By whichever route the first humans left Africa, India seems to have been their first major stopping point, because it is there that are found the first diversifications, outside Africa, of the mitochondrial and Y chromosome trees.

In terms of the mitochondrial DNA tree, the M and N lineages that came out of Africa are still frequent in today's Indian population. The M lineage is very common, and its mutations are older than those of M lineages found farther east, supporting the idea that the Indian subcontinent was settled soon after the African exodus. On the Y chromosome side, several offshoots of the early male lineages are restricted to the Indian subcontinent, a finding consistent with the scenario that the first settlers arrived by a southern route; those offshoots would be expected to occur in the Levant as well as India if the emigrants had taken the northern route out of Africa.[95]

In India there was a historic parting of the ways. Some people continued the coast-hugging, population budding process along the southern shores of Asia, eventually reaching the Australian land mass, China and Japan. Others pushed inland in a northwesterly direction, through the lands that are now Iran and Turkey, and began the long contest with the Neanderthals for the possession of Europe. Both paths tested the power of the new modern people to innovate, survive in hostile surroundings, and overcome daunting obstacles. Consider first the migration to Australia, then the push into Europe.

The group expanding along the coast pushed eastward around India and Indochina, eventually reaching the two lost continents of Sunda and Sahul. With sea level much lower 50,000 years ago than it is now, the Malay peninsula and the islands of Sumatra, Java and Borneo formed a single land mass known as Sunda or Sundaland, which was a southern extension of the Asian land mass. Australia was then connected to New Guinea in the north and to Tasmania in the south, the three islands forming the lost continent known as Sahul, directly south of Sunda.

Apart from fording river mouths, the people expanding along the coastline would not have had to cross open sea until they reached the channel between Sunda and Sahul. This would have been a formidable barrier, some 60 miles wide. Forest fires in Sahul, or the flights of birds, may have indicated the presence of land to watchers from Sunda. In any event, modern humans reached Sahul, an achievement that puts beyond doubt their possession of the seafaring skills required to cross the Gate of Grief as a way out of Africa.

The arrival of the first modern humans in Australia is an important event, not just because they had accomplished an epic migration from their distant homeland in East Africa, but also because it offers one of the first opportunities to link genetic history with archaeological history. On the basis of burials, archaeologists believe Australia was settled shortly after 50,000 years ago. This period is beyond the reach of the radiocarbon method of dating, so an alternative method must be used, known as thermoluminescence. The method is not always reliable but in this case is supported by independent evidence: by 46,000 years ago, all large Australian mammals, birds and reptiles weighing more than 220 pounds had suddenly fallen extinct.[96] The reason was almost certainly the activity of a vigorous new predator, human hunters. The large animals of the Americas were to undergo a similar extinction shortly after the first hunters reached the New World.

It is perhaps surprising that Australia should hold the earliest archaeological sites outside Africa in which the presence of modern humans has so far been established. The likely reason is the comparative ease of migrating along the coastline instead of venturing inland. The sea route provided a reliable source of food and an easy means of travel, save for crossing the Sunda-Sahul passage. Since sea level was then much lower and many former coastal sites are now submerged, that could explain why no intermediate stages of the journey have yet come to light.



Many geneticists believe that the first modern humans came out of Africa considerably earlier than 50,000 years ago. Dating based on the rate of mutation seen in the tree of human mitochondrial DNA suggests that modern humans first left Africa 65,000 years ago, according to a recent calculation.[97] But genetic dates, though always interesting, depend on many assumptions that may not be realistic, and the dates derived by archaeologists are considerably more reliable. Archaeologists can at present see no sign of modern human presence outside Africa before 46,000 years ago, the date of the Lake Mungo site in southeastern Australia, and sites of similar age in the Levant. They have little patience with the geneticists' proposals that sites of earlier occupation along ancient coastlines now lie beneath sea level, since rather than wait to be engulfed by slowly rising sea levels, people would surely have built new settlements farther inland.

It's possible, of course, that the modern humans leaving Africa really were confined to the water's edge by the archaic humans who had settled Eurasia many thousands of years beforehand. The Neanderthals may have been present at times in the Arabian peninsula and *Homo erectus* occupied East Asia. Though the archaic humans may at first have been able to prevent modern humans from penetrating Eurasia, forcing them to skirt the periphery, the archaics themselves never reached Sahul. That could perhaps account for the odd fact that the oldest modern human remains come from the place at the remotest part of the journey, Australia.

Another reason for Australia being the first recorded landfall, however, is climate. The ancestral population was not adapted to northern climates. As discussed further in chapter 6, people may have needed to evolve special adaptations to colonize the colder regions of Eurasia. The first emigrants may have been confined by climate to the coasts of East Asia and warmer regions like Sunda and Sahul.

Be this as it may, the archaeologists are probably correct in their position that modern humans should not be assumed to have left Africa any earlier than 50,000 years ago, a date that is consistent both with the behavioral changes evident from archaeological sites within Africa, and with the date, 46,000 years ago, at which modern humans were clearly present in Australia.

But if archaeologists are right on the date of exit, geneticists may have the better case on the number of migrations: just one.

Because Sahul lies so far off the beaten track, away from the subsequent movements and mixings of the human population, Australia's aboriginal tribes may hold in their genes a fascinating portrait of the first emigrants from Africa. But differences in the robusticity of early skeletons, and the arrival of people with a semi-domesticated dog (the dingo), suggest that several extra waves of immigrants reached Australia after the first one. Because of political constraints on taking samples from aboriginal peoples, it's at present impossible to sort out these various waves of early immigrants as fully as geneticists would like.

Before the arrival of Europeans in Australia, the original inhabitants were divided into some 600 tribes, each composed of some 500 to 1,000 people and possessing its own dialect and territory. These tribes seem to have married within themselves, with little gene flow between them, and because of their antiquity each built up a distinctive genetic profile with special variants not seen elsewhere in the world. An analysis of mitochondrial DNA from the Walbiri tribe of the Northern Territory showed they possessed several lineages not found among any other tribe, indicating a considerable degree of genetic differentiation between them.[98]

In contrast to the diversity of mitochondrial DNA types, there are far fewer Y chromosome variations, with half of all male aborigines carrying one with the same distinctive genetic signature. This may result from what geneticists call a founder effect—the reduced genetic diversity of populations founded by a small number of individuals.[99] Other factors may also have been at work. Polygamy, when some men have many wives and others none, is a powerful reducer of diversity among Y chromosomes. So too is frequent warfare, the burden of which is borne by men.

Australian aboriginal tribes seem to have lived in a state of constant warfare, with defended territories and neutral zones marked for trading. Their tool kit, designed for easy transport over long distances, included weapons like heavy war clubs, a special hooked boomerang, and spear-throwers.[100] The tribes were skillful at surviving in a harsh environment but never developed agriculture. Their special genetics reflects both their antiquity and the effects of genetic drift, promoted by the fragmentation of their population into small warring societies.

Genetic analysis has yielded similar insights into the lifestyle of another of Sahul's early occupants, the people of New Guinea. Australia and New Guinea were joined until about 8,000 years ago, so the peoples of both



places may be descendants of the same migration. Mark Stoneking and colleagues analyzed both the Y chromosome and mitochondrial DNA from people in many New Guinean tribes and found a striking lack of diversity of Y chromosome lineages, especially in the highland tribes of the Dani, Yali, Una and Ketengban.[101] As with the Australian aborigines, reduced diversity could mean either a high degree of polygamy, with just a few men fathering most of a community's children, or a high rate of death in battle.

Both factors seem to have been at work in New Guinean society. All Papuan speaking populations in New Guinea practice patrilocality, with the men staying in their native clan and the women moving to their husband's clan. Most, if not all, New Guinea tribes practiced polygamy, at least until the missionaries arrived. Among the Dani, for example, 29% of the men had more than one wife, the range being from two to nine, while 38% of the men were not married.

Warfare was common in most Papuan societies until the second half of the twentieth century, Stoneking and his colleagues note, and casualty rates were high—about 29% of Dani men were killed in warfare, according to the anthropologist Karl Heider. This death rate is very similar to the male battle casualties among both chimpanzees and the Yanomamo of South America and presumably is driven by the same motive, the reproductive advantage gained by the successful warrior for himself and his male kin.

Warfare among hunter-gatherers is deceptively mild compared with the explosive carnage of modern battlefields. Battle may be opened but called off, like a ball game, if rain stops play, or someone is seriously injured. Heider, like many anthropologists, believed at first that warfare among the Dani was not a terribly serious affair. After his first field trip to New Guinea in 1961 he wrote a book entitled *Grand Valley Dani: Peaceful Warriors*. But after revisiting the Dani for many years, and reconstructing careful genealogies and causes of death, he realized how many men in fact died in battle. If you fight every week, even low casualty rates start to mount.

Like the !Kung San, the Dani fight to kill. They have not discovered how to daub their arrows with a poison like that of the chrysomelid beetles, but they use excrement instead, hoping to cause infection. Like many other human groups and the chimpanzees of Gombe and Kasakela, the Dani know that killing a few of the enemy leaves the remainder thirsting for revenge, so a more effective solution is extermination.

"About 30 percent of all independent highland social groups become extinct in each century because they are defeated," the archaeologist Steven LeBlanc writes of New Guinea tribal warfare. "These groups are either massacred or killed, or the survivors of a particularly deadly encounter flee and take refuge with trading partners or distant relatives. This last place on Earth to have remained unaffected by modern society was not the most peaceful but one of the most warlike ever encountered."[102]

The physical appearance of Australian aborigines is termed australoid, meaning that they have dark skin, wavy or curly hair, slender body build and large teeth. New Guineans are australoid but with minor differences, such as tightly curled hair. That the people of Sahul should look somewhat like sub-Saharan Africans is probably no accident. Because of their relative isolation, australoid peoples may be closer to the first emigrants than are most other living people. But they cannot exactly represent the first modern humans who left Africa because their population includes later immigrants, such as Polynesians, and they have themselves changed a lot through genetic drift.

## The Enigma of the Andaman Islanders

Australian aborigines are not the only trace population left from the original migration. All along the route back to Africa, in remote islands or out of the way places where later invaders could be resisted, there are unusual peoples whose genetics suggest an ancestry from the original emigrants. All are tribal, mostly forest-living groups who have managed to resist intermarriage or integration. They include some of the tribal peoples of India, such as the australoid Chenchus and Koyas of Andhra Pradesh, as well as the Negritos, forest dwellers found in the Andaman Islands, Malaysia and the Philippines. Many of these peoples have dark skin, as if retained from their African origins.

The Andaman Islanders are one of the most intriguing of these relict populations. The Andaman Islands lie in the Bay of Bengal, some 120 miles from the coast of Burma, but with the lower sea levels of 50,000 years ago the distance may have been as little as 40 miles. Since the first emigrants from Africa were capable mariners, as proved by their reaching Sahul, the Andaman Islands would also have lain within their reach.

The islands were long avoided by contemporary sailors, their occupants



having a fearsome reputation for extreme hostility and cannibalism. According to a British survey in 1858, the islands were inhabited by some 13 different tribes, each with its own language and territory, and some in a state of perpetual warfare with each other. Many of the northern tribes, known as the Greater Andamanese, were decimated by contact with western diseases, and within 50 years of British occupation almost all had perished. Only three of the peoples, all from the southern islands, now survive. They are the Onge, the Jarawa and the Sentinelese.

The origin of the Andamanese has long been a puzzle. Their features—short stature, dark skin, peppercorn hair and protruding buttocks, a feature known as steatopygia—are characteristic of African pygmies. "They look like they belong in Africa, yet here they are sitting in this island chain out in the middle of the Indian Ocean," says Peter Underhill, an expert on Y chromosome lineages. "People have been scratching their heads for 200 years asking who are these people and where do they come from."[103]

To address the question, two teams of researchers recently analyzed the islanders' DNA. Erika Hagelberg of the University of Oslo worked with blood samples from the Onge and Jarawa; she also extracted mitochondrial DNA from hair samples that had been collected from the Greater Andamanese by the ethnographer Alfred Radcliffe-Brown from 1906 to 1908.[104] A second team, led by Alan Cooper of the University of Oxford, obtained mitochondrial DNA from a collection of Andamanese skulls in the Natural History Museum in London; the ancient DNA was extracted from the pulp of teeth.[105]

Both teams found that the Andamanese belonged to the M2 mitochondrial lineage, and infer that they were part of the early migration of humans from Africa into southern Asia. The Y chromosomes of the Onge and Jarawa confirm the view that the Andamanese are an ancient, Asian people.

Their physical similarities with the African pygmies seem therefore to be what biologists call a convergent feature, meaning one acquired by independent evolution. Presumably when people start to live in forests, there are advantages in developing particular characteristics like short stature and steatopygia. The Biaka pygmies of the Central African Republic and the Mbuti pygmies of the Congo belong to different mitochondrial DNA lineages and presumably evolved pygmy stature independently of each other and the Andamanese.

With their dark skin and other African features, the Andamanese and other australoid peoples may represent what the early inhabitants of East Asia and Europe looked like before being displaced many thousands of years later by people from northern latitudes.

Another clue to the great age of the Andaman Islanders comes from language. Like the ancient !Kung and Hadza click languages, the Andamanese languages are isolates, meaning they are unlike each other and unlike any known language. The linguist Edward Sapir is said to have told his students that the world's languages are divided into two classes, Andamanese and all the rest.[106] This distinctiveness is another sign of great antiquity,

Joseph Greenberg, in his classification of the world's languages, placed Andamanese in a superfamily he called Indo-Pacific. The other members of Indo-Pacific are Tasmanian and the ancient Papuan languages of New Guinea. Like several of Greenberg's classifications, Indo-Pacific is not widely accepted by other linguists. But the grouping can now be seen to have put together languages that have another striking feature in common—all are spoken by people in remote regions who may be descendants of the first migration of modern humans from Africa to the foundered continent of Sahul.

## The Penetration of East Asia and Indonesia

Australia was not the only destination for the first settlers of Asia. While some people crossed the straits from Sunda to Sahul, others presumably continued eastward around the southern borders of Sunda. They would have followed the coastline northward, up the eastern coast of China until they reached Japan and the Kamchatka peninsula, leaving a trail of settlements in their wake.

These groups, finding the coastlines in either direction inhabited, would eventually have started to push inland. They would have used rivers as highways into the interiors of India, Indochina, China and Central Asia, according to a reconstruction by the medical geneticist Stephen Oppenheimer. "Geography and climate decided the newly arrived occupants of Asia where to go next," he writes. "The rules would have been simple: stay near water, and near reliable rainfall; when moving, avoid deserts and high mountains and follow the game and the rivers."[107]



The penetration of the Eurasian land mass would have brought modern humans into direct conflict with the archaic humans who had long possessed it, certainly with the Neanderthals in the west and perhaps with *Homo erectus* in the east. Possibly this invasion was delayed for many generations until the innovative moderns had developed the necessary weapons and tactics to defeat the archaics or perhaps, less dramatically, until they had evolved the genetic adaptations for living in cold climates. The interaction between these different human species is of the greatest interest, but so far there is little data to go on, except the stark fact that one survived and all others perished.

In the east, for lack of archaeological studies, it is not yet known how widespread were the populations of *Homo erectus*, or whether in fact their disappearance had anything to do with the advance of the moderns. But the two human species did overlap in various ways, according to two quite unexpected pieces of recent evidence. The first comes from that intimate observer of human evolution, the human body louse.

