

PULITZER PRIZE-WINNING AUTHOR

CARL SAGAN

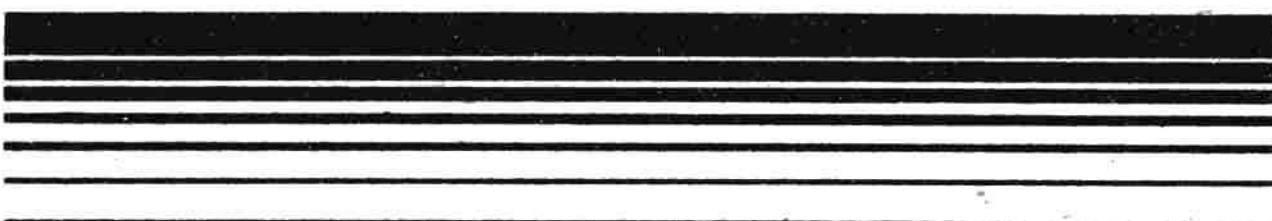
**THE
DRAGONS
OF EDEN**

**/SPECULATIONS
ON THE EVOLUTION OF
HUMAN INTELLIGENCE**

By the author of
BROCA'S BRAIN
and
COSMOS

A powerful and compelling voyage
to the inner space between our ears "will leave the reader
exhilarated and tingling... a masterpiece."

—*Chicago Tribune Book World*



THE DRAGONS OF EDEN

**Speculations on the
Evolution of
Human Intelligence**

Carl Sagan

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Mankind is poised midway between
the gods and the beasts.

PLOTINUS

The main conclusion arrived at in this work, namely, that man is descended from some lowly-organized form, will, I regret to think, be highly distasteful to many persons. But there can hardly be a doubt that we are descended from barbarians. The astonishment which I felt on first seeing a party of Fuegians on a wild and broken shore will never be forgotten by me, for the reflection at once rushed into my mind—such were our ancestors. These men were absolutely naked and bedaubed with paint, their long hair was tangled, their mouths frothed in excitement, and their expression was wild, startled, and distrustful. They possessed hardly any arts, and, like wild animals, lived on what they could catch; they had no government, and were merciless to everyone not of their own small tribe. He who has seen a savage in his native land will not feel much shame, if forced to acknowledge that the blood of some more humble creature flows in his veins. For my own part, I would as soon be descended from that heroic little monkey, who braved his dreaded enemy in order to save the life of his keeper; or from that old baboon who, descending from the mountains, carried away in triumph his young comrade from a crowd of astonished dogs—as from a savage who delights to torture his enemies, offers up bloody sacrifices, practices infanticide without remorse, treats his wives like slaves, knows no decency, and is haunted by the grossest superstitions.

