One Human Minute

Stanisław Lem

Translated by Catherine S. Leach
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Back Cover:

In three scathingly humorous reviews of not-yet-written books, Stanislaw Lem brings us insights into the life of the 21st century. "One Human Minute" summarizes the activities of every person on earth during a single minute. "The Upside-Down Evolution" depicts a battlefield devoid of human activity, where synthetic bugs -- synsects -- vie for supremacy. "The World as Cataclysm" unfolds the universe as a crooked roulette wheel, where cosmic catastrophe prevails over orderly evolution. All reflect the speculative imagination and dark humor that have made Lem a grand master of the science fiction genre.

"It is exhilarating to watch Lem building his argument . . . a splendid performance by a powerful mind." -- Robert Silverberg, *San Francisco Chronicle*

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Note: the original title of this Stanisław Lem's essay is: "Das kreative Vernichtungsprinzip. The World as Holocaust" (1983).

The World as Cataclysm

Introduction

Books with titles like this one began to appear at the end of the twentieth century, but the image of the world contained in them did not become generally known until the next century, for only then did the discoveries germinating in widely separated branches of knowledge come together into a new synthesis. That synthesis -- to put it bluntly -- marked an anti-Copernican revolution in astronomy, in which our notion of the place we occupy in the Universe was stood on its head.

Pre-Copernican astronomy put the Earth in the center of the world; Copernicus deposed it from its privileged position when he discovered that ours is but one of many planets orbiting the Sun. Over the centuries, advances in astronomy strengthened the Copernican hypothesis, showing that not only was Earth not the central body in the solar system but that the system itself was located on the periphery of our Galaxy, the Milky Way. We lived "nowhere in particular" in the Universe, in a stellar suburb.

Astronomy studied the evolution of the stars, biology the evolution of life on Earth; and the paths of their investigations met -- or, rather, converged like two tributaries of a river. Astronomy took for its province the question of the incidence of life in the Universe, and theoretical biology lent its assistance to the task. Thus, in the middle of the twentieth century, CETI (Communication with Extraterrestrial Intelligence) came into being, the first program dedicated to the search for other civilizations.

But the search, conducted for several decades, utilizing ever better and more powerful instruments, found no alien civilization or any trace of a radio signal. So arose the enigma of the silentium universi. The "cosmic silence" received some publicity in the seventies, when it was taken up by the media. The undetectability of "other intelligences" was incomprehensible to scientists. The biologists had already determined what physical-chemical conditions facilitated the emergence of life from inert matter -- and the conditions were not at all exceptional. The astronomers proved the existence of numerous planets around various stars. Observations indicated that a high percentage of the stars in our Galaxy had planets. The obvious conclusion was that life arose frequently in the course of ordinary cosmic changes, that its evolution should be a natural phenomenon in the Universe, and that the crowning of the evolutionary tree with the emergence of intelligent beings likewise belonged to the normal order of things. But, over the decades, the repeated failure to receive extraterrestrial signals, despite the increasing number of observatories that joined the search, contradicted this image of a populated cosmos.

According to the science of the astronomers, biochemists, and biologists, the Universe was full of stars like the Sun and planets like the Earth; by the law of large numbers, therefore, life should be developing on innumerable globes, but radio monitoring indicated, everywhere, a dead void.

The scientists who belonged to CETI and then SETI (Search for Extraterrestrial Intelligence) created various *ad hoc* hypotheses to reconcile the universal presence of life with its universal silence. At first they said that the average distance between civilizations equaled fifty to a hundred light-years. Later they had to increase the distance to six hundred and then to a thousand light-years. And there were hypotheses about the self-destructiveness of intelligence -- such as von Hörner's, which connected the psychozoic "density" of the Universe with its barrenness, claiming that suicide threatened every civilization, as nuclear war was now threatening humanity. The organic evolution of life took billions of years, but its final, technological phase lasted barely a few dozen centuries. Other hypotheses pointed to the dangers that the twentieth century encountered even in the peaceful expansion of technology, whose side effects devastated the reproductive capacities of the biosphere.

Someone said, paraphrasing the famous words of Wittgenstein, "Whereof one cannot speak, thereof one must make poetry." Perhaps Olaf Stapledon, in his fantasy *Last and First Men,* was the first to express our destiny, in this sentence: "The stars create man, and the stars kill him." At the time, however, in the 1930s, these words contained more poetry than truth; they were a metaphor, not a hypothesis qualifying for citizenship in the realm of science.

But any text can hold more meaning than its author gave it. Four hundred years ago, Francis Bacon contended that flying machines were possible, as well as machines that would speed across the Earth and travel on the sea bottom. He certainly did not conceive such devices in any concrete way; but we, reading his words today, not only know that they have come true but also expand their meaning with a multitude of details familiar to us, which only adds weight to his statements.

Something similar happened with the idea that I expressed at the American-Soviet conference of CETI in Burakan in the year 1971. (My text can be found in the book *Problems of CETI,* published by Mir in Moscow in 1975.) I wrote then:

> If the distribution of civilizations in the universe is *not* a matter of chance but is determined by astrophysical conditions of which we are ignorant, though they may be observable phenomena, then there will be less chance of contact the stronger the connection is between the location of the civilization and the nature of its stellar environment -- that is, the more unlike a random distribution is the distribution of civilizations in space. One cannot, *a priori,* rule out the possibility that there exist astronomically observable indicators of the presence of civilization. . . Consequently, the CETI program should also make allowance for the *passing* nature of our astrophysical knowledge, since new discoveries will influence and alter CETI's most fundamental assumptions.

And that is exactly what happened -- or, rather, what is slowly happening. As from the scattered pieces of a jigsaw puzzle, a new picture is emerging from new discoveries in galactic astronomy, from new models for the genesis of the planets and the stars, from the composition of radioisotopes recently found in meteors of the solar system. The history of the solar system is being reconstructed, and the origin of life on Earth, with an import as exciting as it is contrary to all we have accepted until now.

To put the matter most concisely: the hypotheses that reconstruct the past ten billion years of the Milky Way's existence tell us that man emerged because the Universe is a place of catastrophe; that Earth, together with life, owes its existence to a peculiar sequence of catastrophes. It was as a result of violent cataclysms that the Sun gave birth to its family of planets. The solar system emerged from a series of catastrophic disturbances, and only after that could life arise, develop, and eventually establish dominion over the Earth. In the next billion-year period, during which man had no chance to emerge because there was no room on the evolutionary tree, another catastrophe opened the way for anthropogenesis by killing hundreds of millions of Earth's creatures.

