Translated by Joanna Zylinska

SUMMA Technologiae

STANISŁAW LEM

Published by the University of Minnesota Press
111 Third Avenue South, Suite 290
Minneapolis, MN 55401-2520
http://www.upress.umn.edu

ISBN 978-0-8166-8904-0 (ePub)

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Translator's Introduction

Evolution May Be Greater than the Sum of Its Parts, but It's Not All that Great: On Lem's *Summa Technologiae*

Joanna Zylinksa

Is the human a typical phenomenon in the Universe or an exceptional one? Is there a limit to the expansion of a civilization? Would plagiarizing Nature count as fraud? Is consciousness a necessary component of human agency? Should we rather trust our thoughts or our perceptions? Do we control the development of technology, or is technology controlling us? Should we make machines moral? What do human societies and colonies of bacteria have in common? What can we learn from insects? For answers to all these questions and more, Stanisław Lem's *Summa Technologiae* is undoubtedly the place to go.

Lem (1921–2006) is best known to English-speaking readers as the author of the novel *Solaris* (1961), the film versions of which were directed by Andrei Tarkovsky (Grand Prix at the 1972 Cannes Film Festival) and Steven Soderbergh (2002). However, science fiction aficionados all over the world have been reading Lem's original and often surprising novels—translated into over forty languages—for years. Be that as it may, the Polish writer's attitude to science fiction was not unproblematic. Witness his spat with the Science Fiction and Fantasy Writers of America association, which was incensed by Lem's unabashed critique of the majority of the works within the genre as unimaginative, predictable, and focused on a rather narrow idea of the future. Lem's own novels take a rather different approach. Drawing on scientific research, they are deeply philosophical speculations about technology, time, evolution, and the nature (and culture) of humankind. What makes Lem's writings particularly distinct is his ironic writing style, which is full of puns, jokes, and clever asides. Yet, on another level, his gripping stories about space travel, alien life, and human enhancement are also complex philosophical parables about human and nonhuman life in its past, present, and future forms.

The philosophical ambition of Lem's fiction is carried through to what is probably his most accomplished and mature work: a treatise on futurology, technology, and science called *Summa Technologiae* (1964). With a title that is a pastiche of Thomas Aquinas's *Summa Theologiae,* Lem erects a secular edifice of knowledge aimed at rivaling that of his scholastic predecessor. His *Summa* sets out to investigate the premises and assumptions behind the scientific concepts of the day and, in particular, the idea of technology that underpins them. As Lem writes in the book's opening pages: "I shall focus here on various aspects of our civilization that can be guessed and deduced from the premises known to us today, no matter how improbable their actualization. What lies at the foundation of our hypothetical constructions are *technologies, i.e., means of bringing about certain collectively determined goals that have been conditioned by the state of our knowledge and our social aptitude*—and also those goals that no one has identified at the outset."

Despite having been written nearly fifty years ago, *Summa* has lost none of its intellectual vigor or critical significance. Some specific scientific debates may have advanced or been corrected since Lem published *Summa* in 1964, yet it is actually surprising to see how many things he did get right, or even managed to predict—from the limitations of the Search for Extraterrestrial Intelligence (SETI) program through to artificial intelligence, bionics, the theory of search engines (Lem's "ariadnology"), virtual reality (which he terms "phantomatics"), and nanotechnology. However, it is in the multiple layers of its philosophical argument that the ongoing importance of his book lies. Biophysicist Peter Butko, who published an explicatory essay on *Summa* in 2006, describes the book as "an all-encompassing philosophical discourse on evolution: not only evolution of science and technology . . . but also evolution of life, humanity, consciousness, culture, and civilization."[1]

On November 23, 2011, Google marked the sixtieth anniversary of the publication of Lem's first book, *The Cyberiad,* by including an animation created by Daniel Mróz on its main page.

Lem's investigation into the parallel processes involved in biological and technical evolution, and his exploration of the consequences of such parallelism, provides an important philosophical and empirical foundation for concepts that many media theorists use somewhat loosely today, such as "life," "entanglement," and "relationality," while also stripping these concepts of any vitalist hubris. For Lem, evolution "just happened," we might say. Given the current renewed interest in the works of Henri Bergson and his idea of creative evolution, the rereading of Bergson provided by Gilles Deleuze (of whose philosophy Lem probably would not have been a great fan, as we shall see later), as well as the multiple engagements with, and reconceptualizations of, Darwin's work, Lem's critical investigation into the different strands of, and stories about, evolution and the emergence of life on Earth has not lost any of its significance or timeliness. His postulate that we should examine the two types of evolution—biological and technical—

together is more than just an argument by analogy; there is also a clear pragmatic dimension to such parallelism. In his reflections on *Summa* titled "Thirty Years Later," Lem explains that the key idea behind the book was "a conviction that life and the processes examined by the biological sciences will become an inspirational gold mine for future constructions in all phenomena amenable to the engineering approach."[2] It is interesting, then, that we can find an (unwitting) echo of such an entangled evolutionary trajectory in Bernard Stiegler's important work on originary technicity developed in his *Technics and Time, 1* and inspired by the paleontological research of André Leroi-Gourhan—work that has become one of the cornerstones of contemporary philosophy of technology and media theory.

This way of thinking about the emergence of life on Earth is no doubt a blow to anthropocentrism, which positions the human as the pinnacle of all creation. For Lem, not only did evolution not have any plan or overarching idea behind its actions, it also seems to have moved in a series of jumps that were full of mistakes, false starts, repetitions, and blind alleys. He argues that "it would be futile to search for a straight genealogical line of man, since attempts to descend to earth and walk on two feet were made over and over again a countless number of times." As Polish critic and author of many publications on Lem, Jerzy Jarzębski, points out, Lem also draws an important distinction between biological evolution and the evolution of reason, rejecting the assumption that an increase in the latter automatically means improved design capacity. Predating Richard Dawkins's idea of evolution as a blind watchmaker by over two decades, Lem's view of evolution is not just nonromantic; it is also rather ironic—as manifested in the closing chapter of *Summa,* "A Lampoon of Evolution." Evolution is described there as opportunistic, shortsighted, miserly, extravagant, chaotic, and illogical in its design solutions. The product of evolution that is of most interest to us—that is, the human himself—is seen by Lem as "the last relic of Nature," which is itself in the process of being transformed beyond recognition by the invasion of technology the human has introduced into his body and environment. There is no mourning of this impending change on the part of Lem, though, no attempt to defend "Nature's ways" and preserve the essential organic unity of the human, since the latter is seen to be both transient and, to some extent, fictitious. As Butko puts it, "philosophically Lem is a pragmatist who knows that for most humans the measure of all things is humanity. . . . [Yet t]here is no pedestal for humanity in *Summa* we are not the crowning achievement of evolution, and it would indeed be strange if evolution stopped now."[3]

To develop this point, we could combine Lem's thinking about evolutionary design with Stiegler's idea of *originary technicity,* whereby the human is seen as always already technical, having emerged in relation with technology—from flint tools and fire through to steam engines and the Internet. Stiegler explains this exteriorizing movement on the part of the human toward the world by what he terms a *technical tendency,* which supposedly already exists in the older, zoological dynamic. It is this very tendency that makes the (not-yet) human stand up and reach for things in the world and to start making things. "For to make use of his hands, no longer to have paws, is to manipulate—and what hands manipulate are tools and instruments. The hand is the hand only insofar as it allows access to art, to artifice, and to *tekhnē,*" writes Stiegler.[4] In the Stieglerian framework, the traditional Aristotelian model of technology as a mere tool is expanded to include the whole environment—a theoretical maneuver that allows the French philosopher to posit our being in the world as inherently technical. It also invalidates any attempt to condemn technology tout court and to return to an imaginary place of nature as supposedly primary and hence more authentic, truthful, and pure, coming, as it supposedly does, *before* technology. In a similar way, Lem does not permit us to retain any such illusions about nature's workings. For him, this process of human emergence is still ongoing, although it has arguably undergone an acceleration since the age of the

Industrial Revolution. The information deluge that Lem talks about at length in *Summa* is one of the consequences of this acceleration.

