'Superb' **Carl Sagan**

BBC BOOKS

The Ascent of Man

Foreword by **Richard Dawkins**

Jacob Bronowski

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FOREWORD

by Richard Dawkins

'Last renaissance man' has become a cliché, but we forgive a cliché on the rare occasion when it is true. Certainly it is hard to think of a better candidate for the accolade than Jacob Bronowski. You'll find other scientists who can parade a deep parallel knowledge of the arts, or – in one actual case – combine eminence in science with pre-eminence in Chinese history. But who more than Bronowski weaves a deep knowledge of history, art, cultural anthropology, literature and philosophy into one seamless cloth with his science? And does it lightly, effortlessly, never sinking to pretension? Bronowski uses the English language – not his first language, which makes it all the more remarkable – as a painter uses his brush, with mastery all the way from broad canvas to exquisite miniature.

Inspired by the *Mona Lisa*, here is what he has to say about arguably the first and greatest renaissance man, whose drawing of the baby in the womb introduced the television version of *The Ascent of Man*:

> Man is unique not because he does science, and he is unique not because he does art, but because science and art equally are expressions of his marvellous plasticity of mind. And the *Mona Lisa* is a very good example, because after all what did Leonardo

> do for much of his life? He drew anatomical pictures, such as the baby in the womb in the Royal Collection at Windsor. And the brain and the baby is exactly where the plasticity of human behaviour begins.

How deftly Bronowski segues from Leonardo's drawing to the Taung baby: type-specimen of our ancestral genus *Australopithecus*, victim – as we now know, though Bronowski didn't when he performed his mathematical analysis on the tiny skull – of a giant eagle two million years ago.

There's a quotable aphorism on every page of this book, something to treasure, something to stick on your door for all to see, an epitaph, perhaps, for the gravestone of a great scientist. 'Knowledge ... is an unending adventure at the edge of uncertainty.' Uplifting? Yes. Inspiring? Without doubt. But read it in context and it is shocking. The grave turns out to belong to an entire tradition of European scholarship, destroyed by Hitler and his allies almost overnight:

> Europe was no longer hospitable to the imagination – and not just the scientific imagination. A whole conception of culture was in retreat: the conception that human knowledge is personal and responsible, an unending adventure at the edge of uncertainty. Silence fell, as after the trial of Galileo. The great men went out into a threatened world. Max Born. Erwin Schrödinger. Albert Einstein. Sigmund Freud. Thomas Mann. Bertolt Brecht. Arturo Toscanini. Bruno Walter. Marc Chagall.

Words so powerful don't need a raised voice or ostentatious tears. Bronowski's words gained impact from his calm, humane, understated tones, with the engagingly rolled Rs as he looked straight into the camera, spectacles flashing like beacons in the dark.

That was a rare dark passage in a book that is mostly filled with light, and genuinely uplifting. You can hear Bronowski's distinctive voice through this book, and you can see his expressive hand chopping down to cut through complexity and make a point. He stands before a great sculpture, Henry Moore's *The Knife Edge*, to tell us,

> The hand is the cutting edge of the mind. Civilisation is not a collection of finished artefacts, it is the elaboration of processes. In the end, the march of man is the refinement of the hand in action. The most powerful drive in the ascent of man is his pleasure in his own skill. He loves to do what he does well and, having done it well, he loves to do it better. You see it in his science. You see it in the magnificence with which he carves and builds, the loving care, the gaiety, the effrontery. The monuments are supposed to commemorate kings and religions, heroes, dogmas, but in the end the man they commemorate is the builder.

Bronowski was a rationalist and an iconoclast. He was not content to bask in the achievements of science but sought to provoke, to pique, to needle.

> That is the essence of science: ask an impertinent question, and you are on the way to a pertinent answer.

That applies not just to science but to all learning, epitomised, for Bronowski by one of the world's oldest and greatest universities – in Germany as it happens:

> The University is a Mecca to which students come with something less than perfect faith. It is important that students

> bring a certain ragamuffin, barefoot irreverence to their studies; they are not here to worship what is known but to question it.

Bronowski treated the magical speculations of primitive man with sympathy and understanding, but in the end

> ... magic is only a word, not an answer. In itself, magic is a word which explains nothing.

There is magic – the right kind of magic – in science. There is poetry too, and magical poetry on every page of this book. Science is the poetry of reality. If he didn't say that, it is the kind of thing he might have said, articulate polymath and gentle sage, whose wisdom and intelligence symbolises all that is best in the ascent of man.

INTRODUCTION

The first outline of *The Ascent of Man* was written in July 1969 and the last foot of film was shot in December 1972. An undertaking as large as this, though wonderfully exhilarating, is not entered lightly. It demands an unflagging intellectual and physical vigour, a total immersion, which I had to be sure that I could sustain with pleasure; for instance, I had to put off researches that I had already begun; and I ought to explain what moved me to do so.

There has been a deep change in the temper of science in the last twenty years: the focus of attention has shifted from the physical to the life sciences. As a result, science is drawn more and more to the study of individuality. But the interested spectator is hardly aware yet how far-reaching the effect is in changing the image of man that science moulds. As a mathematician trained in physics, I too would have been unaware, had not a series of lucky chances taken me into the life sciences in middle age. I owe a debt for the good fortune that carried me into two seminal fields of science in one lifetime; and though I do not know to whom the debt is due, I conceived *The Ascent of Man* in gratitude to repay it.

