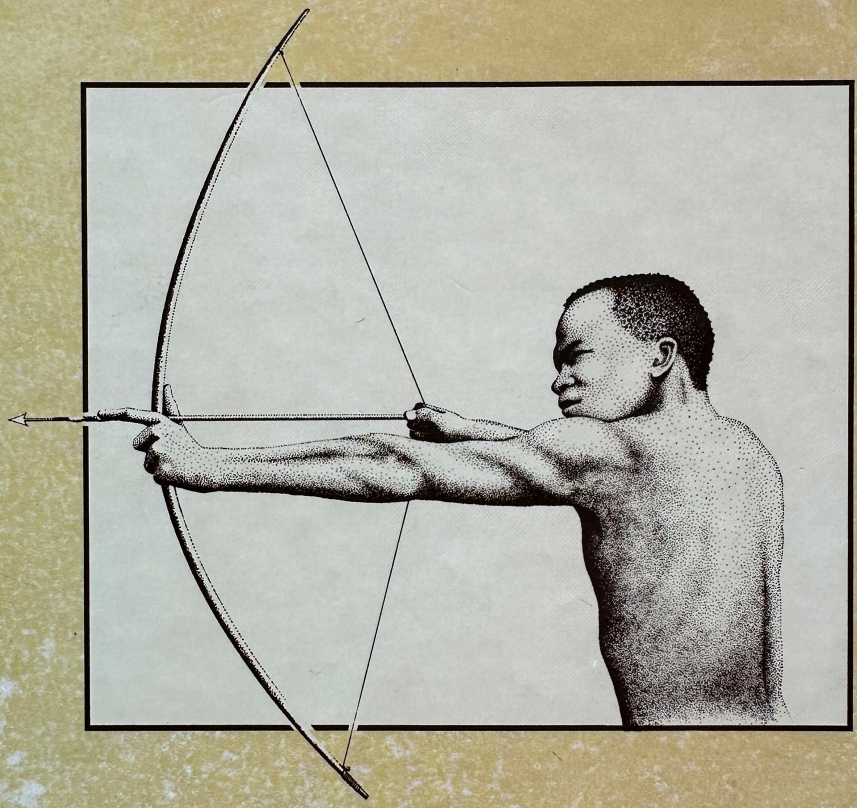
The

Art of Tracking

The origin of science



Louis Liebenberg

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Introduction

According to a popular misconception, nature is "like an open book" to the expert tracker and such an expert needs only enough skill to "read everything that is written in the sand". A more appropriate analogy would be that the expert tracker must be able to "read between the lines". Trackers themselves cannot read everything *in* the sand. Rather, they must be able to read *into* the sand. To interpret tracks and signs trackers must project themselves into the position of the animal in order to create a hypothetical explanation of what the animal was doing. Tracking is not strictly empirical, since it also involves the tracker's imagination. Generally speaking, one may argue that science is not only a product of objective observation of the world through sense perception. It is also a product of the human imagination. A creative hypothesis is not found or discovered in the outside world, it comes from within the human mind.

If the art of tracking is indeed the origin of science, then gaining a better understanding of tracking may help to explain the phenomenal success of science. From an evolutionary point of view, the origin of the creative scientific imagination due to natural selection *by* nature may explain why it is so successful *in* nature. If it is assumed that the modern scientific brain has been adapted in part to the necessity of tracking down animals, what limitations, if any, does such a brain place on the modern scientist's understanding of nature? If modern physicists are thinking with a tracker's brain, how does this influence the theories they create in order to explain the fundamentals of nature? This book will not seek to provide full answers to such questions but rather confine itself to a description of tracking itself and its relation to modern science.

The study of the history of science involves fields ranging from the philosophy and sociology of science to psychology and aesthetics (Holton, 1973). In contemplating the origin of science, and therefore science in its most basic form, this book will include elements from anthropology, archaeology and evolutionary biology. And while the similarities between tracking and modern science may suggest how science originated by means of biological evolution, the differences between them may give some indication of how science subsequently developed by means of cultural evolution.

As perhaps the oldest science, the art of tracking is not only of academic interest, it may also be developed into a new science with many practical applications. One of these applications—at a time when wildlife management has become increasingly important—is in nature conservation. Apart from the advantages in the management of wildlife, tracking may be the most effective means of controlling poaching. Trackers are often able to intercept intruders *before* they do any harm; or where signs of poaching are found, the spoor may be followed and the guilty parties apprehended. By following the spoor of a poacher, traps and snares may be located and

destroyed. Trackers on horseback could patrol areas much larger than conventional patrolling can safeguard. And some trackers may even be able to identify individual poachers by their spoor.

Perhaps an equally important factor in nature conservation is the development of a general awareness of wildlife among the general public. Ignorance by the public at large may well be the most dangerous threat to the survival of many species in the face of "advancement" and "progress". Even keen nature lovers are often unaware of the wealth of animal life around them, simply because most animals are rarely seen. I once encountered a group of about a dozen hikers who walked right over a perfectly clear leopard spoor. Not one of them noticed it, simply because they were not "spoor conscious". To them the leopard simply did not exist. Yet to find a fresh leopard spoor in the wilderness adds an exciting new dimension to hiking. Such a wilderness may appear desolate to the untrained eye, but if you are at least "spoor conscious" it will be full of the signs of wildlife. Even if you never see the animals, the knowledge that they are there is enough. By reconstructing their movements from their footprints, you may be able to visualise the animals and in your imagination actually "see" them. In this way a whole story may unfold, a story of what happened when no one was looking.

A second application of tracking lies in its potential assistance to researchers studying animal behaviour. Trackers have already been employed in studying the ecology and behaviour of lions and leopards in the Kalahari Gemsbok National Park (Bothma, 1986). Most animals are very shy and tend to vanish at the slightest disturbance, while many nocturnal animals may never be seen at all. Direct observations are likely to disturb an animal, making it difficult to study its habits under natural conditions. Tracks, however, give an account of the animal's undisturbed everyday life and so can afford much information which would otherwise remain unknown. Because the traditional tracker's understanding of animal behaviour may differ in some ways from that of the zoologist, the researcher should at least grasp the fundamentals of tracking in order to understand the interpretations of the tracker. In particular, the researcher should be able to decide to what extent the tracker's interpretation is based on empirical evidence, and to what extent it is based on hypothetical assumptions. This is not to say that the traditional tracker is less accurate or "scientific" than the zoologist. Although the zoologist's models of animal behaviour may in some ways be more sophisticated than those of the traditional tracker, there may be many ways in which the traditional tracker's understanding of animal behaviour is better. Kalahari hunter-gatherers have in fact been familiar with aspects of animal behaviour that western scientists have only recently discovered. The interaction between trackers and researchers may change the models of both, resulting in an understanding of animal behaviour that contains elements of traditional tracking and modern zoology but which is more refined and sophisticated than either of the two.

To follow the spoor of an animal successfully requires an in-depth knowledge of that animal's behaviour. Learning to track is therefore a good way for a zoologist to study animal behaviour. Radio-tracking (radio-telemetry) can be combined with spoor interpretation to record not only the movements of the animal between fixes, but also its activities. Combining traditional tracking methods with modern technology may therefore enable the researcher to accomplish much more than either method could accomplish on its own.

Spoor interpretation may also be of great value in determining the distribution of animals, particularly rare species that may never be seen. For example, I once found the spoor of a spotted-necked otter along the Sabi River in the Sabi Sand Nature Reserve. Yet Pienaar *et al.* (1980) maintain that there is no positive evidence of the occurrence of the spotted-necked otter in the Kruger National Park. My discovery in the adjacent Sabi Sand Nature Reserve of the unmistakable spoor of such an otter (claws and webs indicate that it could not have been a Cape clawless otter) suggests that it may well occur in the Kruger National Park. To make a survey of what animals occur in any area, especially those animals which are rarely seen, strips of ground can be prepared at strategic places (like waterholes and paths) to create ideal conditions for near-perfect footprints.

Spoor interpretation could also enable farmers to identify and locate problem animals, in order to take effective action to protect their crop and livestock without inadvertently killing innocent animals. The ability to identify specific problems may enable farmers to solve them in ways that not only protect their economic interests but are also more compatible with nature conservation. Since farmers are the owners of the largest areas of private ground, it is important that conflicts between farming interests and nature conservation should be minimised.

Perhaps the most controversial issue relating to the modern application of tracking is that of "trophy" hunting or hunting for "sport". In considering the ethics of killing animals, a distinction should be made between killing for self-preservation (for food or in self-defence) which is morally justifiable, and the unnecessary killing of animals (for "pleasure" or some other reason) which is morally unacceptable.

Human populations are in direct competition for food and terrain with other animal populations, so the killing of animals is often unavoidable. (Vegetarians who object in principle to the killing of animals must bear in mind that farmers also kill animals to protect their crops.) Furthermore, in today's finite, fenced wildlife reserves, migration to other areas is not possible. An inevitable sequence of events ending in population crashes occurs when populations of certain species reach the ecological carrying capacities of their habitats. In order to avoid an environmental disaster, population reduction by either capture and/or controlled culling becomes essential. The controlled culling of wildlife for venison and other wildlife products is no different morally than farming with domestic stock. And it can be argued that the controlled use of natural resources, including wild animals, will ensure that such resources are perpetuated (Thomson, 1986).

The strongest case that has been made for "trophy" hunting or hunting for "sport" is its economic justification. Controlled hunting as a means of culling can bring in great wealth to a nature reserve (or "game" reserve). "Trophy" hunting can enhance the value of the "game" product well beyond its intrinsic product value and as such can make wildlife utilisation economically more viable than farming. In future, as human population pressures increase, wildlife may have no place in society unless it can justify its own existence by providing economic benefits (Thomson, 1986). Economic justification is, however, not the only criterion that should be considered. (The fact that prostitution can be very profitable does not make it morally acceptable.) I personally find it morally objectionable that people should take pleasure in killing animals for "sport". This also raises the question of whether such people would not be inclined to kill animals illegally when no one is looking, especially in remote wilderness areas where it is difficult to control poaching.

Nevertheless, it must be conceded that some of the most dedicated conservationists have been, and are, "sport" hunters. In contrast, many "armchair conservationists" who are quick to condemn "sport" hunters do very little, if anything, for conservation, while the luxuries they enjoy are products of industrial processes that are responsible for the exploitation, pollution and destruction of the environment. Furthermore, some private nature reserves owe their very existence to "trophy" hunting, since it would be more profitable otherwise for the landowner to farm the land. I personally feel, however, that it is a rather sad reflection on the morality of modern "civilisation" at large that some private landowners should have no option but to resort to "trophy" hunting in order to conserve wildlife.

Many "trophy" hunters argue that it is the skill of the hunt they enjoy, not the killing, and that hunting is a "natural" activity since "man has always been a hunter". When one compares trophy hunting with traditional subsistence hunting, however, these arguments prove to be fallacies. Compared to hunting with the traditional bow and arrow, it does not require much skill to shoot an animal with a powerful rifle fitted with a telescopic sight. The only skill involved is the actual tracking down of the quarry, and this is usually done by a hired tracker, not the "trophy" hunter. The attitudes of "trophy" hunters also contrast sharply with those of hunter-gatherers. The very essence of hunting a "trophy" is one of boastfulness. (One need only look at the way they pose alongside their "kills" for photographs.) In contrast, the successful hunter in a hunter-gatherer community was expected to show humility and gentleness (Lee, 1979).

Hunter-gatherers were not motivated by destructive impulses or pleasure in killing. On the contrary, there is a considerable body of information about recent hunter-gatherers to demonstrate that they were relatively non-aggressive when compared to civilised societies (Fromm, 1973). Studies of the Mbuti, for example, show that hunter-gatherers were in fact very gentle people. The act of hunting was not carried out in an aggressive spirit at all. Owing to the consciousness of depleting natural resources, there was

actually a regret at killing life. In some cases, they even felt compassion for the killed animal (Turnbull, 1965).

I once asked a !Xõ tracker what his feelings were towards animals. He explained that although he does have sympathetic feelings for the animals he kills, he, as a hunter, must eat. He does not feel sorry for an adult antelope, because it is food and it knows that it must avoid hunters. But if a juvenile antelope is caught in his snare, he feels very sad, because it is still very small and does not know anything. His feelings of sympathy even extended to arthropods. He explained that if he sees a beetle with one broken leg, he will feel sorry for it. But he does not feel sorry for a scorpion when he kills it, because it will not feel sorry for him if it stings him.

One morning after he had killed a gemsbok, the same tracker pointed out a fresh gemsbok spoor close to the kill site. With a rather sad expression on his face, he explained that it was the spoor of the killed gemsbok's companion. He further maintained that because they grew up together, the gemsbok would always come back to that spot to look for its lost companion. The sympathetic way in which he told this story brings home the inevitable contradiction created by the way the tracker identifies himself with his quarry. To track down an animal, the tracker must ask himself what he would do if he were that animal. In the process of projecting himself into the position of the animal, he actually *feels* like the animal. The tracker therefore develops a sympathetic relationship with the animal, which he then kills. In the course of this book I hope that the reader will understand this empathetic aspect of the art of tracking, and of the origin of science.

The first part of the book will cover the early development of hominid subsistence. It seeks to situate tracking in the overall context of hominid evolution and to link it to development in creative thinking and imagination. The second part takes a closer look at hunter-gatherers in the Kalahari and their knowledge of spoor and animal behaviour in general. Special attention is given to non-scientific modes of awareness. In the third and final part, an explication is given of the fundamentals of tracking, before ending with a look at the links between the art of tracking and modern science.

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I

The Evolution of Hunter-Gatherer Subsistence

1

Hominid Evolution

A period of hundreds of thousands of years culminated in some of the most important adaptations of the human species: hunting and gathering. From this adaptation comes much of our intellect, emotions and basic social life. Only the last 10 000 years have seen the development of an agricultural way of life, and there is no evidence of significant biological change during that period. In order, therefore, to understand the origin and nature of modern* human behaviour (and the human intellect in particular), we need to understand the evolution of hunter-gatherer subsistence (Washburn and Lancaster, 1968).

Human evolution, however, cannot be treated in isolation from the environment. The environment is not a static background, but an interacting agent, and humans should be seen as a part of the biological community. A full understanding of human evolution would require a study of community evolution as the product of ecological interactions (Foley, 1984a). Nevertheless, since the quest for food is the primary subsistence adaptation, the evolution of hunting and gathering would have played a principal part in hominid evolution. And since the art of tracking is one of the most fundamental and universal factors in hunting, the evolution of tracking would have played an important role in the development of hunting.

The subject of tracking unavoidably emphasises the role of hunting. This is unfortunate since too much emphasis has been put on the role of hunting in the past. The hunting adaptation should be seen in the context of other equally important adaptations. Since it is beyond the scope of this book to deal with all aspects of hunter-gatherer subsistence with equal emphasis, it is important to remember that it deals with only one aspect of a very complex process.

The "hunting hypothesis", which originated at the beginning of the twentieth century, regards the hunting adaptation as the essential variation upon which everything else in human evolution depended. Within that hypothesis, in particular, there has also arisen a tendency to stress human aggression. This tendency has been taken to extremes in the "killer ape" interpretation

* Here I mean "modern" in the archaeological sense of the word.

popularised by Ardrey (1961; 1976) where one characteristic of human behaviour is stressed at the expense of all others (Gowlett, 1984).

It has been pointed out that the traditional "Man the Hunter" formulation of human evolution, with the emphasis on hunting and male dominance, is an outcome of male bias on the part of anthropologists working in a male-dominated world. These anthropologists have played down the evolutionary importance of the women's role: their economic contribution in gathering and sharing food; their role as primary socialisers and pivotal members of the family unit; and their role as female information "bankers" in the success of male hunters. Earlier anthropological bias also denies women's direct involvement in hunting (Dahlberg, 1981). As far as the art of tracking is concerned, we should remember that both men and women were involved.

The art of tracking, as practised by contemporary trackers of the Kalahari, is a science that requires fundamentally the same intellectual abilities as modern physics and mathematics. It may well have been the first creative science practised by the earliest members of anatomically modern (a.m.) *Homo sapiens* who had modern intellects. Natural selection for an ability to interpret tracks and signs may have played a significant role in the evolution of the scientific intellect.

Early Hominids

David Pilbeam (1984) describes how the earliest undoubted evidence of hominids dates back about four million years. The Australopithecines included *Australopithecus afarensis*, *Australopithecus africanus*, *Australopithecus robustus* and *Australopithecus boisei*. Footprint evidence of bipedal hominids, uncovered at Laetoli in Tanzania (see illustration facing page 3) is dated at 3,75 million years ago; and specimens of *Australopithecus afarensis*, including the half-complete skeleton of "Lucy" found at Hadar in Ethiopia, are dated between four and three million years ago. Early forms of *Australopithecus* had primitive ape-like faces with low foreheads, bony ridges over the eyes, flat noses, no chins, large teeth, and brains the size of an African great ape's. They lived in areas of woodland and savannah, away from the tropical forests, and probably survived mainly on vegetable foods. The morphology of the hip, knee and ankle joints indicate that they were bipedal: a fundamental human adaptation, which appears to predate the first clear evidence of tool making and the expansion of the brain.

The Homo *lineage*

Some time around two million years ago a larger-brained hominid, *Homo habilis*, lived contemporaneously with *A. boisei*. Its face was still primitive, but the back teeth were narrower. Its brain was not only larger, but also more sophisticated. For the first time the bulge of Broca's area is evident. This region is essential for speech, which suggests that *Homo habilis* probably had the neurological equipment for at least rudimentary speech (Weaver, 1985).

At the same time that *A. boisei* and *Homo habilis* appear in Africa, so do the first concentrations of used or altered stone, often brought from some

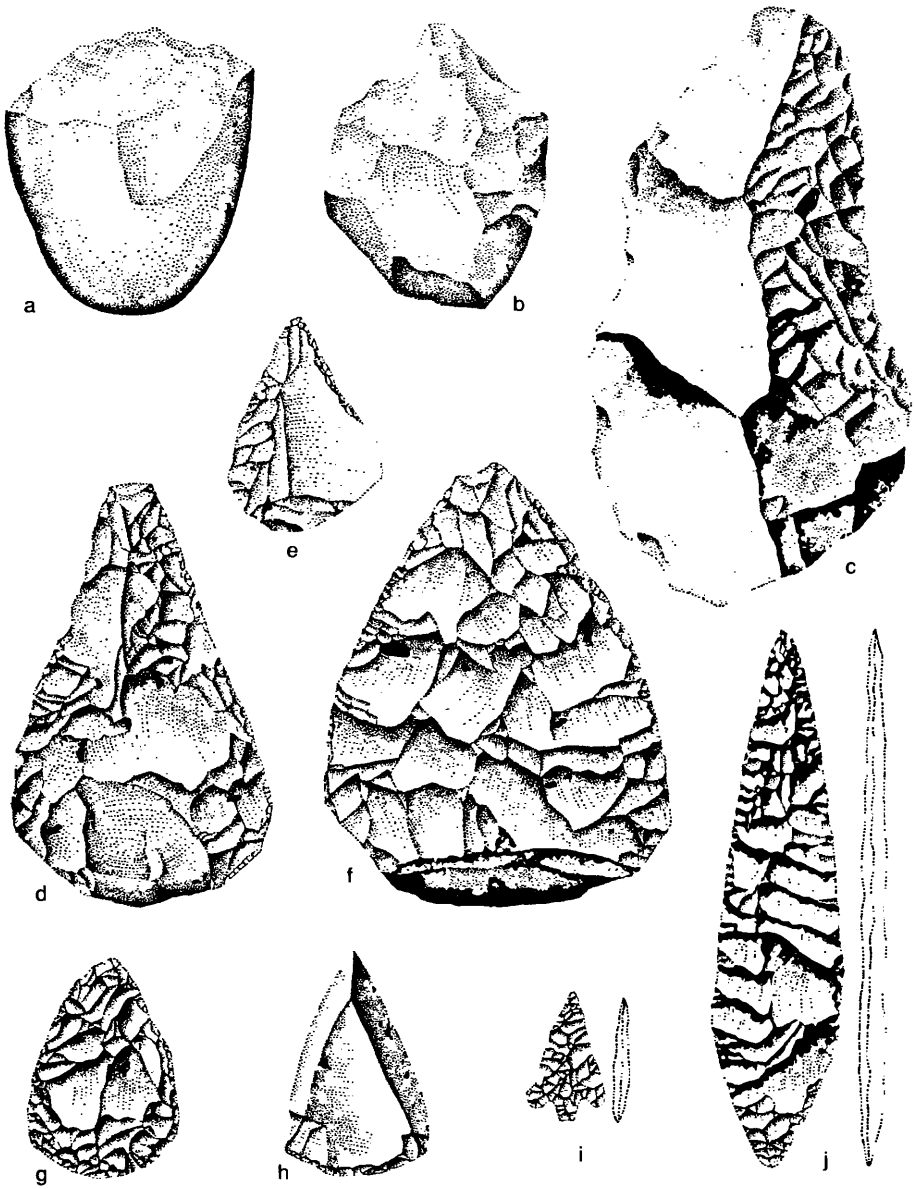
distance away, together with animal remains. These sites may be explained in terms of a shift in diet to include more animal food, generally attributed to *Homo habilis* rather than *A. boisei*. The dietary change and the increase in brain size are also causally linked. It is not known however, whether *Homo habilis* was a hunter-gatherer or still basically vegetarian, adding meat to its diet by scavenging (Pilbeam, 1984). The prevailing view among palaeanthropologists is that *Homo habilis* was temporally and morphologically intermediate between *A. africanus* and *Homo erectus* (Stringer, 1984).

Homo erectus, the first widely distributed hominid species, first appeared in Africa some 1,6 million years ago. Larger-brained than *Homo habilis*, it had front teeth as big as those of earlier hominids, but its back teeth and its face were smaller. It still had a protruding jaw, no chin, thick brow ridges, and a long low skull (Pilbeam, 1984). Evidence of *Homo erectus* is found in east, south and north Africa, as well as south-eastern and eastern Asia. Because *Homo erectus* had a substantially improved ability to exploit the environment, it was able to move into more marginal ecological niches (Weaver, 1985).

Homo erectus was the maker of the Acheulean toolkit, which included large, symmetrically-flaked stone bifaces, or "hand axes". The Acheulean toolkit was a simple but versatile range of chopping, cutting, piercing and pounding tools which presumably were used for butchering meat and preparing plant foods. Elements of the toolkit first appeared about 1,5 million years ago, and the basic design persisted in Africa until about 200 000 years ago, when it was replaced by the more complex Middle Stone Age technology. In western Europe the Acheulean toolkit continued to appear until 100 000 years ago. Such a limited degree of design expression over both time and space may indicate that *Homo erectus* was considerably less skillful and imaginative than *Homo sapiens* (Leakey, 1981).

The earliest direct evidence of the use of fire in the fossil record dates back to about one to 1,5 million years ago (Brain and Sillen, 1988). Although there is no certainty about the hominids, *Australopithecus* and *Homo*, one may assume that some *Homo erectus* populations used fire. It was probably first obtained from natural sources such as accidental fire started by lightning in dry bush or grassland, or volcanoes. Fires could be kept burning like an Olympic flame, fed and nursed, each band having a fire bearer responsible for keeping it alive (Pfeiffer, 1978). Perhaps smoking pipes were invented as a convenient portable source of fire, continually fed with dry grass and kept alive by having air sucked through them. When it was discovered that a particular type of grass provided pleasurable sensations, pipe-smoking might have become a separate tradition.

The first representatives of archaic *Homo sapiens* emerged about 250 000 years ago. Fossils show a mixture of traits characteristic of both *Homo erectus* and *Homo sapiens*, indicative of evolution from the older into the younger species. By 200 000 years ago, there is indication that brain volume was expanding more rapidly, and with the appearance of the Neanderthal



Evolution of hand tools: (a) one of the earliest chopping tools from Olduvai (b) primitive and (c) more evolved hand axes of the Abbevillian stage of Olduvai (d) middle Acheulean handaxe and (e) point (f) Mousterian handaxe and (g) point (h) Levallois point (i) Upper Palaeolithic tanged and barbed point (j) laurel leaf.

variety of archaic *Homo sapiens*, by about 125 000 years ago, the brain had reached its modern size (Weaver, 1985).

Archaic *Homo sapiens* differed from a.m. *Homo sapiens* mainly in the form of the skull. The archaic species had a long, low, and broad skull and a big face surmounted by a massive brow ridge. Their skeletons were much more robust and the muscle attachments on the bones indicate that they were much stronger than we are. The Neanderthals and their contemporaries in other parts of the world were probably as unlike us behaviourally as they were physically (Pilbeam, 1984).

With the emergence of the Neanderthals, the Middle Palaeolithic period was characterised by the development of the Mousterian tradition of tool making, which included hand axes, flakes, scrapers, borers, wood shavers, and spears. Perhaps one of the most significant developments was that the Neanderthals (and many of their contemporaries elsewhere) engaged in ritual burials, possibly indicating belief in a post-mortem spirit. People were buried with stone tools and food (indicated by animal bones) possibly as provisions for the world beyond the grave. Dense accumulations of pollen of bright-coloured flowers further indicate that numerous flowers were placed in the graves (Leakey, 1981). Some Neanderthal populations inhabited regions where no hominids had ventured before, and at a time when the intense cold of the ice age presented considerable challenges for survival in those regions.

The transition from archaic *Homo sapiens* to a.m. *Homo sapiens* occurred at least about 45 000 to 40 000 years ago, although it may have occurred more than 100 000 years ago. Two theories of the origin of a.m. *Homo sapiens* have been distinguished. One theory is that a.m. *Homo sapiens* evolved in a geographically restricted area and then radiated from that centre by migration or gene flow to replace the more archaic forms of *Homo sapiens*. Another theory is that of local morphological continuity where archaic *Homo sapiens* forms in each area are succeeded by a.m. *Homo sapiens* (Stringer, 1984).

Traditional hypotheses on the origin of a.m. *Homo sapiens* have been centred on Europe and the Mediterranean. It has been suggested, for example, that a.m. *Homo sapiens* may have originated in the Middle East. Skeletons that are about 40 000 years old, discovered in a cave on the slopes of Mount Carmel in Israel, are apparently neither modern nor archaic but something of a mixture, possibly indicating local continuity (Leakey, 1981). A Neanderthal skeleton found in south-western France that is only about 31 000 to 35 000 years old, provides evidence that at least some Neanderthals were too distinct and too late to have evolved into a.m. *Homo sapiens*, with whom they overlapped temporally (Stringer, 1984).

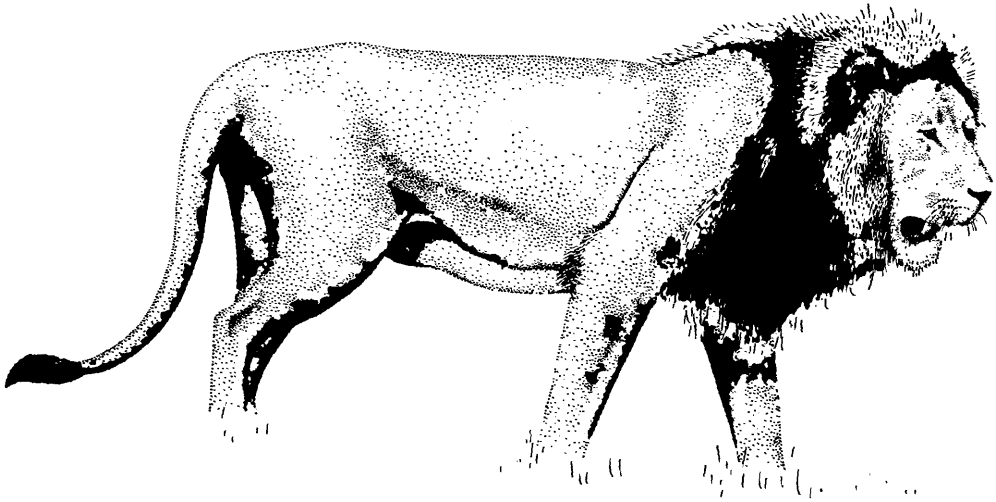
It is also possible that a.m. *Homo sapiens* may have originated in Africa and migrated to other parts of the world. The recent accumulation of a combination of genetic and anatomical data provides evidence for a primary origin of a.m. humans, *Homo sapiens sapiens*, in southern Africa, probably between 50 000 and 200 000 years ago (Mellars, 1988).

Studies of human mitochondrial DNA also suggest that it is likely that modern humans emerged in Africa. It is postulated that the common ancestor of all surviving mtDNA types may have lived perhaps 140 000 to 290 000 years ago. This need not, however, imply that the transformation to a.m. *Homo sapiens* occurred in Africa at this time, since the mtDNA data does not reveal the contributions to this transformation by the genetic and cultural traits of males and females whose mtDNA became extinct. Additional work is also needed to obtain a more exact calibration (Cann, Stoneking and Wilson, 1987).

With the emergence of the Upper Palaeolithic peoples, which included the Cro-Magnons, a.m. *Homo sapiens* possessed a physical appearance similar to our own and a full-sized brain. The brain was no larger overall than that of archaic *Homo sapiens*, but within the more rounded cranium it was expanded at the front and sides, where the nerve circuitry for wider, more complex associations, advanced planning, and other varieties of more abstract thinking is apparently found. It has also been suggested that the shape of the skull may indicate the development of a modern pharynx capable of producing the full range of modern vocalisations, thereby making possible the evolution of a complex language (Pfeiffer, 1978).

Upper Palaeolithic tools were more finely made than before, requiring extremely precise chipping to produce. Tool making techniques included pressure-flaking and using chisel-like stone tools called "burins" to fashion bone and antler into tools. There were many more kinds of special-purpose tools. Variations in stone-tool cultures and evidence of artistic expression increased greatly. Cultural adaptation became specific: different tools were developed for different seasons, and different environments produced different cultures. Major inventions included the first bone needles, harpoons, the spear thrower and the bow and arrow.

Perhaps the most impressive aspect of Upper Palaeolithic culture is the development of art. Paintings and engraving appeared on the walls of caves, often deep inside chambers that are difficult to reach, indicating some possible ritual significance. Even if the true meaning of these cave paintings may never be known, they were clearly produced by highly imaginative and creative individuals.



2

The Evolution of Hominid Subsistence

To reconstruct the context in which the art of tracking may have evolved, it is useful to identify and define various aspects of hunter-gatherer subsistence. While the methods used by recent hunter-gatherers cannot simply be retrojected back into the past (see, for example, Binford, 1968; Freeman, 1968) an analysis of known methods of hunting and gathering may help to recreate the ways in which hominid subsistence may have evolved.

Foraging

Foraging may be defined as the searching for and eating of plant foods as they are found while on the move. It is an activity that does not require transportation, processing or sharing of food in any organised way. The earliest hominid ancestors were probably arboreal creatures who increasingly came down to the ground during the day to forage. As hominids spent more and more time on the ground, where food tends to be dispersed, new forms of locomotion may have been encouraged. Bipedalism, once developed, is more efficient for covering long distances than quadrupedal walking as practised by non-human primates. Since bipedalism also involves raising the head to give a more panoramic view, hominids would have been able to detect danger or spot sources of food on the ground from a greater distance (Shipman, 1986).

As early hominids moved into more open country, leaving the safety of trees, they would have had to adapt to the dangers of predators, possibly in much the same way as baboons did. Baboons, who sleep in trees or on high cliffs, move in a convoy pattern, with males in front and at the rear, protecting the females and young in the middle. Sometimes baboons may also feed together with a herd of impala, thereby complementing each other, since baboons have keen eyesight while impalas have a fine sense of smell (Pfeiffer, 1978).

Though early hominids would have had no effective way of fighting large predators, they may have developed display or bluffing behaviour to ward off attacks. By making loud noises, waving sticks and branches and throwing stones, they may have been able to call a predator's bluff. When chimpanzees and gorillas are aroused, they often grab sticks or branches and swing them about vigorously. A troop of baboons has even been seen to mob a leopard, creating enough noise to deter the predator (Smithers, 1983).

Although there is no evidence that the Australopithecines ever made stone tools, items such as leaves, stems, wood and stones may have been casually adapted as tools in much the same way as seen among chimpanzees. Stone hammers, for example, can be used to crack hard fruits or nuts. Various nature facts have been employed by recent hunter-gatherers, among them sticks, stones, rocks, pebbles, shells, thorns, leaves, twigs, bones, porcupine quills and teeth, which would not be recognised as tools in the archaeological record (Oswalt, 1976).

One of the most important tools used by hunter-gatherers is the simple digging stick. Although it cannot be known when the first digging stick was used, since wood is perishable, it may well have been the first fashioned tool made by hominids. At first, hominids would have simply used broken sticks which happened to have a sharp point because of the way the wood split. Since it was first deliberately sharpened, possibly millions of years ago, the digging stick has remained unchanged until the present. It is still used, for example, by hunter-gatherers of the Kalahari. While we cannot know whether the Australopithecines used the digging stick to supplement their diet with root crops, it is quite possible that *Homo habilis*, who made stone tools, made use of it. The digging stick may also have been vital to *Homo erectus* populations who adapted to more marginal arid regions, since they would have been dependent on root crops for water and food. Studies of tooth wear suggest that roots, bulbs and tubers formed an important component of the diets of *Homo erectus* (Leakey, 1981). The pointed digging stick may also have been the basis for the later development of the wooden spear (Zihlman, 1981).

Gathering

In contrast to foraging, gathering may be defined as the searching for and transporting of plant foods to a home base or midday-rest location, to be processed and shared with other members of the band. Initially gathering may have required the use of tools and containers. At a later stage fire would have been used for cooking. Gathering plant foods may be associated with meat acquisition and a division of labour between women, who are usually responsible for providing plant foods, and men, who are usually responsible for providing meat. Apart from food-sharing, information about plant and animal life would also be shared.

Archaeological evidence indicates that about two million years ago some hominids in Africa were carrying objects around with them, such as stones (Isaac, 1978). They made simple but effective stone tools, and probably carried animal bones, as well as meat, to certain places where this food supply was concentrated. Although it is not known whether some of the Australopithecines were gatherers rather than foragers, it is possible that a shift from individual foraging to co-operative gathering, together with increased meat consumption, may perhaps have represented a significant adaptation with the appearance of the larger-brained *Homo habilis* some two million years ago.

As groups of hominids moved into more inhospitable terrain, resources would have been too thinly spread to allow for casual foraging. Gathering is a much more efficient way of utilising resources than foraging, since a group can spread out from a home base to cover a much larger area. Reciprocal sharing could have ensured that band members returning empty-handed would benefit from those who were successful, with the expectation that such favours would be returned at a later date when fortunes were reversed. Gathering also allows access to a greater variety of plant foods. In foraging, food is limited to whatever can be eaten immediately. Bands may gather a wide range of plant foods, however, whose digestion can be facilitated by grinding, crushing, soaking, cooking or other means of food processing. Various methods of food processing may have been developed over a considerable period of time. While grinding and crushing may have been relatively early developments, cooking would not have been possible before the use of fire by some *Homo erectus* populations. The molar teeth of hominids, which are used mainly for grinding and heavy-duty chewing, remained large until *Homo erectus* times, when they began to become smaller, perhaps because softer, cooked foods were eaten (Pfeiffer, 1978). The home-base fire used for cooking would also have provided protection against predators and warmth against cold nights, allowing hominids to explore cold regions. It is possible that regular sharing, which is a fundamental component of gathering, may only have become a common hominid social adaptation in the context of food processing by means of cooking (Binford, 1984).

Sharing information may save a considerable amount of energy in the food quest. In a foraging baboon troop, as in any organised body of animals, there exists a collective wisdom. The troop as a whole, as an organic repository of information, knows more than any one of its members (Pfeiffer, 1978). In gathering among hominids, this collective wisdom may have been increased considerably as members explored larger areas. Communication would have allowed a much greater knowledge of plant communities, and sharing knowledge of the terrain would have narrowed down the search for plant foods. Men could also have informed women of the location of plant foods, while women could have informed men about the localities of possible sources of meat. Sharing of information about food sources need not necessarily have required a very complex language. The hypothesis that bees communicate the distance and direction of food sources illustrates that a very rudimentary form of language may have been sufficient, although it was probably much more complex than that of bees.

Collecting

Collecting may be defined as the acquisition of animal protein in the form of small, relatively immobile animals. Since it does not require any skill other than that for obtaining plant foods, it could readily have supplemented a diet based mainly on foraged or gathered plant foods. Most primates include

animal food such as insects and small vertebrates in their diet. Chimpanzees, for example, make tools to obtain termites (Pfeiffer, 1978).

Recent hunter-gatherers utilised a wide variety of small animals, such as insects, lizards, snakes, tortoises, turtles, frogs, toads, tadpoles, crabs, shellfish, nestlings, eggs and rodents. Although these animals would have been relatively easy to utilise when found, it is unlikely that collecting would have constituted a major part of hominid diets (Pfeiffer, 1978).

Predation

Predation may be defined as the killing of highly mobile prey without the use of weapons or other cultural means such as trapping, vehicles or domesticated animals. To overcome its prey the predator relies solely on the biologically adapted abilities of stealth, speed, endurance, strength or superior numbers. Chimpanzees, for example, have been known to follow their prey stealthily for a long period, sometimes for more than an hour, in order to sneak up on it. Two or more chimpanzees may co-operate in stalking the prey, arranging themselves spatially in such a way that it cannot escape (Tanaka, 1980). The prey of chimpanzees and baboons is limited to small animals and the young of middle-sized mammals. Chimpanzees do not prey upon animals bigger than themselves and never use weapons to do so. Estimates of the meat intake for Gombe chimpanzees are at least 10 to 20 times lower than that of the Ju/wasi* and other hunter-gatherers (Potts, 1984).

Early hominids may also have preyed upon vulnerable animals in much the same way as baboons and chimpanzees do. Hares can be run down and caught with bare hands, because they have the habit of running for cover and then freezing, relying on their camouflage to escape detection. Some francolins may be caught in a similar way, since they have the habit of only flying up three times when disturbed, after which they simply freeze. (Pfeiffer, 1978).

As hominids adapted to bipedalism, they gained increased efficiency in covering large distances, but at the expense of speed. Since speed is more important for predators, bipedal hominids would have been less efficient predators than quadrupedal chimpanzees or baboons (Shipman, 1986). It is unlikely, therefore, that predation would have played a significant role in meat acquisition by hominids. They were better adapted to scavenging, for which endurance is more important (Shipman, 1986).

Scavenging

Scavenging may be defined as the obtaining of meat from carcasses of animals killed by other species, or of animals that died of non-predatory causes. It has been observed in non-human primates such as chimpanzees, baboons and orangutans. These observations support the idea that early

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* NOTE: Strictly speaking, the term "Ju/wasi" is an approximation of the correct phonological rendering "Žu/ˈhõasi" (after Snyman, 1975). For the sake of continuity, however, we have stayed with the more popular rendering. The Ju/wasi are also known as the ˈKung.

Pleistocene hominids may have scavenged (Hasegawa *et al.*, 1983). Foraging hominids could have utilised any dead animals they happened to find, but they probably would have had access only to skeletal parts of low food utility, after carcasses had been abandoned by predators and scavengers. It is unlikely that early foraging hominids were engaged in anything more than casual scavenging to supplement a diet consisting mainly of plant foods. More active, systematic scavenging (which requires greater mobility) would only have been possible with a subsistence strategy based on a division of labour.

In contrast to casual scavenging, systematic scavenging may be defined as the active search for carcasses. Watching for circling vultures to determine the locality of carcasses, hominids could have significantly increased their access to meat. Bipedalism would have fulfilled the scavengers' needs to cover large areas, since it is more efficient than the quadrupedal walking practised by non-human primates. Having a raised head would have also improved their ability to spot carcasses on the ground. The retention of arboreal adaptations would have reduced the threat of competition, since hominids would have been able to retreat into trees to consume scavenged meat (Shipman, 1986). Conflict with nocturnal animals may have been avoided by scavenging at midday. Although mammalian carnivores watch vultures to locate carcasses, a high percentage of carcasses which are first reached by vultures go untouched by mammalian carnivores. The hominids' access to such a source of meat may therefore have depended on their reaching it before the vultures devoured it (Potts, 1984).

Stone tools would have enabled hominids to cut through tough hides of large animals, giving them access to meat that would have been difficult to get at with their bare hands and teeth. It would also have enabled them to butcher an animal more quickly, thereby allowing them to retreat to safety in order to avoid competition brought by the arrival of dangerous carnivores (Shipman, 1986). Even before modified stone tools were made, stones may have been used to crack bones to gain access to marrow.

While hominids may have had access to carcasses where no other carnivores, except for vultures, were present, competition with other species for meat may in fact have been an important factor in increasing the amount of meat in their diet. The ability to drive off other scavengers, such as jackals and hyaenas, would not only have given hominids access to a larger number of carcasses, but also to greater portions of the carcasses.

A further advance on systematic scavenging might be seen in two variations: pirating and robbing. Pirating may be defined as the appropriation of the fresh kills of other predators by means of greater strength or superior numbers. Lions, for example, may use their superior strength to appropriate the kill of spotted hyaenas. A very large group of spotted hyaenas, on the other hand, may turn the tables and appropriate a lion kill. Pirating has also been observed among non-human primates, and it may have occurred among early hominids. But, since predatory animals that were weaker than

hominids would not have killed very large animals, it is unlikely that hominids would have acquired much meat by pirating.

Meat robbing, on the other hand, may be defined as appropriation of the fresh kills of dangerous predators by means of weapons, fire or bluffing. These methods are intended to compensate for lack of physical strength. The earliest weapons were probably used for self-defence rather than for killing prey. From using weapons for self-defence against predators, some hominids may have developed the ability to use them to drive off scavengers and predators from fresh kills. Stones may have been thrown as missiles, and clubs and spears wielded to ward off attacks. Though some of the smaller and more timid scavengers and predators (such as single or small numbers of jackals, hyaenas, cheetahs or hunting dogs) may have been driven off in this way, it is unlikely that hominids would have been able to chase away large predators such as lions, by physically attacking them.

Fire, which may initially have provided protection against predators, may also have been used more aggressively. By hurling glowing pieces of wood or setting fire to the grass, as recent hunter-gatherers of the Kahalari have been observed to do (Steyn, 1984a), even lions may be driven off.

Finally, bluffing would have increased the effectiveness of meat robbing, not only in reducing the risk of injury by avoiding physical contact, but also in enabling hominids to drive off predators that were too dangerous to confront directly. Although many animals use displays or startle responses in self-defence to bewilder a predator momentarily in order to give themselves time to escape, it seems unlikely that unarmed hominids would have had the confidence to deliberately bluff dangerous predators. While it may be reverted to as a last resort, bluffing dangerous predators to drive them from their kills is a bold aggressive act that requires knowledge of how different predators react under specific conditions. Relying initially on their weapons to frighten off the smaller scavengers and predators, hominids may have discovered that wielding clubs, throwing stones and shouting had the effect of driving them off even before physical contact was made. Weapons might have given some hominids the confidence to confront more dangerous predators.

Baboons have been observed to charge at cheetahs, causing the cats to run off, so it is possible that early hominids may have done the same. Although cheetahs may easily be driven off their kill, they are not so easy to locate before they consume their prey. Cheetahs hunt silently and quickly, usually kill small to medium-sized animals, and consume meat rapidly (Potts, 1984). Robbing the kills of cheetahs would therefore have accounted for only a small amount of meat whenever hominids were lucky enough to find a cheetah who had just killed an animal.

Wild dogs are highly effective hunters that are easy to chase away from their kills (Pfeiffer, 1978), but their habit of hunting in social groups would have made them more formidable to early hominids. The same would also apply to hyaenas hunting in social groups. Large groups also consume meat

on a carcass much more quickly, so that hominids would have had to arrive soon after the kill to obtain a fair portion.

Early hominids may have been able to scavenge and even appropriate stored leopard kills. Knowing that a leopard consumes carcasses over a period of time and temporarily abandons its tree-stored kills, hominids would have been able to scavenge them during the leopard's absence. The leopard's solitary nature and its apparent diurnal timidity towards certain non-human primates and modern humans, suggests that the risk of being confronted by a leopard at its kill during the day may have been low (Cavallo, 1987).

Their size and their sociality make lions the most formidable predators for hominids to deal with, yet recent hunter-gatherers' use of bluffing to appropriate lion kills (see Chapter 5) suggests that hominid scavengers may have done the same. It is not known, however, when this method was first used. To drive lions off their kill requires careful study and timing to choose the right psychological moment. In comparison to other predators, lions would therefore have been much more difficult to drive off, but since they hunt larger prey animals, the meat yield would have been greater.

Generally speaking, the efficiency of meat robbing would have depended on the number of hominids involved, the kind of scavengers or predators confronted and their numbers, and the meat yield. The larger the number of hominids involved, the more effectively they would be able to drive off other carnivores, but the lower the meat yield per hominid would be. While animals like cheetahs could easily be driven off, the meat yield would have been very low. Robbing lion kills, on the other hand, would have been much more difficult, but would have given a higher meat yield. Initially, early hominids may not have been very efficient at the task, but over a period of time they would have become increasingly adept, eventually reaching optimum efficiency. For optimum efficiency, the smallest possible groups of hominids that could effectively deal with large predators such as lions, may have formed, so that several such groups could cover as large as possible an area.

To sum up, scavenging may have been an important and distinct adaptation in hominid evolution. At a time when hominids were only capable of occasionally killing and defending their own prey, they may have relied mostly on scavenging to obtain meat, skin and other substances from carcasses (Shipman, 1986). The development of scavenging which has been traced in this section involved significant cultural adaptations. While it may have been an important adaptation in its own right, in the sense that scavenging constituted the most reliable method of meat acquisition during a major period of hominid evolution, it may have been instrumental in making possible the transition from predation to hunting.

Hunting

Hunting may be defined as the killing of highly mobile prey with the use of weapons, traps, vehicles or domesticated animals. In contrast with

predation, hunting involves cultural adaptations that give the hunters an advantage over their prey.

The transition from predation to hunting possibly occurred when hominids started to throw stones, sticks and clubs to knock down or stun small mammals and birds, thereby increasing their chances of catching the prey. Clubs and pointed sticks used as spears may also have enabled them occasionally to dispatch larger animals that would have been impossible to kill with their bare hands or teeth. Butchering of large animals would have required stone tools to cut through tough hides, so it is unlikely that hominids hunted large animals before they had effective cutting tools.

In all probability, stones, throwing clubs or even the first crude spears would not have been effective enough as missiles to bring down large animals at, or even near, the place where they were attacked. Indeed as hominids adapted to bipedalism they would have lost some speed, becoming less able to catch prey with short, fast charges. They would, however, have gained endurance and become better adapted for persistence hunting.

In persistence hunting the hunter never allows the animal to rest, keeping it constantly on the move until it is exhausted and can easily be killed with clubs or spears. Hunters would concentrate on young animals or animals weakened by injury, illness, hunger or thirst. Since animals cannot tolerate the midday heat, this is usually the best time to run them down. The evolution of the distinctively human sweating apparatus and relative hairlessness would have given hunters an additional advantage by keeping their bodies cool in the midday heat.

In relatively open terrain it may have been possible for hominids to chase an animal persistently without losing sight of it. Several hominids may have co-operated in a relay-race, as wild dogs and baboons have been observed to do. As the animal flees, it tends to run in a wide circle. Such behaviour would have enabled trailing hunters to cut across the arc and take over from the hunter previously chasing the animal.

In woody country or uneven terrain where visibility is limited, the animal would soon run out of sight of the hunters. In such circumstances tracking would have been essential, with the success of the hunt dependent on the nature of the terrain and the tracking abilities of the hominids.