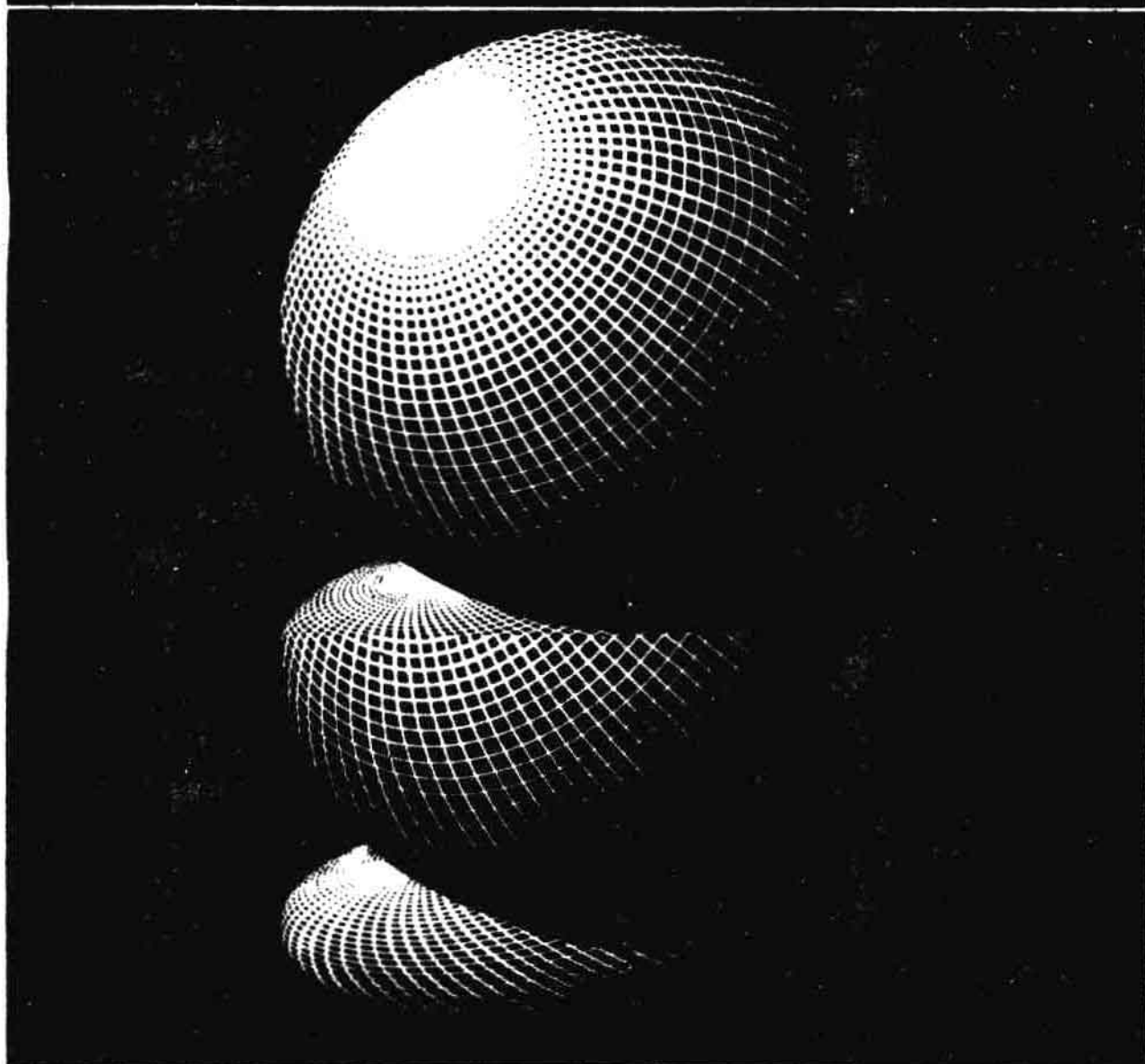
Man may be excused for feeling some pride at having risen, though not through his own exertions, to the very summit of the organic scale; and the fact of his having thus risen, instead of having been aboriginally placed there, may give him hopes for a still higher destiny in the distant future. But we are not here concerned with hopes or fears, only with the truth as far as our reason allows us to discover it. I have given the evidence to the best of my ability; and we must acknowledge, as it seems to me, that man with all his noble qualities, with sympathy which feels for the most debased, with benevolence which extends not only to other men but to the humblest living creature, with his godlike intellect which has penetrated into the movements and constitution of the solar system — with all these exalted powers — Man still bears in his bodily frame the indelible stamp of his lowly origin.

CHARLES DARWIN
The Descent of Man

I am a brother to dragons, and a companion to owls.

Job 30:29

Introduction

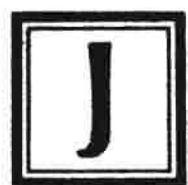


In good speaking, should not the mind
of the speaker know the truth of the
matter about which he is to speak?

PLATO
Phaedrus

I do not know where to find in any
literature, whether ancient or modern,
any adequate account of that nature
with which I am acquainted. Mythology
comes nearest to it of any.

HENRY DAVID THOREAU
The Journal



JACOB BRONOWSKI was one of a small group of men and women in any age who find all of human knowledge—the arts and sciences, philosophy and psychology—interesting and accessible. He was not confined to a single discipline, but ranged over the entire panorama of human learning. His book and television series, *The Ascent of Man*, are a superb teaching tool and a remarkable memorial; they are, in a way, an account of how human beings and human brains grew up together.