The invitation to me from the British Broadcasting Corporation was to present the development of science in a series of television programmes to match those of Lord Clark on *Civilisation*. Television is an admirable medium for exposition in several ways: powerful and immediate to the eye, able to take the spectator bodily into the places

and processes that are described, and conversational enough to make him conscious that what he witnesses are not events but the actions of people. The last of these merits is to my mind the most cogent, and it weighed most with me in agreeing to cast a personal biography of ideas in the form of television essays. The point is that knowledge in general and science in particular does not consist of abstract but of manmade ideas, all the way from its beginnings to its modern and idiosyncratic models. Therefore the underlying concepts that unlock nature must be shown to arise early and in the simplest cultures of man from his basic and specific faculties. And the development of science which joins them in more and more complex conjunctions must be seen to be equally human: discoveries are made by men, not merely by minds, so that they are alive and charged with individuality. If television is not used to make these thoughts concrete, it is wasted.

The unravelling of ideas is, in any case, an intimate and personal endeavour, and here we come to the common ground between television and the printed book. Unlike a lecture or a cinema show, television is not directed to crowds. It is addressed to two or three people in a room, as a conversation face to face – a one-sided conversation for the most part, as the book is, but homely and Socratic nevertheless. To me, absorbed in the philosophic undercurrents of knowledge, this is the most attractive gift of television, by which it may yet become as persuasive an intellectual force as the book.

The printed book has one added freedom beyond this: it is not remorselessly bound to the forward direction of time, as any spoken discourse is. The reader can do what the viewer and the listener cannot, which is to pause and reflect, turn the pages back and the argument over, compare one fact with another and, in general, appreciate the detail of evidence without being distracted by it. I have taken advantage of this more leisurely march of mind whenever I could, in putting on paper now what was first said on

the television screen. What was said had required a great volume of research, which turned up many unexpected links and oddities, and it would have been sad not to capture some of that richness in this book. Indeed, I should have liked to do more, and to interleave the text in detail with the source material and quotations on which it rests. But that would have turned the book into a work for students instead of the general reader.

In rendering the text used on the screen, I have followed the spoken word closely, for two reasons. First, I wanted to preserve the spontaneity of thought in speech, which I had done all I could to foster wherever I went. (For the same reason, I had chosen whenever possible to go to places that were as fresh to me as to the viewer.) Second and more important, I wanted equally to guard the spontaneity of the argument. A spoken argument is informal and heuristic; it singles out the heart of the matter and shows in what way it is crucial and new; and it gives the direction and line of the solution so that, simplified as it is, still the logic is right. For me, this philosophic form of argument is the foundation of science, and nothing should be allowed to obscure it.

The content of these essays is in fact wider than the field of science, and I should not have called them *The Ascent of Man* had I not had in mind other steps in our cultural evolution too. My ambition here has been the same as in my other books, whether in literature or in science: to create a philosophy for the twentieth century which shall be all of one piece. Like them, this series presents a philosophy rather than a history, and a philosophy of nature rather than of science. Its subject is a contemporary version of what used to be called Natural Philosophy. In my view, we are in a better frame of mind today to conceive a natural philosophy than at any time in the last three hundred years. This is because the recent findings in human biology have given a new direction to scientific thought, a shift from

the general to the individual, for the first time since the Renaissance opened the door into the natural world.

There cannot be a philosophy, there cannot even be a decent science, without humanity. I hope that sense of affirmation is manifest in this book. For me, the understanding of nature has as its goal the understanding of human nature, and of the human condition within nature.

To present a view of nature on the scale of this series is as much an experiment as an adventure, and I am grateful to those who made both possible. My first debt is to the Salk Institute for Biological Studies which has long supported my work on the subject of human specificity, and which gave me a year of sabbatical leave to film the programmes. I am greatly indebted also to the British Broadcasting Corporation and its associates, and very particularly there to Aubrey Singer who invented the massive theme and urged it on me for two years before I was persuaded.

The list of those who helped to make the programmes is so long that I must put it on a page of its own, and thank them in a body; it was a pleasure to work with them. However, I cannot pass over the names of the producers that stand at the head of the list, and particularly Adrian Malone and Dick Gilling, whose imaginative ideas transubstantiated the word into flesh and blood.

Two people worked with me on this book, Josephine Gladstone and Sylvia Fitzgerald, and did much more; I am happy to be able to thank them here for their long task. Josephine Gladstone had charge of all the research for the series since 1969, and Sylvia Fitzgerald helped me plan and prepare the script at each successive stage. I could not have had more stimulating colleagues.

J. B.
La Jolla, California
August 1973

CHAPTER ONE

LOWER THAN THE ANGELS

Man is a singular creature. He has a set of gifts which make him unique among the animals: so that, unlike them, he is not a figure in the landscape – he is a shaper of the landscape. In body and in mind he is the explorer of nature, the ubiquitous animal, who did not find but has made his home in every continent.

It is reported that when the Spaniards arrived overland at the Pacific Ocean in 1769 the California Indians used to say that at full moon the fish came and danced on these beaches. And it is true that there is a local variety of fish, the grunion, that comes up out of the water and lays its eggs above the normal high-tide mark. The females bury themselves tail first in the sand and the males gyrate round them and fertilise the eggs as they are being laid. The full moon is important, because it gives the time needed for the eggs to incubate undisturbed in the sand, nine or ten days, between these very high tides and the next ones that will wash the hatched fish out to sea again.