Without the use of missile weapons or the ability to track down animals, early hominids would probably not have been very effective persistence hunters. Persistence hunting requires a high energy expenditure for a low success rate, so even early representatives of the genus *Homo* may have resorted to this method only occasionally. Using a simple spear as a missile weapon, hominids no doubt increased their chances of running down an animal by stalking and wounding it.

In relatively open terrain, where tracking may not have been necessary, it would have been very difficult for hunters to stalk an animal closely enough to wound it fatally with a hand-thrown spear. Recent hunter-gatherers have shown that it is possible to stalk an animal in open terrain and bring it within the range of a spear-thrower or a bow and arrow. With a hand-thrown spear

this would have been much more difficult, although not impossible. Hunting in small groups may have improved the chances of wounding the animal, but at the same time the risk of being detected while stalking would have increased. The optimum size of such a group would therefore have been determined by the advantage of the increased chances of a hit, against the disadvantage of the increased chances of being detected. The success rate of stalking animals in open terrain with hand-thrown spears may have been very low.

The majority of animals brought down by recent hunter-gatherers were not killed upon initial contact, but were usually wounded, stunned or immobilised so that they were incapable of rapid or prolonged flight (Laughlin, 1968). We can assume that hominids who did not have spear-throwers or bows and arrows, were less successful at wounding animals. While a wounded animal may have been followed by sight in relatively open terrain, the chances of successfully stalking and wounding it may have been very small. It may have been much easier to stalk such an animal in woody terrain, but since it could have run out of sight, the animal would have had to be tracked down. We can surmise therefore that hominids were not very successful at stalking and killing animals with missile weapons before they were able to track them down. Furthermore, in woodland or uneven terrain, where visibility was limited, tracking would also have been important in locating animals.

In addition to the development of tracking, technological improvements in missile weapons would have improved the efficiency of stalking and wounding animals. Hunters could have used fire, for example, to harden the points of their spears. A spear with a fire-hardened point found at a site in north Germany indicates that it was in use at least 80 000 years ago (Pfeiffer, 1978). Spears tipped with stone or bone points would have had even greater penetration, but a greater improvement would have been the invention of the spear-thrower. Since the radius of the casting arc was lengthened, the initial velocity was increased, thereby increasing the range of the missile. Spear-throwers (such as those used by the Australian aborigines, for example) were usually made of wood, so it is not known when these were first used. The only surviving prehistoric specimens are made of antler or ivory, and these were made by Upper Palaeolithic Europeans (Coon, 1971).

Without doubt one of the most important inventions in hunting is the bow and arrow. The bow and arrow is the most versatile hunting weapon, since a wide range of animals can be hunted with it, and it can also be used in a wide range of habitats, from open, semi-arid regions to tropical forests. Even in cold regions where suitable wood was unobtainable, the Inuit made bows of musk-ox horns (Coon, 1971).

The earliest direct evidence of the bow and arrow has been found in a 10 000-year-old site in Denmark. An assortment of points closely resembling arrowheads have also been found in Spanish caves, providing indirect evidence that the Solutreans, Upper Palaeolithic people whose toolkits first

appeared about 20 000 years ago, may have used the bow and arrow. We do not know, of course, when it was first invented (Pfeiffer, 1978).

We also do not know when poison was first used. Some recent hunter-gatherers (such as the Aché of Paraguay, South America) hunted with heavy powerful bows and long, feathered arrows to achieve a range of about 50 m (Bicchieri, 1972). So it is possible that the first bows were used to shoot unpoisoned arrows. It is also possible that the first bows and arrows might not have been powerful or accurate enough to deliver a mortal wound with an unpoisoned arrow. If this was true then the use of poison may have been discovered before the invention of the bow and arrow. While the invention of the bow and arrow probably required ingenuity, it is conceivable that the use of poison may have been based on an accident. Having discovered a lethal poison, hunters could have tipped their spears with it, thereby increasing the chances of mortally wounding an animal. Poison spears have been used by the Akoa of the African rain forest, for example, to hunt elephants (Coon, 1971). If the use of poison was known, the first bow and arrow would not have had to be very powerful to be effective. More powerful bows and more accurate feathered arrows may have been developed later.

Turning from weapons, we should mention the use of disguises to improve the efficiency of stalking animals, particularly in open terrain. Wearing animal skins and antlers, and carrying a pair of sticks to represent forelegs, recent hunters have been observed to imitate characteristic postures, movements and sounds (see Chapter 5). Using this disguise, hunters could kill their prey at short range.

Instead of stalking an animal, a hunter could also resort to ambushing. Recent hunter-gatherers have been known to use blinds at waterholes or salt licks. Animals usually approach a waterhole from the downwind direction in order to scent possible danger, and are very wary when they drink. It would be very difficult for a hunter to get close to such animals, so it is unlikely that hominids could have had much success from ambushing before they had effective missile weapons. Even recent hunter-gatherers such as Australian aborigines were not very successful using this method (Pfeiffer, 1978). Ju/wasi hunters regarded hunting from blinds as not very effective, and preferred to track down an animal (Lee, 1979).

Many recent hunter-gatherers used lures to draw animals into ambushes. The Penobscot Indians of Maine would attract the male moose during the mating season by imitating the amorous call of the cow moose through a cone of birchbark. An Ainu hunter would use a complicated blowing device to imitate the cry of a lost fawn in order to attract a doe to within range of his bow (Coon, 1971). But even when disguises were used or animals were ambushed, hunters may only have been able to wound animals. The hunters would then have had to either run down or follow the wounded animals.

The next variation of hunting involved the simplest and probably the earliest form of trapping: the use of natural traps. Many nocturnal animals

lie up in burrows by day. Once an occupied burrow has been found, it does not require much skill simply to dig the animal out or smoke it out (see Chapter 5). An ability to track down fresh spoor may have greatly increased the efficiency of utilising such natural traps.

Artificial traps can be classified according to the forces used. A trap may utilise the weight or momentum of the animal itself, the weight of a suspended object, or the torsion of a spring. Perching birds could be caught by smearing a sticky substance, such as gum, onto branches. Pit traps would have concealed surfaces that collapse under the animal's weight. Single nooses would catch animals by their own momentum, or spring-loaded nooses would make use of the flexibility of wood and of trigger mechanisms. Nooses could also be attached to logs balanced in the crotches of trees, or logs propped up by trigger devices. Deadfalls could be made out of propped-up slabs of stone or heavy logs that would crush small animals. Traps would be set along animal trails and converging piles of brush on either side would lead the animals into it (Coon, 1971). Fishing also involves various forms of trapping. In rivers, traps, weirs, baskets and nets (Steward, 1968) are required, whereas along coasts, intertidal fish traps could be constructed (Inskeep, 1978).

What is unknown is the antiquity of trapping. While natural traps may have been used opportunistically by early hominids, artificial traps were possibly a relatively recent development. Although most traps are very simple in design, they are usually rather ingenious devices, so we can imagine that they could not have been invented before a fairly high level of creative intelligence evolved. Indeed, most traps may only have been invented after a fully modern intellect developed. The success of trapping (on land) also depends on the hunter's ability to interpret tracks and signs, so effective trapping may only have been possible after hunters acquired tracking abilities.

While persistence hunting, stalking, ambushing and trapping were carried out by single or small groups of hunters, large groups of hunters could participate in co-operative hunting methods that would have required some form of social organisation. Some co-operative hunting methods involved not only all the members of a band (including women and children), but also several allied bands. Perhaps the first forms of co-operative hunting were opportunistic, involving small groups of hunters who took advantage of favourable natural conditions. Animals may have been driven into natural traps such as swamps or lakes, or over cliffs. Hominids who were able to control fire may have cut off escape routes by burning grass and brush over large areas. Some of the American Plains Indians, for example, used to set fire to dry grass downwind of a herd of bison grazing near bluffs over rivers (Coon, 1971). As the wind carried the fire towards the bluff, the bison stampeded over the side. The use of fire, however, would have been limited to occasional opportunistic events in specific localities, since the vegetation would have had to recover before it could be burnt down again. In general, then, natural sites for successful co-operative hunts would have

been limited, and opportunities for taking advantage of such sites may only have been occasional. For this reason co-operative hunting could not have been a reliable method of hunting before the invention of artificial guided fences, nets, pitfalls, snares or corrals.

Co-operative mass-killing techniques must have varied considerably in scope and efficiency, depending on the terrain, habitat, animal population densities, the habits of the animals involved, the level of technology required and the social organisation of hunter-gatherers. On a small scale it would involve methods such as the "human surround" or the improvised construction of a brush fence when conditions permitted. On a large scale it may have extended to include the use of a more or less permanent corral several kilometres in circumference with a funnel of wooden posts to guide the animals into the corral (Spies, 1979).

Co-operative hunting methods were highly specialised in the sense that particular methods were developed for specific environmental conditions and aimed at particular species. The Efe of the Ituri Forest in central Africa, for example, developed methods specifically for forest conditions. Once a year all the families of a band would unite for the communal surround, in which men, women and children spread out in a large circle. Making as much noise as possible, they would converge on the centre of the circle. Animals milling around the middle would be dispatched by bowmen (Coon, 1971). Net hunting is also effective in deep jungle (Tanaka, 1980). In the circumpolar world drift- and drive-fences or poles have been used to guide animals into traps such as pitfalls, ambushes, snares or corrals. The larger and more efficient mass-killing techniques were used, for example, in areas of high caribou population density along migration routes. Such mass-killing methods would, however, not have been effective in areas of more diverse fauna and a more scattered caribou population. Even in favourable environments, hunter-gatherers could not have depended on caribou drives alone, and would have had to rely on other methods of hunting as well. Strategies may also have varied according to the seasons (Spies, 1979).

The last aids to hunting we need to consider are domesticated animals, which include dogs, horses and reindeer. The oldest remains considered to be those of domesticated dogs were found in Idaho, North America, dated at about 11 000 B.P.; in northern England dating from about 9 500 B.P.; and in the Middle East dating from about 9 000 B.P. The distance between these finds suggests that dogs were first domesticated in some unknown place a long time before these dates, perhaps even before the end of the ice age. Or dogs could have been domesticated many times in different places. The domestication of dogs may have its origin in the taming of captured wolf pups. A wolf pup readily attaches itself to humans who care for it, substituting them for its own family and pack. Such tame wolves, on the way to becoming dogs, would have increased the security of the home base of hunter-gatherers, alerting people to danger and chasing away wild animals (Leonard, 1973). Dogs have been used by recent hunter-gatherers to track down animals and hold them at bay. Hunting with dogs, however,

may have been limited to certain species, and then only to complement other hunting methods. Specialised uses have been shown among the Inuit, for example, to detect the breathing holes of seals, and to pull sledges. It is not known when dogs were first used as hunting aids, but once put to this purpose, they may have greatly increased the efficiency of hunting.

Carvings of horse-heads engraved with what appear to be rope harnesses found in France indicate that Upper Palaeolithic people may have either ridden or used horses for traction about 15 000 years ago. What is more, evidence provided by patterns of tooth wear indicative of crib-biting, which is unknown in wild horses, supports the theory that horses may have been domesticated in France at least 30 000 years ago. It is not known, however, what these horses were used for (Leakey, 1981). The first domesticated horses may have been used as a source of food or for transporting heavy loads, so it is not known when horses were first used in hunting. But once mastered, the ability to ride horses would have changed hunting dramatically (see, for example, Chapter 5). While hunting from horseback may well have originated in Europe in Upper Palaeolithic times, it has been introduced to hunter-gatherers of southern Africa only during the last hundred years or so. Domesticated reindeer were used as hunting aids before reindeer domestication became a self-sustainable livelihood. Small herds of tame does, for example, were used as decoys for rutting wild bucks.

Domestic reindeer were also used in unique ways of hunting by the Nganasan living in the Taymyr Peninsula area in Russia. Sledges drawn by reindeer provided them with fast transport, enabling them to encircle herds to drive them into lakes or into V-shaped drive corridors. Apart from sledges drawn by dogs or reindeer, vehicles used for hunting included water craft such as boats, canoes and kayaks (Spies, 1979).

In considering the possible evolution of hunting, it seems reasonable to assume that some of the simpler methods were developed earliest. Since the first hunters may not have been very successful, hunting may have played a relatively minor role in subsistence. Universal methods such as persistence hunting, stalking, ambushing and perhaps trapping may have played a fundamental role in the evolution of hunting in general. It is also possible that unknown methods played an important role, since it is conceivable that at earlier stages of hominid evolution, hunting methods may have been used that have not been practised by recent hunter-gatherers. As new methods were developed, hunters would have made use of a variety of methods, depending on which methods were best suited for particular conditions or situations. Different methods may have varied according to the seasons, and specific methods may have been best for specific animals.

Specialised methods, such as cooperative hunting and the use of domesticated animals and vehicles, would not have played a fundamental role in the evolution of hunting in general and may only have been developed after more universal hunting methods were well established. Specialised methods could only be used if more universal methods were available as a back-up when they failed, so they could not have been relied upon before

universal methods were developed. Since specialised methods were developed for very specific environmental and social conditions, it is unlikely that the development of such methods played a significant role in human evolution in general. An adaptation that was successful in only very specific conditions would not have enabled hominids to adapt successfully to other environmental conditions.

If selective pressures for hunting played a significant role in human evolution, it is most likely that universal hunting methods may have been important adaptations. Only universal methods would have enabled hominids to adapt successfully to the wide range of environments that they inhabited. The success of universal methods such as persistence hunting, stalking, ambushing and trapping would have depended on two important factors, namely the tracking abilities of the hunters and the technological development of weapons and traps.

As far as the origin of hunting is concerned, interpretations of the archaeological record have varied considerably. According to one view, the Australopithecines had to hunt for their food in the savanna (Washburn and Moore, 1980). Another view holds that changes in the brain and endocrines occurred from about two million years ago by which hominids, such as *Homo erectus*, became social hunters (Young, 1981; as quoted in Binford, 1984). Many older views on the evolution of hunting, however, have been based on assumptions and speculations that are questionable (Binford, 1981).

An example of such a questionable archaeological interpretation is the set of conclusions drawn from the data of the Torralba site in Spain. An estimated minimum of 115 animals, including elephants, horses, cervids, bovids, rhino, birds, and some carnivores, were recovered from the site. Some 611 tools were also found. This data set has been interpreted as evidence of highly organised cooperative hunting, involving large groups of hunters, perhaps in the order of 100 individuals or more, possibly using fire to drive animals into a marsh. Yet the animal remains may have accumulated over a period of several tens of thousands of years. Even if it is assumed that only 10 000 years are involved, an average of only one animal may have died every 87 years. For a normal glacial environment such a death rate could be attributed to natural causes. Animals such as elephants seek water when their temperatures go up, so the most common place of death is in such a marsh-bog setting. Such conditions also favour the preservation of bones. Furthermore, the accumulation of stone tools may be attributed to scavenging by hominids, rather than hunting (Binford, 1981). This example shows that archaeological sites that have been interpreted as being evidence of hunting may well represent the remains of animals that have been scavenged.

It is still not known with confidence how the earliest stone-tool-using hominids acquired animal foods and what the relative contribution of hunting and/or scavenging was to subsistence activities (Bunn and Blumenschine, 1987). An analysis of the Middle Stone Age Klasies River Mouth fauna from

the southern Cape of South Africa suggests that larger bovids seem to have been primarily if not exclusively scavenged, while smaller bovids may have been hunted (Blumenschine, 1986). It has even been suggested that hunting may not have played an important role in hominid subsistence before the appearance of a.m. *Homo sapiens*, and that hunting may only have become a more important subsistence strategy than scavenging with the appearance of behaviourally modern hominids (Binford, 1984). Scavenging may well have played an important role in human evolution and it is possible that hunting only became an important subsistence strategy relatively late in human evolution.

Hominid Subsistence Adaptation

Both the food requirements of hominid populations and the availability of food resources would have played an important role in the evolution of hominid subsistence. Firstly, the food requirements of a population in any particular area would have been determined mainly by that population's density. Secondly, the availability of food resources would have depended on the environment and on the abilities of the hominids to utilise available food resources. In biological evolution, change may occur for its own sake, but the direction of change is determined by selective pressures that make adaptation a necessity. Thus we need to consider the impact of population pressure and environmental pressure on adaptations to hominid subsistence.

Among animals, tendencies towards overpopulation play an important role in evolutionary change, in which intra-specific competition based on excessive reproduction is the essence of natural selection. Among human communities, population growth may be considered as a contributing factor in cultural change. While a growing density of people may have first led to territorial expansion and the infiltration of unused ecological zones, it may have brought about an intensification of economic activity once the potential for territorial expansion had been exhausted. This would have entailed the exploitation of new resources and the development of new technologies needed in the quest for food (Cohen, 1977). For example, hominids may have turned to edible plant foods that were formerly avoided because of more palatable or more easily obtainable foods. New methods of food preparation may also have increased the variety of edible foods.

Concerning environmental pressures, one can see that early hominids in Africa, for example, would have had to respond to the cyclic alternation between savanna, forest and desert in different ways. They could have reacted to the shifts in their habitat by migrating along with the vegetation belts. Where this was not possible, they would have had to adapt to new environments by switching their dietary patterns to new resources. They could also have moved into habitats previously unoccupied by hominid populations, adopting new and appropriate subsistence strategies (Roberts, 1984).

The earliest hominids that moved from a forest to a savanna environment would have had to live on lower-quality plant foods. This would have

required either more extensive foraging to collect larger quantities of plant foods, or else supplementing with meat a diet consisting mainly of vegetable foods. Meat contains more calories per unit weight than most plant foods, so the inclusion of more meat into the diet would have formed a considerable advantage. The high protein content of meat would also have met the high-quality food requirements demanded by the enlargement of the brain and body (Foley, 1984b). Furthermore, hominid populations that adapted to more marginal environments, such as arid or cold regions, would have had to increase the percentage of meat in their diets as vegetable foods became sparser. It seems arguable, therefore, that adaptation to marginal environments played an important role in developing more efficient methods of acquiring meat.

As hominids developed new subsistence strategies in response to selective pressures, emphasis would have shifted to the new strategies while retaining previous ones. An initial strategy based mainly on foraging plant foods, supplemented by collecting small animals, casual scavenging and occasional predation, may have developed into one of gathering plant foods and systematic scavenging, while retaining foraging, collecting and occasional predation as secondary strategies. Even with the development of hunter-gatherer subsistence, foraging, collecting and scavenging would still have played a role, since hunter-gatherers would have used every available strategy to exploit natural resources in the most efficient way. In the shifts of emphasis from foraging to gathering, from casual to systematic scavenging, and from predation to hunting, significant cultural adaptations occurred.

In response to selective pressures, hominid populations adapted either biologically, thereby evolving into new species, or culturally as far as the abilities of the particular species enabled them to do so. According to the model of phyletic gradualism, new species arise from the slow and steady transformation of entire populations. In contrast, the model of punctuated equilibria holds that new species arise very rapidly in small, peripherally isolated local populations, beyond the area of its ancestors. According to this model, the history of evolution is one of homeostatic equilibria, disturbed only "rarely" by rapid and episodic events of speciation (Eldredge and Gould, 1972). While such biological adaptation occurs by means of natural selection of random genetic variations, cultural adaptation occurs as a result of learned behaviour. Cultural development represents a fundamental shift in evolutionary levels during which change can happen much more rapidly. Nevertheless, biological evolution and cultural evolution may have impacted one upon the other in a positive feedback relationship (Gowlett, 1984).

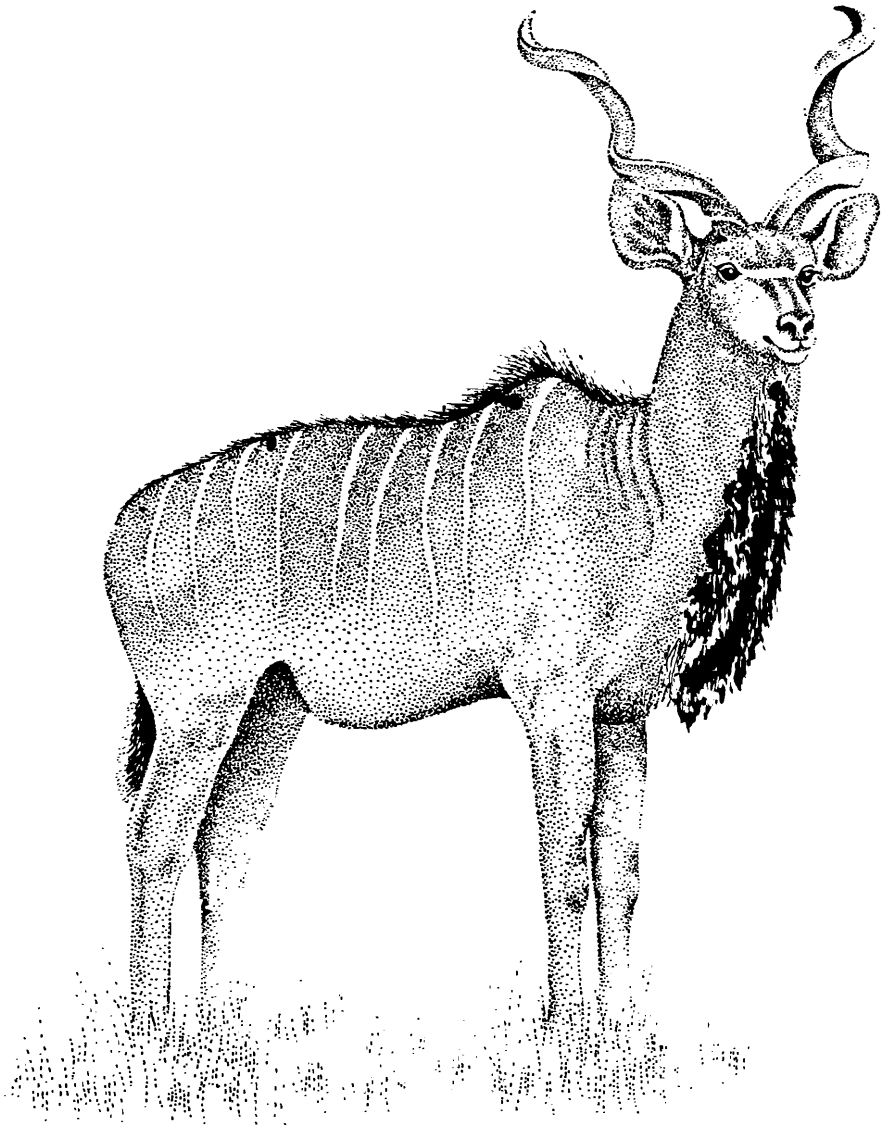
Since the abilities of the earliest hominids to adapt culturally were probably very limited, they would have responded to selective pressures probably with biological adaptation. Larger-brained hominids, who were probably more intelligent, would have been able to respond partially to selective pressures with cultural adaptation. They would have adapted biologically only under pressures that were so severe that they were unable to adapt culturally. As hominids increasingly relied on cultural adaptations, biolog-

ical evolution of the brain would have carried greater adaptive advantage than other aspects of biological fitness. And as hominids became more intelligent their capacity to adapt culturally would have increased, and the necessity to adapt biologically would have diminished. So hominid evolution would have involved a decrease in the relative importance of biological evolution as the relative importance of cultural evolution increased. Above all, the success of hunter-gatherer subsistence lay in its flexibility and cultural adaptability. This permitted a single species, *Homo sapiens*, to occupy most of the earth and adapt to a wide range of habitats, from forests and savannas to deserts and arctic conditions, with a minimum of biological adaptation (Washburn and Lancaster, 1968).

During the evolution of hominid subsistence, natural selection could only bring about adaptations that were of immediate survival value. Evolution does not progress towards some goal in the future. While some earlier adaptations in hominid evolution may have been instrumental in making later adaptation possible, earlier adaptations were not made "for" later adaptations, but for their own sake. So, for example, adaptations such as gathering and systematic scavenging may have been instrumental in making the evolution of hunting possible, but they did not evolve "so that" hunting could evolve. Rather, gathering and systematic scavenging were distinct and successful adaptations in their own right, irrespective of whether hunting would have evolved later or not. At any stage in hominid evolution, hominids were successfully adapted to their particular environments.

If hunting only became an important subsistence strategy relatively late in human evolution, it could not have played a significant role in the enlargement of the hominid brain. And hominids did not evolve large brains "for" hunting (Gould, 1980). Rather, an increasingly complex gatherer-scavenger subsistence involving economic intensification, social organisation, language and technological developments possibly required increasing levels of intelligence to deal with the correspondingly larger amounts of information necessary for survival.

If a trend towards increased hunting coincided with the appearance of fully modern humans, however, one could argue that hunting may have played a significant role in the evolution of the modern intellect. If this were true, then it seems most likely that the most universal hunting methods were involved. Many specialised hunting methods may have been developed only after the appearance of fully modern humans and so would not have played a role in the evolution of the human intellect. Since the art of tracking, however, is one of the most fundamental and universal factors in hunting, the evolution of tracking may have played an important role in the development of hunting.



3

The Evolution of Tracking

In order to reconstruct how tracking may have evolved, we need to distinguish between three levels of tracking: simple, systematic and speculative. Simple tracking may be regarded as following footprints in ideal tracking conditions where the prints are clear and easy to follow. These conditions are found, for example, in soft barren substrate or snow, where footprints are not obscured by vegetation and where there are not many other animal prints to confuse the tracker. Systematic tracking involves the systematic gathering of information from signs, until a detailed indication is built up of what the animal was doing and where it was going (see Chapter 8). It is a more refined form of simple tracking, and requires an ability to recognise and interpret signs in conditions where footprints are not obvious or easy to follow. Speculative tracking involves the creation of a working hypothesis on the basis of the initial interpretation of signs, a knowledge of animal behaviour and a knowledge of the terrain. Having built a hypothetical reconstruction of the animal's activities in their mind, the trackers then look for signs where they expect to find them (see Chapter 8).

Simple and systematic tracking are both based essentially on inductive-deductive reasoning (see Chapter 11), but systematic tracking in difficult tracking conditions requires much greater skill to recognise signs and probably a much higher level of intelligence. Tracking conditions may vary considerably, so that the degree of difficulty may vary gradually from very easy through to very difficult. One cannot make a clear distinction between simple and systematic tracking. The difference lies in the degree of skill, and the skill required for systematic tracking depends on how difficult tracking conditions are. In contrast to simple and systematic tracking, speculative tracking is based on hypothetico-deductive reasoning (see Chapter 11), and involves a fundamentally new way of thinking.

The suggestion that tracking, as practised by recent hunter-gatherers in savanna-woodland conditions, requires above average scientific intellectual abilities (see Chapter 6), implies that it is unlikely that tracking could have originated in a savanna-woodland habitat. It is most likely that tracking evolved in conditions where tracking is easiest. Simple tracking may have developed into systematic tracking in increasingly difficult tracking conditions. Speculative tracking may have developed in very difficult tracking

conditions where systematic tracking became inefficient. Modern trackers practise a combination of systematic and speculative tracking, and the two types of tracking play complementary roles.

Ideal conditions for simple tracking are found in two extreme types of environment, namely arid environments where the ground is sparsely covered with vegetation, and cold environments where simple tracking is possible in snow. For this reason it is unlikely that simple tracking could have been practised before hominids adapted to these marginal habitats. As hominids entered more marginal arid or cold environments, vegetable foods would have been less abundant, and hominids may have had to increase the percentage of meat in their diets. Marginal areas, however, usually contain lower animal population densities and decreasing opportunities for scavenging. Hominids may have had to depend to a greater extent on hunting for subsistence. But conditions for tracking would have been easier and the development of tracking would have greatly increased their hunting success.

In relatively open country with high animal densities, such as savanna grasslands, hominids may have been able to locate animals by scanning an area, and then running them down in plain sight. Using weapons to wound animals would have increased their chances of running them down. Where visibility was limited (owing to hills, dunes or vegetation), and with ideal tracking conditions, hunters could simply have followed the footprints of animals which had run out of sight. As the animal had already been seen and associated with the footprints, this represents the simplest form of tracking, since it does not require any spoor interpretation.

In terrain where visibility was limited with low animal densities, however, hunters would have had very limited success in locating animals by scanning. It would therefore have been necessary to locate animals by means of simple tracking. In such circumstances, the hunter would have needed at least to recognise footprints. Further assets would have included a number of skills. Firstly, the ability to determine the direction of travel would have doubled his chances of success, since he would not have followed the spoor in the wrong direction. The ability to recognise fresh spoor would have given the hunter a reasonable chance of overtaking the animal. An ability to determine the speed of travel, either by the way sand or snow had been kicked up, or by the relative position of footprints, would have enabled hunters to concentrate on the spoor of slow-moving animals. Finally, the ability to recognise the spoor of specific animals may have allowed the hunter to select the spoor of animals that are easiest to run down or that give the greatest amount of meat.

Tracking in Arid Conditions

One biome in which tracking may have originated is in a relatively barren semi-desert or desert environment. Here, ideal tracking conditions would be determined by the substrate, vegetation cover, animal population densities and weather conditions. It is much easier to track in soft, sandy substrate

than in hard, stony substrate. Spoor may not be well defined in soft sand, however, so it may be difficult to identify. Lacking definition, it may also be confused with similar but older spoor, since the colour differences between fresh and old spoor in dry, loose sand may be very subtle. The sparseness of the vegetation cover also determines how easy it is to follow spoor. In semi-desert or desert environments animal population densities are very low, leaving fewer proximate signs to confuse the tracker.

Two kinds of weather conditions play an important role in simple tracking. After wind has obliterated all old spoor, it is much easier to follow the spoor of a particular animal, although that spoor may also be obliterated by the wind. For simple tracking, ideal weather conditions would be a strong wind during the night so that all old spoor is obliterated, leaving only fresh spoor made after the wind has stopped blowing, with no wind blowing while the hunter follows the spoor. In practice the wind may vary throughout the day, sometimes making it easier for the hunter and other times making it more difficult. A very light wind may also obliterate spoor in exposed areas, such as the tops or upwind sides of dunes, while footprints in sheltered areas may be preserved. A trail may therefore be obliterated partially, leaving gaps where the spoor may be lost.

When rain has obliterated old spoor, fresh spoor are easier to follow. Footprints in wet sand are also much clearer than in loose dry sand where footprints may lack definition. It is also much easier to distinguish one set of spoor from another in wet sand. Footprints remain clear much longer in wet sand, even after the sand has dried into a crust. In arid environments it does not rain very often, however, so such opportunities would be limited. After good rains the ground may be covered more densely with grass. Conditions for simple tracking would therefore be more difficult in the rainy season than in the dry season.

A good example of ideal tracking conditions may be found in semi-arid savanna such as in the southern Kalahari dunelands. These dunelands are characterised by long, roughly parallel dunes, sparsely covered with grass, shrubs and scattered trees. There is no natural surface water, and river beds may contain only occasional pools for a few months, weeks or days. In most years the rivers are entirely dry. On average about 10 rainstorms may account for about 150 mm of rainfall each year from February to May (Bannister and Gordon, 1983; Steyn, 1984b). Although there is no surface water for most of the year, animals obtain their moisture requirements from plants. The tsamma melon in particular is an important source of water for animals (Steyn, 1984b).

The most numerous large animal in the southern Kalahari is the gemsbok. The gemsbok prefers to frequent the dunes in the dry season, and goes down to the watercourses when rain falls. Its large size, relative abundance and preference for dunelands may have made the gemsbok one of the most important animals in the development of tracking in semi-arid environments. The sparse vegetation cover and soft sand would have provided ideal tracking conditions. The dunes would have offered limited visibility

for scanning, since a hunter standing on top of a dune would not be able to see animals in the valleys beyond the nearest dunes, so making tracking a necessity.

In general, the most likely environment for the development of tracking would have been an optimum combination of ideal tracking conditions, abundant wildlife, limited visibility which would have made tracking a necessity, and adequate water resources. If tracking evolved in southern Africa, then the semi-arid savanna of the southern Kalahari would have been the most likely place. Other areas in Africa that may have provided similar conditions for simple tracking are eastern Africa and the belt of semi-desert south of the Sahara.

From ideal tracking conditions, one can discover a continuity of increasingly difficult tracking conditions. Tracking becomes less easy as the substrate becomes harder, as the vegetation becomes denser and as the density of animal populations increases (see Chapter 8).

Since tracking conditions may continuously become more and more difficult, the transition from simple tracking in ideal tracking conditions to systematic tracking in difficult tracking conditions may have been very gradual. Such a gradual transition may, however, have occurred over a very long time or a very short time, depending on the selective pressures involved. Such a continuum of increasingly difficult tracking conditions can be seen, for example, when the differences among the southern, central and northern Kalahari are considered. Throughout the Kalahari the substrate is mainly sand, so the main differences are determined by the steadily increasing rainfall from 150 mm per year in the southern Kalahari through to more than 600 mm per year in the northern Kalahari. While the southern Kalahari dunelands are relatively barren, the central Kalahari is characterised by open grasslands alternating with patches of bushes and trees or solitary trees, and the northern Kalahari by savanna-woodland.

While it is easy to follow footprints in barren sand, it becomes increasingly difficult as the grass becomes denser. In grassland it becomes necessary to recognise signs of animals in the way the grass is bent over in the direction of travel. If all other signs have been obliterated by wind or rain, skilled systematic trackers may be able to follow spoor in grass at quite a fast rate, but their progress would be complicated by similar signs of other animals.

As the vegetation becomes denser, systematic tracking becomes less and less effective. In savanna-woodland, visibility is also limited by the vegetation, so hunters become increasingly dependent on their tracking abilities to locate animals. In such conditions systematic tracking may not have been adequate, and speculative tracking may have become a necessity. In woodland, speculative tracking is also more appropriate, since there is a limited number of routes that animals can take through dense bushes, allowing the tracker to anticipate the most likely route taken. Animals are also more inclined to make use of paths among bushes.

Apart from denser vegetation, harder substrate would also have made the transition from systematic to systematic/speculative tracking a necessity.

Only with the development of systematic/speculative tracking may trackers have had a reasonable success rate in difficult tracking conditions, and hunter-gatherers have been able to adapt successfully to a wide range of habitats.

Tracking in snow

Other biomes in which tracking may have originated are taiga and tundra environments, where simple tracking may have been practised in snow. Ideal conditions occur when a thin layer of fine snow — a few centimetres thick and not too wet — lies on a hard level substrate. Footprints are then clear, sharp, and easy to distinguish. In loose snow the edges of tracks usually fall in, obliterating the track. In very thick snow the tracks appear as deep holes which may be difficult to identify. During a thaw, particularly when the sun is shining, a track will quickly become enlarged, since its edges will thaw rapidly (Bang and Dahlstrom, 1972).

The taiga is found in the circumpolar world in the sub-arctic and north temperate zone of Europe, Asia and America. Characterised by long, severe winters with a constant snow cover, the taiga consists of coniferous trees such as pine, fir, spruce and hemlock. During the warmer months a thick layer of needles and dead twigs covers the ground and the presence of this acidic layer coupled with the shade cast by the mature trees, prevents the flourishing of undergrowth in the forests. Only scant herb and shrub layers may be found. Mammals include reindeer, caribou, elk, moose, lynx, snow-shoe hare, wolf, fox, marten, weasel or ermine (Curtis, 1979; Encyclopaedia Britannica, Vol 7, 1963).

Where the climate is too cold and the winters too long for conifers, the taiga grades into the tundra. The tundra forms a continuous belt across northern Europe, Asia and North America, from the northern limit of the taiga to the Polar sea. The tundra is a form of treeless grassland dominated by herbaceous plants, such as grasses, sedges, rushes and heather, with a ground layer of mosses and lichens. The freeze-thaw process of the permafrost, a layer of permanently frozen subsoil, keeps the plants small and stunted. Typical mammals include reindeer, caribou, musk ox, ermine, arctic hare, arctic fox and lemmings (Curtis, 1979; Encyclopaedia Britannica, Vol 7, 1963).

In taiga and tundra environments, opportunities for simple tracking in snow would be limited to the long winters. Since simple tracking would not have been possible during the warmer, snowless months, hunter-gatherers who were unable to practise systematic/speculative tracking on dry ground would have had to rely on vegetable foods, scavenging, and hunting methods that do not require tracking. Meat accumulated during the winter months may also have been dried and stored for the summer months. In the warmer regions, vegetable foods such as nuts, bulbs, roots, seeds, berries and the inner bark of willow trees may have been gathered in summer. In the colder tundra areas, however, gathering would not have played a significant role in subsistence, since there are scarcely any vegetable foods that can be

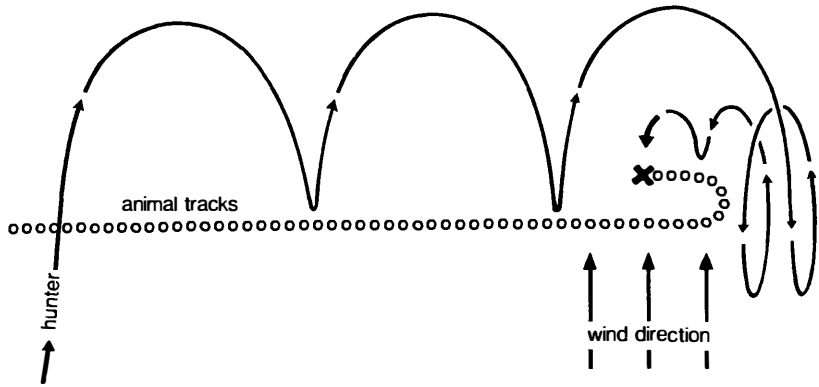
consumed by humans. Scavenging and opportunistic hunting may therefore have played an important role in the summer months. In the taiga forests hunters may have had limited success in locating animals, since visibility would have been limited by the trees, and animals that are faster than hunters could not have been run down, since they would have quickly run out of sight. Opportunistic hunting in the taiga during summer may therefore have been limited to running down fawns, weak or injured animals, or capturing small animals and animals sleeping in burrows. In the open tundra, hunters may have been able to run down animals in summer if they could always keep them in sight. Locating animals by scanning would also have been easier in the open tundra. During the summer months, therefore, hunting may have been easier in the open tundra than in the taiga forests.

During the long cold winters the emphasis may have been on tracking down animals in snow. In the taiga forests, where visibility is limited, animals could be located by tracking. Following footprints in snow would also have enabled hunters to run down animals in forests. The cover provided by trees would have made it easier to stalk and wound animals, so hunting in winter may have been easier in forests than in open tundra. In the open tundra, animals located by scanning could be run down, and on occasions when hunters lost sight of animals, they could simply follow their footprints. In hilly tundra country, visibility may have been limited, so tracking in snow may also have been necessary to locate animals.

In the intergradation between the taiga and tundra biomes, some hunter-gatherers may have been able to take advantage of both types of environments, depending on which provided the best conditions for hunting at different times of the year. During the summer, when there is no snow, persistence hunting may have been easier in the open tundra. In the winter, on the other hand, hunting may have been easier in the taiga forests. It would therefore have been advantageous for nomadic hunter-gatherers to live in the forests during the winter and on the open tundra during the summer. The Lebenstedt site in Germany, for example, indicates that the Neanderthals who lived there occupied the open tundra only during the warmer summer months, and probably retreated into the forest during the winter (Constable, 1973).

Even for recent hunter-gatherers of the northern taiga forests, hunting was best in winter (Coon, 1971). Animals move slowly on account of the snow. This means that locating them by tracking is easier, since they are easier to overtake. Running them down in snow is also easier. Recent hunter-gatherers have been known to run down reindeer over long distances in the spring when the snowcrust conditions make reindeer movement difficult. Hunters wearing snowshoes also trailed animals in heavy snow until they were exhausted (Spies, 1979). The invention of the snowshoe may have played an important role in making hunting in snow more efficient. It is not known when the snowshoe was invented. It may be assumed, however, that hunter-gatherers who inhabited cold regions had clothing, including shoes, to protect them against the cold. It would not require much intelligence

to discover that it is easier to walk in deep snow wearing bigger shoes. Hominids that were intelligent enough to invent clothing and shoes were probably also intelligent enough to invent some form of snowshoe.



Semicircular tracking in snow

A special way of hunting moose in snow was used, for example, by the Kutchin of North America. The hunter knew that the animal followed a certain vegetation zone, feeding in the early morning and late afternoon, and resting at midday. Before stopping to feed or lie down, the moose would double back on its trail on the downwind side, so that it could smell any person or predator following it. Instead of simply following the trail, the hunter would walk in a series of loops downwind of the trail, until he overshot it. He would then walk back in smaller loops, still downwind, and being careful not to make any noise, until he got to within bowshot (Coon, 1971).

In taiga and tundra conditions the transition from simple tracking in snow to systematic and systematic/speculative tracking on dry ground would have been much more abrupt than such a transition in arid conditions, since the same continuity of tracking conditions does not exist. Moving from ideal tracking conditions in snow to tracking on dry ground would have been very difficult, since there would have been no intermediate conditions.

From simple tracking in snow during winter, hunter-gatherers living in taiga forests may have developed systematic tracking in the thick layer of pine needles that covered the ground in the summer. At first glance, tracking in pine needles appears to be very difficult. Where an animal is moving slowly on a level surface, for example, no clear footprints may be perceptible. When the animal moves faster or on a slope, however, its hoofs may slip on the pine needles, pushing the pine needles forward. Where the pine needles have been pushed forward, the fresh spoor is visible as a dark hollow as the darker coloured needles underneath the surface needles are exposed, and by the shade of the hollow itself. Sometimes, when the needles are removed, a clear footprint may be revealed in the sand below

the needles. Tracking is easiest when the animal has been running in a thick layer of needles, as its feet dig into the needles and leave hollows that are easily recognised. This may have enabled skilled systematic trackers to run down animals. When moving from one locality to another, animals usually use paths. In these paths, the ground is often exposed in patches, where spoor can easily be identified. Paths may therefore have enabled systematic trackers to locate animals in forests. If hunters were able to develop a high level of skill in systematic tracking, they may have developed systematic/speculative tracking in more difficult tracking conditions.

Hunters who had been practising simple tracking in snow on the open tundra, may have been able to develop systematic tracking in grasslands during the summer. Tracking conditions may have varied considerably depending on the vegetation. Systematic tracking is, for example, relatively easy in long, straight grass, but very difficult in short, curly grass. If hunters were able to develop systematic tracking in grassland, they may have developed systematic/speculative tracking in more difficult tracking conditions, such as light woodlands to increasingly dense woodland vegetation.

It is also possible that the transition from simple tracking in snow to systematic/speculative tracking on dry ground may have been too abrupt. Hunters who had been practising simple tracking during the long, severe taiga and tundra winters may not have been able to develop systematic, speculative tracking during the summers. If so, then tracking may well have evolved in arid conditions, rather than cold conditions. Both possibilities, however, are plausible.

The Origin of Tracking

Simple tracking could not have been developed before hominids adapted to marginal arid or cold environments. It is therefore unlikely that early hominids developed the art of tracking. Some *Homo erectus* populations which inhabited marginal habitats, may have had the opportunity to develop simple tracking. They may have had limited success, however, and even if the opportunity to develop simple tracking arose, they did not necessarily develop systematic or systematic/speculative tracking.

It is very likely that some archaic *Homo sapiens* populations, which inhabited marginal arid or cold regions, developed at least simple tracking. It is also possible that they may have developed some degree of skill in systematic tracking. Some may have become dependent on simple or simple/systematic tracking for their survival, so that a change to more difficult tracking conditions may have provided strong selective pressure for the transition from simple/systematic tracking to systematic/speculative tracking. For selective pressures for speculative tracking to have been strong enough for the transition to occur, systematic tracking in difficult tracking conditions could not have been efficient enough for survival. A low success rate of systematic tracking may have supplemented simple tracking in ideal conditions. In difficult tracking conditions, systematic/speculative tracking may have become a necessity for survival.

Ideal tracking conditions and subsequent changes to difficult tracking conditions may have been caused by climatic changes. During the last glacial maximum, most low-latitude regions were relatively dry. The rainfall decreased, so that what had been savanna country dried up into near-desert. The semi-arid fringe areas around many deserts expanded. The rain forests of the tropics were reduced to isolated refugia, and some parts where there were forests, became active sand deserts. The conditions known for the last glacial maximum may tentatively be used as a model for previous glacial maxima for which conditions are not known (Constable, 1973; Roberts, 1984). In Europe the boreal, mixed deciduous and Mediterranean woodlands were reduced to isolated southern refugia during glacial stages, and replaced by steppic and tundra-like associations. In East Asia the forest belts were displaced southwards (Roberts, 1984).

During glacial maxima ideal tracking conditions may have existed in both the more extensive arid low-latitude regions and the cold high-latitude regions. During the warmer interglacials, the arid low-latitude regions may have been reduced, forcing hunter-gatherers to adapt to higher rainfall conditions. A change from semi-desert conditions to savanna grassland and woodland conditions may have been instrumental in the development of simple tracking into systematic/speculative tracking. In the cold high-latitude regions, the warmer interglacials would have been characterised by shorter winters and longer summers. As the winters became shorter, simple tracking in snow would have been possible for shorter periods, so that hunter-gatherers may have become increasingly dependent on systematic and systematic/speculative tracking. At the same time the open tundra would have been replaced by forest and woodland, resulting in increased dependence on tracking.

In order to consider the possible archaeological recognition of the evolution of tracking, one must first examine the archaeological distinction of scavenging and hunting. The much more rapid and thorough consumption by initial consumers of young as compared to adult individuals, results in the predominant availability of adults to scavengers. Furthermore, only the young of particularly large species are likely to survive initial consumption frequently enough to be a component of a scavenger diet. A scavenger will also rarely encounter edible tissues remaining on carcasses of small species and, owing to the greater abundance of medium-sized adults over larger species, will derive the most regular scavenging opportunities from medium-sized adult carcasses. Archaeological faunal assemblages accumulated through scavenging should therefore be characterised by a predominance of adults over younger individuals, with most young being those of large species, and a predominance of medium-sized adult and larger carcasses over those of smaller carcasses (Blumenschine, 1986a).

The sequence in which carcass parts are consumed by modern non-human carnivores may also form the basis for distinguishing archaeological assemblages accumulated though hunting or scavenging. This sequence proceeds from the hindquarter flesh, to the rib-cage and forequarter flesh,

to the head flesh, to the hind limb marrow, to the forelimb marrow, and lastly, to the head contents. Bone assemblages accumulated by scavenging should therefore be increasingly represented by skeletal parts that are eaten from by initial consumers in progressively later stages of the consumption sequence. Assemblages accumulated by hunting should show a more complete series of body parts, and particularly one biased towards those higher yielding parts that are typically consumed in the earlier stages of the sequence (Blumenschine, 1986b).

Another characteristic of bone assemblages accumulated through scavenging relates to the skeletal distribution of defleshing cut marks inflicted by hominids using stone tools. A high proportion of cut marks should occur on head and lower limb bones, with increasingly lower frequencies being found on parts defleshed progressively earlier in the consumption sequence. Smaller species should also be represented by a greater predominance of latterly consumed skeletal parts, and displaying defleshing cut marks on a more limited series of body parts than larger species (Blumenschine, 1986a).

If the art of tracking originated in arid conditions and developed in savanna grassland and woodland, then this may be indicated in the archaeological record by the species of animals hunted. Simple tracking may be represented by species adapted to arid conditions, such as gemsbok, red hartebeest and springbok. Systematic tracking may be represented mainly by grassland species in areas where the substrate is soft. Systematic/speculative tracking may be represented by grassland species together with woodland species. Speculative tracking may therefore be indicated by the inclusion of woodland species, such as kudu, that may not have been hunted by means of systematic tracking. Systematic/speculative tracking may also be indicated by hunting in areas of hard substrate where systematic tracking may have been too difficult.