David Reed, a louse specialist at the Florida Museum of Natural History, has found that people around the world carry two distinct groups of body lice that look alike but have genetically different histories. He made the discovery by constructing genealogies of the lice's mitochondrial DNA, just like other geneticists have done for people. But whereas all human mitochondrial DNA falls on the branches of a single tree, the louse DNA falls into two separate clusters. One of the clusters matches the human mitochondrial DNA tree both in date and geographical distribution, just as would be expected if the lice had divided into separate populations like their human hosts after the dispersal from Africa. The second cluster of louse DNA coalesces with the first but only in the distant past, some 1.8 million years ago, as if it had been living for most of the time on a different host.

Lice are highly specialized organisms and human lice cannot live for more than a few hours away from the warmth and sustenance of the human body. So this second cluster of lice must have been living on humans; it's just that they were of a different species, Dr. Reed believes. He suggests that they traveled out Africa with the ancestors of *Homo erectus* and much later switched across to the modern humans who came into physical contact with the *Homo erectus* populations in Asia some 50,000 years ago.[108]

A second and even more astonishing overlap between modern humans and

*Homo erectus* was recently reported from the Indonesian island of Flores, which lies between Indonesia and Australia. From the floor of a riverside cave, archaeologists recovered a series of fossil human remains of which the oldest is 95,000 years and the youngest 13,000 years. The remains belong to some seven individuals and include one complete skull. These people stood about three and half feet tall but were not human pygmies. Rather, they were a downsized version of *Homo erectus*, according to their discoverers and other experts.[109]

Island geography imposes special evolutionary constraints on arriving species, often propelling small species to giant size and downsizing large ones. The island of Flores was home to a species of giant rat and to lizards that evolved into the carnivorous Komodo dragons, 10 feet in length, as well as an even larger lizard, now extinct. This lost world was roamed by packs of pygmy elephants. And its human occupants too, it seems, were also downsized.

The little Floresians present many paradoxes with which paleoanthropologists are still grappling. They made sophisticated stone tools similar to those crafted by modern humans and unlike any previously associated with *Homo erectus*. Yet their brains, miniaturized along with their bodies, were about the same size as those of chimpanzees and the australopithecines, neither of which could fashion stone tools. Skeptics suggest that if the Floresians made the tools found with them, they must be modern humans, perhaps of some pathological form. But other experts say the surviving skull is clearly of *erectus* descent and shows no sign of pathology.

On present evidence it seems that the little Floresians were descendants of *Homo erectus* who managed to endure some 35,000 years into the modern era, long after the rest of their species had perished. They owed their survival to living unobtrusively in a forest on a remote island. The only way that *erectus* could survive in the modern era, it seems, was by becoming essentially invisible to the new arrivals.

## The Long Struggle against the Neanderthals

Unlike the still fragmentary evidence about the fate of *Homo erectus*, much more is known about the interactions of modern humans with the Neanderthals, the archaic humans who occupied Europe and the Near East. The Neanderthals, who evolved west of the Urals some 127,000 years ago, were a



strikingly distinct variation on the human theme. Their bodies were stocky, with barrel chests and muscles like weightlifters'. They had large heads, with bony brow ridges on the front of their skulls, and strange buns or ridges on the back.

These special features may have been either a biological adaptation to cold, or the result of genetic drift, the random change in gene frequencies between generations. Genetic drift is especially powerful in reshaping small populations, as the early Neanderthals may have been.

Neanderthal remains include many broken and healed bones, suggesting their lifestyle was physically taxing—whether because of hunting game or each other is hard to say. Some skeletons bear injuries so severe that their owners seem likely to have depended on others to survive, suggesting that Neanderthals looked after their sick. They also, on occasion, practiced cannibalism, to judge by the cut and burned bones found at several sites. In both their pleasant and less pleasant behaviors, in other words, they were quite human.

Their brain size covered the same range, and in some cases exceeded, that of modern humans.[110] But their behavior was quite different. They used the same unvarying tool kit as anatomically modern humans, the forebears of the behaviorally modern people. They buried their dead in shallow graves, but there is no indisputable evidence that the burials were accompanied by ritual. At the Shanidar cave, in northwestern Iraq, a skeleton exhumed with large amounts of pollen pleasantly suggested floral tributes from fellow Neanderthals. But until any similar burial is found, the simpler explanation is that the pollen was imported by the rodents whose burrows honeycombed the grave fill.[111] There is some evidence that the Neanderthals were less socially cohesive.[112] Although they seem to have displaced anatomically modern humans from the Near East 100,000 years ago, they were unprepared for the highly innovative behavior of the humans who arrived on their doorstep 45,000 years ago.

"It is not difficult to understand why the Neanderthals failed to survive after behaviorally modern humans appeared," writes the paleoanthropologist Richard Klein. "The archaeological record shows that in virtually every detectable aspect—artifacts, site modification, ability to adapt to extreme environments, subsistence and so forth—the Neanderthals were behaviorally inferior to their modern successors, and to judge from their distinctive morphology, this behavioral inferiority may have been rooted in their biological makeup."[113] It is impossible to tell from their skeletal remains whether or not Neanderthals could speak, but the crux of their behavioral inferiority may have lain in their possessing only a crude, syntax-free protolanguage, or perhaps no language at all.

Some anthropologists have argued that the first modern humans may have interbred with Neanderthals. Given the hostility of human hunter-gatherer societies toward each other, and the extreme fear that the Neanderthals seem likely to have evoked in modern humans, it is hard to imagine that the two species enjoyed hanging out with each other, let alone that they would welcome an exchange of marriage partners. The human mitochondrial DNA and Y chromosome trees each coalesce to a single ancestor in Africa, with no sign of a Neanderthal contribution in either lineage.

The genetic separateness of Neanderthals was emphasized in 1997 in a dramatic feat of research by Matthias Krings and Svante Pääbo, then of the University of Munich in Germany. They managed to extract mitochondrial DNA from the original specimen of Neanderthal, some 40,000 years old, which was found in the Neander valley near Düsseldorf in 1856.[114] The DNA of the chromosomes in the cell's nucleus degrades quickly after death but the little ring of mitochondrial DNA, with about 1,000 copies in each cell, has a better chance of surviving for long periods. The extraction of the DNA was a technical tour de force, which many others had attempted but failed to do, in part because the method for amplifying DNA is prone to increase not just the target DNA but, even more so, the contaminating samples of human DNA that abound in every laboratory and handled object.

The Munich team managed to decipher only a small segment of mitochondrial DNA but enough to show that it differed significantly in its sequence of DNA units from that of modern humans. Mitochondrial DNA has now been extracted from a total of four Neanderthal fossils, situated in Germany, Russia and Croatia. All have DNA similar to each other and different from that of modern humans. Pääbo and colleagues have shown that Neanderthal mitochondrial DNA also differs from that of early modern humans, which weighs against the likelihood that Neanderthals made some mitochondrial genetic contribution to the modern human gene pool that has since been lost.[115]

But mitochondrial DNA represents only a small fraction of the genome,



so the possibility that some Neanderthal genes may have been incorporated elsewhere in the genome cannot at present be ruled out.[116] Though a large scale intermingling of the two populations seems highly unlikely, modern humans may on occasion have enslaved and interbred with Neanderthal women. If so, Neanderthals, being adapted to the cold, would doubtless have had several useful genes to offer to modern humans and traces of these may yet be found even though the mitochondrial lineages have gone extinct.

Krings and Pääbo estimate that the mitochondrial ancestress of humans and Neanderthals lived 465,000 years ago, give or take a couple of hundred thousand years either way. Genes usually split sometime before populations split, so this means Neanderthals split away from the hominid line sometime after 465,000 years ago. Their presumed predecessors, known as *Homo heidelbergensis*, are known in Europe from around 500,000 years ago, but it is not until 127,000 years ago that distinctive Neanderthal fossils appear.

The Neanderthals' home territory stretched from Spain in the west to points east of the Caspian sea. In the Near East it included the lands that are now Turkey, Iraq and Iran. Perhaps modern humans first entered Neanderthal territory directly from Africa. But if, as suggested above, there was only a single emigration, the one that reached India, then modern humans would have arrived in Neanderthal territory by a route that led from northern India through Iran and Turkey. These invaders reached the Near East about 45,000 years ago and, according to the archaeological evidence, moved steadily across Europe.

As the moderns advanced, the Neanderthals became restricted to peripheral refuges such as the Italian and Iberian peninsulas. With one puzzling exception, the Châtelperronian culture of 40,000 years ago, the Neanderthals stuck to their unchanging Mousterian tool kit, never learning from the innovative technology of their successors.[117]

There is no way to know for certain the nature of the interaction between the two human species. It is unlikely to have been pleasant. Hunter-gatherer societies cannot support standing armies, so it is probably wrong to think of the modern human entry into Europe as a military campaign. It was more a slow infiltration. Given that Pleistocene Europe had no highway system, the new arrivals may well have traveled by boat, along the northern coast of the Mediterranean and up the rivers of central Europe.[118] In winter, the frozen rivers would have made natural footpaths through the wilderness.

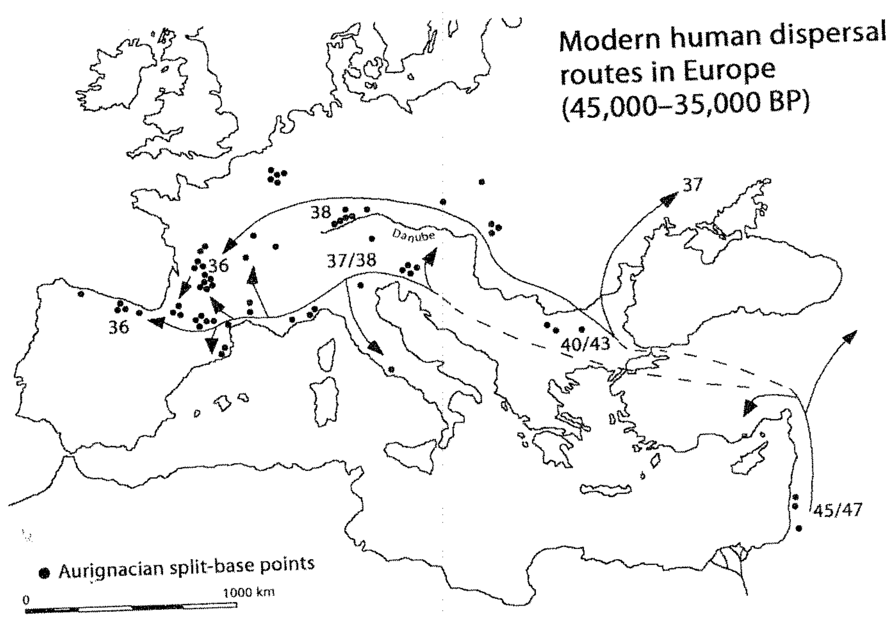



FIGURE 5.2. THE ARRIVAL OF MODERN HUMANS IN EUROPE.
Some of the African emigrants who reached India expanded to the northwest, through Iran and Turkey, eventually reaching Europe. Their slow-motion occupation of Europe took some 15,000 years, because of resistance from the indigenous Neanderthal population. Dots show sites occupied by Aurignacians, the name given by archaeologists to the culture of the first modern humans. Dates, in thousands of years before the present, are from radiocarbon measurements, and may be 3,000 years or so younger than calendar dates.

The modern humans probably moved as they always did, expanding into new territory as communities split, not exploring for the sake of adventure. Each new community would have skirmished with the local Neanderthals, who perhaps risked being killed by their fellows if they retreated into the territory owned by neighboring clans and had to hold on to their own territory or face extinction. Year by year, the moderns' territory expanded and the Neanderthals' shrank. From the extraordinary length of the process—a border war that took 15,000 years to move across Europe—it is evident that they did not yield easily. But by 30,000 years ago the Neanderthals had disappeared from their final refuges in the Iberian peninsula.



## The Moderns' Conquest

With the extinction of the Neanderthals, the archaics had been driven from the Eurasian land mass. Only the little Floresians survived, hidden in the forests of their remote island home. Modern humans, in the 20,000 years since their ancestors crossed the Gate of Grief, had occupied much of the world. Their populations, though still sparse, stretched across Eurasia, Sunda, Sahul and Africa.

But this was no imperium on which the sun never set, just a patchwork of tribes with no long range communication and no central authority. Archaeologists have found no towns or villages from this period; people still lived in a state of nature, wholly dependent on hunting and gathering for their existence.

For much of the period during which the exodus from Africa unfolded, from 50,000 to 30,000 years ago, people everywhere may have looked pretty much the same. Everyone outside Africa was descended from the 150 emigrants, who in turn were drawn from the host population in Africa.

The first modern humans were an African species that had suddenly expanded its range. For many millennia people would presumably all have had dark skin, just as do the relict populations of Australia, New Guinea and the Andaman Islands. It seems likely that the first modern humans who reached Europe 45,000 years ago would also have retained black skin and other African features. The Neanderthals, on the other hand, may have lived in northern climates long enough for the melanocortin receptor gene, which controls skin color, to have reverted back to its default state of producing pale skin. Though there exists no direct evidence as to skin color, and the point is only a curiosity, the Neanderthals may have had light skin and their conquerors black. Early Europeans, including the great artists of the Chauvet cave in France, may have retained the dark skin and other badges of their African origin for many thousands of years.

But despite the initial unity of the far-flung human family, regional differences inevitably arose. For archaeologists, the most striking are artistic. There is nothing to match the great painted caves of Europe, even though rock art of the same era is also known from Australia. "We must wonder," writes the archaeologist Ofer Bar-Yosef in discussing the art of this period, "why western Europe and, in particular, the Franco-Cantabrian region is so different from the rest of the Upper Paleolithic World. It is not the lack of limestone caves or suitable rock surfaces that prevented other social groups or their shamans from leaving behind similar paintings and engravings. Possibly this local flourish had to do with the vagaries and pressures faced by foragers in two major refugia regions at the ends of the inhabited world—western Europe and Australia—where there are claims for rock art of the same general age."[119]

There was a significant difference, or the seeds of a difference, between the European and Australian antipodes of the modern human advance from Africa. The Australian and New Guinean branch soon settled into a time warp of perpetual stagnation. They were still living with Paleolithic technology when their European cousins came visiting 45,000 years later. They never broke free from the triple bonds of patrilocal society, nomadic mobility and tribal aggression. For some reason the modern people who reached Europe and the Far East were able to escape this trap and to enter on a phase of steady and continued innovation.

Why these different modes of development occurred is one of the more puzzling questions of prehistory. Historians and social scientists, from the nature of their disciplines, tend to offer purely cultural or environmental explanations for all human differences. From a biologist's point of view, however, it seems likely that genetic influences would also have been at work, not least because it is hard to prevent an organism from responding genetically to a persistent environmental challenge. When people inhabit polar regions, they adapt genetically to the cold by developing the physique of Eskimos. When people go to live in tropical forests, they may develop pygmy stature, a change that has occurred independently at least three times since the diaspora from the ancestral homeland. Dispersed in small populations from Africa to Australia, from East Asia to Europe, the people of the Upper Paleolithic would have been subject to different evolutionary pressures and to the random effects of genetic drift.