Creation through destruction (and consequent release of tensions) occupies the central place in this new picture of the world. Or one could put it thus: Earth arose because the proto-Sun entered a region of destruction; life arose because Earth left that region; man arose because in the next billion years destruction once again descended on Earth.

Stubbornly opposing the indeterminism of quantum mechanics, Einstein said, "God does not play dice with the world." By this he meant that chance cannot decide atomic phenomena. It turned out, however, that God plays dice not only on the atomic scale but with the galaxies, the stars, the planets, the birth of life, and the emergence of intelligence. We owe our existence as much to catastrophes that occurred at the right place and the right time as to those that did *not* take place in other epochs and places. We came into the world having passed -- during the history of our star, then of the planet, then of biogenesis and evolution -- through the eyes of many needles. The nine billion years separating the protosolar cloud of gases from *Homo sapiens* can therefore be compared to a gigantic slalom in which no gate was missed. We know now that there were many such "gates," and that any veering from the slalom run would have precluded the rise of man. What we do not know is how "wide" was this track, with its curves and gates -- or, in other words, the probability of this "perfect run" whose goal was anthropogenesis.

So the world that the science of the next century will recognize will be a group of *random* catastrophes, creative as well as destructive. Note that the *group* is random, whereas each of the catastrophes in it conforms to the laws of physics.

I

In roulette, losses are the rule for the vast majority of players. Otherwise, every Monte Carlo-type gambling casino would quickly go bankrupt. The player who leaves the gaming table with a profit is the exception to the rule. The one who wins often is a rare exception, and the one who makes a fortune because the ball lands on his number almost every time is an extraordinary exception; his incredible luck is written up in the papers.

A player can take no credit for a run of wins, because there is no betting strategy that will guarantee a win. The roulette wheel is an instrument of chance; that is, its end states cannot be predicted. Since the ball always stops at one of thirty-six numbers, the player has one chance out of thirty-six to win in every game. The player who places his bet on the same number twice has one chance in 1,296 to win twice, because the probabilities of chance events not interdependent (as on the roulette wheel) must be multiplied by one another. The probability of winning three in a row is 1:46,656. The chance is very small, but it is calculable, because the number of end states of every game is the same: thirty-six. If, however, in calculating the player's chances, we wished to take into account incidental phenomena (earthquakes, bomb attacks, the player's death from a heart attack, etc.), the task would become impossible. Similarly, when someone picks flowers in a meadow under artillery fire and returns home safe, bouquet in hand, his survival cannot be put into statistical form, either. It cannot be done, although the incalculability -- and, therefore, the unpredictability -- has nothing to do with the kind of unpredictability that characterizes quantum-atomic phenomena. The fate of the flower picker under fire could be made a statistic only if there were very many flower pickers, and if, in addition, the distribution of the flowers in the meadow were known, and the time of their picking, and the average number of shells per unit of shelled surface.

The determination of this statistic is complicated, moreover, by the fact that the shells that miss the picker destroy flowers, thereby changing their distribution in the meadow. The picker who is killed is dropped from the game of picking flowers under fire, just as the roulette player who was lucky at the start but then lost his shirt is dropped.

An observer watching the group of galaxies for billions of years could treat them like roulette wheels or meadows with flower pickers and discover the statistical laws to which the stars and planets are subject. From that, he would be able to establish how often life appears in the Universe and how often it evolves to the point where intelligent beings arise.

Such an observer could have been a long-lived civilization -- or, more precisely, successive generations of its astronomers.

If, however, the meadow with flowers is shelled in a chaotic fashion (which means that the density of shots does not fluctuate around a certain average and therefore is not calculable), or if the roulette wheel is not "honest," then even such an observer will not be able to determine the statistics of the frequency of intelligence in the Universe.

The impossibility of determining such a statistic is practical rather than theoretical. It does not lie in the nature of matter itself, like the Heisenberg uncertainty principle, but "only" in the incalculable overlapping of different random series, which are independent of one another and take place on varied scales of magnitude: galactic, stellar, planetary, and molecular.

A galaxy treated as a roulette wheel on which life can be "won" is not an "honest" roulette wheel. An honest roulette wheel manifests one and only one probability distribution (1:36 for each play). For roulette wheels that are shaken, that change shape during the game, that keep using different balls, there is no such statistical uniformity. All roulette wheels and all spiral galaxies are certainly similar to one another, but they are not exactly the same. A galaxy can behave like a roulette wheel placed near a stove; when the stove is hot, the heat will distort the disk, which will, in turn, affect the distribution of the winning numbers. A brilliant physicist can measure the influence of temperature on the roulette wheel, but if, in addition, the floor shakes from the trucks outside, his measurement will be off.

In this sense, the galactic game of life and death is a game played on a loaded roulette wheel.

Earlier, I referred to Einstein's belief that God does not play dice with the world. I can now expand on what I said there. God not only plays dice with the world, he also plays an honest game -- with perfect, identical dice -- but only on the smallest scale, the atomic. Galaxies, on the other hand, are huge divine roulette wheels that are not honest. Please note that "honesty" here is understood mathematically (statistically) and not morally.

Observing a radioactive element, we can establish its half life -- that is, how long one has to wait for half its atoms to decay. This decay is governed by statistically honest chance, since it is the same throughout the Universe for this element. Whether it sits in the laboratory, in the depths of the Earth, in a meteor, or in a cosmic nebula, its atoms behave the same way.

Whereas a galaxy, a mechanism that produces stars, planets, and occasionally life, does so -- as a mechanism of chance -- dishonestly, because incalculably.

Its creations are governed neither by determinism nor by the sort of indeterminism we find in the world of quanta. Therefore the course of the galactic "game for life" can be known only *ex post facto,* after we have won. One can reconstruct what has taken place -- although it was not, in the beginning, foreseeable -- but not with exactitude; it is like re-creating the history of human tribes in the era when people were still illiterate and left behind no chronicles or documents, only the work of their hands, which the archaeologist unearths. Galactic cosmology then becomes "stellar-planetary archaeology." This archaeology studies the particular game whose winning stake is *us*.

II

A good three-quarters of the galaxies, like our Milky Way, are spiral disks with a nucleus and two arms. This galactic formation of gaseous clouds, dust, and stars (which gradually are born and die in it) revolves, its nucleus whirling at a greater angular velocity than the arms, which, falling behind, bend, thereby giving the whole the shape of a spiral.