The framework for Lem's argument in the book is provided by the (then nascent) discipline of cybernetics, as evidenced by the following passage:

> Every technology is actually an artificial extension of the innate tendency possessed by all living beings to gain mastery over their environment, or at least not to surrender to it in their struggle for survival. Homeostasis—a sophisticated name for aiming toward a state of equilibrium, or for continued existence despite the ongoing changes—has produced gravity-resistant calcareous and chitinous skeletons; mobility-enabling legs, wings, and fins; fangs, horns, jaws, and digestive systems that enable eating; and carapaces and masking shapes that serve as a defense against being eaten. Finally, in its effort to make organisms independent of their surroundings, homeostasis implemented the regulation of body temperature. In this way, islets of decreasing entropy emerged in the world of general entropic increase.

The very history of our civilization, with what Lem terms "its anthropoid prologue and its possible extensions," is thus seen as a cybernetic process of expanding the range of homeostasis—which is another way of defining humanity's transformation of its environment—over several thousand years. Now that cybernetic thinking has made serious inroads into media studies, science and technology studies, and digital humanities, thanks to the pioneering work of N. Katherine Hayles, Cary Wolfe, and Bruce Clarke,[5] among others, it is fascinating to be able to see Lem as a willing yet already critical adopter of this particular framework for thinking about the world and about the natural and technical processes taking place within it. Interestingly, Lem is also able to situate the study of cybernetics in the political context of the Cold War period, with its impending nuclear threat, and to tell the story of the relationship between science and politics from the perspective of the "Eastern bloc," which he sees as undergoing a series of oscillations between conflict and détente with its

Western counterpart. In this way, *Summa* serves as an important companion to Hayles's *How We Became Posthuman,* which traces the origins of cybernetics via the Macy conferences in the context of the research funding and the bipolar systemic thinking enabled by the Cold War.

Moving beyond the anthropocentric framework in which the human is seen as occupying the very top of the chain of beings, Lem nevertheless spends a good deal of time considering humans' singularity in the cosmic universe as well as their moral and political responsibility. As pointed out by Peter Swirski, in *Summa,* Lem distances himself from "Enlightenment ideals, according to which humanity could transcend tribalism and build a better future on a planetary scale."[6] Instead, he focuses on "our ubiquitous and seemingly unstoppable drive for conflict and aggression."[7] The Polish author remains skeptical as to "the rationality of Homo sapiens, whom—like Jonathan Swift before him—he sees as *Homo rationis capax.*"[8] As Lem himself puts it rather ominously in the first chapter of *Summa,* "man knows more about his dangerous tendencies than he did a hundred years ago, and in the next hundred years, his knowledge will be even more advanced. Then he will make use of it." It becomes quite clear from both *Summa* and Lem's other writings (in particular, the short pieces on science and philosophy he wrote in the later part of his life)[9] that he is not very optimistic about the human as the product of evolution—not just in terms of our future developmental prospects, as mentioned previously, but also in terms of our current ethicopolitical situation. This is perhaps unsurprising since, as explained earlier, evolution for Lem cannot be trusted with "knowing what it is doing." Neither, seemingly, can we—at least not always or consistently. This limited knowledge results from an underlying conflict Lem identifies "between a conscious mind that can think and an underlying program that determines action," that is, genes, as explained by Hayles. The latter goes on to suggest that the crisis of agency in Lem's writings is therefore "bodied forth as an inescapable and tragic condition of thinking mind(s)."[10]

Indeed, it is the ethical aspect of his discourse on nature, science, and technology that arguably raises the most thought-provoking and timely questions. Outlining his ethical standpoint in a long interview with Swirski conducted in 1994, Lem starts from the premise that "the traditionally inherited types of ethics are all rapidly becoming impotent."[11] Living through the collapse of various forms of authority, secularization, the emergence of both extreme nationalisms and extreme regionalisms, and the pathologies of escapism, the human being in the second half of the twentieth century finds himself for Lem in a kind of *horror vacui,* "giving us as a result a new type of 'man without conscience.'"[12] Such pessimism and sorrow about the human condition is obviously a familiar trope in both philosophy and literature. Yet we have to distinguish here between the pessimistic view of the human as encapsulated by many metaphysical narratives, including those of the dominant religions, whereby man is suffering from some kind of original sin or some other innate fault that predisposes him to doing evil, and the more skeptical–realist argument, which evaluates human faults empirically, so to speak, on the basis of historical experience. Furthermore, this positing of the potential to do evil is an argument through subtraction: the human will eventually make use of his knowledge, as Lem claims, and put it to various uses, including harmful ones, because there is nothing inherent either in him or in the world to stop this course of action. Having acquired technical knowledge through the parallel processes of biological and technical evolution, the human nevertheless lacks any inherent political wisdom, or *sophia,* as Stiegler puts it,[13] which is why there is nothing to stop him producing weapons rather than utensils, to prevent him from making war rather than love. Political systems, state and organizational policies, moral codes, and cultural values may serve as barriers to such negative and damaging turns of events. However, in most cases, politics and ethics find it difficult to catch up with the development of science. As a consequence, they arrive too late to prevent various events from happening. This restricted freedom with regard to his own agency, combined with the lack of knowledge about being with others in the world, contribute to the human's tragic condition.

Morality for Lem is a "genuinely human contribution to human history" that endows "the immorality of the Darwinian model with a human touch, a structural sense," while also allowing the author to close the literary work "with a clear-cut point," as argued by Jarzębski.[14] At the same time, Jarzębski indicates some logical weaknesses in Lem's narrative, especially with regard to the latter's belief in the unconstrained development of reason—which, Lem claims, will at some point overcome human intelligence and move in yet unspecified but possibly dangerous directions: toward a cosmic death, say. While pointing out that traditional theology deals better with issues of impending apocalypse and the end of the world, Jarzębski highlights the eschatological aspects of Lem's own thinking around such issues. This perhaps explains Lem's tendency "to construct worlds equipped with a kind of umbilical cord, or a gateway, to transcendence understood in physical and definitely lay terms. It makes it possible to remove eschatological questions into the other world, disburdening us from the duty of answering them within the bounds of the known cosmos."[15] I would argue that in such cases, Lem resorts, unwittingly perhaps, to smuggling some shards of humanism through the back door of his argument. His at times Swiftian misanthropy covers up a sorrow over the human condition and a desire for it to be better—something that can only ever be enacted in metaphysics or in fiction. This is where Lem's sharp critique of the sociopolitical quietism of Buddhism as outlined in *Summa* becomes to some extent applicable to his own technoscientific speculations.

Yet we should not underestimate the power of Lem's multifaceted critique, which, as with the technologies he writes about, could in the right hands become a force of a true intellectual and cultural transformation in a world in which science needs to be treated seriously but where any authority is ultimately constrained and fallible. Indeed, throughout his argument, Lem mercilessly applies Occam's razor to many of the assumptions and premises held by science, while also remaining fascinated by scientific debates and discoveries. Although he himself remains rather skeptical with regard to any kind of -isms in literary theory and seems rather short-tempered about many thinkers and schools of thought—he is very critical of "this lunatic Derrida," considers Hegel an "idiot," and sneers at patients of Freudian psychoanalysts who dream in sex symbols, while those of Jungian ones supposedly dream in archetypes—his skepticism (or rather "fallibilism," as Paisley Livingston suggests[16]) with regard to the nature of cognition is combined with an exploration of some nonhuman forces at work in the world that escapes human control. These are predominantly natural forces, as evidenced in the turns and twists of evolution, but Lem also shows interest in individual human agency being overcome by, competing with, but sometimes also working in collaboration with an agency of "the system"—be it biological, social, or political. This perhaps explains his repeated engagement with questions of accident, chance, and luck, with game theory—so popular in the 1960s—providing him with a useful framework to analyze the goings-on of the modern world. Yet, as mentioned earlier, we should not go back to Lem for historical reasons alone. What distinguishes Lem from the vast majority of philosophers of technology is his wit—understood as both sharp intellect and sense of humor—as well as his awareness of the narrative, storytelling character of both his philosophy and his science. (This is not to say that science is "made up," only that it relies not just on mathematical language but also on culturally specific semiotic descriptors and that its conventions and assumptions change over time.)