It has been suggested that faunal remains from Klasies River Mouth Caves indicate that during the Middle Stone Age the exploitation of cover-loving, medium-sized animals was part of a scavenging strategy, whereas the exploitation of grassland antelope was a component of a hunting strategy. Towards the end of the Middle Stone Age there was a trend towards increased hunting and a more marginal role for scavenging. During the Late Stone Age there was an increase in the hunting and/or trapping of cover-loving animals (Binford, 1984). If this interpretation is correct it is possible that the increase in hunting of grassland species may represent the development of systematic tracking during the Middle Stone Age in southern Africa, while the increase in hunting of cover-loving animals may indicate the development of systematic/speculative tracking in the Late Stone Age.

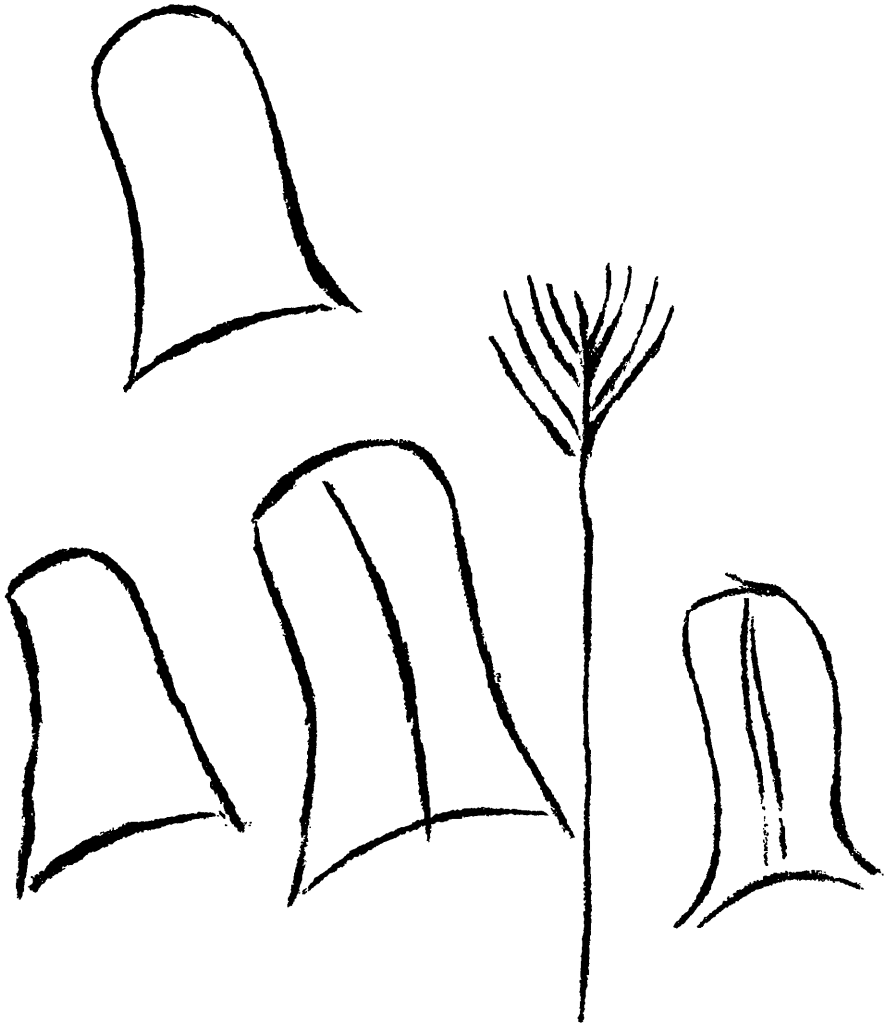
If the art of tracking originated in cold environments, then simple tracking may be indicated in the archaeological record by the remains of animals hunted in winter, while animals were mainly scavenged in summer. The transition to systematic/speculative tracking may be indicated by an increase in hunting and a decrease in the relative importance of scavenging during summer. It is possible that tracking may have originated in both arid and

cold environments, and that systematic/speculative tracking may have developed independently in different regions through parallel evolution. The environments to which the various populations adapted were so different, however, and the possible genetic solutions to problems of adaptation so numerous, that it would have been extremely unlikely that the same genetic results would be reached independently (Bodmer and Cavalli–Sforza, 1976).

It is also possible that simple tracking may have been developed in both arid and cold environments, but that the transition to systematic/speculative tracking may have occurred in only one of the two alternatives.

If the transition from simple tracking in snow to systematic/speculative tracking on dry ground was too abrupt, then hunters in cold environments may not have been able to adapt to warmer conditions. The Neanderthals, for example, may have been successful hunters in the cold winters, while relying on plant foods and scavenging in the summers. While food from hunting may have been relatively abundant during the long winters, the short summers may have been lean periods supplemented only by dried meats. The extremely cold conditions in Europe were interrupted by a sudden climatic change, reaching a thermal maximum between about 44 000 and 42 000 B.P. when summer temperatures were higher than that of the present day (Scott, 1984). This may have contributed to the decline in the Neanderthal population. They may not have been able to adapt to tracking on dry ground during the long summers, and only small pockets may have survived in cold regions. In the warmer areas where they may only have survived in small populations, systematic/speculative trackers from Africa may have replaced them. The Neanderthals were adapted to cold conditions, and the distinctiveness of early a.m. *Homo sapiens* limb proportions may suggest gene flow or population movement from warmer environments at the transition to a.m. *Homo sapiens* in Eurasia (Stringer, 1984). It is therefore possible that systematic/speculative trackers may have evolved in Africa, rather than Eurasia.

It has been argued that simple tracking may perhaps have been practised by some *Homo erectus* populations and most likely by at least some archaic *Homo sapiens* populations. By the time a.m. *Homo sapiens* appeared, it is possible that some hunters were highly skilled systematic trackers. The suggestion that modern tracking, as practised by recent hunter-gatherers, requires above average scientific intellectual abilities also implies that it is unlikely that such abilities developed before the evolution of the modern intellect. Once the modern brain evolved, hunters would have had the potential to develop modern tracking. Modern tracking may have been developed only some time after the modern brain evolved. If hunters were already practising simple and/or systematic tracking, it would be surprising if they did not develop speculative tracking as soon as they had the ability. If speculative tracking developed at the same time that the modern brain evolved, then selective pressures for modern tracking may have been at least partially responsible for the evolution of the modern brain.



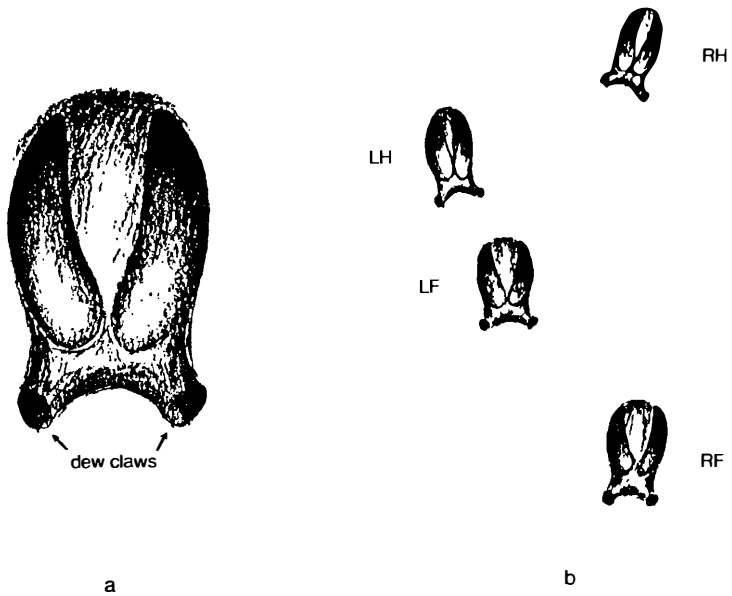
4

The Origin of Science and Art

It seems unlikely that the modern human brain evolved before the appearance of a.m. *Homo sapiens* and although a modern brain may have evolved with the appearance of a.m. *Homo sapiens*, a modern cranium does not necessarily imply a modern intellect. Indeed, the modern intellect may only have evolved some time after a.m. *Homo sapiens* appeared. Modern tracking had probably not been developed before the evolution of the modern intellect. Although this development may have occurred later, evidence for the existence of a modern intellect may indicate that the *potential* for developing modern tracking was also present.

To discover the earliest evidence of tracking we must examine the animal footprints depicted in prehistoric cave art. One useful example is an early Magdalenian painting in the cave of El Castillo, north-west Spain, depicting bell-shaped figures in reddish-brown paint (see illustration opposite this page, after Marshack, 1972; Prideaux, 1973). These figures (which have been interpreted by Andre Leroi–Gourhan as stylised female sex organs), closely resemble ungulate hoofprints in soft substrate (see illustration A on page 42). The points at the back of the footprints reproduce the impression created by the dew claws when the animal's feet sink into soft mud or snow. The forefeet are usually larger than the hind feet, and in soft substrate the forefeet appear also more splayed than the hind. The lines down the middle of the middle and lower right footprints may indicate that they are more splayed than the other two. If this is so, the middle footprint would represent that of the left forefoot, and the lower right footprint that of the right forefoot. The extreme left footprint would then represent that of the left hind foot, and the uppermost footprint that of the right hind foot. Taken as a whole this track group closely resembles that of a jumping animal (see illustration B on page 42, after Bang and Dahlstrom, 1972). The footfall sequence is first the right fore followed by the left fore, and then the left hind followed by the right hind. For large, heavy animals jumping is a very exhausting method of locomotion and almost only used in very soft substrate, such as soft mud or deep snow, or to clear obstacles (Bang and Dahlstrom, 1972). What the reddish-brown colour of the figures suggests is that they may represent footprints in soft mud or wet sand, rather than snow.

What is remarkable about this painting is the artist's attention to detail and his/her ability to provide a meaningful interpretation of spoor. If the



A. Hoofprint in soft substrate
B. Jumping gait

figures do indeed represent footprints in soft mud rather than snow, we can surmise that the artist-hunter did not merely practise simple tracking but was capable at least of systematic tracking, and possibly speculative tracking. The jumping gait in soft substrate may have a special significance: hunters may perhaps have driven animals into soft mud to exhaust them. That the hunter was an artist is surely indicative that s/he possessed a creative imagination and may have had the intellectual abilities to be a modern systematic/speculative tracker.

From the evidence of Upper Palaeolithic art it would appear that the intellectual abilities used in art were far higher than those required for subsistence. An indication of advanced intellectual abilities is also given by evidence of notation, such as notches grouped according to the phases of the lunar cycle. According to Darwinian theory, species evolve in order to become more successful in their adaptive strategy. This raises the question of what would have been the adaptive value of art if it apparently required an intellect far higher than was necessary for subsistence (Marshack, 1972; Marshack, as quoted in Lewin, 1979). I would suggest that the apparent paradox may be resolved if it can be shown that art played an important role in subsistence and therefore had adaptive value. Furthermore, it needs to be shown that the intellectual abilities evident from Upper Palaeolithic art were necessary for survival.

Prehistoric art has been variously interpreted as a medium of hunting magic, or as part of sacred rituals or initiation ceremonies Paintings have

also been interpreted as symbolising male and female images, reflecting a fundamental division in the world, or as representing social relations within bands and between them. Since there are many possibilities, the true symbolic meaning of prehistoric art, if any, may never be known (Leakey, 1981).

If we consider the very nature of creativity, it is unlikely that a single explanation can account for all the reasons why art was practised. Rather, art was probably used in many ways and developed for a multitude of reasons. Indeed, one can argue that the adaptive value of art may well reside in the fact that the aesthetic pleasure derived from it is not merely a function of the transmission of useful information. The aesthetic pleasure has a quality which makes people enjoy it repeatedly. Information is therefore not related in a manner that would be dull and boring. The adaptive value of art can best be illustrated by the role storytelling plays in hunter-gatherer subsistence.

Hunter-gatherers share their knowledge and experience with each other in storytelling around the campfire. Although this seems to involve relatively little direct transmission of information or formal teaching, much knowledge is gained *indirectly* in a relaxed social context. Hunter-gatherers take great delight in lengthy, detailed and very gripping narrations of events they have experienced, with non-verbal expression used to dramatise their stories. Artistic expression is involved in relating events in an entertaining way, thereby ensuring a continuous flow of information. Storytelling in this way acts as a medium for the shared group knowledge of a band (Blurton Jones and Konner, 1976; Biesele, 1983; see Chapter 6).

The art of storytelling is enjoyed by all individuals irrespective of whether potentially useful information may or may not be of use to anyone subsequently. For some individuals a particular story may be enjoyed even if the information transmitted is of no use to them. For other individuals a story may incidentally have potential usefulness, since some of the information transmitted may be useful at a later stage when the listeners find themselves in circumstances similar to that experienced by the storyteller. Storytelling therefore owes its effectiveness as a medium for the shared group knowledge to the fact that it provides aesthetic pleasure irrespective of whether or not the information transmitted may be useful.

Not only may art have played some role in transmitting scientific information in hunter-gatherer societies, there also seems to be a correspondence between the intellectual processes involved in science and in art.

The aesthetic appreciation in art combines an element of empathy. When one contemplates a work of art, one projects oneself into the form of the work of art, and one's feelings are determined by what is found there (Read, 1968). In the process one may in a sense identify with the artist (Fry, 1920). Empathy in art, I would argue, corresponds to the element of anthropomorphism in science and in particular in the art of tracking (see Chapter 11). If this correspondence indicates a fundamental similarity in the creative processes in both science and art, then archaeological records of

art may provide indirect evidence of the scientific abilities of prehistoric humans.

Indications of an anthropomorphic way of thinking are also found in Upper Palaeolithic art. Some figures, for example, appear to be half-human, half-animal. Although these figures may simply depict hunters wearing animal disguises, it is conceivable that the artists may have attached some symbolic significance to it. Perhaps such depictions symbolise the way trackers identified themselves with their quarry.

Turning to the possible origins of science, it is necessary to distinguish between knowledge based on inductive-deductive reasoning and creative science based on hypothetico-deductive reasoning (see Chapter 11). In hunter-gatherer subsistence, the two most important domains of natural science are those of plant life and animal life.

Gathering plant foods requires much knowledge, but involves little skill once specimens are located, because the immobility of plants reduces the number of variables involved (Silberbauer, 1981). Although a great amount of knowledge is required for gathering plant foods, it is relatively easy to learn and to apply. Hunter-gatherers themselves regard gathering as a monotonous activity (Marshall, 1976b). The transition from foraging to gathering probably involved mainly sociological and to a lesser extent, technological, adaptations. It may not have required a fundamental change in the nature of the knowledge of plants.

Knowledge of edible plants may be gained by means of a trial-and-error accumulation of knowledge based on inductive-deductive reasoning. Knowledge acquired in this way can then be passed on from one generation to the next. Food-gathering does not require imaginative theories to explain plant life or to predict novel facts based on hypothetico-deductive reasoning. It is not possible for a food-gatherer to predict, for example, whether an unknown plant is edible or not, or which plants can be expected in unknown plant communities. Predictions as to where to look for plant foods are based on experience, and are therefore essentially inductive-deductive.

While plant life is relatively static, animal life is dynamic, involving a multitude of variables that are continuously changing. Animals are not only highly mobile, living in complex communities, but are also capable of actively avoiding hunters. Apart from involving knowledge based on direct observation of animal behaviour, both simple and systematic tracking also involve knowledge founded on the recognition of signs and the association of particular signs with specific animals and their observed behaviour. Since such knowledge is derived from direct observation and association, it is essentially based on inductive-deductive reasoning. The reasoning processes involved in simple and systematic tracking probably do not differ fundamentally from those used by predators who track down their quarry by following a scent trail. The main difference is that, while other predators rely on their sense of smell to follow scent, human simple/systematic trackers must rely mainly on sight to detect signs that are often very complex and sparse. The greater complexity of signs may require more extensive

knowledge to interpret, but the mental processes involved may well be the same.

The transition from simple/systematic to modern systematic/speculative tracking, however, may have involved a fundamentally new way of thinking. Apart from information based on direct observations and recognition of signs, speculative tracking also requires the interpretation of signs in terms of creative hypotheses. The modern tracker creates imaginative reconstructions to explain what the animals were doing, and on this basis makes novel predictions in unique circumstances. Speculative tracking involves a continuous process of conjecture and refutation to deal with complex, dynamic, ever-changing variables. Modern tracking not only requires inductive-deductive reasoning, but also creative hypothetico-deductive reasoning.

As far as written records are concerned, the critical or rationalist tradition of science can be traced back to the early Greek philosophic schools. Characteristic features of the scientific attitude are freedom of thought, critical debate and rational discussion. Thales, the founder of the Ionian school, seems to have created the tradition that one ought to tolerate criticism. Historically, the Ionian school was the first in which pupils criticised their masters, in one generation after the other (Popper, 1963). The critical attitude of contemporary Kalahari Desert trackers, and the role of critical discussion in tracking (see Chapter 6), suggest, however, that the rationalist tradition of science may well have been practised by hunter-gatherers long before the Greek philosophic schools were founded.

It was once assumed not only that rational science originated with the Greek philosophic schools, but that the belief systems of prehistoric hunter-gatherers were dominated by superstitions and irrational beliefs. Hunter-gatherers were believed to have acted on the basis of exceedingly limited information, much of that information being wrong (see, for example, Popper, 1963; Washburn, 1978). These assumptions led to an apparent paradox in understanding human evolution: the brain evolved both in size and in neurological complexity over some millions of years. A fully modern brain had evolved at a time when all humans were hunter-gatherers. Yet the same brain that has been adapted for the needs of hunter-gatherer subsistence, today deals with the subtleties of modern mathematics and physics (Washburn, 1978).

This apparent paradox may be resolved if it is assumed that at least some of the first fully modern* hunter-gatherers were capable of a scientific approach, and that the intellectual requirements of modern* science were, at least among the most intelligent members of hunter-gatherer bands, a necessity for the survival of modern* hunter-gatherer societies. The first creative science, practised by possibly some of the earliest members of a.m. *Homo sapiens* who had modern* intellects, may have been the art of tracking. In-

* With "modern hunter-gatherers" and "modern intellects", the term "modern" is used in the archaeological sense of the word. With "modern science" and "modern physics" the term "modern" refers to science and physics practised in the twentieth century.

deed, the art of tracking is a science that requires fundamentally the same intellectual abilities as modern* physics (see Chapter 11). Since mathematics, which may be regarded as quasi-empirical, involves essentially the same intellectual processes as science (Lakatos, 1978b), the intellectual requirements of tracking are therefore also those that are required for mathematics.

In this view, tracking represents science in its most basic form. As a collective research programme of a relatively small number of interacting individuals (see Chapter 11), the art of tracking would not have been as sophisticated as the accumulated corpus of modern physics, since modern physics is the result of the collective efforts of a large number of some of the world's best intellects and has been developed over a long period of time. Yet the human brain has probably not changed significantly since the appearance of modern hunter-gatherers: some trackers in the past probably were, and perhaps today are, just as ingenious as the most ingenious modern mathematicians and physicists.

For a hunter-gatherer population to have survived, it would not have been necessary for all hunters to be good trackers (see Chapter 6). As long as about half the hunters were reasonably good trackers, of which some were excellent trackers, the population as a whole would have survived. A very small percentage of trackers may have had the scientific ingenuity equivalent to that of the best of modern scientists. This small percentage of excellent trackers would have made a significant contribution to the collective research programmes of the communities as a whole, in the same way that a small percentage of modern scientists makes the most valuable contribution to modern science (see Chapter 11).

In principle, there is no limit to the degree of sophistication to which a particularly ingenious individual could develop the art of tracking. In practice, however, the tracker's knowledge is limited by his her own observations of nature and the information transmitted through oral tradition. In contrast the modern scientist has relatively easy access to a greater body of knowledge available in libraries, uses sophisticated instruments to make highly accurate observations, or computers to make complex calculations, and participates in scientific research programmes that involve the collective efforts of large numbers of scientists who individually specialise in different fields of study.

I would argue that the differences between the art of tracking and modern science are mainly technological and sociological. Fundamentally they involve the same reasoning processes and require the same intellectual abilities. The modern scientist may know much more than the tracker, but he/she does not necessarily understand nature any better than the intelligent hunter-gatherer. What the expert tracker lacks in quantity of knowledge (compared to the modern scientist), he/she may well make up for in subtlety and refinement. The intelligent hunter-gatherer may be just as rational in his/her understanding of nature as the intelligent modern scientist. Conversely, the intelligent modern scientist may be just as irrational as the intelligent hunter-gatherer. One of the paradoxes of progress is that, contrary to expectation,

the growth of our knowledge about nature has not made it easier to reach rational decisions (Stent, 1978).

Perhaps one of the most important intellectual abilities that made the evolution of science and art possible is creativity. Science and art are, however, not the only creative aspects of human culture. As we shall see in the next section, the entire lives of hunter-gatherers in the Kalahari Desert were steeped in creative thinking.

Love, for example, is also a creative activity (Fromm, 1957), and plays a fundamental role in social relations. A characteristic feature of hunter-gatherer societies was the egalitarian sharing of food (see Chapter 5). What was perhaps most significant was that hunters and gatherers did not all contribute the same amount of food. The best hunters contributed much more meat than the poorest hunters (see Chapter 6). Furthermore, women provided more plant foods than men provided meat, except in the higher latitudes (see Chapter 5). This means that the better hunters contributed more meat than they expected to receive in return, while women provided more plant food than the meat they expected to receive in return, especially the women who were married to the less successful hunters. For egalitarian sharing to have been possible, the most successful hunters and gatherers had to have the capacity to give more than they expected to receive in return. The active character of love is primarily giving, not receiving (Fromm, 1957). Love was therefore a necessity in hunter-gatherer subsistence, and may well have originated with the evolution of hunter-gatherer societies.

Furthermore, art not only played an important role in relation to science, but also in relation to social cooperation. Folklore, rock paintings and other expressive forms were integral parts of the communication systems of hunter-gatherers. The visual and verbal arts, which made information-exchange both routine and enjoyable, provided the framework for survival information. The tales and pictures codified positive attitudes towards social arrangements upon which the survival of hunter-gatherer societies depended (Biesele, 1983).

In hunter-gatherer societies there were no clear-cut demarcations between science, art, folklore, myths, religion or social relationships, since all aspects of their culture were integrated into a holistic understanding of nature. The various aspects of their culture were intertwined with one another in a way that made them inseparable. This is in contrast to industrialised societies, in which various aspects of culture are separated into distinct institutions. At universities, for example, students study science, art, literature, sociology or religion in separate departments which have very little to do with each other. And once they are qualified, they follow careers which tend to separate them even more from other disciplines.

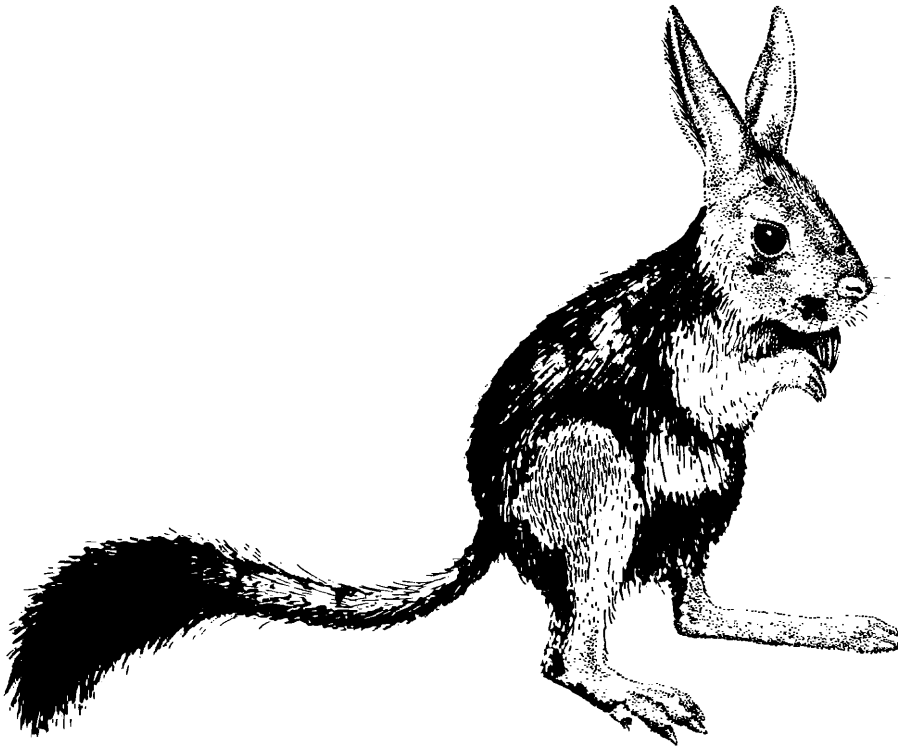
Although one can trace the origins of various aspects of modern industrialised cultures to possibly the first modern hunter-gatherer societies, the original context within which they evolved was probably fundamentally different from their contemporary context. Furthermore, recent hunter-gatherer societies may have differed in fundamental ways from the first modern

hunter-gatherer societies and even more so from hunter-gatherer societies that may perhaps have existed before the evolution of modern humans.

As a result of the hunter-gatherer adaptation, the human mind evolved the abilities to develop a complex language, to socialise, to love, to practise religion, to invent technology and to create science and art. Of the many complex abilities of the human intellect, it is possible that the development of the art of tracking played a significant role in the evolution of the scientific faculty. In this view, creative science (in the form of modern tracking) may have originated at the same time, or soon after the appearance of a.m. *Homo sapiens*. Alternatively creative science may have originated just before or at the same time as the appearance of art. Significantly the earliest evidence of tracking lies in the form of footprints in prehistoric art.

II

Hunter-Gatherers of the Kalahari



5

Hunter-Gatherer Subsistence

In order to place the art of tracking among the Kalahari hunter-gatherers in its traditional context, it is necessary to look at hunter-gatherer subsistence in recent times. Hunter-gatherers were not isolated, static, unchanging societies, but experienced continuous cultural change just as other tribes, chiefdoms and nations did (Wilmsen, 1983). Over the course of centuries, hunter-gatherer bands in different regions developed a wide diversity of material and non-material cultures. In time, some aspects of their culture, such as language, religious beliefs and even their economy, underwent so many changes that hunter-gatherers of southern Africa can not be said to have had an homogeneous culture (Bredekamp, 1986).

About 2 000 years ago some of the hunter-gatherers of southern Africa began to make contact with Khoikhoi pastoralists. The Khoikhoi, who probably developed from Khoisan hunter-gatherer societies in southern Africa, were mainly dependent on a pastoral economy, but were also hunters and food-gatherers. When livestock were depleted by disasters such as drought, disease or theft, Khoikhoi herders reverted to hunting and gathering. Some hunter-gatherers, on the other hand, adopted pastoral economies. A complex process of interaction, intermarriage, acculturation and assimilation occurred over centuries between hunter-gatherers and migrating Khoikhoi herders. Hunter-gatherers were therefore not isolated from the influences of pastoralists (Bredekamp, 1986).

Early Iron Age agropastoralist economies were active in southern Africa, including the Kalahari, for at least the past millennium, and cultural interaction, such as trade networks, would have influenced hunter-gatherers (Wilmsen, 1983). So, for example, iron replaced bone as the primary material for arrowheads and spearheads.

Initially some hunter-gatherers were absorbed by new cultures. As pressures increased, however, the incompatibility of large scale agropastoralism with hunter-gathering economies caused conflict. With the arrival of European settlers at the Cape, conflict became frequent. The use of firearms not only resulted in the depletion of the larger animals, thereby destroying hunter-gatherers' means of subsistence, but also resulted in the virtual extermination of hunter-gatherers in large regions of southern Africa in a war which continued for almost two centuries (Willcox, 1978).

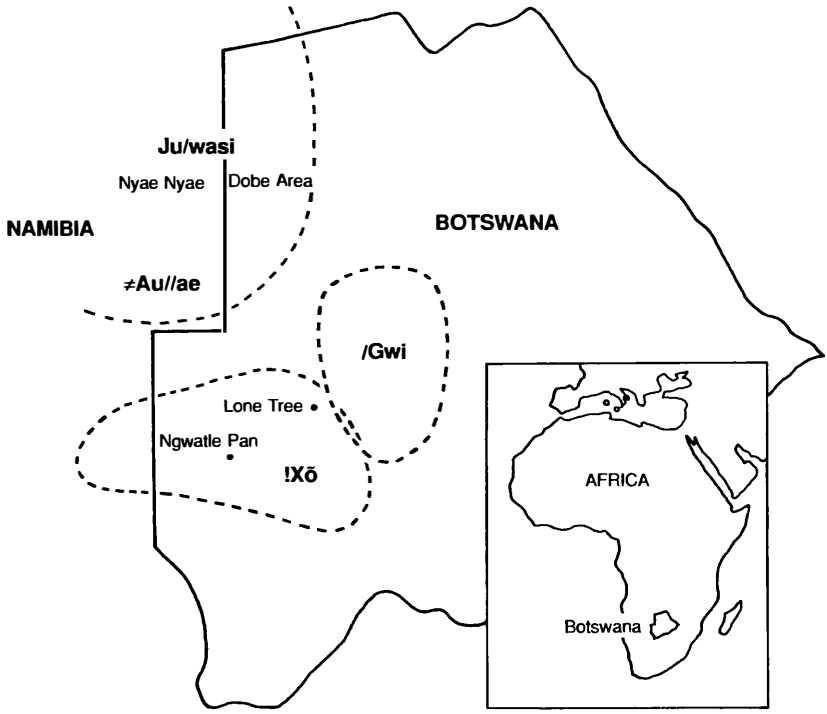
In different regions of southern Africa hunter-gatherers have experienced varying degrees of acculturation, depending on the extent of their contact with other cultures. In the semi-arid regions of the Kalahari, where pastoralism or agriculture were, until recently, not viable, hunter-gatherers experienced relatively little acculturation until a few decades ago. Recently, at a time when they were still primarily dependent on hunting and gathering for their subsistence, Kalahari hunter-gatherers obtained blankets, clothing and cooking utensils from neighbouring pastoralists.

Hunter-gatherer subsistence in the Kalahari discussed in this chapter is based on anthropological fieldwork over a period starting in the 1950's and extending to the 1970's. My own fieldwork, conducted in 1985, was limited to a study of the hunting and tracking practised by two groups of !Xõ hunter-gatherers who still hunt on a regular basis. During the past two decades change has been rapid, particularly due to the influx of pastoralists into their territories, and the close-knit, self-sufficient organisation of band society is gone (Silberbauer, 1981). Although some hunter-gatherers still practise their traditional religion and attitudes to the environment, all have been acculturated to some extent (Campbell, pers. comm. 1985).

Hunting and gathering economies had a local character in that hunter-gatherers adapted themselves quite differently to the different ecological areas of the Kalahari. Ecological adaptation involved specialised knowledge about a given area, and hunter-gatherers who felt secure in their knowledge of their home territory, may not have been able to find food in unknown territory (Biesele, 1971). Hunter-gatherers were opportunists who used the fluctuations in their habitat to their own best advantage. In order to take such advantage, they had to plan their moves, keeping the widest possible range of options open so that they could switch from one course of action to another (Silberbauer, 1981). In the central Kalahari the optimum size of permanent groups of hunter-gatherers was between 50 and 70. In the rainy season food was plentiful enough to support a large group, but in the dry season a /Gwi band had to split up into its constituent nuclear families (Silberbauer, 1965).

For the Ju/wasi of the Dobe area the distribution of water sources was the most important ecological determinant of their subsistence. During the rainy season they lived at temporary pools in the midst of nut forests. Only the most palatable and abundant foods that were the least distance from water were collected. As time went on they had to travel further and further to collect food. They usually occupied a camp for a period of weeks or months and ate their way out of it. During the dry season, groups were based at the permanent waterholes. They would eat out an increasing radius of desirable foods, and as the water-food distance increased, the subsistence effort increased. People either walked longer distances for desirable food or had to be content to eat less desirable foods (Lee, 1969).

Contrary to popular belief the hunter-gathering way of life was not a constant struggle, maintained in the face of adversity, and ending in early death. Specialised knowledge and social co-operation ensured that hunter-



Distribution of language groups in Botswana/Namibia (after Tanaka, 1980; Lee and De Vore, 1976)

gatherer subsistence was reliable and based on known resources. Adult Ju/wasi were able to make a living for the whole band by working on average, two to three days a week. Some days people worked hard, other days they did not work, and some individuals worked more than others. Since the northern Kalahari is marginal habitat, hunter-gatherers in the past (who could have inhabited much more attractive environments) would have had an even more substantial subsistence base (Lee, 1969).

Food gatherers went out in two's and three's and each woman gathered plant foods on her own. A knowledge of the composition of plant communities was used to narrow the search for individual species. Gatherers needed to know their location and their season of availability and had to have the ability to recognise useful species. They avoided stripping an area of a species, leaving a residue so that regeneration was not imperilled. Locally scarce specimens were not exploited even when these were found while gathering other species. While gathering was mainly done by women, men returning from unsuccessful hunts usually gathered food on their way home (Silberbauer, 1981).

In the Dobe area food resources were varied and abundant. 85 plant species and 54 animal species were classified by the Ju/wasi as edible (Lee, 1969). Only 10 species of mammals, however, were regularly hunted for food. Plant foods constituted the greatest component of the diet, while meat constituted a third or less, depending on the time of the year and the fortunes of the hunters (Lee, 1969; Silberbauer, 1981).

In the southern Kalahari hunting may have played a more important subsistence role than in the central and northern Kalahari (Steyn, 1984a). In the central Kalahari, where pools of rainwater are found for only six to eight weeks of the year, plant foods were also the main source of fluids (Silberbauer, 1981).

For the Ju'wasi of the Dobe area, it was found that their food input exceeded the energy requirements by about 165 calories per person per day, which indicates that they did not lead a substandard existence on the edge of starvation as has been commonly supposed. These observations were made during the second year of a severe drought, which seriously dislocated pastoralists and farmers, while the foraging economy of the hunter-gatherers was not seriously affected (Lee, 1969).

Individual ownership was limited to an individual's clothing, a man's weapons and implements and a woman's household goods. As they moved their villages frequently and as all goods had to be carried by the family owning them, non-essential material goods were not accumulated. The band territory and all its assets were not owned individually but communally, by the whole band (Silberbauer, 1965). Generalised reciprocity, which was the norm within local groups, ensured that if there was any food within the band, it was shared out equally by its owner. Meat was shared with all members, including those who never contributed any, along definite lines of sharing. This assured that the owner of the meat would be repaid in kind at a future date when he himself came home empty handed. Thus the resource of sharing was in itself an invaluable asset in a risky environment like the Kalahari (Biesele, 1971). Rains can be so patchy and uneven in the Kalahari that in a given year, while some parts may have normal rainfall, other parts may get no rainfall. In times of food shortages a band could move over to the territory of an allied band. The system of band alliances therefore provided an effective insurance against starvation in lean times (Silberbauer, 1965).

Hunting

In the Kalahari hunting requires great effort and in energy returns, is a less rewarding activity than gathering vegetable foods, which provide the major part of the diet. Nevertheless, the hunt holds a central place in the community and camp life. In storytelling around the campfire at night men give graphic descriptions of hunts of the recent and distant past. Furthermore, animal products may provide essential nutrients that may be lacking in the vegetable diet, and overall provide about 40 per cent of the calories (Lee, 1979).

While hunting is an important activity in hunter-gatherer subsistence, successful hunters, who may naturally be pleased with themselves, are expected to show humility and gentleness. To the Ju/wasi, for example, announcing a kill is a sign of arrogance and is strongly discouraged. Many good hunters also do no hunting at all for weeks or months at a time. After a run of successful hunts a hunter will stop hunting in order to give other men the chance to reciprocate. A hunter's success might be appreciated up to a point, but too much success might draw the envy and resentment of others. One of the contradictions in the communal life of hunter-gatherers is the pressure on the one hand to prove oneself by hunting and to be generous, and the counterpressure on the other against being too successful. To solve this problem, bursts of active hunting are alternated by periods of inactivity "to cool their hearts and make them gentle" (Lee, 1979).

Wild animals are shy and alert. Because of the limitations of their weapons, hunters require a profound knowledge of the behaviour of animals and their environment as well as an outstanding ability to track and stalk. Much of this knowledge can be taught, but the ability to use it can only be gained by long practice and experience (Silberbauer, 1965). To find animals requires all the information on their movements which can be gained from others' observations and the hunter's own interpretation of signs. Women, when out gathering vegetable food, watch for animals and their spoor and report what they have seen when they return to the village. Hunters will spend many hours discussing the habits and movements of animals. Magical information based on divination and dreams may also be used to decide whether to hunt and may give the hunter a feeling of confidence (Lee, 1979). On the basis of information available the hunter decides on a rough strategy for the hunt.

Hunters set out singly or in small hunting parties of two to four men although women have been known to hunt (Heinz, 1978b). It is more advantageous for small parties to search for animals in different directions than for hunters to form larger parties. With more small parties a larger area can be covered, thereby improving the chances of success. Hunting parties are formed freely and voluntarily, and are always changing. Although no one is in command, an informal leadership may develop and parties tend to form around certain good hunters. Hunting parties do not compete against each other, but rather complement one another, and if any party brings in a big animal, the meat will be shared (Marshall, 1976a).

Hunters move at a brisk pace, scanning the ground for signs of animals. Tracks encountered are commented on by means of gesture, indicating the direction and speed of movement, as well as the distance the animal is estimated to have covered since making the tracks. Flicking of the fingers indicates a very fresh trail, and also that the animal may be nearby. Fresh spoor may also be discussed in soft whispers. Taking care not to betray their presence, they will carefully scout the land, sometimes climbing into trees to gain a better view. The hunter's knowledge of the terrain and animal

behaviour, enables him to look for animals where they will most likely be found.

Equipment

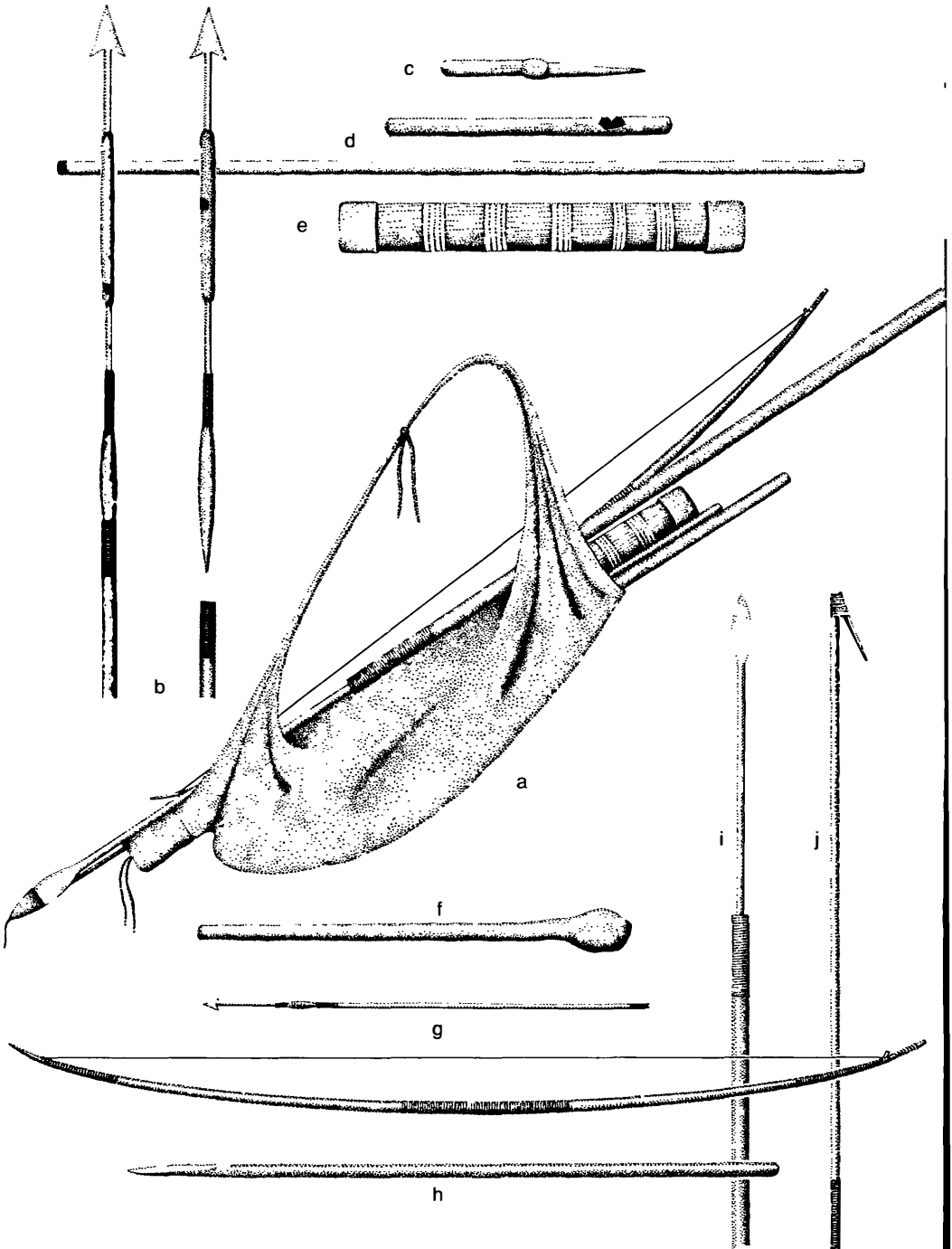
A hunter carries a leather hunting bag, slung over his left shoulder. His bow may be run through slits in the straps of the bag, while loops and a small sheath attached to the bag hold the spear. His poison arrows are carried in a bark quiver sewn into the bag. In the bag he carries a knife, club, snares, a carrying net and a smaller quiver containing a repair kit of spare parts of arrows, lengths of prepared sinew for repairing bowstrings or bindings, gum for fixing bindings and a small supply of poison cocoons. He may also carry with him a spring-hare probe.

The bow is about one metre long and two centimetres in diameter in the middle and tapered to points at both ends. Several woods may be used, but a straight stick of *Grewia flava* is usually chosen. It is strengthened with sinew bindings for approximately 10 cm at both ends and at the grip, which is set slightly below the middle. The bowstring is made from the sinews taken from the back muscle of eland or the long sinews from the legs of big animals, especially giraffe. A short stick or strip of thick leather is bound about 10 cm from the one end. The bowstring is looped around the other end of the bow, led between the stick and bow-stave, wound around several times and fastened with a loop. To tighten the bowstring the windings are twisted and pushed against the stick, which pinches the string to keep it from slipping

When not in use the string is slackened so that the bow retains its spring for as long as possible and so that the string does not break if it shrinks when wet. The string also stretches with use. To stop it from splitting as it dries, the bow is treated with fat, while the string is treated similarly to keep it supple. When tightened, the correct tension of the string is determined by its musical pitch. Although an arrow can be shot beyond 100 m, the effective accurate range is limited to about 25 m.

The arrow, which is about 50 to 60 cm long, consists of four parts: namely the head, sleeve, link-shaft and main shaft. The head may be simple, unbarbed, tapered points made of bone, wood or a porcupine quill, or a barbed point made of metal. Before metal was obtained by trade, barbed points were made of bone. The simple points are used for birds and small animals, and are usually not poisoned, while poisoned barbed points are used for large animals. The sleeve, a short section of reed bound with sinew to prevent it from bursting, fits over the shaft of the arrowhead and over the forward point of the link-shaft. The link-shaft is about 5 cm long and tapered to a point at both ends. One end of the link-shaft is smeared with glue and fitted into the sleeve, which is also glued onto the shaft of the arrowhead. A yellow gum from an acacia tree is used as glue. The other end of the link-shaft is inserted into the main reed shaft without glue.

The connection with the main shaft is firm enough to hold the arrow together in flight, but once the arrow is shot into the animal it will give way



Hunter-gatherer equipment: (a) hunting bag (b) arrow points (c) gum (d) fire sticks (e) repair kit (f) club (g) bow and arrow (h) digging stick (i) spear (j) springhare probe

so that the arrow will not be pulled out as the animal runs through the bush or rubs against a tree or tries to pull it out with its teeth. The poisoned point remains embedded in the animal, giving the poison time to work. The main shaft is made of reed and bound with sinew at the ends. At the back end there is a wooden plug which is notched to receive the bowstring.

To prepare the arrow for poison, the shaft of the arrowhead is wound with sinew which is glued down, since the poison adheres better to the sinew than to the bare shaft. The poison is applied to the shaft of the arrowhead, behind the barbs. To prevent accidents, no poison is applied to the tip itself and the arrows are carried with the heads downwards in the quiver.

A wide variety of poisons have been used in various parts of southern Africa. Some were derived from plants, such as the root of a plant in the asparagus family or the pod of a tree called *!gaowa* (Marshall, 1976a). Poisons were also obtained from snakes such as the puffadder (*Bitis arietans*), horned adder (*Bitis caudalis* or *Bitis cornuta*) and especially the Cape cobra (*Naja nivea*) as well as scorpions and spiders (Steyn, 1984a).

The poison mainly used by the Ju/wasi, /Gwi and !Xõ comes from the larvae of beetles of the Chrysomelidae family and their parasites. One species of *Polyclada*, which feeds on *Sclerocarya caffra* trees, and two species of *Diamphidia*, which feed on the two species of *Commiphora* trees, are used. Their larvae are parasitised by the larvae of a host-specific *Lebistina* beetle belonging to the family Carabidae. The cocoons are found about 50 to 100 cm below the surface of the ground under the tree they feed on (Skaife, 1953). Poison larvae are handled with great care. The poison is deadly if it enters the bloodstream through scratches or cracks on the hunter's hands, and can blind a person if it gets into the eyes (Marshall, 1976a). After poisoning their arrows they wash their hands very carefully. Although highly toxic, it may be taken orally without ill effects (Silberbauer, 1981).

The poison usually takes 6 to 24 hours or more to kill an animal (Lee, 1979). Some animals, such as giraffe and wildebeest, are more resistant to the effects of the poison than are kudu, gemsbok or eland (Silberbauer, 1965). Small animals usually die sooner than larger ones. If the animal is shot in the heart it will die rapidly, while a larger animal wounded in a fleshy part may not die for two or three days (Marshall, 1976a). I have seen a wildebeest, shot with two well-aimed arrows from about 25 m, drop to the ground immediately. Apparently fresh poison also works quicker than old, dehydrated poison.

Natural traps

Several species are killed below the ground in their burrows, or driven from their burrows and killed as they emerge. Animals such as antbears, porcupines and spring-hares are nocturnal and lie up in burrows by day. Hunters examine recently excavated burrows to see if they are occupied. Occupied burrows may also be located by following fresh spoor. Animals like antbears may travel up to 30 km in a night (Smithers, 1983), so the

spoor would have had to be made just before sunrise when the animal was returning to its burrow. The hunter may block off the entrance and dig down to the trapped animal from above. Smoke may also be used to drive the animal from the burrow so that the animal may be killed at close quarters. Animals such as the pangolin, porcupine, caracal, African wild cat and brown hyaena may be driven out by smoke. Some animals, such as the jackal, bat-eared fox and honey badger cannot be driven out with smoke, while the antbear seals off the fire by blocking the burrow with sand, so that it must be dug out. To catch ground squirrels or suricates, the entrance of a burrow is covered with sand and a half-closed hand is pushed into the loose sand. The hunter waits until an animal digs open the hole, then seizes it behind the neck (Steyn, 1984a).