Every landscape in the world is full of these exact and beautiful adaptations, by which an animal fits into its environment like one cog-wheel into another. The sleeping hedgehog waits for the spring to burst its metabolism into life. The humming-bird beats the air and dips its needle-fine beak into hanging blossoms. Butterflies

mimic leaves and even noxious creatures to deceive their predators. The mole plods through the ground as if he had been designed as a mechanical shuttle.

So millions of years of evolution have shaped the grunion to fit and sit exactly with the tides. But nature – that is, biological evolution – has not fitted man to any specific environment. On the contrary, by comparison with the grunion he has a rather crude survival kit; and yet – this is the paradox of the human condition – one that fits him to all environments. Among the multitude of animals which scamper, fly, burrow and swim around us, man is the only one who is not locked into his environment. His imagination, his reason, his emotional subtlety and toughness, make it possible for him not to accept the environment but to change it. And that series of inventions, by which man from age to age has remade his environment, is a different kind of evolution – not biological, but cultural evolution. I call that brilliant sequence of cultural peaks *The Ascent of Man.*

I use the word ascent with a precise meaning. Man is distinguished from other animals by his imaginative gifts. He makes plans, inventions, new discoveries, by putting different talents together; and his discoveries become more subtle and penetrating, as he learns to combine his talents in more complex and intimate ways. So the great discoveries of different ages and different cultures, in technique, in science, in the arts, express in their progression a richer and more intricate conjunction of human faculties, an ascending trellis of his gifts.

Of course, it is tempting – very tempting to a scientist – to hope that the most original achievements of the mind are also the most recent. And we do indeed have cause to be proud of some modern work. Think of the unravelling of the code of heredity in the DNA

spiral; or the work going forward on the special faculties of the human brain. Think of the philosophic insight that saw into the Theory of Relativity or the minute behaviour of matter on the atomic scale.

Yet to admire only our own successes, as if they had no past (and were sure of the future), would make a caricature of knowledge. For human achievement, and science in particular, is not a museum of finished constructions. It is a progress, in which the first experiments of the alchemists also have a formative place, and the sophisticated arithmetic that the Mayan astronomers of Central America invented for themselves independently of the Old World. The stonework of Machu Picchu in the Andes and the geometry of the Alhambra in Moorish Spain seem to us, five centuries later, exquisite works of decorative art. But if we stop our appreciation there, we miss the originality of the two cultures that made them. Within their time, they are constructions as arresting and important for their peoples as the architecture of DNA for us.

In every age there is a turning-point, a new way of seeing and asserting the coherence of the world. It is frozen in the statues of Easter Island that put a stop to time – and in the medieval clocks in Europe that once also seemed to say the last word about the heavens for ever. Each culture tries to fix its visionary moment, when it was transformed by a new conception either of nature or of man. But in retrospect, what commands our attention as much are the continuities – the thoughts that run or recur from one civilisation to another. There is nothing in modern chemistry more unexpected than putting together alloys with new properties; that was discovered after the time of the birth of Christ in South America, and long before that in Asia. Splitting and fusing the atom both derive, conceptually, from a discovery made in prehistory: that stone and all matter has a structure along which it can be split and put together in new arrangements. And man made biological

inventions almost as early: agriculture – the domestication of wild wheat, for example – and the improbable idea of taming and then riding the horse.

In following the turning-points and the continuities of culture, I shall follow a general but not a strict chronological order, because what interests me is the history of man's mind as an unfolding of his different talents. I shall be relating his ideas, and particularly his scientific ideas, to their origins in the gifts with which nature has endowed man, and which make him unique. What I present, what has fascinated me for many years, is the way in which man's ideas express what is essentially human in his nature.

So these programmes or essays are a journey through intellectual history, a personal journey to the high points of man's achievement. Man ascends by discovering the fullness of his own gifts (his talents or faculties) and what he creates on the way are monuments to the stages in his understanding of nature and of self – what the poet W. B. Yeats called 'monuments of unageing intellect'.

Where should one begin? With the Creation – with the creation of man himself. Charles Darwin pointed the way with *The Origin of Species* in 1859, and then in his book of 1871, *The Descent of Man*. It is almost certain now that man first evolved in Africa near the equator. Typical of the places where his evolution may have begun is the savannah country that stretches out across Northern Kenya and South West Ethiopia near Lake Rudolf. The lake lies in a long ribbon north and south along the Great Rift Valley, hemmed in by over four million years of thick sediments that settled in the basin of what was formerly a much more extensive lake. Much of its water comes by way of the winding, sluggish Omo. For the origins of man, this is a possible area: the valley of the river Omo in Ethiopia near Lake Rudolf.

The ancient stories used to put the creation of man into a golden age and a beautiful, legendary landscape. If I were telling the story of Genesis now, I should be standing in the Garden of Eden. But this is manifestly not the Garden of Eden. And yet I am at the navel of the world, at the birthplace of man, here in the East African Rift Valley, near the equator. The slumped levels in the Omo basin, the bluffs, the barren delta, record a historic past of man. And if this ever was a Garden of Eden, why, it withered millions of years ago.