Striking proof of the human tendency to develop local genetic variations has recently emerged from Iceland, whose population has been thoroughly studied by geneticists looking for the roots of disease. Iceland has been settled for just 1,000 years, by settlers from Norway, Britain and Ireland. Yet distinctive genetic variations have already arisen in each of eleven localities in



Iceland, according to a test developed by DeCode Genetics, a gene-finding company based in Reykjavik. The reason is that Icelanders, like people throughout the world, have tended to live, marry and die in the same place, and distinctive genetic variations have had time to develop in each locality, even in just 1,000 years. By scanning a person's genome, DeCode's researchers can specify where in Iceland that individual's parents and grandparents came from. The test is based on analyzing the sequence of DNA units at just 40 sites along the genome.[120]

If a detectable degree of local genetic differentiation has developed in Iceland in a mere 1,000 years, much greater differences are likely to have arisen among populations in the rest of the world, much of which has been settled for 40 times longer and where there have been many social and geographic impediments to the free flow of genes.

Genetic differentiation would certainly have started to act on the human populations of the Upper Paleolithic era. Bruce Lahn, a geneticist at the University of Chicago, has made a striking discovery about the evolution of two genes involved in the construction of the human brain. Each gene has several alternative versions, or alleles, but in each case one specific allele has become much more widespread than the others in certain populations. For an allele to rise to high frequency very quickly is a signature of natural selection hard at work. So presumably each allele conferred some very strong selective advantage.

One of the alleles is an alternative version of a gene known as microcephalin. The allele appeared around 37,000 years ago (though anytime between 60,000 and 14,000 years is possible) and is now carried by some 70% of many populations of Europe and East Asia. The allele is much less common in sub-Saharan Africa, where it is typically carried by from zero to about 25% of the population.

Just some 6,000 years ago a new allele of another brain gene, known as ASPM, appeared in the Middle East or Europe and rapidly rose to prominence, being carried by about 50% of people in these populations. The allele is less common in East Asia and occurs hardly at all in sub-Saharan Africans.[121]

What made the two alleles spread so quickly? It seems likely that each conferred some cognitive advantage, perhaps a slight one yet enough for natural selection to work on.

In Lahn's view, many genes are likely to be involved in constructing the human brain. He has found alleles of two of these genes, both of which happen to be quite common in Europeans and East Asians, but there almost certainly exist alleles of other genes that may be more common in other populations. Each population may therefore have used a different set of alleles to accomplish the same purpose, a well known biological process known as convergent evolution.

Resistance to malaria, for instance, is mediated by protective alleles in a number of genes, but Africans are protected by one set of alleles and Mediterranean peoples by a different, though often overlapping, set. The reason is that new alleles arise by mutation, a random process, and each population must make use of whatever alleles it has available. An advantageous allele may spread over time to neighboring populations, but will be more common in the place where it first arose. Lahn believes he is seeing the same phenomenon with alleles that have increased cognitive powers, and has just chanced on two alleles that happen to be common in European and Middle Eastern populations. "It is likely that different populations would have a different make-up of these genes, so it may all come out in the wash," he says.

Perhaps because of the sensitivity of suggesting that one population might have become genetically more acute than another, several critics asserted that the alleles could have become more common for some reason having nothing to do with the brain, such as conferring resistance to disease.[122] But there is at present no evidence that the microcephalin or ASPM genes do anything other than determine brain size. Some genes do play more than one role, but no other functions have yet been detected for microcephalin or ASPM. Their role in the brain, however, is well established. They first came to light because they are disabled in people with microcephaly, causing the brain to be much smaller than usual, particularly in the cerebral hemispheres that are the site of the brain's higher cognitive functions.

This strange condition seemed a throwback to the time 2.5 million years ago when the human brain was a third of its present size. In 2004 Lahn established that microcephalin and ASPM, along with several other brain genes, had undergone far more rapid evolution along the line of descent from monkeys to humans than had the counterpart genes in rodents.[123] The finding suggested that the brain has grown larger because a succession of



new and more powerful versions of genes like microcephalin and ASPM were favored by natural selection. The most recent alleles of microcephalin and ASPM are just a continuation of this process, in Lahn's view.

A firm conclusion from Lahn's finding is that human evolution continued after the dispersal of the ancestral population 50,000 years ago, and took different forms in different populations. Much of this evolution may have been convergent, as each population adapted with different alleles to the same challenges. But convergent evolution does not necessarily proceed in lockstep in each separate population. So it could be that the spread of the microcephalin allele some 37,000 years ago expanded the cognitive powers of Caucasian populations and underlay such striking cultural advances as the Aurignacian people's adeptness at painting caves, while other populations developed such capabilities later.

When the ancestral human population dispersed across the world 50,000 years ago, evolution set in motion a grand experiment: each population, in its fiercely guarded territory, would develop in its own way. This development would be both cultural, leading to a vast family of different languages, religions and lifestyles, and also genetic, as the members of each society responded to different climates, ecologies and social arrangements of their own making. Isolated on their separate continents, the far flung branches of the human family were to follow different trajectories as each adapted to the strange world that lay beyond the boundaries of their ancestral homeland.

3. Brian Fagan, *Cro-Magnon: How the Ice Age Gave Birth to the First Modern Humans* (New York: Bloomsbury Press, 2010). ISBN 13:978-1-59691-582-4.Chap. 10, 'The Power of the Hunt' (pp. 197-217). 21 of 295



enough detail to be sure, females are always depicted without clothes. Almost invariably, too, they are women in their prime reproductive years, with round figures from about age seventeen to forty. He also observes that most of the women have full figures and are even corpulent, characteristics that both biologically and socially represent fecundity. In what may be overtones of sexual invitation, the artists stressed the erotic parts of the body—breasts, buttocks, hips, and thighs—whereas the arms, faces, hands, and even ears and eyes are de-emphasized. In the same vein, there are also hundreds of explicit human images on the walls of Cro-Magnon caves, some little more than graffiti, others depicting sex organs, a few copulation. Guthrie writes, "So these distant ancestors, in good humor, made marks of passion and desire in ivory and on limestone walls. We have these identical traits of overwhelming obsession. They are not the refuse of illicit orgies nor are they the accoutrements of holy shrines, just casual breasts and vulvae scattered among lines of tail and antler—marks that played with the brain and made life more interesting."[21]

If Guthrie is on the right track, then the Gravettian Venuses, with their fat-filled breasts and buttocks, were an erotic signal of attractiveness in a society where fat consumption and increased weight helped survival. The figures are depictions not of pregnant women, but of full-figured women carrying fat in ways that are very different from pregnancy, when women carry their young high. Also, the proportions of the fat are displayed in ways that are consistent with obesity. So the voluptuous women of Cro-Magnon art may symbolize erotic potency, the periods of optimum sexual desirability when they carried weight: after the growth spurt of puberty and when babies had been weaned. Some of the doodles may just reflect teenage hormones operating at full bore.

There's an unexpected logic in Guthrie's theory, and it jibes well with the essentially simple foundations of Cro-Magnon life, which revolved around the realities of periods of abundance and scarcity. Above all, their survival depended on efficient harvesting of the bestiary that surrounded them on every side.



CHAPTER 10

# *The Power of the Hunt*

THE VÉZÈRE VALLEY, FRANCE. The men have watched for reindeer for days. They sit, warmly clad, on high crags above the valley in the cool fall sunshine of twenty-five thousand years ago. Below them, the mud brown Vézère flows sluggishly, riffling gently across the shallows of the ancient crossing place. Nearby, the camp is abuzz with expectation, spears and spear throwers at the ready, scrapers and knives close to hand. A still-warm breeze stirs the leaves of the dark conifers at water's edge. And the hunters wait and wait.

Next day, a gray morning dawns. Light mist whispers atop the trees. Croaking ptarmigan feed in the short, still-green grass of autumn. There's a soft backdrop of movement in the gloom, as if of gentle breathing. Suddenly, a cry summons the hunt. The reindeer are coming! Excited men, women, and children leap to their feet and grab weapons and tools, hunters to the fore, lining the riverbanks, nestled among boulders and trees. Each hunter carries a bundle of spears and his spear thrower. The press of reindeer arrives, heading northward, a crowding host of beasts fifty yards wide. The stream of animals parts on either side of a grove of trees and then comes together again as the host approaches the sloping riverbank. Moments later, the leaders enter the ford and splash across to the other side. Those behind them move inexorably in their footsteps, an orderly, intent highway of living things. Some cross in deeper water with powerful, buoyant legs, antlered heads atilt, packed so closely together that you could cross the river on their backs.

Dozens of beasts flow to the other bank before the hunters strike.

They rise from behind rocks and trees and move forward, aiming at the nearest animals in the shallows. The thud of spears hitting living flesh echoes across the valley. Crossing reindeer fall before the onslaught, trapped in the river by the momentum of the animals pressing forward and cutting off their retreat. Those approaching the ford break formation. They run back and forth in short bursts, upstream, then downstream, before stampeding along the riverbank and out of sight. The ford is a battlefield of dead and wounded beasts. Wounded reindeer flail helplessly, trying to rise on their haunches and escape. Others raise their heads and look at the hunters as they die. The men prance among them, jumping nimbly clear of slashing antlers. They deliver death blows with spears and clubs. Some they kill with sharp stone knives, severing their spinal columns with a quick slash. Reindeer blood pumps into the stream. The Vézère turns dark red. Long crimson streamers of brighter color streak far downstream before the current disperses them. Minutes after the hunt, more than thirty reindeer lie still at the ford.

Now the hard work begins. The men drag the carcasses from the water to the sloping riverbank. There they split open the bellies with a single long stroke, reaching inside the stomach cavity to disembowel their prey. They remove the liver and kidneys, then detach the hindquarters from the trunk. Reindeer tongues are a delicacy, so they avulse them by slicing through the skin under the tongue. People grab hunks of fresh meat and fat, wolfing them down as the blood spills over their chins and clothes. Meanwhile, deftly and without fuss, men and women skin each animal, helped by their sons and daughters, who learn the art alongside them.

Back in camp, men and women dump heavy loads of skins and flesh. While the hunters dismember the carcasses, cut off the flesh, and hang it up in strips to dry, the women scrape the fat off the skins and then peg them out on frames or the ground to dry. People reach for a limb bone, smash it open, tap it on a rock, and suck out the yellow marrow. Marrow is fat and is always a delicacy. Reindeer tongues cook on sticks over the hearths. The bands will eat well tonight.

As the shadows lengthen, the men sit around a fire just outside the camp telling tales of the hunt. Their sons sit with them, hanging on every word, reveling in the storytelling. The gentle sounds of animal



movement are still a backdrop to their consciousness, as the endless migration ebbs for the night. A man suddenly points. Another reindeer herd is crossing the ford just upstream of the camp. This time, the hunters only watch. The beasts cross the stream in a solid mass, then move onto higher ground. They head straight for the campfire, then split into two groups as they flow past the hearth, completely oblivious to the sitting Cro-Magnons. Three of the beasts come so close that the men wave and shout at them with an easy familiarity and literally push them away. Moments later, they are gone, melting into the dark shadows. The people around the fire are completely unfazed, for they think of the reindeer as friends, living beings just like themselves.[1]

Day after day, the hunters prey on the migrating reindeer as they cross the river. Ambush after ambush does nothing to stem the purposeful herds. Then, after a week or two, the seasonal migration ends abruptly, almost as if a faucet has been turned off. The hunters dry the last of the flesh and stake out the final hides. Everyone gorges on fat and marrow while they can. The women have smashed up spongy backbone and limb ends and boiled them in simple containers to extract as much grease as possible. They store as much reindeer fat as they can in leather bags, to be hung high off the ground in their rock shelter bases for the winter. The most important hunts of the year have ended, but memories of them will endure throughout the approaching cold season . . .

*Rangifer tarandus,* THE reindeer, must have been the stuff of legend and ritual to the men and women who lived off them. Thousands of fragmentary *Rangifer* bones lie in the occupation levels of Gravettian rock shelters in southwestern France, but they presumably represent but a fraction of the enormous numbers of reindeer taken by Cro-Magnon hunters every year. Many of the bones in the shelters may have come from solitary hunts during summer and winter, when small groups of reindeer browsed in quiet river valleys. A hunter and his son might stalk a beast, or a group of young men go after an animal crossing a stream, just as they did with other game, like ibex and red deer. But almost all the reindeer taken during the year must have come from the harvests of spring—when thousands of them would have migrated to the foothills of the Pyrenees to avoid the heat and mosquitoes in the deep river valleys of the Dordogne, among them the Célé and the Vézère—and fall, when they would have returned from higher elevations (figure 10.1).

I use the word *harvest* because the spring and fall hunts were just that: organized reapings involving several bands and considerable numbers of people engaged in mass kills and large-scale butchery. Why, then, do we find relatively few traces of the enormous numbers of carcasses butchered and processed by the Gravettians? The answer may be a simple one. Most of the reindeer bones we know about come from caves and rock shelters where people lived. Most spring and fall hunts were probably stayed from temporary camps. By the time the hunts were over, huge piles of rotting reindeer carcasses would have surrounded the encampments. The fresh meat would have attracted lions,

**Figure 10.1** *Reindeer migration near Abri Pataud in the Vezère Valley in Gravettian times, c. 25,000 years ago. Illustration by Eric Guerrier. Musée de l'Abri Pataud aux Eyzies-de Tayac, Dordogne and Institut de Paléontologie Humaine. Drawing executed under the supervision of Professor Henry de Lumley.*



hyenas, and wolves like magnets. Even upwind, the smell of decaying carcasses, and the flies, would have been pervasive. No sane hunting band would have lingered at such places longer than necessary, even with large, smoky fires burning. They would have collapsed their tents and moved on, carrying large amounts of meat and hides back to their base camp to be dried, smoked, and processed for later use. Grease rendering by boiling softer body parts would have yielded large quantities of fat that would keep for months. Within a few years, the piles of reindeer bones at the temporary camps would have decayed and vanished, leaving nothing for the archaeologist to explore thousands of years later. Some groups did, of course, prey on migrating herds from rock shelters, like the Abri Pataud, near the Vézère, described below. But the lack of known kill sites is in dramatic contrast to the prevalence of earlier kill sites in the Don Valley, mentioned in chapter 6.

The people would have hunted migrating reindeer in spring, but like humans, the beasts would have been lean and fat deprived after the long winter months. The herds were in their best condition in late summer and fall. Their coats were soft and springy. A mature reindeer can carry 30 pounds (13.6 kilograms) of fat under its hide. This is why the fall hunt was of prime importance to the Cro-Magnons, for it was then that they acquired their stocks of fat, hides, and dried flesh to meet winter needs. We know just how important it was, for little has changed for subsistence hunters since then. As was often the case for historic caribou hunters in Canada's Barren Lands, there must have been years when there was insufficient fat to provide both food and fuel. Yet the people managed to stay alive in unheated dwellings because of efficient clothing, by spending a great deal of time under heavy furs, by sleeping in close proximity, and by burning off the fat stored in their bodies from summer. For about six to eight months a year, depending on the severity of the winter, most Cro-Magnon bands would have relied on stored food from late-summer and fall hunts. Spring and early summer would have been a stressful time of potential hunger even in good years.

*Rangifer tarandus* is an eclectic feeder, consuming lichens and other foods in delicate plant communities. Reindeer move constantly, which minimizes the effects of fluctuations on their food supplies. They also dislike both heat and mosquitoes. Their seasonal migrations were the Cro-Magnon equivalent of the annual inundation that watered the fields of ancient Egyptian farmers thousands of years later. Not that the migrations were a certainty: quite the contrary. Like the Nile, which is capricious in its flooding, reindeer could behave unpredictably. They would change migration routes without apparent reason, use several unfamiliar defiles, or arrive in far smaller numbers than usual. But if the bones from Vézère rock shelters are to be believed, they were among the familiar staples of Cro-Magnon life for thousands of years.