Because spring-hares seldom feed further than 400 m from their burrows (Smithers, 1983), occupied burrows can be located by following up fresh tracks. Tracking spring-hare is not easy, since the tracks are several metres apart and do not follow a straight course. In order to anticipate the distance and direction of the next set of tracks, the tracker must interpret the depth and angle of the imprint, together with the direction in which sand has been thrown (Wannenburgh, 1979). When an occupied warren is located, a spring-hare is caught with a barbed probe which is 4 to 5 m long. The barb is a sharp-pointed steenbok horn bound to one end of the probe. The probe is pushed into the burrow and thrust and pulled until the barb hooks into the spring-hare. The position of the impaled animal is indicated by the length of probe down the hole, and the hunter digs down from above it (Silberbauer, 1981).

Artificial traps and snares

Snaring is used by young boys and older men. Young boys gain experience in studying animal behaviour from the feedback of successful and unsuccessful snaring. Old men use their knowledge and experience, while the demands on their eyesight or physical fitness is minimal (Lee, 1979). The snare consists of a rope, which is spring-loaded by a springy sapling, with a noose and trigger on the ground. When the trigger is released the sapling springs back to tighten the noose.

Success in snaring depends on the hunter's ability to interpret fresh tracks and predict and influence an animal's movements and actions. Snares for steenbok and duiker are set across their paths or in breaks in unobtrusive barriers which have been erected to guide the animals onto the snare. For birds such as guineafowls, francolins, korhaans or bustards, the noose is pegged out around the bait. For each species a specific bait is used, depending on the bird's preference, and the snares are set in their favoured feeding grounds or close to their nests. For ostriches, dehydrated bones are used as bait, using large bones to attract their attention and a small bone set in the trigger mechanism. The snare is set up under a tree bearing their favourite pods.

In earlier times pit traps were also dug (Steyn, 1984a). These were dug in animal paths and covered with grass. A rock painting depicts the use of barriers designed to direct the animals along a route where pit traps had been dug (Woodhouse, 1984). An animal falling into the pit would be impaled on gemsbok horns or sharpened and fire-hardened sticks. Pit-traps were effectively used to trap hippopotamuses when they came out of the water at night to graze. Their habit of using characteristic paths made them very vulnerable to trapping.

Ambush

When hunting from a blind at a waterhole or salt lick, the hunter waits for the prey to come to him. This method was not often used in the Kalahari, as mobile hunting and tracking were much more effective (Lee, 1979).

Co-operative hunts

Several hunters may co-operate to drive animals into an ambush. In the past, animals such as springbok were driven towards waiting hunters. Ostrich feather brushes or wands were planted in the ground. When driven towards the line of brushes the animals were diverted past the waiting hunters who positioned themselves to shoot the passing buck (Bleek and Lloyd, 1911).

A group of hunters may also co-operate to drive animals into natural or artificial traps. In mountainous regions animals were sometimes driven over cliffs to their deaths. Rock paintings in the Drakensberg depict hunting scenes showing eland being driven over a cliff (Woodhouse, 1984). A rock painting in the southern Cape showing a vertical string of buck, nose to tail, may illustrate animals driven over a cliff. It appears that the leading animal is about to crash onto a rock (Willcox, 1984).

Rock paintings in the western Cape have been interpreted as illustrating that net hunting may have been practised in mountainous regions. Nets may have been strung out across narrow kloofs, into which antelope were then driven and caught (Manhire, Parkington and Yates, 1985).

Persistence hunting

Occasionally, small animals may be knocked down with a throwing club and finished off at close quarters, or if the animal is stunned and takes off, it may be run down. Large birds may also be knocked down with throwing clubs. The young of small mammal species are frequently run down on foot and caught by hand (Lee, 1979). Slow-moving animals, such as antbears and porcupines, are easily run down when encountered in open country (Silberbauer, 1981). Animals such as eland, kudu, gemsbok, hartebeest, duiker, steenbok, cheetah, caracal and African wild cat may be run down in the hotter part of the day and killed when they are exhausted. The animal is stalked and startled to make it run while the hunter follows at a steady pace. This process is repeated until the animal is exhausted and can be finished off with a spear or club (Steyn, 1984a).

!Xõ hunters at Lone Tree Borehole, for example, use this method, and concentrate on different species at different times of the year. Steenbok,

duiker and gemsbok are run down in the rainy season, because the wet sand forces open their hoofs, thereby stiffening the joints. Kudu, eland and red hartebeest are run down in the dry season, because they tire more easily on loose sand.

In the early summer, before the rains break, animals are poorly nourished. If a ruminant is prevented from chewing its cud on the chase, it develops indigestion which eventually slows it down. This enables the hunters to come close enough to kill it with spears (Heinz, 1978b).

In woodland, where visibility is limited by the vegetation, the animals may run out of sight and hunters must track them down before they have a chance to get enough rest. When running down a herd of kudu, for example, trackers will look to either side of the trail to see if one of the animals has broken away from the rest of the herd. They will then follow the animal that broke away. When it starts to tire, the weakest animal usually breaks away from the herd, to hide in the bush, while the others continue to flee. (Since a predator will probably follow the scent of the herd, the stronger animals have a better chance of outrunning it, while the weaker animals have a chance to escape unnoticed from where they have hidden themselves.)

The success of this method depends on how quickly the animal can be tracked down. The most important factors are the hunter's tracking abilities and how difficult, or easy, the terrain is for tracking. In the immediate vicinity of Lone Tree Borehole the grass has been heavily overgrazed by cattle and the ground is quite barren, so it is relatively easy to follow spoor in the sand. The woodland, on the other hand, is still adequately vegetated for browsers like kudu. Further away from the borehole, where the ground is less barren, it becomes more difficult to track down animals quickly, while in areas where the ground is hard it would be very difficult to track fast enough to exhaust the animals. In difficult terrain the chances of success are slender unless the animal is weakened by injury, illness, or hunger and thirst.

Hunting with bow and poison arrow

Although it is very difficult to hunt with bow and arrow, it is the most versatile method, since most species, from steenbok to giraffe, can be hunted with it. In some areas of the Kalahari, especially after drought years, animals are so sparse that hunters may search for days before seeing an animal or finding spoor fresh enough to be worth following. In relatively open terrain, hunters may be able to spot animals from quite far, but in woodland, hunters cannot see very far, so they are completely dependent on their tracking abilities to locate animals.

When fresh spoor is found, hunters will estimate its age and how fast the animal was moving to decide whether it is worth following up. In thick bush, where there may be no clear footprints, or on hard ground, where only scuff marks may be evident, trackers may not be able to identify the animal. When this happens they will have to follow the trail, looking for signs such as disturbed vegetation and scuff marks, until clear footprints are

found. They will reconstruct what the animal was doing and predict where it was going.

While following up a fresh lead, hunters will readily abandon it for a better lead, such as the spoor of another animal superimposed on top of the spoor they are following. Signs that the animal was resting may imply that the trail leaving the resting place may be considerably fresher than the trail leading to it. An animal's favoured feeding ground may be indicated by spoor of the same animal from preceding days. Ideally, the quarry should be feeding and moving slowly, so that it is easier for the hunters to catch up from behind.

While feeding antelope may walk a zigzag route from one bush to another, they generally move into the wind. To save time, trackers do not follow the zigzag course of the spoor, but anticipate its general direction by following a straight course, leaving the spoor at times to pick it up further ahead. If several trackers work together as a team, they may spread out so that if one tracker loses the spoor where the animal has suddenly changed direction, another tracker will pick it up and continue. When the spoor is very fresh, all the hunters must be on the down-wind side of the trail, and while one hunter concentrates on tracking, the others will look out for the animal. Using their knowledge of an animal's feeding preferences, hunters will look under trees and bushes where the animal will most likely be feeding. If the wind direction is not favourable, the hunters may have to predict where the animal may be and leave the spoor to approach it from below the wind.

When a herd is sighted, the behaviour of the whole herd is studied. It is important to note whether the animals are wary or nervous, or relaxed and therefore more likely to remain where they are. The position of sentry animals are noted. Herds generally move upwind, so the foremost animals are likely to scent danger from ahead, while the hindmost animals on the downwind side are nearly always wary and difficult to approach. An animal is selected for its size, but other factors are also important. A lame, but not lean, animal will not run as far as a healthy one would after being wounded. Temperament and "personality" are also taken into account when assessing how far an animal is likely to run before succumbing to the poison (Silberbauer, 1965; 1981).

Whether bulls or cows are easier to hunt depends on the species and the time of the year. Kudu and gemsbok bulls are more alert when they are in mixed herds before the cows calve, and therefore more difficult to shoot, but cows run further than bulls when wounded. A hartebeest cow, on the other hand, may only run a short distance when wounded. If the hunters remain undetected, it may stop and stand for a while, giving the hunters a chance to have a second shot (Silberbauer, 1981).

Stalking their quarry from below the wind, hunters first advance crouching, making use of the available cover. In open grassland the hunters must approach the animal in full sight. This is done by making themselves resemble animals, leaning over with their backs almost parallel to the ground and their arms close to their sides (Marshall, 1976a).

In the past, disguises were also used to facilitate stalking. For example, a hunter would use a male ostrich skin with feathers on and a piece of wood for the head and neck, while imitating the "roaring" of a male ostrich. As he approached the ostriches, a male ostrich would charge to chase away the intruder, at which it would be shot with an arrow at close range (Steyn, 1984a). Hunters also use skin disguises to stimulate curiosity behaviour. Curiosity behaviour is characterised by an animal standing motionless, looking towards an advancing or unusual object. In some situations the animal may actually approach the object of attention while maintaining a fixed stare in its direction (Thackeray, 1983).

Hunters do not necessarily have to remain invisible to be unnoticed, as prey animals are apparently only able to recognise humans and other potential dangers by their scent and/or movement and not by their shapes, sizes or colours (Silberbauer, 1981). As the hunter moves forward he watches the animal for any sign of alarm, especially in the movement of its ears. When it raises its head or turns in his direction, he freezes, holding perfectly still until it turns away or drops its head again, at which he moves forward again (Lee, 1979). As the hunters get closer they may sink to all fours, and when very close, wriggle forward on their elbows, to get within the shooting range of about 25 m.

Two hunters may stalk together so that there is a better chance of at least one hitting the target, or if both hit the target, to increase the amount of poison injected. Alternatively, a second hunter may position himself along the animal's probable escape route to shoot it as it runs by. After their first shots, they try to remain unnoticed, for there might be another opportunity to shoot, or if they do not startle the herd, the wounded animal may remain close by.

When the animal has been shot, the hunters study its tracks for future recognition. If it was in a stampeding herd, its spoor may be mingled with others and trampled on. Apart from the characteristics of the individual animal's spoor, it may also be distinguished by the fact that the wounded animal will not walk in the same way as healthy animals do. Blood spoor may also be evident. The arrows are retrieved and accounted for to confirm whether the animal was wounded or not. If all the arrows are found, it was not hit, but if one or more are missing, it may be wounded. If the main shaft of an arrow is found next to the animal's spoor, it may have a deep wound with the detachable arrowhead inside it. The whole arrow may be found intact if it has been worked out of the wound by muscular contraction, but if little poison is left on the fore shaft, most of the poison may already have been absorbed and it may still kill the animal (Lee, 1979).

After making initial observations, the hunters start to follow the spoor to study it in more detail. The animal's speed and direction are determined, as well as its strength, and whether it shows signs of weakening. Blood spoor may indicate how seriously it is wounded, and whether it will die or recover. Signs of the animal milling around and stamping its feet indicate that it is agitated, which is an early symptom of poisoning. Bursts of panic-stricken

running will tire the animal, and the poison will work faster through the system. Well-advanced poisoning is indicated by black blood or blood in the faeces, which will also have a peculiar smell. It is estimated how far the animal will go and when and where it will collapse. Because the poison works slowly at first, only an approximate estimate can be made, but as the animal grows weaker better estimates are possible. The hunters also look for signs of large carnivores in the vicinity, as they may scavenge most of the meat before the hunters reach it (Lee, 1979).

If it is still early in the day, the hunters will continue to follow the spoor, but not too closely, for if they startle the animal it will run faster and further. They stay well back, out of sight and hearing, relying on their interpretation of the spoor. They must, however, follow it closely enough to prevent predators from killing and devouring the weakened animal before they do (Marshall, 1976a; Silberbauer, 1981). If it is late in the afternoon, the men may camp on the trail and resume tracking at first light. If they are close to their village, however, they may spend the night at home and return with helpers in the morning. Although a well-placed shot may kill the animal immediately, the poison usually takes six to 24 hours to work, and may sometimes take up to three days (Lee, 1979; Marshall, 1976a).

Until the animal has been killed, the hunters abstain from food or drink, as they believe it will strengthen the wounded animal (Silberbauer, 1981; Lee, 1979). If the hunt takes very long, they may take some water, at the risk of giving the animal some strength. When I asked some hunters what the most important factor is for successful tracking, they answered that they track best when they are hungry. Perhaps a tracker becomes sluggish when he has eaten too much, giving the animal a better chance to escape and thereby creating the impression that the animal has gained strength.

In the morning the hunters pick up the trail and must try to find the animal before predators or scavengers have stolen the meat. Dogs may be used to track down the wounded animal, but usually hunters do the tracking themselves. When it is clear from the spoor that the animal is very weak, they close in and spear or club it to death. If the animal has died during the night, predators or scavengers may have beaten the hunters to the kill site. Circling vultures may indicate where the animal has died, and if the hunters hurry over to the place marked by the descending vultures, they may still salvage some of the meat.

When hunters find a pride of lions at the carcass, they first study them carefully to determine how hungry they are. If the lions have just started eating, they will not easily be driven off. On the other hand, if they are full and lazy, they may be reluctant to move. Choosing the right psychological moment, the hunters rush at them, shouting and waving their arms to drive the lions off the kill (Silberbauer, 1965; Lee, 1979).

Meat robbing

Lions are sometimes used as a source of meat by robbing their prey. When hunters observe a large number of circling vultures, they run to the point and

drive off the predators. Apart from the above-mentioned technique, grass fires may also be used to drive off predators (Silberbauer, 1965; Tanaka, 1980; Steyn, 1984a).

Hunting with dogs

It is not known when dogs were first used for hunting by hunter-gatherers of the Kalahari, but the first Europeans to encounter them reported the practice, and some rock paintings depict dogs in association with humans (Tanaka, 1980). In the southern Kalahari the gemsbok has been the most important species because of its size, its occurrence in fair numbers and the relative ease with which it could be hunted with the aid of dogs (Steyn, 1984a). Modern hunters of Ngwatle Pan, for example, only hunt with dogs, although they have hunted with bow and arrow in the past.

Hunting with dogs is much more efficient and easier than without dogs, but is limited mainly to gemsbok and small animals like the bat-eared fox. Unlike most antelopes, which flee from dogs, the gemsbok will usually stand and fight. This enables the hunter to kill it while the dogs hold it at bay. It is usually killed with spears, but poison arrows may also be used. While wildebeest, hartebeest, eland and springbok usually flee from dogs, females with young calves can be hunted with dogs, because the mother will stand to defend her calf. Smaller animals like the bat-eared fox are often run down by dogs, but the meat yield is small. In areas where gemsbok are not abundant, hunting with dogs is a complementary method, and more emphasis may be placed on hunting with bow and arrow.

Dogs are only capable of killing relatively small animals by themselves. Since dogs do not instinctively hunt antelope the size of gemsbok, they must be taught to do so. The feet of gemsbok are boiled in water, which is then given to the dogs to drink, so that they learn to associate the scent of gemsbok with food. Young dogs also learn from experienced dogs when they accompany them on hunts.

Even when hunting with dogs, hunters must have a thorough understanding of tracking, animal behaviour and the environment. On the basis of spoor interpretation of animal movements of previous days, the hunters will direct the dogs to bring them within range of the animals. Dogs usually only react to scent and sounds in their immediate vicinity. On their own they are only successful at running down small animals like the bat-eared fox which have been flushed out in front of them. Generally dogs give chase to anything that moves, even springbok that they could never catch. To successfully locate and hunt gemsbok over long distances, the hunters must therefore direct the dogs.

When fresh spoor is encountered the hunters will decide, depending on how long ago the animal was there and how fast it was moving, whether it is worth following up. They may also decide to track down a particular animal, which may be selected for its size, sex or condition, and encourage the dogs to follow its scent. In closed terrain the dogs usually detect gemsbok first, but in open terrain the hunters can see further than the dogs. If the gemsbok

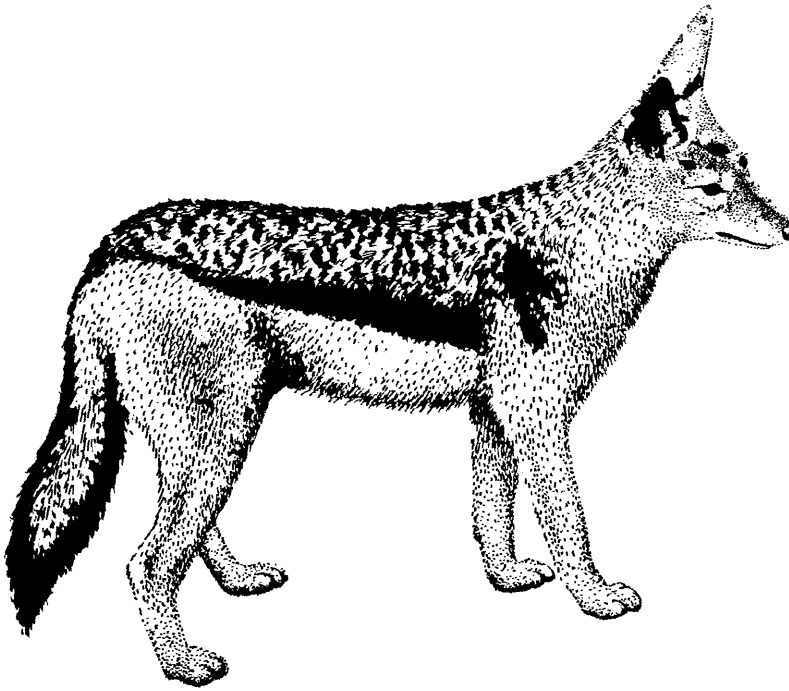
is spotted from a distance, the hunters will keep bushes between them and it to stay out of sight as they approach it, until they are close enough to chase the dogs after it. When the dogs give chase, the way a gemsbok reacts may indicate whether it will stand and fight or flee. If a gemsbok runs fast with its head held high, it will probably flee, but if it runs with its head held low, swinging it from side to side, it will probably stand to fight the dogs. If there are several gemsbok, they may run off in different directions as the dogs run in among them. Depending on each gemsbok's reaction and other factors such as size, sex and condition, the hunters will decide which one to follow.

A gemsbok will not stand and fight in the open, so it has to be followed into denser woody vegetation. When it disappears out of sight, the hunters must track it down, until the dogs can give chase again. In denser vegetation the hunters may not be able to see the gemsbok's reaction to the dogs, but they can tell from its spoor whether it was running fast (in which case the dogs would have probably lost it) or whether it was running more slowly, and the way it was kicking up sand as it was swinging its head from side to side, in which case it might back up into a bush to fight off the dogs.

With its hindquarters protected by a thick bush, a gemsbok can successfully fight off several dogs. While the dogs hold the gemsbok at bay, the hunters stalk it to spear it at short range. To deliver a fatal wound, the hunter must come to within about 10 m of it. To do this the hunter must remain unseen until he can dash in to throw his spear and dash away to avoid the gemsbok's retaliation, as it may kill him if he is not careful.

Hunting from horseback

Rock paintings in the Drakensberg and surrounding districts dating from the middle of the nineteenth century illustrate hunters using horses acquired from immigrant European farmers (Townley Johnson, 1979; Woodhouse, 1984). In recent times hunters of the Kalahari have been hunting increasingly from horseback. The relative ease with which antelope can be hunted from horseback, especially when dogs are also used, has changed hunting dramatically wherever horses have been introduced. Although it is much more efficient, it does not require the skill, expertise and ingenuity required for hunting with the bow and arrow.



6

Scientific Knowledge of Spoor and Animal Behaviour

The learning process

Although they receive very little formal instruction, children of Kalahari hunter-gatherers are exposed to a continuous process of learning in the form of play activities and informal storytelling. From as early as three years old, a boy plays with a little bow of wood and twine with arrows of grass stems, shooting at still targets or dung-beetles and grasshoppers. As he grows older, he will hunt lizards, mice and small birds. By stalking these small animals he studies their behaviour, so that he not only gains experience in stalking but acquires knowledge which he may use later when hunting large animals. Older boys spend much time studying animal tracks. They may follow the spoor of insects, scorpions, and at a later stage small mammals such as mongooses, and reconstruct their feeding patterns and habits. In this way their knowledge and tracking skills are developed through continuous study of all the animals in their environment. Throughout their growing years, children spend many hours listening intently to the conversation of their elders. Much information is also transmitted among the children themselves, from the older to the younger (Heinz, 1978a).

Hunters share their knowledge and experience with each other in storytelling around the campfire, in which hunts and events are described in minute detail. Although there seems to be relatively little direct transmission of information or formal teaching, much knowledge is gained indirectly in a relaxed social context. Knowledge gained informally is assimilated more easily than knowledge gained under direct instruction, to which people generally have an adverse reaction. Hunters take great delight in lengthy, detailed and very gripping narrations of events they have experienced, using non-verbal expression to dramatise their stories. Although they do not take licence with the facts, artistic expression is used to relate events in an entertaining way, thereby ensuring a continuous flow of information. Storytelling therefore acts as a medium for the shared group knowledge of a band (Blurton Jones and Konner, 1976; Biesele, 1983).

When a boy is about 12 years old, he starts to accompany his father, uncles or elder brothers on hunts. By this time he will have gained much

knowledge of animal behaviour through hunting small animals and listening to storytelling. With unpoisoned arrows and a scaled-down bow and quiver, the boy hunts mongooses, genets, hares and large birds. He learns to set snares, thereby developing his ability to interpret spoor and predict the movements of steenbok, duiker and terrestrial birds. He also hunts the young of steenbok, duiker and that of larger antelope.

Ju/wasi hunters maintain that hunting is not something that one teaches, it is something that one just does. You have to teach yourself (Blurton Jones and Konner, 1976). Tracking itself is not something that can be taught directly and much depends on the boy's ability to teach himself. Even when signs are pointed out by an experienced tracker, it is necessary to analyse them carefully and critically in order to understand them. For example, a critical attitude—the basis of scientific enquiry (Popper, 1963)—was demonstrated by a young !Xõ tracker who not only questioned the spoor interpretation of his elder, but also suggested a better interpretation. A !Xõ tracker explained that if a young man does not learn to think for himself his "head will only be half full", that is, he cannot simply be told how to track, he must discover it for himself. It is not just a question of practice and experience, but involves the cultivation of a creative way of thinking. Furthermore, it is not possible for his elders to teach him everything he needs to know, since he must continually acquire new knowledge and solve unique problems in a never-ending process of discovery.

With his first successful killing of a large antelope such as a kudu or gemsbok (which may be at the age of 15 to 18 years), a boy assumes adult status as a hunter. A hunter's career reaches a peak between the ages of 30 to 45. During this time he has an optimum combination of physical fitness, skill, wisdom and experience. Even after his prime his skill and experience grows with age. An old man may work with a young man, often his son, who thus makes the most of the older man's wisdom and experience when they interpret the spoor. The younger man will then do most of the shooting (Lee, 1979).

Mental qualities

Within each age group there is a wide range of hunting abilities from modest to excellent. A study of Ju/wasi hunters has shown that in the younger age groups, from 15 to 38 years old, 95 to 100 per cent of all the kudu kills were made by the better half of the hunters, while in the older age groups, from 39 to 49+ years old, 70 per cent of the kudu kills were made by the better half. Furthermore, in the younger age groups, 70 per cent of all the kudu kills were made by only 17 per cent of the hunters, while almost half the hunters made no kudu kills at all (Lee, 1979).

If above average eyesight or physical fitness were the main factors determining hunting success, one would expect the poorer half of hunters in a particular age group to contribute an even smaller percentage as they grow older. Hunting does not require exceptional physical fitness, and during the course of their normal activities hunters get enough regular walking exer-

cise for any of them to be fit enough to hunt. Although one cannot track with poor eyesight, a tracker does not need exceptional eyesight. It is more important to know what to look for and where to look for it (Lyell, 1929). Excellent eyesight might help in systematic tracking, but it will make no difference in speculative tracking. Skill in stalking and shooting are acquired at a relatively early age and do not improve with age. When a young man accompanies an old man, the young man will do the shooting.

The fact that the better half of hunters made most of the kudu kills may be explained by the hypothesis that tracking, which is intellectually the most demanding aspect of hunting kudu (since it is a woodland species), requires above average scientific intellectual abilities. The difference between the age groups may be because younger trackers must rely more on their own creative abilities, while older trackers can rely more on knowledge gained through their own as well as others' experience. The poorer half of hunters in a particular age group can therefore contribute a larger percentage of the total number of kills as they gain experience with age.

The suggestion that above average scientific intellectual abilities are required for tracking is also consistent with studies of the Hadza of Tanzania. The Hadza also hunted with bow and poison arrows, and relied extensively on tracking down the animal after it was shot. Large animals were killed by a small minority of the adult men. Perhaps as many as half of the adult men failed to kill even one large animal a year, and some men scarcely killed a single large animal during their entire adult lives (Woodburn, 1968).

Mental qualities listed by Ju/wasi hunters as essential in hunting include alertness (*chiho*), sense (*kxai≠n*), knowledge (*chi!ã*) and cleverness (*/xudi*) (Blurton Jones and Konner, 1976). The /Gwi use the word */xudi* for ingenuity, i.e. the ability to devise a novel and effective solution to a problem (Silberbauer, 1981). The art of tracking involves a process of creative problem-solving in which hypotheses are continually tested against spoor evidence, rejecting those which do not stand up and replacing them with better hypotheses. Intuition is important in dealing with complex variables, such as in estimating the age of spoor or interpreting spoor in loose sand. Concentration and memory also play a vital role in tracking.

In dealing with scientific knowledge, hunters are careful to discriminate objective data from theory and interpretation (Blurton Jones and Konner, 1976). Behaviour reconstructed from tracks is regarded with great confidence, but is distinguished from data based on direct observation. A distinction is also made between behaviour actually seen or reconstructed from tracks and behaviour that they think may happen. While hunters admit ignorance very readily, some may give a hypothetical explanation of a phenomenon that is not clearly understood. They also discriminate observed data from what they have heard someone else say they have seen and seem to expect scepticism of each other (Blurton Jones and Konner, 1976). Such scepticism is in fact the hallmark of scientific behaviour (Lakatos, 1978a).

Spoor interpretation

The ability of Kalahari hunter-gatherers to interpret spoor is cultivated over a lifetime and developed to an exceptionally high degree. For example, men and women are able to identify the footprints of an individual person. In order to do this, however, trackers must be familiar with that person's spoor. Although they will be able to tell that a spoor belongs to someone they do not know, they will not be able to identify a stranger by his/her spoor until they have studied it carefully over a period of time. While women usually have smaller and narrower feet than men, the size and shape of each individual's feet differ in subtle ways. Someone with a slender body build has slender feet, while someone who is stocky has shorter and relatively broader feet. A person's spoor is also characterised by the way s/he treads and walks. It may be characterised by the length of stride, the way the ball of the foot is twisted, the way the toes may be pointing inwards or outwards, the way the toes are splayed or curled in, the way the foot throws up sand or characteristic scuff marks. Each person has an individual mannerism when walking which can be identified in his/her spoor. These phenomena enable experienced trackers to identify an individual's spoor even in soft sand where the exact shapes of the feet may not be clear.

The small size of hunter-gatherer bands makes it easier for trackers to identify the spoor of another person. Since the spoor of adults are easily distinguished from those of children, and the spoor of men from those of women, this leaves a relatively small number of similar spoor to differentiate from each other. Furthermore, because each person only knows a relatively small number of individuals, they can get to know each other, including their spoor, much better than would be possible in large communities. In very large communities, such as in villages or cities, it may not be possible to differentiate the very large numbers of similar spoor. It is therefore difficult for city dwellers, especially if they are not familiar with tracking, to understand how it is possible for trackers to identify the spoor of an individual. When I asked a group of !Xõ trackers if they could identify the spoor of individuals, they found it very amusing that I should ask them such a stupid question. To them it is difficult to understand that some people can *not* do it.

!Xõ hunters can identify the spoor of most animal species larger than mongooses, while the spoor of very small animals such as mice, small birds, reptiles and arthropods can be identified as belonging to a member of a group of animals. Even in loose sand, where footprints are not very distinct, the spoor of different mongoose species can be identified and steenbok spoor can be distinguished from duiker spoor. Where I myself was not convinced that a small animal's spoor in loose sand could be identified, they followed the spoor until a neat imprint was found that I could identify to my own satisfaction. In very soft sand, the way the steenbok or duiker treads determines the way the sand falls in. The steenbok treads deeply, with its hoofs pointing down into the sand, while the duiker treads flat-footed. The spoor of diurnal mice are distinguished from the spoor of nocturnal

mice, in that diurnal mice apparently keep to paths while nocturnal mice run everywhere. The spoor of diurnal and nocturnal mice may also be distinguished by an intuitive estimate of the spoor age, which may indicate whether it was made during the day or night.

Their ability to identify spoor goes far beyond their immediate needs in hunting. When I showed a group of !Xõ trackers my spoor illustrations (Liebenberg, 1990), one tracker identified the spoor of a large ant, which one would not expect to be relevant to hunting. They also identified the spoor of many other small animals, such as that of beetles, scorpion, millipede, legless skink and lizards. Among the illustrations of bird spoor, they not only identified the dove spoor, but specifically singled out the Namaqua dove spoor as being that of a Namaqua dove. My spoor illustrations generally caused great excitement, and women and children enthusiastically took part in the discussions. The women seemed just as knowledgeable on spoor as the men and in fact one young woman almost put the men to shame.

Sometimes hunters do make mistakes in identifying spoor of smaller animals. After estimating the age of the spoor of an ostrich, a tracker pointed to a "mouse" footprint superimposed on that of the ostrich spoor to substantiate his claim. Although the details of the little footprint in the soft sand were too indistinct to distinguish, the trail was not that of a mouse, and after studying it more closely, I pointed out to him that it was the spoor of a small bird. When he realised his mistake, he said that he had looked too quickly. He explained that one must not look too quickly at spoor, because you will "see it differently". One must, he maintained, study spoor carefully and think before you make a decision. He was probably so anxious to substantiate his estimate of the age of the ostrich spoor that his mind was prejudiced to "recognise" the small bird spoor as a "mouse spoor" (see Chapter 8).

The sex of an animal is usually distinguished by the size and shape of the footprints. Where males are larger and more massive than females, their spoor are larger and the footprints of the forefeet are relatively broader than those of the females (see Fig. 18). Females apparently also tread more gently than males. !Xõ trackers correctly differentiated the sexes when I showed them my illustrations of kudu spoor, and similarly differentiated my illustrations of lion and leopard spoor. While they seem to be able to determine the sex of large animals from their spoor, they did not always seem to be able to distinguish that of smaller animals such as springbok, steenbok and duiker. They explained that the spoor of the forefeet of female steenbok are broader than those of the male, because female steenbok are more massive than male steenbok. They were not always sure, however, and hunters often differed in their interpretation. It is not always possible to distinguish the sex of smaller animals from their spoor since the differences are very small. The sex of animals is also determined by association (see Chapter 10) or the relative position of urine to the back feet or faeces (see Chapter 9).

The age of a growing animal is indicated by the size of the spoor which increases until the animal reaches adulthood and correlates with the size of

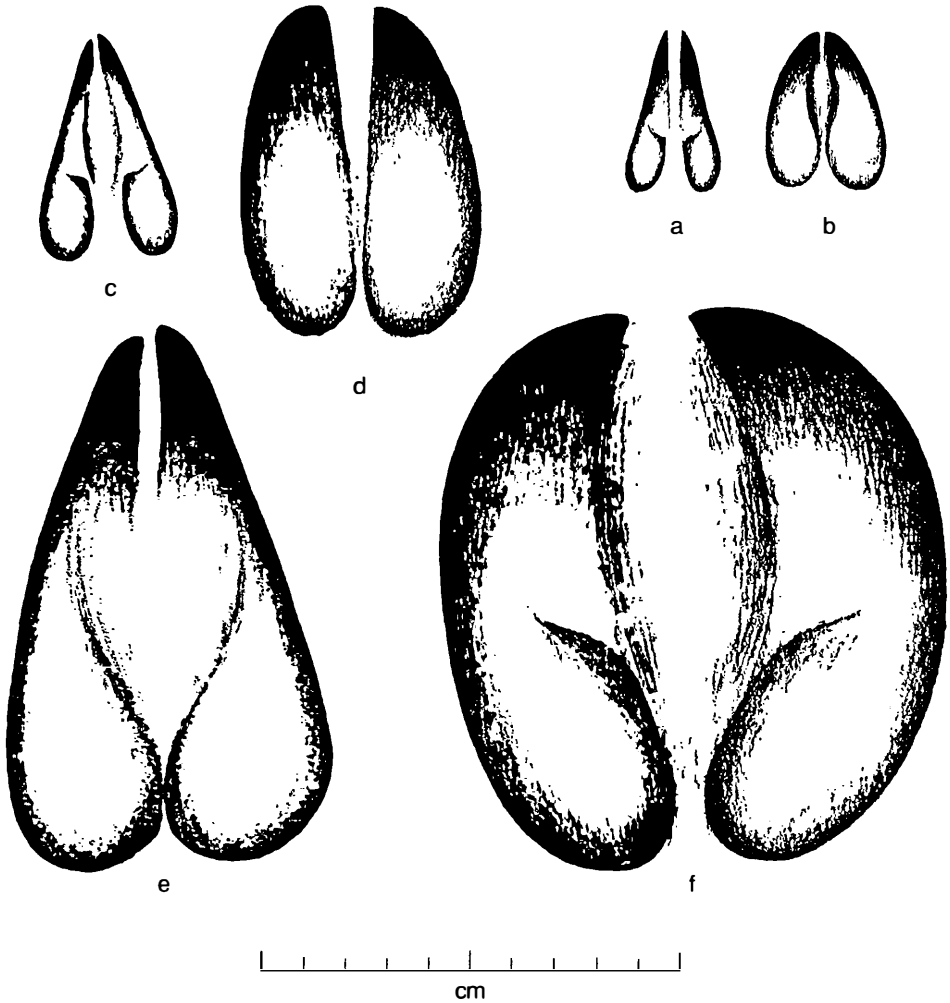
the animal. The edges of the hoofs of young antelope will also be clean and sharp, and the toes may splay out because it treads gently. As an antelope grows older the hoofs become worn and the edges may be chipped. The hoofs of an old antelope may be very worn and blunted with age, and it may show signs of weakness in the way it walks. The condition of an animal is indicated by the way it treads and walks. For example, a healthy, fat animal will tread deeply and firmly, while a weak, lean animal may tread weakly and drag its feet, or show signs of limping.

With regard to large animals such as kudu, gemsbok and eland, hunters can apparently identify the spoor of individual animals in the same way as they identify the spoor of individual persons. Although I have not been able to confirm this, I believe that it is possible. In my own experience of studying animal tracks, I have never found two animals whose footprints are exactly the same. The sizes and shapes of each individual animal's footprints differ in subtle ways. The hoofs of antelope may also be chipped, which would be characteristic of the individual animal. Spoor may also be characterised by the way the animal walks. In the case of smaller animals, such as springbok, it is usually not possible for a hunter to identify the spoor of an individual animal, except when an animal's spoor has an unusual feature. It may sometimes be possible if a hoof is broken, skew or unusually long, or if the animal drags its feet in a characteristic way. The subtle differences in shapes and sizes of each individual animal's spoor are usually too small to be distinguished in smaller animals. Since !Xõ trackers could infer from spoor interpretation that the nocturnal porcupine is monogamous (see p.82), it is clear that they can identify individual porcupines by their spoor. And if they can identify individual porcupines by their spoor, they can probably identify the spoor of individual animals larger than porcupines.

Some people are said to have a "photographic memory" or eidetic imagery. Such people can hold visual images in their short-term memory that are almost photographic in clarity. Studies with children indicate that eidetic imagery is quite rare (in industrialised societies). The existing evidence also indicates that there are even fewer individuals who retain eidetic imagery after adolescence (Atkinson, Atkinson and Hilgard, 1981).

It is possible that through continuous practise since childhood, Kalahari trackers may have a highly developed eidetic imagery. The rarity of eidetic imagery in industrialised societies, particularly after adolescence, may suggest the low importance of such visual imagery in industrialised cultures. The eidetic imagery may simply be lost due to lack of use, or even repressed by our authoritarian modern educational institutions. In contrast, the hunter-gatherer's very survival may have depended on a highly refined eidetic imagery.

While !Xõ trackers have no difficulty in recognising differences in the spoor of different animals, not all of them can explain why they differ as they do. When asked, for example, why the spoor of a steenbok is different from that of a duiker, a standard answer would be: "Because that



The right fore spoor of (a) steenbok (b) duiker (c) springbok (d) kudu (e) gemsbok (f) eland

is how God made them". However, some trackers are able to give very good explanations of general characteristics of spoor.

One !Xõ tracker pointed out that the spoor of steenbok, springbok and gemsbok are the same, i.e. the animals all have sharp, pointed hoofs, while the spoor of duiker, kudu and eland are the same, i.e. the animals all have rounded hoofs (see illustration above). He also explained why some antelope have sharp. pointed hoofs while others have rounded hoofs. In order to escape danger, the steenbok, like the springbok, must run very fast over the open plains. (Steenbok and springbok are species which inhabit

open country.) Their sharp, pointed hoofs tread deeply, pointing down into the sand, to obtain a good grip. The steenbok, he said, runs faster than the duiker, while the springbok runs faster than the kudu. The duiker and the kudu cannot run fast because they have heavy bodies, relative to their sizes. Their hoofs are more rounded for agility and they tread flat-footed to support their weight. They keep to thick bush and to escape danger, they run a zigzag course through the bushes and then hide themselves. (Duiker and kudu are woodland species and do not occur in open grassland.) The duiker and kudu, he maintained, run "cunningly" to escape their enemies.

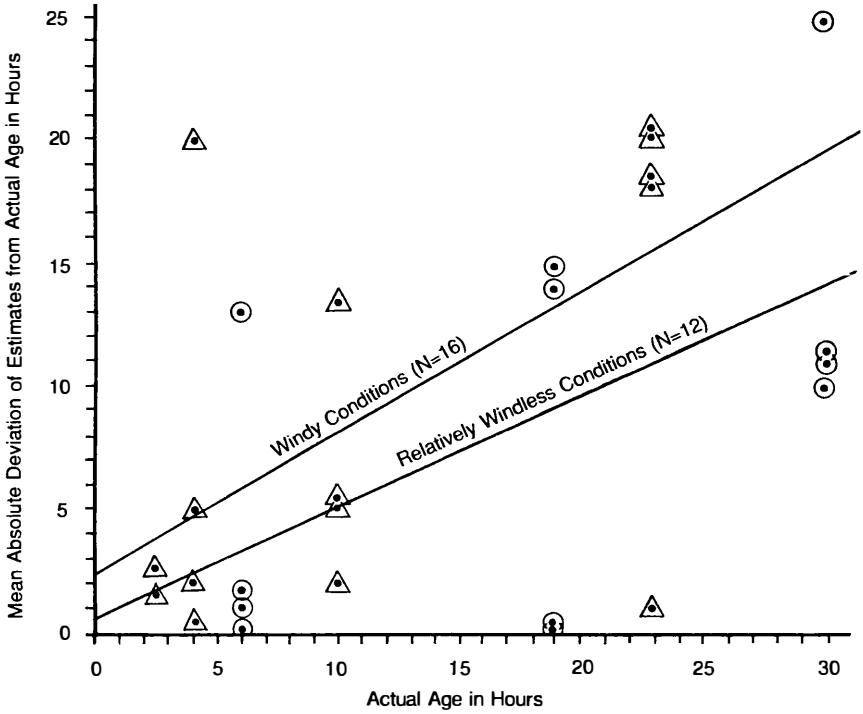
Estimating the Age of Spoor

One of the most difficult aspects of tracking is estimating the age of spoor. An ability to determine the age of spoor can be acquired only through considerable experience, and while some trackers seem to be as good as one could expect them to be, others do not seem to be very good at all. Due to the complexity of the variables involved, estimates are usually at best intuitive.

An indication of the accuracy of intuitive estimates of spoor age is given by a graph plotting the Mean Absolute Deviation of estimates from the actual age against the actual age (see illustration on opposite page). A deviation was obtained by taking the absolute value of the difference between the estimated age and the actual age. Before testing the hunters, I marked some of my own footprints over a period of time, so that I knew how old they were, but the hunters did not. They had to make intuitive estimates based only on the rate the footprints lost definition due to weathering processes. There were, for example, no superimposed animal tracks to assist them in their estimations. They indicated the age by pointing to where the sun would have been on that day or the day before. Four !Xõ trackers were tested, and the data used is that of the two who had the best results: N!am!kabe and N!ate of Lone Tree. The other two were not very good at all.

The results are not necessarily representative of all hunters, since a much larger number of trackers could have been tested. It can be expected that the accuracy of estimates will vary from one individual to another, and there may well be some hunters who are better than the ones I tested.

The Method of Least Squares was used to calculate the slope and intercept of the straight line which gives the best fit to the data. The bottom line is for estimates made in conditions where there was very little wind during the period in question. The top line is for estimates made in windy conditions. Although the samples are very small, N=12 and N=16 respectively, the linear correlation coefficients indicate that there is a 90 per cent confidence that the data are positively correlated. The graph indicates, for example, that for relatively windless conditions and for spoor about 10 hours old the mean deviation is about five hours. Assuming the sample is representative and that tracker's errors are normally or Gaussian distributed, this implies that in relatively windless conditions approximately 60 per cent of a tracker's estimates may vary from five hours to 15 hours if the actual age of the



Accuracy of intuitive estimates of spoor age. Data points for a test in relatively windless conditions are circled and those for a test in windy conditions are enclosed by triangles.

spoor is 10 hours (Stewart, pers. comm.). Trackers' estimates are usually more accurate for fresher spoor, becoming less accurate for older spoor. The fact that the fitted line for windy conditions lies above the fitted line for relatively windless conditions indicates a higher error for windy conditions.

While intuitive estimates based on weathering processes may not always be very accurate, a tracker can sometimes make more accurate estimations. Signs that involve rapid moisture loss may give a fairly accurate indication of the age of the spoor when it is still very fresh, such as droppings that are still slimy or sticky, or very fresh urine. Saliva on bushes where an animal was feeding also indicates that the spoor is very fresh. When an animal has been drinking at a waterhole, splash marks will be very fresh, since the water evaporates quickly. If it is still early in the morning, and the animal's footprints are superimposed on top of fresh tracks of a diurnal animal, such as a small bird, then there is a reliable upper limit to the age of the spoor. If the animal was resting in the shade, a fairly accurate estimation of the position of the sun at that time can be made. When a very strong wind is blowing, tracks may rapidly lose definition, so clear, distinct footprints will be very fresh.

When tracking down an animal, a high degree of accuracy is not important in determining the age of older spoor. All that is important for the trackers to know at this stage is whether or not they have a reasonable chance of overtaking the animal. A positive lead may be better than nothing, and a spoor may be abandoned to take up a fresher spoor, such as a spoor superimposed on top of the spoor being followed. During the hunt trackers will continually re-evaluate the age of the spoor so that even if they are sometimes way off the mark, their estimates will on average become better and better as they close in on their quarry. It is crucial to know when the spoor is very fresh since trackers must move stealthily when they are close to the animal. Each time that the hunters I accompanied indicated that the spoor was very fresh, it was not long before the animal was spotted a short distance away. In the art of tracking approximate estimates are sufficient to serve their purpose. Greater accuracy is not required, since hunters can make allowance for possible errors.

Time, Distance and Direction

Estimating the age of the spoor, the distance the animal may have travelled, and the direction of travel requires quantitative measures of time, distance and direction. The shortest time interval, used when spoor is estimated to be very fresh, is indicated by flicking the fingers. The shorter the interval, the greater the excitement indicated by the flicking of the fingers. This gesture implies that the animal is expected to be in the near or immediate vicinity, and that the hunters must move more stealthily, since they might be within hearing range of the animal.

When spoor is not very fresh, the time when the animal is estimated to have passed that spot is indicated by pointing to the position in the sky where the sun would have been. Time measurements dividing the day that are frequently used are: First Light; Dawn; Sunrise; Morning; Mid-morning; Midday; Mid-afternoon; Late Afternoon; Sunset; After Sunset; Dusk; Late Evening (until zodiacal light disappears); Proper Night, after about 10 p.m.; Midnight; False Dawn (when the eastern horizon begins to lighten); and the time when the stars being to fade. A period of a few days is measured in terms of the number of days, while a period of more than a week or so is referred to as "a clump of days", "a big clump of days" or "many days" (Silberbauer, 1981).

Distance is measured in terms of the time it takes to walk it. The distance implied depends on the speed walked, so the circumstances must be known. A woman gathering food may cover one or two kilometres in an hour, while a man walking at a brisk pace could cover six or seven kilometres in the same time. Long distances are measured in terms of the number of nights one would sleep while making the journey, and fractions of a remaining day in terms of the position in the sky of the sun on arrival. The optimal route is not a straight line, but a compromise between distance, ease of travel and convenience of food supplies along the route. Ease of travel

may, for example, involve avoiding thick bush, but taking advantage of shade (Silberbauer, 1981).

Direction is expressed in terms relative to named localities. The directional meaning of a locality therefore changes as your own position changes (Silberbauer, 1981). Hunter-gatherers also orientate themselves by visualising the uniform and flat landscape of the Kalahari as a complex of smaller and larger plant communities, and by recognising the position, shape, size and peculiar constitution of each plant community (Heinz, 1978a).

These quantitative measures are by no means as accurate as those used, for example, in modern physical science. In the art of tracking, however, greater accuracy is not required. These measures are sufficiently accurate for the estimates to serve their purpose in a hunting context. Owing to the complexity of variables involved, it may not be possible to make estimates with any greater accuracy. Judging by the accuracy of intuitive estimates of spoor age by two trackers tested (see page 76), and the opportunities given where they could have made more accurate estimations, any greater "accuracy" would be meaningless.

Interpretation of Activities

The interpretation of an animal's activities and prediction of its movements is based not only on spoor evidence alone, but also on a knowledge of the animal's behaviour and the environment. The gait of the animal is indicated by the relative positions of the footprints (see Chapter 10). The speed at which the animal was moving is indicated by the distances between the footprints, as well as the way sand is kicked up. Signs on the ground made by the animal's body and limbs may be interpreted by visualising what the animal was doing. When explaining these signs, hunters may mimic the animal to show you what the animals were doing. For example, a tracker may point out where a jackal sat and scratched itself. Activities like these are evident from the spoor itself, and do not require any further reconstructions.

The way an animal moves may further imply activities not evident in the spoor itself. If, for example, the footprints of a fox indicate that it was moving very slowly, this may imply that it was hunting for mice, lizards, scorpions and insects, and that it was moving slowly so as not to be seen while scenting for its prey. The hunting activity itself is not evident from the spoor, unless signs of a catch are found, but is indicated by the way the fox moves when hunting. It should be stressed that the signs of the fox moving very slowly do not necessarily imply that it *was* hunting, only that it *may* have been hunting, since it could have been moving slowly for a different reason. Signs of a kill, however, would confirm that it was in fact hunting.