I have chosen this place because it has a unique structure. In this valley was laid down, over the last four million years, layer upon layer of volcanic ash, interbedded with broad bands of shale and mudstone. The deep deposit was formed at different times, one stratum after another, visibly separated according to age: four million years ago, three million years ago, over two million years ago, somewhat under two million years ago. And then the Rift Valley buckled it and stood it on end, so that now it makes a map in time, which we see stretching into the distance and the past. The record of time in the strata, which is usually buried underfoot, has been tip-tilted in the cliffs that flank the Omo, and spread out like the ribs of a fan.

These cliffs are the strata on edge: in the foreground the bottom level, four million years old, and beyond that the next lowest, well over three million years old. The remains of a creature like man appear beyond that, and the remains of the animals that lived at the same time.

The animals are a surprise, because it turns out that they have changed so little. When we find in the sludge of two million years ago the fossils of the creature who was to become man, we are struck by the differences between his skeleton and ours – by the development of the skull, for instance. So, naturally, we expect

The animals are a surprise, because it turns out that they have changed so little.

Modern and fossil nyala horns from Omo. The fossil horns are over two million years old.

the animals of the savannah also to have changed greatly. But the fossil record in Africa shows that this is not so. Look as the hunter does at the Topi antelope now. The ancestor of man that hunted its ancestor two million years ago would at once recognise the Topi today. But he would not recognise the hunter today, black or white, as his own descendant.

Yet it is not hunting in itself (or any other single pursuit) that has changed man. For we find that among the animals the hunter has changed as little as the hunted. The serval cat is still powerful in pursuit, and the oryx is still swift in flight; both perpetuate the same relation between their species as they did long ago. Human evolution began when the African climate changed to drought: the lakes shrank, the forest thinned out to savannah. And evidently it was fortunate for the forerunner of man that he was not well adapted to these conditions. For the environment exacts a price for the survival of the fittest; it captures them. When animals like Grevy's zebra were adapted to the dry savannah, it became a trap in time as well as space; they stayed where they were, and much as they were. The most gracefully adapted of all these animals is surely Grant's gazelle; yet its lovely leap never took it out of the savannah.

In a parched African landscape like Omo, man first put his foot to the ground. That seems a pedestrian way to begin the Ascent of Man, and yet it is crucial. Two million years ago, the first certain ancestor of man walked with a foot which is almost indistinguishable from the foot of modern man. The fact is that when he put his foot on the ground and walked upright, man made a commitment to a new integration of life and therefore of his limbs.

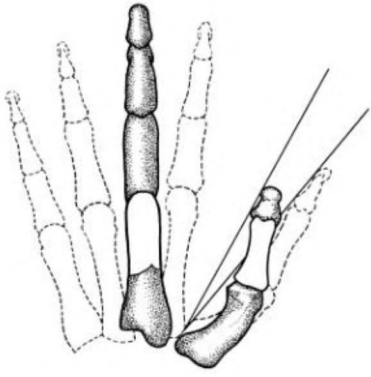
The one to concentrate on, of course, is the head, because of all human organs it has undergone the most far-reaching and formative changes. Happily, the head leaves a lasting fossil (unlike the soft organs), and though it is less informative about the brain than we

should like, at least it gives us some measure of its size. A number of fossil skulls have been found in Southern Africa in the last fifty years which establish the characteristic structure of the head when it began to be man-like. The picture on page 27 shows what it looked like over two million years ago. It is a historic skull, found not at Omo, but south of the equator at a place called Taung, by an anatomist called Raymond Dart. It is a baby, five to six years old, and though the face is nearly complete, part of the skull is sadly missing. In 1924 it was a puzzling find, the first of its kind, and was treated with caution even after Dart's pioneering work on it.

Yet Dart instantly recognised two extraordinary features. One is that the *foramen magnum* (that is, the hole in the skull that the spinal cord comes up through to the brain) is upright; so that this was a child that held its head up. That is one man-like feature; for in the monkeys and apes the head hangs forward from the spine, and does not sit upright on top of it. And the other is the teeth. The teeth are always tell-tale. Here they are small, they are square – these are still the child's milk teeth – they are not the great, fighting canines that the apes have. That means that this was a creature that was going to forage with its hands and not its mouth. The evidence of the teeth also implies that it was probably eating meat, raw meat; and so the hand-using creature was almost certainly making tools, pebble-tools, stone choppers, to carve it and to hunt.

Dart called this creature *Australopithecus*. It is not a name that I like; it just means Southern Ape, but it is a confusing name for an African creature that for the first time was not an ape. I suspect that Dart, who was born in Australia, put a pinch of mischief into his choice of the name.

It took ten years before more skulls were found – adult skulls now – and it was not until late in the 1950s that the story of *Australopithecus*