Summa is therefore an example of a different kind of philosophy of technology, one that combines rigorous intellectual analysis with a linguistic playfulness more readily associated with literature. Even though science, with its methodology rooted in objectivity and the rational method,[17] provides an unabashed foundation for the standpoint Lem adopts throughout *Summa,* he is arguably more interested in signaling certain problems and posing questions about them[18] than in offering any determined visions of either the present or the future. Combining scientific rigor with philosophical speculation, Lem humbly declares, "I do not see myself as subjectively infallible."[19] He is thus a skeptic, as much concerned with looking at developments in science and technology as he is with exploring indeterminacy in science and the limits of human cognition. This may also explain his lack of generosity toward certain schools of thought that do not comply with his adopted framework (or that are simply not to his liking). For example, Lem has no time for structuralism in literary theory, although he does not bat an eye about game theory's structuralist foundations; admits to not reading philosophy too intensely as it is, for him, a mere derivative of science (which obviously limits philosophy to its analytical incarnation); and considers women an "unnecessary complication"[20] in both literary and scholarly endeavors.

Arguably, literature offers a unique space in which such deliberations can occur most productively and most freely—with his "fictions about science" strongly rooted in science (as opposed to science fiction, which most often maintains only a cursory relation to science) providing a testing ground for many of his thought experiments. Although in its philosophical style and the nature of its scholarly argument, *Summa* belongs to a different genre than Lem's novels, they are all bound by a unique literariness, which manifests itself in their author's engagement with language as a plastic material of a creative cultural process that yields itself to experimentation, while also showing some "resistance of material" at times. Jarzębski goes so far as to suggest that for Lem, evolution itself is also a "narrative."[21] Again, this does not mean that it did not really happen, only that it requires various narrative renditions to be conveyed as a concept —or transmitted, to borrow from the communications discourse favored in *Summa*—to human receivers in their particular sociocultural and philosophical milieux. A certain paradox emerges here because evolution, as Jarzębski has it, cannot be comprehended by reason—“hence the only way to cope with it is to impose a human, quasi-sensible narrative onto it,” which is why it must be “absorbed into human history, compared with something we know.”[22] Arguably, *Summa* is an attempt to deal with this very paradox.

Speaking of Lem’s aforementioned literariness, many critics have commented on what Andy Sawyer calls the writer’s “overwritten style” as well as his “love of the grotesque, of imagistic and linguistic excess”—which, for Sawyer, makes Lem a “master of the baroque.”[23] This baroque and frequently playful style can be a source of joy to Lem’s readers but also a source of frustration to his translators. The long line of excellent decoders of Lem’s linguistic and conceptual experiments—Michael Kandel, Antonia Lloyd-Jones, Peter Swirski—have demonstrated true linguistic mastery in being able to translate many of his neologisms and complex turns of phrase. Lem himself seemed very much aware that the translator’s task is to some extent open-ended when he said, “Optimal strategies of literary interpretation never exist uniquely, but come in interrelated and correlated sets. It is pretty much the same with translations. There are several different translations of Shakespeare, most of them very good, yet not only are they not identical, but in fact quite divergent. And there is no way to avoid this. Some readers will always like this translation of *Hamlet,* while others will find a different one much more congenial.”[24] We could easily replace *Hamlet* with *Summa* here, of course—a reassuring note from an author who was supposedly famous for writing “divorce letters” to his many translators!

In the light of the preceding, translating *Summa* has been an interesting intellectual and linguistic adventure for me. On being approached by Professor Mark Poster and the University of Minnesota Press back in 2009 to consider translating the book, I found it an extremely tempting proposition, which is not to say I jumped at the opportunity or that my subsequent decision to take it on was not accompanied by any trepidation on my part. (That said, Lem’s anecdote about a visit he had from a “young lady” who wanted to translate Summa but, "for all the effort, . . . was forced to give up"[25] only served to spur me on!) As a regular Lem reader, a translator of science and humanities academic texts prior to my academic career, and now a scholar working in the very areas of philosophy of technology and ethics with which *Summa* concerns itself, I was aware I would be dealing with an exciting yet difficult text that would no doubt permeate my own philosophical spectrum and linguistic repertoire. This is indeed what has happened: I have been thoroughly "Lemmed." For example, Lem's thinking haunts the book *Life after New Media: Mediation as a Vital Process,*[26] which I cowrote with Sarah Kember while translating *Summa*. It helped me outline what we could describe as *critical vitalism,* whereby evolutionary processes are treated seriously but not idolatrously and where life in its biological and philosophical enactments requires a human intervention to make sense of it and to control its random unfolding.

First published in Polish in 1964, *Summa* was reissued again 1964, with subsequent editions (to which Lem made some alterations) coming out in 1967 and 1974. This translation is based on the fourth edition of the book from 1974, as this is arguably the most mature and up-to-date edition. Butko explains that "*Summa* is essentially a work in progress: Lem corrected mistakes and updated his thinking, based in part on feedback from readers who are often scientists and experts in their respective fields."[27] *Summa* was reissued in Poland in 2000, and then once again, after Lem's death, as part Lem's collected works published in 2009–11 by *Gazeta Wyborcza*'s publisher, Agora SA —a phenomenon that testifies to the ongoing popularity and significance of Lem in his native country. Lem himself seemed to remain convinced about the long-lasting timeliness of *Summa*'s argument, a timeliness that went well beyond the fulfillment of any particular scientific prophecies of his, when he confessed to the Polish literary critic Stanisław Bereś that "from my discursive books *Summa Technologiae* is the only one I am happy with. This does not mean that one should not change it; but, if one does not have to, one should not do it. It has survived and is still very much alive."[28] Yet Lem also admitted in 1991 that he would gladly publish "a new critical edition of *Summa,* much enlarged to include—in the margins, footnotes, or in some other way—my commentary on the things I wrote in the 1960s."[29] His two essays, "Twenty Years Later" (written in 1982 and appended to *Summa*'s fourth edition, in which Lem offers his reflections on futurology) and "Thirty Years Later" (in which he engages with a critical review of his book by Polish philosopher Leszek Kolakowski), reveal a certain sadness on the author's part that the book "sank without a trace,"[30] while also updating the examples from *Summa* with their later scientific equivalents (e.g., synthetic biology and virtual reality devices such as Eye Phone and Data Glove). Those latter efforts were aimed at demonstrating how many of the inventions and discoveries Lem did manage to predict correctly in *Summa*—notwithstanding his suspicions toward humanity's futurological aspirations. "Nothing ages as fast as the future,"[31] he quipped.

The aim of this translation, prepared specially for the University of Minnesota Press's Electronic Mediations series—a series that has been instrumental in setting new pathways in studies of new technologies and new media over more than a decade—is to offer an accurate rendition of Lem's text in its mature fourth edition from 1974, while also attending to the quirks of his language. While some of the scientific material or even terminology is now out of date, there was no attempt here to "update" Lem for the twenty-first century because the book has indeed "survived and is still very much alive." As every translator inevitably does, I had to make a number of decisions with regard to style, grammar, and a linguistic rendition of particular concepts. I was mindful of Lem's rather strong position on adjusting the third person singular *he,* which he expressed in the following terms: "I am terribly irritated by the contemporary injunction in North America that when one writes about someone, say a physicist, it has to be in the form 'he' or 'she.' I am thoroughly opposed to this, and when they requested my permission to use this in the American translations, I categorically refused. I told them that they could print my texts, but only as they were. This is the same kind of absurdity as referring to God as a 'she'—a peculiar concept, given that he is male in all monotheistic religions. I don't see a reason for changing this; I did not start the convention."[32] The Polish term *rozum,* which is to some extent foundational to the argument of the book, can be translated either as "reason" or "intelligence" (also in phrases such as *istota rozumna,* "rational" or "intelligent being"). I have opted for the latter translation because of its ubiquity in astrophysics and artificial intelligence research. Lem's *Konstruktor* has been rendered here as a "Designer," but I also want readers to be aware of the engineering connotations of this term. Lem's use of capitalization throughout the volume seems to have been a conscious stylistic and visual feature, which deserves special attention. Words such as *evolution, designer, history,* or *nature* normally appear in lowercase throughout the text, yet suddenly one of them will be capitalized—presumably to draw the reader's attention to the importance of this particular concept at a given moment. I have retained the use of capitals as per the original.

I received advice on scientific concepts and ideas, and on their historical alterations, from many various sources: from Witold Maciejewski at the Astrophysics Research Institute at Liverpool John Moores University through to arXiv.org. Thanks are also due to Gary Hall and Sarah Kember, who were careful and patient readers of different sections of the translation, and to my home institution, Goldsmiths, University of London, for allowing me time to work on this project. Last, but not least, I am grateful to McGill University (where the Lem spirit is very much alive) for inviting me as their Beaverbrook Visiting Scholar in 2011.

