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Man and Information in the Mirror of Science: Past, Present, and Future

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Abstract—Modern science highlights the role of information in the origins and life of man. The information revolution of the 20th century has become a crucial factor in the development of society. The aggravation of global problems of civilization compels mankind to pursue the path of sustainable development. The only possible way out of crisis is a noospheric strategy of the world community. This strategy builds upon the achievements of informatics and cutting-edge information technology.

Keywords: nature of man, information, society, socialization, information revolution, global problems, noospheric strategy, informatics

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INTRODUCTION

Among the recently published books about man, I want to draw the reader's attention to two works, which were published in different countries and diverge greatly in content. The first one came from the pen of an outstanding biologist, Nobel Prize winner Ilya Mechnikov (Élie Metchnikoff) (1845–1916): it is his well-known book *The Nature of Man* [1]. The second one was written by the modern Israeli historian of world culture Yuval Noah Harari, and his work: *Sapiens: A Brief History of Humankind*, was the number one best-selling book according to *The New York Times* [2].

The historical span between these two monographs is approximately 1 century: Mechnikov's book was first published in 1903; the last edition during the author's lifetime (the fifth one) is dated 1915; Harari's book was originally published in Israel in 2011. Thus, chronologically these works are separated by a century, and what century: the dynamic, even tempestuous 20th one...

The two books share a common object of analysis, i.e., man, his nature and essence, the meaning of existence of mankind on the Earth, and the possible prospects of humanity.

In understanding the origin and nature of man, both authors stand firmly on scientific ground (for instance, they highly appreciated the teachings of Charles Darwin and recognize the fundamental importance of his theory of evolution of biological species), which is understandable: they are both scientists. It is science with its proven facts (rather than religion, mysticism, or any other version of esotericism) that provides solid ground for their reasoning and conclusions. It is telling that Mechnikov ends his book with the following words:

"If there can be formed an ideal that is able to unite men into a kind of religion of the future, this ideal must be founded on scientific principles. And if it is true, as has been asserted so often, that man can live by faith alone, the faith must be in the power of science" [1, p. 316].

Harari's book too abounds in evidence that its author always relies on scientific facts: it is no coincidence that today, as he notes (although on a different topic), "everything depends on the people in the labs" [2, p. 395].

Another quality that the two books have in common is that their authors not only analyze the past and present of man but also make predictions about the future of mankind.

However, there is one aspect in which these books essentially diverge, and I admit that my attention was drawn, first and foremost, to this very aspect: information. While Harari makes numerous mentions of the concept of information (which is by no means a tribute to fashion, as we will soon see below), Mechnikov does not write about information even once. This is what a time of 100 years between two books written by scientists can do. The 20th century has passed...

THE NATURE OF MAN IN THE CONTEXT OF HIS ORIGIN

Some time ago, driven by logic, science arrived, step by step, at a conclusion that humans appeared in nature in the course of evolution from simpler (in

terms of life manifestations and functions) living beings. In this respect, Darwinism is known to have played a crucial role (despite all the existing criticisms).

—One often tends to reduce a dispute with Darwin's teaching to the question: Did man descend from apes or not? Many people are still, and were even more so at the time of Darwin, outraged at the very possibility of having a hairy parody of man as an ancestor. However, Darwin did not assert that man descended from apes. He wrote that apes were the closest relatives of our distant ancestors. All attempts to refute this idea by scientific methods have failed. On the contrary, new data collected by geneticists keep coming to support it [3, p. 6].

This last idea matters not only today (e.g., in the context of development of genetics); this view manifested itself long ago. Relying on Darwin's theory, Mechnikov summarized the current understanding, in the early 20th century, of the origin of man:

—Putting the known facts together, we may infer that man is a case of the arrested development of some simian of ancient days, as it were, a simian monster from the zoological point of view, although not from the aesthetic one. Man may be regarded as a prodigy sprung from an ape, born with a larger brain and an intelligence more highly developed than occurred in his parents... It must be admitted that certain kinds of organisms, instead of evolving at a very slow pace, spring up suddenly, and that in such a case nature proceeds with a considerable pace. Darwin foresaw this possibility, but it has been made plain to us by the remarkable studies of the botanist Hugo de Vries [1, p. 80].