The arms, however, do not move at the same speed as the stars.

A spiral galaxy owes its unchanging form to its *density waves,* in which the stars behave like molecules in an ordinary gas.

Orbiting at different speeds, the stars that are considerably removed from the nucleus remain outside the arm, while those near the nucleus overtake and pass through the spiral arm. Only the stars halfway out from the nucleus move at the same velocity as the arms. This is the so-called synchronous (corotational) circle. About five billion years ago, the cloud of gases from which the Sun and the planets were to form was situated near the inner edge of a spiral arm. It overtook that arm slowly -- on the order of one kilometer per second. The cloud, entering deep into the density wave, became contaminated by isotopes of iodine and plutonium, the radioactive residue of a supernova that had exploded in the vicinity. The isotopes decayed, until another element, xenon, was formed from them. Meanwhile, the cloud was compressed by the density wave in which it moved, and this caused condensation until a young star -- the Sun -- arose. At the end of this period, some four and a half billion years ago, another supernova exploded in the neighborhood; it contaminated the circumsolar nebula (not all the protosolar gas had been concentrated yet in the Sun) with radioactive aluminum. This hastened, perhaps even caused, the emergence of the planets. Computer simulations show that, in order for a disk of gases whirling around a young star to undergo segmentation and condense into planets, some outside intervention is necessary, like the giant push supplied by the supernova that exploded not far from the Sun.

How do we know all this? From the composition of radioisotopes in the meteors of the solar system. Knowing the half life of the isotopes of iodine, plutonium, and aluminum, we can calculate when the protosolar cloud was contaminated by them. This took place at least twice; a different time of decay enables us to establish that the first contamination took place shortly after the protosolar cloud entered the inner edge of the galactic arm, and the second contamination (by radioactive aluminum) occurred some three hundred million years later.

The Sun, therefore, spent the earliest phase of its development in a region of strong radiation and shock waves that caused the formation of the planets; then, accompanied by the already cooling and solidifying planets, it left that zone. It came out into a region of high vacuum free of stellar catastrophes; thus life was able to develop on Earth without lethal disturbances.

This picture puts a big question mark over the Copernican idea that says the Earth (together with the Sun) does *not* occupy a special, favored place, but a "typical" one.

Had the Sun been on the far periphery of the Galaxy and, traveling slowly, *not* crossed a spiral arm, it certainly would not have formed the planets. Planet formation requires "midwife assistance" in the form of violent events, such as a shock wave from an exploding supernova (at least one).

Had the Sun, in giving birth to the planets, been close to the galactic nucleus, thus traveling faster than the arms of the spiral, it would have passed through them often. Frequent irradiations and shocks would then have made the emergence of life on Earth impossible, or would have destroyed it in an early phase of development.

Similarly, had the Sun orbited at the exact corotational point of the Galaxy, never leaving its arm, life would also not have been able to establish itself on our planet. Sooner or later it would have been killed by a neighboring supernova (supernovas explode most often within the galactic arms). Also, the average distance between stars is considerably smaller within the arms than between the arms.

Therefore, the conditions favoring planet formation prevail *within* the spiral arms, while the conditions that contribute to the emergence and development of life prevail in the space *between* the arms.

These conditions are not met by the stars circling near the nucleus of the Galaxy, or by the stars on its rim, or, finally, by the stars whose orbits coincide with the corotational circle -- only by those in the vicinity of this circle.

One also has to realize that an eruption of a supernova too close by, instead of "squeezing" the protosolar cloud and accelerating its planetary condensation, would scatter it like dandelion fluff. Too distant an explosion, on the other hand, might be an insufficient spur to planet formation. So the successive explosions of the supernovas in the neighborhood of the Sun must have been "properly" synchronized with the successive stages of its development as a star, as a planetary system, and, finally, as a system in which life arose.

The protosolar cloud was a "player" who approached the roulette wheel with the necessary initial capital, who increased that capital by playing and winning, and who then left the casino in time, preserving everything his run of luck had given him.

It appears that biogenic planets, and therefore planets capable of giving rise to civilizations, should be found primarily near the corotational circle of the Galaxy.

If we accept this reconstruction of the history of our system, we will be forced to revise our previous notions regarding the psychozoic density of the Universe.

We are fairly sure that none of the stars in the Sun's vicinity -- within a radius of fifty light-years -- is home to any civilization that possesses a communications technology at least equal to ours.

The radius of the corotational circle is about 10^5 parsecs -- that is, 34,000 light-years. The whole Galaxy has more than 150 billion stars. Assuming that a third of the stars are located in the nucleus and the thick bases of the spiral arms, we obtain -- for the arms themselves -- a total of 100 billion stars. We do not know how thick to make the torus, a figure in the shape of an automobile tire, which, if drawn around the corotational circle, will contain the whole zone favoring the emergence of life-bearing planets. Let us assume that in the zone that makes up the biogenic torus lie a hundred-thousandth of all the stars of the galactic spiral -- that means millions. The entire circumference of the corotational circle is about 215,000 light-years. If *each* of the stars there produced one civilization, the average distance between two inhabited planets would equal 5 light-years. But the stars near the corotational circle are not spread out evenly in space. Moreover, planet-bearing stars are more likely to be found *within* the spiral arms, and stars with a planet on which life can evolve without fatal disturbances are more likely to be found in the space *between* the arms, where there is less exposure to stellar upheavals. However, most of the stars are inside the arms, where stars are most densely concentrated.

Therefore one should seek signals of extraterrestrial intelligence along the corotational arc *ahead* of the Sun and *behind* the Sun on the galactic plane -- that is, between the stellar clouds of Perseus and Sagittarius, because the stars there, like our Sun, have the galactic passage behind them and are now moving, like our solar system, in the empty space between the arms.

But these simplified statistical reflections have little value. Let us return to our reconstructed history of the Sun and its planets.

Where the corotational circle intersects the spiral arms, their thickness is about three hundred parsecs. The protosolar gas cloud, moving along an orbit at an angle of seven or eight degrees to the plane of the Galaxy, entered the arm for the first time about 4.9 billion years ago. For three hundred million years the cloud underwent the stormy conditions of passage through the entire width of the arm; since it left the arm, it has been traveling through calm space. That trip has lasted much longer than the passage through the arm, because the corotational circle, along which the Sun moves, intersects the spiral arms at a sharp angle, making the arc of the solar orbit between the arms longer than the arc within the arm.