The context of the spoor — the environment and a knowledge of the animal's behaviour — may enable the tracker to extrapolate from the spoor evidence in order to predict the movements and activities of an animal. Discussing the spoor of two black-backed jackals that were trotting in the direction of a nearby pan, for example, !Xõ trackers maintained that the jackals (a male and female which they said were a mating pair) were going

to scavenge for meat, possibly at the pan. They then went on to say that after eating some meat, the jackals would go and lie down during the midday heat, and in the late afternoon would go back for more meat, after which they would hunt for mice. A similar extrapolation was made from the spoor of a suricate that was trotting away from a nearby pan. The trackers explained that it was coming from its warren in the hard ground in the pan and was on its way to look for scorpions where the ground is soft and sandy.

When hunting, the ability to extrapolate from spoor evidence is important to predict the possible whereabouts of an animal. While tracking down a solitary wildebeest spoor of the previous evening, !Xõ trackers pointed out evidence of trampling which indicated that the animal had slept at that spot. They explained consequently that the spoor leaving the sleeping place had been made early that morning and was therefore relatively fresh. The spoor then followed a straight course, indicating that the animal was on its way to a specific destination. After a while, one tracker started to investigate several sets of footprints in a particular area. He pointed out that these footprints all belonged to the same animal, but were made during previous days. He explained that that particular area was the feeding ground of that particular wildebeest. Since it was, by that time, about midday, it could be expected that the wildebeest may be resting in the shade in the near vicinity. The trackers then followed up the fresh spoor, moving stealthily as the spoor became very fresh, until one of them spotted the animal in the shade of a tree, not very far from the area that was identified as its feeding ground. The interpretation of the spoor was based not on the evidence of the spoor alone, but also on their knowledge of the animal's behaviour, on the context of the spoor in the environment and on the time of the day. All this enabled the trackers to create a reconstruction of the animal's activities which contained more information than was evident from the spoor itself.

Another example shows how Ju/wasi trackers successfully predicted the whereabouts of kudu (Marshall, 1956). Estimating the age of the spoor from some moist dung of the kudu, and judging from the direction of the spoor, a tracker predicted that the kudu had moved to the west to a clearing the tracker already knew was there. The tracker's knowledge of the environment enabled him to extrapolate from the spoor evidence to predict where the animal may have been found Such predictions may not always be correct, but when they are, the tracker can save time by taking short cuts. When a prediction proves to be incorrect, the tracker must of course investigate alternative possibilities.

Usually tracking involves predicting where the animal was going but sometimes it may be more advantageous to determine where the animal was coming from. Discussing the signs of where an ostrich had enjoyed a dust-bath, !Xõ trackers explained that if one wanted to find the bird's nest, to take the eggs, it would be quicker to backtrack in order to determine where it had come from, rather than tracking to determine where it was going to. This is because an ostrich apparently has a dust-bath directly after

it has left the nest, and then goes on to feed in the veld, only returning to the nest later that day. The distance back to the nest is therefore much shorter than the distance covered after it had a dust-bath. The decision to backtrack cannot be made on grounds of the evidence of the dust-bath itself, but requires a knowledge of the ostrich's habits. This knowledge may, of course, be gained by studying the spoor coming to and going away from the dust-bath, thereby reconstructing the activities of the ostrich throughout the day. The tracker does not have to observe the animal itself to acquire knowledge of its daily habits.

The reconstruction through spoor evidence of events that have not actually been seen is an important component of the process of acquiring new knowledge in tracking. An example of this is the reconstruction given by Ju/wasi trackers of the hunting conduct of a pair of lions (Blurton Jones and Konner, 1976). They described how the lions approached together to a certain point and then split up. One lion continued a short distance and then lay down to wait. The other lion encircled the prey and then pounced on it, whereupon the waiting lion rushed up to join in the attack. While the paths taken by the two lions were clear from the spoor, the interpretation of the relative timing of the attacks was based on the way they moved. The subsequent tracks of the lion who lay down did not indicate that it was stalking its prey or was about to leap at it, but indicated that it was running in an erect posture. It should be noted that the reconstruction of the relative timing of the attacks was only hypothetical, i.e. the waiting lion did not necessarily get up only after the other lion started the attack. It is possible that the waiting lion got up into an erect posture before the other lion attacked in order to chase the prey towards the lion who encircled it. If this had been true, however, there would have been signs indicating that the prey was fleeing towards the lion who first pounced on it.

The ability to reconstruct activities that have not been seen enables the tracker to study the activities of nocturnal animals whose behaviour would otherwise be unknown. For example, !Xõ trackers maintain that a spring-hare feeds the whole evening, but goes back into its burrow at midnight to rest for a while, after which it will come out again to feed until the morning. It will go back into its hole before first light, and not come out again before dark. I have not been able to establish the truth of their claim that it goes back into its burrow during the night, but this would be indicated by tracks leaving and entering the burrow twice during the course of one night. Their claim that it "rests for a while" at midnight may perhaps be based on analogy with diurnal animals which rest at midday. While the resting period of diurnal animals corresponds with the hottest time of the day, however, the "resting period" of the spring-hare does not seem to be related to temperature, i.e. it could not, for example, be related to the coldest part of the night, which is just before sunrise.

Other examples of the known activities of nocturnal animals include their mating ceremonies described by !Xõ trackers (Heinz, 1978a). They maintained that the courtship of the caracal lasts over a period of four days,

and that the male leaves the female after mating and does not return until the cubs are born. The porcupine, also a nocturnal animal, is said to live in burrows which it takes away from antbears by contaminating the hole with its own urine. Porcupines apparently play extensively at different places before mating, and it has been further maintained that after mating a union lasts for life (Heinz, 1978a). Recent research has shown that porcupines are monogamous (Van Aarde, 1987). The !Xõ trackers' knowledge of this fact suggests their ability to recognise an *individual* porcupine by its spoor. An example of a hypothetical proposition is their statement that they suspect that pangolins mate underground, because neither mating activities nor mating places have ever been seen.

When dealing with sparse spoor evidence, the interpretation of individual trackers may differ considerably. !Xõ trackers, for example, gave different interpretations of dried-out droppings from a large antelope in a pan after the footprints had been obliterated completely by the wind. One tracker, Kayate, identified it as being that of a gemsbok, while another, N!am!kabe, maintained that it was that of a hartebeest. A third tracker, Boroh//xao, supported Kayate's interpretation while a fourth tracker, Ñ!ate, supported N!am!kabe's interpretation, so they could not reach consensus on it. I did not have enough experience to know who was correct or if it was in fact possible under the circumstances to tell whether the already dried-out droppings, in the absence of footprints, could be identified as being either that of gemsbok or hartebeest, so this point remains unresolved.

Kayate then said that the antelope licked for salt, but he did not know in which direction it went because he could not see its spoor. N!am!kabe, however, had a more creative approach. He proposed that the antelope came from the east and went off to the west to its feeding ground. He went on to say that it did not come back that morning, but went on to another pan. From that pan it would have gone in the other direction to where the grass is green. Although the only sign of the animal was its droppings, the identity of which was disputed, he reconstructed the animal's movements on the basis of the estimated age of the droppings, the direction the wind was blowing at the time it was deposited, the fact that antelope usually move into the wind (to scent danger from ahead), its daily feeding and salt-licking habits and his knowledge of the environment. His hypothetical reconstruction went beyond the direct evidence of the signs, but enabled him to make a prediction which, if followed up, would either be confirmed or refuted. Sometimes his predictions may have been refuted, but sometimes they may have been correct, but when they were, it would have given him a better chance of locating the animal than the more conservative tracker, who would have had no lead at all.

While sparse spoor evidence will be of no use to the conservative, systematic tracker, who does not go beyond direct evidence, the more creative, speculative tracker may make bold conjectures, enabling him to predict where the animal may have gone. This ability would give the speculative tracker a considerable advantage in difficult terrain, where footprints are not

always clear. The ability to solve problems in an imaginative way would also enable the speculative tracker to learn more about animal behaviour from spoor. Scientific progress is determined primarily by human creative imagination and not by the trial-and-error accumulation of facts (Lakatos, 1978a).

Knowledge of Animal Behaviour

The /Gwi, !Xò and Ju/wasi knowledge of animal behaviour essentially has an anthropomorphic nature. Animal behaviour is perceived as rational and directed by motives based on values (or the negation of those values) that are either held by hunter-gatherers themselves or by other peoples known to them. These motivational and value systems of animals do not correspond in all respects with human systems, but are modified to fit the perceived circumstances of the animals themselves (Silberbauer, 1981; Heinz, 1978a; Blurton Jones and Konner, 1976).

Despite its anthropomorphic nature, their knowledge of animal behaviour is sufficiently accurate for planning hunting tactics and for anticipating and predicting the activities of animals. Although their knowledge is at variance with that of European ethologists, it has withstood the vigorous empirical testing imposed by its use, illustrating the view that alternative cognitive maps can, up to a certain level of analysis, serve as equally effective equivalents (Silberbauer, 1981). The anthropomorphic nature of their knowledge of animal behaviour is not necessarily unscientific. It may, on the contrary, be a result of the creative scientific process itself. Anthropomorphism may well have its origins in the way trackers must identify themselves with an animal. When tracking, they must think in terms of what they would have done if they had been the animal in order to anticipate and predict its movements (see Chapters 8 and 11).

The behaviour of animals is seen by the /Gwi as bound by the natural order of N!adima (God). Such behaviour can be accounted for in terms of knowable regularities, and is believed to be rational and directed by intelligence. Each species is perceived to have characteristic behaviour, which is governed by its *kxodzi* (customs), and each has its particular *kxwisa* (speech, language). Animals are believed to have acquired special capabilities by means of rational thought. These capabilities are believed to have been passed on by the discoverers or inventors in that population, and were thereby institutionalised as elements of the species' customs (Silberbauer, 1981).

Mutually beneficial species and even some that are hostile to one another are believed to be able to understand one another's language, and some animals are believed to be able to understand a certain amount of /Gwi. A limited amount of the language of some species, such as the alarm calls of birds, can also be understood by humans (Silberbauer, 1981).

It has long been assumed by modern scientists that animals cannot communicate by means of symbolic expression as humans do. It was thought that while humans use arbitrary sounds (words) to represent abstract concepts, animals can only express emotion. Recent research suggests, how-

ever, that the sophistication of animal language has been underestimated. It has been found, for example, that vervets have different alarm calls for their three main predators, namely leopards, eagles and snakes. Other vervets react to each type of call in the appropriate way, each type of predator requiring different evasive action. This implies that vervets could be using symbolic language in which specific concepts or objects are represented by arbitrary sounds. Furthermore, it was found that calls that were perceived by monkeys as being different, each with a different meaning, could not always be differentiated by the human ear. It is therefore likely that humans would underestimate the extent to which animals are using signals to convey information. Evidence also indicates that the appropriate use of various alarm calls are learned. Japanese macaques living in different areas have been found to use local dialects, suggesting that they have been culturally transmitted rather than genetically inherited (Dunbar, 1985).

The belief of hunter-gatherers that each species has its own language may therefore not be very far from the truth. And if some animals do have a language, then it is conceivable that some behavioural strategies, or "customs", may be passed on to younger and inexperienced members of the group. After learning to associate specific sounds with specific reactions, the inexperienced member may learn why specific reactions are necessary to avoid specific animals. The use of language may therefore "tell" the inexperienced member that a specific animal is dangerous and what it must do to evade it. The knowledge of some animals that a specific animal is dangerous and what to do to evade it might not be instinctive, but learned. While some behavioural patterns may be inherited genetically, it is possible that in some animals some behavioural strategies may be culturally transmitted in the same way that language may be culturally transmitted.

Examples of animal language most commonly encountered by hunters are the alarm calls and mobbing behaviour of birds. !Xõ hunters maintain that when they are stalking their quarry, small birds, who can see them from where they are sitting high up in the trees, will "tell" the antelope about the hunters. Birds are also said to "laugh" at the hunters when they are stalking, thereby betraying the hunters' presence. While birds may sometimes be a nuisance, they also help hunters at times. !Xõ hunters say that if they see a blackfaced babbler, *Turdoides melanops*, the morning after an antelope has been shot with a poison arrow, they will watch the bird carefully, because it will show them where the animal has foundered. If the dead animal is close by, the bird will go and sit on it. If the bird sits on the spoor and then flies far away, however, the hunters claim that this means that the animal has died far away.

!Xõ hunters also maintain that birds may warn them of danger, such as snakes, leopards or lions. Warnings are not only in the form of alarm calls, but may be transmitted by displays or other behaviour. For example, a little bird may act strangely in a bush, indicating possible danger hidden from view or a courser may swoop down at something, indicating the presence of a leopard or a lion.

In times of danger or disturbance, many bird species produce characteristic calls which may vary from "general purpose" distress calls to special alarm calls given in response to specific predators. When one individual spots a predator, its alarm call will alert the whole group. It is therefore not necessary for all individuals of a group to be alert the whole time. Mobbing involves deliberate predator harassment by prey species. It is particularly characteristic of small passerines. Squirrels also mob snakes, while hyaenas are known to mob lions. In birds, mobbing attacks are often associated with characteristic calls, which are unlike alarm calls. Swooping flights with a snarling call may be made close to predators. Mobbing may have a deterrent effect on a predator in that it may indicate to the predator that it has been spotted. It may also facilitate the cultural transmission of predator recognition (Barnard, 1983).

The trackers' ability to interpret spoor enables them to reconstruct the context of a particular animal's communication even where they could hear it, but not see it. By estimating the distance and direction of a call, trackers can go to the place where the animal was and study its tracks to determine what it was doing. So, for example, !Xõ hunters are able to interpret the nocturnal calls of jackals. When a jackal gives a long, smooth howl that diminishes in loudness (WHAaaa...), then it is simply maintaining contact with other jackals. If, on the other hand, it gives a shuddering howl, diminishing in loudness and ending in a soft cough (WHA-ha-ha-ha...umph), then it is following the spoor of a scavenger or large predator. !Xõ trackers explain that it "stutters" because it is afraid. If the jackal gives the shuddering howl only once, then it was following a hyaena spoor. It has left the spoor after the first call because it will not get much meat by following the hyaena. If, however, it repeats the shuddering howl several times, then it is following the spoor of a leopard or a lion. It continues to follow the spoor because it knows that the spoor will lead to a lot of meat. The morning after we had heard a single shuddering call, for example, the hunters pointed out the spoor of a jackal superimposed on that of a brown hyaena. Apart from warning the hunters of the danger of lions at night, jackal calls may indicate the recent movements of predators and scavengers, which may be taken into account when planning hunting strategy.

The /Gwi and !Xõ folk knowledge contains more information about ethology, anatomy and physiology of mammals than about other classes. Their concepts of mammalian ethology are also more overtly anthropomorphic than those concerning other classes (Silberbauer, 1981; Heinz, 1978a). Each of the large mammal species, which can be prey, a competitor for prey, or a danger, has a specific name. Many of the small mammals that are peripheral to the hunter's interest—such as the rodents—are given generic terms or derived names. Their knowledge of antelopes is the most extensive of all animals. It includes information on their food habitat, habits, social behaviour and reproduction. They know for each species whether it is solitary or social; whether there is a strict or loose matriarchal system; whether bulls run together according to age groups or not; or if there is a father-son re-

lationship as in the kudu. They also gather information on relationships with other species, including symbiotic associations. Their knowledge of reproduction includes information on heat, gestation period, the number of young, the age of the mother when she had her first-born, when and where the young is dropped, and how the female hides her young. Attitudes towards offspring are also known. Both male and female steenbok, for example, have been seen to run up to a hunter, crying and bleating for the release of a calf. Their knowledge also includes such aspects as antelope behaviour towards the sick and wounded, and its reaction towards the dead (Heinz, 1978a).

When interpreting mammal behaviour, anthropomorphic terms are used to describe individual animals. The prey animal is expected to do its best to avoid the hunters, using the strength and intelligence characteristic of its species. While the hunter expects to overcome the difficulties that challenge his own skill and cunning (such as the animal's behaviour and other circumstances), there is always the possibility of being outwitted or otherwise frustrated by the individual animal's idiosyncratic behaviour. Some animals are said to be ingenious in the ways they outwit the hunter. Others, who do not conform to the customs of the species, are said to be stupid. When studying a herd to select their target, hunters classify individual animals, using terms associated with human attributes of personality and character. Those animals that are judged to present too much difficulty because of their contrariness or courage are rejected. Some animals are cowardly or cheating. Others are insolent or conceited and may therefore be likely targets. /Gwi hunters use more than 18 categories which provide the basis for predicting the animal's behaviour before and after it has been shot. The /Gwi also project their own values and habits in explaining the social structure of groups and other types of mammal behaviour (Silberbauer, 1981).

One of the easiest animals to shoot is the solitary bull. The solitary bull acts as if he were abnormal. He eats, sleeps and walks without interest in others of his species, even in period of rut, and he is usually fat. Even when he may notice something suspicious, he immediately forgets what drew his attention and continues to graze, unlike a bull in a herd who never fails to react to a disturbance. Once a male is out of a herd, he can never join another herd because each animal has its own herd smell. Not all solitary animals are old or abnormal. Among wildebeest, eland and hartebeest, animals that were once wounded and were unable to keep up with the herd, but have subsequently recovered, are also forced to wander on their own. If two such animals meet up, they will stay together, but other herds will not let them in, and they are not allowed to take females from herds. This type of behaviour does not, however, apply to springbok, gemsbok and kudu (Heinz, 1978a).

The knowledge of hunters includes details such as the fact that hyaenas watch the flight direction of vultures to determine the direction of new sources of food. They even have a detailed knowledge of most of the small mammals, such as gerbils, shrews, mice, bats, mongooses and

ground squirrels (Heinz, 1978a). Although birds are not as closely observed and as well known as mammals, the /Gwi and !Xõ have a considerable knowledge of bird behaviour. Birds are considered to be intelligent creatures and are thought to react to many situations in the way humans would. The explanation of bird behaviour is also anthropomorphic in character (Silberbauer, 1981; Heinz, 1978a).

The lesser importance of birds, compared with mammals, is also indicated by the greater incidence of generic and derived names of birds. Most birds regularly caught for food have specific names. Specific non-derived names are also given to many birds that are of no economic importance but which are either very common or have unusual habits, such as the nightjar (*Camprimulgus europaens* and *C. tristigma*), the Namaqua dove (*Oena capensis*), the lesser striped swallow (*Hirundo abyssinica*) and the European swift (*Apus apus*). The majority of birds have derived names. Many of these are onomatopoeic, echoing the bird's call. Others are descriptive of some aspect of the bird's behaviour (Silberbauer, 1981).

The behaviour of birds is of practical value as an indicator of situations that are of importance to hunters. We have already noted the importance of alarm cries and mobbing behaviour. A pool of water can be detected at a considerable distance by observing the flight patterns of some birds. The morning flight direction of cattle egrets or ox-peckers may indicate the direction of ungulates. Swallows that hawk low-flying insects in humid weather often indicate coming rain. To interpret bird behaviour requires a knowledge of both normal behaviour as well as significant deviations from normal patterns (Silberbauer, 1981).

Among reptiles, the snakes, legless skinks and amphisbaena are grouped under the same term. Those that are common or regarded as delicacies have specific names, while less common species have derived names. Although only a few species of snakes are lethal, all are regarded as dangerous to some degree. While the consequences of snake-bite is greatly feared, habitual watchfulness makes the probability of being bitten remote. The legged skinks, agamas, lizards, geckos and chameleons form a vague, covert taxon. Those that are hunted for their meat and a few considered to be dangerous to humans, have specific names. Many, however, have no names and are virtually ignored. Tortoise species all have specific names. Tortoises are economically important as a source of meat and their shells are used as ladles and bowls (Silberbauer, 1981).

Frogs and toads are grouped together under one generic term. Only the bullfrog, *Rana sp.*, which is a delicacy, has a specific name. Their knowledge contains fairly detailed information on the feeding, breeding and hibernating habits of many of the species, even those that are unnamed (Silberbauer, 1981).

Invertebrates play the least significant role in the lives of hunters. Classification coincides to some extent with the taxonomy of European entomologists at the level of orders. Named classes are usually those containing members that are useful, dangerous, particularly striking in appearance, or

nuisances. Within these taxa are individually named species. Those of great importance (such as the beetle from whose larva poison is derived) have specific names, while species of lesser importance have derived names. Hunters have an extensive knowledge of the honey bee which goes far beyond their practical requirements, in spite of the fact that the aggressiveness of the African honey bee does not encourage close observation. Their knowledge of the physiology, ethology and ecology of some invertebrate species is fairly detailed in relation to the species' interaction with hunter-gatherers (Silberbauer, 1981).

To sum up, the extent of hunters' knowledge of animal behaviour progressively declines in relation to mammals, birds, reptiles and amphibians, and is least in relation to invertebrates. The extent to which human characteristics are attributed to animals are also the greatest with mammals and least with invertebrates (Silberbauer, 1981). Furthermore, hunters' interest in animal life is not limited to the animals they hunt, but appears to be in direct proportion to their potential relevance to tracking and the ability of hunters to distinguish their spoor. Every animal, down to the smallest invertebrate that leaves a characteristic spoor is relevant to tracking. While hunters study animal behaviour far beyond their immediate utilitarian needs in hunting, even the most obscure detail may be used at some point in the future to interpret spoor. If, for example, the spoor of a millipede or a particular mongoose species is superimposed on the spoor of the trackers' quarry, then that particular bit of information will only be useful to the trackers if they have a detailed knowledge of the daily habits of the animals in question.

Yet the relevance of animal behaviour to tracking is limited to the trackers' ability to identify spoor. Insect species, for example, are difficult to identify by their spoor since many species have identical spoor. The relevance of insect spoor is therefore confined to what all insects, which have a similar spoor, have in common. The same applies to the spoor of small rodents or of small passerines. For example, hunters know that all passerines are diurnal, but that some mice are diurnal, while others are nocturnal. The spoor of mammals the size of mongooses and larger are all distinguishable, as well as those of large birds. It would appear that species whose spoor can be identified are all given specific names by hunters, while groups of species whose spoor are indistinguishable are given generic or derived names. Thus, although most doves have the same name, the Namaqua dove is given a distinct species name by the !Xõ and the /Gwi. When I showed my spoor illustrations of dove spoor to a group of !Xõ trackers, they were able to single out the spoor of a Namaqua dove.

In order to put the hunters' knowledge of animal behaviour into perspective, it must be understood from the trackers' point of view. As was noted earlier, in order to understand animals, the trackers must identify themselves with an animal. Yet in so doing they must inevitably project their own values onto that of the animal. In tracking, the basic form of information is a sign, and the trackers' knowledge of animal behaviour is used to create a model in terms of which the sign is interpreted.

The Scientific Process

A scientific research programme consists of a set of hypotheses that form a "hard core" which is protected from refutation by a "protective belt" of auxiliary hypotheses (Lakatos, 1978a; see Chapter 11). The art of tracking involves an ongoing process of problem-solving and often new hypotheses must be created to explain signs that cannot be explained in terms of the hunter's "hard core" hypotheses. When hunting with dogs, for example, hunters concentrate on gemsbok. Unlike other antelope which flee from dogs, gemsbok will usually stand and fight the dogs, giving the hunters the opportunity to kill it. This may be regarded as a "hard core" hypothesis upon which the hunter bases his initial assumptions when he hunts with dogs.

Nevertheless, there are exceptions to the rule, which are explained in terms of auxiliary hypotheses. Firstly, although other antelope usually flee from dogs, a female will stand to protect her young. Secondly, not all gemsbok will stand and fight, and those that do, will not always do so. When a gemsbok is encountered in the open (which is usual), it will not stand and fight in the open, but will flee into a more wooded area where it can protect its rear by standing against a thick bush, while fighting off the dogs in front of it. As the gemsbok flee into more wooded areas, hunters can see from the way they run which will stand to fight the dogs and which will not stop. This is explained in terms of the animals' "personalities". Some gemsbok are said to be courageous, while others are more timid.

These hypotheses are used to create a model on which the hunter bases his strategy. When he encounters fresh gemsbok spoor, his initial strategy is based on the assumption that the gemsbok he is pursuing will stand and fight the dogs. Only after the gemsbok has reacted to the dogs will the hunter be able to predict if a specific gemsbok will stand or flee. Similarly, if the spoor of other antelope are encountered, it is assumed that they will flee, unless the spoor of a female with her young are found. These hypotheses may not always enable the hunter to predict the reactions of gemsbok. On one hunt, !Xõ hunters pursued a gemsbok into a wooded area. Although the signs all indicated that this particular gemsbok would stand and fight, it did not, leaving the hunters somewhat puzzled. On their way back the hunters stopped to study fresh lion tracks close to where the gemsbok had passed. They pointed to signs indicating that two lions had been leaping at each other in play. One hunter later explained why the gemsbok did not stand and fight as they had expected it to. As the dogs chased it past that point, the gemsbok scented the fresh lion spoor, "thought" that it was being chased by lions, and carried on running.

To explain why the gemsbok did not react as expected, circumstantial evidence was used to create an additional auxiliary hypothesis. It should be noted that the presence of fresh lion tracks need not necessarily have related to the gemsbok's actions. It was only a *possible* explanation. Yet it was not simply an *ad hoc* explanation, since it did have predictive value. If the explanation had been correct, then the hunter could have decided to avoid

areas with fresh lion spoor in future, since the chances of success would have been diminished by its presence. By not wasting time on gemsbok that would not stop in any case, the hunter would have improved his chances of success. Conversely, if his hypothesis had been incorrect, then potentially good leads would not have been followed up. Then the hunter's chances of success might have decreased, since he might not have taken advantage of spoor that could have led to success.

The predictive value of a hypothesis based on spoor interpretation, therefore, may either increase or decrease a hunter's chances of success. As tracking involves a continuous process of problem-solving, incorrect hypotheses may be refuted while hypotheses that consistently enable the tracker to make successful predictions will be retained. If a hunter's auxiliary hypotheses enable him to successfully predict new facts, he has a progressive research programme. If, on the other hand, new hypotheses do not enable the hunter to predict new facts, his research programme may degenerate.

As new information is gathered, the hunter's theories of animal behaviour may become more and more sophisticated. New hypotheses are created to explain signs that may contradict his initial expectations, in order to make new predictions. Scientific knowledge is not gained by trial and error. Rather, novel facts are predicted by means of hypotheses that explain signs that would otherwise be meaningless. To return to the earlier example, if the hunter had not explained the gemsbok's actions in terms of the presence of fresh lion tracks, the possible influence of fresh lion spoor on gemsbok would not have been known. Then the presence of the lion tracks would have been simply an incidental observation, with no meaningful value to the hunter.

In science, no theory can be shown to be true, even if it is true, for the number of possibly true theories is infinite (Popper, 1972). Apart from the fact that a specific set of signs in a particular context may be interpreted in many possible ways in tracking, the theories in terms of which the signs are interpreted may themselves have many alternatives. Even at the most basic level of spoor interpretation it may be possible to create alternative reconstructions to explain signs. On one hunt, for example, Ju/wasi trackers rejected a hypothesis that the animal was wounded high on the body in favour of a hypothesis that it was wounded in the foot (Blurton Jones and Konner, 1976). One hunter showed that grass, which had blood smeared near its tip, was first bent to the ground by the passing animal and then smeared with blood by its foot. It then returned to the upright position after the animal passed, creating the appearance that the animal was wounded high on the body.

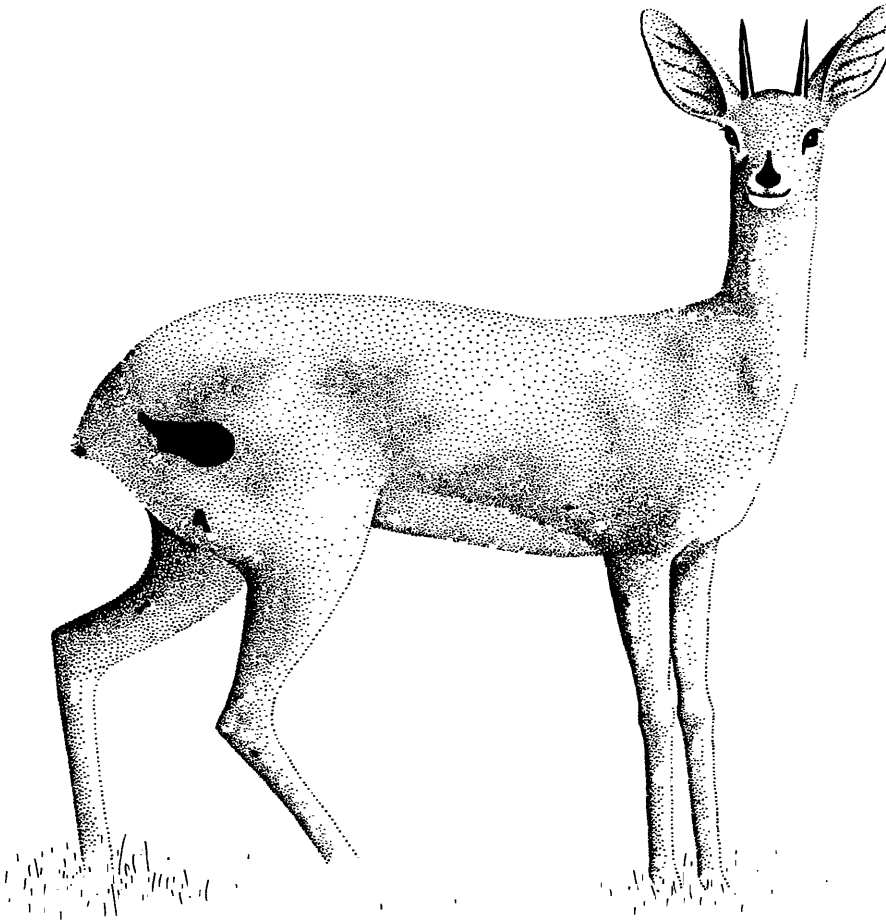
Critical discussion is the basis of rational scientific enquiry (Popper, 1963). If two or more men are hunting together they will discuss the evidence of signs and debate the merits of various hypotheses. In the course of tracking an animal, hypotheses will be tested continually against the spoor, replacing those that are refuted by better ones. Scientists do not, however, always

reach consensus by means of rational argument. In modern science, scientists may use every means at their disposal to achieve their aims, including methods such as propaganda and lobbying (Feyerabend, 1975). In tracking, which is much more individualistic than modern science, an individual hunter with a dominant personality, for example, may be able to put across his argument in a forceful manner in order to influence other hunters.

On one occasion, two !Xõ trackers, Kayate and N!am!kabe, could not reach agreement on their interpretations of the spoor. Kayate, who was the dominant personality among the group of four hunters, managed to persuade the other two, N!ate and Boroh//xao, that he was right, and so his interpretation was accepted by consensus. Judging by my own interpretation of the spoor, however, I believed N!am!kabe was correct. Apart from the fact that Kayate had a more dominant personality, N!am!kabe was a stutterer, which put him at a disadvantage. With all the click sounds in the !Xõ language, he often had great difficulty in putting across a convincing argument. Of the four hunters, N!am!kabe was the most imaginative tracker, so his original ideas were often not accepted by the others. The other three often mocked him for "telling stories". Yet on the one hunt, after the other three had already given up hope, it was his insight and determination that resulted in the successful tracking down of a wildebeest. Scientists, contrary to the *belief* that they never knowingly depart from the truth, are always "telling stories" (Medawar, 1967).

Apart from their critical attitude, Kalahari trackers also show extensive curiosity. Direct observations are often embellished with an immense amount of detail. The evident delight with which they describe their observations suggests that hunters find such observations interesting for their own sake. They have a greater interest in animal behaviour than is required for the practicalities of any specific hunt. They explore problems and acquire knowledge far beyond the utilitarian. The /Gwi, !Xõ and Ju/wasi appear to know more about many aspects of animal behaviour than European scientists. A large store of information is accumulated and communicated, which may or may not turn out to be useful in hunting. This may well be of adaptive value, since knowledge that is gained when not needed, may be useful at another time (Blurton Jones and Konner, 1976; Heinz, 1978a; Silberbauer, 1981).

Science involves a continuous process of discovery. The /Gwi recognise fluctuations in the extent of their knowledge and of changes in their culture. They believe that much knowledge was lost in the smallpox epidemic of 1950 when many bands were decimated and dispersed. Since then, some of the old knowledge has been rediscovered, and new knowledge added. While recognising the merits of known and tested solutions, they accept change and feel free to devise novel solutions to problems (Silberbauer, 1981).



7

Non-scientific Aspects of Hunting

While their scientific knowledge deals with direct sense perceptions and rational thought, hunter-gatherers of the Kalahari also make use of information that is acquired by means of peripheral perception and intuitions, as well as non-rational beliefs.

Peripheral perception

!Xõ hunters maintain that if, while they are hunting, they feel a "burning sensation" in the middle of their foreheads, just above the eyes, then they know that their quarry is just ahead of them. Some hunters say that this feeling on their foreheads is accompanied by perspiring under the arms They also claim that they can sometimes "feel" the near presence of their quarry in this way even before they find its spoor. One could argue that, when hunters are tracking an animal, they analyse the complexity of signs, make an intuitive estimate of the age of the spoor within a specific context and then intuitively know that the animal may be just ahead of them. This intense concentration may give rise to the experience of a "burning sensation" on the forehead and the perspiration under the arms. We are constantly bombarded by a multitude of stimuli to which we cannot attend. By selective attention our brains are able to select those stimuli that are relevant, while ignoring others. By means of peripheral perception we are also able to register stimuli that we do not know we perceive (Atkinson, Atkinson and Hilgard, 1981).

Even before the hunter consciously sees the animal's spoor, he may subconsciously perceive subtle signs of the animal's presence, such as the distant twittering of ox-peckers or the barely perceptible scent of the animal, lingering in the air. The hunter may be able to perceive signs of an animal selectively and subconsciously, and this perception may find expression as intuitive feelings.

!Xõ hunters can apparently also "feel" danger, such as the presence of a leopard or a lion. One hunter described the experience in graphic detail, acting out his feelings and reactions. First he would feel his hair standing on end at the back of his head, after which his heart would start beating "wildly". His whole body would then go cold with fear. Sometimes, after feeling this sensation, he might have noticed a small bird acting strangely,

which would have indicated the presence of a leopard or a lion hidden from view. When "feeling" danger, the hunter may have registered signs of danger (such as a little bird acting strangely) by means of peripheral perception, without knowing it. Then he may have felt intuitively that something was wrong. This could have led to a sensation of fear, which in turn may have alerted him to the presence of the little bird, thereby corroborating his first impressions.

Presentiments

More than 100 years ago Bleek described presentiments experienced by /Xam hunter-gatherers. They could feel in their bodies that certain events were going to happen. These feelings were a kind of beating of the flesh, which told them things. Those who were stupid, who did not understand these teachings, disobeyed them and got into trouble, such as being killed by a lion. The beatings told those who understood them which way they should not go, for example, or which arrow they should not use. It was a means by which they could get or perceive meat, or could perceive people coming by it. While dreams were regarded as speaking falsely and therefore as being deceptive, presentiments were regarded as speaking the truth (Bleek and Lloyd, 1911).

When the hunter felt a tapping at his ribs, he would say that a springbok seemed to be coming, for he could feel the black hair (on the sides of the springbok). He would say that he could "feel the springbok sensation". The hunter would feel the tapping when the springbok was coming and it was scratching itself with its horns, and with its foot. The hunter would feel a sensation in the calves of his legs when the springbok's blood was going to run down them, for he would always feel blood when he was about to kill a springbok. He would feel a sensation behind his back of the blood running down when he carried a springbok. He would have a sensation in his feet as he felt the feet of the springbok rustling through the bushes. The hunter would have a sensation in his face on account of the blackness of the stripe on the face of the springbok and he would feel a sensation in his eyes, on account of the black marks on the eyes of the springbok (Bleek and Lloyd, 1911).

These sensations described by Bleek may well be a result of the way in which the tracker identifies himself with the animal when tracking. In order to anticipate and predict the animal's movements, the tracker must think in terms of what he would do if he were that animal, and in his imagination, he must *become* that animal. The tracker may therefore almost *feel* like the animal. The tracker's presentiments may be a result of intuitive thought processes, self-fulfilling prophecies, selective memory, or perhaps some unknown process.

Both groups of !Xõ hunters whom I accompanied on hunts maintain that they experience presentiments which tell them that they will have a successful hunt that day or that they have caught an animal in a trap or snare. These hunters claim that they often have "feelings" before they go

out on a hunt, which tell them that they will be successful. They maintain that when they feel an "itching" sensation in their right hand palms, or if they perspire and feel a "burning" sensation under their armpits, then they know they will come back with meat that day.

If these presentiments do have predictive value, as the !Xõ hunters claim they do, it is possible that the hunter may, on the basis of extensive spoor information collected during the previous days, be able to know intuitively that his chances of success are fairly good. It is possible that he may make a subconscious evaluation of a multitude of signs observed over a period of time, and that his intuitive prediction may be revealed in the form of "feelings" which the hunter has learned to associate with successful hunts.

The perspiring under the armpits and "itching" of the palms may be the result of mental concentration during a complex problem-solving process, similar to the way a student may perspire due to tension during examinations, or when trying to solve a difficult problem. It is possible that hunters have learned to associate the state of mental tension, that causes them to perspire in this way, with a reasonable chance of success. In the past, intuitive feelings of confidence may have corresponded with actual successes, so that when the hunter now feels such a sensation, he believes he will be successful.

Even if their "presentiments" have no real predictive value, the *belief* that they do may have a real effect on the outcome of the hunt. The belief that they will be successful when they have these presentiments may make them more motivated, thereby increasing their chances of success. Conversely, the belief that they will have no luck when they have not "felt" anything, may discourage them to the extent that they may lack the motivation needed to be successful. The hunter's belief in presentiments may therefore result in them becoming self-fulfilling prophecies.

It is also possible that the hunter's belief in presentiments may simply be a case of selective memory. Only predictions that were coincidentally successful are remembered, while unsuccessful predictions are simply forgotten. One's mind tends to remember unusual incidents, such as successful predictions, while insignificant incidents tend to slip from one's memory. The hunter's selective memory may therefore lead him to believe that presentiments work.

It is not known how reliable the presentiments of !Xõ hunters really are. I witnessed a few occasions when their presentiments proved to be correct, and none proved incorrect. Nevertheless, such observations were not enough to make it statistically significant, so it could have been coincidence. One hunter explained that if he feels he will be successful and he is not, it is because his body is "ill". He also said that sometimes when he doesn't feel anything, he is successful. But he claimed that such presentiments work most of the time. Irrespective of whether their presentiments are either intuitive, self-fulfilling prophecies, selective memory or a combination of these, or perhaps some process which needs further research, !Xõ hunters appear

to have great faith in them. As far as the hunters are concerned, presentiments play a very real part in their hunting success.

Divining

Some hunters, such as the Ju/wasi, use sets of disks, usually made of leather, for divination. (The !Xõ hunters whom I accompanied on hunts did not make use of divining.) The matters on which the disks are consulted are mundane, not occult. The disks are believed to be capable of revealing recent or current events and circumstances and foretelling the near future. Hunters consult the disks before going out on a hunt to determine in what direction to look for animals (Marshall, 1976a).

Hunters may express different opinions. They insist that some can interpret better than others, and mock each other for ignorance in disk reading. The meaning of the message, which is determined from the position into which the disks fall with respect to each other, is apparently not governed by fixed rules. The interpretations are a product of the imaginations of the hunters, who are free to see in the disks whatever comes to their minds. Hunters know so much about animal behaviour and spoor information about animal movements that their intuitive interpretation is more likely to be right than wrong. They may also selectively remember the predictions that were coincidentally right, while the wrong ones slip out of their memories (Marshall, 1976a). It is also possible that the effect of divining is to randomise the routes or areas searched. Hunters know that animals learn the habits of humans and adjust their behaviour accordingly. To guard against the possibility of falling into a predictable routine, divining may introduce an unpredictable component to the hunter's strategies (Laughlin, 1968).

Hunting magic

When a Ju/wasi hunter feels that he is down on his luck, he may ask another hunter to touch up his first buck tattoos, by opening the old cuts and rubbing fresh medicine into them. He may also discard his present bow and quiver and build a new set. If a hunter has made a small kill and wants to make a big one, he may rub the blood of the small kill on his bow in order to strengthen it. Other forms of hunting magic revolve around the correct butchering and distribution of meat. The use of hunting magic helps to restore and maintain the confidence of the hunter by giving him the feeling that unseen forces are favourable to him (Lee, 1979). Even if hunting magic has no real effect, the psychological effect on the hunter's motivation may well increase his chances of success.

Myth and Religion

It is not possible to draw a clear distinction between the scientific knowledge and myth of Kalahari hunter-gatherers. Fundamental similarities occur in the nature of science and myth. The line of demarcation between science and metaphysics cannot be drawn too sharply, and it may be argued that most scientific theories originate in myth (Popper, 1963). Science is much closer to myth than scientific philosophy may be prepared to admit and the two

overlap in many ways (Feyerabend, 1975). One of the more obvious ways is where non-rational beliefs form part of the body of scientific knowledge used to make predictions in the hunting context.

The /Gwi believe that some species possess knowledge that transcends that of humans. The bateleur eagle (*Terathopius ecaudatus*) is believed to know when a hunter will be successful and will hover above him, thereby acting as an omen of sure success. Some steenbok (*Raphicerus campestris*) are thought to possess a magical means of protecting themselves from a hunter's arrows, while the duiker (*Sylvicapra grimmia*), is believed to practise sorcery against its animal enemies and even against conspecific rivals. Baboons, because of their legendary love of trickery and teasing, are believed to eavesdrop on hunters and to pass on their plans to the intended prey animals (Silberbauer, 1981).

A number of irrational beliefs about animals may be enumerated, but in general these seem to play a small role in the hunter's interaction with animals (Blurton Jones and Konner, 1976). It can be expected that rational scientific knowledge will be relatively more important, since the success of the hunt depends on its predictive value. However, irrational beliefs may well affect the outcome of a hunt. The sight of a hovering bateleur eagle may motivate a hunter, thereby increasing his chances of success. Or the belief in the steenbok's magical means of avoiding arrows may cause the hunter to take extra care when stalking it, thereby increasing his chances of shooting it.

Cultural traditions vary greatly among the various Khoisan groups, so that a complex, interpenetrating patchwork of systems of belief is spread over large areas. Religion and folklore can only be discussed by referring to specific groups, specific places and historical times. There is not only a diversity of belief between groups, but also within single groups. This diversity is partly due to the impact that outstanding individuals may exercise on local traditions. These are then further complicated by outside influences (Biesele, 1978).

Yet all story traditions of Khoisan hunter-gatherers are homogeneous in one important respect: all animals were formerly people and only later became animals. Stories deal with animals in their human aspect, though the characters already possess traits that will be typical of their animal aspect. The characters may turn into animals when they find themselves in situations where they need their animal powers. Such stories thus often account for the origins of different species (Biesele, 1976; 1978; Blurton Jones and Konner, 1976). Although this account of the origin of animal species may seem peculiar from a modern evolutionary point of view, it is quite plausible from the trackers' point of view. We have seen that the trackers identify themselves with that animal by thinking what they would do if they *became* that animal. It follows that an animal, with its human characteristics attributed to it by hunters in their anthropomorphic reconstruction of animal behaviour, once *was* human and acquired animal characteristics when it needed them.

The religious beliefs of hunter-gatherers are central to their world-view in that such beliefs articulate their diverse areas of knowledge and belief in a coherent whole. The same variation exists in the details of their religious beliefs, as exists in the details of their general knowledge. Yet most groups of Khoisan hunter-gatherers believe in a greater and a lesser god. In general the greater god is regarded as a supreme good being and the creator. It is omnipotent, omnipresent, eternal and omniscient. It is known to be anthropomorphic, or at least the human shape is one of the shapes it assumes. Its human characteristics, however, are only part of its identity, the totality of which is beyond human comprehension. The lesser god is treacherous and vengeful. While good fortune is usually attributed to the will of the greater god, misfortune is attributed to the lesser god (Silberbauer, 1981; Biesele, 1978).

Hunter-gatherers are pragmatic and realistic in their outlook on the world. The religious beliefs of the !Xõ, for example, are not characterised by fear, intimidation or haunting. When !Xõ hunters fear something, that fear is well founded. They fear things which they know are dangerous, such as snakes, leopards or lions. All phenomena which they cannot readily understand are attributed to the will of the greater god. The !Xõ are aware of their own limitations and ignorance of things, thereby exhibiting a deep sense of religious humility (Heinz, 1978a).

Religious belief is so fundamental to the hunters' way of thinking that it cannot be separated from hunting itself. At the end of the day, if they have had no luck in tracking down an animal, !Xõ hunters will say that the greater god did not "give" them an animal that day. If, on the other hand, they have had a successful hunt, they will say that the greater god was good to them.

III

The Fundamentals of Tracking

8

Principles of Tracking

Spoor Information

Before going out on a hunt, hunters discuss all the information at their disposal and work out a strategy that will maximise their chances of success. With a detailed knowledge of the country, they will be able to identify areas regularly visited by animals, such as waterholes, pans, dense thickets and the animal paths that connect them. Their knowledge of the habits of animals will also enable them to predict what their movement may be and at what times they may visit certain areas. They will discuss hunts of the recent and distant past, and apply the knowledge they have gained from them. Each hunt is therefore a continuation of previous hunts, taking advantage of experience gained over many years.

Interpretation of spoor on recent outings may also enable the hunters to identify favoured feeding grounds and resting places. These may be indicated by the signs of animals visiting the same places repeatedly. On each outing the trackers will systematically take note of all signs of animal movement, identifying all spoor and making an estimate of the animal's size, sex, the age of the spoor, where it came from, how fast it was moving and where it was going. All information on recent animal movements, gained from their own as well as others' observations, will be taken into account when predicting the whereabouts of the most favoured quarry.

In selecting a quarry, hunters will not only take into account its size, and therefore the meat yield, but also the ease or difficulty with which it can be captured, that is, the amount of energy that will be expended to gain a certain meat yield. When setting out, hunters may have several working leads based on recent tracks. Once they have set out, however, they may change their initial strategy as new information is gathered to follow up a more promising lead.

Recognition of signs

The city dweller may find it difficult to appreciate the subtlety and refinement of the tracker's perception of signs. In cities, "signs" (such as in advertising, clothing, noise, etc.) all compete with each other for one's attention in an artificial environment. This results in a blunting of the senses, so people lose their sensitivity to their environment. In contrast, animals in

nature have evolved to be inconspicuous and tracks and signs are all very subtle, so the tracker must develop a sensitivity to the environment The tracker's ability to recognise and interpret natural signs may therefore seem quite uncanny to the uninitiated city dweller.

To be able to recognise signs the tracker must know what to look for and where to look. Someone who is not familiar with spoor may not recognise them, even when looking straight at them. It may seem as if no signs are present at all. For example, when tracking through grass, trackers will look for trampled grass, or if the ground is covered with pebbles, they will look for pebbles displaced from their sockets. To recognise a specific animal's spoor, the trackers will look for signs characteristic of that animal.

In order to recognise slight disturbances in nature, trackers must know the pattern of undisturbed nature. They must be familiar with the terrain, the ground and the vegetation in its natural state. Only when they are familiar with all these aspects will they be able to recognise very subtle disturbances in it. For example, a disturbance may be revealed by colour differences of overturned pebbles, stones and leaves, whose underside is usually darker than the sun-bleached top side.

