CHAPTER ONE

Prologue

We're all of us guinea pigs in the laboratory of God.
Humanity is just work in progress (Tennessee Williams)[1]

Scientists have unravelled the human genome. It is time to take stock. What really makes us human? Philosophers and scientists have long argued about it. I believe it is our innate propensity for quest.

The word is derived from the Latin verb *quaerere*, to search, to seek. From it we have query and inquisitiveness on the one hand, conquest on the other. Together the words describe the qualities that have made us masters of life on earth: we search for new horizons, we seek explanations for the phenomena around us, but we also strive to dominate our fellow creatures.

Yet to search is a fundamental quality of all living organisms: it is as integral to life as growth and reproduction. Plants search and so do microbes: we all know that plants have a tendency to grow towards the light—the sun is their only source of energy—and some microbes swim towards a source of food. So it is not surprising that animals, sharing a common ancestor with plants and microbes, also search: primarily for food and a mate, and in the non-aquatic animals for water and shelter also. As animals have become more highly developed over the past half billion years, so has their capacity to search. It has reached its peak in *Homo sapiens*. Not only do we search for food and water, for a mate and for shelter, but we also search for no apparent reason at all: it is curiosity alone, not need, that has led men to seek the source of the Nile and to unravel the origin of the stars.

Pedants may argue that I am using the word 'search' in two different senses. Plants and microbes respond to light and food in an involuntary, preprogrammed, manner: it is simply a question of being attracted to a source of light or a concentration of nutrients. Man's search is voluntary and variable. Some of us are curious about the origin of thunderstorms and earthquakes, others are no more interested in their causes than in the way an automobile or a computer works, but might like to find out why the most popular star of the day has abandoned her boyfriend and what the zodiac holds in store for them this month; they search the media and surf the Internet for the answers. You are searching for something—entertainment, knowledge—at this very moment of holding *Quest* in your hand.

Physiologists and biochemists, however, have taught us that there is little fundamental difference between an involuntary act like the beating of one's heart and a voluntary one like the raising of an eyebrow, between an involuntary feeling like fear and a voluntary one like deciding to read this book: the underlying mechanisms are virtually the same. I will not go into details at this stage, except to point out that all life—whether that of a bacterium or a plant, an animal or a human—depends on chemical reactions between the fundamental units of matter called molecules.

Two types of molecule are the most important for anything that is alive: genes, which biochemists also know as DNA, and proteins. Genes are related to proteins in the way that an architect's blueprint is related to the building he will construct: it defines its shape and its size. A gene is a set of instructions for making a protein: it specifies its size and its shape. What proteins do is to endow matter with life: with movement and growth, with reproduction and an awareness of the environment, with the ability to search. It is the proteins underlying the voluntary and involuntary responses of animals that are similar. Moreover, we now know that some of the genes involved in the responses of plants and microbes—their search for light and food—have been retained in animals and man: in other words, some of the proteins that enable us to search are structurally related to proteins possessed by much simpler, and older, forms of life.

If there is a continuity of function, and of the underlying molecules, from ancient bacteria to fish and to birds and to mammals, what is it that distinguishes one primate—*Homo sapiens*—from all other organisms, and especially from that primate's nearest relatives, *Pan* *troglodytes*, the common chimpanzee, and *Pan paniscus*, the bonobo or pygmy chimpanzee? Could it be something as subtle as a heightened propensity for quest?

For 150 years, since Darwin's time, anthropologists have tried to identify the qualities that identify man's unique behaviour, but they have failed. As each suggested characteristic is sought among non-human primates, it has been found: the use of simple tools, an ability to reason, the feeling of misery or joy, consciousness and an awareness of self, the appreciation of humour, the comprehension of words and an understanding of language.[2] The quality may be expressed only to a very minor extent, and merely in one or other species that has been taught by humans, but it leaves us unable to pinpoint a defining feature of man. Attempts to do so, by writers as recent as Kenan Malik (2000) in *Man, Beast and Zombie*, fail to convince. They have merely fudged the issue by ascribing man's uniqueness to some non-genetic behavioural trait, like the development of 'memes', a subject to which we shall return in the Epilogue.

So, in *The Rise and Fall of the Third Chimpanzee*, the biologist Jared Diamond rightly describes man as just another primate, to be classified in the same genus as the bonobo and the common chimpanzee: provocatively, he calls that genus *Homo* rather than *Pan*. Desmond Morris had done much the same in his book, *The Naked Ape*, 30 years earlier.[3] No single feature, it appears, characterises *Homo sapiens*: wisdom (*sapientia*) is certainly not one. If no discrete attribute explains the essential difference between chimpanzee and man, we must look for a number of features—none of which is unique to man—that in combination have somehow resulted in his altered behaviour, in his increased ability for quest. What might those features be?