The diagram (after L. S. Marochkin, *Priroda* [Nature], no. 6, 1982) shows our Galaxy, the radius of the corotational circle, and the orbit of the solar system around the galactic nucleus. The speed with which the Sun and the planets move relative to the spiral arms is a subject of controversy. The diagram shows our system having passed through *both* arms. If that was the case, then the first passage was made by a cloud of gas and dust, which began condensing noticeably only when it crossed the second galactic arm. Whether we have behind us one or two passages is not important, because it has to do with the age of the cloud -- that is, with when it first formed -- and not with when it began the fragmentation that was the first stage of astrogenesis. Stars are born in a similar way even now.

An isolated cloud cannot contract gravitationally into a star because it would preserve its angular momentum (in accordance with the laws of motion) and rotate faster the smaller its radius. If eventually a star formed, it would rotate at the equator with a speed exceeding light, but this is impossible: the centrifugal forces would tear it apart much earlier. So stars emerge in great numbers from separate fragments of a cloud, in the course of processes that are gradual at first but become increasingly violent. Moving apart during condensation, the fragments of cloud take away part of the young stars' angular momentum. If one speaks of "the yield of astrogenesis" as the ratio between the mass of the original cloud and the combined mass of the stars formed from it, that yield is not large. The Galaxy is therefore a "producer" that squanders the initial capital of matter. But the scattered parts of the star-bearing clouds eventually begin to contract gravitationally again, and the process repeats itself.

When the cloud contracts, not every cloud fragment behaves the same. When the great collapse begins that leads to the formation of a star, the center of the cloud is denser than its periphery. For this reason, the star-creating fragments vary in size. In the center, they are two to four times the Sun's size; on the circumference, ten to twenty times. From inner condensates there can form small, long-lived stars that burn with more or less the same brightness for billions of years. The Sun is one of these. On the other hand, the large, peripheral stars can generate supernovas, which, after an astronomically short life, are blown apart by powerful explosions.

How our particular cloud began to condense we do not know; all we can re-create is the fate of that local fragment in which the Sun and the planets had their origin. When the process began, the nearby supernovas contaminated the protosolar cloud with radioactive particles. At least two such contaminations occurred. The first time, the protosolar cloud was contaminated with isotopes of iodine and plutonium, probably near the inner edge of the spiral arm; the second time (three hundred million years later), deep inside the spiral, another supernova bombarded it with the radioactive isotope of aluminum.

From the degree to which these isotopes have been transformed, by radioactive decay, into other elements, one can tell when each contamination occurred. The short-lived isotopes of iodine and plutonium went to a stable isotope of xenon, and the radioactive isotope of aluminum became magnesium. The xenon and the magnesium have been found in meteors of our solar system. Comparing these data with the age of the Earth's crust (using as a yardstick the times of decay of uranium and thorium, the long-lived isotopes contained in it), one can reconstruct approximate if not exact "scenarios" of the solar cosmogony.

The diagram shows the scenario by which a gaseous cloud first passed through the spiral nine and a half billion years ago. Its density was still subcritical then, so there was no fragmentation and formation of condensates. That occurred only after its entrance into the next arm of the Galaxy, 4.6 billion years ago. On the outer edge of the condensates, conditions favored the rise of supernovas; on the inside, of smaller stars, like the Sun. Subjected to compression and the explosions of the supernovas, the protosolar fragment changed into the young Sun and the planets, comets, and meteors. This cosmogonic scenario is simplified: the fragmentation of the gaseous clouds is random; through the enormous expanse of the arms run shock fronts, produced by various cataclysms; erupting supernovas can take part in generating such fronts.

Galaxies continue to give birth to stars, because the Universe in which we live, while certainly not young, is not yet old. Computer simulations reaching far into the future show that in the end all the star-generating material will be depleted, the stars will be extinguished, and whole galaxies will "vaporize" into radiation and particles.

From this "thermodynamic death" we are separated by some 10^{100} years. Long before that -- in 10^{15} years -- all the stars will lose their planets from having other stars pass close to them. The planets, whether lifeless or inhabited, torn from their orbits by strong perturbations, will be swallowed in endless darkness and a temperature close to absolute zero. Paradoxically, it is easier to describe what will become of the Universe in 10^{15} or in 10^{100} years, or what took place in the first few minutes of its existence, than to reconstruct the different stages of solar and terrestrial history. It is even more difficult to foresee what will become of our system when it leaves the calm space that stretches between Perseus and Sagittarius, between the stellar clouds of the two galactic arms. Assuming that the difference between the speed of the Sun and the spiral equals one kilometer per second, we shall reach the next spiral in five hundred million years.

In dealing with cosmogony, astrophysics proceeds like a detective gathering circumstantial evidence: there are only a few "footprints and exhibits," from which, like the scattered pieces of a jigsaw puzzle (and many of the pieces are lost), one must put together a consistent whole. What is worse, it appears that from these bits of evidence one can build a number of unidentical models. Not all the data, especially in the case that interests us, are numerically determinable (for example, the difference between the orbital speed of the Sun and that of the galactic spiral). In addition, the spiral arms themselves are not so compact, and do not move through space so clearly and regularly, as in our diagram. Finally, all spiral nebulae are similar, but similar in the way people are who are of different heights, weights, ages, races, sexes, and so on.

Nevertheless, cosmological work on the Milky Way is getting closer and closer to the true state of things. Stars are born mainly inside the spiral arms; supernovas explode most frequently inside those arms; the Sun is definitely located near the corotational circle, therefore not just "anywhere" in the Galaxy -- because, as was shown, the conditions prevailing in the corotational zone are different both from those near the nucleus and from those on the edges of the spiral disk.

With computer simulation cosmologists will be able, in a short time, to consider a multitude of variations of star and planetary formation, which not long ago was extremely tedious and time-consuming work. Meanwhile, observational astrophysics is providing new and more precise data for these simulations. The investigation, however, is still in progress; the material evidence and the mathematical guesswork, pointing to the Perpetrators, have acquired the force of a solidly based hypothesis. These are not groundless speculations. The indictment of the spiral nebula for being both mother and infanticide has been placed before the tribunal of astronomy. The trial goes on; the final verdict has not yet been reached.