Reindeer teeth are a fascinating chronicle of Cro-Magnon hunting life. The Canadian archaeologist Bryan Gordon has studied the complex movements of late Ice Age hunters in southwestern France by measuring the growth increments on reindeer and caribou teeth.[2] During the warm months of summer, the teeth display thick, clear growth marks, whereas those for winter are dark and thin—somewhat like the familiar growth rings displayed by tree trunks. Gordon compared ancient teeth with those from modern beasts, which gave an indication of the ages of reindeer killed at different Cro-Magnon sites. He then matched the teeth of two-year-old reindeer from La Madeleine rock shelter, on the Vézère, with those of two-year-old reindeer from Canecaude, in the Pyrenees, 124 miles (200 kilometers) away. All the teeth had two winter increments, but those from La Madeleine had thin spring ones, whereas those from Canecaude bore increments characteristic of late-spring and fall growth. The two sites are sufficiently far apart to represent the normal positions of winter and summer ranges of moving reindeer herds. Gordon believes that there were spring and fall migrations that had reindeer herds traveling between 180 and 250 miles (200 and 400 kilometers) in a few weeks—an equivalent distance to that traveled by caribou in the Canadian Barren Lands.

Gordon's research hints at very complex group movements that persisted over thousands of years. By the closing millennia of the Last Glacial Maximum, after eighteen thousand years ago, there were eight reindeer ranges in the West that we can identify, three in southwestern France, and others to the north and east. Both before and after the Late Glacial Maximum, the annual round of Cro-Magnon groups in the West revolved around these ranges and the antlers, fat, hides, and meat they provided.



THREE GREAT CRO-MAGNON rock shelters lie near Les Eyzies: La Ferrassie, occupied by both Neanderthals and Cro-Magnons; the Abri Pataud, predominantly a Gravettian camp; and Laugerie Haute, most intensively used somewhat later. The inhabitants of all three preyed on reindeer, red deer, and, of course, other game. They used these shelters as base camps over many thousands of years. By about twenty-five thousand years ago, La Ferrassie's overhang was almost completely shattered by ice and frost, rendering it virtually useless as a stopping place. By then, Gravettian groups had long occupied the Abri Pataud (the rock shelter of Pataud), at the foot of the cliff on the other side of the Vézère River.

During the nineteenth century, the Pataud family farm nestled under the cliff, complete with bread oven, pigsties, and toolsheds. Farmer Martial Pataud found the prehistoric shelter while constructing a track to his buildings, but had absolutely no interest in archaeology. With Pataud's reluctant permission, a stream of early archaeologists dug small trenches into the deposits under the farm. Fortunately, he resolutely opposed any large-scale digging on his property. There matters lay until 1949, when the Harvard archaeologist Hallam Movius rented a tract of the property for a trial dig. The results were so promising that he purchased the land encompassing the shelter in 1957 and deeded it to the French National Museum of Natural History. Movius demolished the farm's barn and used the stone to build a new house for Martial Pataud's descendants a short distance away. He then directed six seasons of digging into the depths of the Abri Pataud, from 1958 to 1964. The old farmhouse became the site laboratory.

The Abri Pataud dig was a state-of-the-art field investigation, conducted with all the rigor of mid-twentieth-century science (figure 10.2).[3] This was no quick probing of densely backed occupation levels, as had been the case with earlier diggings at places like Laugerie Haute, but a minute dissection of a rock shelter occupied first by some Aurignacians and then mainly by Gravettians from about 34,500 to 20,500 years ago.

## *Zooarchaeology, or "the bones come together, bone to its bone"*

How do we know about Cro-Magnon hunting practices? Our information comes from two sources. Modern-day accounts of traditional hunting in the Arctic are a mine of information, given the reasonable assumption that there are only a limited number of ways in which you can drive reindeer or trap an arctic fox. The bones of the prey butchered by the hunters and their families are the most valuable archive, but one that is frustratingly difficult to piece together. Animals were not only meat and hides; they provided raw materials for antler and bone tools, bags, thongs, and clothing. Tongues and entrails were eagerly devoured; long bones provided marrow; animal fat gave energy and warmth throughout the year. Usually, all that remains are discarded, shattered bone fragments, trodden into rock shelter floors and thrown into hearths or pits. When push comes to shove, almost all animal bones from archaeological sites are too fragmentary for identification. Fortunately, however, some body parts, such as teeth, jaws, horns, and some limb bone joints, are readily identifiable when compared with either modern-day animal bones or well-preserved fossil skeletons. You can easily distinguish the bones of *Rangifer tarandus* from those of a wild horse, for example.

The plot thickens once the identifications are made, for it is not just a matter of totting up the percentages of the bones. What one researcher once called the "archaeological animal" (the counted bones) is a very different beast from the actual animal that was killed, butchered, and carried, at least in part, back to camp. By carefully inventorying the individual body parts in an occupation level, one can sometimes obtain a count of the minimum number of animals in the collection, but it's an approximation at best. Once you have a count of individuals, you then confront other questions. Are the changes in the numbers of, say, reindeer and horses found in, say, an Aurignacian occupation layer and a Gravettian one a reflection of changed hunting



practices, or simply chance? Does the overwhelming dominance of reindeer in the layers of the Abri Pataud mean that the inhabitants pursued them to the exclusion of other beasts? Were these chance hunts, or the result of harvesting spring and fall migrations? Some answers can come from identifying the ages of the animals, by examining horn cores or upper and lower jaws with at least some of the teeth intact. Growth rings in reindeer teeth are helpful for studying ages and migration seasons, too. A high proportion of juveniles or young adults can imply selective hunting, as can a focus on older beasts. The Cro-Magnons were such efficient hunters that they took prey of all ages.

A great deal of zooarchaeology involves turning percentages and animal counts into meaningful interpretations of human behavior. One approach involves studies of living hunters, notably the Nunamiut caribou hunters of Alaska, studied by archaeologist Lewis Binford some years ago. He found that Nunamiut food-procurement strategy was based on complicated decisions that involved not only the distribution of food in different seasons but also the storage potential of different animals and their parts, as well as the logistics of obtaining, carrying, and storing meat. Was it, for example, easier to move people to the herds or to carry meat back to base? We have to remember that fragmentary animal bones in the laboratory reflect intangible but logical decisions made thousands of years ago.

Every Cro-Magnon man or woman knew how to butcher animals of every size with sharp-edged stone knives. They acquired the skills while still children, perhaps first with reindeer and other medium-sized animals that were relatively straightforward to skin and dismember. Arctic foxes and other fur-bearing animals were another matter, for the pelt had to remain as intact as possible. Thousands of fox bones from Cro-Magnon sites show how the skinner cut through the hide at the feet and worked up from there. This kind of skinning was very different from the near-industrial-scale butchery needed when harvesting reindeer or horse migrations. Studies of breakage patterns show us how the Cro-Magnons disarticulated limbs, broke skulls open to get at tongues, and smashed limb bones for the marrow, using simple, effective methods that varied little over the centuries and are still in use today.

Like so much else in Cro-Magnon archaeology, their food remains are a palimpsest of information, teased out from seemingly insignificant bone fragments that usually reflect a few seconds of human behavior thousands of years ago.

It's safe to say that this remarkable excavation set new standards in rock shelter research that have been the basis of all later Cro-Magnon investigations. Over seven seasons of slow-moving digging, the excavators recovered almost 1.5 million finds—artifacts, food remains, and art objects—in packed occupation layers compressed under huge boulders from the shelter roof that had to be removed before excavations could commence.

Excavating the tightly compacted layers of a rock shelter is about the most challenging form of archaeological excavation of all, especially if you are as meticulous as Hallam Movius, who was obsessed with accurate recording and comprehensive data recovery. He installed a pipe grid over the archaeological deposits so that he could measure the exact position of every significant artifact, every feature. (He excavated before the computer era came to archaeological digs. Today's archaeologists rely almost entirely on electronic recording.) Stone-tool making debris, animal-bone fragments, hearths, and clusters of tools used for different activities chronicled dozens of short visits to the rock shelter. Using brushes, dental picks, and trowels, dozens of archaeology students removed each occupation layer inch by inch, spending as much time recording as they did excavating. The excavators plotted every hearth, as well as the artifacts and food remains around it, teasing details of the activities carried out there from seemingly inconspicuous objects. Just maintaining the diagrams of the stratified natural layers and various human occupations was a full-time job, as was plotting the emerging levels. The bags of finds went to the field laboratory, where Movius and



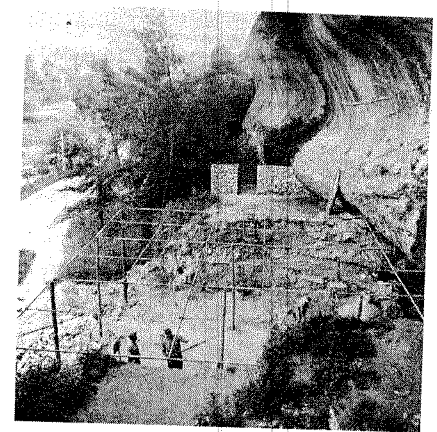


**Figure 10.2** *Abri Pataud excavations. The metal pipe grid was used for measuring the positions of individual finds. © President and Fellows of Harvard College, Peabody Museum #2004.24.33363.*

more students sorted the material. They monitored the artifacts carefully for significant changes or innovations, worked on the dig, and sorted finds. The laboratory research took years. Almost fifty thousand artifacts came from about forty encampments at the Abri Pataud, grouped in fourteen archaeological layers. The burins alone formed an important doctoral dissertation that took years to complete.

Studies of the collections continue to this day, but the general history of the Abri Pataud is now well known. Some Aurignacians were the first visitors to the shelter, between about 34,500 and 29,000 years ago. They left their split-based bone points, burins, scrapers, and other distinctive tools behind them. Between 28,000 and 20,500 years ago, Gravettian visitors used the shelter intensively in a series of occupations that are divided archaeologically into four stages marked by different tool types. From our point of view, the differences are minor and need not detain us here. Every band that used the site made burins and scrapers, used for processing antler, bone, and skins. They also manufactured enormous numbers of sharp Gravettian knives or projectile points that grew progressively smaller as time went on, a reflection of lighter, more efficient weapons, some of them armed with barbs as well as single points.

One Gravettian occupation, dating to about twenty-four thousand years ago, centered on a substantial, tentlike structure erected between the cliff and some boulders at the front of the shelter (see color plate 5). Poles sloping between the floor and the back wall provided a sturdy framework for a covering of sewn hides. Piles of stoneworking debris lay outside the dwelling. You can imagine the great rock shelter on an unusually warm late-winter day. The sun casts long shadows across a litter of much-fragmented bone and stone blades, interspersed with boulders. Spears lean against the back wall, where leather bags of frozen reindeer fat hang high above the floor. A fire of dry branches sends white smoke to hover under the overhang on this windless morning. A woman in a thin shirt and long pants tends the fire, which lies outside a weathered hide shelter erected around stout poles. Inside, an old woman swathed in reindeer hides sleeps restlessly next to a smaller fire. The smoke rises between rows of socks and boots hung up to dry. Two men in summer parkas sit on boulders outside the tent. The younger one strikes blades off a flint core. His father uses a burin to groove fresh bone, soaked overnight in water to soften it. The movement of the burin fills the rack shelter with scraping noises, which mingle with the shouts of children playing on the slope down to the frozen river below. A pervasive scent of human sweat, rotting flesh, and drying furs drifts across the camp . . .

The packed layers of the Abri Pataud tell us that Gravettian life by the Vézère changed little over a span of more than seven thousand years. The inhabitants hunted wild horses—compact, well-muscled beasts with small heads—and aurochs, whose bones appear in the shelter. Above all, however, they preyed on reindeer, whose bones represent between 80 and 90 percent of all the animal bones in the occupation layers. Much of the time, the climate was cold and dry, the valley covered with patches of short grass, with coniferous trees on hillsides and near the rivers. During brief warmer spells, the hunters targeted more stags and wild boar. Most of the time, though, the staple was *Rangifer tarandus*. They also hunted many smaller species, many of them fur-bearing animals, including rabbits, and snared ptarmigan, grouse, and ducks. By any measure, these people were efficient, ingenious hunters. Everyone, man or woman, adolescent or small child, lived in intimate association



with their surroundings in a way that is unimaginable to modern Westerners. Above all, their art tells us that they were consummate observers.

The Cro-Magnons spent most of their time not hunting but watching—for hours, days, even weeks. They lived among a bestiary whose behavior they knew as well as their own. They were familiar with the animals routines of feeding and drinking, birth, courting, and death. Every hunter knew when reindeer were in top condition, the subtle color changes in the fur of arctic foxes, the sometimes dramatic changes in appearance that accompanied different social behaviors in all manner of beasts. Every Cro-Magnon knew more about animal behavior than most twenty-first-century biologists. They lived so close to their prey that they were part of their quarry's lives. It was this knowledge, based on meticulous observation, that made them successful hunters.[4]

You need only look at the details of cave paintings and engravings on antler fragments and weapons to realize this. Individual paintings and smaller engraved pieces tell us much about late Ice Age animals.[5] A reindeer raises itself to a standing position by using its forelimbs. A male sniffs the genitals of a female as they lie engraved on an antler beam. The differing sizes of their antlers portray their sexes. Horse manes are full, just as they were in life; the bison depicted on cave walls lack the thick pads of hair characteristic of American bison, an adaptation to their violent head-to-head clashing.

Cro-Magnon art, when examined judiciously, is a mine of information about the species the people hunted. For instance, a hunter watching large herbivores spends at least half of his time watching them eat. Cro-Magnon artists sometimes depicted habitual grazers doing just that. Horses normally prefer medium-height grasses but occasionally will stretch their necks downward to crop much shorter grass. The artists painted or engraved some of them feeding in this manner, as they did such quiet activities as a bison grooming its flank. But they drew many more animals with their tails alert or in threat postures. The artists had a "distinct taste for excitement."[6] At La Mouthe cave, near Les Eyzies, we see two mammoths sparring head-to-head, as they also do at other caves, like the large cavern of Rouffignac. There are courting scenes between reindeer. The artists depicted *Rangifer* in autumn, with fully developed antlers, and the distinctive summer and winter coats of horses, which in very cold environments, in winter, grew hair around the jaw that looked almost like a beard. All the horses in Grotte de Chauvet wear such winter coats. Bison painted in northern Spanish caves like Altamira often have reddish bay hair and black legs, manes, and tails. Those further north bear less-spectacular coats, often gray-brown.

The Cro-Magnons surrounded themselves with depictions of the most challenging and formidable members of the bestiary, some of whom were too dangerous to be staple prey. It's a mistake to think of Cro-Magnon art as being confined to caves and other places far from daylight. Every hunter carried a small arsenal of more-permanent weapons (as opposed to disposable projectile points) that he decorated for himself, perhaps with slashed lines or geometric or curved patterns, or with depictions of the animals that surrounded him on every side. There are doodles and crude sketches, simple engravings, and the occasional depictions that are masterpieces, executed by individuals with true artistic talent. Only a small fraction of this mobile art has survived the millennia. More of it must have adorned perishable substances like hides and wood than more-durable and harder-to-work antler, bone, clay, ivory, and stone.