In order to recognise a specific sign, trackers may have a preconceived image of a typical sign. Such a typical sign may be defined by certain characteristics which enable the trackers to recognise specific patterns in signs with corresponding characteristics. Without such preconceived images many signs may be overlooked, but with a preconceived image of a specific animal's spoor in mind, trackers may tend to "recognise" spoor in markings that may be made by another animal, or even in random markings. Their minds will be prejudiced to see what they want to see, so in order to avoid making such errors they must be careful not to make decisions too soon. Since decisions taken at a glance can often be erroneous, trackers need to take time to study new signs in detail when they are first encountered. While the existence of preconceived images may help to recognise signs, the tracker needs to avoid the preconditioned tendency to look for one set of phenomena in the environment to the exclusion of all others. If trackers go out with the intention of seeing a particular set of phenomena, that intention will shut their minds off from everything else (Brown, 1983). This is illustrated by naturalists who have trained themselves to detect the smallest signs of a particular speciality but who miss almost everything else. Trackers need to vary their vision in order to see new things.

The same principle applies to spotting animals. Animals that are well camouflaged will not easily be seen by the untrained eye. Only if trackers know what to look for, will they recognise the animal. The shape of an animal is defined by the shadows which contrast with the highlighted parts. To make them inconspicuous their body shapes are broken up by contrasting colours. While one naturally tends to look *at* dense cover, one should make a positive effort to look *through* the cover to recognise the animal behind it. A technique for detecting animal movement involves looking towards the horizon and allowing your vision to "spread out". Instead of focussing on a

single object, allow the eyes to soften and take in everything in a wide semi-sphere, thereby increasing your field of vision. Everything is a little fuzzy because your eyes are not focussed, but they are much more sensitive to movement. To identify a movement, you simply focus on it (Brown, 1983).

Trackers will always try to identify the trail positively by some distinguishing mark or mannerism in order not to lose it in any similar spoor. They will look for such features in the footprints as well as for an individual manner of walking. Often the hoofs of antelope may be broken or have chipped edges, or they may leave a characteristic scuff mark as they walk. The experienced tracker will memorise a spoor and be able to distinguish that individual animal's spoor from others. When following a spoor, a tracker will walk next to it, not on it, taking care not to spoil the trail so that it can easily be found again if the spoor is lost.

The shadows cast by ridges in the spoor show up best if the spoor is kept between the tracker and the sun. When the sun casts its light from a position ahead of the spoor, the shadows cast by small ridges and indentations in the spoor will be clearly visible. When the sun casts its light from a position behind the tracker, however, these shadows will be hidden by the ridges that cast them. Tracking is also easiest in the morning and late afternoon, since the shadows cast by the ridges in the spoor are longer and stand out better than at or near midday. As the sun moves higher in the sky, the shadows grow shorter. At midday, spoor may cast no shadows at all, making them difficult to see in the glare of the sunlight (Grainger, 1967).

Trackers will never look down at their feet if they can help it, since this will slow them down. By looking up, well ahead of themselves (approximately five to 10 m depending on the terrain) they are able to track much faster and with greater ease. Unless they need to study the spoor more closely, they do not examine every sign. If they see a sign 10 m ahead, they can ignore the intervening signs and continue to look for spoor further ahead. While looking well ahead, however, trackers must be careful not to miss a sudden change in direction which the trail might take. Over difficult terrain it may not be possible to see signs well ahead, so the trackers will have to look at the ground in front of them and move more slowly. Trackers must also avoid concentrating all their attention on the tracks, thereby ignoring everything around them. Tracking requires intermittent attention, a constant refocussing between minute detail of the track and the whole pattern of the environment (Brown, 1978).

Factors that determine the degree of skill required to recognise, identify and interpret spoor are the information content of signs, the sparseness of signs and the number of proximate signs. The information content of a sign can be defined as the amount of information that can be derived from it. Well-defined footprints in damp, soft ground may provide detailed information on the identity, sex, size, mass, age, condition and activities of an animal; a barely perceptible scuff mark on hard substrate may indicate nothing more than the fact that some disturbance has occurred. Inhibiting factors on the information content of signs include: the relative hardness of

the substrate; the presence of loose sand; the density of vegetation cover; and the action of wind and rain.

The sparseness of signs depends on the substrate, vegetation and weather conditions. On soft, barren substrate every footprint may be clearly defined and it would not require much skill simply to follow the trail. On harder substrate, footprints may not be well defined, while on very hard substrate or on a rocky surface, spoor may be hardly perceptible at all. While footprints are more difficult to see on ground covered with vegetation than on relatively barren ground, depending on the density of the vegetation cover, signs in the vegetation itself may indicate the animal's route. The type of vegetation may also determine the sparseness of signs. While it may be easy to distinguish an animal's trail through long grass, it may be very difficult to recognise signs in some types of scrubs, such as in fynbos. The sparseness of signs also depends on the extent to which signs have been obliterated by wind or rain.

Proximate signs may be defined as signs made by other animals in the vicinity of the spoor of the quarry. These signs may have been made before, at the same time, or after the spoor of the quarry was made, and if superimposed onto each other could give an indication of the age of the quarry's spoor. While the tracker may benefit from superimposed spoor, too many proximate signs may sometimes make tracking more difficult. On substrate where footprints are not well defined or where the ground is densely covered with vegetation, the quarry's spoor may be confused with similar proximate signs. In difficult terrain with high animal densities it may be very difficult to distinguish the quarry's spoor from proximate signs. Yet in such areas it may, however, not be necessary to locate animals by means of tracking, since the chances are that the hunter will see an animal sooner or later by simply scanning the area. It would still be more difficult, though, to track down the wounded animal.

Anticipation and prediction

Although trackers may follow a trail simply by looking for one sign after the other, this can become so time-consuming that they may never catch up with their quarry. Unless the animal is resting in the midday heat, it may be moving on at a steady pace, and the trackers must therefore progress at a much faster pace in order to overtake it. Instead of looking for one sign at a time, the trackers can place themselves in the position of their quarry in order to anticipate the route it may have taken. They can then decide in advance where they can expect to find signs, instead of wasting time looking for them. The trackers may look for spoor in obvious places such as openings between bushes. In thick bushes they may look for the most accessible throughways. Where the spoor crosses an open clearing, they may look for access ways on the other side of the clearing. If the animal has been moving from shade to shade, they may look for spoor in the shade ahead.

Animals usually make use of a network of paths to move from one locality to another. If it is clear that an animal has been using a particular path, the path may simply be followed up to a point where it forks into two or more paths, or where the animal has left the path. Where one of several paths may have been used, the trackers must of course determine which path that specific animal used. This may not always be easy, since many animals may use the same paths.

When a herd is followed, it is not necessary to follow one specific animal. A herd may use several paths running more or less parallel to one another. As long as any one of the animals is followed, the movement of the whole herd may be determined. If the trackers lose the spoor of one, they can still pick up the spoor of another. In areas of high animal densities that have much-used interlinking animal paths it may seem impossible to follow tracks. Once tracks have been located on a specific path, however, it is possible to follow the path even though no further tracks may be seen. By looking to either side of the path, the trackers can establish if the animal has moved away from the path and they can then follow the new trail (Williams, 1976).

When trackers come to hard, stony ground, where tracks are virtually impossible to discern (apart from the odd small pebble that has been overturned) they may move around the patch of hard ground in order to find the spoor in softer ground (Williams, 1976). Should they lose the spoor, they may first search obvious places for signs, choosing several likely access ways through the bush in the general direction of movement. When several trackers work together, they may simply fan out and quarter the ground until someone finds the spoor. Experienced trackers are able to anticipate more or less where the animal was going and will not waste time in one spot looking for signs, but will rather look further ahead.

Knowledge of the terrain and animal behaviour may also allow trackers to save valuable time by predicting the animal's movements. Once the general direction of movement is established and it is known that an animal path, river or any other natural boundary lies ahead, they may leave the spoor and move to these places and cut across the trail by sweeping back and forth across the predicted direction in order to pick up tracks a considerable distance ahead (Williams, 1976). If the animal has been moving in a straight line at a steady pace, and it is known that there is a waterhole or pan further ahead, the tracker may leave the spoor to look for signs of it at the waterhole or pan. To be able to predict the movements of an animal, trackers must know the animal and its environment to such an extent that they can identify themselves with that animal. They must be able to visualise how the animal was moving around, and place themselves in its position.

Since signs may be fractional or partly obliterated, it is not always possible to make a complete reconstruction of the animal's movements and activities based on spoor evidence alone. Trackers may therefore have to create a working hypothesis in which spoor evidence is supplemented with hypothetical assumptions based not only on their knowledge of animal

behaviour, but also on their creative ability to solve new problems and discover new information. The working hypothesis may be a reconstruction of what the animal was doing, how fast it was moving, when it was there, where it was going to and where it might be at that time (Blurton Jones and Konner, 1976). Such a working hypothesis may then enable the trackers to predict the animal's movements. As new information is gathered, they may have to revise their working hypothesis, creating a better reconstruction of the animal's activities. Anticipating and predicting an animal's movements, therefore, involves a continuous process of problem-solving, creating new hypotheses and discovering new information.

Systematic and speculative tracking

Two fundamentally different types of tracking may be distinguished, namely systematic tracking on the one hand, and speculative tracking on the other. Systematic tracking involves the systematic gathering of information from signs, until it provides a detailed indication of what the animal was doing and where it was going. In order to reconstruct the animal's activities, the emphasis is primarily on gathering empirical evidence in the form of spoor and other signs. Speculative tracking involves the creation of a working hypothesis on the basis of initial interpretation of signs, a knowledge of animal behaviour and a knowledge of the terrain. With a hypothetical reconstruction of the animal's activities in mind, trackers then look for signs where they expect to find them. The emphasis is primarily on speculation, looking for signs only to confirm or refute their expectations. When their expectations are confirmed, their hypothetical reconstructions are reinforced. When their expectations prove to be incorrect, they must revise their working hypotheses and investigate other alternatives.

In systematic tracking, trackers do not go beyond the evidence of signs and they do not conjecture possibilities which they have not experienced before. Their anticipation and prediction of the spoor are based on repeated experience of similar situations and therefore they do not predict anything new. Even when a prediction is based on experience, however, it may not necessarily be correct in that particular instance. Systematic tracking is essentially based on inductive-deductive reasoning (see Chapter 11).

In speculative tracking the trackers go beyond the evidence of signs. Anticipation and prediction are based on imaginative preconceptions. They conjecture possibilities which are either confirmed or refuted. Even when their expectations are confirmed, this does not imply that their hypotheses are correct, since they may still prove to be incorrect. When their expectations prove to be incorrect, a process of negative feedback takes place, in which they modify their working hypotheses to correspond with spoor evidence. Speculative tracking involves a continuous process of conjecture and refutation and is based on hypothetico-deductive reasoning (see Chapter 11).

Systematic tracking involves a cautious approach. Since the trackers do not go beyond direct evidence, the chances of losing the spoor are small.

Even anticipation and prediction do not involve a great risk of losing the spoor, since they are based on repeated experience. Provided the trackers can progress fast enough, they will eventually overtake their quarry. While systematic tracking may be very efficient in relatively easy terrain, it may prove to be very time-consuming in difficult terrain.

Speculative tracking, on the other hand, requires a bold approach. Anticipating the animal's movements, by looking at the terrain ahead and identifying themselves with the animal on the basis of their knowledge of the animal's behaviour, the trackers may follow an imaginary route, saving much time by only looking for signs where they expect to find them. By predicting where the animal may have been going, the trackers can leave the spoor, take a short cut, and look for the spoor further ahead. While speculative tracking may save much time, thereby increasing the chances of overtaking the animal, it nevertheless involves a much greater risk of losing the spoor and much time may be wasted in finding it again. Alternatively, systematic tracking may prove to be so time-consuming in difficult terrain, that it may be more efficient to risk losing the spoor occasionally for the time that can be saved by speculative tracking.

In principle, there is a fundamental difference between systematic and speculative tracking. In practice, however, they are complementary, and a tracker may apply both types of tracking, so that there may not always be a clear distinction between the two. Ideally, a tracker should know to what extent either systematic or speculative tracking, or a combination of both, would be most efficient in particular circumstances. In very easy terrain, systematic tracking may be so quick that it may not be worth risking losing the spoor by speculation. In very difficult terrain, a tracker may not get very far with systematic tracking, so that speculative tracking may be the only way to overtake the quarry. Usually tracking conditions will vary between these two extremes, requiring an optimal combination of both types of tracking.

While systematic and speculative tracking are two complementary types of tracking, individual trackers may, under the same circumstances, tend to be either more systematic or more speculative (see, for example, Chapter 6). The difference in approach by individual trackers may be the product of different types of scientific minds.

Modern scientists may broadly be divided into two types: systematic and speculative. This classification is arbitrary, however, since the majority of scientists probably fall somewhere between the two extremes, combining characteristics of both types. The systematic scientist works by gradual, systematic steps, accumulating data until a generalisation or hypothesis is obvious. Discovery of new facts is achieved through patience and manual dexterity. Although systematic scientists may have a high intelligence which enables them to classify, reason and deduce, they may not have much creative originality. In contrast, speculative scientists create a hypothesis first or early in the investigation, and then test it by experiment. Making bold guesses they work largely by intuition, go beyond generalisation of observed

facts, and only then call on logic and reason to confirm the findings. While speculative scientists may be highly creative, they may not be storehouses of knowledge and may not necessarily be highly intelligent in the usual sense. Systematic and speculative types of minds represent extremes and most scientists probably combine some characteristics of both. Both types of scientists are necessary, for they tend to have complementary roles in the advancement of science (Beveridge, 1950).

The way systematic and speculative trackers acquire new knowledge may be analogous to the way modern scientists do. Systematic trackers may develop their scientific knowledge by systematically accumulating empirical data based on spoor evidence and direct observation of animal behaviour. Speculative trackers may develop their scientific knowledge by first creating hypotheses and then looking for spoor evidence to support their theory. Though some trackers may be inclined to be more systematic and others more speculative, most trackers would probably combine characteristics of both, varying from one extreme to the other.

In the hunting process systematic and speculative trackers may complement one another. When hunting in teams of two or more trackers, systematic and speculative trackers may be in constant dialogue, so that some form of consensus is reached (see, for example, Chapter 6). Such a consensus may represent an optimal combination of the two extremes, but trackers do not always agree on their interpretations of spoor or on the best strategy to adopt.

Systematic and speculative trackers may also have complementary roles in advancing and maintaining the shared pool of scientific knowledge of a band or alliance of bands. Systematic trackers, on the one hand, may be able to accumulate and retain more knowledge, including knowledge gained from others. Speculative trackers, on the other hand, may be creative innovators, developing new knowledge, especially in changing circumstances, or rediscovering knowledge that may have been lost.

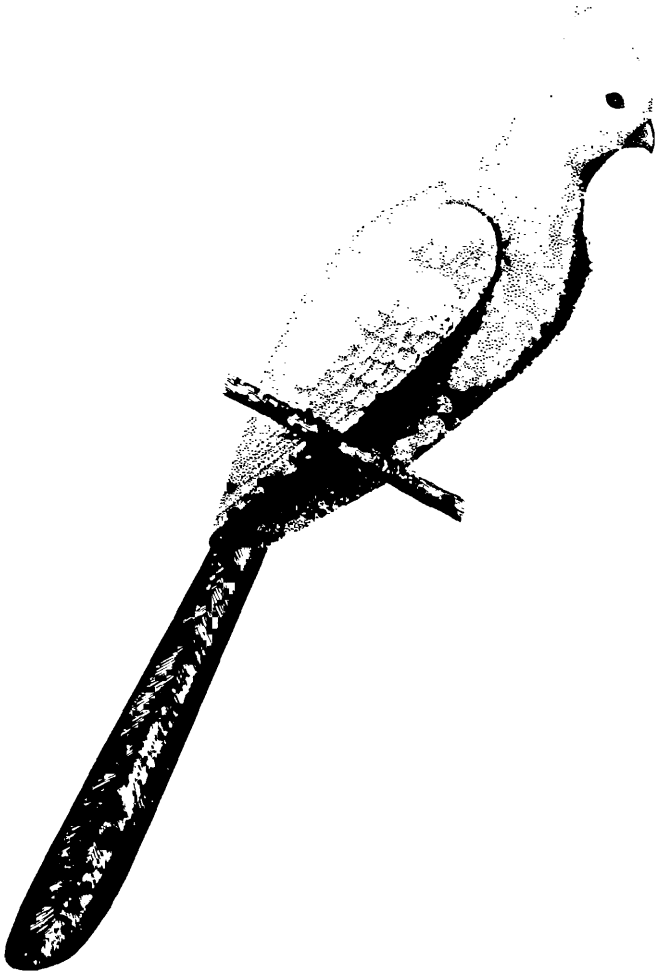
Stealth

When the spoor is still old and the animal so far ahead of the trackers that it will not be alerted in any case, speed is more important than stealth. Moving cautiously at this stage would only waste time, making it difficult to catch up with the animal, which may be moving further ahead at a steady pace. When the spoor is very fresh, however, and the animal may be close by, the hunters must slow down and move as stealthily as possible. Moving as quietly as they can, hunters will avoid stepping on dry leaves and twigs, and take great care when moving through dry grass. Being barefoot, they are able not only to tread softly, but can feel any dry leaves or twigs underfoot. Their soft tread may also prevent animals being alerted by vibrations through the ground. When a few hunters work together, they communicate with hand signals. When they cannot see one another, they may use bird calls and whistling. Once the animal has been sighted, they may come together and discuss their strategy in soft whispers.

If the hunters are in close proximity to the animal, it is important that they remain downwind of it, that is, in a position where the wind is blowing away from the animal in the direction of the hunters. It is also important that their quarry does not have the opportunity to cross their tracks, since the lingering human scent will alert it (Wynne–Jones, 1980). Most animals prefer to keep the wind in their faces when travelling so that they can scent danger ahead of them. The trackers will therefore usually be downwind from them as they approach from behind. If the wind direction becomes unfavourable, however, the hunters may have to leave the spoor to search for their quarry from the downwind side. !Xõ hunters maintain that if a fly sits on a hunter, it can carry his scent to his quarry, thereby alerting it.

As the hunters close in on their quarry, they must make sure that they see it before it sees them. !Xõ trackers maintain that an animal keeps looking back down its own trail, always on the alert for danger from behind. When the spoor is very fresh, the hunters may have to leave the spoor so that the animal does not see them first. Animals usually rest facing downwind, so that they can see danger approaching from the downwind side, while they can smell danger coming from behind. An animal may also double back on its spoor and circle downwind before settling down to rest. A predator following its trail will move past the resting animal on the upwind side before realising that the animal has doubled back, so the resting animal will smell the predator in time to make its escape.

When stalking an animal, hunters will use the cover of bushes, going down on their hands and knees where necessary. In long grass they will go down on their stomachs, pulling themselves forward with their elbows. The most important thing is not to attract attention by sudden movements. The hunters will take their time, moving slowly when the animal is not looking, and not moving when the animal is looking in their direction. When stalking their quarry, hunters must also be careful not to disturb other animals. A disturbed animal will give its alarm signal, thereby alerting all animals in the vicinity, including the hunters' quarry.



9

Classification of Signs

In the narrowest sense of the word "spoor" simply means "footprint", but in tracking it has a much wider meaning, including all signs found on the ground or indicated by disturbed vegetation. Tracking also involves signs such as scent, urine and faeces, saliva, pellets, feeding signs, vocal and other auditory signs, visual signs, incidental signs, circumstantial signs, blood spoor, skeletal signs, paths, homes and shelters. Spoor are not confined to living creatures. Leaves and twigs rolling in the wind, long grass sweeping the ground or dislodged stones rolling down a steep slope leave their distinctive spoor. Markings left by implements, weapons or objects may indicate the activities of the persons who used them, and vehicles also leave tracks.

Spoor

Spoor includes a wide range of signs, from obvious footprints, which provide detailed information on the identity and activities of an animal, to very subtle signs which may indicate no more than that some disturbance has occurred. Although it provides less information than ground spoor, disturbed vegetation may provide a quicker means of tracking. Long grass bent over, for example, can be seen from a considerable distance as the light is reflected from it, and can be followed at a relatively high speed. Signs of spoor may vary considerably with terrain, weather conditions, season, time of day and age.

Clear footprints in soft ground or a thin layer of fine snow, provide the most detailed information on the identity and activities of an animal or person. Footprints vary depending on the substrate on which they were made and the speed at which the animal was moving. Perfectly clear prints are seldom found and usually only fragments of prints or partially obliterated prints are evident. Fresh footprints usually show up slightly darker in colour than the surrounding ground. On hard ground where there may be no definite indentations, footprints may show up as shiny patches of dirt due to the change of reflective properties of the ground. Scuff marks in the shape of scraped patches normally stand out as a different shade from the surface around it. These may occur with accidental scuffing or abrupt turning of

the foot to create pivot marks on the ground. In walking across ground and then stepping on rocks, some dirt may be transferred onto the rocks.

Wind and rain building up soil deposits around a pebble will form a little crater which becomes visible when the pebble is dislodged from its socket. If a pebble has been kicked out, it can also give an indication of the direction of movement. A freshly turned pebble or stone will generally appear different in colour, usually darker, from surrounding stones. A pebble that has been stepped on will be embedded in the ground. If a small twig or dry branch is stepped on a depression in the ground directly beneath it will normally be visible. Dead twigs and branches on the ground may be broken or cracked. To determine if the fracture is recent or old, similar twigs can be broken and compared. In contrast to a fresh break, an old break will appear dull and weathered (Robbins, 1977).

A freshly turned dry leaf will appear darker in colour as the shaded part is exposed, compared to the sun-bleached surrounding leaves. Some mud may also cling to the side that was underneath. When the ground is covered with dry leaves, a trail of crushed leaves may be left behind. Where leaves lie thick and impressions made on them do not show at all, it may be possible to scrape them aside to examine the earth underneath. Where moss is present, there may be signs of its having been scraped off trees, exposed roots or rocks. It may be in the form of a scuff mark, a bruise, or it may be completely scraped off.

A very distinct path will be made as tall grass or similar vegetation is bent in the direction of travel. Grass trampled or flattened presents a shiny surface to the sun which makes the route followed a lighter colour than the surrounding grass. The easiest spoor to follow are those made through patches of tall grass which have not been used before. When an animal moves through dense bush or reeds, branches or reeds will be pulled in the direction of travel and some interlacing may occur when they are released. Leaves turned upward will also be lighter coloured. Soft, green vegetation may be bruised or cut and branches or twigs may be bent or broken. Displaced at an angle, the colour of bent or broken vegetation may have different reflective properties. Bark may also be scratched or chipped.

Where dew or frost occurs, or after rain, the uniform distribution of droplets or ice will present a shiny surface. An animal will leave a distinct path that will show up as a dark line where the drops or ice have been shed. When an animal crossing a stream has to step into the water, water or wet mud may be displaced from the stream. The direction of travel is indicated by the wet marks on the ground where the animal has left the stream. The presence of animals which spend most of their time in the river, e.g. otters, may be detected by splash marks or even wet paw marks on the rocks. Since these signs are soon lost as the water is evaporated by the sun or wind, they usually indicate that the animal is still in the near vicinity. If the river bottom can be seen, disturbed mud or overturned rocks or stones may be detected. Close to the water's edge, soft mud may also leave clear impressions.

Broken cobwebs may indicate that an animal moved through an opening between bushes, or conversely, cobwebs across an opening indicate than an animal did not move through it. Disused holes in the ground are usually indicated by cobwebs in the opening, while occupied holes will be clean.

Scent

Animals produce secretions that leave a trail perceptible to the sense of smell. Many species have special glands which produce a secretion with a scent which is not only specific to the species, but also to the individual animal. These glands may be concentrated in special scent organs on the animal's feet, from where the scent is transferred to the tracks. They may also have scent organs on the head or body, often around the tail region, which may be used to deposit scent at specific places by rubbing it on to vegetation or on to the ground. Scent marking can also be carried out with urine and faeces (Bang and Dahlstrom, 1972).

Scent plays an important role in the lives of animals. In the breeding season males are attracted to females by special odours. The males of many species scent-mark their territories with urine to warn other males. All animals that track follow scent, while humans, who do not have a good sense of smell, have to use dogs. Scent is influenced by temperature and weather conditions. Cool, calm conditions may help to preserve scent, while heat and wind may erase the scent trail. Conditions are better in the morning and evening than at midday, and also better in winter than in summer. Wet ground is better than dry ground, but rain may obliterate scent (Heinz, 1978a). Scent also diminishes with time, so that dogs must follow a relatively fresh trail.

When very close to the animals, experienced trackers can sometimes smell and identify animals such as elephant, buffalo, wildebeest, zebra, waterbuck, giraffe and lion before they have seen the animals (Young, 1986). After it has rained for a few days, when the air is very humid, a tracker may also be able to scent animals if the wind is right (Heinz, 1978a). Fresh droppings and urine also have a distinctive smell.

Urine and faeces

Fresh urine and faeces, frequently indicated by flies and dung-beetles, often help to identify spoor, especially if the ground is too hard to provide clear footprints. It can also give an indication of the age of the spoor. It should be kept in mind that the faeces of a single species may vary considerably from area to area, depending on the diet of the animal, its size and condition, the time of the year and the age of the faeces.

According to Bang and Dahlstrom (1972), the position of the urine patch relative to the footprints can indicate the sex of the animal. An antelope urinates with the hind legs straddled, which indicates where the animal was standing. The urine patch of the male will be between the tracks of the forefeet and hind feet, whereas that of the female will be between or behind the hind feet tracks. The relative position of a urine patch to faeces

deposited at the same time can also indicate the sex of the animal. Looking at the footprints to determine the direction, a urine patch in front of the faeces usually indicates a male, whereas a urine patch on top of or behind the faeces, usually indicates a female.

A detailed examination of faeces will produce much information on what the animal has been feeding on. Faeces consists of the indigestible parts of the food, such as hair, feathers, bone splinters, pieces of chitin from insects, undigested plant matter and mucus. The form and size of mammal droppings are usually characteristic of a species. The size will also depend on the animal's age, the droppings of young animals being smaller than those of adults. The shape may also depend on the composition of the food. Lush grass may produce a soft, sometimes liquid faeces, whereas dry grass may produce hard, dry droppings. An animal's summer and winter droppings may also exhibit a difference due not only to the composition of the food, but also to the liquid content. In the dry season the liquid content will be less and the droppings may be much smaller than in the wet season. Droppings also shrink as they dry out, so that old droppings may be much smaller than fresh droppings.

The droppings of herbivores are generally small and round, while those of carnivores are often cylindrical or sausage-shaped, with a point at one end. Since plant food has a relatively poor nutritional value, herbivores have to eat large quantities, and therefore they produce large amounts of faeces which usually betray their presence (Bang and Dahlstrom, 1972). Meat, on the other hand, has a high nutritional value and most of it can be utilised by carnivores, which therefore produce much less faeces.

While many animals deposit their faeces at random, some use special latrines where large quantities may accumulate. Some, like cats, bury their faeces. Others use their faeces for scent to mark their territories, in which case it may be deposited in an elevated position such as on a tree stump or a rock so that the scent is effectively disseminated.

Saliva

Saliva may sometimes be seen on leaves where an animal has been feeding or on the ground at a salt lick. Fresh cuds may also be found on the ground. These signs may indicate that the spoor is very fresh, since it does not take long for saliva to evaporate, especially on a hot day.

Pellets

Many birds regurgitate those parts of their food which they cannot digest in compressed pellets covered with mucus. These may contain fur, feathers, chitin from insects, bones, pieces of mollusc shell and undigested plant material. The diameter and shape of the pellets varies according to the species. Some birds produce almost spherical pellets; others produce cylindrical pellets with one or both ends rounded or pointed. The consistency, which may be firm or so loose that the pellet easily falls apart, depends on what the bird has been eating. Since each species has certain food preferences the

contents of the pellet may help to identify the species concerned. The location of the pellets will also indicate the preferred habitat of the species, which may help to narrow down the possibilities. Pellets are usually found at the birds' roosting sites and nests, and sometimes in feeding areas (Bang and Dahlstrom, 1972).

Feeding signs

A detailed knowledge of the diets of animals for a particular area and time of the year can help a tracker to identify spoor from feeding signs. Diets are very complex, however, and more than one animal can eat the same food. The remains left by large carnivores are usually also utilised by smaller carnivores and scavengers. Conversely, if the identity of the animal is already known from footprints, then feeding signs can give an indication of what that particular animal has been eating.

Feeding signs can also help when following a spoor. With regard to browsers, if it is known for which bushes the antelope has a preference, the tracker may leave the spoor and go to the next bush where the antelope might have been feeding. Feeding elephants may leave a trail of broken branches. Circling vultures can also help to locate feeding predators or a wounded animal. When these vultures settle in a tree instead of on the ground, the predator may still be feeding (Lyell, 1929).

Since we have noted that herbivores have to feed often and in large amounts, they may have many feeding sites close to one another. Since carnivores only need to eat a relatively small amount, the trail of a carnivore must be followed for long distances before evidence of a kill site is found. Most animals prefer to remain hidden when feeding, and may take their food to a special feeding place where they can be safe while feeding. Some animals may have feeding places out in the open. The larger carnivores, for example, have nothing to fear, while animals such as squirrels may position themselves where they can detect an approaching enemy at a distance.

Apart from the choice of food, evidence in the form of marks left by the teeth or beak and the methods of handling the food may also give an indication of the animal involved. The location of the feeding site will also be in the preferred habitat of the species concerned. Some feeding signs, such as the debarking of trees, may even be identified after some years, but feeding signs are usually obliterated relatively quickly.

Vocal and other auditory signs

Vocal signs such as alarm calls can warn either the hunters or their quarry of danger. Since an alarm call usually alerts all other animals in the vicinity, hunters must be careful not to let other animals betray their presence. The grey lourie, *Corythaixoides concolor*, or "go-away" bird (shown opposite page 111), a source of annoyance to hunters, utters a loud drawn-out "go-away" call when disturbed, and will often follow or fly ahead of intruders, thus alarming the quarry (Grainger, 1967). Baboons may alert other animals by loud barks, or a kudu may give a short bark before running

off. Guineafowl may also frighten animals by rising and clacking. In order to avoid dangerous situations, it is important for hunters to recognise the sounds made by hunting or feeding lions, or when lions are mating or have cubs with them (Young, 1985). A disturbance may also be indicated by the absence of vocal signs, such as the sudden silence of chirping crickets. Other auditory signs may include rustling grass or bushes, crushing leaves, breaking twigs and branches, stones and pebbles kicked in flight, splashing water or galloping hoofs. Depending on the quality of the sound, it may be possible to distinguish between a light or heavy animal, or one that is moving slowly or swiftly. A soft rustling sound in the grass may indicate a snake hidden from view. A sudden rustling of bushes may indicate a fleeing animal. A slow, heavy rustling of reeds at the water's edge may indicate a crocodile. Cupping one's hands behind one's ears can help to isolate and amplify particular sounds.

Visual signs

Apart from the actual sighting of an animal itself, visual signs will include all signs of movement where the animal may be hidden from view. An animal's presence may be betrayed by moving bushes or long grass. A fleeing animal may only be detected by the sudden movement of branches. When the slow rustling sound of a crocodile in tall reeds is heard, its position may be indicated by the moving tips of the reeds. The presence of a crocodile under water can be detected by small bubbles rising to the surface.

Incidental signs

Incidental signs are signs which may not necessarily be associated with the spoor in question. Such signs may include tufts of hair, feathers or porcupine quills. It should be noted that, although tufts of hair or feathers may belong to the animal in question, they may also have been blown there by the wind. Similarly porcupine quills found next to a spoor that is difficult to identify, may not belong to that particular animal, but may have been lying there for some time.

Circumstantial signs

Circumstantial signs are any indirect signs in the immediate vicinity of an animal or person which may betray its presence. Such signs are usually seen in the behaviour of other animals. Birds may betray the presence of hunters to animals. Ox-peckers are most frequently found near large ungulates, such as buffalo, eland and kudu, upon which they clamber about looking for ticks and blood-sucking flies. When approached, they will fly up and about, thus alarming the animals. Animals may become restless. Baboons will move in short sprints and make a lot of noise. Antelope and buffalo often stand and stare at intruders. Birds may also indicate the presence of snakes or dangerous animals such as a leopard or lion (Grainger, 1967).

Blood spoor

A wounded animal may leave a "blood spoor" in the form of spots or drops on the ground and vegetation. An indication of the height of the wound may be given by marks on the surrounding shrubs. Blood from a flesh wound or vein will be dark, while clear blood with air bubbles will come from the lungs. A wound in the abdomen or intestines will be indicated by blood with stomach contents. If the wound is only slight, blood spots will decrease when bleeding slackens or stops and the animal will continue running. If the animal's condition worsens and it decreases its speed, blood spots may be closer together and gathered in pools (Wynne–Jones, 1980).

Skeletal signs

Skeletal signs indicate the remains of animals and can be identified by the size and shape of the skull, the teeth and, if present, the horns. Skeletal signs may also be the feeding signs of carnivores.

Territorial signs

Territorial boundaries may be scent-marked with urine, faeces or scent transferred to bushes from special scent organs. Scent will not usually be perceptible to humans, but territorial signs may be visible in the form of latrines, pawing and horning of shrubbery. Some small antelope wipe their preorbital glands on the tips of grass or twigs, leaving a black tarry secretion (Smithers, 1983).

Paths

Most animals have a network of paths or runs which they follow most of the time. Animals know these paths very well so that they can take flight along them when disturbed. At night animals are guided by the scent created by continuous use. Paths will always take the route that is easiest to follow, going around obstacles. Several animal species may sometimes use the same path or parts of it. They may also use paths and roads made by humans, incorporating these into their own network of paths. Paths are usually most distinct in the vicinity of good feeding places and especially around waterholes. In the immediate vicinity of a waterhole, paths are most distinct as animal movement is concentrated towards it, forming a clearing around the waterhole itself. Further away from the waterhole paths become less distinct as they radiate outwards, branching off into smaller paths. Where smaller paths join to form a larger path, or where small paths join up with a main path, the large path usually points towards the waterhole. In heavily wooded areas and forests, a network of paths are usually the only accessible routes that animals can follow through the thick undergrowth (Bang and Dahlstrom, 1972).

Homes and shelters

Most animals continually move their sleeping quarters, and may only have a fixed home during the breeding season to protect the young. Some animals

do not even have fixed homes during the breeding season, the young being capable of leaving their birth-place soon after they are born, and are continually shifting the places where they sleep. Only a few animals have a permanent home which they use throughout the year. Homes are usually inconspicuous and in sheltered or inaccessible places so that they are difficult to find. In the breeding season they may be betrayed by the activities of the adults bringing food for the young. They may also be detected by tracking the animal's trail until it eventually reaches the home or shelter (Bang and Dahlstrom, 1972).

The most common homes found are birds' nests. They are usually well sheltered among the leaves of trees and bushes or in ground vegetation. Nests of different species are characterised by their position, size, structure and materials used and vary considerably in appearance. Some small mammals build their homes in vegetation and may look very much like birds' nests. Squirrels build their drays in trees, usually close to the trunk. They are spherical and consist of loosely plaited twigs lined with grass or leaves (Bang and Dahlstrom, 1972).

Animals which do not construct homes or shelters, and simply lie down to rest in a sheltered place, often leave a depression with distinct impressions of the animal's limbs and body. The size of the depression, together with other signs such as footprints and droppings may give an indication of the animal that was resting there. Hares create distinctive forms in sheltered places in long grass or next to bushes. The hare scrapes away the leaves and then lies down in a shallow depression which makes the hare very difficult to detect (Bang and Dahlstrom, 1972).

Many animals make their homes in the ground, often with a system of burrows. These may have a main entrance as well as an escape exit. Underground burrows may sometimes be revealed by heaps of excavated soil, such as mole hills. Homes may consist of an extended network of burrows, housing a whole colony of animals, such as suricates or ground squirrels. Many burrowers, like antbears, play an important ecological role in that their disused holes are often used by other animals for shelter. The occupant of a burrow may be identified by looking at the size of the entrance hole, its position, the method used to remove excavated soil, as well as tracks and droppings in front of and inside the entrance. An occupied burrow will show fresh signs of use, while a disused burrow will have fallen leaves collected in the entrance, cobwebs spun across the opening, or it may be overgrown (Bang and Dahlstrom, 1972).

cm

10
Spoor Interpretation

Variations between species

Different species can be identified by variations that are characteristic of particular species. The most notable characteristics are usually determined by functional and environmental adaptations of the feet. Similar species may also be differentiated by subtle differences in the size and shape of the feet. Understanding characteristic features of spoor enables the tracker to analyse fractional or partly obliterated spoor which may otherwise be difficult to identify and interpret.

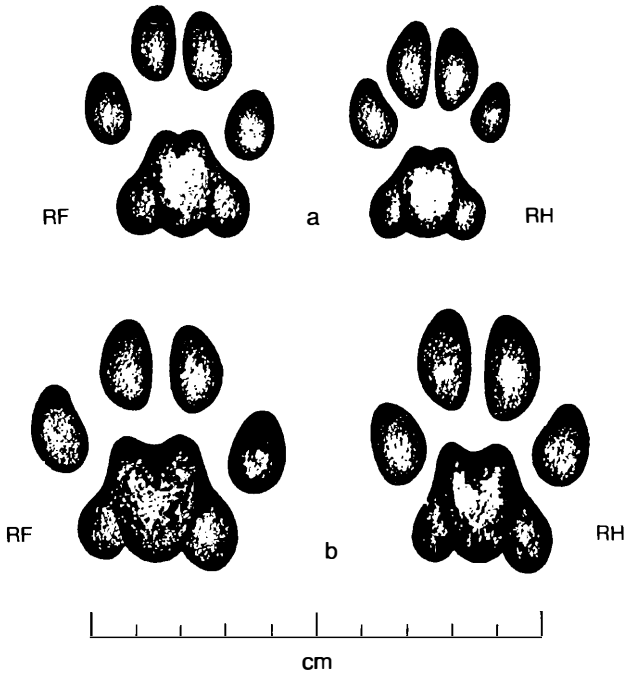
Functional adaptations of feet may be for specific types of locomotion, for use as tools or as weapons. Feet adapted for speed will have only a small area in contact with the ground. The feet of predators have soft pads for stealth, some have sharp claws to hold down their prey, while others have short, blunt claws for traction. Some animals have claws that are well developed to act as digging tools, or that are adapted for grooming.

Feet may have specific environmental adaptations for different types of terrestrial, aquatic or arboreal environments. Feet adapted to soft muddy ground require a large contact area for support. In soft, sandy terrain sharp pointed hoofs can dig into the sand to obtain a firm grip, while on firm ground hoofs need to be rounder. On hard, rocky surfaces small rounded hoofs can find small footholds and indentations for swift, agile movement. Some animals, like otters, are adapted to semi-aquatic environments and are able to move on dry ground and swim well. Other animals, like seals, are mainly adapted to an aquatic environment. Animals adapted to swimming usually have webbed toes to increase the area of their feet and therefore, the resistance with which they pull themselves through the water. Animals adapted to arboreal environments usually have sharp claws which dig into the bark of trees, such as squirrels, or they have opposable toes which can grasp branches, such as monkeys and birds. Some animals, such as cats, are not only terrestrial, but are also able to climb trees.

Apart from functional and environmental adaptations, feet may also have redundant features. The first toe of many species, for example, is reduced and has become redundant, but may still show in the spoor.

Facing page: right fore and right hind lion spoor: top, adult female; middle, young male; bottom, adult male. Scale in centimetres.

Heavier animals usually have larger feet to support their mass, but the shape of the feet is also determined by the animal's body structure. A strongly built animal usually has broader feet and rounder toes, while an animal with a slender body build has more narrow feet with slender toes. This can be seen when comparing the spoor of the bat-eared fox with that of the Cape fox, or the spoor of the caracal with that of the serval (see below). It can also be seen in variations in the shape of hoofs of ungulates.



Right fore and right hind spoor of (a) serval and (b) caracal

The exact shape of an animal's foot need not have any specific function, but may be an arbitrary shape determined by a random variation which has become characteristic of a species. All adaptations are the result of random variations that have been selected for specific functions. It is possible that some random variations have not specifically been selected, but have become characteristic of a species. The hoofs of antelope may have straight sides, hollow sides or rounded sides, with no apparent reason why any one variation should be an advantage. Yet these features may be characteristic of a species.

Variations within a species

While species can be identified by characteristic features, there also exist individual variations within a species. These variations make it possible for

an experienced tracker to determine the sex as well as an approximate estimation of the animal's age, size and mass. A tracker may also be able to identify a specific individual animal by its spoor.

The sexes are usually distinguished by the fact that the males are usually larger than the females, or with exceptions like the spotted hyaena and some of the smaller antelopes, the females are larger than the males. This is evident not only in the larger sizes of the spoor, but the more massive body structure is evident in the fact that the forefeet are usually proportionally broader. While the spoor of adult males are usually larger than that of adult females, those of young males may be the same size as adult females, but the forefeet may be broader due to their more massive body structure (see illustration facing page 125). The sexes may also be distinguished by association. The spoor of an adult in close association with a young animal is probably that of a female with her young. Nursery herds may be identified by the presence of several young, or the absence of young may indicate a bachelor herd. When a species is gregarious, a solitary individual will probably be an adult male. The sex may also be determined by the relative position of the urine to the back feet or faeces (see Chapter 9).

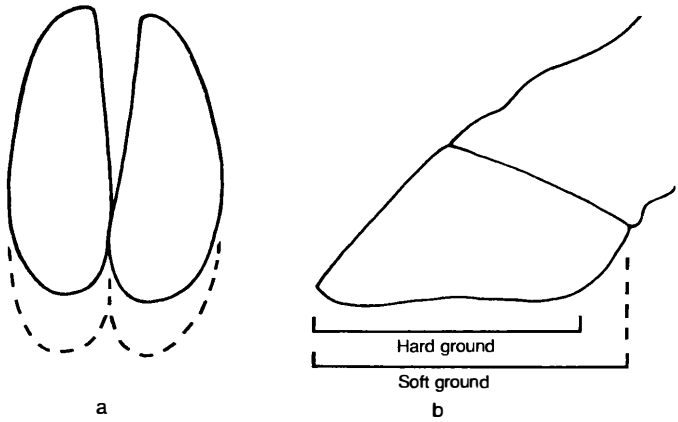
The age of an animal may be indicated by the size of the feet. The hoofs of young antelope will also have sharper edges, while old individuals may have blunted hoofs with chipped edges. With animals with padded feet, younger individuals may have more rounded pads. Some animals have specific breeding periods. If it is known at what time of year an animal is born, a reasonably accurate estimate of its age can be made.

The size of an animal is proportional to the size of the spoor, while its mass is indicated by the depth of the imprint. It should be noted that the depth of the imprint also depends on the firmness of the ground. Two animals may be the same size, in which case their spoor will be the same size, but the one may be more massive and therefore make deeper imprints. A small animal may have the same mass as a larger animal, but have smaller spoor which will consequently leave deeper imprints. A larger animal must be proportionally more massive than a smaller animal to leave the same depth of imprints. The depth of the imprint is determined by the pressure exerted. The pressure is equal to the weight of the animal divided by the area in contact with the ground at any one time. The weight, or gravitational force, is equal to the mass of the animal multiplied by the acceleration due to gravity at the earth's surface. The depth of the imprint is also determined by the pressure exerted due to the acceleration of the animal. When running or jumping an animal will leave deeper imprints than when it is walking slowly. An animal with a more massive body structure usually has broader footprints than a more slender animal. The size of an animal will be determined by its age, sex, as well as the normal variability in sizes in a population.

Apart from features characteristic to the species, there also exist random variations within the species which may vary from individual to individual. The exact shape of every individual is unique so that it is, in principle, possible to identify an individual animal. In practise this requires considerable

experience, and is usually only possible with large animals. With elephant and rhinoceros it is easy to identify an individual by the random pattern of cracks underneath the feet.

The shape of feet may also be altered by environmental factors. In hard terrain, hoofs of ungulates may be blunted by excessive wear, or in soft, sandy terrain, they may grow elongated hoofs due to lack of natural wear. Similarly, animals such as jackals may grow elongated claws in soft terrain or their claws may be worn down in hard terrain. Accidental alteration may also occur. A claw may be broken or lost Hoofs may be chipped or broken.



(a) The right fore footprint of a kudu on hard ground (solid line) and soft ground (dashed line).
(b) Side view of a kudu hoof, showing those parts of the hoof that make contact on hard ground and on soft ground.

Variations of an individual animal's spoor

The shape of a footprint may vary considerably depending on the substrate. In very soft ground an antelope's toes splay and the feet sink in to make a longer imprint as the back of the feet also show in the spoor. On hard, dusty ground the back of the feet may not show, so that the spoor is shorter. The toes of padded feet are rounded in soft ground, but will spread out on firm ground to appear larger and different in shape. On very hard ground only the tips or edges of hoofs may show, or only the claws of padded feet may show. In soft sand a spoor loses definition and it requires considerable experience to identify and interpret it.

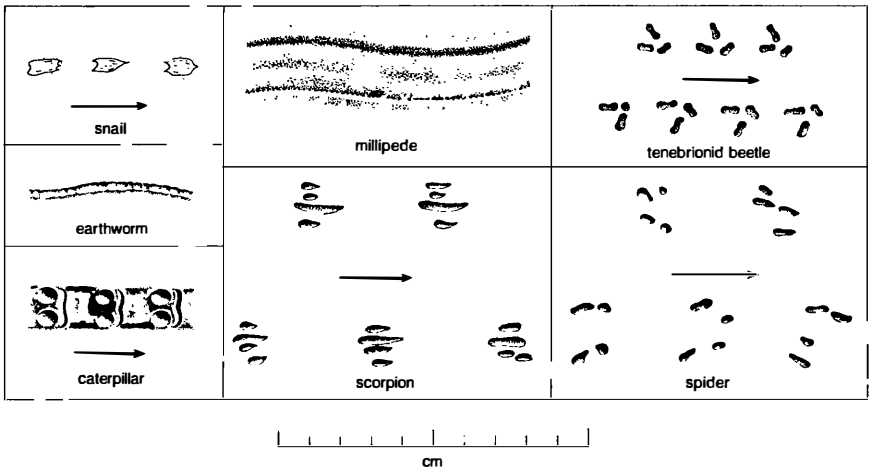
Movement and activities also change the shape of spoor. The feet may have slipped to create the impression of elongated toes. Twisting and dragging of the feet may partly obliterate some of the features. The forefeet and hind feet may be superimposed, so that the toes of one foot may be confused with that of another. When moving slowly an animal's toes may be

together, while they may splay out when running. The spoor also indicates whether the animal was lying, sitting, standing, walking, trotting, running or jumping. Different activities may be evident, such as digging, scratching, eating, drinking, mating or fighting. The condition of the animal may also be evident in the spoor. The spoor may also indicate whether the animal is still fresh, tired, or injured.

Spoor of invertebrates

The snail moves by waves of muscular contractions, moving from the front to the back of the foot. The contracting muscles push against the ground, thereby pushing the body forwards. The snail slides forward over the slime secreted by a gland at the front end of the foot, supported by the edge of the foot which acts like a ski (Kennis, 1969). The slime is usually still visible long after it has dried, and presents a shiny surface.

The earthworm moves by waves of muscular contractions which either contract or stretch out the body. When it contracts its body, the front end of the body is anchored by hairs that are pointing backwards, while the rear end slides forward. When it stretches out again, the rear end is anchored by the backward pointing hairs while the front end slides forward. To move backwards the worm points the hairs forward and simply executes the same movements (Kennis, 1969).