III

In a discussion of the history of our solar system in the Galaxy, it is suitable to use legal terminology: cosmology, engaged in the reconstruction of past events, acts like an examining magistrate in a case where there is no hard evidence against the accused, only a set of incriminating circumstances. The cosmologist, like the judge, tries to determine what happened in a given concrete instance. He does not have to worry about how often such an instance may occur or what the probability of its occurring was. But in contrast to the judiciary, cosmology tries to learn much more about the matter. If a champagne bottle -- with thick glass and the characteristic hollow at the bottom -- is thrown out the window and breaks, then by repeating the experiment we will see that the neck and the bottom usually end up in single pieces while the rest of the glass breaks into many fragments of different shapes.

There is no precise answer to the question of how often, in breaking bottles, one can obtain exactly the same fragments. One can establish only how many pieces the bottles break into most often. Such a statistic is easily arrived at by repeating the experiment many times under the same conditions (the distance the bottle falls, whether it falls on concrete or wood, etc.). But it may also happen that the bottle, in falling, will hit a football kicked by one of the children playing in the yard, will thus bounce and fly through the window of the elderly lady on the floor below who keeps goldfish in an aquarium, will fall into the aquarium, sink, and fill with water, unbroken. Everyone will agree that, although highly improbable, such an event is still possible; people will see it not as a supernatural phenomenon, a miracle, but only as an extraordinary coincidence.

Yet such coincidences cannot be put into statistics. Besides Newton's laws of motion and the glass's strength, one would have to take into consideration how often the children played football in the yard, how often the football collided with falling bottles during the game, how often the old lady left her window open, how often the fish tank stood near the window; if we wanted to have a "general theory of champagne bottles that fall into aquariums undamaged after being hit by footballs," taking into account all the bottles, children, houses, yards, goldfish, aquariums, and windows in the world, we would never accomplish it with statistics.

The key question in re-creating the history of the solar system and life on Earth is: Did something happen on the order of simple bottle-breaking, which could be put into statistics, or was it, instead, something like the football and the aquarium?

Phenomena that are statistically calculable do not become statistically incalculable suddenly, at a well-defined boundary, but, rather, by degrees. The scholar takes a position of cognitive optimism; that is, he assumes that the subjects he studies will yield to calculation. It is nicest if they do so deterministically: the angle of incidence is equal to the angle of reflection; a body immersed in water loses exactly as much of its weight as the weight of the water it displaces; and so on. It is not quite so nice if calculable probability has to substitute for certainty. But it is not nice at all when absolutely nothing can be calculated. It is commonly said that when nothing can be calculated and nothing predicted, one has chaos. Yet "chaos" in the exact sciences does not mean that we know nothing whatever, that what we have to deal with is absolute disorder. There is no "absolute disorder." Even in the tale of the bottle and the football there is no chaos. Every event, taken separately, obeys the laws of physics, and of deterministic physics, not quantum physics, because we can measure the force with which the child kicked the ball, the angle of impact between bottle and ball, the speed of both bodies at that instant, the path the bottle described when it bounced off the ball, and the speed with which it fell into the aquarium and filled with water. Each step of the sequence, taken separately, is subject to mechanics and statistics, but the *sequence itself* is not (that is, one cannot establish how often a thing that has happened will happen).

The point is that all theories of "broad scope" in physics are incomplete, because they say nothing about the initial states. The initial states have to be brought into the theory from the outside. It is obvious, however, that when some initial state must be achieved precisely by chance in order to produce the initial state of the next occurrence, also precisely defined, and so on, then a certainty that transcends the realm of probabilities becomes an unknown, about which nothing can be said except that "something very unusual took place."

That is why I said at the beginning that the world is a group of random catastrophes governed by precise laws.

To the question "How often does what happened with the Sun and the Earth happen in the Universe?" there is no answer yet, because we are not sure in which category of events to place the case.

With advances in astrophysics and cosmology the matter will gradually be clarified. Much that the experts said at the CETI meeting in Burakan in 1971 is now out of date or has been shown to be incorrect. In ten or twenty years, no doubt, many things that are mysterious today will be explained.

The Moon played a large if not decisive role in the emergence of life on Earth. Life could start only in aqueous solutions of certain chemical compounds, and not in the deep seas but in coastal shallows. The frequent but gentle mixing produced by the tidal ebb and flow caused by the Moon hastened the protobiogenesis in these solutions.

But less is known about how the moons of the planets came into being than about how the planets themselves formed. For now, one cannot rule out the possibility that the formation of planetary satellites is as "extraordinary" as the story of the bottle and the aquarium. An ordinary shock wave from a supernova seems sufficient to cause ring fragmentation of a protosolar nebular disk, but for moons to condense around planets, something like the intersection of two circular waves may be needed, as when two stones are dropped into water (not far apart) and the ripples radiate outward. In other words, for moons to form, a second supernova may be needed, also not far from the protosolar system.

If not all these questions are answered, there will still be some answers, and thus the probability of life's arising in the Universe -- the biogenetic yield or frequency -- will acquire an approximate numerical value. The value may prove to be large, in which case we will be right to expect the presence of life in an innumerable wealth of forms on the multitude of planets in the trillion galaxies that surround us.

But even if that happens, books with the titles I predicted will appear. I will now proceed to show the reason. The grim truth is: without a global destruction of life, man would not have arisen.

IV

How does the new view of life in the Universe differ from the old? We have long known that the birth of life on a planet must be preceded by a long chain of specific events, beginning with the formation of a long-lived and evenly burning star like the Sun, and that this star must create a planetary family. But we did not know that the arms of a spiral galaxy are (or can be) alternate cradles and guillotines of life, depending on the stage of development of the star-generating material when it passes through the spiral and on the place in the arm where the passage occurs.

At the symposium in Burakan I was the only one to hold that the distribution of life-generating heavenly bodies was dependent on events of extraplanetary and extrastellar (galactic) magnitude. Obviously, I, too, was unaware that the chain of events included the motion of the star-generating cloud around the corotational circle; that inside the cloud, the "right" synchronization of astrogenesis and eruptions of supernovas on the cloud's circumference was necessary; and moreover -- *conditio sine qua non est longa vita* -- that the system where biogenesis began had to depart immediately from the spiral's stormy zone for the calm expanse of space between the arms.

At the end of the seventies it became fashionable to include in cosmological hypotheses a factor called the Anthropic Principle. This factor reduces the enigma of the initial state of the Universe to an argument *ad hominem:* if conditions had been very different, the question would not have arisen, since there would have been no one to ask it.

It is not hard to see that as a cosmological criterion the Anthropic Principle (the appearance of *Homo sapiens* was inherent in the Big Bang) has about as much cognitive value as the "Schnapps Principle."