Summa Technologiae

1.

Dilemmas

We are going to speak of the future. Yet isn't discoursing about future events a rather inappropriate occupation for those who are lost in the transience of the here and now? Indeed, to seek out our great-great-grandsons' problems when we cannot really cope with the overload generated by our own looks like a scholasticism of the most ridiculous kind. If we could at least use the excuse that we are trying to find some optimism-enhancing strategies, or acting out of love for the truth, which is to manifest itself clearly in the future. (In our vision, such a future would be free from all kinds of storms, both metaphorical and literal ones, after our climate has been brought under control.) But the justification for my argument does not lie in scholarly passion or in an unshakeable optimism that would guarantee a favorable turn of events, no matter what happens. My justification is even simpler, more sober and probably also more modest, because, in setting off to write about tomorrow, I am only doing what I am capable of doing—no matter how well, since this is my only ability. And if this is the case, then my labor will not be any less or any more unnecessary than any other kind of work, as they are all based on the fact that the world exists and that it will continue to exist.

Having thus demonstrated that my intention is free from indecency, let us look into the subject matter and method of this book. I shall focus here on various aspects of our civilization that can be guessed and deduced from the premises known to us today, no matter how improbable their actualization. What lies at the foundation of our hypothetical constructions are *technologies, i.e., means of bringing about certain collectively determined goals that have been conditioned by the state of our knowledge and our social aptitude*—and also those goals that no one has identified at the outset.

The mechanism of individual technologies, both actual and possible ones, does not interest me much. I would not have to look into it if man's creative activity were free, in a godlike manner, from being polluted by unknowledge—if, now or in the future, we could fulfill our goal in the purest way possible by being able to match the methodological precision of Genesis; if, in saying "let there be light," we could obtain as a final product light itself, without any unwanted additives. However, the previously mentioned splitting of goals, or even the replacement of one goal with another, often an undesirable one, is a classic phenomenon. Malcontents are able to see a similar kind of disturbance even in God's work—especially ever since the launch of a prototype of the intelligent being and the subsequent passing of the *Homo sapiens* model to the production stage. But we shall leave this aspect of our deliberations to theotechnologists. It is enough to say that man hardly ever knows what he is actually doing—at least he does not know for sure. Let me illustrate this point with a rather extreme example: the destruction of Life on Earth, which is entirely possible today, was not actually the goal of any of the discoverers of atomic energy.

It is therefore somewhat out of necessity that technologies are of interest to me, since a given civilization embraces everything society has desired, but also everything else that has not been part of anyone's plan. At times, frequently even, a technology is born from an accident—like when one was looking for the philosopher's stone but invented porcelain instead—but the role of intention, or conscious purpose, in all the causative efforts oriented toward technology increases with the growth of knowledge itself. In becoming more infrequent, surprises can actually reach almost apocalyptic dimensions. This is what has been stated previously.

There are few technologies that could not be classified as double-edged, as illustrated by the example of the scythes that were attached to the wheels of the Hittite battle carts or the proverbial plowshares that had been beaten into swords.[1] Every technology is actually an artificial extension of the innate tendency possessed by all living beings to gain mastery over their environment, or at least not to surrender to it in their struggle for survival. Homeostasis—a sophisticated name for aiming toward a state of equilibrium, or for continued existence despite the ongoing changes—has produced gravity-resistant calcareous and chitinous skeletons; mobility-enabling legs, wings, and fins; fangs, horns, jaws, and digestive systems that enable eating; and carapaces and masking shapes that serve as a defense against being eaten. Finally, in its effort to make organisms independent of their surroundings, homeostasis implemented the regulation of body temperature. In this way, islets of decreasing entropy emerged in the world of general entropic increase. Biological evolution is not limited to this process since it builds higher entities—not islets anymore, but whole islands of homeostasis—from organisms, from phyla, classes, and plant and animal species. In this way, it shapes the surface and atmosphere of the planet. Animate nature, or the biosphere, involves both a collaboration and a mutual voraciousness; it is an alliance that is inextricably linked with struggle—as indicated by all the hierarchies examined by the ecologists. We can find among those hierarchies, especially among animal forms, pyramids at the top of which stand great predators. The latter feed on smaller animals, which in turn feed on even smaller ones. Only at the very bottom, at the base of the state known as "life," a green transformer that is omnipresent on land and in oceans converts solar into biochemical energy. Through a trillion ephemeral reeds, it maintains within itself a bulk of life that changes in its form but that never completely disappears.

Using technologies as its organs, man's homeostatic activity has turned him into the master of the Earth; yet he is only powerful in the eyes of an apologist such as himself. Faced with climatic disturbances, earthquakes, and the rare but real danger of the fall of meteorites, man is in fact as helpless as he was during the last ice age. Of course, he has come up with ways of helping those who have been affected by various cataclysms. He can even predict some of them—although not very accurately. It is still a long way to homeostasis on a planetary scale, not to mention stellar homeostasis. Unlike most animals, man does not adjust to his surroundings but rather transforms those surroundings according to his needs. Will he ever be able to do this with the stars? Will a technique of remotely directing inner transformations of the Sun emerge at some point, perhaps in a far-away future, so that creatures that are transient when compared with the duration of the solar mass can freely direct its billion-year fire? It seems possible to me, and I am saying this not to worship the rather excessively venerated human genius but, on the contrary, to open up the possibility of a contrast. So far, man has not enlarged himself in any way. But what has increased significantly is his ability to do good and evil to others. Someone who is capable of switching stars on and off will also be capable of annihilating whole inhabited globes, transforming himself in this way from an astrotechnician to a starbuster—and thus a criminal on a large cosmic scale. If the former is possible (no matter how improbable it seems and how little chance it has of coming about), so is the latter.

Such improbability, I should explain, does not derive from my belief in the necessary triumph of Ormuzd over Ahriman.[2] I do not trust any promises, nor do I believe in any assurances built on so-called humanism. The only way to deal with technology is with another technology. Man knows more about his dangerous tendencies than he did a hundred years ago, and in the next hundred years, his knowledge will be even more advanced. Then he will make use of it.

The acceleration of scientific and technological development has become so obvious that one does not have to be an expert to notice it. I think the mutability of the living conditions caused by it is one of the factors that negatively affect the formation of homeostatic systems that regulate our customs and norms. When the entire life of a future generation ceases to be a repetition of their parents' lives, what kinds of lessons and instructions can the old, experienced as they are, offer to the young? This disruption to the models of activity and their ideals by the very element of constant mutation is actually masked by another process, one that is more distinctive and that certainly has more serious immediate consequences. This process involves accelerating the oscillations of the self-awakening system of positive feedback with a very small negative component, that is, the East–West system—which, in recent years, has been oscillating between world crisis and détente.

It goes without saying that it is precisely thanks to this acceleration in the accumulation of knowledge and in the emergence of new technologies that we have an opportunity to take a serious look at our current topic. No one is questioning the fact that the changes that are occurring are rapid and sudden. Anyone who would say that the year 2000 is going to be very much like our present times would immediately become a laughingstock. Yet such attempts to project the (idealized) present condition into the future have not always been considered absurd, as evidenced by the example of Bellamy's utopia (1960), which described the 2000s from the perspective of the second half of the nineteenth century. Bellamy consciously ignored all the possible inventions that were still not known to his contemporaries. As a righteous humanist, he thought that changes caused by technoevolution were not significant either for the functioning of societies or for an individual psyche. Today we do not have to wait for the arrival of our grandchildren to make someone laugh at the naïveté of such prophesying. Anyone can have some fun by just putting in a drawer for a few years what is currently being described as a believable image of tomorrow.

And thus the rapid speed of change, which becomes an impetus for deliberations such as ours, also reduces the viability of any prophecies. I am not even thinking here of innocent popularizers, as the blame lies with their learned masters. P. M. S. Blackett, a well-known English physicist and one of the founders of operational research (the early work on mathematical strategy)—and thus a kind of professional foreteller—in his book of 1948 predicted the future development of atomic weapons and their military consequences up to the year 1960 as inadequately as one could only imagine. Even I was familiar with a 1946 book by the Austrian physicist Thirring, who was the first to have publicly described the theory of the hydrogen bomb. And yet it seemed to Blackett that nuclear weapons would not exceed a kiloton range because megatons (a term which, incidentally, did not exist at the time) would not have any targets that would be worth destroying. Today there is increasing talk of begatons (a billion tons of TNT). The prophets of astronautics did not fare any better. There were, of course, also reverse errors: around 1955, it was believed that the fusion of hydrogen into helium observed in the stars would generate industrial energy in the near future. Current estimates situate the production of the microfusion cell[3] in the 1990s, or even later. But it is not so much the development of a particular technology that is at issue but rather the unknown consequences of such a development.