The archive of drab stone tools and dark bones that has come down to us does a disservice to its creators, and to what must have been bright and colorful societies. Body paint denoted social status and affiliation; bright and muted colors alike marked spears and other artifacts; bird feathers may have formed headdresses. People may have even made brightly painted wooden masks. Their taste for color and contrast was surely as well developed as our own. Painting and engraving were ubiquitous in Gravettian life, as much a part of the fabric of daily existence as spears or knives. Much of the art was pragmatic and personal, part of a colorful and dangerous existence, a way in which people marked their possessions, commemorated their social affiliations, and expressed their individuality.

Some of the wall art may also have been purely decorative. At the



Roc-de-Sers rock shelter, in France's Charente, a frieze of twenty engraved rocks once ran the length of the shelter wall. One of the boulders at the mouth of the shelter bears an image of two fighting mountain goats. They lock horns, as ibex do during the rutting season as they win mates. At another shelter, Le Fourneau de Diables, near Les Eyzies, artists carved two aurochs on a large rock, which once stood at a slight angle, its edges buried in scree. The great animals, with their lyre-shaped horns, were but two of twelve images engraved and carved on this one rock. Such friezes were visible in daylight and in common view.[7]

In the profound darkness of subterranean chambers, it was a different matter. Here the powerful forces of the supernatural realm pressed on visitors, apparently from behind the rock faces. Paintings flickered in an illusion of movement in the light of a pine brand or a fat lamp. One can imagine visitors of all ages clambering into the depths of the Pech Merle cave, near Cabrerets, in the Lot. The large cavern boasts lower chambers that were never painted, but near the ancient, now-blocked entrance a jumble of finger flutings appear on the ceiling, a large area of rectilinear and curved lines, which include some naturalistic images, among them a mammoth. Under the floor below it lies a woman facing left, her body bent forward, breasts hanging, large buttocks clearly shown. She may have worn a headdress. She looks very similar to an engraved female figure at the Cussac cave, in the Dordogne, dated to about 25,100 years ago. Pech Merle also boasts one of the most famous of all Cro-Magnon friezes. Two black horses face in opposite directions, the head of the right-hand animal emphasized by the natural shape of the rock (see color plate 8). Large black dots surround the beasts and adorn their bodies. Six black hand stencils lie close by, while a red fish appears above the horses. The right-hand horse was painted 24,640 years ago.[8]

The meaning of the cave art eludes us, except, perhaps, for the hand imprints. Hand imprints and animals—the association goes back deep into Cro-Magnon history to the Aurignacians and Grotte de Chauvet with a persistence that suggests that people acquired some form of power from contact with dark rock faces beneath the earth (see color plate 9). Powerful testimony also comes from the Gargas cave, in the Pyrenees foothills.[9] Generations of visitors—men, women, children, even infants—left their hand impressions on the walls of the cave's lower level. Some of them lie close to cracks in the walls filled with bone slivers that were deliberately placed there. One of the bone offerings dates to 26,860 years ago. There are more than two hundred hand stencils in this one chamber alone. A small niche elsewhere in the cave frames a black hand stencil surrounded by the relief of the wall. All the fingers are shortened, as they are in many Gargas handprints, presumably deliberately, for reasons that elude us. The participants used red iron oxide or black manganese oxide to outline their hands, which created the impression that their hands had melted into the rock. Once the hands were withdrawn, the impression would ensure vivid proof of contact with the supernatural world.

IT'S EASY TO be seduced by images of a macabre carnival of game drives and mass killings, when in fact much Cro-Magnon hunting involved small numbers of people, sometimes only individuals. The routine of daily life, year in, year out, revolved around the small-scale hunt: the pursuit of red deer at the edges of forests, the quiet trapping of ptarmigan or grouse by women, a couple of arctic hares snared along a trail. The limitations of being on foot, of lightweight, if accurate, weaponry, meant that most hunts required taking not bison or rhinoceroses but deer or ibex, a solitary reindeer or a horse, or unspectacular hours spent tracking arctic foxes during short winter days. Above all, everyone watched animals. If modern-day hunters are any guide, they attributed complex emotions and feelings to them as they watched, sometimes simply out of curiosity.

Hunting larger, more formidable game like an aurochs or a bison was dangerous business and would have required careful preparation. There were always a few such beasts around, familiar denizens of the local valleys to be avoided because of their uncertain tempers and unpredictable behavior. To hunt such a dangerous beast was a major undertaking that would have involved several bands and infinite patience . . .

The massive bull aurochs is a magnificent beast with forward-angled, lyre-shaped horns and a pale stripe down its spine. It grazes alone at the edge of the trees, tail flicking away the summer flies, its black body hard



to discern against the dark forest. The hunters and their sons have watched it for days. They track it as it moves down to the stream to drink, snorting fiercely at another bull nearby. They flit from tree to tree in the midday shadows while their prey moves majestically down a narrow forest trail. No one is in a hurry, for they know that their seemingly peaceful quarry can turn aggressive in a moment. It dwarfs even the tallest hunter; its horns can rip open an attacking wolf in a second.

Each night, the hunting party talk about the bull. They dissect its every move, its behavior, its likely reaction to an attack, its daily, and surprisingly predictable, routine. There's a spot along the forest track where it labors through soft brown sand and mud still wet from a spring thaw, a place where trees arch overhead. This is the strategic point for the hunt. Under the direction of a scarred, weather-beaten elder, the hunters collect sharpened antlers and sticks, watch the aurochs out of sight, and then quickly excavate a deep pit in the soft ground with their hands and some reindeer shoulder blades. The boys climb down into the deepening hole and scrabble out the soft clay. Then their fathers set sharp antler stakes in the muddy pit and cover it with branches and then sand. The most experienced hunter climbs onto a branch above the pit with a heavy thrusting spear, while the others hide in the surrounding forest with a carefully folded strong fiber net by their feet. They keep watch in vain that evening. The aurochs stays by the stream, wary of a pride of lions it sees nearby. The hunters wait.

The lions move on, and the aurochs relaxes. Toward midday, the aurochs moves along the familiar track. With a violent crash, it stumbles into the hidden pit. As it bellows and tosses its great horns, the hunter overhead thrusts his spear between the bull's shoulders. His companions quickly throw the net over the raging horns, dancing nimbly away from the flailing head. They hurl spear after spear into its flanks. The tiring beast struggles frantically, but sinks into the churned-up mud. As it slows, the hunters approach cautiously to deliver the death blows . . .

OVER THOUSANDS OF years, the routine of Cro-Magnon life remained unchanged from one generation to the next. Their existence revolved around the cycle of the seasons, familiar environments and landscapes, the customary movements from sheltered winter base camps into summer encampments, and the annual gatherings where neighboring bands came together for a few brief days. Experience counted for everything, the cumulative lore of generations passed from father to son, mother to daughter, knowledgeable hunter to neophyte. The passage of time was cyclical, too, marked by the constant realities of birth and death, by abundance and scarcity, and, above all, by the mass hunts of summer and fall. As long as these hunts continued, survival was ensured. The world of the ancestors and the living continued to pass on to those still unborn.

Mass hunts may have been seasonal events, but they provided about the only way in which Cro-Magnons could harvest large quantities of meat and hides in a short time, essential for survival through long winters. To acquire a rich harvest, they made sophisticated use of the terrain within their hunting territories. The hunters were well aware of the limitations of their short-range weaponry. To overcome them, they became masters at using terrain as natural corrals, at preparing ambushes near fords and swamps, in narrow culs-de-sac and small valleys. It was no coincidence that some painted caves, like Pech-Merle, lay close to deep canyons where horses and other animals could be ambushed. In northern Spain, hunters would prey on ibex and deer at the choke points at the heads of river valleys and their tributaries. Such hunts had an immensely long history throughout Europe, although we lack much evidence of them in the West. As early as thirty-nine thousand years ago, and probably earlier, hunting bands at Kostenki and Borshchevo, in the Don Valley, were driving horses and reindeer into side ravines in regular mass hunts.[10]

Like reindeer, horses were an important source of bone marrow, fat, hide, and meat.[11] Their hooves could serve as small containers or be boiled to extract a form of glue. Late Ice Age horses were very different from domesticated forms. Aggressive, agile, and fierce, they were compact beasts whose closest living relative may be the Przewalski horse of Mongolia. Now extinct except in zoos, the latter was first observed by Colonel Nikolai Przewalski in 1880 and last seen in the wild in 1969. With their large heads, dun coats, and white bellies, Przewalskis closely resemble the



horses depicted on late Ice Age cave walls, which often display the characteristic pendulous belly and sometimes even feature the striping found on these beasts (see figure 11.1). As Cro-Magnon hunters well knew, the best way to kill the nimble animals was by using the landscape.

This would not have been a matter of finding a strategically placed cliff and stampeding a herd to their deaths, as Plains Indians did with bison. You can stampede a bison herd by using skillful driving maneuvers that send the leaders into a panic, setting off a headlong flight. When the front runners reach the cliff face, the sheer weight of the herd behind them pushes dozens of individuals over the edge. Wild horses behave very differently. We know from studies of feral herds that when confronted with danger, individuals break away sharply, flee in single file, or just scatter. The only way you can kill a horse herd is by confining the beasts within a box canyon or small valley, which is exactly what Cro-Magnon hunters did at Solutré, near the modern city of Mâcon, at the southern edge of Burgundy in central France.

Each spring and summer, horse herds migrateed between their winter grazing grounds, in the floodplain of the Saône River, and the cooler, insect-free foothills of the Massif Central, where they spent the warmer months and could find plentiful snowmelt for watering. They passed through a valley that served as a natural corridor past a conspicuous landmark, the Roche de Solutré, which forms part of an escarpment sheltered from northwesterly winds. Here the herds paused to graze. Here, too, the hunters lurked in an unchanging routine of slaughter that repeated itself year after year between thirty-two thousand and twelve thousand years ago.

The south slope of the limestone ridge at Solutré is relatively gradual but broken terrain, ideal as a form of natural corral that was a cul-de-sac in the higher ground of the escarpment. After days of watching, the hunters would have decided on a strategy for the kill. Perhaps they herded the beasts with a drive line, gently waving hides to steer them, or lit a row of fires, or even constructed drive lanes marked by stone cairns (now long vanished). It was a question not so much of driving the herd but of pointing it in the right direction, a task that required careful placement of men, women, and children; taking account of the wind direction; and having the hunters in place in the cul-de-sac. Many generations of cumulative experience went into the Solutré horse hunts, especially into anticipating the behavior of the trapped horses. The waiting spearmen knew the spooked herd would scatter in different directions, only to be hemmed in by the terrain. They could pick them off quickly in the confusion and dispatch any terrified beasts that tried to climb the rugged slopes. Their strategies worked successfully for over twenty thousand years.

The first archaeologist to work at Solutré was Adrien Arcelin, a local archivist who found a weathered flint spearhead while walking beneath the escarpment with his parents in 1866. He became obsessed with what he believed was a Stone Age kill site. Arcelin dug deep trenches into the cul-de-sac and under the imposing cliffs of the Roche de Solutré. Influenced by romantic accounts of Plains Indian bison drives, he speculated that Stone Age hunters had driven their prey over the cliffs high above. He was soon proved wrong. No bones came from the base of the Roche, only from the niche-like cul-de-sac on the western side, where stone projectile points abounded.

Four long excavation campaigns began with Arcelin's investigations and culminated in a meticulous investigation involving a team of scholars led by Jean Combier and Anta Montet-White, between 1968 and 1998.[12] The Combier and Montet-White excavations focused on bone-filled layers undisturbed by earlier excavators. The team obtained radiocarbon dates and enough material for a long-term study of what was, by any standards, an impressive kill site with a long history. We now know that Neanderthals were the first to kill horses here, about fifty-five thousand years ago. Then there was a gap of nearly twenty millennia, represented by over six feet (two meters) of sterile soil, before Aurignacian bands arrived about thirty-four thousand years ago. They were sporadic visitors until about twenty-nine thousand years ago.

By twenty-eight thousand years ago, Gravettian hunters had inaugurated a pattern of seasonal killing that was to persist for thousands of years during a period of rapid climatic shifts leading up to the Last Glacial Maximum. Most of the time, the climate was cold, the escarpment surrounded by the kind of open steppe favored by wild horses and reindeer. Overwhelmingly, the hunters targeted horses. The bands descended



on the kill site between May and November, apparently preferring young stallions, whose bones abound there. Each year, the hunters would kill indiscriminately, slaughtering far more animals than they needed in brief orgies of killing. By twenty-five thousand years ago, Solutré had become a massive kill site, with deep layers of horse bones lying under the surface, even paving the ground. At least thirty thousand horses perished in Cro-Magnon hunts here, many of them unnecessarily. We know this because the packed bone deposits yield entire backbones and back legs, many of them with few signs of butchery with stone knives, as if the hunters simply took what they could immediately eat or dry, then left dozens of carcasses to rot.

We can imagine the Solutré kill site littered with whitened bones when the hunters arrive, dodging the hundreds of beasts grazing near the cliffs. Then days of careful preparation culminate in the frenzy of the hunt. The short grass becomes trampled and bloody, dead horses limp on the ground, others flailing helplessly in their death throes. Now the butchery commences. Men and women swarm over the beasts, gutting them rapidly, cutting out their tongues, and skinning them for their hides. They quickly remove tendons as well. There is meat in abundance, far more than the people could ever eat, but time is short, given the hovering predators. So they cut off strips of flesh to dry and perhaps choice leg bones for their marrow and immediate consumption, then leave the rest to rot. They move away, oblivious to the flies that swarm over the carcasses and to the hyenas that move in, out of spear's range. Within a few days, the accumulation of rotting flesh and bones is all that remains of the kill, the remnants of a promiscuous slaughter that can be smelled miles downwind.

The hunts continued until the increasing cold of the Last Glacial Maximum drove the hunters southward into warmer environments. By 21,500 years ago, the extreme cold had made Solutré and most more-open environments untenable. The hunts ended, as the Cro-Magnon population of the West shrank until about 19,000 years ago, when a slightly warmer and more humid interval allowed Cro-Magnons to return to Solutré. It's a measure of the severity of the climate that this time they hunted reindeer, not horses.

4. Robert Wright, *Nonzero: The Logic of Human Destiny* (New York: Vintage, 2000). ISBN 0-679-44252-9. Chap. 6, 'The Inevitability of Agriculture' (pp. 65-77). 13 of 435

All of this brings us back to Kant's emphasis on "unsocial sociability." The realm of "sociability"—the geographic scope within which peace reigns—has grown massively since our hunter-gatherer days. And commensurately massive quantities of unsociability have been overcome. Yet they are often overcome under the ironic stimulus of higher-order unsociability. To put this dynamic of cultural evolution in the Darwinian language of natural selection: what is "selected for" is larger and larger expanses of non-zero-sumness, but one of the main selectors is the zero-sum dimension of war. In this sense, waging war, in the end, *is* waging peace.

An authority on human behavior once remarked that if two people stare at each other for more than a few seconds, it means they are about to either make love or fight. Something similar might be said about human societies. If two nearby societies are in contact for any length of time, they will either trade or fight. The first *is* non-zero-sum social integration, and the second ultimately brings it.

# THE INEVITABILITY OF AGRICULTURE

The farmer takes a wife, the farmer takes a wife . . .