Examples of invertebrate spoor

The caterpillar moves in much the same way as the earthworm, but anchors the front end of its body with its true legs and the rear end of its body with the abdominal feet. The track usually shows the prints of the pair of abdominal feet on the last segment. The *Geometridae*, also known as loopers or measuring worms, crawl by looping their bodies when

the rear end is brought forward, and then stretching out the front end again (Potgieter, du Plessis and Skaife, 1971).

Millipedes have two pairs of legs to each segment and move slowly and steadily in an almost straight path. The legs move forward in waves starting with the front legs, as each leg is followed by the one behind it. Antlions always move backwards, tail first, with their bodies just beneath the surface of the sand. Their trails are visible as slight raised ridges on the sand, winding in all directions as they search for suitable sites for their pits. Insects, which have six legs, move the front and back legs of the one side together with the middle legs of the other side. Their trail is characterised by groups of three footprints on either side. The trails of scorpions, spiders and sun-spiders are characterised by groups of four footprints on either side of the trail. Those of scorpions are usually in tighter groups while those of spiders are more spread out.

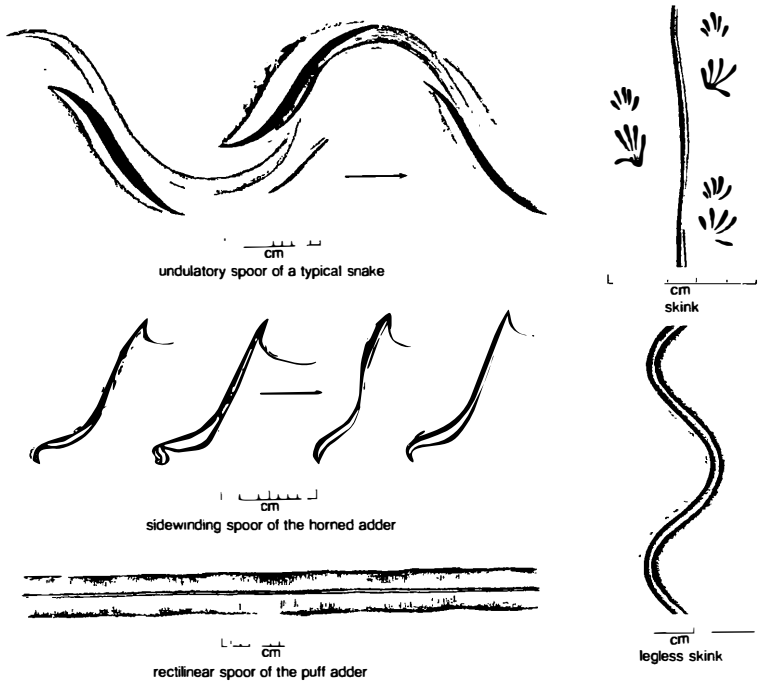
Spoor of Amphibians

The frog is adapted to the leaping mode of locomotion, mainly for leaping to safety in water. The individual bones of the hind limb are long, and when the frog is in the sitting position they are arranged in such a way that they form an efficient system of levers. Upon contraction of the appropriate muscles the entire limb is straightened, providing a powerful forward thrust enabling it to jump a considerable distance. In toads the skeletal components of the hind limb are less elongated so that they can only hop or run, while in some the legs are so reduced that they can only walk or crawl. Frogs and toads have four toes on each forefoot and five toes on each hind foot. In predominantly aquatic forms, which have webbing between the toes, the lever system type of hind limb makes them powerful swimmers (Potgieter, du Plessis and Skaife, 1971).

Spoor of Reptiles

The crocodile is amphibious and riparian and uses only the tail for propulsion when swimming. On land it walks slowly, lifting its body from the ground, and dragging its tail in the sand. It has five toes on the front feet and four toes on the hind feet, the first toe being absent (Potgieter, du Plessis and Skaife, 1971).

Although lizards are usually distinguishable from snakes by the presence of limbs, many lizards are limbless and resemble snakes in so many other respects that they cannot be distinguished easily. The fore and hind feet have five toes and although the limbs are generally well developed, many groups show a transition to complete absence of limbs. The digits also show a wide adaptation to environmental conditions and may be provided with sharp claws for running or climbing on rough surfaces, e.g. agamas and leguans, may be fringed or webbed for moving over soft, yielding sand, e.g. desert-living species, end in adhesive pads for climbing up smooth surfaces, e.g. geckos, or be bound together to form two opposable bundles for grasping, e.g. chameleons. Skinks, *Scincidae*, show every graduation from reduction



Spoor of reptiles

to complete absence of limbs, e.g. the legless skink (Potgieter, du Plessis and Skaife, 1971).

Lizards which have small limbs, progress by throwing the body from side to side, thus advancing first one of a pair of limbs and then the other. As the limbs develop in size and power, they take over an increasing proportion of the function of locomotion and the contortions of the trunk are reduced. Some lizards with large hind legs are quadrupedal when moving slowly, but at high speed the forelegs are too small to equal the stride of the longer pair, and the animal runs only on its hind legs, using the tail for balance. The legless skink "swims" through loose sand with an undulating progression in much the same way as snakes swim in water (Potgieter, du Plessis and Skaife, 1971).

Snakes use their bodies for locomotion in either rectinilear or undulatory progression. The fastest-moving species, such as the mambas, tree snakes and some of the grass and sand snakes, do not exceed 8 km/h. The majority of snakes cannot move more than about 6,5 km h, i.e. a man's brisk walking pace. Although the speed of strike appears to be very fast, it is only between 12 and 16 km/h (FitzSimons, 1970).

Rectilinear or caterpillar progression is in practically a straight line and is characteristic of heavy-bodied snakes such as pythons and adders when on

an unhurried, leisurely prowl. Forward movement is brought about by the belly muscles moving the large ventral plates forward in alternative waves to enable the overlapping posterior edges of the latter to obtain a hold on any roughness of the ground so that the body is drawn forward over them. Many burrowing snakes adopt a concertina variation of the caterpillar progression for moving along underground tunnels. Certain arboreal species, such as the Spotted Bush Snake and other tree snakes, have a broad belly and tail shields strongly keeled or notched, which enables them to crawl up almost vertical tree trunks by hooking on to the slightest of projections and pushing the body upwards by caterpillar progression (FitzSimons, 1970).

In undulatory or serpentine progression, movement is by a series of lateral undulations of waves from the front backwards, in which each outward bend or curve pushes up against an uneven or rough surface and pushes the snake forwards. This method of progression is normally effected by most snakes, as well as pythons and adders when moving fast, and is much faster than rectilinear or caterpillar progression. The sidewinding variation, in which the body is lifted up from the ground in undulating motions, is adopted by certain sand-living forms, such as Peringuey's adder and other small desert-living adders. Most snakes, except perhaps certain burrowing types, are excellent swimmers and move over the surface of the water in the same undulating, serpentine fashion as adopted on the ground. Movement for snakes depends on a rough or uneven surface or substratum, and forward movement is practically impossible on a very smooth or polished surface (FitzSimons, 1970).

Of the land tortoises, family Testudinidae, two species of padlopers, the Parrot-beaked tortoise, *Homopus areolatus*, and the Greater Padloper, *Homopus femoralis*, have four claws on the fore and hind feet. All other tortoises, including three species of padlopers, have five claws on the forefeet and four claws on the hind feet. When walking, each foot is lifted and set down on the ground at a different time. In the slow trot, diagonal front and hind feet are placed in pairs, with two feet always on the ground. Side-necked terrapins, family Pelomedusidae, are characterised by having five claws on the fore and hind feet. Soft-shelled terrapins, family Trionychidae, have only three claws on each foot. Sea turtles, superfamily Chelonioidea, have limbs that are modified into flippers, which retain only one or two claws. Sea turtles leave distinctive spoor in the sand when they come out of the sea to lay their eggs on beaches above the high-water mark (Branch, 1988).

Spoor of Birds

Structure of feet

A bird treads only on its toes and the metatarsus, which is the long bone nearest to the foot, never touches the ground when it is walking. The foot never has more than four toes, of which three usually point forwards and one is turned backwards. When compared to the foot of a mammal, it is

the fifth toe which has disappeared and the first which is usually turned backwards (Bang and Dahlstrom, 1972).

Some birds, like woodpeckers, *Picidae*, have the first and fourth toes behind and the second and third toes in front (zygodactylous). Trogons, *Trogonidae*, have the first and second toes behind and the third and fourth toes in front. The feet of swifts, *Micropodidae*, are weak and tiny, and the first to fourth toes are normally all in front, while birds like mousebirds, *Coliidae*, have the first toe reversible to the back or front (pamprodactylous). Some birds, like hornbills, *Bucerotidae*, have toes joined or partly joined at the base (syndactyl) (McLachlan and Liversidge, 1978).

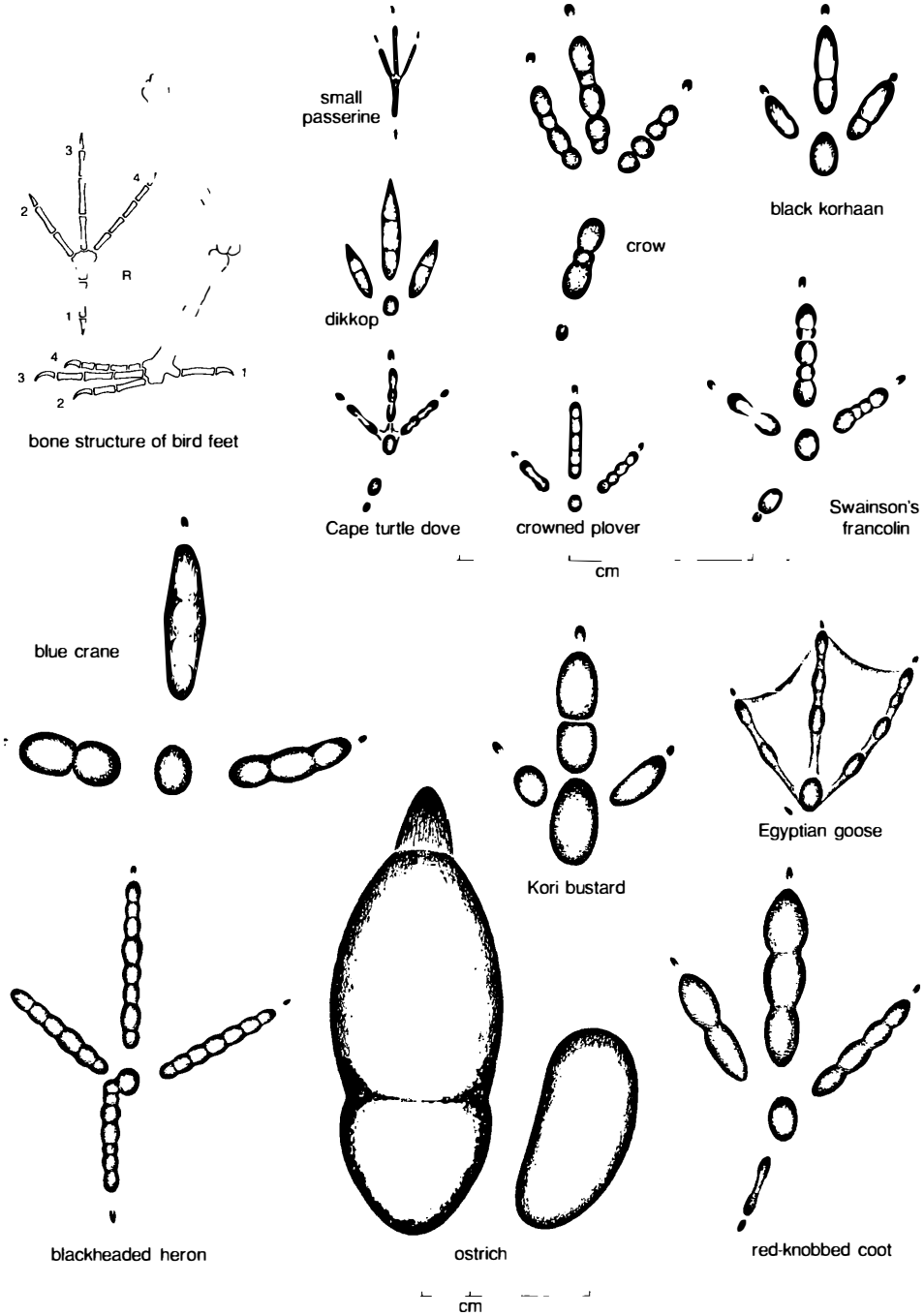
The third toe is usually the longest, followed by the fourth and the second. The first toe may be long, but is more often small and positioned so high that it leaves no mark in the track. Sometimes only the claw of the first toe leaves a mark. In some birds the first toe is completely absent, while the ostrich only has two toes on each foot, the third and fourth. The first toe consists of one phalange, and the second toe of two phalanges, the third toe of three phalanges and the fourth toe of four phalanges. The outermost joint of each toe carries a claw (Bang and Dahlstrom, 1972).

Types of feet

The passerines, which live mainly in trees and bushes, have feet adapted for perching. They have long pointed claws and a relatively long first toe which is opposable to the front toes, so that the foot can firmly grip a branch. They have long, slender front toes with an acute angle between the outer toes. Birds like woodpeckers have two toes at the back to act as braces to help them hold on as they peck at trees. Pigeons and doves have perching feet with long toes, but the angle between the outer toes is larger so that they are better adapted to walking. The crow has thick toes which are also suited for perching and walking. The feet of birds of prey are adapted for gripping their prey so that the powerful, sharp talons tighten reflexively when grasping their prey. The back claws of eagles are particularly powerful to kill their prey as they strike it.

The first toes of francolins and guineafowls are reduced so that they are better adapted to a terrestrial way of life, but still able to roost in trees. Since they spend most of their time on the ground, they do not need a long back toe that is required for an arboreal way of life and a short back toe is adequate for roosting. Their legs are powerful with thick toes that are widely spread and adapted for walking and running. They have strong, blunt claws which are well adapted for scratching for food in the ground.

Birds that are exclusively terrestrial, like korhaans and bustards, have no back toe, since they do not need one for perching and a back toe is disadvantageous for running. The three front toes are thick and strong, and the angle between the toes is smaller. This reduces the area of contact with the ground so that they are better adapted for running. They have strong, blunt claws for traction when running and also to help them scratch for food in the ground. Coursers and dikkops also have toes adapted for running.


small passerine
black korhaan
crow
dikkop
bone structure of bird feet
Cape turtle dove
crowned plover
Swainson's francolin
cm
blue crane
Egyptian goose
Kori bustard
blackheaded heron
ostrich
red-knobbed coot
cm

The ostrich, which is the fastest runner of all birds, only has two toes. While the small fourth toe is for balance when walking slowly, it is the large third toe with a thick, strong claw that is adapted for running.

Some birds, like plovers, have feet that are adapted for either terrestrial foraging or wading on shore-lines. The hind toe is either reduced or absent, and the three front toes are long and slender and widely spread to give them support in soft mud. While some, like the crowned plover, are mainly terrestrial, others, like the blacksmith plover and wattled plover, forage on dry land as well as on shore-lines, and others, like the threebanded plover, forage mainly on shore-lines. Cranes and storks are also adapted to terrestrial foraging or wading. Their hind toes are reduced and elevated, and the three front toes widely spread to give support and balance in soft mud.

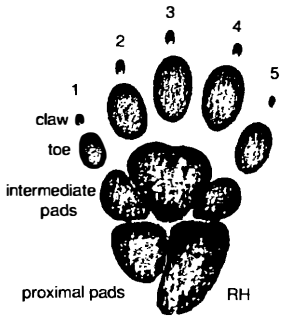
Wading birds have long, slender toes which are widely spread and therefore well adapted for walking on a soft substrate without sinking in. The first toe is usually small, as in the moorhen, but may be large as in herons, or completely absent as in the oystercatcher. The heron's long first toe is adapted for their arboreal habits, as it enables them to grip a branch. The jacanas have very long toes with long, almost straight claws, especially on the hind toe, to distribute their weight over floating vegetation.

The feet of the coot, finfoot and grebes are intermediate between those of waders and swimming birds. Their feet are very large with long front toes each of which have a series of lobate webs for swimming. Their hind toes are reduced. In swimming birds the surface of the foot is enlarged by a web which joins the three front toes in birds like ducks and gulls, and all four toes in birds like cormorants and pelicans. In swimming the toes are held apart so that the foot presents a large surface area when pushed backwards through the water. The toes are then folded together as the foot moves forward, so that it presents a minimum surface area and little resistance (Bang and Dahlstrom, 1972).

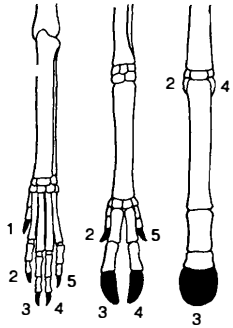
Spoor of Mammals

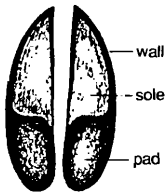
Structure of feet

The original primitive mammals had five clawed toes on each foot and they were plantigrade, that is, they trod on the whole sole of the foot. This primitive type of foot is found in some of the insectivores and rodents. In animals with five well-developed toes, they are numbered from one to five beginning with the inner toe, which corresponds with the thumb of the human hand. The third toe is the longest, followed in order by the fourth, second, fifth and first. If all five toes show in the footprint the inner toe is the shortest. In many cases the first toe only makes a weak impression, sometimes none at all, and the footprint will show four toes, with the outer toe the shortest. If all five toes are showing and the shortest toe is on the left side of the footprint, the track was made by the right foot. If only four toes are showing and the shortest toe is on the right side of the footprint, then the track was also made by the right foot (Bang and Dahlstrom, 1972).



porcupine





cloven hoof

water mongoose

large grey mongoose

white-tailed mongoose

murid

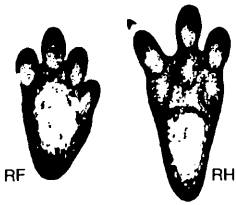
yellow mongoose

suricate

striped polecat

slender mongoose

bat-eared fox



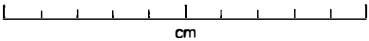
rock dassie

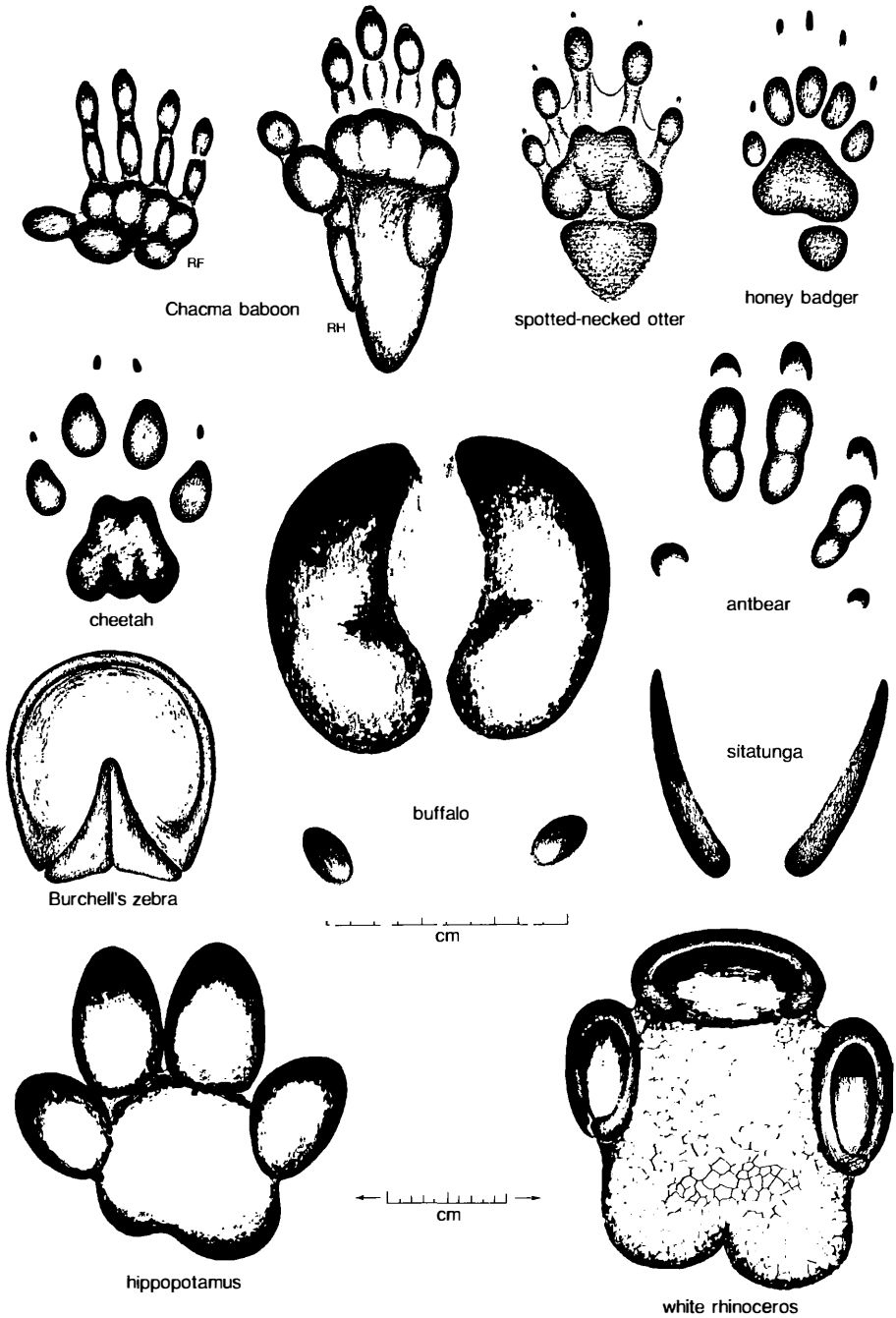
steenbok

common duiker

klipspringer

springhare




RF
Chacma baboon
RH
spotted-necked otter
honey badger
cheetah
antbear
sitatunga
buffalo
Burchell's zebra
cm
hippopotamus
cm
white rhinoceros

The underside of the feet are protected by pads which are thick, elastic masses of connective tissue covered by a strong, flexible, horny layer. The secretion from sweat glands in the pads is transferred to the footprint, giving it a scent. The pads themselves are naked but in most animals the skin between them is covered in hair (Bang and Dahlstrom, 1972). There is a toe pad beneath the tip of each toe, which is also known as a digital pad. Behind the toe pads there is a further row of pads, called the intermediate pads. The intermediate pads of the forefeet are also known as the palmar pads, while the intermediate pads of the hind foot are also known as the plantar pads. In many animals the intermediate pads are fused to form one large pad. In addition, some animals have one or two proximal pads, which lie further back on the foot. The proximal pads of the forefoot are also known as the metacarpal pads, while the proximal pads of the hind foot are also known as the metatarsal pads.

The skeletal structure of the forefoot consists of the carpal bones, metacarpal bones and phalanges while that of the hind foot consists of the tarsal bones, metatarsal bones and phalanges. While the first toe consists of two phalanges, the other toes each consist of three phalanges. Each toe of the forefoot articulates with a metacarpal bone, which in turn articulates with a distal carpal bone. The toes of the hind foot articulate with the metatarsal bones, which in turn articulate with the distal tarsal bones.

Primates, including humans, support their weight on the whole foot. Most mammals support their weight on the distal ends, or heads, of the metacarpal bones and the phalanges of the forefeet and the distal ends of the metatarsal and phalanges of the hind feet. Most ungulates support their weight only on the tips of the distal phalanges of the third and fourth toes.

Plantigrade animals have relatively short limbs and normally move at a steady pace, because the construction of their feet is not well adapted for jumping or for running any distance. An animal that runs fast and over long distances must have long limbs and the area of foot in contact with the ground must be as small as possible. In order to obtain a firm grip on the ground, the foot must exert the greatest possible pressure to dig into the ground. Since pressure is equal to force per area, for any given force, which depends on the mass of the animal and its acceleration, the contact area must be as small as possible to ensure the greatest possible pressure. Animals whose survival depends on their ability to run very fast, do so on their toes or on the tips of their toes. By the elongation of the limb bones they have evolved long slender legs, and at the same time there has been a reduction in the number of toes. The toes on which they support their weight have also become very powerfully developed. The most common reduction involves the first toe which may disappear completely so that the animal becomes four-toed. The second and fifth toes may be reduced, as in antelope, to form dew claws, while the weight is supported on the third and fourth toes. In the equids the third toe is fully developed and ends in a hoof, and only the vestiges of the second and fourth, the splint bones, are present (Bang and Dahlstrom, 1972).

In most mammals the prints of the forefeet are larger and broader than those of the hind feet (see Fig. 18). The toes of the forefeet are usually also more splayed than those of the hind feet. This is because the forefeet need to cover a larger area to support the head and forequarters of the body, which are usually heavier than the hindquarters. Some mammals, such as rodents and otters, have larger hind feet because the hindquarters are more massive than the head and forequarters. The forefeet are rounder in shape than the narrower hind feet, because the forelegs are almost perpendicular to the ground and the hind legs are at an angle to the ground. A cylinder that is perpendicular to a plane has a circular cross section, while a cylinder that meets a plane at an angle has an elliptical cross section.

Types of Feet

The feet of most insectivores and rodents are protected by small round pads while the thin, sharp claws are an adaptation to climbing. So, for example, squirrels are able to climb up a vertical tree trunk by digging their sharp claws into the bark of the tree. Hedgehogs and porcupines have larger pads to support their more massive bodies. While the claws of the forefeet of the porcupine, canerats and spring-hare are well adapted for digging, the broad pointed claws of the hind feet of the spring-hare are adapted for throwing the loosened soil clear of the excavations.

All predators have well-developed pads which are adapted for stealth. Some also have well-developed proximal pads to give them support on soft muddy ground. This can be seen in some of the mongooses. The mongooses can be arranged from the relatively primitive to the relatively specialised according to the genera: *Herpestes*, *Galerella*, *Atilax*, *Helogale*, *Mungos*, *Ichneumia*, *Rhynchogale*, *Bdeogale*, *Paracynictis*, *Cynictis*, *Suricata* (Hinton and Dunn, 1967). The relatively primitive mongooses, like the large grey mongoose and the watermongoose, have well-developed proximal pads on the forefeet and the first toe is present, which gives them support on soft muddy ground. The proximal pad and the first toe gradually disappear towards the relatively specialised mongoose. So, for example, the proximal pads and first toes of the white-tailed mongoose have become redundant and do not show in the spoor, except for the first claw of the forefoot that marks clearly. The relatively specialised mongooses only show four toes, with no proximal pad, in the spoor. While some, like the yellow mongoose, have five toes on the forefoot and four on the hind, others, like the suricate, only have four toes on the fore and hind feet. The area of the feet in contact with the ground becomes less as they are adapted to drier or more arid conditions. Otters not only have well-developed proximal pads to give them support on soft muddy ground, abut also have webs between the toes for swimming.

While some mongooses, like the slender mongoose, have thin sharp claws for climbing trees, many mongooses, as well as the suricate, striped polecat, honey badger and bat-eared fox have long, strong claws on the forefeet adapted for digging. Some predators, like wild dogs and cheetahs, which

hunt in open terrain and rely on their speed to capture their prey, have short, blunt claws which act like spikes to prevent slipping. Some, like the cheetah and caracal, have ridges under the intermediate pads to give them additional traction. Most of the cats rely on stealth to stalk their prey in terrain that provides adequate cover. Even though the claws may be protracted to prevent slipping while charging, they cannot maintain high speeds, so they embrace their prey and hold it with their sharp claws, to stop it from getting away, until the killing bite can be delivered. When not in use, their sharp claws are retracted into sheaths to protect them from wearing down. The claws are protractile rather than retractable since their normal position, with the muscles at rest, is retracted within the sheaths while they are extended by the ligaments when required (Smithers, 1983).

The padded feet of the rock dassie allows it to negotiate steep and often smooth rocky surfaces. The soles of the feet are naked, the skin thick and padded with glandular tissue which keeps the surface permanently moist. The toes are short, ending in hoof-like nails. The inner toe of the hind foot has a curved grooming claw (Smithers, 1983). Hares lack pads which are replaced by a tight, springy layer of strong stiff hairs (Bang and Dahlstrom, 1972). While the claws prevent slipping, the hairs muffle the sound of the feet as they run. The dense growth of hair in the sole of the foot tends to obliterate the characteristics of the footprint.

The hands and feet of primates are adapted to grasping branches and are ideally suited for an arboreal way of life. This also enables them to hold their food while sitting in trees and has made the use of tools possible. Bushbabies have grooming claws on the second toes of their hind feet (Smithers, 1983). Antbears and pangolins have well-developed, strong claws for breaking open and digging into termite nests.

The feet of elephants, rhinoceroses and hippopotamuses are mainly adapted to support their massive bodies. Rhinoceroses and hippopotamuses have large broad toes to increase the area of their feet in contact with the ground. Elephants have springy feet which consist of a mass of soft muscles and ligaments, enabling them to move very silently (Lyell, 1929).

Equids only have one toe, the third, on each leg and only tread on the outermost toe joint which has a well-developed hoof. A hoof is a modified claw, and the wall of the hoof usually extends a short distance beyond the sole. In soft sand the toe pad, or "frog", shows clearly in the spoor. In tracks on very hard substrates only the edge of the hoof will appear in the footprint, as is also the case with animals with cloven hoofs. Hoofs are an adaptation for speed which is essential for the survival of an ungulate.

Ungulates with cloven hoofs have four toes, the first toe being absent, but they only tread on the tips of the third and fourth, which are well developed. The second and fifth toes, the dew claws, are much smaller and are at the rear of the foot. They are usually positioned so high up on the leg that they do not touch the ground, except when the animal treads in soft mud. The hoof consists of the wall which encloses the sole and the toe pad behind the sole. In very distinct tracks the toe pad may appear as a round depression.

In some cases it extends to the tip of the hoof. The impressions of the two halves of the hoof are usually almost mirror images of each other, but when they are not the same size the inner hoof is usually the shorter. The track made by the forefoot is larger and more splayed than that of the hind foot and when moving fast the front hoofs splay even more.

Apart from random variations, the shape of hoofs are adapted to different conditions. The more massive ungulates, such as buffalo and eland, have broad round hoofs, while the lighter antelopes have slender, narrow hoofs. Very sharp, pointed hoofs are an adaptation for speed, especially on soft, sandy substrate, and act like spikes to prevent slipping. Steenbok, oribi and springbok which prefer open terrain, have to rely on speed to escape being captured, and have sharp, pointed hoofs. Larger antelope, like gemsbok, which prefer open country, have hoofs that are broad to support their massive bodies, but pointed for speed, especially in soft sand. On the other extreme, the klipspringer has small rounded hoofs which are adapted for agility in rocky terrain. The small, rounded hoofs not only ensure a firm foothold on rocky surfaces, but also enable the klipspringer to abruptly change direction as it swiftly leaps from rock to rock.

Many variations occur that vary from sharply pointed to rounded hoofs. While specialisation, such as adaptation for speed in open terrain or agility in rocky terrain has advantages, it also has disadvantages, for as more efficient performance is gained for a given function, efficiency in performance of alternative or complementary functions is lost. In contrast, a generalised form preserves a more or less versatile balance in performing various functions, although less efficiently in each case than forms specialised for each alternative. So, for example, the heart shaped hoof, such as that of the duiker, bushbuck and kudu, is not as specialised, but more versatile. These antelope rely more on cover to escape detection, and when detected rely on a combination of speed and agility to swiftly find their way among bushes and other obstacles. For the smaller duikers very sharply pointed hoofs may be a disadvantage as they tend to fork up leaves in their forest habitat. Hoofs that are too rounded may slip on the leaves.

Another specialised adaptation is the long, slender, widely splayed hoofs of the sitatunga, which are adapted to soft muddy substrate. Due to surface tension, toes that are splayed out distribute the weight over a larger area. The toes of reedbuck may be close together on firm substrate, but splay out in soft mud.

Indirect Identification of Spoor

Apart from direct interpretation of the spoor itself, indirect interpretation based on the context within which the spoor is found may help to determine the identity of the animal in question. If a spoor could be that of any one of several similar species, those that do not occur in that locality may be ruled out. The type of terrain in which a spoor is found can also narrow down the possibilities, since it can be expected that the spoor of an animal will usually be found in its preferred habitat. Some animals are found only near lakes,

marshes or rivers, while others prefer arid conditions. Some are adapted to open plains, some to closed woodland, some to forests and others to rocky hillsides or mountain slopes. When tracking an animal it can be expected that its movements will be confined mainly to its preferred habitat. The habits of animals may also help to determine their identity. If an estimate of the age of the spoor can be made, for example, whether before or after dew was formed, it may be determined whether it belongs to a nocturnal or diurnal animal. If it is known whether that animal occurs solitarily, in pairs or in groups, it can be expected that their spoor will indicate their numbers accordingly. Any habit that is characteristic of a species may help to identify that species by its spoor.

Interpretation of Activities

Apart from identifying animal tracks and being able to follow a trail, trackers must also be able to interpret the animal's activities so that they can anticipate and predict its movements.

Lying, sitting and standing

When an animal has been lying down, this may be indicated by imprints made by its body and its legs folded underneath the body. Where an animal has been lying down in grass, the grass will be flattened out in the shape of its body. The sitting position is usually indicated by the hind limbs showing right up to the heels with the imprints of the forefeet in between and the tail showing behind. Some animals, like suricates, may sit on their haunches or stand up on their hind feet, supporting themselves with their tails. When standing, the feet are usually apart and pointing slightly outwards, especially the forefeet.

Gaits

When footprints are neat and clear, showing all the fine detail they could possibly show, this usually indicates that the animal was standing still or moving slowly. If the animal was moving fast, the toes would have splayed, the feet might have slipped, sand might have been kicked up and the footprint may be partly obliterated. The direction of movement and the length of the stride may be indicated by the depth and angle of the imprint together with the direction in which the sand was thrown. These signs may be particularly important when tracking animals like the spring-hare, whose tracks may be several metres apart and do not follow a straight course. The length of the stride indicates the speed of the animal, while the positions of the tracks relative to each other reflects the animals' gait * (Fig. 26). The positioning of many animal tracks is so characteristic that the animal that made them can be identified without looking at the individual footprints. In cases where footprints are indistinct and show no details, identification may depend entirely upon the relative positions of the tracks.

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* NOTE: References used for this section on gaits are: Bang and Dahlstrom, 1972; Encyclopaedia Britannica, 1963.

Walking

When walking, each of the four feet is lifted and set down on the ground at a different time, each limb moving separately. The legs are moved in a definite order: the right foreleg is followed by the left hind leg, which is followed by the left foreleg, which is followed by the right hind leg, and so on. The hind foot is always placed close to the point where the forefoot was placed, so that its track is made a little behind, right over or just in front of the track of the forefoot, depending on the speed the animal was walking. Where the forefoot track is covered by that of the hind foot, the tracks are said to register.

When walking slowly, the hind foot track will be behind the forefoot track, and when walking fast the hind foot track will be in front of the forefoot track. In the slow walk, only one foot is moved at a time, with three feet always on the ground. This is the normal walk of heavy animals such as buffalo and rhinoceroses, while antelope move in this way while grazing. In the normal and fast walk of most animals, two feet are in motion at the same time, each foot being followed by the next one when it is halfway through its stride, while two feet are always on the ground. In the running walk the tempo is so fast that in some phases only a single foot is on the ground at a time. The running walk is not as speedy as the trot and few animals adopt it naturally, except the elephant, whose only speedy gait it is. The centre of gravity is shifted with each footfall, or four times in each cycle, so that it is a tiring gait at speed.

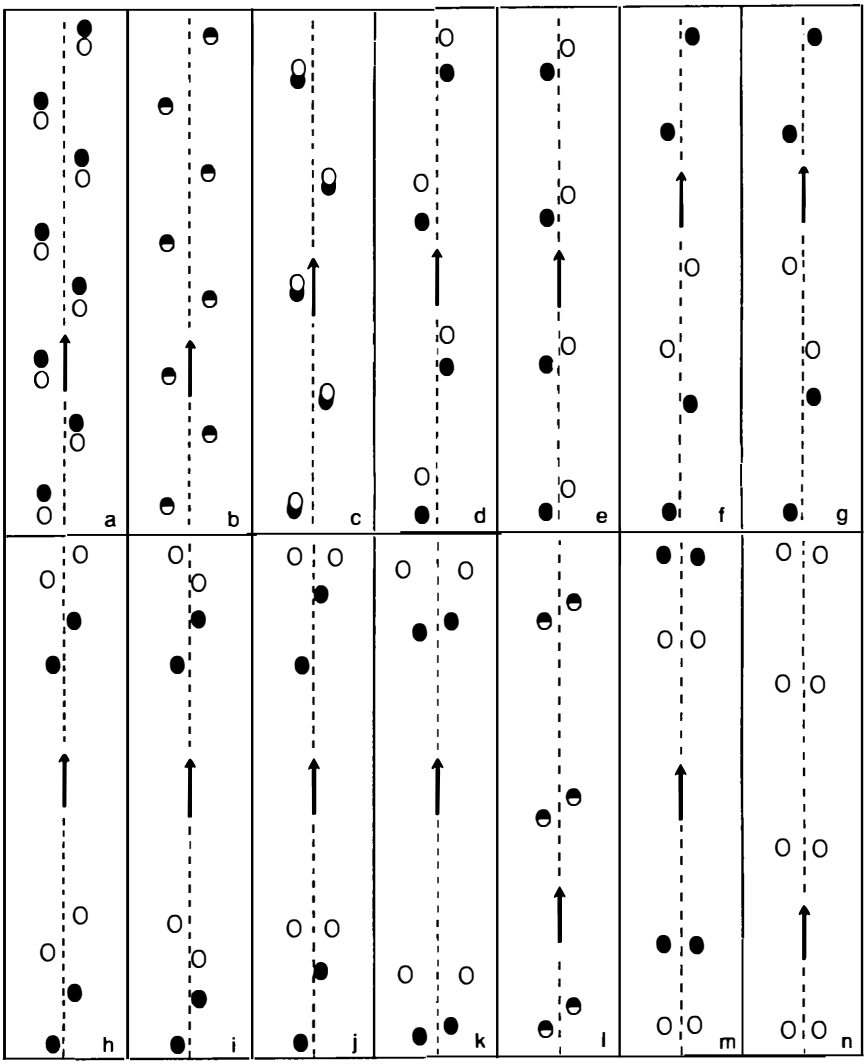
Pacing

When pacing, the foreleg and hind leg of the same side move at the same time. At a walking speed, this gait is used by antelope like springbok and blesbok. For animals whose legs are very long in proportion to their bodies, it has the advantage that the forelegs are never in the way of the hind legs. At a fast trotting tempo, it is used by camels, some dogs and occasionally horses. Horses can also be taught to pace.

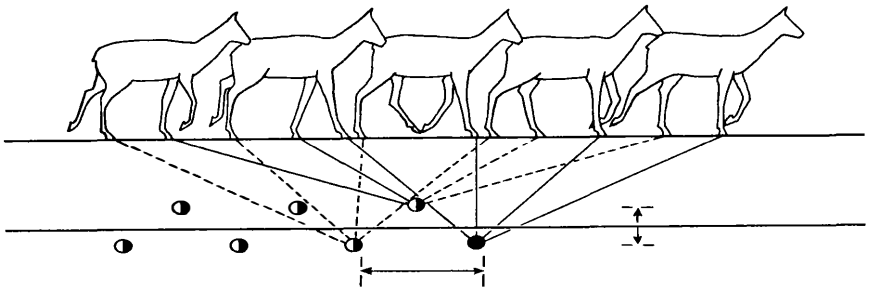
Trotting

When trotting the diagonal feet are placed in pairs at the same time. For example, the right forefoot and left hind foot are lifted and set down at the same time, and then the left forefoot and right hind foot. With the slow trot two feet are always on the ground. This is used by sluggish or clumsy animals such as tortoises and badgers. With the fast trot there is an interval of suspension with no feet on the ground. The animal's centre of gravity moves along in a more or less straight horizontal line, and little or no energy is expended in lifting the body with each stride. At a given rate of travel trotting is the least energy-consuming and least tiring gait.

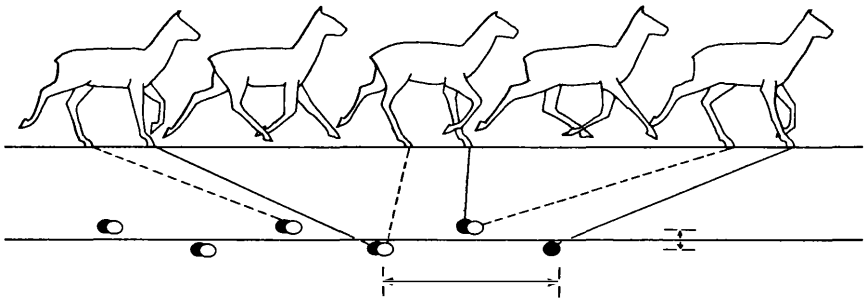
The trail is very similar to that produced by walking, but the stride is greater and the straddle less. The length of the stride is the distance between two successive tracks from the same foot, and the straddle is the distance, at a right angle to the direction of motion, between the left and right tracks.



Relative positions of footprints for different gaits. The fore-foot tracks are indicated by black dots and the hind-foot tracks by white dots. Where the hind-foot tracks register on the fore-foot tracks it is indicated by a half-black and half-white dots. (a) slow walk (b) normal walk (c) trot (d) fast trot (e) trot with obliquely positioned footprints (e.g. foxes, jackals and some dogs) (f) transverse gallop (g) lateral gallop (h) transverse jump or bound (i) lateral jump or bound (j) half bound (k) jump with hind-feet tracks side by side (l) jump with hind-feet tracks registered in fore-feet tracks (m) stotting (n) bipedal hops (After Bang and Dahlstrom, 1972)



WALKING: 1 The right hind-foot is placed in the track of the right fore-foot, which has just left the ground, when the right fore-foot is half way through its stride, the left hind-foot leaves the ground, while the other two feet are on the ground. **2** The right fore-foot is placed on the ground, while the left hind-foot is half way through its stride. **3** The left fore-foot leaves the ground just before the left hind-foot is placed in its track, while the animal is supported on the other two legs. **4** The left hind-foot is placed on the ground while the left fore-foot is moved forwards. **5** The right fore-foot is lifted, while the left hind-foot and right fore-foot are on the ground. The position is as in No.1, but with the opposite feet. The left fore-foot will be placed on the ground, followed by the right hind-foot, and so on. (After Bang and Dahlstrom, 1972)



TROTTING: 1 With the left fore-foot and right hind-foot already off the ground, the animal takes off from the right fore-foot and left hind-foot. **2** While the animal is in the air, the left fore-foot and the right hind-leg are moved forwards. **3** The left fore-foot and the right hind-foot are placed on the ground simultaneously. The right hind-foor registers approximately in the track of the right fore-foot. **4** The animal is again in the air while the right fore-leg and the left hind-leg now move forwards. **5** The right fore-foot and the left hind-foot are placed on the ground. The left hind-foot registers approximately in the track of the left fore-foot. (After Bang and Dahlstrom, 1972)

The faster an animal trots the greater is the stride and the smaller is the straddle, so that in a very fast trot the tracks of the right and left side almost lie on a single line. On firm ground the hind foot usually strikes the ground in front of the tracks made by the forefoot, and the faster the speed, the further in front it is.

Some animals, like foxes, jackals and some dogs, leave a trotting tail in which both forefoot tracks lie on one side and both hind foot tracks on the other side. The trail consists of a row of obliquely positioned pairs of footprints, each of which consists of a forefoot track with a hind foot track placed obliquely forwards and to one side. This trail is due to the fact that the animal trots with its body positioned at an angle to the direction of travel so that the forelegs are never in the way of the hind legs. Now and again it may shift the rear part of its body to the other side.

Galloping

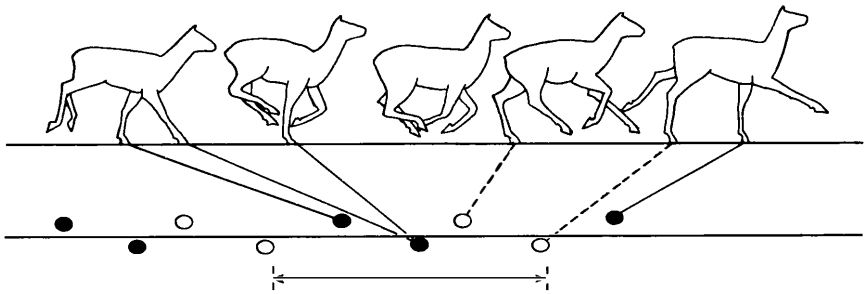
The gallop is the fastest gait of most of the larger mammals. In contrast with the jump, all four limbs take part in moving the animal forward. As in the jump, there is a phase in which the animal is airborne, but in contrast to the jump the animal usually takes off from the forelimbs. The four legs work in quick succession one after the other. The footfall sequence varies with the speed or kind of animal. In the transverse gallop either one of the hind feet is followed by the other and then by the diagonal forefoot, followed by the other forefoot. In the lateral gallop either one of the hind feet is followed by the other and then by the forefoot on the same side, followed by the other forefoot. An animal may lead with either front foot or change from one to the other. Animals like horses, rhinoceroses, goats, sheep, cattle and cats seem to prefer the transverse gallop, while the lateral gallop is favoured by dogs, deer, antelope and giraffe.

Bounding

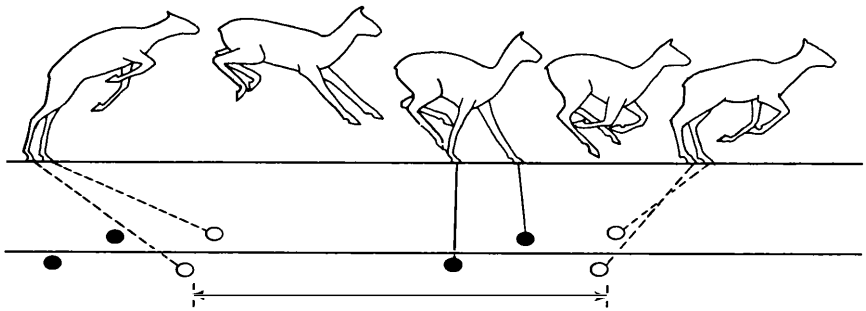
As the speed of the gallop increases the gait becomes more like a jump. The bound is a fast gait intermediate between a gallop and a jump, in which the take-off by the hind limbs lifts it from the ground and propels it into the air. Mammals with short legs or long, limper bodies use the hind legs close together or even employ them as a unit to accomplish the half bound or the bound, but the forefeet are used separately. There are many possible transitions between a jump and a gallop so that it is not possible to define any sharp boundary between them.

Jumping or Hopping

In jumping or hopping the animal is momentarily airborne, taking off with both hind legs so that it is projected forwards in an arc, landing on the forelegs, which usually hit the ground one a little in front of the other. The forelegs carry the animal a short distance forwards, and then leave the ground again. The hind legs then land a little in front of the forefoot tracks. A jumping trail consists of groups of four footprints. The two forefoot tracks will lie close to each other, with one a little behind the other, and



GALLOPING: 1 The animal is supported on the fore-legs, but is shifting its weight from the left fore-leg to its right. The hind-legs are moving forwards. **2** In the take-off the weight of the animal is supported only on the right fore-foot. **3** The animal is in the air while the hind-legs move forwards. **4** The left hind-foot touches the ground, while the other legs move forwards. **5** The animal is supported on the right hind-leg and left fore-leg, but as the right fore-foot is placed on the ground, the hind-legs will move forwards as in No.1. (After Bang and Dahlstrom, 1972)



JUMPING: 1 The animal pushes off from the hind-legs. **2** The animal is in the air with the fore-legs stretched out before landing. **3** The right fore-foot reaches the ground a fraction before the left fore-foot, after which the fore-feet leaves the ground again. **4** The animal is in the air with all four legs tucked up under it. **5** The hind-legs reach the ground and start a new jump. (After Bang and Dahlstrom, 1972)

in front of them the hind foot tracks will lie more or less side by side. In some animals one or both of the hind feet may register in the tracks of the forefeet. Jumping or hopping is the commonest gait of many small animals with powerful hind legs, such as small rodents.