We have so far discredited any predictions regarding progress, thus in a way clipping the branch on which we have been trying to undertake a series of daring exercises—mainly the casting of an eye into the future. Having shown how hopeless such an undertaking can be, we would be better off occupying ourselves with something else. Yet we are not going to give up that easily. The risk exposed can actually stimulate further debate. Besides, even if we are to make a series of gigantic mistakes, we will find ourselves in exquisite company. For an infinite variety of reasons that turn making predictions into a thankless task, I shall list several such mistakes that are particularly displeasing to the artist.

First, transformations that lead to a sudden turn in existing technologies sometimes burst forth like Athena from Zeus's head—to the surprise of everyone, including the experts. The twentieth century has already been taken aback several times by the newly emergent hegemonies, such as, for example, cybernetics. Enamored of the scarcity of means and considering—not incorrectly—that similar maneuvers are one of the cardinal sins against the art of composition, the artist hates such deus ex machina devices. But what shall we do when History turns out to be so easy to please?

Furthermore, we are always inclined to extend the course of new technologies into the future by means of straight lines, hence "the world full of balloons" or "the total steam world" of the nineteenth-century utopians and draftsmen—both of which seem most amusing today. Hence also the contemporary attempt to populate outer space with space "ships," including a brave "crew," "watch officers," "helmsmen," and so on, on board. It is not that one should not write like this, but this kind of writing belongs to a genre of fantasy; it is a form of "reverse" nineteenth-century historical novel. In the way one used to ascribe the motivations and psychological traits of contemporary monarchs to the pharaohs, one represents today the corsairs and pirates of the thirtieth century. We can surely amuse ourselves like this, provided we remember we are only playing. However, History has nothing to do with such simplifications. It does not show us any straight paths of development but rather uses the curvilinear zigzags of nonlinear evolution. This means that the conventions of elegant design have to be abandoned, unfortunately.

Third, a literary work has a beginning, a middle, and an end. The entanglement of plots, the interweaving of temporalities, and the use of other devices aimed at modernizing fiction have not so far liquidated this structure. Generally speaking, we have a tendency to place any phenomenon within a closed schema. Let us imagine a 1930s thinker who has been presented with the following imaginary situation: in 1960, the world will be divided into two antagonistic parts, each one of which will be in the possession of some terrible weapons, capable of annihilating the other half. What will the outcome be? Our thinker would no doubt answer: total annihilation or total disarmament (but he would also most certainly add that our idea is weak because it is so melodramatic and unbelievable). Yet so far this kind of prediction has not delivered much. Please note that it has been over fifteen years since the emergence of the "balance of fear"[4] three times as long as it had taken to manufacture the first atomic bombs. To a certain degree, the world is like a sick man who believes that either he is going to get better soon or die very quickly and to whom it does not even occur that he can, moaning as he does, and going through some short-term ups and downs, go on living until old age. Yet this comparison is rather shortsighted . . . unless we invent some medication that will manage to cure this man's sickness completely but that will pass on to him some new problems resulting from the fact that even if he is given an artificial heart, it will be placed on a little trolley connected to it with a bendy pipe. This is, of course, nonsensical, but we are talking about the price of such a total cure. Liberation from oppression (humanity's atomic independence from the limited oil and coal resources, say) has its price, while the amount of expected repayment and its period, as well as the method of its delivery, usually come as a surprise. The mass application of atomic energy for peaceful aims carries with it a gigantic problem of radioactive waste, which we still do not know what we should do about. The development of nuclear weapons can quickly lead to a situation in which today's proposals for disarmament, together with our "annihilation proposals," will turn out to be anachronistic. It is hard to determine whether it is going to be a change for the better or for the worse. The overall threat may increase (e.g., inner striking power will get bigger and will thus require us to build shelters from reinforced concrete), but the possibility of its actualization will decrease—or the other way round. Other combinations are also possible. In any case, the global system remains unbalanced, not only in the sense that it can tip toward war, as there is nothing new about that, but primarily because it is evolving as a whole. At the moment, it seems somewhat "scarier" than it was in the era of kilotons, since we have megatons today, but it is only a transitional phase. Contrary to popular belief, one should not think that an increase in charge power and in the velocity of their carriers, or the development of "antimissile missiles," represents the only possible gradient of this evolution. We are entering higher and higher levels of military technology, as a result of which it is not only conventional battleships and bombers, strategies and staff, that are becoming obsolete: so is the very idea of global antagonism. I have no idea how it is going to evolve. Instead, I am going to introduce briefly a novel by Olaf Stapledon,[5] the "plot" of which spans over two billion years of human civilization.

Martians, a species of viruses capable of aggregating into jellylike "intelligent clouds," attack the Earth.

People fight the invasion for a long time, without knowing that they are dealing with an intelligent life-form and not with a cosmic cataclysm. The "victory or defeat" alternative does not ensue. After centuries of struggle, the viruses undergo a transmutation so deep that they enter the human genotype, which leads to the emergence of a new kind of *Homo sapiens*.

I think this is a beautiful model of a historical phenomenon on a yet unknown scale. The probability of this phenomenon taking place is not that relevant; I am more interested in its structure. History does not deal with tripartite closed schemas entailing "a beginning, a middle, and an end." It is only in a novel that a character's life gets immobilized into a certain image, before the words "The End" appear, thus filling the author with aesthetic delight. It is only in a novel that we must have an end, a happy or an unhappy one, but certainly one that closes things off on the level of composition. Yet the history of humankind does not know, and I hope *will* not know, such definitive closures or "final ends."

2.

Two Evolutions

It is difficult for us to understand the process whereby ancient technologies emerged. Their utilitarian character and their teleological structure remain undisputed, yet they did not have any individual designers or inventors. Trying to get to the origins of early technologies is a dangerous task. Successful technologies used to have myth or superstition as their "theoretical foundation"their application was either preceded by a magic ritual (medicinal herbs supposedly owed their properties to a formula that was being recited while collecting or applying those herbs), or they themselves became a form of ritual, in which a pragmatic element was irrevocably linked with a mystical one (the ritual of shipbuilding, in which the production process was a form of liturgy). When it comes to becoming aware of the ultimate goal, the structure of a collective task can today approach the realization of a task achieved by an individual. But it was different in the old days, when one could only speak of technical goals of ancient societies metaphorically.

The shift from the Paleolithic to the Neolithic period, the Neolithic revolution—which rivals the atomic one in terms of its cultural significance—was not the consequence of an idea of farming "popping into the head" of some kind of Einstein of the Stone Age, who then "convinced" his contemporaries about the advantages of this new technology. It was an extremely slow process, a creeping transformation, exceeding the life span of many generations—from using the plants one found as nutrition through to nomadic hunting and gathering and then sedentarization. The changes occurring within the lifetime of a single generation were hardly noticeable. In other words, each generation would encounter an apparently unchanged technology, as "natural" as sunrises and sunsets. This mode of emergence of technological practice has not disappeared altogether since the cultural significance of every great technology reaches much further than just the lifetime of each individual generation—which is why its future-oriented consequences of a systemic, habitual, and ethical kind, as well as the very direction in which it is pushing humanity, not only are not a subject of anyone's conscious intention but also effectively defy the recognition of the existence of such significance or the definition of its nature. With this terrifying sentence (terrifying in style, not content), we are opening a section on the metatheory of the gradients of man's technical evolution. We say "meta" because it is not the delineation of its direction or the determination of its consequences that preoccupies us for the time being but rather a more general and overarching phenomenon. Who causes whom? Does technology cause us, or do we cause it?[1] Does it lead us wherever it wishes, even to perdition, or can we make it bend before our pursuit? But what drives this pursuit if not technical thought? Is it always the same, or is the "humanity–technology" relation itself historically variable? If the latter is the case, then where is this unknown quantity heading? Who will gain the upper hand, a strategic space for civilization's maneuvers: humanity, which is freely choosing from the widely available arsenal of technological means, or maybe technology, which, through automation, will successfully conclude the process of removing humans from its territory? Are there any thinkable technologies that are impossible to actualize, now and in the future? What would determine such a possibility—the structure of the world or our own limitations? Is there another potential direction in which our civilization could develop, other than a technical one? Is our trajectory in the Universe typical? Is it the norm—or an aberration?