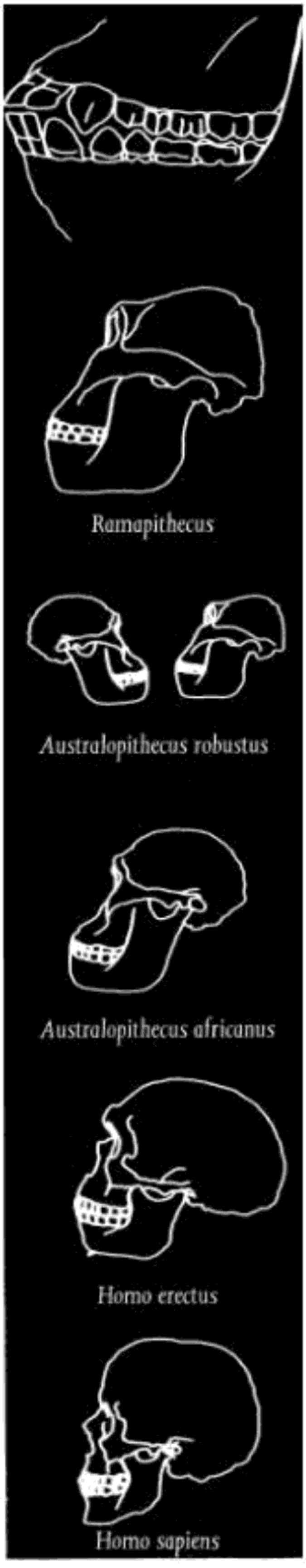


(*Left*) I do not know how the Taung baby began life, but to me it still remains the primordial infant from which the whole adventure of man began.
The Taung child's skull

(*Right*) The ancestor of man had a short thumb, and therefore could not manipulate very delicately.
Finds of finger and thumb bones of Australopithecus *from the lowest beds of Olduvi Gorge superimposed on the bones of a modern hand*

was substantially pieced together. It started in South Africa, then it moved north to Olduvai Gorge in Tanzania, and most recently the richest finds of fossils and tools have turned up in the basin of Lake Rudolf. This history is one of the scientific delights of the century. It is every bit as exciting as the discoveries in physics before 1940, and those in biology since 1950; and it is as rewarding as either of those in the light that it throws on our nature as human beings.

For me, the little *Australopithecus* baby has a personal history. In 1950, when its humanity was by no means accepted, I was



(*Left*) The head is the spring which drives cultural evolution.
Computer-graphic display of stages in evolution of the head

action until the blood can be cleaned with fresh oxygen.

So far, there is nothing to distinguish the athlete from the gazelle – all that, in one way or another, is the normal metabolism of an animal in flight. But there is a cardinal difference: the runner was not in flight. The shot that set him off was the starter's pistol, and what he was experiencing, deliberately, was not fear but exaltation. The runner is like a child at play; his actions are an adventure in freedom, and the only purpose of his breathless chemistry was to explore the limits of his own strength.

Naturally there are physical differences between man and the other animals, even between man and the apes. In the act of vaulting, the athlete grasps his pole, for example, with an exact grip that no ape can quite match. Yet such differences are secondary by comparison with the overriding difference, which is that the athlete is an adult whose behaviour is not driven by his immediate environment, as

animal actions are. In themselves, his actions make no practical sense at all; they are an exercise that is not directed to the present. The athlete's mind is fixed ahead of him, building up his skill; and he vaults in imagination into the future.

Poised for that leap, the pole-vaulter is a capsule of human abilities: the grasp of the hand, the arch of the foot, the muscles of the shoulder and pelvis – the pole itself, in which energy is stored and released like a bow firing an arrow. The radical character in that complex is the sense of foresight, that is, the ability to fix an objective ahead and rigorously hold his attention on it. The athlete's performance unfolds a continued plan, from one extreme to the other, it is the invention of the pole, the concentration of the mind at the moment before leaping, which give it the stamp of humanity.

The head is more than a symbolic image of man; it is the seat of foresight and, in that respect, the spring which drives cultural evolution. Therefore if I am to take the ascent of man back to its beginnings in the animal, it is the evolution of the head and the skull that has to be traced. Unhappily, over the fifty million years or so to be talked about, there are only six or seven essentially distinct skulls which we can identify as stages in that evolution. Buried in the fossil record there must be many other intermediate steps, some of which will be found; but meanwhile we must conjecture what happened, approximately, by interpolating between the known skulls. The best way to calculate these geometrical transitions from skull to skull is on a computer; so that, in order to trace the continuity, I present them on a computer with a visual display which will lead from one to the next.

Begin fifty million years ago with a small tree-dwelling creature, a lemur; the name, appropriately, is that of the Roman spirits of

the dead. The fossil skull belongs to the lemur family *Adapis*, and was found in chalky deposits outside Paris. When the skull is turned upside down, you can see the *foramen magnum* far at the back – this is a creature that hung, not held, its head on the spine. The likelihood is that it ate insects as well as fruits, and it has more than the thirty-two teeth that man and most primates now have.

The fossil lemur has some essential marks of the primates, that is, the family of monkey, ape and man. From remains of the whole skeleton we know that it has finger nails, not claws. It has a thumb that can be opposed at least in part to the hand. And it has in the skull two features that really mark the way to the beginning of man. The snout is short; the eyes are large and widely spaced. That means that there has been selection against the sense of smell and in favour of the sense of vision. The eye-sockets are still rather sideways in the skull, on either side of the snout; but compared with the eyes of earlier insect eaters, the lemur's have begun to move to the front and to give some stereoscopic vision. These are small signs of an evolutionary development towards the sophisticated structure of the human face; and yet, from that, man begins.

That was fifty million years ago, in very round figures. In the next twenty million years, the line that leads to the monkeys branches away from the main line to the apes and man. The next creature on the main line, thirty million years ago, was the fossil skull found in the Fayurn in Egypt, and named *Aegyptopithecus*. He has a shorter snout than the lemur, his teeth are ape-like, and he is larger – yet still lives in the trees. But from now on the ancestors of the apes and man spent part of their time on the ground.