Hundreds of characteristics distinguish man from chimpanzee. The most obvious to a casual observer are less body hair, a different type of face, much shorter arms, an upright gait. To a specialist the features he focuses on are those connected with his particular discipline. An anatomist will describe in detail the shape of the jaw and the pelvis as well as every other bone in the body, a nutritionist will examine the diet in regard to the consumption of animal as opposed to vegetable protein, an anthropologist will focus on the earlier onset of reproductive ability and the shorter life span, a sociologist will observe the mating behaviour in terms of the duration of sexual urge and number of partners, a statistician will note the relative differences in height between male and female and might comment on the larger breasts of human females and the longer sexual organ of human males.[4]

We will concentrate on just four features that have accompanied the evolution of man from other primates. The first is a change in the spine that makes him walk upright. This increases his view of the horizon and simultaneously frees his hands: you may be able to wipe the sweat off your brow and to peel a banana walking along, but a chimpanzee does so sitting down. The second is a modification in the relative length of thumb and fingers and in the muscles that control their movement. We can bend our thumb and move it past each of our finger tips better than a chimpanzee: our precision grip allows us to sense the shape of objects and to fashion these in a superior way. Some of us can learn to play a violin or take out an appendix; a chimpanzee would perform clumsily at either of these tasks. The third distinguishing feature is the vocal cord. It lies within the larynx, through which all primates breathe; the cord is positioned lower down in humans and made into an intricate voice box through just two small pieces of cartilage. The result is that we can produce an enormous diversity of sounds—just listen to the range of Luciano Pavarotti's voice or the recordings of Maria Callas—whereas a chimpanzee can merely grunt. Yet we are born with a primitive vocal cord high up in the larynx, just like an ape. Babies can only whimper and cry, although like chimpanzees they are able to breathe and swallow at the same time: adult humans cannot. So a slight lowering of the vocal cord at around a year or so of age is all it takes to endow a human with the power of speech. The fourth attribute relates to the millions of neurons or nerve cells that are responsible for thought and memory, for the power of reasoning. They are contained in the region of the brain known as the cortex. Their function is precisely the same in chimpanzees and humans: the only difference is that we have three times as many.

I believe that it is the combination of these four attributes that has enabled man to search more widely—both physically and mentally—than any other animal. In stressing that it is a combination of qualities that characterises man, I am doing no more than adapting to a species the definition of individuality formulated by the immunologist Peter Medawar: 'One individual differs from all others not because he has unique endowments but because he has a unique *combination* of endowments.'[5] On the other hand, man's heightened ability to search depends so much on his use of language that I might have chosen to focus on the attribute of speech alone. In a beguiling book entitled *Grooming, Gossip and the Evolution of Language*, the anthropologist Robin Dunbar has done just that. He suggests that gossiping among humans is an extension of grooming among apes and that it is gossip that has led to the evolution of language and thence to man's complex behaviour. But while speech undoubtedly contributes to man's superior ability for quest, it alone does not account for the emergence of civilisations and the development of culture. Chattering does not produce the great pyramid of Cheops, neither does it lead to the Mona Lisa or the theory of relativity. Quest does.

The four anatomical differences between man and chimpanzee on which I have focused—upright gait, agile hand, sophisticated vocal cord and greater quantity of cortical neurons—have arisen gradually over the past 5 million years or so. Their appearance was pure chance; their retention is due only to the fact that their owners—successive species of primate—outbred others of their kind. None represents a sudden and dramatic change of form, any more than does the evolution of terrestrial animals from fish, or of birds from reptiles. Each of the four anatomical features is specified by a number of genes. As yet these have not all been identified, but it is probable that they belong to families that are similar in humans and chimpanzees. As we shall see in Chapter 4, the genes responsible for human characteristics are homologues of genes specifying comparable functions in other primates: so far as searching is concerned, it would appear unnecessary to postulate the existence of 'human' genes in order to define the essential differences between man and ape.