True, the production of schnapps was made possible thanks to the properties of matter in *this* Universe, but one can perfectly well imagine the history of *this* Universe, *this* Sun, *this* Earth, and *this* human race *without* the emergence of schnapps. Schnapps originated because people engaged in the production of different beverages, including those that contained alcohol, sugar, juniper berries, and herbal extracts. This answer is sensible, though general. Whereas to answer the question "How did schnapps come about?" with "It came about because *such* was the initial state of the Universe" is ridiculous. One might just as well say that Volkswagens or postage stamps owe their existence to the initial state of the Universe. Such an answer explains *ignotum per ignotius.* It is also a *circulus in explicando:* that which *could* arise, did arise. But such an answer ignores the most distinctive property of the proto-Universe. According to the obligatory Big Bang Theory, the Universe was born in an explosion that simultaneously created matter, time, and space.

Traces of this world-creating explosion remain in the Universe to this day as residual radiation present everywhere in the stellar background. In the twenty billion years of the Universe's existence, the radiation of the first moment has cooled to a few degrees above absolute zero. But that residual radiation ought not to be the same across the whole canopy of sky. The Universe originated from a point of infinitely great density and in the course of 10^{-35} of a second expanded to the volume of a soccer ball. Even at that moment it was too large and was expanding too rapidly to remain perfectly homogeneous. Causal connections of events are limited by the maximum speed of interaction, which is the speed of light. Such connections were able to last only in regions with dimensions of 10^{-25} centimeter, but 10^{78} such regions could fit in a universe the size of a soccer ball. What took place in some regions, therefore, could not influence the events in others. And therefore the Universe ought to have expanded heterogeneously and not kept the symmetry of those everywhere-identical properties that we nevertheless observe in it. The Big Bang Theory is saved by the hypothesis that in the creational explosion an *immense number of universes* formed simultaneously. Our Universe was only one of them.

A theory published in 1982 reconciles the homogeneity of the actual Universe with the nonhomogeneity of its expansion through the premise that the proto-Universe was not a universe but a "poliverse." A poliverse hypothesis can be found in a little book of mine called *Imaginary Magnitude,* which I wrote ten years earlier, in 1972. The similarity of my speculations to the theories that appeared later gives me courage to speculate further.

Let us recall the champagne bottle that bounced off the football, flew through the open window, and fell into the aquarium. Impossible though it is to calculate the statistical probability of such an accident, we recognize that the accident was possible (that is, it did not contradict the laws of nature; it was not a miracle). And if the bottle had fallen into an aquarium full of stagnant water and dead fish and had splashed, sending a few fish eggs into a bucket of fresh water standing nearby, and if live fish were born from those eggs, it would be an event even rarer, even more exceptional than if there had been no bucket, eggs, or resultant little fish.

Suppose that the children are still playing football; that someone is still tossing champagne bottles out of the second-floor window every now and then; that the next empty bottle, bouncing off the football (which just then intersects the path of its fall), flies into the bucket, so that the little fish born from the roe are splashed out and into butter sizzling on a frying pan. The lady of the house, who had intended to make an omelet, on her return to the kitchen finds little fried fish in the pan.

Would *this* be an "absolute impossibility"? One cannot maintain that. All one can say is that it was an accident *sui generis,* one whose full course (beginning with the first champagne bottle) will never be repeated *exactly* the same way. It is just too improbable. The slightest deviation will cause the bottle not to land in the kitchen, because it will not ricochet off the football "as it should"; or it will break on the floor; or it will sink in the aquarium and nothing more will happen; or it will splash some roe but the roe will not fall into the bucket and produce fish. Then, too, the bucket could be empty, or filled with laundry soaking in a detergent lethal to fish. And so on.

When we bring the Anthropic Principle into cosmology, we are saying that the appearance of man has crowned the evolution of life on Earth with intelligence, since the emergence of intelligent beings becomes more probable the longer that evolution lasts. Leaving the terrain of what today is considered certain or reasonably certain, I will move on to what the science of the next century will contribute to the subject.

V

First, evidence will be gathered showing that the limb of the evolutionary tree that created the mammals would not have branched and would not have given them primacy among the animals had there not been, sixty-five million years ago, between the Cretaceous and Tertiary, a catastrophe in the form of an enormous, 3.5-to-4-trillion-ton meteorite.

Up to that time, the dominant animals were the reptiles. They reigned on land, on water, and in the air for two hundred million years. Attempting to explain their abrupt extinction at the end of the Mesozoic, the evolutionists attributed to these reptiles the traits of contemporary reptiles: cold-bloodedness, primitive organs, and a hairless body covered only by scales or horned armor. And when they reconstructed the appearance and way of life of these animals on the basis of the skeletal fragments found, they did so according to their biases. One could call this "mammal chauvinism." Paleontologists have said, for example, that the large reptiles, like the brontosaurus, were incapable of moving on dry land and spent their life in shallow water, feeding on plants. Or that the two-legged reptiles, though ambulatory, were awkward, dragging long, heavy tails over the ground. And so on.

Only in the second half of the twentieth century was it learned that the Mesozoic reptiles were as warm-blooded as mammals; that many species -- especially the flying ones -- had a furlike coat; that the two-legged reptiles did not lumber along dragging their tails, but in speed matched the ostrich, although they weighed up to two hundred times more: the tail, held horizontally by special ligaments, served as a counterweight for the forward-leaning body when it ran. Even the largest saurians moved freely on land.

Unable to go into a comparative study of extinct and modern species here, I will give one example of the skill, never since equaled, possessed by certain flying reptiles. The "biological flying record" does not belong to the birds, and still less to the flying mammals, the bats. The largest animal of Earth's atmosphere was *Quetzalcoatlus northrofii,* whose body mass exceeded man's. But it was only one of a group of species given the name Titanopterygia. These were reptiles that glided over the ocean and fed on fish. We do not know how they were able to land and take off, since the weight of their body meant that to do so they would have required a muscular strength beyond that of the animals (and birds) of today. When their fossils were found in Texas and Argentina, it was first thought that these giants of the air, equal in wingspan to a small or even medium plane (thirteen to fifteen meters), spent their lives and built their nests at the top of crags, from which they hurled themselves into the air, spreading their wings. But if they were unable to take off from level ground, they would all, to the last specimen, have been condemned to death if they landed only once in a flat place. Some of these great soarers lived off carrion -- but carrion is not found on peaks. Moreover, their enormous bones were found in places devoid of mountains. For experts in aerodynamics, these reptiles present a puzzle. No explanation holds up. A colossus like Quetzalcoatlus could not light on trees; that would cause frequent injury or actual fracture to the wings. The largest specimen of flying bird known is a certain extinct vulture with a wingspan of nearly seven meters; doubling its size quadruples the force needed to rise into the air. The large flying reptiles could not take off by running, either, because their legs were too short and weak.