As seen from Mechnikov's text, by "some simian" (the possible parent of the unusual child), the scientist meant a chimpanzee, gorilla, or orangutan.

A little further below we read:

"Some anthropoid ape, having at a certain period become varied in specific characters, produced offspring endowed with new properties. The brain, of abnormal size, placed in a spacious cranium, allowed the rapid development of intellectual faculties much more advanced than those of the parent and those of the original species. This peculiarity would be transmitted to the descendants, and, as it was of very considerable advantage in the struggle for existence, the new race would hold its own, propagate, and prevail." [1, p. 81].

Harari drew, ironic in form but scientific in meaning, a similar picture of the origin of man. After explaining the biological concepts of species, genus, and family and giving examples of families in the animal kingdom, he wrote:

"*Homo sapiens*, too, belongs to a family. This banal fact used to be one of history's most closely guarded secrets. *Homo sapiens* long preferred to view itself as set apart from animals, an orphan bereft of family, lacking siblings or cousins, and, most importantly, without parents. However, that's just not the case. Like it or not, we are members of a large and particularly noisy family called the great apes. Our closest living relatives include chimpanzees, gorillas, and orangutans. The chimpanzees are the closest. Just 6 million years ago, a single female ape had two daughters. One became the ancestor of all chimpanzees, the other is our own grandmother" [2].

Despite the ironic form, the last phrase too has an utterly scientific meaning if one recalls genetic mutations in the animate world: biologists define mutation as a sudden inherited change in a certain attribute or property of an organism.

Fairly convincing (and no less witty) are the facts presented by Harari to explain and support his thesis about our "brothers and sisters," i.e., other species of the genus *Homo* [2]. Of these, the best known are Neanderthals, but science also has evidence of the existence of Upright Man, Man from the Solo Valley, Man from Lake Rudolfo, and, finally, Denisovan Man, whose remnants were found in 2010 during excavations in Denisova Cave in Siberia. All these sibling species were wiped out from life and history by *Homo sapiens* (Wise Man) in the course of interspecies competition. Now, it is clear why the author gave a telling title to the small section about our siblings: "Skeletons in the Cupboard"...

The purely natural origin of man from the animal world suggests that his own body is also natural (i.e., not supernatural), being based on the body of the parental species. As noted by Mechnikov, for a long time in world culture, "human nature was regarded as being composed of two hostile elements, a body and a soul. The soul alone was to be honoured, while the body was regarded as the vile source of evils" [1, p. 37]. However, it is not surprising that this eminent biologist, physiologist, and physician focused his attention on the role of human body.

The position of the author of *The Nature of Man* regarding the core questions of anthropology is defined by his understanding of the unity of two opposing tendencies: harmonies and disharmonies, in all living organisms. On the one hand, "harmonies in nature are constantly met with in the world of living beings" [1, p. 55]. On the other hand, the opposite phenomena are equally important, i.e., disharmonies, which are, however, entirely meaningless in the life of both individuals and biological species as a whole (disharmonies are often associated with morphological vestiges): "Rudimentary and useless organs are widely distributed, and we find them in many places. Familiar instances are the atrophied eyes of animals that live in the dark and the sometimes rudimentary sexual organs of many plants and animals" [1, p. 56]. The human body is also known to have rudimentary organs.

In his study of man, Mechnikov scrutinized disharmonies in the organization of the digestive system, in the organization and activities of the reproductive apparatus, in the family and social instincts, and even in the instinct of self-preservation (here he analyzes such phenomena as old age, fear of death, and suicide). The scientist comes to the conclusion that "our strong will to live is opposed to the infirmities of age and the shortness of life. Here lies the greatest disharmony in the constitution of man" [1, p. 267]. Another crucial thought: "...man must not be content with the gifts of nature; he must direct them by his own efforts. Just as he has been able to modify the nature of animals and plants, man must attempt to modify his own constitution, so as to readjust its disharmonies" [1, p. 316]. Strictly speaking, this readjustment has been under way for a long time (suffice it to recall spectacles, hearing aids, prostheses, etc.).