We shall try to find answers to these questions—although our search will not always yield unequivocal results. Our starting point will be provided by a graphic chart illustrating the classification of effectors, that is, systems capable of acting, which Pierre de Latil included in his book, *Thinking by Machine* (1956). He distinguishes three main classes of effectors. The first class of determined effectors contains simple tools (such as a hammer), complex tools (an adding machine, a classic machine), and tools linked to the environment (with no feedback) such as, for example, an automatic fire detector. The second class—that of organized effectors—contains feedback systems: machines with built-in determinism of action (self-regulators, e.g., those of a steam engine), machines with a variable goal of action (programmable from outside, e.g., an electric brain), and self-programming machines (systems capable of self-organization). Animals and man belong to the latter class. There are also systems that possess one more degree of freedom —systems that, to achieve their goals, are capable of changing themselves. (De Latil calls this a "who" freedom, in the sense that whereas man has been "given" his organization and body material, systems of this higher class, which do not just possess freedom on the level of their building material, can radically transform their own systemic organization. A living species that is undergoing biological evolution would be an example of such systems.) De Latil's hypothetical effector of an even higher class also has freedom on the level of the choice of material from which it "builds itself." As an example of such an effector with the highest degree of freedom, de Latil proposes the mechanism of the spontaneous generation of cosmic matter as outlined in Hoyle's theory.[2] It is easy to see that technical evolution is a far less hypothetical system of this kind, one that is also much easier to verify. It manifests all the characteristics of a feedback system that is programmable "from within," that is, self-organizing, and that also possesses freedom with regard to its total transformation (the way a living and evolving species does), as well as freedom of choice with regard to its building material (since technology has at its disposal everything the Universe contains).

I have summarized the classification of systems with increasing degrees of freedom as proposed by de Latil, removing from it some highly contentious details regarding their categorization. Before we move on with our discussion, we should perhaps add that this classification, in the form presented here, is not complete. One can imagine systems possessing yet another degree of freedom, since selection from among the materials contained within the Universe is necessarily limited to the "parts catalog" the Universe possesses. Yet we can also think of a system that, not being content with what is provided, creates materials "off-catalog," that is, materials that do not exist in the Universe. A theosophist would perhaps be inclined to designate such a "self-organizing system with a maximum degree of freedom" as God. However, such a hypothesis is not necessary for us since we can conclude, even on the basis of the limited knowledge we have today, that creating "off-catalog" parts (e.g., subatomic particles that the Universe does not contain "normally") is possible. Why? Because the Universe does not actualize all of its possible material structures. As we know, it does not create, say, in the stars—or anywhere else—typewriters; yet the "potentiality" of such typewriters is contained within it. The same applies, we can assume, to the phenomena that contain the (at least yet) unrealized states of matter and energy in the Universe, in the space and time that carry them.

Similarities

We know nothing certain about the origins of evolution. What we do know rather well is the dynamics of the emergence of a new species—from its birth through its developmental peak to its decline.

There are almost as many evolutionary paths as there are species, and they all have numerous characteristics in common. A new species appears in the world unnoticed. Its appearance seems to come from what already exists, and this borrowing seems to testify to the inventive inertia of the Designer. At the beginning, there is not much indication that this upheaval in its inner organization, to which a species will owe its later development, has in fact already taken place. The first specimens are usually small; they also sport a number of primitive features, as if their birth had been hurried and fraught with uncertainty. For a period of time, they vegetate in a semisecretive state, barely managing to compete with the established species—which are already optimally adapted to the tasks of the world. Then, eventually, prompted by the change to the general equilibrium resulting from the seemingly insignificant transformations in the environment (whereby a species's environment includes not only the geological world but also all the other species vegetating in it), a new kind of expansion takes off. Entering the already occupied territories, a species openly shows its lead over its competitors in the struggle for life. When it enters an empty unconquered space, it bursts into evolutionary radiation, which in one go initiates the emergence of a whole range of variations. In these variations, the disappearance of the remnants of primitivism in a species is accompanied by the emergence of new systemic solutions that are ever more bravely dominating its outer appearance and its new functions. This is the route a species takes to reach its developmental peak. Through the process, it gives a name to the whole epoch. The period of rule on land, in the sea, or in the air lasts a long time. Then a homeostatic equilibrium is eventually disturbed once again—yet this still does not signal defeat. The evolutionary dynamics of a species gains some hitherto unobserved new traits. In its core branch, the specimens are getting bigger, as if gigantism was to provide protection against the threat. Evolutionary radiations start to take place again, this time often marked by hyperspecialization.

The lateral branches attempt to penetrate into environments in which competition is comparatively weaker. From time to time, that latter maneuver culminates in success. Then, when all the traces of the giants—whose emergence was a defense strategy on the part of the core species against its extinction—have disappeared, when all the simultaneous efforts to the contrary have also failed (as some evolutionary lines promptly head toward dwarfism), the descendants of the lateral branch, having happily encountered propitious conditions inside the peripheral area of their competition, continue their existence almost without change. In this way, they serve as the last proof of the primeval abundance and power of a species.

Please forgive my somewhat pompous style, a rhetoric that has not been supported with any examples. Any vagueness here stems from the fact that I have been talking about two kinds of evolution at the same time: biological and technical.

As a matter of fact, their dominant characteristics show a great number of surprising analogies. It is not only that the first amphibians were similar to fish, while the mammals resembled small lizards. The first airplane, the first automobile, or the first radio owed its appearance to the replication of the forms that preceded it. The first birds were feathered flying lizards; the first automobile was a spitting image of the coach with a guillotined shaft; the airplane had been "copied" from the kite (or even the bird), the radio from the already existing telephone. Those prototypes tended to be rather undersized, while their primitive design left a lot to be desired. The first bird, the ancestor of the horse or the elephant, was quite tiny; the first steam locomotive was not much bigger than a regular cart, while the first electric locomotive was even smaller. A new principle of biological or technical design initially deserves pity more than enthusiasm. Ancient mechanical vehicles moved more slowly than horse-driven ones; the first airplane could barely manage to lift itself off the ground; and listening to radio broadcasts was no fun even when compared with the tinny sound of the gramophone. Similarly, the first land animals were no longer good swimmers, yet they still had not mastered the art of walking. The feathered lizard—the archaeopteryx—did not as much fly as flutter. Only during the process of perfecting those traits did the previously mentioned "radiations" take place. Just as the birds conquered the sky and the herbivorous mammals the steppe, the combustion engine vehicle took mastery over the roads, thus giving rise to ever more specialized varieties. In the "struggle for life," the automobile not only pushed out the stagecoach but also "gave birth" to the bus, the truck, the bulldozer, the fire engine, the tank, the off-road vehicle, and dozens of other means of transport. The airplane, taking control over the "ecological niche" of the airspace, was probably developing even faster, changing several times the already fixed shapes and types of drive (the piston engine was replaced by the turbo engine, then by the turbo-piston engine, and eventually by the jet engine; when it came to shorter distances, the winged airplane found a serious rival in the helicopter; and so on). It is worth noticing that just as the predator's strategy affects the strategy of its prey, so the classical airplane defends itself against the helicopter's invasion. It does this by creating a prototype of the winged plane, which—owing to the change of direction of the thrust—is capable of taking off and landing vertically. It is a struggle for the maximum universality of function, one that is very well known to any evolutionist.

The two means of transport discussed earlier have not yet reached their developmental peak, which is why we cannot talk about their late forms. It was a different story with the piloted hot air balloon, which, when threatened by machines whose weight exceeded that of air, developed symptoms of elephantiasis, so typical of the predecline blossom of dying evolutionary branches. The last zeppelins of the 1930s can be easily compared with the atlantosauruses and brontosauruses of the Cretaceous period. Gigantic size was also achieved by the last exemplars of the steam-driven freight train, before it was made obsolete by diesel and electric locomotives. When looking for signs of descending evolution, which is attempting to overcome the danger it faces with secondary radiations, we can turn to radio and cinema. The competition from television led to a sudden “radiation of variations” among radio sets and to their appearance in new “ecological niches.” In this way, miniaturized, pocket, and other kinds of radio sets —including those affected by hyperspecialization, such as high-fidelity radios with stereophonic sound, integrated hi-fi recorders, and so on—came into being. Cinema itself, in its battle against television, has considerably increased the size of the screen and is even demonstrating a tendency to “surround” the viewer with it (videorama, Circarama).[3] One can also imagine further development of mechanical vehicles, which will make wheel drive obsolete. When the current automobile is eventually replaced by an “air-cushion vehicle,” it is quite likely that, say, a small combustion-driven lawnmower will be the last descendant of the classical car—still vegetating in a “lateral branch.” Its design will be a remote reflection of the automobile period, just as certain specimens of lizards from the archipelagos of the Indian Ocean are the last remaining descendants of the large Mesozoic reptiles.