—*From the nursery song "The Farmer in the Dell"*

A favorite pastime of archaeologists is to invent competing explanations for the domestication of plants and animals, which first happened around 10,000 years ago. Perhaps, one theory has it, a hotter climate, by drying up once-fertile lands, made the hunter-gatherer lifestyle suddenly precarious, and people groped for a new livelihood. Or maybe the extinction of giant elk, woolly mammoth, and other big game had the same effect. Or, on the other hand, maybe the key was a more *benign* environment, a climate which happened to nourish certain plants that were good candidates for domestication.

And then there is a simpler theory: Farming was just a good idea. It was a good idea in the same sense that the various tools and techniques constituting the hunter-gatherer lifestyle had been good ideas, and thus had been added to the human repertoire.

This was the radical position taken in 1960 by the University of Chicago archaeologist Robert Braidwood. Reviewing his own fieldwork in the Middle East, where farming first appeared, he depicted agriculture's advent as merely "the culmination of an ever increasing cultural differentiation and specialization of human communities." So far as he could tell, "there is no reason to complicate the story with extraneous 'causes.' "

Braidwood is considered the founder of the modern study of agriculture's origins, but this particular opinion wasn't destined for veneration. Notwithstanding his injunction against complicating the story, archaeologists have continued to complicate the story. The abovecited "causes," and others, still jockey for preeminence. More than two decades after Braidwood insisted that agriculture needs no special explanation, an archaeologist, summarizing the consensus, declared that agriculture is "not yet satisfactorily explained." The search for causes continues. An air of mystery still surrounds the origins of agriculture.

Indeed, if anything, the air thickens. Some scholars now say that, paradoxically, early farmers would actually have had to work longer and harder to grow food than to just get it the old-fashioned way, by hunting and gathering. Thus the logic behind the origins of agriculture, we are told, is much less straightforward than it seemed back in Braidwood's day.

This view poses a problem for cultural evolutionists—or, at least, for hard-core cultural evolutionists, such as me. After all, if farming was such an unappetizing prospect, how could humanity have been virtually certain to take it up eventually? Shouldn't passage through this threshold be counted as a lucky break, a chance venture that could just as easily have been the road not taken? And, if so, doesn't that make all that followed farming—ancient civilizations, less ancient civilizations, and so on—look far from inevitable?

Plainly, before we can get on with the rest of this book we must dispel some of the mystery surrounding agriculture's origins and deflate the ongoing search for "causes." Conveniently, that will give us a chance to dispel some misconceptions that persist to varying degrees within the social sciences and in various ways sap enthusiasm for hard-core cultural evolutionism.

## HAPPY HOUR

The case against agriculture's being a natural cultural advance began to gather momentum with the surprising discovery that hunting and gathering isn't such a bad way to make a living. The !Kung San, Richard Lee found in the 1960s, work just a few hours a day—hunting, digging roots, harvesting mongongo trees—and then it's Miller time. In 1972, the anthropologist Marshall Sahlins (a former cultural evolutionist turned skeptic of cultural evolutionism) dubbed hunter-gatherers "the original affluent society" on grounds that "all the people's material wants are easily satisfied."

And the problem isn't just that primitive agriculture may have been a regression in terms of sheer efficiency. The more populous villages that farming ushered in would presumably foment disease; and the low-protein, high-starch content of some staple crops might be unhealthy. Studying the bones of early farmers, some archaeologists have concluded that they had shorter lives, and more rotten teeth, than hunter-gatherers.



This brings us to *misconception number one:* that cultural evolutionists believe *change is guided by farsighted reason.* Actually, cultural evolution has involved little advanced planning. No prehistoric hunter-gatherers assembled a committee to decide whether a growing reliance on starchy foods would eventually promote tooth decay. Planted food slowly replaced wild food over many generations. And slowly the planted food became less like its wild ancestors; it got domesticated. The question isn't why hunter-gatherers "chose" farming, but why they chose the long series of tiny steps leading imperceptibly to it.

Part of the answer is that these hunter-gatherers were people. People are innately curious. They fiddle around with nature and try to bend it to their will.

Consider the Kumeyaay of southern California. Technically, they were a hunter-gatherer people. But, when encountered by the Spanish in the eighteenth century, they had transfigured the landscape. At high altitudes they planted groves of oaks and pines, whose nuts they harvested. Elsewhere they planted yucca and wild grapes. Near villages they planted cactus for liquid refreshment. The Kumeyaay burned off unwanted plants to pave the way for their favorites and razed dense shrubs to attract deer.

None of the plants they cultivated were domesticated. So this massive intervention didn't qualify as farming. Still, is it really likely that the Kumeyaay could have gone another 1,000 years without breeding juicier grapes?†

The Kumeyaay are far from the only "hunter-gatherers" who have given nature a helping hand. Australian aborigines replant the tops of the wild yams they eat. And remember the Shoshone of the Great Basin, often taken as paragons of the primitive? They burned off unwanted foliage, and some Shoshone planted wild food species. Some even used irrigation.

Hunter-gatherer societies that cultivate plants but haven't yet domesticated any are sometimes called "proto-agricultural." Dozens of such societies have been observed. You might think that anthropologists would look at all these societies and say, "The impulse to groom nature seems strong and widespread—maybe the coming of agriculture wasn't so unlikely after all." You would be wrong. Often, the reaction is the opposite. Proto-agriculture, we are told, just goes to show that many hunter-gatherers *knew* enough to become full-fledged farmers yet chose not to.

Often underlying such pronouncements is the unspoken premise that cultures are static; they have assumed final form; it wasn't just that the Kumeyaay *hadn't* taken up farming, but that they *didn't* take up farming—end of story. Thus an evolutionary view of culture is dismissed by assuming that cultures are not in the process of evolving.

## THE MYTH OF EQUILIBRIUM

The assumption that primitive cultures are static is grounded in *misconception number two: the idea of intrinsic equilibrium*—the idea that cultures stay the same unless jostled by such outside forces as retreating glaciers or sudden drought. Happily, this notion has lost favor among many archaeologists and anthropologists. But it has more than its share of defenders—that is, more than zero—and has deeply influenced thinking not just about agriculture but about culture generally. A recent archaeology textbook asserts that cultures do not "change in any patterned fashion as long as they are successfully adapted to their environments and the environment does not change." It is the assumption of equilibrium that compels archaeologists to seek an external "cause" for any development as dramatic as agriculture.

Subscribers to the equilibrium fallacy underestimate the unsettling nature of human innovation—the extent to which new ideas and techniques spring from within societies and transform them. But downplaying our species' genius is not the only problem. As we've seen, the main impediment to farming isn't thought to be a lack of inventiveness, but rather a lack of necessity. As Marvin Harris has put it, "What keeps hunter-collectors from switching over to agriculture is not ideas but cost/benefits. The idea of agriculture is useless when you can get all the meat and vegetables you want from a few hours of hunting and collecting per week."

Here, aiding and abetting the "equilibrium" fallacy, is *misconception number three: that human societies are fundamentally unified,* devoted to meeting their *collective* needs. The mistake gets back to the romantic notion of hunter-gatherer societies as oases of communal bliss. All for



one and one for all. And if all are getting enough food, then why should anyone bother trying something new?

The answer is that hunter-gatherers are in truth just like us. They're competitive, they're status-hungry, and, above all, they are individuals. In those hunter-gatherer societies that are proto-agricultural, the clusters of cultivated wild foods aren't typically community property; usually they are owned by a particular family or extended family that dispenses the harvest as it sees fit. Once you start thinking of hunter-gatherers as driven by the physical and psychic needs of themselves and their families, there is no shortage of reasons why they might cultivate plants in their spare time.

Consider (once again) the Northwest Coast Indians, whose lavish use of cultivated wild plants is now coming to light through the work of the geographer Douglas Deur. A Kwakiutl household might have its own salt-marsh garden for clover roots or silverweed roots (nutritional delicacies), and might tend plots of wild berries or edible ferns. In hard times—when, say, the salmon weren't running—the family might eat the entire harvest. But often the food would serve the family's interests more obliquely. Being a gastronomical delight, it could be swapped for candlefish oil, and sometimes crates of garden-grown food were paired with other foods and handicrafts to fetch a prized copper shield. Often such exchanges took place between villages, orchestrated by Big Men, but non-zero-sumness also welled up within villages. A household might "give" food to a needy neighbor, with a view to future reciprocation. In the meanwhile, the giver, in addition to having garnered an IOU, enjoyed some status elevation. And families chronically in a position to "give" enjoyed chronically high status, like philanthropists.

Even in modern suburbs and small towns, avid gardeners win local esteem by giving neighbors fresh tomatoes or flowers. This strikes most of us as normal behavior. But the possibility that people might behave the same way in a primitive economy—where both the gift and the ensuing IOU were of much greater value—seems rarely if ever to cross the minds of archaeologists as they ponder the mystery of agriculture.

The various benefits of gardening were an incentive to refine it. There's evidence that the Northwest Coast Indians were weeding out the less robust specimens, the first step toward domestication. And, to expand the level land in their uneven habitat, they built retaining walls, which had the added virtue of holding nutrient-rich soils. The Kwakiutl word for "garden" means "place of manufactured soil."

In addition to the Northwest Coast Indians and other proto-agricultural hunter-gatherer societies, there are "cultural fossils" further along in the evolution toward agriculture.† Various "horticultural" societies grow domesticated crops in gardens but still rely on some hunting and gathering. Most of these societies resemble the Northwest Coast Indians, with gardening a private enterprise that pays off at the family level.

Thus, a young Yanomamo man in the jungles of South America, having just gotten married, will clear a garden for plantains, maize, cotton, tobacco, and other crops. He is not doing this for the good of his whole village. Indeed, he may surround the coveted tobacco with a fence, even plant sharp bones as booby traps. When he shares his harvest, he will do so selectively, cementing friendships, incurring unwritten IOU's, repaying his own debts, amassing status.

## THE FARMER TAKES A WIFE (OR TWO)

Could something as ephemeral as status really entice people into becoming agricultural innovators even when they face no regular shortage of food? The answer comes from looking at the top of the pecking order—at the Big Man or "Head Man," a version of which is found among the Yanomamo and horticultural societies generally.† Big Men tend to have not just big gardens, but big numbers of choice wives.

The idea here isn't that aspiring Big Men necessarily sketch out a systematic plan for acquiring multiple wives. During the biological evolution of our species, one of the benefits of male status was easier access to sex. (So too with our nearest relatives—chimpanzees, bonobos, gorillas.) Because of this correlation between status and fecundity, genes imbuing males with a thirst for status have fared well by natural selection.† The resulting drive to impress people needn't bring conscious awareness of its reason for being—any more than hunger entails a knowledge of nutrition. Status just feels gratifying; it seems to be its own reward, even if its ultimate evolutionary purpose was genetic proliferation.

On the other hand, conscious awareness of the sexual payoff for farming is, if not necessary, hardly out of the question. When Soni of the Solomon Islands (three chapters ago) was preparing those thirty-two succulent pigs that he wasn't going to get to eat, he no doubt knew that the more adroit Solomon Islands feast givers—that is, Big Men—got as many as five wives. Indeed, sometimes the link between amassing food and amassing wives is explicit. Among the Northwest Coast Indians and some other polygamous peoples, loads of garden-grown food could be part of the "brideprice" paid for a wife.



Archaeologists, faced with the observed correlation between a farmer's status and wealth on the one hand, and his number of wives and offspring on the other, have tended to get things backward. Big Men are said to seek multiple wives "since many wives produce more food than one wife" and to have many children "since many children produce more food than few children." To be sure, Big Men may value the labor provided by a large family. But, in terms of the ultimate logic of their quest—the Darwinian logic that selected the genes that fuel the quest—they are amassing food to amass wives, not the other way around. If the food pays off nutritionally, that's great, but even if it doesn't, it is valuable, because it raises their status relative to competing males. Among the Trobriand Islanders, one anthropologist reports, farmers aimed to "accumulate so many yams that they may rot in storehouses and stimulate the envy of rivals."

The problem with scholars mystified by agriculture's origins isn't that they are unaware of status hierarchies in horticultural and fully agrarian societies. The problem is that they tend to view the hierarchy as a *product* of domestication—in which case it couldn't be a cause. Hence, *misconception number four: the notion of the "egalitarian" hunter-gatherer band.*

We've already suggested that the venerable notion of the utterly communal hunter-gatherer band is suspiciously romantic; that the !Kung San, for example, are subtly permeated by selfishness. Are they also prone to social climbing? The answer isn't obvious, since wealth—even in the form of a little extra food—is hard to accumulate; they live in a desert and often relocate. But it's a good bet that if gardening were more practical, they would find that cultivating extra food was a good way to win wives and influence people. Of course, as the most industrious men exploited this fact most fully, accumulating wives and power, social inequality might grow. Still, social climbing would have been the cause of the farming, not just the result.

In a sense, this thought experiment has already been conducted—

in the form of the //Gana, nearby Bushmen who supplement their hunting and gathering with farming. Among //Gana men, the anthropologist Elizabeth Cashdan has noted, the allotment of sexual resources is quite unequal; one-fourth of the men have more than one wife. Writing in 1980, near the heyday of hunter-gatherer romanticism, Cashdan heretically argued that it would be wrong to see the //Gana's social inequality as having *emerged* with agriculture. After all, she noted, about 5 percent of !Kung men had more than one wife. The reason the struggle for status is so subtle among the !Kung, she contended, is their precariousness; shortfall could strike any given family, so it is in each family's interest to support an ethic of sharing, as insurance. The //Gana, Cashdan wrote, illustrate "the *lifting* of the constraints that produce strict egalitarianism among other Kalahari hunter-gatherers."

And full-fledged domestication is not the first step in that lifting. "Proto-agricultural" hunter-gatherer societies broadly are more likely than the average hunter-gatherer society to have conspicuous disparities in status. Apparently the Northwest Coast Indians aren't the only people who found that home-grown food is a social lever.

It would be an exaggeration to say that all archaeologists who ponder the origins of agriculture have ignored the quest for status. Brian Hayden has championed a maverick "competitive feasting" theory, inspired by the Potlatch and other, less famous, forms of inter-village feasting. The idea is that if in any society some aspiring Big Man—some Soni—can get fellow villagers to produce lots of food, he can use it to elevate his status in feasts with other villages. In the process he can acquire political influence within his own village.

So far so good. But Hayden describes the Big Man as a genetically distinct "personality type" present in all societies—the "aggrandizer." These aggrandizers are "empire builders; they seek to control human affairs for their own benefit and gratification." In short, they are bad guys, different from such good and innocent souls as you, me, and Hayden. This is in some ways a comforting worldview, but it is at odds with modern Darwinian theory, not to mention observed social reality. To be sure, some people, for whatever reason, are more ambitious than others. But there's a little Big Man in all of us. We are all social climbers by nature. Some just manage to climb higher than others.

What does it matter whether social ambition is a property of our whole species, rather than just of the Henry Fords and Margaret



Thatchers of the world? Well, the more widespread the urge to impress, the stronger the force that drives cultural evolution. If everyone is always striving for social status, then every increment in the evolution of agriculture, from the tiniest, scruffiest garden on up, is easy to explain; there's a kind of arms race with food as the weapon.