Of course, not all his conclusions, which date back 100 years, remain valid today. A classic example is how science treats the appendix (the vermiform appendage of the human caecum). Here, Mechnikov holds a strong opinion (which appears to have been popular in other epochs as well):

"Appendicitis is usually a grave disease, and is fatal in from 8 to 10% of cases. It would be difficult to find anywhere else in the human body so flagrant a case of natural disharmony. The organ in question may be obliterated or removed without disturbance of function, and, moreover, in its normal condition is a frequent cause of serious illness [1, p. 92]."

However, modern American physicians share a different point of view, treating the appendix, not as a rudiment of our animal origins and a harmful "accumulator of inflammation," but as an integral element of body's immune system, involved in maintaining normal homeostasis. Similarly, modern researchers reveal the pertinence of other "superfluous" human organs, such as glands, adenoids, spleen, and even the coccyx (which was considered until recently nothing but "simian heritage").

Clearly, the human body did change over time and the more time that elapsed, the greater those changes were. A major change with a profound impact on the further development of man was upright walking (i.e., the freeing of the forelimbs, which man was then able to use not only for movement but also for other activities). It was this change that gave man the ability to work with his enormous potential of transformation.

However, an even more crucial thrust that spurred the development from animal ancestors to humans came from an abrupt change in the volume (and then the associative capacity) of the brain. Mechnikov wrote:

"Man, who is a descendant of some anthropoid ape, has inherited a constitution adapted to an environment very different from that which now surrounds him. Man has a brain very much more highly developed than that of his ancestors and has entered on a new path in the evolution of higher organisms. The sudden change in his natural conditions has brought about a large series of organic disharmonies that become more and more acutely felt as he becomes more intelligent and more sensitive [1, p. 300]."

Harari gave clear quantitative characteristics of this biological revolution.

"Despite their many differences, all human species share several defining characteristics. Most notably, humans have extraordinarily large brains compared to other animals. Mammals that weigh 60 kilograms have an average brain size of 200 cubic centimeters. The earliest men and women, 2.5 million years ago, had brains of about 600 cubic centimeters. Modern *Sapiens* have a brain averaging 1200–1400 cubic centimeters. Neanderthal brains were even bigger... The fact is that a jumbo brain is a jumbo drain on the body. It's not easy to carry around, especially when encased inside a massive skull. It's even harder to fuel. In *Homo sapiens*, the brain accounts for about 2–3% of total body weight, but it consumes 25% of the body's energy when the body is at rest. By comparison, the brains of other apes require only 8% of rest-time energy. Archaic humans paid for their large brains in two ways. First, they spent more time in search of food. Secondly, their muscles atrophied" [2].

However, it was the brain that made the progress of human civilization possible.

Modern science pays huge attention to human brains. The world renowned Dutch neuroscientist Dick Swaab, who was director of the Netherlands Institute for Brain Research of the Royal Netherlands Academy of Sciences for more than a quarter of a century (1978–2005), actually proved that "we are our brains" [4]: all life and social manifestations without exception, all aspects of man are most closely tied to his brain. Ultimately, the functioning of the brain defines the content of human's consciousness, creates its inner world and its "I," the quintessence of its personality. Thus, it is the brain that most directly affect the changes in the nature of man: from purely animal-like in our ancestors to biopsychosocial today.

INFORMATION AS A FACTOR THAT DISTINGUISHED MAN FROM WILDLIFE

The brain in animate nature is certainly not an end in itself. The brain forms and develops in the organisms of living beings to optimize the gathering, processing, and use of vital information so that its carriers could better survive in the environment. Figuratively speaking, the brain is the central headquarters of the nervous system, i.e., a system of cells that specialize in the information aspect of life support.