Another ten million years on take us to twenty million years ago, when there were what we should now call anthropoid apes

in East Africa, Europe and Asia. A classical find made by Louis Leakey goes by the dignified name of *Proconsul*, and there was at least one other widespread genus, *Dryopithecus*. (The name *Proconsul* is a piece of anthropological wit; it was coined to suggest that he was an ancestor of a famous chimpanzee at the London Zoo in 1931 whose nickname was Consul.) The brain is markedly larger, the eyes are now fully forward in stereoscopic vision. These developments tell us how the main ape-and-man line was moving. But if, as is possible, it had already branched again, then so far as man is concerned, alas, this creature is on the branch line – the ape line. The teeth show us that he is an ape, because the way in which the jaw is locked by the big canines is not man-like.

It is the change in the teeth that signals the separation of the line that leads to man, when it comes. The first harbinger that we have is *Ramapithecus*, found in Kenya and in India. This creature is fourteen million years old, and we only have pieces of the jaw. But it is clear that the teeth are level and more human. The great canines of the anthropoid apes are gone, the face is much flatter, and we are evidently near a branching of the evolutionary tree; some anthropologists would boldly put *Ramapithecus* among the hominids.

There is now a blank in the fossil record of five to ten million years. Inevitably, the blank hides the most intriguing part of the story, when the hominid line to man is firmly separated from the line to the modern apes. But we have found no unequivocal record of that, yet. Then, perhaps five million years ago, we come certainly to the relatives of man.

A cousin of man, not in the direct line to us, is a heavily-built *Australopithecus* who is a vegetarian. *Australopithecus robustus* is manlike and his line does not lead elsewhere; it has simply become extinct. The evidence that he lived on plants is again in his teeth, and

it is quite direct: the teeth that survive are pitted by the fine grit that he picked up with the roots that he ate.

His cousin on the line to man is lighter – visibly so in the jaw – and is probably a meat-eater. He is the nearest thing we have to what used to be called the 'missing link': *Australopithecus africanus*, one of a number of fossil skulls found at Sterkfontein in the Transvaal and elsewhere in Africa, a fully grown female. The Taung child, with which I began, would have grown up to be like her; fully erect, walking, and with a largish brain weighing between a pound and a pound and a half. That is the size of the brain of a big ape now; but of course this was a small creature standing only four feet high. Indeed, recent finds by Richard Leakey suggest that by two million years ago the brain was larger even than that.

And with that larger brain the ancestors of man made two major inventions, for one of which we have visible evidence and for the other inferential evidence. First, the visible invention. Two million years ago *Australopithecus* made rudimentary stone tools where a simple blow has put an edge on the pebble. And for the next million years, man in his further evolution did not change this type of tool. He had made the fundamental invention, the purposeful act which prepares and stores a pebble for later use. By that lunge of skill and foresight, a symbolic act of discovery of the future, he had released the brake which the environment imposes on all other creatures. The steady use of the same tool for so long shows the strength of the invention. It was held in a simple way, by pressing its thick end against the palm of the hand in a power-grip. (The ancestors of man had a short thumb, and therefore could not manipulate very delicately, but could use the power-grip.) And, of course, it is a meat-eater's tool almost certainly, to strike and to cut.

The other invention is social, and we infer it by more subtle arithmetic. Skulls and skeletons of *Australopithecus* that have now

life, make him creative. Every animal leaves traces of what it was; man alone leaves traces of what he created.

Change in diet is important in a changing species over a time as long as fifty million years. The earliest creatures in the sequence leading to man were nimble-eyed and delicate-fingered insect and fruit eaters like the lemurs. Early apes and hominids, from *Aegyptopithecus* and *Proconsul* to the heavy *Australopithecus*, are thought to have spent their days rummaging mainly for vegetarian foods. But the light *Australopithecus* broke the ancient primate habit of vegetarianism.

The change from a vegetarian to an omnivorous diet, once made, persisted in *Homo erectus*, Neanderthal man and *Homo sapiens*. From the ancestral light *Australopithecus* onwards, the family of man ate some meat: small animals at first, larger ones later. Meat is a more concentrated protein than plant, and eating meat cuts down the bulk and the time spent in eating by two-thirds. The consequences for the evolution of man were far-reaching. He had more time free, and could spend it in more indirect ways, to get food from sources (such as large animals) which could not be tackled by hungry brute force. Evidently that helped to promote (by natural selection) the tendency of all primates to interpose an internal delay in the brain between stimulus and response, until it developed into the full human ability to postpone the gratification of desire.

But the most marked effect of an indirect strategy to enhance the food supply is, of course, to foster social action and communication. A slow creature like man can stalk, pursue and corner a large savannah animal that is adapted for flight only by co-operation. Hunting requires conscious planning and organisation by means of language, as well as special weapons. Indeed, language as we use it has something of the character of a hunting plan, in that (unlike the

animals) we instruct one another in sentences which are put together from movable units. The hunt is a communal undertaking of which the climax, but only the climax, is the kill.

Hunting cannot support a growing population in one place; the limit for the savannah was not more than two people to the square mile. At that density, the total land surface of the earth could only support the present population of California, about twenty millions, and could not support the population of Great Britain. The choice for the hunters was brutal: starve or move.