This conclusion applies to all other functions of humans and chimpanzees as well, and sits easily with the fact that our genetic make-up resembles that of a chimpanzee by 95%.[6] But a difference of 5% might still mean that more than 1000 genes are uniquely

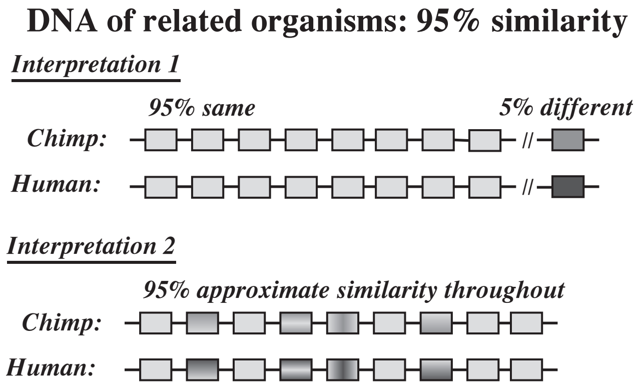

Figure 1.1 The genetic make-up of chimpanzees and humans. See text and Note 24 to Chapter 2 for details.

human as opposed to chimpanzee-like, and those who subscribe to this view continue to search for characteristically human genes. I do not believe they will find them. My interpretation, which is shared with many molecular scientists, is different. To us, the '95% similarity' implies that *all* the genes of chimpanzees and humans are *on average* 95% similar and 5% different: some genes, like that for the alpha chain of haemoglobin, are identical; other genes, like that for insulin, are almost identical; yet other genes differ by more than 5%, but even these belong to the same gene family, specifying the same function, in humans and chimpanzees. There are no 'human' as opposed to 'chimpanzee' genes at all (Figure 1.1).

To summarise the gist of this book. All living organisms, from bacteria to plants and to animals, search. In humans, the propensity for quest is amplified; in other primates, it is constrained. Man has come to dominate the world and every creature on it; the chimpanzee is in danger of extinction.[7]

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Quest is divided into four parts. In the first, we consider the genetic basis of searching. In order to do so, the molecular nature of life has to be appreciated. There is both unity and diversity. All organisms are made up of the same *kind* of molecules, but no two organisms, even of the same species, are exactly alike: they differ in the fine structure of their constituent DNA and proteins. As a result, one shrub grows taller than its neighbour, one amoeba swims faster than its mate, one pigeon coos louder than its sibling, one human being is more inquisitive than another. It is such subtleties of molecular structure that also underlie the emergence of new species: of us humans from an ancient bacterium, as explained in Chapter 2.

I have alluded to the search by plants for the light of the sun and by microbes for food. Because these are relatively simple systems, many of the molecules that underlie the search have been defined. It turns out that several of them, proteins as well as smaller molecules like vitamins, play a role also in the physiological processes that underlie searching by higher organisms. As will become apparent in Chapter 3, vision—which is crucial to an animal's ability to search—is based on a mechanism that has its origin in the responses of plants and certain microbes to light.

As aquatic organisms moved on to land 400 million years ago, the search widened. As mammals began to replace reptiles some 65 million years ago, the search widened yet again. And as the forerunners of modern man began to evolve from other primates around 5 million years ago, the ability to search increased even further: the advantages of the attributes I have identified when looking for food and water, a possible predator, or a new environment in which to settle, are clear. The benefits of successful searching in terms of survival and passing on one's genes—the concept of the selfish gene[8]—are obvious. Recently discovered molecules related to human quest are introduced in Chapter 4.

The second part of the book traces the quest of modern man, of *Homo sapiens*. It is essentially the story of the last 100,000 years, analysed in terms of man's unceasing search. Each of the topics I describe is a measure of the behavioural differences between human and chimpanzee: each stems from nothing more than man's superior means to engage in the primeval act of quest. His brain questions and dreams up new challenges: his hands respond. What, then, have the consequences been? Man's search for new environments has taken him beyond his African origins to Asia and to Europe, and subsequently to every part of the globe. In most places except the polar ice caps, arid deserts and snow-capped mountains, some members of the species decided to settle, and in many cases their descendants are there to this day. The exploratory drive of humans, from walking out of the Great Rift valley in east Africa to landing on the moon, is illustrated with appropriate examples in Chapter 5.

Ten thousand years ago men began to feel more secure in keeping predators at bay. They began to cultivate their own crops and to domesticate animals for food and work. As the nomadic life was abandoned for that of a settled community, some groups were not content to remain where they were. They searched for fresh places in which to settle and they began to look for novel ways in which to carry out their daily lives: not just more comfortably in buildings and palaces made of stone, not merely more hygienically, with piped water and drains, but surrounded by pleasing objects also. Civilisations emerged. Their birth, and the part that heredity plays in producing leaders and men of culture, are examined in Chapter 6.

The achievements associated with those civilisations—in Mesopotamia and Egypt, in China and India and Crete, in central and southern America—are compared with the relative dearth of accomplishments elsewhere in Chapter 7. The development of language, which is the forerunner of the written word, and the basis of scholarship and art, constitute Chapter 8.