The morphological analogies between the dynamics of bio- and technoevolution, which can be represented with a slowly ascending curve that is then to descend from its peak toward decline on a graph chart, do not cover all the convergences between these two large areas. One can identify some other, even more surprising convergences. For example, in certain living organisms, there exist a high number of exceptionally unique traits whose origin and survival cannot be explained by their adaptation values. We can mention here, alongside the well-known cockscomb, the fantastic plumage of some male birds, such as the peacock or the pheasant, and even the saillike spinal outgrowths of fossil reptiles.[4] Similarly, the majority of products of a given technology possess seemingly superfluous or nonfunctional traits that cannot be explained by the way these products work or by what they are supposed to do. We can posit here an extremely interesting but also somewhat amusing similarity with an invasion, which is taking place inside biological and technological construction processes: in the former case, it is an invasion by the criteria of sexual selection, in the latter by fashion. If, for the sake of clarity, we limit our analysis to the example of the contemporary motor vehicle, we shall see that the car's main features are forced on the designer by the current state of technology. So, for instance, when using rear wheel drive together with a front-mounted engine, the engineer has to place the transmission tunnel of the propeller shaft within the car's interior. However, between the requirement not to change the design of the vehicle's "systemic" organization, on one hand, and the requirements and tastes of the vehicle's recipient, on the other, lies a vast space of "inventive freedom" because the said recipient can be offered various shapes and colors for his vehicle, various shapes and sizes of the windows, additional embellishments, chrome plating, and so on. In bioevolution, the counterpart of product differentiation, which results from fashion pressure, is provided by the multifarious shapes of secondary sexual characteristics. Those characteristics were initially the result of accidental changes, that is, mutations. They became fixed in the generations that followed due to the privileging of their owners as sexual partners. And thus the counterpart of the car's tail, chrome-plated embellishments, fantastically shaped cooling pipes, and head and rear lights can be found in mating colors, crests, unusual outgrowths, and last but not least, in the unique distribution of fat tissue, combined with the facial features that are sexually appealing.

Of course, the sluggishness of "sexual fashion" is much greater in bioevolution than in technology since Nature the Designer is incapable of altering the models it produces each year. However, the essence of this phenomenon, that is, the unique influence of "impractical," "insignificant," and "nonteleological" factors on the shape and development of living creatures and technological products, can be detected and verified in a large number of randomly selected examples.

We could find some other, even more inconspicuous similarities between these two large evolutionary trees. For example, in bioevolution, there is the phenomenon of mimicry, that is, the adaptation of an appearance of one species to that of another, which proves beneficial for the "imitators." Nonvenomous insects can be a spitting image of some remote yet dangerous species; they can even "pretend" to be a single body part of a creature that has nothing in common with insects—I have in mind here the amazing "cat's eyes" on the wings of certain butterflies. Analogies to mimicry can also be found in technoevolution. The lion's share of nineteenth-century metalwork and smithery emerged as a result of imitating botanical forms (the ironwork in bridge structures, handrails, street lanterns, and fences, or even the funnel “crowns” of old locomotives, all “pretended” to be botanical designs). Everyday objects such as fountain pens, cigarette lighters, lamps, and typewriters often have aerodynamic shapes these days, masquerading as forms designed in the aerospace industry—which is an industry of high-speed technologies. Yet this kind of mimicry lacks the profound justification that is evident in its biological counterpart. What we have here is the influence of dominant technologies over lower-level, secondary ones. Fashion also has much to say in this respect. In any case, it is usually impossible to detect to what extent a given shape has been determined by the designer’s supply and to what extent by the buyer’s demand. We are faced here with circular processes in which causes become effects and effects causes and in which numerous instances of positive and negative feedback are at work: living organisms in biology or subsequent industrial products in the technical civilization are only tiny elements of these higher processes.

The preceding statement also reveals the genesis of the similarity between the two evolutions. Both are material processes with almost the same number of degrees of freedom and with similar dynamic laws. These processes take place in a self-organizing system —a term that applies to the Earth’s biosphere as a whole as much as it does to the totality of man’s technical activities. A system of this kind is characterized by the phenomenon of “progress,” that is, an increase in homeostatic capability, which has an ultrastable equilibrium as its direct goal.[5]

Drawing on examples from biology will also turn out to be useful and productive in our further deliberations. Alongside the similarities, these two types of evolution demonstrate some far-reaching differences, a thorough examination of which may reveal both the limitations and the deficiencies of that perfect Designer that Nature is supposed to be and the unexpected opportunities (as well as dangers) that the rapid development of technology poses in human hands. I say “in human hands” because technical evolution is not, for the time being at least, people-free; it only achieves its full being having been “complemented by mankind.” It is here perhaps that the biggest difference lies: bioevolution is beyond all doubt an amoral process, which is something we cannot say about technical evolution.

Differences

The first difference between our two evolutions is genetic and centers on the question of their driving forces. Nature is the “cause” of bioevolution, Man of technical evolution. An attempt to explain the “starting point” of bioevolution is still causing great difficulty. The problem of the origin of life occupies a significant place in our discussion, as solving it will need to involve more than just determining the causes of a given historical fact related to the Earth’s remote past. We are not so much concerned with the fact itself as with the consequences it still bears on any further development of technology. Its development has resulted in a situation in which any further progress will not be possible unless we gain accurate knowledge about extremely complex phenomena—phenomena as complex as life itself. This is not to say that we want to "imitate" a living cell. We do not imitate the mechanics of bird flight even if we do fly ourselves. It is not imitation that is at stake here but understanding. And it is this attempt to understand biogenesis "from the designer's point of view" that is causing such immense difficulties.

Traditional biology appeals to thermodynamics as a reliable arbiter. The latter declares the shift from greater to lesser complexity to be the norm. Yet the emergence of life was a reverse process. Even if we do accept as a general law the hypothesis regarding "a minimal complication threshold"—the crossing of which results in a material system not only maintaining its current organization despite external disturbances but even passing it on, unchanged, to the organisms of its descendants—this hypothesis does not explain anything on a genetic level. At some point an organism must have crossed this threshold for the first time. What is most significant here is whether this was as a result of a so-called accident or of causal necessity. In other words, was the "beginning" of life an exceptional event (like winning the lottery) or a typical one (like losing it)?

When talking about the spontaneous generation of life, biologists say that it must have been a gradual process, consisting of a number of stages, with each subsequent stage on the way to the emergence of the first cell having its own determined probability. The formation of amino acids in the primeval ocean as a result of electrical discharges was, for instance, quite probable, while the formation of peptides from them was a little less probable, yet it still had quite a good chance of taking place. The spontaneous synthesis of enzymes—those catalysts of life, the steersmen of its biochemical reactions—was, in turn, a rather unusual occurrence (even if it was necessary for the emergence of life). In an area ruled by probability, we are faced with statistical laws. Thermodynamics is actually one such law. From its point of view, the water in a pot placed over fire will boil, but this is not absolutely certain. There is a possibility of this water freezing over fire, even if the likelihood of this happening is astronomically low. The argument that even phenomena that seem most improbable from a thermodynamic point of view always eventually take place, as long as one waits for them patiently—and the evolution of life was "patient" enough, as it took billions of years—sounds convincing, provided we do not expose it to mathematical reasoning. Indeed, thermodynamics can swallow even the spontaneous formation of proteins in amino acid solutions, but it does not allow for the biogenesis of enzymes. If the whole of the Earth was an ocean of protein solution, if its radius was five times bigger than it actually is, it still would not have had enough mass for an accidental emergence of the kinds of highly specialized enzymes that are needed to engineer life. The number of all possible enzymes is higher than the number of stars in the whole Universe. If the proteins in the primeval ocean had had to wait for their spontaneous generation, this could have taken all eternity. And thus, to explain the emergence of a certain stage of biogenesis, we have to resort to postulating a highly improbable phenomenon: "winning the jackpot" in the previously mentioned cosmic lottery.