His last chapter/episode, called “The Long Childhood,” describes the extended period of time—longer relative to our lifespan than for any other species—in which young humans are dependent on adults and exhibit immense plasticity—that is, the ability to learn from their environment and their culture. Most organisms on Earth depend on their genetic information, which is “prewired” into their nervous systems, to a much greater extent than they do on their extragenetic information, which is acquired during their lifetimes. For human beings, and indeed for all mammals, it is the other way around. While our behavior is still significantly controlled by our genetic inheritance, we have, through our brains, a much richer opportunity to blaze new behavioral and cultural pathways on short time scales. We have made a kind of bargain with nature: our children will be difficult to raise, but their capacity for new learning will greatly enhance the chances of survival of the human species. In addition, human beings have, in the most recent few tenths of

a percent of our existence, invented not only extragenetic but also extrasomatic knowledge: information stored outside our bodies, of which writing is the most notable example.

The time scale for evolutionary or genetic change is very long. A characteristic period for the emergence of one advanced species from another is perhaps a hundred thousand years; and very often the difference in behavior between closely related species—say, lions and tigers—do not seem very great. An example of recent evolution of organ systems in humans is our toes. The big toe plays an important function in balance while walking; the other toes have much less obvious utility. They are clearly evolved from fingerlike appendages for grasping and swinging, like those of arboreal apes and monkeys. This evolution constitutes a respecialization—the adaptation of an organ system originally evolved for one function to another and quite different function—which required about ten million years to emerge. (The feet of the mountain gorilla have undergone a similar although quite independent evolution.)

But today we do not *have* ten million years to wait for the next advance. We live in a time when our world is changing at an unprecedented rate. While the changes are largely of our own making, they cannot be ignored. We must adjust and adapt and control, or we perish.

Only an extragenetic learning system can possibly cope with the swiftly changing circumstances that our species faces. Thus the recent rapid evolution of human intelligence is not only the cause of but also the only conceivable solution to the many serious problems that beset us. A better understanding of the nature and evolution of human intelligence just possibly might help us to deal intelligently with our unknown and perilous future.

I am interested in the evolution of intelligence for another reason as well. We now have at our command,

for the first time in human history, a powerful tool—the large radio telescope—which is capable of communication over immense interstellar distances. We are just beginning to employ it in a halting and tentative manner, but with a perceptibly increasing pace, to determine whether other civilizations on unimaginably distant and exotic worlds may be sending radio messages to us. Both the existence of those other civilizations and the nature of the messages they may be sending depend on the universality of the process of evolution of intelligence that has occurred on Earth. Conceivably, some hints or insights helpful in the quest for extraterrestrial intelligence might be derived from an investigation of the evolution of terrestrial intelligence.

I was pleased and honored to deliver the first Jacob Bronowski Memorial Lecture in Natural Philosophy in November 1975, at the University of Toronto. In writing this book, I have expanded substantially the scope of that lecture, and have been in return provided with an exhilarating opportunity to learn something about subjects in which I am not expert. I found irresistible the temptation to synthesize some of what I learned into a coherent picture, and to tender some hypotheses on the nature and evolution of human intelligence that may be novel, or that at least have not been widely discussed.

The subject is a difficult one. While I have formal training in biology, and have worked for many years on the origin and early evolution of life, I have little formal education in, for example, the anatomy and physiology of the brain. Accordingly, I proffer the following ideas with a substantial degree of trepidation; I know very well that many of them are speculative and can be proved or disproved only on the anvil of experiment. At the very least, this inquiry has provided me with an opportunity to look into an entrancing subject; perhaps my remarks will stimulate others to look more deeply.

The great principle of biology—the one that, as far as we know, distinguishes the biological from the physical sciences—is evolution by natural selection, the brilliant discovery of Charles Darwin and Alfred Russel Wallace in the middle of the nineteenth century.* It is through natural selection, the preferential survival and replication of organisms that are by accident better adapted to their environments, that the elegance and beauty of contemporary life forms have emerged. The development of an organ system as complex as the brain must be inextricably tied to the earlier history of life, its fits and starts and dead ends, the tortuous adaptation of organisms to conditions that change once again, leaving the life form that once was supremely adapted again in danger of extinction. Evolution is adventitious and not foresighted. Only through the deaths of an immense number of slightly maladapted organisms are we, brains and all, here today.