When the charge of "primitivism" as the cause of extinction was dropped, the opposite replaced it -- overspecialization. The reptiles died out, supposedly, because they were too narrowly adapted to their environment; they perished because of a change in climate.

Climatic changes have indeed occurred in the history of the Earth. Everyone knows about the ice ages. The extinction of life at the junction of the Cretaceous and Tertiary periods was also preceded by a cooling; but the cooling did not lead to an ice age. What is more important, no change of climate ever caused the massive extinction of so many species of animals and plants at once. Their fossil remains suddenly vanish in the geological strata of the next period. The figures show that no animal survived whose body weight exceeded twenty kilograms. Never before had there been such a global annihilation. Many invertebrates became extinct then, on land and in the sea almost simultaneously. It was like a biblical plague: day turned into night, and the darkness lasted about two years. Not only could the Sun not be seen anywhere on the Earth's surface, but its rays provided less illumination than does the full moon. All the large diurnal animals died out. But the small, ratlike mammals, nocturnal scavengers, survived. Out of these remnants of the great zoocide, new species arose during the Tertiary, including the one that bore the fruit of anthropogenesis. The darkness, cutting the Earth off from the Sun's energy, destroyed most of the green vegetation, since it made photosynthesis impossible. A multitude of algae also died.

I cannot go into more detail now, but, though the mechanism and the consequences of the catastrophe were certainly more complex than is presented here, the *scope* is the same. The balance sheet looks like this. Man could not emerge from the differentiated biological legacy of the Mesozoic, because that mass represented capital invested in species incapable of anthropogenesis. The investment (as always in evolution) was irreversible; the capital was lost. New capital began to form from the surviving vestiges of life scattered over the Earth. It increased and multiplied until the rise of the hominids and anthropoids.

If evolution's huge investment in the Thecodontia, Saurischia, Ornithischia, and in the Rhamphorhynchoidea and Pterodactyloidea had not ended in a great crash sixty-five million years ago, the mammals would not have taken over the planet. We owe our existence to that catastrophe. We emerged and multiplied into the billions only because billions of other creatures suffered annihilation. Hence the title, *The World as Cataclysm.* The scientific search for evidence has led us only to the random author of our species -- an indirect albeit a necessary author. It was not the meteor that created us: that only opened the way. The massive destruction that laid waste the Earth thereby made room for more evolutionary experiments. It remains an open question whether, without the meteor catastrophe, intelligence would have appeared on Earth in another form -- a nonhuman, nonanthropoid form.

VI

Where there is No One -- therefore no feelings, friendly or hostile, no love or hate -- there are also no intentions. The Universe, being neither a Person nor the work of any Person, cannot be accused of bias in its action: it simply is what it is and does what it does. What it does is create, again and again, by destroying. Some stars "must" explode and disintegrate so that the heavy elements formed in their nuclear cauldrons can disperse and give a start -- billions of years later -- to planets and, once in a while, organic life. Others, supernovas, "must" undergo catastrophic destruction in order that galactic clouds of hydrogen, compressed by the explosions, can condense into sunlike, long-lived stars that calmly and steadily warm their family of planets, who also owe their existence to these catastrophes.

But must intelligence, too, begin in lethal cataclysm?

The twenty-first century will not have a definitive answer to that question. It will continue to gather evidence and will fashion a new picture of the world: a collection of random catastrophes governed by precise laws. But it will not provide the final explanation for intelligence.

It will dispel, to be sure, many illusions that persist in science. For example, it will establish beyond any doubt that a brain of high volume is not equivalent to a brain of high intelligence, for which largeness is a necessary but not a sufficient condition. The extraordinary intelligence with which dolphins are supposedly endowed because their brains are larger and more complex than man's, this dolphin intellect about which so much has been written in our time, will be shown to be a myth. A large brain was indeed needed if the dolphins were to compete successfully in the same ocean with the "stupid" sharks. It allowed them to enter and survive in a niche occupied for millions of years by predator fish -- but nothing more.

From this it follows that no statement can be made regarding the chances of intelligence arising among the reptiles had there been no meteor.

A slow but practically constant growth in neural mass characterizes the evolution of *all* animals, with the exception of certain parasites. But even if that growth were to continue over a time measured in hundreds of millions of years, through the Cretaceous and Tertiary, it would not guarantee the emergence of intelligent saurians.

The crater-pocked surfaces of all the moons in our planetary system are like photographs of the past, a frozen picture of the beginning of this system, which was also created out of destruction. All the bodies orbited the young Sun in frequently intersecting paths, and collisions resulted. Thanks to these catastrophes, the large bodies -- the planets -- increased in mass, while the bodies of small mass, in colliding with the planets, "vanished" from the system. I said earlier that about 4.6 billion years ago the Sun and its planetary family left the stormy region of the galactic spiral and moved off into calm space. But this does not mean that the interior of the solar system was then calm. Collisions of planets with meteorites and comets were still going on when life began on Earth. Moreover, leaving the spiral arm was not like walking out of a house; radiation and stars do not suddenly cease to exist at any one point. During the first billion years of its existence, the Earth was still continually exposed to shocks, though the supernovas were distant enough not to devastate it and turn it into a dead globe. The hard radiation (X rays and gamma rays) coming from space was a factor both creative and destructive, since it accelerated the rate of mutation in the proto-organisms.

Some insects are a hundred times less vulnerable to the lethal effect of radioactivity than vertebrates. This is really very strange when you consider that the hereditary substance of all living systems is basically the same. They differ from one another in the way buildings of various cultures, epochs, and architectural styles differ; the building material -- brick and stone -- is the same everywhere, as is the mortar that keeps the whole together.

The difference in vulnerability to lethal radiation must have been caused by events extremely distant in time, by catastrophes in the era when the first insects (or, rather, their ancestors) came into being, about 430 million years ago. It is not impossible, however, that the "insensitivity" of certain organic forms to radiation fatal to most others developed one billion years ago.

