Carl Sagan's Cosmic Connection

An Exraterrestrial Perspective

Carl Sagan

produced by Jerome Agel

New contributions by
Freeman Dyson, Ann Druyan,
and David Morrison

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Contents

Foreword by Freeman J. Dyson xi

Carl Sagan: A New Sense of the Sacred
by Ann Druyan xvii

Preface xxix

PART ONE COSMIC PERSPECTIVES

1. A Transitional Animal 3
2. The Unicorn of Cetus 9
3. A Message from Earth 17
4. A Message to Earth 21
5. Experiments in Utopias 35
6. Chauvinism 41
7. Space Exploration as a Human Enterprise
I. The Scientific Interest 51
8. Space Exploration as a Human Enterprise
II. The Public Interest 59
9. Space Exploration as a Human Enterprise
III. The Historical Interest 66

PART TWO THE SOLAR SYSTEM

10. On Teaching the First Grade 73
11. "The Ancient and Legendary Gods of Old" 77
12. The Venus Detective Story 81
13. Venus Is Hell 87
14. Science and "Intelligence" 95
15. The Moons of Barsoom 101
16. The Mountains of Mars
I. Observations from Earth 114
17. The Mountain of Mars
II. Observations from Space 123
18. The Canals of Mars 129
19. The Lost Pictures of Mars 135
20. The Ice Age and the Cauldron 141
21. Beginnings and Ends of the Earth 145
22. Terraforming the Planets 148
23. The Exploration and Utilization of the
Solar System 157

PART THREE BEYOND THE SOLAR SYSTEM

24. Some of My Best Friends Are Dolphins 169
25. "Hello, Central Casting? Send Me
Twenty Extraterrestrials" 182

26. The Cosmic Connection 186
27. Extraterrestrial Life: An Idea Whose Time Has Come 192
28. Has the Earth Been Visited? 199
29. A Search Strategy for Detecting Extraterrestrial Intelligence 209
30. If We Succeed . . . 215
31. Cables, Drums, and Seashells 221
32. The Night Freight to the Stars 227
33. Astroengineering 229
34. Twenty Questions: A Classification of Cosmic Civilizations 233
35. Galactic Cultural Exchanges 241
36. A Passage to Elsewhen 245
37. Starfolk 1. A Fable 249
38. Starfolk 2. A Future 257
39. Starfolk 3. The Cosmic Cheshire Cats 263
Epilog to Carl Sagan's *The Cosmic Connection* by David Morrison 268
About the Author, Producer, and Contributors 295
Index 298

1. A Transitional Animal

Five billion years ago, when the Sun turned on, the Solar System was transformed from inky blackness to a flood of light. In the inner parts of the Solar System, the early planets were irregular collections of rock and metal—the debris, the minor constituents of the initial cloud, the material that had not been blown away after the Sun ignited.

These planets heated as they formed. Gases trapped in their interiors were exuded to form atmospheres. Their surfaces melted. Volcanoes were common.

The early atmospheres were composed of the most abundant atoms and were rich in hydrogen. Sunlight, falling on the molecules of the early atmosphere, excited them, induced molecular collisions, and produced larger molecules. Under the inexorable laws of chemistry and physics these molecules interacted, fell into the oceans, and further developed to produce larger molecules—molecules much more complex than the initial atoms of which they had formed, but still microscopic by any human standard.

These molecules, remarkably enough, are the ones of which we are made: The building blocks of the nucleic acids, which are our hereditary material, and the building blocks of the proteins, the molecular journeymen that perform the work of the cell, were produced from the atmosphere and oceans of the early Earth. We know this because we can make these molecules today by duplicating the primitive conditions.

Eventually, many billions of years ago, a molecule was formed that had a remarkable capability. It was able to produce, out of the molecular building blocks of the surrounding waters, a fairly accurate copy of itself. In such a molecular system there is a set of instructions, a molecular code, containing the sequence of building blocks from which the larger molecule is constructed. When, by accident, there is a change in the sequence, the copy is likewise changed. Such a molecular system—capable of replication, mutation, and replication of its mutations—can be called ''alive.'' It is a collection of molecules that can evolve by natural selection. Those molecules able to replicate faster, or to reprocess building blocks from their surroundings into a more useful variety, reproduced more efficiently than their competitors—and eventually dominated.

But conditions gradually changed. Hydrogen escaped to space. Production of the molecular building blocks declined. The foodstuffs formerly available in great abundance dwindled. Life was expelled from the molecular Garden of Eden. Only those simple collections of molecules able to transform their surroundings, able to produce efficient molecular machines for the conversion of simple into complex molecules, were able to survive. By isolating themselves from their surroundings, by maintaining the earlier idyllic conditions, those molecules that surrounded themselves by membranes had an advantage. The first cells arose.

With molecular building blocks no longer available for free, organisms had to work hard to make such building blocks. Plants are the result. Plants start with air and water, minerals and sunlight, and produce molecular building blocks of high complexity. Animals, such as human beings, are parasites on the plants.

Changing climate and competition among what was now a wide diversity of organisms produced greater and greater specialization, a sophistication of function, and an elaboration of form. A rich array of plants and animals began to cover the Earth. Out of the initial oceans in which life arose, new environments, such as the land and the air, were colonized. Organisms now live from the top of Mount Everest to the deepest portions of the abyssal depths. Organisms live in hot, concentrated solutions of sulfuric acid and in dry Antarctic valleys. Organisms live on the water adsorbed on a single crystal of salt.

Life forms developed that were finely attuned to their specific environments, exquisitely adapted to the conditions. But the conditions changed. The organisms were too specialized. They died. Other organisms were less well adapted, but they were more generalized. The conditions changed, the climate varied, but the organisms were able to continue. Many more species of organisms have died during the history of the Earth than are alive today. The secret of evolution is time and death.