Stotting

Stotting is performed by animals such as springbok and oribi when they are under stress or being chased. The back is arched and the legs held stiffly downwards as it leaps off the ground. It lands on all four legs simultaneously and then shoots up into the air again, repeating it several times. During stotting the white dorsal fan is fully exposed, which may act as a signal to other members of the herd (Smithers, 1983).

Bipedal hop

In the bipedal hop both hind feet are used in unison while the forefeet are held close to the body. A long tail is usually used for balance. This gait is used by mammals with powerful hind legs and reduced forelegs, such as the spring-hare and the bushbaby. In the trail the tracks occur in pairs. On the ground, the smallest passerines, such as tits and sparrows, normally move by hopping, so that their tracks usually occur in pairs. Medium-sized species, such as thrushes, and larger passerines, such as crows, walk as well as hop.

Bipedal walk and run

Bipedal walking, in which the hind legs are used alternately, produces tracks in a zigzag or sometimes in a straight line. When running, the length of the stride is greater than in walking, but the straddle is less. All terrestrial birds walk or run. With some birds, like plovers, the toes are widely spread when walking, but when running the toes are closer together. Some lizards run only on their hind legs, using the tail for balance. Except for humans and pangolins, mammals do not normally employ the bipedal walk or run. Monkeys, baboons and other primates may use it momentarily, sometimes while carrying something.

Actions

Apart from specific gaits, the various actions of the animal may also be indicated by the tracks. Signs of digging may be characteristic of the species, such as the distinctive claw-marks made by the spring-hare or the antbear, or the narrow hole dug by the bat-eared fox. The type of food dug out, whether roots, bulbs or termites, may indicate the animal involved. Animals like baboons turn over rocks to look for insects, spiders or scorpions, or pull up clumps of grass and shake off the soil before eating them. Feeding signs of specific animals may not only indicate what they were feeding on, but also how they were feeding. The methods of handling food may also be characteristic of a species.

Grooming activities may be indicated by the position in which the animal was sitting to scratch itself. Signs of rolling on the ground may be evident

where an animal was having a dust-bath or where it was wallowing in mud. Animals like rhinoceroses rub themselves against logs which become well worn after a time of repeated use. Territorial male antelopes may demonstrate threat by pawing and horning of shrubbery. Ground horning in moist, soft ground may also be carried out by some antelope.

To interpret activities, the tracker must visualise the actions of the feet that created the various disturbances of the ground in and around the track. Signs that the animal's feet pushed into the ground may indicate a sudden stop in a sidestep. A smooth shallow hill outside the print may indicate pressure exerted both downward and in the direction of the dome as the result of a sudden launch, such as when the animal jumps or leaps. Dirt spreading out in front of the tracks usually indicates a fast gait, or when it spreads out behind the track, indicates rapid acceleration. If it is spread out in a circular pattern around the track, it indicates a sudden whirl or pivot. Drag marks at the front or back of tracks may indicate fatigue, injury or high speed. Slide marks may indicate that the animal was sliding to a sudden stop. On muddy surfaces or on a slope there may be slip marks. Virtually all conceivable actions leave distinctive markings which may make it possible for the tracker to reconstruct the animal's activities (Brown, 1983).

Determining the age of spoor

One of the most difficult aspects of spoor interpretation is determining the age of spoor. Only a very experienced tracker can determine the age with reasonable accuracy, while absolute accuracy is probably impossible. Although the age of spoor is usually determined by means of visual signs, scent and taste may also give an indication of spoor age. Australian aborigines, for example, smell the tracks to tell how fresh they are, and the Akoa lay their tongues on the compressed earth to taste how fresh elephant tracks are (Coon, 1971).

The distance the animal may be from the spoor under observation does not only depend on how old the spoor is, but also how fast the animal has been moving. If the animal has been moving fast, even a fresh spoor may not be worth pursuing, since the hunter may never catch up with the animal. On the other hand, a spoor may be old, but the animal may have lain down to rest not too far away and may still be in the near vicinity. A fresh spoor of an animal that has been browsing, moving slowly from bush to bush, will make an ideal quarry to track down.

When making an estimate of the age of the spoor and the speed at which the animal was moving, it is important to decide whether or not the animal may be close enough to pursue, and whether or not the animal may be close enough for it to see, hear or smell the hunters approaching. If the animal is too far ahead to catch up, a lot of energy will be wasted in fruitless pursuit. If the animal is close enough to pursue, but not close enough for it to detect the hunters, the hunters do not have to worry about moving stealthily and can move ahead as fast as possible to catch up with it. At this stage moving

stealthily will only waste time, in which case the hunters may never catch up with the animal. However, if the animal is very close, the hunters must move stealthily, communicate with sign language and look ahead of them so that they will see the animal before it sees them. Although a reasonable estimate of the age of spoor is important, absolute accuracy is not necessary, since hunters can make allowances for any inaccuracy.

A reasonably accurate way of determining the age of spoor is possible when an animal has been resting in the shade of a bush. The position of the marks on the ground where the animal was lying or standing indicate where the shade was, and therefore what the position of the sun was, so it is possible to calculate from the movement of the sun when the animal rested (Grainger, 1967).

During the hotter hours of the day animals usually stand in the shade or some, like blesbok and bontebok, may on hot days stand in orientated groups facing the sun. On cold mornings some animals, like the Cape mountain zebra, stand with their bodies at right angles to the sun's rays, or during heavy rainstorms, they stand with their backs to the rain. At night animals will stand or lie out in the open without being orientated in any way. The various positions and situations in which the tracks of a standing animal may be found may all give an indication of when the animal was standing there. If the tracks of a moving animal go under the west side of some trees, it indicates that the animal might have caught the morning shade. If the tracks go under the east side, they might have caught the afternoon shade. If they go under either side, the animal might have been moving at midday (Lee, 1979).

When studying the ageing processes of spoor, a tracker can only make an intuitive estimate of the age. In some cases, where the ageing process is relatively rapid, it is possible to make a reasonably accurate estimate of the age of spoor. However, due to the complexity of factors involved, an accurate estimate is usually not possible, especially where the ageing processes are slow and may vary considerably depending on the circumstances. An intuitive estimate also becomes less and less accurate for older spoor (see Chapter 6).

Heat and humidity, which determine the rate at which moisture content is lost, may vary considerably depending on the time of the day, the prevailing weather conditions and the season. Spoor age faster in the heat of the day than during the cooler part of the day or night. On a hot, dry day spoor will age faster than on a cool, humid day, so the rate of ageing may vary considerably from one season to another.

Wind not only increases the rate at which moisture is lost, but also has an eroding effect. The rate at which wind changes a spoor will not only depend on how strong it is blowing, but also how long it was blowing. A strong wind that drops after a short while may have the same effect as a slight breeze that blows for a long time. Tracks made in shade and shelter will also be less affected by the sun and wind The rate at which the wind

erodes the spoor also depends on the soil hardness (Brown, 1983). A spoor in hard soil or clay may be eroded more slowly than a spoor in soft sand.

The most accurate indications of spoor age are provided by signs that involve rapid moisture loss, since these signs change relatively rapidly in the early stages. Examples of such signs are saliva on the leaves or on the ground where the animal has been feeding or licking for salt, fresh urine and droppings, and water that has been splashed on the ground next to waterholes or rivers.

A damp patch of urine, which may have a white foam when very fresh, dries into a hard crust of sand. Droppings, which are covered with mucus when very fresh will still be sticky when reasonably fresh and dry from the outside as they get older. In the case of large animals, such as elephants, fresh droppings will also be warm and may stay warm inside for a while (Grainger, 1967). Colour changes may depend on the animal's diet and may vary from one animal to another. Droppings also shrink when they dry out. The time it takes for droppings to dry out depends on the initial moisture content, which will be more when the animal has been eating green grass than when it has been eating dry grass, and may therefore also be less in the dry season than in the rainy season. The rate of drying out will also depend on the heat and humidity, as well as the wind. Urine and droppings will also take longer to dry out in the shade or in a sheltered spot. While the rate of change is relatively rapid in the early stages, once dried out the ageing processes are much slower and therefore much more difficult to estimate. Eventually the hard crust of sand formed by urine will start crumbling, while dried out droppings will slowly pulverise.

Another sign that changes rapidly in the early stages is created when an animal walks through a river or a puddle of water, or steps into the water when drinking. As the animal steps out of the water, its wet feet will leave wet footprints and splash marks that may dry out at a very rapid rate, depending on the heat, humidity and wind. In direct sunlight the water may evaporate within minutes. Where the animal has stepped into the water, some silt may be stirred up which may take quite a while to resettle (Robbins, 1977). In muddy ground, tracks may dry out in a very short time or may remain wet for a long time, depending on the moisture content of the ground and the weather conditions. Usually the elevated edges of the footprints dry out first, while the deepest hollows of the track remain moist longest. In very moist ground, water may run down and collect in the deepest part of the track, where it may remain for a very long time. Wet ground can be very misleading as any spoor remains visible and looks fresh for a considerable time. Once dried out, footprints may retain their fresh, sharp appearance for a very long time, so it will be very difficult to make an accurate estimate of their age (Grainger, 1967).

The rate at which the wind erodes a spoor is usually difficult to estimate, because it may vary considerably depending on how strong and for how long the wind was blowing. It may also be complicated by wind that has not been blowing constantly. Fresh footprints will have sharp edges which

will be rounded off by the wind. Footprints will lose definition and leaves, seeds and loose sand will gather in them. Leaf spoor, created by leaves rolling in the wind, may also be superimposed on the tracks.

The rate of discolouring of spoor is also difficult to estimate, since changes may be very subtle and the rate of change may be very slow. Fresh footprints expose the darker colour of the ground beneath the surface, which will gradually change to the colour of the ground on top as it is exposed to the sun. When stones and leaves are overturned, their darker undersides will be exposed, which will also gradually become lighter in colour. Broken vegetation will discolour at the break, and the rate of change may differ for different types of vegetation as well as the prevailing weather conditions. To get an indication of the colour change, a new break may be made and compared with the old break. Leaves may be knocked down by a moving animal, or dropped by a feeding animal. These leaves may still be green when they have been dropped on the ground and will discolour as they dry out. Apart from being bruised or broken, the amount of springback of a flattened tuft of grass may also give an indication of when it was stepped upon (Robbins, 1977).

The activities of an animal may give an approximate estimate of the age of spoor if its habits are known. If an animal is either diurnal or nocturnal, the tracks will have been made either in the day or the night. During the midday heat an animal may rest up in a dense thicket, or at night it may sleep out in the open. Animals may go to waterholes or pans at specific times of the day, and move to their favoured grounds according to a set routine.

With a detailed knowledge of the habits and movements of other animals, the relative age of a spoor may be indicated by superimposed animal spoor. If the spoor of a nocturnal animal is superimposed on the quarry's spoor, the quarry's spoor was probably made during the night or the previous day. Furthermore, if the quarry is diurnal, then its spoor will have been made the previous day. If the quarry's spoor is superimposed on a nocturnal animal's spoor, the quarry's spoor was probably made during the night or earlier that same day, and if the quarry is diurnal, it would have been made that same day. In the process of tracking the quarry, the spoor of several animals may be found either superimposed on top of the quarry's spoor, or the quarry's spoor superimposed on the spoor of other animals, so that an upper and lower limit for the age of the quarry's spoor may be determined. The quarry's spoor may be superimposed on footprints of animals going towards a waterhole, but the footprints of animals going away from the waterhole may be superimposed on that quarry's spoor, indicating that the quarry's spoor was made at about the time the animals went to the waterhole (Grainger, 1967). If the pit of an ant-lion larva is stepped on, it will reconstruct it. If the pit inside a footprint is still being reconstructed, it may give an accurate indication of how old the spoor is. Spoor that are most commonly superimposed on footprints are usually those of mice and

insects (which may be either diurnal or nocturnal) and small birds (which are diurnal).

Apart from indicating the age of the quarry's spoor relative to that of other animals, it may also indicate the age of its spoor relative to an alternative quarry. For example, while tracking down a gemsbok, hunters may find the spoor of a wildebeest superimposed on that of the gemsbok, and they may then decide to rather follow up the fresher wildebeest spoor.

Dew, mist and rain may also give an indication of the relative age of spoor. If dew has fallen on top of the spoor, the spoor was made during the night or the previous day, while spoor on top of the dew would have been made earlier that same day. Dew dripping from branches may also form pock marks in spoor made during the night or early morning. Spoor through long grass, made before dew or rain, will be covered with drops. If made after dew or rain, the drops will be shed off. If rain or mist has fallen since the track was made, there will be pock marks in the tracks. Conversely, if a track was made after rain or mist have fallen, there will be pock marks around but not inside it. Heavy ground fog will also smooth down spoor and leave pock marks under leafy branches (Grainger, 1967).

Although superimposed animal spoor, dew, mist or rain do not give an indication of the actual age of the spoor, they give an indication of the chronological sequence of a series of events. As more information is gathered, trackers may revise their hypotheses to create a more detailed sequence of events, combining information on the animal's own activities with information on when these occurred relative to other animals' activities.

Reconstruction of Activities

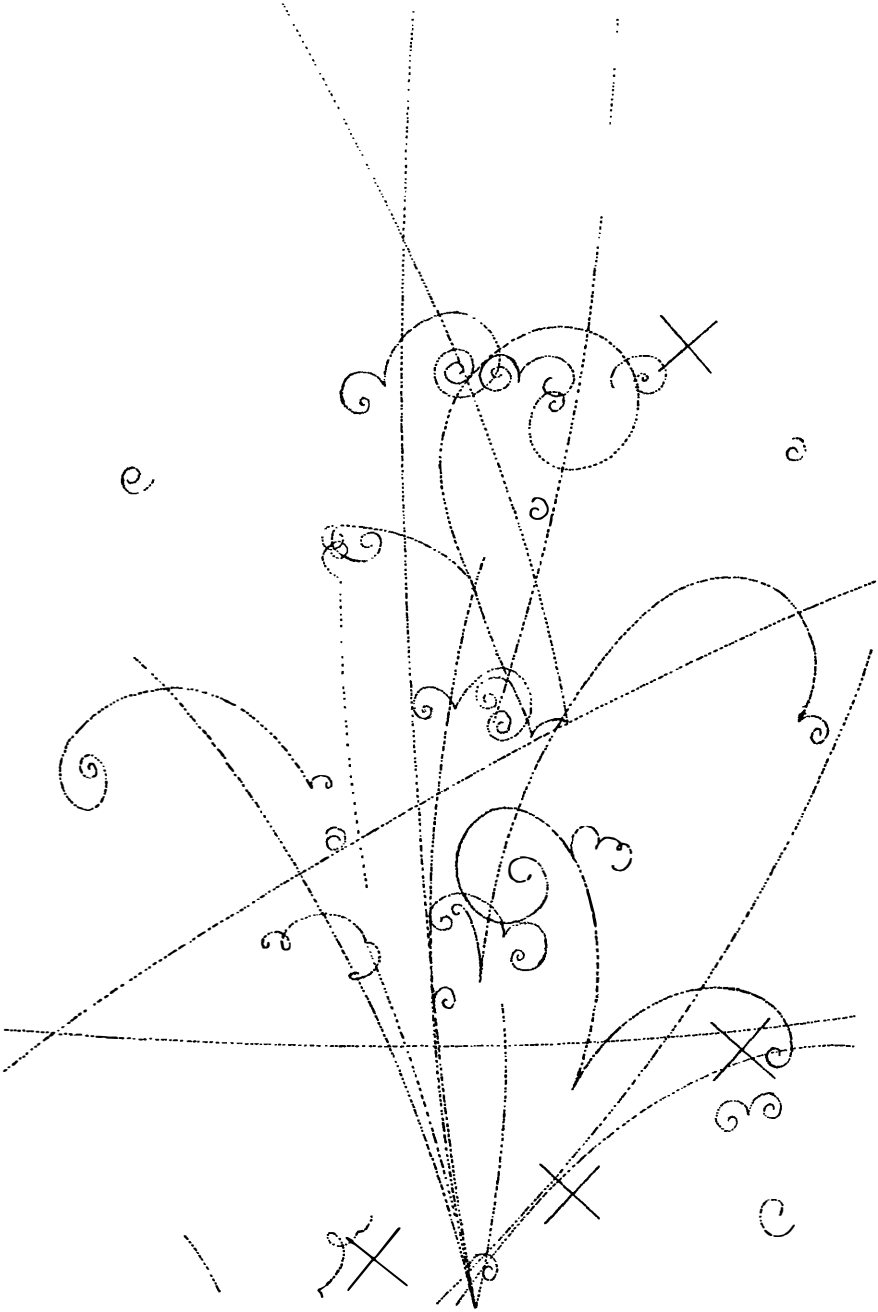
To reconstruct an animal's activities, specific actions and movements must be seen in the context of the animal's whole environment at specific times and places. Where an animal is moving at a steady pace in a specific direction, or following the easiest route along a well defined path, and it is known that there is a waterhole ahead, it may be predicted that the animal is going to the waterhole. A browsing antelope will move slowly from bush to bush, usually in an upwind direction, so a tracker who knows its favourite food will be able to anticipate the next bush the antelope will go to.

The animal's relationship with other animals also influences its actions and reactions. If a walking or trotting animal stops to look at something, this will be indicated by the forefeet being turned in the direction the animal was looking. There may be signs of a confrontation of a territorial male antelope with an intruder, showing pawing marks and horning of shrubbery by the one, and signs of flight by the other; or signs of fighting between two serious competitors. Signs of a sudden stampede may indicate that the animals were fleeing from danger, and the tracks of a predator may be found close by. Tracks may also show where a predator stalked its prey, and rushed up to bring down the fleeing animal. The fleeing animal may have been crashing

through bushes, and its skeletal remains may be surrounded by signs of its last struggle, followed by signs of feeding predators with the spoor of scavengers superimposed on those of the predators.

Since tracks may be partly obliterated or difficult to see, they may only exhibit fractional evidence, so the reconstruction of these animal's activities will have to be based on creative hypotheses. To interpret the spoor, trackers must use their imagination to visualise what the animal was doing to create such markings. Such a reconstruction will contain more information than is evident from the spoor, and will therefore be partly factual and partly hypothetical. As new factual information is gathered in the process of tracking, hypotheses may have to be revised or substituted by better ones.

A detailed knowledge of an animal's habits, which may partly be based on hypothetical spoor interpretation, as well as a knowledge of the environment, may enable trackers to extrapolate from incomplete evidence to recreate a complete account of the animal's activities (see examples in Chapter 6). Spoor interpretation need not only be based on evidence from the spoor itself, but also on activities which may be indicated by the spoor in the context of the environment and in the light of the tracker's knowledge of the animal's behaviour. A hypothetical reconstruction of the animal's activities may enable trackers to anticipate and predict the animal's movements.



11

Scientific Research Programmes

In order to resolve the apparent paradox of how a human scientific intellect that became capable of dealing with the subtleties of mathematics and physics evolved at a time when humans were still hunter-gatherers, it has been suggested in Chapter 4 that tracking is a science that involves essentially the same intellectual abilities as physics and mathematics. To substantiate the claim that the art of tracking involves the same intellectual processes as modern science, and that it may therefore represent the origin of science, it is necessary to point out a few of the similarities between tracking and modern physics. If the art of tracking represents the origin of science, it may also be instructive to consider some of the differences between it and modern science.

It is perhaps interesting to note in passing that tracking is often used as a metaphor in particle physics. Physicists, for example, study "particle tracks" created in bubble chambers (Fig. 27). A book on particle physics by R.D. Hill (1963) is entitled *Tracking Down Particles*. And in a book on *The Scientist* for the non-scientist, the authors, Margenau and Bergamini (1966), illustrate the scientific method with an essay on "The Pursuit of Omega Minus", with subheads like "The Call to the Hunt", "Large Weapons for a Small Quarry", "Closing in on the Quarry", and "A Still-greater Hunt Ahead". Although physicists probably never intended it to be more than just a metaphor, the analogy between tracking and physics may well be more than just metaphorical. Indeed, a solution to the apparent paradox of how humans evolved a scientific intellect capable of creating physics, may perhaps *not* be found by showing that a tracker thinks like a physicist, but rather by showing that a physicist thinks like a tracker.

The Logic of Science

In the logic of science one may distinguish between inductive-deductive and hypothetico-deductive reasoning. Inductive-deductive reasoning involves a process in which the premisses are obtained by generalising observed particulars. These are then assumed to be representative of universal principles. This initial process of induction starts with the assumption that statements about a number of individual animals, for example, can lead to generalisations about a species of which they are members. Such generalisations are

then used as premisses for the deduction of statements about particular observations. A more concrete example would be the way spoor are identified as that of an animal belonging to a particular species.

The inductive stage of the argument may be as follows: all the members of a particular species that have been observed produced spoor which had certain characteristics, and no member of that species had been observed to produce spoor that did not have those characteristics. We therefore assume that all members of that species produce spoor which have those specific characteristics. Furthermore, no animals which did not belong to that particular species have been observed to produce spoor which had exactly the same characteristics. We therefore assume that only members of the particular species in question produce spoor which have those specific characteristics.

The deductive stage of the argument would then be as follows: we assume that all members of a particular species and only members of that particular species produce spoor which have specific characteristics. We conclude, therefore, that any particular spoor observed to have those specific characteristics would have been produced by a member of that species.

In the inductive stage, generalisations are based on a limited number of particular observations, while in the deductive stage the identity of a particular spoor is deduced from assumed general premisses. In the deductive stage, the conclusions follow logically from the given premisses. The premisses, however, have been reached by a process of induction which involved assumptions that cannot be logically justified (see below). Since the truth of the premisses cannot be established logically, it follows that the truth of the conclusions cannot be established by the premisses from which they are deduced. Although particular conclusions may be confirmed empirically, the truth of the conclusions does not imply that the premisses are true.

Apart from the identity of spoor, other generalisations may be used as premisses to distinguish special features of spoor, such as those indicating the sex, age, size or mass of the animal, or characteristic markings that indicate specific gaits or activities. Generalisations about the habits, preferred habitat, sociability, feeding patterns, and other aspects of the behaviour of animals may also be assumed premisses from which to make certain deductions in the interpretation of spoor.

In this book the meaning of "induction" is limited to induction by simple enumeration. A typical induction by simple enumeration has the form:

a_1	has	the	property	P
a_2	"	"	"	P
a_3	"	"	"	P
. . .	. . .	. . .	. . .	. . .
a_n	"	"	"	P
All a's	have	the	property	P

In an inductive argument by simple enumeration, the premisses and conclusions contain the same descriptive terms (Losee, 1972). It is therefore simply a process of empirical generalisation. Empirical generalisations constitute no progress in science, since they may only lead to the discovery of facts similar to those already known (Lakatos, 1978a).

Inductive-deductive reasoning is based on direct observations and ordinarily recognises apparent regularities in nature. Inductive knowledge, therefore, is based on a trial-and-error accumulation of facts and generalisations derived by simple enumeration of instances. It does not explain observations and cannot result in the prediction of novel facts. It can only predict particular observations similar to those that have been observed in the past. Predictions are therefore simply based on experience.

In contrast to inductive-deductive reasoning, hypothetico-deductive reasoning involves the explanation of observations in terms of hypothetical causes. The hypotheses may then be used as premisses in conjunction with initial conditions from which certain implications may be deduced. Some of the implications deduced in such a way may include novel predictions. Hypothetico-deductive reasoning is an exploratory dialogue between the imaginative and the critical, which alternate and interact. A hypothesis is formed by a process which is not illogical but non-logical, i.e. outside logic. But once a hypothesis has been formed it can be exposed to criticism (Medawar, 1969). In theoretical physics, for example, a theory is built on fundamental concepts and postulates, or laws, from which conclusions can be deduced. There is no logical path to these fundamental laws. They can only be reached through intuition based on a sympathetic understanding of experience. These fundamental concepts and principles are "free inventions of the human intellect" (Einstein, 1954).

A characteristic feature of a theoretical science is that it explains the visible world by a postulated invisible world. So in physics visible matter is explained by hypotheses about an invisible structure which is too small to be seen (Popper, 1963). Similarly, in the art of tracking, visible tracks and signs are explained in terms of invisible activities. A sympathetic understanding of animal behaviour (see section on The Scientific Imagination below) enables the tracker to visualise what the animal may have been doing in order to create hypotheses that explain how visible signs were made and how they are connected. Visible signs are therefore connected by invisible processes. These postulated connections are inventions of the tracker's imagination. Although these hypothetical connections cannot be seen, the conclusions that can be deduced from them enables the tracker to anticipate and predict visible signs.

A theoretical science such as physics is analogous to tracking in the sense that observable properties of the visible world may be regarded as *signs* of invisible structures or processes. The force of gravity cannot actually be seen. Its postulated existence is only indicated by observable effects on bodies similar to those that such a force would have on bodies. Nuclear particles also cannot be seen. Physicists can only see signs, such as "parti-

cle tracks", that correspond to those that would be made by hypothetical particles.

Perhaps the most significant feature of hypothetico-deductive reasoning is that in a progressive research programme a hypothesis may enable the scientist to predict novel facts that would not otherwise have been known (Lakatos, 1978a). In the process of tracking down an animal, a tracker must explain spoor in order to anticipate and predict where to find spoor further ahead, and eventually where to find the animal itself. If the anticipation and prediction of spoor is simply based on previous experience (i.e. based on inductive-deductive reasoning), it does not involve the prediction of novel facts. But when a tracker is confronted with a set of tracks and signs that cannot be explained in terms of previous experience, a new hypothesis must be created. If successful, such a hypothesis may enable the tracker to predict novel facts about the animal's behaviour. Within the context of tracking, hypothetico-deductive reasoning may enable the tracker to acquire new knowledge that would not otherwise have been known (see, for example, Chapter 6).

Hypothetico-deductive reasoning is a constant interplay or interaction between hypotheses and the logical consequences they give rise to. Deduction guarantees that if hypotheses are true, then the inferences drawn from them will also be true. But even if these logical conclusions are true, it does not follow that the hypotheses which gave rise to them are true, since false hypotheses can lead to true conclusions (Medawar, 1969). Hypothetico-deductive reasoning may be described as a cybernetic process, in the sense that continuous adjustment and reformulation of hypotheses is brought about through a process of negative feedback from their deductive consequences. If their logical consequences are true, hypotheses need not be altered, but if they are false, corrections have to be made (Medawar, 1967).

The art of tracking may be regarded as a continuous cybernetic process. In each individual hunt, working hypotheses are created to reconstruct the animal's activities in order to predict where it was going. Such hypotheses are continuously revised as new spoor information confirms or contradicts the tracker's expectations. Even though the tracker's knowledge of animal behaviour is based on experience gained from previous hunts, each hunt may result in new knowledge and revisions of previous knowledge. In the same fashion the collective research programme of a group of interacting trackers will also be expanded and revised continuously.

To return to an earlier theme, we said that the process of induction involves assumptions that cannot be logically justified, and that hypotheses are formed by non-logical processes. Induction is based on the assumption that instances, of which we have had no experience, will resemble those of which we have had experience. Yet there can be no demonstrative arguments to prove that such an assumption must be valid. We can at least conceive a change in the course of nature, which sufficiently proves that such a change is not absolutely impossible. Our assumption that the future will resemble the past is not based on logical arguments: it

is based entirely on habit. Induction from experience has no logical justification (Hume, 1739).

Even though the process by which hypotheses are created is not logical, hypotheses—once formed—are also generalised and assumed to be universally true. The "problem of induction" therefore also applies to hypothetico-deductive reasoning. Just as empirical generalisations that were true in the past need not necessarily be true in the future, hypotheses that were true in the past (although it can never be known that they were true even if they were true), need not necessarily be true in the future. It is reasonable to act on the assumption that the future, will, in many ways, be like the past, and that well-tested theories will continue to hold, since we have no better assumption to act upon. It is also reasonable to believe, however, that the future will be very different from the past in many important ways, and that such a course of action will at times result in failure (Popper, 1963).

The implication of the "problem of induction" is that scientific theories cannot be verified Scientific theories may well be true, but even when they are, we can never know that they are true (Popper, 1963). Even factual propositions cannot be proven from experience (Popper, 1959). If factual propositions cannot be proven then they are fallible. And if they are fallible the clashes between theories and factual propositions are not "falsifications", but merely inconsistencies. So theories cannot be conclusively falsified either. Furthermore, a theory can always be protected from falsification by modifying some of the auxiliary hypotheses. Scientific theories are not only equally unprovable and equally improbable, but they are also equally unfalsifiable. Generally speaking, theories and hypotheses cannot be appraised in isolation; rather, a continuous series of theories should be seen within the context of an ongoing research programme (Lakatos, 1978a).

The Scientific Imagination

The creative process is far too complex to deal with adequately in a short section. Nevertheless, it may be instructive to look at one aspect of creativity in science that seems to be vital in the art of tracking. A characteristic feature of the scientific knowledge of hunter-gatherers is the anthropomorphic nature of their models of animal behaviour. This anthropomorphic element is not necessarily unscientific. On the contrary, it may well be a result of the creative scientific imagination. Indeed, anthropomorphic projection has been noted as an essential and important element in scientific work (Holton, 1973).

Our concept of causality may have had its origin in anthropomorphic projection. The concept could have arisen as a kind of projection of human experience into the world of nature. When you throw a stone, tension is felt in the muscles. When something similar is observed in nature, such as a thrown stone striking another, it is easy to imagine that one stone is having an experience analogous to our experience of throwing a stone. The striking stone does something to the other stone that makes the second one

move. It is easy to see how people of primitive cultures could suppose that elements in nature were animated as they themselves were (Carnap, 1966).

Even today elements of animistic thinking tend to persist. When a stone shatters a window, most people, including scientists, will say that event B, the breaking of the window, was *caused* by event A, the collision of the stone with the glass. But what is meant when it is said that event B was caused by event A? It might be said that event A "brought about" event B, or "produced" event B. When trying to explain the meaning of "cause", people fall back on metaphorical phrases such as "bring about", "bring forth", "create", or "produce", which are taken from human activity (Carnap, 1966).

Causal relation implies predictability (Carnap, 1966). The process of subjective simulation, whereby we simulate subjectively the events around us, is essentially a predictive attitude. When a scientist is interested in a given situation, he/she tries to simulate the situation subjectively to achieve a form of internal representation (Monod, 1975). In nuclear physics, the experimenter's preconceived image of the process under investigation determines the outcome of the observations. This image is a symbolic, anthropomorphic representation of the basically inconceivable atomic processes (Deutsch, 1959)

The creative scientific imagination may function by evoking potential or imagined sense impressions. Some physicists think of an atom by evoking a visual image of what they would see if the atomic model existed on a scale accessible to sense impressions. At the same time the physicist realises that it is in principle inaccessible to direct sensory perception (Deutsch, 1959). When a scientist has such a visual image, the nature of the seeing or sensing is almost as though he/she felt like the object being visualised (Walkup, 1967). In thinking about a phenomenon they are interested in, some physicists, even in highly abstract theoretical physics, may more or less identify themselves with, for example, a nuclear particle and may even ask: "What would I do if I was that particle?" (Monod, 1975).

This paradox becomes more striking as science becomes more sophisticated. In any advanced science even the simplest observation involves a formidable apparatus of theory. The ratio of signal to noise is extremely small in the laboratory, where the energy, the size and the period of persistence of the phenomena studied are minute compared to the other attendant data. Observations in nuclear physics can only be understood and used if, from the very beginning, the scientist has a well-structured image of the actual connections between the events taking place. Thus modern science is not entirely depersonalised, cold and abstract. Rather, the nuclear physicist may project human relationships into his/her equipment and data. The symbolic power of useful scientific concepts lies in the fact that many of these concepts have been importing anthropomorphic projections from the world of human drama (Holton, 1973).

In the art of tracking the anthropomorphic way of thinking arises from the tracker's need to identify him/herself with the animal in order to anticipate and predict its movements. The tracker must visualise what it would be like to be that animal within that particular environmental context. In doing this

the tracker must ask: "What would I have done if I was that animal?". To be able to do this the tracker must know the animal very well. But in the process the tracker superimposes his/her own way of thinking onto that of the animal, thereby creating a model of animal behaviour in which the animal is understood to have certain human characteristics.

The creation of such a preconceived image of what the animal was doing is particularly important in difficult tracking conditions. In conditions where signs are sparse, the information content of signs are very little, and where there are many proximate signs that could confuse the tracker (i.e. where the ratio of signal to noise is very small), the tracker needs a preconceived image to recognise the relevant signs and to establish the connections between them.

Considering the role of the anthropomorphic way of thinking in science, it is by no means obvious why a physicist should think in such a way. On the contrary, it would appear to be a rather paradoxical way to understand highly abstract physical concepts. On the other hand, it is quite clear why a tracker should think in such a way. This may well suggest that the creative scientific imagination had its origin in the evolution of the art of tracking.

Intuition

Intuition may be defined as reaching a conclusion on the basis of less explicit information than is ordinarily required to reach that conclusion. It usually occurs in situations where there is not enough time to appraise certain data, where the data are too complex for normal inferential processes, where the relevant data are heavily confounded with irrelevant data, and when data are excessively limited. Intuition is an inferential process in which some of the premisses are contained in the stimulus event and some of them in the coding system of the perceiver, so the conclusions may go beyond the information given (Westcott, 1968).

When a conclusion is reached intuitively, the thinker usually does not know how he/she reached the conclusion. A great variety of cues may be used for reaching a conclusion, without the individual having any idea of what the cues are or how they are being used. Some elements of the intuitive process may be conscious, while associative links may be made unconsciously. Information may be derived from diverse and complex contexts, and may be gained incidentally, peripherally or perhaps subliminally. Although the individual may not know how a conclusion is reached, intuition is primarily based on information received from the environment through normal sensory channels and acted upon by usual cognitive manipulations. Intuition differs from normal inference only in the sense that the individual is unaware of the process involved. Such a definition of intuition may include creativity, but intuition may not always be creative. Intuitive conclusions are not necessarily novel or unusual (Westcott, 1968).

The art of tracking involves many situations in which intuitive conclusions must be made. In difficult tracking conditions where signs may be sparse, where signs have very little information content and where a multitude

of proximate signs may confuse the tracker, spoor interpretation may be largely intuitive. Subtle variations in footprints that indicate the sex, size, age and the condition of the animal may not be well defined, and can only be determined intuitively, especially in conditions where footprints are not clear. In loose sand, for instance, spoor may have lost definition as the grains of sand slid together and as the wind gradually eroded the edges. On hard ground only fractions of footprints may be discernible. In such conditions the tracker must intuitively visualise what the spoor looked like before it lost definition. Similarly a large number of complex variables must be taken into account to estimate the age of spoor so the tracker's estimate may at best be intuitive.

During the course of tracking, a tracker is constantly taking in a multitude of signs. On the basis of spoor information gathered over a period of time a tracker may be able to intuitively predict the success of a hunt. Such an intuitive prediction may be revealed in the form of "feelings" or presentiments (see Chapter 7). In the process of tracking down an animal, or even before an animal's tracks have been encountered, a tracker may "feel" the near presence of their quarry by means of peripheral perception. The tracker may, on the basis of a complexity of signs, some of which may have been subconsciously perceived, intuitively know that the animal may be near. Hunters may also intuitively "feel" danger by means of peripheral perception (see Chapter 7).

While it is clear that intuition plays an important role in tracking, and therefore in hunting, it also plays an important role in other spheres of hunter-gatherer societies. In their social relationships, for example, the sensitivity of /Gwi men and women to each other cannot be appreciated by people living in urban situations, where perceptions of others have been blunted by fragmented and shallow relationships (Silberbauer, 1981). Modern societies in general, and education in particular, does more to stifle than to encourage intuitive thinking. It is usually the more independent and less socialised individuals who are more likely to be intuitive thinkers (Westcott, 1968). It may well be that the more independent and less socialised individuals are more intuitive because they are less inclined to be stifled by society. If modern society and education were less stifling, perhaps more people would be more intuitive. This may well be the case in hunter-gatherer societies, where intuition plays an important role not only in tracking, but also in social relations.

The Scientific Process

Since hunter-gatherers of the Kalahari no longer live a nomadic way of life, it is not possible to study the art of tracking in its original context. In particular, it is not known how trackers from different bands interacted and how new ideas were exchanged and shared by hunter-gatherer societies as a whole. Nevertheless, a hypothetical reconstruction of the art of tracking as a collective research programme of a community of interacting trackers may help to explain how science originated.

As mentioned before, a research programme consists of a developing series of theories. It has a tenacious "hard core" and a heuristic which includes a set of problem-solving techniques. A "protective belt" of auxiliary hypotheses, on the basis of which initial conditions are established, protects the "hard core" from refutations. Anomalies, which always occur, are not regarded as refutations of the "hard core", but of some hypothesis in the "protective belt". While the "hard core" remains intact, the "protective belt" is constantly modified, increased and complicated (Lakatos, 1978a).

A research programme is theoretically progressive if modifications lead to new unexpected predictions and it is empirically progressive if at least some of these novel predictions are corroborated. If anomalies are dealt with by simply making suitable *ad hoc* adjustments which do not lead to the prediction of novel facts, or whose novel predictions failed, then the research programme is degenerating. One research programme supersedes another if it predicts progressively all that its rival predicts as well as some novel predictions that its rival does not predict (Lakatos, 1978a).

In considering the art of tracking as a scientific research programme, it is useful to distinguish three levels of research activity: firstly, each hunt may be regarded as a small scale "research programme"; secondly each individual tracker may be seen to have his/her own "individual research programme"; and thirdly, a group of trackers who interact with one another may be seen to have a "collective research programme".

The public component of modern science, which consists of published papers, finished research reports and authoritative textbooks, mainly emphasises the "collective" aspect of science, while the private aspects of the actual research of individual scientists remains hidden from public view. Although these private aspects are obviously of primary importance in the creative scientific process, they are often ignored in public discussions of science itself. The art of tracking, however, is much more individualistic than modern science, or at least the "public" side of modern science. The survival of hunters ultimately depends on the success of particular hunts, and the success of particular hunts depends on the tracking abilities of each individual tracker. To understand the art of tracking as a collective research programme, it is therefore necessary to consider it from the perspective of individual trackers and particular hunts.

Each particular hunt may be regarded as a small scale "research programme" (or perhaps a "search programme"), consisting of a series of problem-solving events. Every hunt is a new experience (or "experiment"), in which new problems may be encountered which may require new solutions, confirming or refuting previous hypotheses. The tracker sets out on a hunt on the assumption that the animal can be expected to act in accordance with a set of hypotheses. These hypotheses may constitute the "hard core" of his/her individual research programme. Once the hunt is in progress, new information may contradict the tracker's initial expectations, so auxiliary hypotheses may have to be summoned to explain the spoor and predict the animal's movements. As the hunt progresses and more and

more information is gathered, initial working hypotheses that have been refuted may have to be revised and new hypotheses added so that the tracker can develop a better and more complete reconstruction of what the animal was doing. As a hunter gains experience, each hunt may be seen as a continuation of previous hunts.

During the course of a hunter's experience, some hypotheses may be progressive, while others may be degenerative. If the tracker's progressive hypotheses outweigh the degenerative hypotheses, his/her individual research programme will be progressive. Such a tracker will therefore become more successful as a hunter. Conversely, if a tracker's research programme is degenerating, s/he will not become more successful and may even become less successful. Interaction between trackers will ensure that the ideas of the most successful hunters will be adopted by the less successful hunters. Conversely, the views of the least successful hunters will be disregarded by others. The "collective research programme" of a band will therefore be progressive rather than degenerative, since the more successful programmes of the better hunters will supersede those of the less successful hunters.

In hunter-gatherer bands, the meat provided by successful hunters was shared with others, including unsuccessful hunters. Since hunters could depend on others for meat when they failed, they had the freedom to be wrong at times. The principle of sharing therefore gave trackers a degree of "academic freedom" to explore new ideas. The success or failure of new ideas, i.e. the predictive value of new ideas, would determine whether they would be taken up into the collective research programme of a band.

Thus the art of tracking, within the original context of hunter-gatherer subsistence, would have been a science with a high degree of individual freedom and flexibility. It would also have been subject to a process of "natural selection", since the success of the tracker's ideas would have determined the success of the hunt, upon which the survival of the band ultimately depended. It was not crucial that all hunters in a band were highly successful trackers, and there would have been room for some trackers to have degenerating research programmes. But the survival of the band would have depended on the existence of at least a reasonable number of trackers with progressive research programmes. While some hunters may have "degenerated" at times, the most successful trackers would have determined the progressiveness of the collective research programme. The "hard core" of the collective research programme consisting of a number of well established hypotheses or theories, would have been transmitted by means of oral tradition, while a "protective belt" of auxiliary hypotheses would have been constantly modified and adapted.

Tradition has a fundamental role in science. The creation of traditions brings some order into the world we live in, thereby making it rationally predictable. Without tradition, knowledge would be impossible. The advance of knowledge consists in our modification of earlier knowledge, and everything about our traditional knowledge is open to critical examination. Traditions therefore have the important double function of not only creat-

ing some order, but also giving us something upon which we can operate, something that can be criticised and changed. Progress in science must proceed within the framework of scientific theories, some of which are criticised in the light of others (Popper, 1963).

The very nature of oral tradition may have made a continuous process of discovery a necessity. In time, knowledge may be forgotten and when someone dies a large amount of knowledge may be lost. In a small band, with only ten hunters, of whom only five may have been reasonable trackers, of whom only one or two may have been excellent trackers, it is unlikely that they could have remembered enough information to deal with every conceivable problem that could arise in tracking. The number of possible hypothetical connections that could be made between all the signs a tracker may encounter in a lifetime of hunting may well be infinite. At best, they may have been able to perpetuate through oral tradition the "hard core" of a collective research programme, while new auxiliary hypotheses would have had to be invented continuously to deal with new problems as they arose. As an ongoing research programme involving a continuous process of discovery, the art of tracking would have had a high degree of adaptability in changing circumstances.

The Evolution of Science

As mentioned earlier in Part I, the similarities between tracking and modern science may suggest how science originated by means of biological evolution. Moreover, the differences between them may give some indication of how science subsequently developed by means of cultural evolution. One of the more obvious ways in which the modern scientist differs from the tracker is that the scientist has access to much more knowledge by means of documentation. He/she may use sophisticated instruments to make highly accurate observations (especially of phenomena that cannot be seen by the naked eye), may use computers to make complicated calculations and may participate in scientific research programmes that involve the collective efforts of large numbers of scientists who may each specialise in different fields of study. As a whole, modern science is obviously much more sophisticated than tracking.

Part of the problem of modern science, however, is that individual scientists must rely to a large extent on documented knowledge. Even though documented scientific knowledge is open to criticism in principle, it is impossible in practice for the individual scientist to appraise critically everything he/she reads. If the scientist attempted to do this, he/she would simply never get down to doing original research. The scientist must therefore rely on the author of a work and on experimental results being repeated by at last some independent researchers. While the scientist may have access to a large amount of information, accepting the validity of the information requires to a certain degree an act of faith in others. This has the inherent danger that well-established knowledge may become dogmatic, which may result in irrational beliefs becoming entrenched in science.

A further problem is that computers and instruments are made by humans and are therefore subject to human error. It is impossible in practice for the individual scientist to check for all the possible errors involved, including conceptual errors, design errors and manufacturing errors. The use of computers and instruments will then always entail uncertainties that are beyond the control of the individual scientist. Although documentation, the use of computers and instruments and the large-scale of modern collective research may have considerable advantages, they also introduce new uncertainties. The individual scientist's access to a large body of knowledge does not necessarily make it easier to reach a rational decision. The tracker, by contrast, is in direct contact with nature. Ideas and interpretations are continuously tested in nature itself. Signs are observed directly (without interference of observational instruments), and hypotheses may predict further observations in the immediate vicinity. Hypothetical interpretations are therefore open to direct criticism by any individual tracker.

A characteristic feature of an advanced science such as modern physics is the complex hierarchical structure of hypotheses and the fact that the chain of reasoning from observational "facts" to the most general hypotheses may be very long (Holton, 1973). In contrast, the art of tracking does not have a complex hierarchical structure and the chain of reasoning from observation to the most basic hypotheses is fairly short. Yet the lack of a formal hierarchical structure in tracking allows for a greater multitude of basic hypotheses. Furthermore, the hierarchical structure of an advanced science also makes it less accessible to people who do not have sufficient background knowledge. This situation gives rise to an authoritarian élitism in modern science.

The most influential and dominant tradition among modern scientists in the approach to scientific theories is élitism. According to this view, the layman or the outsider cannot understand and therefore cannot appraise scientific theories. Only a privileged scientific élite can judge their own work. Within the scientific élite there is an authority structure, which means that the scientific community is predominantly authoritarian in its appraisal of scientific theories (Lakatos, 1978b). Although authoritarian elitism may be the dominant tradition among modern scientists it should be pointed out that it is by no means the only school of thought. Scepticism, including Feyerabend's (1975) "epistemological anarchism", denies that scientists can have any authority to appraise theories. Scepticism regards scientific theories as just one belief-system which is epistemologically no more "right" than any other belief-system. Demarcationism, on the other hand, holds that there exists criteria which allow the educated layman to demarcate science from non-science, and better from worse knowledge. Demarcationists therefore have a democratic respect for the layman (Lakatos, 1978b). In contrast to the relatively authoritarian nature of modern scientists, trackers are much more egalitarian. Even young trackers may, for example, disagree with their elders and propose alternative interpretations of spoor (see Chapter 6).

A further characteristic feature of modern science is the authoritarian practice of education. Knowledge is presented in the form of infallible systems based on conceptual frameworks that are not subject to discussion (Lakatos, 1978b). Science students accept theories not on the basis of evidence, but on the authority of teachers and textbooks. Until the very last stages in the education of a scientist, textbooks are systematically substituted for the creative scientific literature on which they are based. The student does not have to read the original works of pioneer scientists of the past. Rather, everything the student needs to know, as far as his/her education is concerned, is recapitulated in a far briefer, more precise, and more systematic form in a number of up-to-date textbooks. This type of education has been very effective for normal-scientific work (such as puzzle-solving) within the tradition defined by the textbooks. But this type of scientific training is not well designed to produce the scientist who will easily discover a fresh approach (Kuhn, 1962). The learning process in tracking differs once again in that it is an informal, dynamic process of continuous problem-solving. Even from childhood, the young tracker is exposed to the scientific process (see Chapter 6).

A striking fact about science is that it has flowered in those few cultures where strict limits were not set by authorities, such as among the Ancient Greeks and in western Europe since the dawn of liberal thought. On the other hand, science is extraordinarily barren in the authoritarian cultures of the world. It is in the comparatively more open and free societies that most scientific creation and advance are taking place (Magee, 1975). This may well be because science had its origin in relatively egalitarian hunter-gatherer societies, where there was an almost complete absence of authoritarianism. To the extent that societies have become increasingly authoritarian, creative science has been stifled and suppressed.

None of the differences between modern science and the art of tracking require a fundamentally new way of thinking. The differences are mainly technical and sociological. Although modern science is much more sophisticated, it has grown mainly quantitatively, not qualitatively. The creative scientific process itself has not changed and the intellectual abilities required for tracking and modern science are essentially the same.

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