Actually, food is just one of the weapons. Political organization is another. From the early days of agricultural history, as Hayden's theory hints and the Sonis of the world show, coalition-building comes into play. Leaders who can harness non-zero-sum logic to draw people into cooperative effort prevail in competition for status and other social resources, inviting future leaders to do the same on a larger scale.

### MILLER TIME RECONSIDERED

Once you realize that man does not live by bread alone—that status and sex are nice, too—the claim that hunting and gathering beats primitive farming as a subsistence technology begins to lose relevance. Of course, the logic behind agriculture would be even stronger if it turned out that this claim about hunter-gatherers was wrong, or at least exaggerated, in the first place. And it may have been. The seminal calculations of the !Kung workday—two or three hours, then party time—have been put to skeptical scrutiny and found wanting. The calculators forgot to include time spent processing the food, making spears, and so on. It now appears that *these* hunter-gatherers, at least, work roughly as hard as horticulturalists.

Further evidence that hunter-gatherer life is not a year-round vacation can be found in proto-agricultural societies. The Shoshone's planted wild foods, one anthropologist observed, were "insurance" crops, and "frequently served as crucial secondary staples." So too with primarily hunter-gatherer but incipiently horticultural societies, such as the Siriono of Bolivia. While trekking through the forest in search of game, writes another scholar, they would visit their scattered gardens, "depending on them as secure sources of food energy."

All of this suggests that the layperson's common-sense notions about life among prehistoric hunter-gatherers is on target: adversity was part of life, shortage loomed over the horizon, and fortune favored the prepared. Between the quest for status and the quest for sheer survival, we have a powerful impetus behind the evolution of agriculture.

The impetus gets even stronger when we add one more factor: our old friend from the previous chapter, war. How would war encourage agriculture? In primitive war, few things come in handier than sheer manpower. And agriculture supports much larger settlements than hunting and gathering does. One of the earliest known farm towns, the ancient, excavated village of Jericho, housed hundreds of people on around six acres. Not huge by modern urban standards, but compare it to what lies beneath: remnants of a hunter-gatherer camp one-fifth as large. Imagine a battle between these two villages, and you'll see that farming was a compelling lifestyle. Whether or not early farmers thought about the military edge their lifestyle offered, war would have helped the lifestyle spread.

Perhaps fittingly, Jericho is surrounded by a wall. At four meters high and three meters thick, with cylindrical watchtowers, this wall may have once been the largest capital project in the history of the world—a monument to the non-zero-sumness created by conflict between groups and thus intensified by farming.†

## THREE STRUGGLES

In the end, then, the claim that agriculture is "not yet satisfactorily explained" is misleading at best. If anything, the coming of farming was "overdetermined"—there is a surplus, not a shortage, of plausible explanations: the struggle for status within societies, armed struggle between societies, and the struggle against scarcity. Of course, "excessive" explanatory power is no scientific vice when the three explanations are logically compatible.

The archaeological record bears the clear marks of the first two struggles—wars and status competition. During the Mesolithic, just before the emergence of farming, wood and bone armor appear, cemeteries contain lots of people who died violently, and artists start depicting archery battles. Meanwhile, *within* societies, status competition is getting more conspicuous, with more and more bracelets, beads, and amber pendants showing up in high-status graves. (Were people trading food for these, adding an incentive to expand food production? There's no archaeological way of knowing, but such exchanges have been seen among hunter-gatherers, as when the Pomo of northern California got acorns and fish for their beads. In any event, Jericho, the quintessential farm town, would eventually become a regional trade center.)

The third struggle—against scarcity—doesn't leave such clear records. But we can say this much: even assuming this struggle wasn't a central force behind the evolution of agriculture, it would have kicked in if given enough time. As the planet's population grew—and indeed it grew faster and faster as hunter-gatherer societies grew more and more complex—the day was bound to come when nature's cornucopia couldn't feed the teeming masses, however ingenious their hunting and gathering.



Whatever the relative importance of these three struggles in driving the evolution of food procurement technologies, the effect was evident before farming. These technologies evolved from the Upper Paleolithic, with its well-crafted stone blades, through the Mesolithic, with its sickles, bows and arrows, mortars and pestles, nets and fancy traps. During the Upper Paleolithic, the menu grew beyond traditional staples—nuts, roots, and big game—to include birds, dangerous animals (lions, boar), and smaller animals, such as rabbits. With the Mesolithic tool kit, the menu expanded further, encompassing snails, lizards, frogs, grass seeds, lots of fish and shellfish, and lots of plants, including poisonous ones that had to be detoxified. At one hunter-gatherer village near the Euphrates River around 10,000 B.C., people were processing 157 species of plants. (With this growing environmental mastery, there was less and less need to migrate, so gardening made more and more sense. Sedentism seems to have preceded full-fledged domestication in most, if not all, cases.)

This long, clear trend—the ever-more-intensive search for food—is rather at odds with the image of hunter-gatherers sitting around picking their teeth until some external change created a sudden need for agriculture. More specifically, it is at odds with the assumption that a hunter-gatherer band wouldn't embrace new food techniques unless they were clearly less arduous than the old ones. As the scholars T. Douglas Price and James A. Brown have noted, additions to the hunter-gatherer diet during the millennia preceding agriculture were often "more costly in terms of procurement and processing" than were existing foods.

All of this leaves agriculture looking less revolutionary than evolutionary. Hunter-gatherers had long been working hard to intensify their yield, getting more and more food from a given acre of land. Farming was "no great conceptual break with traditional subsistence patterns," in the words of Mark Nathan Cohen, one of the first anthropologists to voice doubts about the notion of a natural "equilibrium."

To be sure, agriculture would ultimately prove revolutionary, a technology that would restructure society. Indeed, the rate of social change after agriculture so surpassed the more sedate pre-agricultural rate that it is fair to speak of a kind of "equilibrium" being disrupted. But the point is that the disruptor wasn't some external and whimsical force, such as drought or retreating glaciers, but rather internal and inherent forces, such as social striving and population growth.

Moreover, however "sudden" the changes wrought by farming, the *nature* of the changes was nothing new. Agriculture's ultimate social implication—sharply elevated social complexity and non-zero-sumness—had long been manifesting itself more slowly. Toward the end of the hunter-gatherer era there were more storage huts and other capital projects requiring political leadership, more long-distance alliances, and more trade—not to mention more kinds of food and tools than ever before.

In short, Robert Braidwood was right to dismiss the "mystery" of agriculture back in 1960 by depicting farming as merely "the culmination of an ever increasing cultural differentiation and specialization." Standard attempts to explain domestication as a response to epic change—a suddenly more barren landscape, or a suddenly more fertile landscape—are indeed unnecessary. Certainly environmental changes can *add* to the logic of farming, and help explain why it arose in one area before another. But if the question is why farming evolved *at all,* we needn't delve into the details of climate, flora, and fauna. Given enough time, it was bound to happen.

This notion of a persistent and universal evolutionary logic behind farming helps explain an otherwise puzzling fact: farming kept getting invented, and once invented, it tended to spread. The consensus among archaeologists is that farming arose anew at least five times—three times in the New World, twice in the Old World—and possibly seven. Surely this is no coincidence.

Of course, different cultures reached this threshold at different speeds. We've already seen some reasons for lags in cultural evolution, and there are others. The biologist Jared Diamond, in his book *Guns, Germs, and Steel,* has explained many such disparities via geography. For example: some areas are more blessed with readily domesticable species than others. And species spread east–west more easily than north–south because the climate changes less, so Eurasia was a better place for crops to diffuse than were the Americas or Africa. Even so, areas that are in these or other ways handicapped often surmount their handicaps.



In fairness to archaeologists, it should be noted that few would deny directional pattern in the archaeological record, and some would even agree that the advent of agriculture was quite likely, given long enough. Still, once you start throwing around words like "inexorable," or "virtually inevitable," almost all archaeologists grow skeptical, if not disdainful.

There is an irony in the refusal of so many scholars to embrace hard-core evolutionism, and concede the stubborn force behind culture's ascent to higher levels of organization. As we've seen in this chapter, it is an overly "integrated" view of human society that blinds many of them to this integrative power. By thinking of hunter-gatherer societies as tightly organic, naturally and deeply cooperative, devoid of envy and one-upmanship, they overlook the subtle but strong, and ultimately productive, forces of competition within any human society—Kant's "unsocial sociability." The harmony they wrongly perceive leaves them deaf to ongoing harmonization.

At the outset of this chapter, we suggested that perhaps farming arose simply because it was a "good idea." But "good" in what sense? In the sense that it helped people avoid starvation? In the sense that it helped people win wars? In the sense that it helped people gain status? Yes—in the sense that it helped people do the things that people try to do. And, by virtue of thus satisfying people, the idea of farming was "good" in another, very fundamental, sense: it was good at getting itself spread; in cultural evolution's war of all against all, the concept of farming was a survivor.

5. Cyril Aydon, *Humankind: 150,000 Years of Human History* (London: Robinson, 2007). ISBN 978-1-84529-748-0. Chap. 3, 'Putting Down Roots' (pp. 21-33). 13 of 420

Arctic, life revolved around hunting and fishing. There, the ability to skin large animals, and turn those skins into coats and trousers, was a matter of life and death. The mammoth-hunters of southern Russia passed the winter in tents made of skins, with mammoth bones for pegs and poles, eating meat from the freezer (storage pits in the permafrost) which they thawed out over the fire. In Australia, the descendants of that first fleet of 50,000 years before dined off wild duck, which they hunted with boomerangs. Their contemporaries in the American Midwest hunted bison with spears.

But whatever the food, and whatever the implements and weapons used, over most of the earth, human life was still the life of the small band, consisting of no more than twenty or thirty adults and a few children. Permanent settlement was the exception, not the rule. And children were few, because having many children would have been a liability. These bands needed to travel light. In a world full of predators, a woman with a child at her breast and a toddler to watch over was a luxury a wandering band could not afford.

In spite of these difficulties, world population continued to grow, from an estimated 500,000 in 30,000 BC to 10 million in 6000 BC. Such a rate of growth may appear unexceptional by the standards of the last few hundred years, but compared with what had gone before, these were dramatic figures. Something, clearly, was working in humanity's favour. That something was the most important revolution in human history.



# 3

# PUTTING DOWN ROOTS

Most of the increase in human population between 30,000 BC and 6000 BC occurred towards the end of that period. Before 11,000 BC, ice sheets covered the whole of northern Europe (including most of Britain), Central Asia and northern North America, and this limited the amount of land suitable for human existence. Cave-dwelling bands, who clothed themselves with animal skins and knew how to use fire, were able to survive in the ice-covered regions, but their numbers were small. As time went by, improvements in hunting technology – the invention of the bow and arrow, the spear-thrower and the harpoon – enabled more people to live off a given area of land. But for hunting and gathering to support a substantial increase in population, the amount of land available had to increase. From around 11,000 BC, as the ice retreated, new feeding grounds opened up to the animals that were the hunters' prey, and their numbers increased. As the hunters followed them, their numbers increased too. As frozen rivers thawed out, fishing grounds became more widespread, and fish – and fishermen – became more abundant. For those who were not merely hunters but gatherers as well, there was a double benefit: as the grasses spread into new areas, so did the fruit trees and the wild cereals such as wheat and barley.

The benefits of climate change were widespread. A side-effect of the icy conditions in regions near the Poles had been reduced rainfall in lands nearer the equator. This had limited the range of many plants, and the animals that fed on them. But as the climate warmed, many places enjoyed increased rainfall, with a consequent increase in the richness of plant and animal life.

Suddenly, there was more of everything. Clever people continued to invent tools and weapons, enabling more mouths to be fed. But this did not amount to a new way of life; it was simply an improvement to ways of life that had persisted for thousands of years. No matter how efficient gatherers and hunters became at their traditional pursuits, they were never going to become property agents or software engineers. For this, something fundamental had to change.

Suppose a band of hunter-gatherers find themselves on the banks of a lake teeming with fish, where reeds flourish and animals come to drink. Their reaction will be to linger. What is the point of running miles after food, when the food insists on coming to you? After a while, more people arrive; but food is plentiful, and so is land, so there is no need to fight over either. Old habits die hard, and, at first, individual family groups keep their distance. After a few years, thatched dwellings line the lakeside, and the smell of grilled fish and roasted meat and the laughter of playing children fill the air. Soon, the children of neighbouring families are playing together; and the more gregarious parents are inviting the parents of their children's friends to fish suppers.

But doorstep delivery of meat and fish is only one of the delights of this new location. Like all communities, this one contains people who like cooking, and others who have a special feeling for plants. Between them, they discover that the countryside around them is full of wild cereals that are good



to eat, especially if cooked. Soon they are making porridge. The plant-lovers – who are about to become gardeners – naturally select the cereals with the biggest ears, containing the plumpest seeds. Sometimes, when they come back from a harvesting trip, they spill some of the grain on the ground, which is rich with nutrients brought down by the river that feeds the lake and spread by its floods. Some of this grain, already carefully selected, takes root. Soon the area around the settlement is home to an interesting crop of grass, with more than usually big ears, containing noticeably plump grain. One day, a particularly bright gardener-in-the-making hits upon the idea of selecting the very best ears from this already choice collection not for eating, but for planting. The next year, someone suggests that the best grain from that crop should be set aside, and used as seed for the following year.

It is obvious where this is leading. Locate the lake shore in Palestine – or make it a river valley in central China – and we have a speeded-up version of the Agricultural (or Neolithic) Revolution: the fundamental change in living habits that made our modern world possible.

While the term 'Agricultural Revolution' is used by historians and archaeologists, it doesn't signify the overnight initiation of a new process. The term 'proto-farming' is used by some writers to describe the long transitional period during which gatherers must have experimented with relocating and irrigating wild plants, before they settled down to practise farming as a permanent way of life. The process was a series of steps, adapting to changing circumstances over an extended period.

One of the reasons why people tend to over-dramatize the emergence of settled agriculture is that they start from a misinterpretation of the term 'hunter-gatherer'. The Agricultural Revolution was not a sudden switch from a lifestyle in which *men* chased antelopes, to one in which *men* got their kicks from growing bigger vegetables than their next door neighbours. In most hunter-gatherer societies, food gathering is as important as hunting, and in many, it is overwhelmingly more important. Cultures such as that of the Inuit of North America, in which meat accounts for most of the food intake, are not typical: they are the result of developments brought about by a harsh environment. In the softer climates where settled agriculture first arose, there must have been a long learning period during which women *and* men acquired a profound understanding of wild food plants and the ways of gentler animals. When they found themselves in places where the idea of settlement seemed attractive, they were already in possession of most of the knowledge they needed to embark upon an agricultural way of life.

Although our thought experiment shows *how* the change to a farming culture *could* have happened, it does not explain *why*. *Why* questions are usually about motivation: 'Why did you do that?' or 'Why did the chicken cross the road?'. We can't ask that kind of question about the Agricultural Revolution, because it wasn't the result of deliberate intention. Nobody said, 'I'm fed up with hunting and gathering – let's invent urban civilization.' No one *chose* this new way of life. Cultural change is the result of thousands of individual choices about desired outcomes over long periods of time. Such changes occur gradually, without anyone willing them, and often without anyone realizing that they *are* occurring.

The question we now need to ask is 'Where, and when, and in what kinds of environment, did the changes take place that led to the replacement of hunter-gathering by agricultural civilizations?' Thanks to the discoveries made by archaeologists during the past hundred years, this is a question we are well on our way to answering.