Among the adaptations that seem to be useful is one that we call intelligence. Intelligence is an extension of an evolutionary tendency apparent in the simplest organisms—the tendency toward control of the environment. The standby biological method of control has been the hereditary material: Information passed on by nucleic acids from generation to generation—information on how to build a nest; information on the fear of falling, or of snakes, or of the dark; information on how to fly south for the winter. But intelligence requires information of an adaptive quality developed during the lifetime of a single individual. A variety of organisms on the Earth today have this quality we call intelligence: The dolphins have it, and so do the great apes. But it is most evident in the organism called Man.

In Man, not only is adaptive information acquired in the lifetime of a single individual, but it is passed on extra-genetically through learning, through books, through education. It is this, more than anything else, that has raised Man to his present pre-eminent status on the planet Earth.

We are the product of 4.5 billion years of fortuitous, slow, biological evolution. There is no reason to think that the evolutionary process has stopped. Man is a transitional animal. He is not the climax of creation.

The Earth and the Sun have life expectancies of many more billions of years. The future development of man will likely be a cooperative arrangement among controlled biological evolution, genetic engineering, and an intimate partnership between organisms and intelligent machines. But no one is in a position to make accurate predictions of this future evolution. All that is clear is that we cannot remain static.

In our earliest history, so far as we can tell, individuals held an allegiance toward their immediate tribal group, which may have numbered no more than ten or twenty individuals, all of whom were related by consanguinity. As time went on, the need for cooperative behavior—in the hunting of large animals or large herds, in agriculture, and in the development of cities—forced human beings into larger and larger groups. The group that was identified with, the tribal unit, enlarged at each stage of this evolution. Today, a particular instant in the 4.5-billion-year history of Earth and in the several-million-year history of mankind, most human beings owe their primary allegiance to the nation-state (although some of the most dangerous political problems still arise from tribal conflicts involving smaller population units).

Many visionary leaders have imagined a time when the allegiance of an individual human being is not to his particular nation-state, religion, race, or economic group, but to mankind as a whole; when the benefit to a human being of another sex, race, religion, or political persuasion ten thousand miles away is as precious to us as to our neighbor or our brother. The trend is in this direction, but it is agonizingly slow. There is a serious question whether such a global self-identification of mankind can be achieved before we destroy ourselves with the technological forces our intelligence has unleashed.

In a very real sense human beings are machines constructed by the nucleic acids to arrange for the efficient replication of more nucleic acids. In a sense our strongest urges, noblest enterprises, most compelling necessities, and apparent free wills are all an expression of the information coded in the genetic material: We are, in a way, temporary ambulatory repositories for our nucleic acids. This does not deny our humanity; it does not prevent us from pursuing the good, the true, and the beautiful. But it would be a great mistake to ignore where we have come from in our attempt to determine where we are going.

There is no doubt that our instinctual apparatus has changed little from the hunter-gatherer days of several hundred thousand years ago. Our society has changed enormously from those times, and the greatest problems of survival in the contemporary world can be understood in terms of this conflict—between what we feel we must do because of our primeval instincts and what we know we must do because of our extragenetic learning.

If we survive these perilous times, it is clear that even an identification with all of mankind is not the ultimate desirable identification. If we have a profound respect for other human beings as co-equal recipients of this precious patrimony of 4.5 billion years of evolution, why should the identification not apply also to all the other organisms on Earth, which are equally the product of 4.5 billion years of evolution? We care for a small fraction of the organisms on Earth—dogs, cats, and cows, for example—because they are useful or because they flatter us. But spiders and salamanders, salmon and sunflowers are equally our brothers and sisters.

I believe that the difficulty we all experience in extending our identification horizons in this way is itself genetic. Ants of one tribe will fight to the death intrusions by ants of another. Human history is filled with monstrous cases of small differences—in skin pigmentation, or abstruse theological speculation, or manner of dress and hair style—being the cause of harassment, enslavement, and murder.

A being quite like us, but with a small physiological difference—a third eye, say, or blue hair covering the nose and forehead—somehow evokes feelings of revulsion. Such feelings may have had adaptive value at one time in defending our small tribe against the beasts and neighbors. But in our times, such feelings are obsolete and dangerous.

The time has come for a respect, a reverence, not just for all human beings, but for all life forms—as we would have respect for a masterpiece of sculpture or an exquisitely tooled machine. This, of course, does not mean that we should abandon the imperatives for our own survival. Respect for the tetanus bacillus does not extend to volunteering our body as a culture medium. But at the same time we can recall that here is an organism with a biochemistry that tracks back deep into our planet's past. The tetanus bacillus is poisoned by molecular oxygen, which we breathe so freely. The tetanus bacillus, but not we, would be at home in the hydrogen-rich, oxygen-free atmosphere of primitive Earth.

A reverence for all life is implemented in a few of the religions of the planet Earth—for example, among the Jains of India. And something like this idea is responsible for vegetarianism, at least in the minds of many practitioners of this dietary constraint. But why is it better to kill plants than animals?

Human beings can survive only by killing other organisms. But we can make ecological compensation by also growing other organisms; by encouraging the forest; by preventing the wholesale slaughter of organisms such as seals and whales, imagined to have industrial or commercial value; by outlawing gratuitous hunting, and by making the environment of Earth more livable—for all its inhabitants.

There may be a time, as I describe in Part III of this book, when contact will be made with another intelligence on a planet of some far-distant star, beings with billions of years of quite independent evolution, beings with no prospect of looking very much like us—although they may think very much like us. It is important that we extend our identification horizons, not just down to the simplest and most humble forms of life on our own planet, but also up to the exotic and advanced forms of life that may inhabit, with us, our vast galaxy of stars.