Biology is more like history than it is like physics;

* Since the time of the famous Victorian debate between Bishop Wilberforce and T. H. Huxley, there has been a steady and notably unproductive barrage fired against the Darwin/Wallace ideas, often by those with doctrinal axes to grind. Evolution is a fact amply demonstrated by the fossil record and by contemporary molecular biology. Natural selection is a successful theory devised to explain the fact of evolution. For a very polite response to recent criticisms of natural selection, including the quaint view that it is a tautology (“Those who survive survive”), see the article by Gould (1976) listed in the references at the back of this book. Darwin was, of course, a man of his times and occasionally given—as in his remarks on the inhabitants of Tierra del Fuego quoted above—to self-congratulatory comparisons of Europeans with other peoples. In fact, human society in pretechnological times was much more like that of the compassionate, communal and cultured Bushman hunter-gatherers of the Kalahari Desert than the Fuegians Darwin, with some justification, derided. But the Darwinian insights—on the existence of evolution, on natural selection as its prime cause, and on the relevance of these concepts to the nature of human beings—are landmarks in the history of human inquiry, the more so because of the dogged resistance which such ideas evoked in Victorian England, as, to a lesser extent, they still do today.

the accidents and errors and lucky happenstances of the past powerfully prefigure the present. In approaching as difficult a biological problem as the nature and evolution of human intelligence, it seems to me at least prudent to give substantial weight to arguments derived from the evolution of the brain.

My fundamental premise about the brain is that its workings—what we sometimes call “mind”—are a consequence of its anatomy and physiology, and nothing more. “Mind” may be a consequence of the action of the components of the brain severally or collectively. Some processes may be a function of the brain as a whole. A few students of the subject seem to have concluded that, because they have been unable to isolate and localize all higher brain functions, no future generation of neuroanatomists will be able to achieve this objective. But absence of evidence is not evidence of absence. The entire recent history of biology shows that we are, to a remarkable degree, the results of the interactions of an extremely complex array of molecules; and the aspect of biology that was once considered its holy of holies, the nature of the genetic material, has now been fundamentally understood in terms of the chemistry of its constituent nucleic acids, DNA and RNA, and their operational agents, the proteins. There are many instances in science, and particularly in biology, where those closest to the intricacies of the subject have a more highly developed (and ultimately erroneous) sense of its intractability than those at some remove. On the other hand, those at too great a distance may, I am well aware, mistake ignorance for perspective. At any rate, both because of the clear trend in the recent history of biology and because there is not a shred of evidence to support it, I will not in these pages entertain any hypotheses on what used to be called the mind-body dualism, the idea that inhabiting the matter of the body is something made of quite different stuff, called mind.

Part of the enjoyment and indeed delight of this subject is its contact with all areas of human endeavor, particularly with the possible interaction between insights obtained from brain physiology and insights obtained from human introspection. There is, fortunately, a long history of the latter, and in former times the richest, most intricate and most profound of these were called myths. "Myths," declared Salustius in the fourth century, "are things which never happened but always are." In the Platonic dialogues and *The Republic*, every time Socrates cranks up a myth—the parable of the cave, to take the most celebrated example—we know that we have arrived at something central.

I am not here employing the word "myth" in its present popular meaning of something widely believed and contrary to fact, but rather in its earlier sense, as a metaphor of some subtlety on a subject difficult to describe in any other way. Accordingly, I have interspersed in the discussion on the following pages occasional excursions into myths, ancient and modern. The title of the book itself comes from the unexpected aptness of several different myths, traditional and contemporary.

While I hope that some of my conclusions may be of interest to those whose profession is the study of human intelligence, I have written this book for the interested layman. Chapter 2 presents arguments of somewhat greater difficulty than the rest of this inquiry, but still, I hope, accessible with only a little effort. Thereafter, the book should be smooth sailing. Occasional technical terms are usually defined when first introduced, and are collected in the glossary. The figures and the glossary are additional tools to aid those with no formal background in science, although understanding my arguments and agreeing with them are not, I suspect, the same thing.

In 1754, Jean Jacques Rousseau, in the opening para-

graph of his *Dissertation on the Origin and Foundation of the Inequity of Mankind*, wrote:

Important as it may be, in order to judge rightly of the natural state of man, to consider him from his origin . . . I shall not follow his organization through its successive developments. . . . On this subject I could form none but vague and almost imaginary conjectures. Comparative anatomy has as yet made too little progress, and the observations of naturalists are too uncertain to afford an adequate basis for any solid reasoning.

Rousseau's cautions of more than two centuries ago are valid still. But there has been remarkable progress in investigating both comparative brain anatomy and animal and human behavior, which he correctly recognized as critical to the problem. It may not be premature today to attempt a preliminary synthesis.