There was not one Agricultural Revolution, but several, in various parts of the world. Each took place in a different way, and involved different crops and methods of cultivation. Table 3.1 contains a list of six regions where we know that independent revolutions of this kind occurred, though there were undoubtedly others. Of these six, the one that has been most



**3.1 The Emergence of Agriculture**

| | Region | Period of Emergence | Key Domesticates: Plants | Key Domesticates: Animals |
|---|---|---|---|---|
| 1 | The Fertile Crescent (Palestine to Iran) | *c.* 8000 BC | Wheat<br>Barley | Goats<br>Sheep<br>Cows<br>Pigs |
| 2 | Central China (Yangtze) | *c.* 6500 BC | Rice | Pigs<br>Water-buffaloes |
| 3 | North China (Yellow River) | *c.* 6500 BC | Millet | Chickens<br>Pigs |
| 4 | Central America (Mexico) | *c.* 3000 BC | Maize<br>Squash<br>Beans | |
| 5 | South America (Peru/Chile) | c. 2500 BC | Potatoes<br>Quinoa | Llamas<br>Alpacas<br>Guinea-pigs |
| 6 | Sub-Saharan Africa | *c.* 2000 BC | Sorghum<br>Millet | Cows |

Source: B. D. Smith, *The Emergence of Agriculture* (Scientific American Library, 1995)

intensively researched occurred in the 'Fertile Crescent' – the stretch of country extending from southern Palestine, through Syria, southern Turkey and northern Iraq, into western Iran. The others occurred in the Yellow River Valley, in northern China; in the valley of the River Yangtze, in central China; in central Mexico; on the Andean Plateau, from Colombia, through Peru, to northern Chile; and in Africa south of the Sahara.

The dates shown in the table are roughly when the populations of the various regions made the change from a wandering lifestyle to a settled system of agriculture. These dates are approximate and, of course, could well be pushed further back, as a result of future discoveries. This applies particularly to north and central China, which have not been subject to as much archaeological exploration as the Fertile Crescent.

How did the change take place? The geography and climate of each region were different, as were the plants and animals available to the settlers. But one factor was common in all of them: the process of domestication, the incorporation of plants and animals into a partnership with human beings. It was only when men and women (with the help of their children) domesticated wild species that farming truly began.

Domestication has two elements: *manipulation* and the *creation of dependence*. Manipulation means the careful selection of the most desirable specimens from successive generations of plants and animals so as to breed more useful varieties. In the case of wheat, wild species were grown in carefully prepared soils, and the seed for subsequent crops was selected for qualities of size, hardiness and high yield. By continued repetition of this process, new varieties were created that yielded more, and better, flour, and – most importantly – could be relied upon to breed true to type. In the case of sheep, the new varieties provided bigger joints and juicier meat. Later on, they were bred to have thick woolly coats, in place of the mostly shorter-haired skins of their wild ancestors. In western Asia, sheep were also bred to give copious supplies of milk, which the peoples of the region were able to digest (something many adults elsewhere in the world have never been able to do). The most striking example of human manipulation of a wild species – the wolf – was also one of the earliest. Wolves, as well as sheep, have an instinct to follow a leader. Cubs from a pack caught hanging around a camp could be taught to



follow a human leader instead. In the wolf's case, selective breeding over many generations resulted in a new sub-species – the dog – which could be relied upon not to eat the sheep, and also to prevent wolves from eating them.

Important as such manipulation was, its contribution to the making of the Agricultural Revolution should not be exaggerated. Much of the selection that led to the evolution of new varieties of animals and plants must have been unintentional. Every time a herdsman killed a big, bad-tempered bull, or an unusually menacing ram, he was automatically reducing the incidence of genes for large size and aggression in the population at large. (Early domesticated varieties were invariably smaller than their wild forebears.) Every time a woman collected wild wheat and kept some of the seed for planting, she was automatically selecting those genes that caused the grain to remain firmly in the ears until it was harvested.

The other defining feature of domestication is the creation of dependence. As selective breeding continues down the generations, animals and plants become more dependent upon human beings. Dogs might still be able to manage in the wild individually, if they had to, but they would rather not. And if they did have to, they might not survive for long as a separate species. In the case of sheep, a stage is soon reached in which the new variety is unable to survive without human protection. The same can equally be true of a crop like maize, where the tight heads of domesticated varieties are unable to release their seed without human intervention. This is what distinguishes the cultivation of wild plants, and the management of wild herds, from true domestication. Domesticated varieties are human creations, and most of them would quickly cease to exist without human intervention.

But for domestication to be possible, there had to be settlement. Because towns and cities could not have come into existence without an agricultural base, it is often assumed that agriculture must have come first, and that settlement must have followed. But that was true only of large settlements.

Until human beings settled in specific places and created villages, agriculture could not exist at all, so in a very real sense the village is the source of civilization.

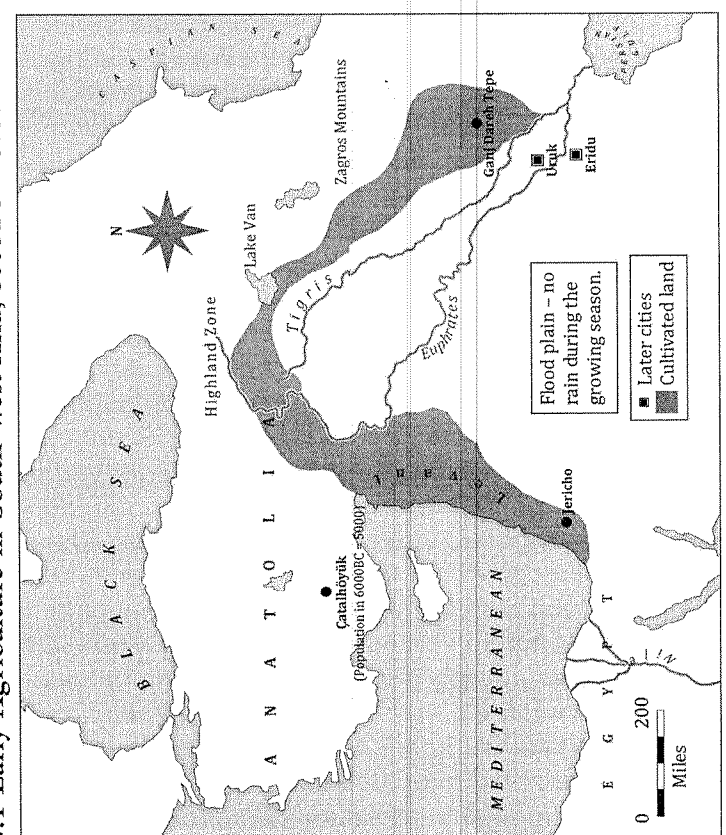
The earliest agricultural village so far discovered is in the West Bank area of Palestine, 15 miles north of Jericho. There, on the site of the ancient city of the same name, beneath more than twenty layers of later settlements, lie the remains of a village that, around 8000 BC, was home to at least 300 people. They lived in mud-brick houses, on the edge of a spring-fed lake. They grew figs, two kinds of wheat and two kinds of barley, which they harvested with wooden-handled flint sickles. They introduced excitement into their lives, and variety into their diet, by hunting the wild sheep and gazelle that lived nearby.

Although Jericho is the oldest farming village so far discovered, other settlements have been dated around that time in the western portion of the Fertile Crescent, which archaeologists call the Levantine Corridor. That this region, so bare and arid today, should have been the birthplace of the world's first agricultural villages might seem strange. But 'Fertile Crescent' is an apt description of the area from Palestine to western Iran as it was then: a green, wooded country, filled with game.

Despite its name, the region did not have a particularly fertile soil. The plains to the south, fed by the flooding of great rivers, were potentially much richer. But they received little rain, so were irrelevant in an age without artificial irrigation. The foothills around the Fertile Crescent, on the other hand, enjoyed reliable year-round rainfall, and had a soil in which wild forms of wheat and barley were perfectly at home.

Scientists who have considered the history of manipulation of wild species believe that 300 years is all that would have been needed to develop domestic strains from the wild varieties that existed in the surrounding countryside. It is a conclusion that would not surprise a modern plant breeder. It also makes sense. It is difficult to imagine a Stone Age farmer having the patience to persevere in breeding generations of






**3.1 Early Agriculture in South-west Asia, 8000 BC – 6000 BC**

One of several regions of the world in which agriculture arose independently. The shaded area – 'The Fertile Crescent' – was almost certainly the earliest such region. Source: B. Smith, *The Emergence of Agriculture* (Scientific American Library, 1995).

cereals if they displayed little improvement over the course of his entire working life.

Just as the development of arable farming depended upon locally available wild cereals, so the development of livestock farming depended upon a supply of animals suitable for domestication. In this respect, too, the countries of the Fertile Crescent were a farmer's dream. The ideal candidate for domestication is a docile, slow-moving animal that is easy to catch, tolerant of confinement and breeds happily in captivity. It helps if it is not too fussy about what it eats, and if its instinct is to follow a leader. That such a creature should exist in the wild sounds too good to be true; but the settlers in the Fertile Crescent found themselves in the company of not one, but three: the sheep, the goat and the cow. With such an availability of ready meat, and such a variety of wild grains, the area was like an outdoor supermarket. It is no wonder that the human beings who discovered it decided to camp on its doorstep, and concentrate on improving the stock.

Although the earliest agricultural settlements are found at the western end of the Fertile Crescent, and although it was there that cereals were first domesticated, it was at the eastern end that a system of mixed farming, combining field crops and livestock, first appeared. Excavations at Ganj Dareh Tepe, a site in west-central Iran, dating from around 7000 BC, have yielded evidence of domestication of both goats and barley. This was a region with a long history of herding wild goats, and from here the practice of keeping goats later spread to the Levant.

The last of the three animals to be domesticated was the cow. This was a daring venture, and an impressive achievement. The wild ancestor of the cow was the aurochs, a massive creature standing six foot high at the shoulder, with long, curved, forward-pointing horns. It survived in the wild until the seventeenth century, a formidable beast whose domestication is a tribute to the spirit and determination of the early



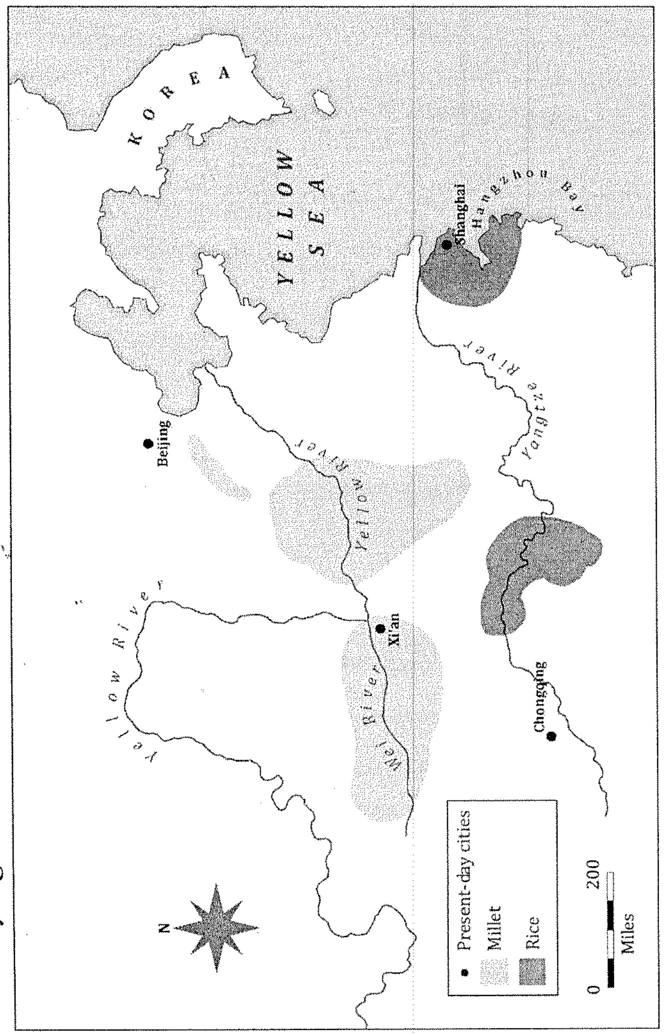
farmers who fenced it in, and from it bred the smaller, more docile creature we know today.

A different kind of agriculture arose in the valley of the River Yangtze, in central China. There abundant rain created a region of wetlands and inter-connecting lakes unique outside the tropics. The naturally occurring cereal was rice, and there is evidence of the harvesting of wild rice as early as 12,000 BC. Rice likes to have wet feet during the growing season. Water was something the Yangtze Valley had in abundance, so the settlers there set about providing their improved rice strains with the environment they appreciated, building retaining walls on the valley slopes to create flooded fields while the rice was growing. Then they breached the walls, releasing the water and enabling the rice to dry out. This was the origin of the paddy-field system of rice cultivation, which is such a feature of the Chinese landscape today.

The oldest farming villages so far uncovered in the Yangtze Valley date back to around 6500 BC. This is a thousand years later than the earliest excavated in the Levant, but it is possible that future excavations will cause this date to be pushed back. Like the Fertile Crescent, the Yangtze region had wild animals that tasted good and were amenable to domestication. The heaven-sent species in this case were the wild pig, with its ability to transform all kinds of refuse into delicious meat, and the water buffalo, a creature that seemed purpose-made for day-long toil in the fields, with shoulder blades that made perfect spades for working them.

Four hundred miles to the north, in the valley of the Yellow River, nature had set out another tempting stall. This was an area of sparse rainfall and cold winters – no place for rice. However, it contained several species of wild millet – a plant that thrives in dry conditions. For the people who settled there, millet provided a useful addition to a diet already rich in fish, venison and assorted wild plants. In the intervals between fish suppers and venison roasts, they passed the time with

### 3.2 Early Agriculture in China, 6500 BC – 5500 BC




The earliest settlements reliably dated in the Yellow River region are almost as old as the earliest in the Fertile Crescent.
Source: B. Smith, *The Emergence of Agriculture* (Scientific American Library, 1995).



experiments designed to improve the yields of the wild millets, and in cross-breeding them to produce new varieties. These experiments yielded two varieties – broomhorn and foxtail – that would later assume an importance in the economies of East and South-east Asia second only to rice. Both are valuable food sources in their own right and can also be fed to pigs and chickens. Pigs and chickens ran wild in the Yellow River Valley and it did not take a genius to make the connection between them and domesticated millet. By 5000 BC, the chickens and the pigs were in pens, and chicken drumsticks and spare ribs had become a staple of the local diet. The discarded bones are a familiar sight on archaeological digs today.

To understand this transition to a farming way of life, one needs to distinguish between individual acts of domestication and the overall process of creating an agricultural society. The point was made on page 28 that something like 300 years – ten human generations – was all that it would have taken to derive domesticated strains of plants from their wild forebears. In the case of animals, it would of course have taken longer. But in either case, the timescale suggested is very short, when set against the huge significance of the changes wrought.

To explain the apparent contradiction, let us consider what happened in the Fertile Crescent. The domestication of sheep and the domestication of goats happened in different places, and at different dates. Neither coincided precisely, in time or place, with the domestication of wheat or barley. Individually, none of them may have taken more than a few hundred years. But the assembling of the total package, that constituted the agricultural revolution in that part of the world, must have involved at least a thousand years of experiment and information exchange, and several thousand years of previous apprenticeship in the cultivation of wild plants, and the herding of wild animals.