From the shaping of the first flint stone and the lighting of a fire more than a million years ago, man has worked with his hands. The technologies of the stone age, of China and Islam, have defined the way we lead our lives. But every improvement is accompanied by a new instrument of war. Chapter 9 is devoted to these topics and to an assessment of the relationship between technology and wealth. It closes with the innovations of one man: Leonardo da Vinci. No one has been able to match Leonardo in combining dexterity of hand with ingenuity of mind.

Early man must often have been frightened by the natural world around him: by thunder and lightning, by hurricanes and floods, by volcanic eruptions and earthquakes. He searched for explanations. And the best explanation all came up with, whether in Sumeria, Egypt, India, China, Crete, Central or South America, was religion: belief in some supernatural beings that are ultimately responsible for events that the people do not understand and cannot control. The explanations proved so satisfactory that the faiths that developed —Hinduism, Buddhism, Judaism and its offspring Christianity and Islam—are practised throughout the world to this very day: by millions of educated men and women of every profession, in temples and shrines, in mosques and synagogues, in churches and in the home. Yet when pressed, few admit to ascribing natural phenomena to some sort of deity any more. What do they seek? An answer is attempted in Chapter 10.

Divine origins for physical events started to be questioned by Greek philosophers seeking alternative interpretations 2000 years ago. Attempts at scientific reasoning then stagnated until explanations for events such as the transition of day into night, winter into spring, began to emerge in the sixteenth century (although we still use terms like 'sunset' and 'sunrise'). A scientific explanation differs from all others in having universal validity: the concept that the earth moves round the sun and not the other way round is as true in Rome as it is in Krakow. Science—questioning beliefs through experiments that lead to a hypothesis, or a hypothesis followed by experimentation—is the same wherever it is practised. Scientists are explorers, too: they search for stars that are trillions of light years away, for particles that are billions of times smaller than a molecule of sugar; for the traces of animals that have been extinct for millions of years, for strains of virus that are only now appearing. Chapter 11 recounts the contributions of some scientific geniuses and asks a simple question: will we soon have discovered all there is to know, or is the search unending?

The third part of this book focuses on current controversy regarding science and technology. The knowledge that we have gained during the last two decades regarding the manipulation of genes—of plants as well as of animals, including man—is leading to enormous changes in agriculture and medicine. The search to generate crops that are resistant to drought, to cold or to pests, that produce a higher yield of wheat or maize or sugar beet or sweet potato, leads to obvious economic advantages that are especially important for the underdeveloped countries of the world. Yet there is much heated debate over genetically modifying foods, and the dispute over doing the same for people is at boiling point. Should human cloning be permitted? Should genes that cause disease be replaced by healthy versions? Should organ transplants from animals be encouraged? Should people be allowed to freeze their body cells in order to have access to them if the need arises? Do the benefits of tinkering with nature outweigh the risks? Is unrestricted quest by scientists acceptable? An objective view is attempted in Chapters 12 and 13.

In the final part we look into the future. Where will man's quest lead him in the next 100 years, where in the next million? Of course, we can only speculate. In the short term I predict that a waning of inquisitiveness—'dumbing down'—that is occurring in Western societies today will lead to their decline compared with the cultures of eastern Asia. Overall, though, humans will be as stupid and as inventive, as kind and as cruel, as they now are: the experience of past events has proved to have little impact on man's behaviour, and a century produces but an imperceptible alteration of his genes. To consider evolutionary change in humans, we need to think in terms of millions of years, not centuries. Over such a time scale, will man's quest lead to the appearence of a new species of *Homo*? Or will his searches result in his own destruction, in the extinction of *Homo quaerens*, before then? A guess is presented in Chapter 14.

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As the idea for writing this book grew in my mind, I began to wonder why no one else had considered quest as a quality that is both distinctive of humans and yet fundamental to all forms of life. Was this idea rubbish or was it self-evident? I spoke to scientific colleagues and approached anthropologists: they listened politely, smiled and suggested that I talk to someone else, as this was not really their field. Others reacted in similar vein. The important point is that no one was able to refer me to an article or a book where it had all been said before. That, at least, was encouraging.