They moved away over prodigious distances. By a million years ago, they were in North Africa. By seven hundred thousand years ago, or even earlier, they were in Java. By four hundred thousand years ago, they had fanned out and marched north, to China in the east and Europe in the west. These incredible spreading migrations made man, from an early time, a widely dispersed species, even though his total numbers were quite small – perhaps one million.

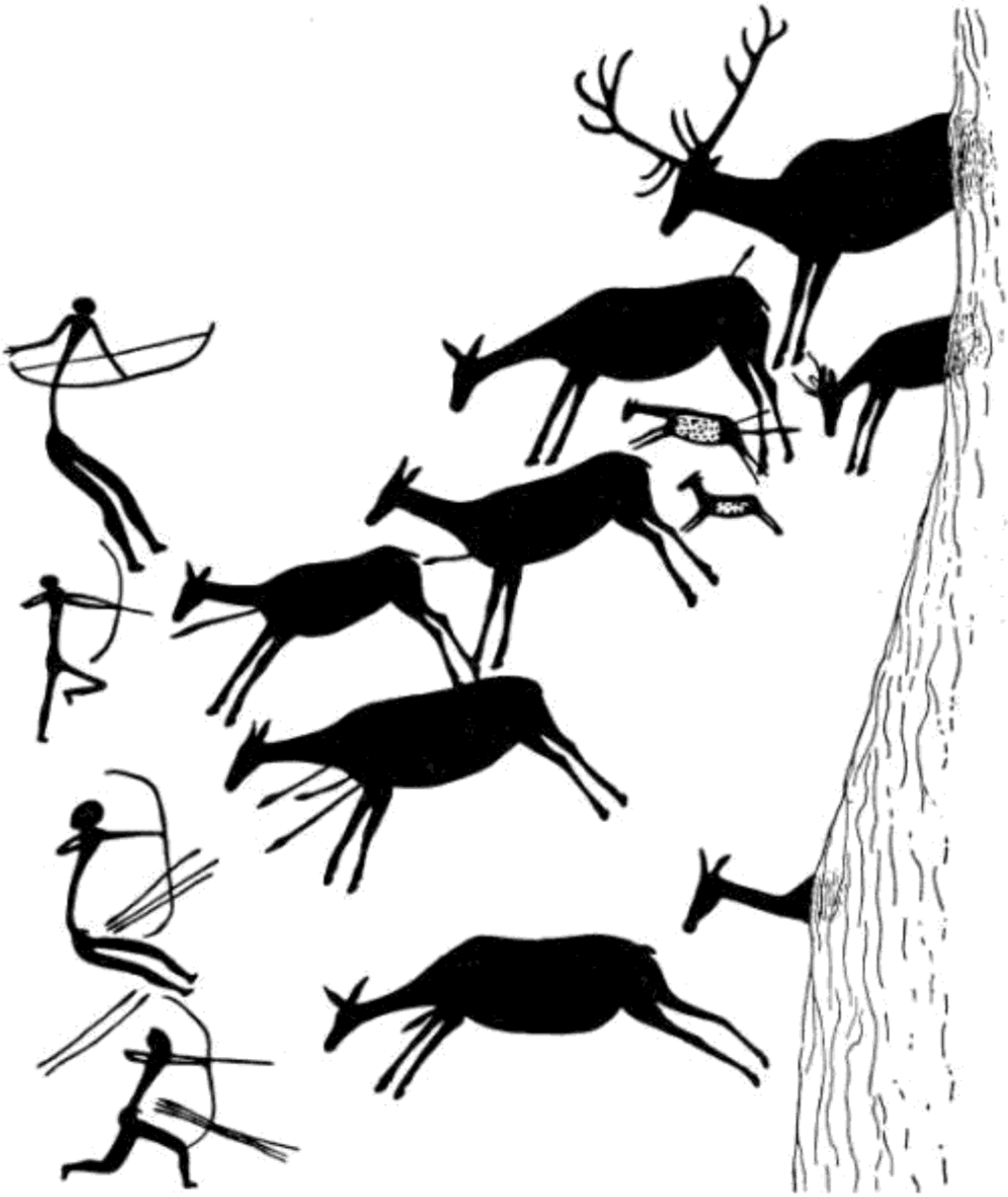
What is even more forbidding is that man moved north just after the climate there was turning to ice. In the great cold the ice, as it were, grew out of the ground. The northern climate had been temperate for immemorial ages – literally for several hundred million years. Yet before *Homo erectus* settled in China and northern Europe, a sequence of three separate Ice Ages began.

The first was past its fiercest when Peking man lived in caves, four hundred thousand years ago. It is no surprise to find fire used in those caves for the first time. The ice moved south and retreated three times, and the land changed each time. The icecaps at their largest contained so much of the earth's water that the level of the sea fell four hundred feet. After the second Ice Age, over two hundred thousand years ago, Neanderthal man with his big brain appears, and he became important in the last Ice Age.

The cultures of man that we recognise best began to form in the most recent Ice Age, within the last hundred or even fifty thousand years. That is when we find the elaborate tools that point to sophisticated forms of hunting: the spear-thrower, for example, and the baton that may be a straightening tool; the fully barbed harpoon; and, of course, the flint master tools that were needed to make the hunting tools.