Will the coming century witness a revival of the theory put forth by the early nineteenth-century French paleontologist and anatomist Cuvier, called catastrophism? It saw geological processes, like mountain-formation, climate changes, the rise and disappearance of seas, as violent and sudden transformations -- planetary catastrophes. The theory was developed further by Cuvier's student, d'Orbigny, in the middle of the nineteenth century; according to him, the organic world of the Earth perished and arose anew many times in successive acts of creation.

This union of catastrophism with creationism was laid to rest by Darwin's theory, but the funeral was premature. Catastrophes on the largest scale, cosmic, are an indispensable condition not only for the evolution of stars but also for the evolution of life. It was the human mind that created the alternative of either "destruction or creation" and that has continued to impose it on the world since the dawn of our history. Man considered the mutual exclusiveness of destruction and creation as self-evident when he faced his own mortality and set it against his will to live. That opposition is the common foundation for all the hundreds of our cultures; one finds it in the most ancient myths, creation legends, and religious beliefs, and in the science that arose a few thousand years later. Faith as well as science endowed the visible world with properties that eliminated blind, incalculable chance as the author of all events. The war of good and evil present in all religions does not always end, in every faith, with the victory of good, but in every one it establishes a clear *order* of existence. The sacred as well as the profane rest on that universal order. Thus, chance, the ultimate arbiter of existence, was not present in any of the beliefs of the past.* Science, too, long resisted acknowledging the creative and incalculable role of chance in the shaping of reality.

Human beliefs can be divided roughly into those that offer comfort and those that offer order vis-à-vis the given world. The first type promises reward, salvation, a final reckoning of sins and merits, to be crowned in the hereafter with an ultimate justice. To an imperfect world is added a perfect continuation. Most likely such beliefs owe their great longevity, generation after generation, to their property of soothing our complaints against the world. On the other hand, the old myths, instead of offering the peace and promise of a just goodness in a well-run eternity -- whatever one may say about paradise and heaven, not a scrap of chance exists there: no one will go to hell as a result of divine error or oversight, and no one will find himself in a posthumous jam because a foul-up prevents him from entering nirvana -- the old myths offer an order that is often cruel but necessary. Neither the goodness nor the order resembles a lottery.

Culture exists and has always existed in order to make every accident, every kind of arbitrariness, appear in a benevolent or at least necessary light. The common denominator of all cultures, the source of ritual, of all commandments, of every taboo, is this: for everything there is one and only one measure. Cultures have taken chance in small, careful doses -- for fun, as games and amusements. Chance, when domesticated and held in tight rein as a game or lottery, ceases to be dangerous. We play the lottery because we want to; no one forces us.

A believer can see chance in the breaking of a glass or in a wasp sting, but he does not attribute death to chance. In his thoughtless head, Divine Omnipotence and Omniscience seem to assign a *subordinate* role to accidents. And science, for as long as it could, treated chance as the effect of currently insufficient knowledge, as an ignorance that a future discovery would dispel. These are not jests; Einstein was not joking when he declared that "God does not play dice," because "He is subtle, but He is not malicious." This meant: the order of the world is difficult to know, but since it is rational, it is possible to know.

The end of the twentieth century has seen a general turning away from those thousands of years of stubbornly, desperately held beliefs. The destruction-or-creation alternative must finally be rejected. The huge clouds of dark, cold gases circling in the arms of galaxies are slowly undergoing fragmentation into parts as unpredictable as shattered glass. The laws of Nature act not *in spite of* random events but *through* them. The statistical fury of the stars, a billion times aborting in order to give birth once to life, a life slain by a chance catastrophe in millions of its species in order to yield intelligence once -- this is the rule, not the exception, in the Universe.

Suns form from the destruction of other stars; the remains of protostellar clouds congeal into planets. Life is one of the rare winners in this lottery, and intelligence an even rarer winner in the subsequent draws: it owes its appearance to natural selection -- that is, to death, which improves the survivors -- and to catastrophes that can abruptly increase the odds for the emergence of intelligent beings.

The link between the structure of the world and the structure of life is no longer doubted, but the Universe is an enormously profligate investor, squandering its initial capital on the roulette wheels that are galaxies. (What brings regularity to the game is the law of large numbers.) Man, shaped by these properties of matter, properties that appeared when the world appeared, turns out to be a rare exception to the rule of destruction: man, the survivor of hecatombs and holocausts. Creation and destruction alternate, overlap, interact, reciprocate, and from them there is no escape or appeal.

Such is the picture that science is building little by little -- so far without comment. It pieces the picture together from discoveries in biology and cosmology, like a mosaic from pebbles found one at a time. I could stop here, but I will take another moment to consider the final question that we are permitted to ask.

VII

I have sketched a picture of the reality that the science of the twenty-first century will popularize, because even today the outlines are visible. This picture will receive the seal of approval of the best experts. The question which I wish to pursue where even speculation cannot reach has to do with the permanence of this world-view. Will it be the last?

The history of science shows that each picture of the world, in turn, was thought to be the last; then it was revised, only to crumble eventually like the pattern of a broken mosaic, and the labor of putting it together was taken up anew by the next generation. Religious beliefs stand on dogmas whose rejection has always been tantamount first to vile heresy, later to the birth of another religion. Living faith, to those who profess it, is the Ultimate Truth; there is no appeal. In science, there is nothing ultimate and everything can be appealed. The "certainties" of scientific knowledge are not all equally certain, and there is nothing to indicate that we are getting close to the Goal of Cognition, that final fusion of Immovable Knowledge with Irresistible Ignorance. Our increments of reliable knowledge, proved through concrete application, are unquestionable. In science, we know more than our nineteenth-century predecessors; they, in turn, knew more than their forefathers -- but at the same time we recognize the world's inexhaustibility, the fathomlessness of its secrets, for we see that each atom, each "elementary particle," turns out to be a bottomless well. It is this astounding bottomlessness of knowledge (though everybody is accustomed now to this marathon without a finish line) that renders every "ultimate view of reality" suspect. It may be that the *principium creationis per destructionem* will prove to be but a phase of our diagnosis that applies the human measure to a thing as inhuman as the Universe. It may be that someday a *deus ex machine* will cope with these inhuman, overcomplicated measurements, inaccessible to our poor animal brains: an alienated, human-initiated machine intelligence -- or, rather, the product, pretermechanical, of a human-launched evolution of synthetic mind. But here I overstep the twenty-first century into a darkness that no speculation can illumine.

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