Then Richard Dawkins came to the rescue. He thought that the late Sir Alister Hardy, Professor of Zoology at Oxford half a century ago, had suggested something along these lines. He recalled an article somewhere, but could not remember the exact reference. Perhaps Arthur Cain, a former colleague of Hardy's who had moved to Liverpool but was now retired, could help? By the time I was able to track him down, he had, sadly, died. I resumed my search. Another Oxford zoologist, Mark Ridley, thought that the elusive article might be in one of the Gifford Lectures that Hardy had delivered shortly after his retirement. Success! As the following quotation shows, my idea was neither foolish nor obvious. On the contrary, by writing this book I seem to have answered the question that Hardy posed. Listen to his own words:

> Nevertheless, out of this process of evolution, from *somewhere* has come the urge, or love of adventure, in Man that can drive him to risk his life in climbing Everest or in reaching the South Pole or the Moon. Is it altogether too naive to believe that this exploratory drive, this curiosity, has had its beginnings in some deep-seated part of animal behaviour which is fundamental to the stream of life?[9]

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To write this book I have chosen to delve into subjects like religion and anthropology, history and art, in which I have received no formal training: I am but a humble biochemist. But the search for expression of my thoughts is in my genes. Was not my grandfather an artist, his wife a musician, my uncle a writer and my mother a philosopher? The reader must forgive my errors in what follows. I have written as a scientist, but have allowed my thoughts to wander.

In my mind's eye I see, now, a group of our earliest ancestors walking upright along the Olduvai Gorge in northern Tanzania, looking for food; now, Archimedes at Syracuse, pondering how to measure the relative amounts of gold and silver in King Hieron's crown; now, Christopher Columbus standing in the bow of the Santa Maria, scanning the western horizon in the search for land; now, Claude Monet in his garden at Giverny, striving to depict the sunlight as it falls upon the water lilies; now, Adolf Hitler and

Heinrich Himmler in the Berlin chancellery seeking faster ways to annihilate an entire people; now, Mother Theresa in the slums of Calcutta, endeavouring to let a few starving souls die with dignity; now, a group of white-coated scientists in their laboratory trying to insert a frost-resistant gene into a tomato plant. I see humans but I know that I am witnessing nothing more than the expression of a fundamental quality of living matter: the ability to search. Since I began writing, the sequence of the human genome has been unravelled. It will still be a long time before the function of all the proteins specified by our genes, and the complicated cross-talk between them, is identified. But if you believe, as I do, that such molecular interactions are the basis for our complex behaviour, for our heightened propensity for quest, then join me in a journey of 3.5 billion years that I will try to tell you in just under 400 pages.

Notes

1. From *Camino Real* (1953).
2. See, for example, Carl Sagan and Ann Druyan, op. cit.; a useful summary is on p 399. Good accounts of tool technology and social customs in chimpanzees are given by Frans B. M. de Waal and by A. Whiten *et al.*, in *Nature* **399**: 635–636 and 682–685; 1999 respectively. For a discussion of the chimpanzee's mind in relation to our own, see Steven J. Mithen, op. cit., especially pp 73–94; see also Jane Goodall, op. cit.
3. Jean-Jacques Rousseau, in 1753 (100 years before Darwin's *Origin of Species*), even classified chimpanzees and humans as members of the same species; the power of speech, he presciently suggested, was at the beginning 'not natural to man'. From Carl Sagan and Ann Druyan, op. cit., p 273.
4. But chimpanzees have bigger testicles—producing more sperm—and are able to copulate once an hour throughout an entire day (with different females). Bonobos are particularly fecund; they are also the only species of primate, apart from man, that mates in the 'missionary position'. See Carl Sagan and Ann Druyan, op. cit., p 310.
5. See Peter Medawar, *The Uniqueness of the Individual*, 2nd edn. Dover Publications, New York, 1981, p 134.
6. For over two decades the figure was assumed to be 98.5%. See Roy J. Britten, 'Divergence between samples of chimpanzee and human DNA

sequences is 5%, counting indels', *Proc. Natl Acad. Sci. USA* **99**: 13633–13635; 2002.

7. In 1996 there were around 10,000 bonobos in the wild (all in the Congo); 4 years later the number had shrunk to half. See *Nature* **405**: 262; 2000.
8. The hypothesis was stated with clarity by Edward O. Wilson (1975) loc. cit., p 3 ('The Morality of the Gene') and enriched by Richard Dawkins' use of the word 'selfish' in *The Selfish Gene*, op. cit. For a spirited critique of the concept, see Gabriel Dover, 'Anti-Dawkins', in *Alas, Poor Darwin*, Hilary and Steven Rose (eds), op. cit., pp 47–66.
9. Hardy compared evolution to a stream: the former starts at a single point and branches out, the latter begins at many locations and finishes up at one mouth; evolution loses entropy as it progresses, a stream and its tributaries gain entropy during their downward flow. See A. C. Hardy op. cit.