Let us be honest: if all of us, including the scientists, were intelligent robots and not flesh-and-bone creatures, then the number of scientists who would be willing to accept such a probabilistic version of the hypothesis about the origin of life could be counted on the fingers of one hand. The fact that the number of such scientists is higher does not so much result from the general conviction about the truthfulness of this hypothesis as from the simple fact that we are alive, which means that we ourselves represent a persuasive, albeit indirect, argument to support biogenesis. It is because two or even four billion years is enough to form a species and its evolution but not to form a living cell by means of repeated, blind "draws" from the statistical bag of all possibilities.

The issue presented in this way is not only improbable from the point of view of scientific methodology (which deals with typical phenomena, not accidental ones that border on unpredictability) but also announces a rather unequivocal verdict. It declares that any attempt to "engineer life," or even to "engineer very complex systems," is futile, given that the latter's emergence is determined by an exceptionally rare accident.

Luckily, this is a false approach. It is based on the fact that we only know two types of systems: very simple ones, such as the machines we have built so far, and extremely complex ones, such as all living beings. The lack of any intermediate links has led us to hold on too tightly to a thermodynamic explanation of phenomena, without taking into account the gradual emergence of systemic laws in systems aiming to achieve equilibrium. If the situation is as constricted as it is in the example of the clock—where equilibrium amounts to the stopping of its pendulum—we do not have enough material to extrapolate to systems with multiple dynamic possibilities, such as a planet on which biogenesis is starting to take place or a laboratory in which scientists are constructing self-organizing systems.

Such systems, still relatively simple today, are the indirect links for which we have been looking. Their emergence, for example, in the form of living organisms, is no "jackpot in the lottery of accidents." It is rather a manifestation of the necessary states of dynamic equilibrium within systems featuring many different elements and tendencies. And thus the process of self-organization is not unique but rather typical, while the emergence of life is only one possible enactment of the process of homeostatic organization, which is widespread in the Universe. This process does not disturb in any way the thermodynamic equilibrium in the Universe, as this equilibrium is global, allowing as it does for the occurrence of many phenomena—such as, for example, the formation of heavier (and thus more complex) elements from lighter (and thus simpler) ones.

And thus a Monte Carlo–type hypothesis of the cosmic roulette—which is a naïve methodological extension of thinking based on the knowledge of extremely simple mechanisms—is replaced by a theory of "cosmic panevolutionism." The latter transforms us from beings condemned to wait passively for an arrival of some extremely rare circumstances into designers capable of making choices from among the staggering overabundance of possibilities. Those possibilities are contained in the so far rather general instructions for building self-organizing systems of ever increasing degrees of complexity.

What the frequency of the cosmic occurrence of these "parabiological evolutions" postulated previously is, and whether they actually culminate in the emergence of what our human understanding calls "psyche," is a different matter. But this is a subject for a separate discussion, one that would require us to draw on an extensive assembly of facts from the field of astrophysical observation.

Nature, the Great Designer, has been conducting its experiments for billions of years, developing from the once obtained material (although this point is still debatable) everything that is possible. Spying on its tireless activity, man as the son of Mother Nature and Father Chance has been wondering for centuries about the meaning of this deadly serious game, in all its finality. This is certainly a pointless activity if he is to continue asking this question forever. It will be a different story, though, as soon as he starts answering the question himself, taking over Nature's convoluted secrets and initiating Technical Evolution in his own image.

The second difference between the two evolutions under discussion concerns methodology, that is, the "how" question. Biological evolution can be divided into two stages. The first one covers the period from the "start" from inanimate matter to the emergence of living cells—which became clearly demarcated from their surroundings. While we are quite familiar with the laws and general behavior of evolution during its second stage—that of the emergence of the species—as well as with the many specific paths it took, we cannot really say anything certain about its initial phase. This initial stage remained underappreciated for a long time, both for its scope and for the range of phenomena that had taken place during it. Today we can estimate that it lasted for at least half of the total evolutionary time, that is, around two billion years, yet some experts still complain about its short duration. Importantly, it is then that the cell as an elementary building block of biological material emerged, manifesting the same core structure both in the trilobite from a billion years ago and in chamomile, the hydra, the crocodile, and the human being of today. The universality of this building material is most astonishing and in fact rather hard to comprehend. The cells of the paramecium, of the mammalian muscle, of the plant leaf, of the snail's lymph glands, and of the abdominal gland of an insect all have the same basic components that a nucleus has —with its mechanism that allows for the transfer of hereditary information, which has been perfected on a molecular level—and also that the enzymatic system of mitochondria and the Golgi apparatus have. Every one of such cells contains the potential for dynamic homeostasis, for selective specialization, and also for the hierarchical construction of multicellular organisms. One of the fundamental laws of bioevolution is the short-term planning of its activities, since every change directly services current adaptive needs. Evolution cannot enact the kinds of changes that would only work as a preparatory introduction for the changes that are to take place in millions of years. It does not "know" anything about what is going to happen in millions of years since it is a blind designer, working by "trial and error." Unlike an engineer, it cannot "stop" the faulty machine of life to embark on its radical redesign, having reconsidered its design principles.

This is why we are so astonished and shocked by its "original foresight," which it showed during the prologue to the multiact drama of the species, when it created the building material so versatile and malleable that it is unlike any other. Since, as we said earlier, evolution is incapable of carrying out any sudden radical reconstructions, all of its hereditary mechanisms—its ultrastability, together with the accidental element of mutation (without which there would be no change, and hence no development) that interferes with this ultrastability, the division of the sexes, reproductive potential, and even those characteristics of the living tissue that manifest themselves most clearly in the central nervous system—all of these had already been inserted, we may say, into the Archeozoic cell billions of years ago. This kind of completely different. Figuratively speaking, Nature had to presuppose in its biological building material all the potentialities that were to be actualized much later. Man, in turn, tended to initiate his technologies and then abandon them to move on to some new ones. Being relatively free with regard to his choice of building material, having at his disposal high and low temperatures; metals and minerals; gases, solids, and liquids, he was seemingly capable of achieving more than Evolution did. Evolution was always limited to what had been given to it—tepid water solutions, gluey multiparticle substances, a relatively limited number of elements that appeared in the Archeozoic seas and oceans—but it squeezed out absolutely everything that was possible from such a limited starter kit. Ultimately, for the time being, the "technology" of living matter is head and shoulders above our human engineering—which is being supported by all the resources of socially acquired theoretical knowledge.

In other words, the universality of our technologies is minimal. Technical evolution has so far been moving in a kind of reverse direction to biological evolution in that it has only been creating narrowly specialized devices. The human hand was a model for the majority of tools, yet each time it was only one of its movements or gestures—finger clenching, one straight finger revolving around a longitudinal axis thanks to the movements in the wrist and elbow joints, a fist—that was respectively imitated by the pliers, drill, and hammer. So-called universal machine tools are in fact rather highly specialized. Even automated factories—the construction of which is only just starting to take

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working of bioevolution, whose billion-year-long empirical practices, that is, its "false solutions" to the problem of preserving life posed by the new conditions, claimed hecatombs of victims. The essence of technology's "empirical era" lay not so much in its lack of theoretical solutions as in the derivative character of those solutions. First we had the steam engine, then thermodynamics, just as first we had the airplane and then flight theory, or just as we first built bridges and then learned how to make calculations for them. We could risk saying that technological empiricism develops as far as it can. Edison tried to invent something like an "atomic engine," but this did not—and could not—come to much because, whereas a dynamo can be built through trial and error, an atomic reactor cannot.

Technological empiricism does not naturally mean blindly tossing from one badly thought-out experiment to another. The empiricist inventor usually has an idea, or rather—thanks to what he has already achieved (or what others had achieved before him)—he can see a short stretch of the road ahead of him. The sequence of his actions is regulated by negative feedback (the failure of an experiment explains every time that this is the wrong way). As a result, the road he takes is like a zigzag, but it is certainly going somewhere and has a definite direction. Gaining theoretical knowledge allows for a sudden leap ahead. During the Second World War, the Germans did not have a theory of supersonic rockets' ballistic flight. They derived the shape of their V2 from multiple empirical trials (conducted on reductionist models in an aerodynamic

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