It is clear that then, as now, inventions may be rare but they spread fast through a culture. For example, the Magdalenian hunters of southern Europe fifteen thousand years ago invented the harpoon. In the early period of the invention, the Magdalenian harpoons were unbarbed; then they were barbed with a single row of fish hooks; and at the end of the period, when the flowering of cave art took place, they were fully barbed with a double row of hooks. The Magdalenian hunters decorated their bone tools, and they can be pinned to precise periods in time and to exact geographical locations by the refinement of style which they carry. They are, in a true sense, fossils that recount the cultural evolution of man in an orderly progression.

Man survived the fierce test of the Ice Ages because he had the flexibility of mind to recognise inventions and to turn them into community property. Evidently the Ice Ages worked a profound change in the way man could live. They forced him to depend less on plants and more on animals. The rigours of hunting on the edge of the ice also changed the strategy of hunting. It became less attractive to stalk single animals, however large. The better alternative was to follow herds and not to lose them – to learn to anticipate and in the end to adopt their habits, including their wandering migrations. This is a peculiar adaptation – the transhumance mode of life on the move. It has some of the earlier qualities of hunting, because it is a pursuit; the place and the pace



Fossils that recount the cultural evolution of man in an orderly progression.

Rock painting of a reindeer hunt, Los Caballos Shelter, Valtorta Gorge, Castellon, Eastern Spain. The invention of the bow and arrow came at the end of the last Ice Age.

are set by the food animal. And it has some of the later qualities of herding, because the animal is tended and, as it were, stored as a mobile reservoir of food.

The transhumance way of life is itself a cultural fossil now, and has barely survived. The only people that still live in this way are the Lapps in the extreme north of Scandinavia, who follow the reindeer as they did during the Ice Age. The ancestors of the Lapps may have come north from the Franco-Cantabrian cave area of the Pyrenees in the wake of the reindeer as the last icecaps retreated from southern Europe twelve thousand years ago. There are thirty thousand people and three hundred thousand reindeer, and their way of life is coming to an end even now. The herds go on their own migration across the fiords from one icy pasture of lichen to another, and the Lapps go with them. But the Lapps are not herdsmen; they do not control the reindeer, they have not domesticated it. They simply move where the herds move.

Even though the reindeer herds are in effect still wild, the Lapps have some of the traditional inventions for controlling single animals that other cultures also discovered: for example, they make some males manageable as draught animals by castrating them. It is a strange relationship. The Lapps are entirely dependent on the reindeer – they eat the meat, a pound a head each every day, they use the sinews and fur and hides and bones, they drink the milk, they even use the antlers. And yet the Lapps are freer than the reindeer, because their mode of life is a cultural adaptation and not a biological one. The adaptation that the Lapps have made, the transhumance life on the move in a landscape of ice, is a choice that they can change; it is not irreversible, as biological mutations are. For a biological adaptation is an inborn form of behaviour; but a culture is a learned form of behaviour – a communally preferred form, which (like other inventions) has been adopted by a whole society.

time add those arts that now astonish us: decorations with animal shapes? Why, above all, did he come to caves like this, live in them, and then make paintings of animals not where he lived but in places that were dark, secret, remote, hidden, inaccessible?

The obvious thing to say is that in these places the animal was magical. No doubt that is right; but magic is only a word, not an answer. In itself, magic is a word which explains nothing. It says that man believed he had power, but what power? We still want to know what the power was that the hunters believed they got from the paintings.

Here I can only give you my personal view. I think that the power that we see expressed here for the first time is the power of anticipation: the forward-looking imagination. In these paintings the hunter was made familiar with dangers which he knew he had to face but to which he had not yet come. When the hunter was brought here into the secret dark and the light was suddenly flashed on the pictures, he saw the bison as he would have to face him, he saw the running deer, he saw the turning boar. And he felt alone with them as he would in the hunt. The moment of fear was made present to him; his spear-arm flexed with an experience which he would have and which he needed not to be afraid of. The painter had frozen the moment of fear, and the hunter entered it through the painting as if through an air-lock.

For us, the cave paintings re-create the hunter's way of life as a glimpse of history; we look through them into the past. But for the hunter, I suggest, they were a peep-hole into the future; he looked ahead. In either direction, the cave paintings act as a kind of telescope tube of the imagination: they direct the mind from what is seen to what can be inferred or conjectured. Indeed, this is so in the very action of painting; for all its superb observation, the flat picture only means something to the eye because the mind fills it out with

roundness and movement, a reality by inference, which is not actually seen but is imagined.

Art and science are both uniquely human actions, outside the range of anything that an animal can do. And here we see that they derive from the same human faculty: the ability to visualise the future, to foresee what may happen and plan to anticipate it, and to represent it to ourselves in images that we project and move about inside our head, or in a square of light on the dark wall of a cave or a television screen.

We also look here through the telescope of the imagination; the imagination is a telescope in time, we are looking back at the experience of the past. The men who made these paintings, the men who were present, looked through that telescope forward. They looked along the ascent of man because what we call cultural evolution is essentially a constant growing and widening of the human imagination.

The men who made the weapons and the men who made the paintings were doing the same thing – anticipating a future as only man can do, inferring what is to come from what is here. There are many gifts that are unique in man; but at the centre of them all, the root from which all knowledge grows, lies the ability to draw conclusions from what we see to what we do not see, to move our minds through space and time, and to recognise ourselves in the past on the steps to the present. All over these caves the print of the hand says: 'This is my mark. This is man.'