—The brain is built from nerve cells called neurons. Weighing around 3 pounds, the brain contains 100 billion neurons (fifteen times the number of peo-

ple on earth). The neurons are outnumbered ten to one by glial cells. It was formerly thought that these were only present to hold neurons together (*glia* comes from the Greek word for "glue"). However, recent studies have shown that these cells, which humans possess more of than any other organism, are crucial to the transfer of chemical messages and therefore to all brain processes, including the formation of long-term memory. This sheds interesting light on the finding that Einstein's brain contained an unusually large number glial cells [4].

Of course, the secrets of genius are not the issue; here we are talking about the distant era when man came apart from nature, when the newly born mankind had as yet innumerable stages to go through before it produced Einstein... The most noteworthy point in the thinking of the modern scientist is as follows: it is not only that human brains have a record number of neurons that matters. This fact itself has long been known, but it is now reinforced by a recent discovery that the brain has an order of magnitude greater number of other cells, serving a different purpose, i.e., the glial cells (humans have more of these cells than other living creatures); these cells play a decisive role in all brain processes because the chemical transmission of information hinges on them.

Evidently, the deep underlying causes that set humans apart from nature and defined their special role on our planet belong, to a large extent, to the domain of information: due to certain conditions and natural factors, this species proved to be capable of using information for its own benefit much more efficiently than the other species. Moreover, much later (in the 20th century) we came to see the fundamental importance of information in animate nature as a holistic entity [5–10, pp. 88–96]: information is the key to the modern understanding of life itself and the fundamental difference between animate and inanimate matter. At the same time, modern science attaches particular importance to the distinction between the information level of humans and of everything that existed in nature before them.

Harari emphasized that approximately 70000 years ago *Homo sapiens* became the subject of a cognitive revolution. This revolution was primarily associated with the creation of a very flexible language that differed fundamentally from all other languages in the animal world because this information system allowed humans to create from a limited number of signals, that is, sounds and signs, an unlimited number of phrases, serving as shells for thoughts and judgments. Thus, humans developed not only a qualitatively different language, incomparably richer than those of all other animals, *Homo sapiens* developed a new type of thinking and cognition, different from higher animals, which think in concrete images. (Before humans the latter type of thinking was the top achievement of nature in the cognitive sphere).

It was this new type of thinking together with the qualitatively new language that became the logical basis of human consciousness, which gradually began to create the inner world of human beings, i.e., their personal content. There is no doubt that this change was indeed a cognitive revolution.

Thus, "our unique language evolved as a means of sharing information about the world. However, the most important information that needed to be conveyed was about humans... *Homo sapiens* is primarily a social animal. Social cooperation is our key for survival and reproduction" [2]. Accordingly, in human society, information has long been the main means of *socialization* of each individual, i.e., filling his or her consciousness with social content and transforming a human child not simply into an adult but into a member of society. Exceptions from this general law are extremely rare (although they do occur). Naturally, nothing like that could ever happen in the animal world: an animal's offspring always grows into a member of a purely biological community (flock, pack, etc.) and this is still the case with primates of the same genus as humans.

The foundations of social order are rooted in the appearance and historical existence of specific information forms created and systematically used by humans. Among these, Harari places emphasis on myths.

"Any large-scale human cooperation, whether a modern state, a medieval church, an ancient city or an archaic tribe, is rooted in common myths that exist only in peoples collective imagination. Churches are rooted in common religious myths... States are rooted in common national myths... Two lawyers who have never met can nevertheless combine efforts to defend a complete stranger because they both believe in the existence of laws, justice, human rights, and the money paid in fees... People easily understand that "primitives" cement their social order by believing in ghosts and spirits, and gathering each full moon to dance together around the campfire. What we fail to appreciate is that our modern institutions function on exactly the same basis [2]."

Of course, one can argue here with the author of this fascinating book about the relationship between the strictly subjective beliefs and the objective content of the various historical forms of social community. After all, it is known that in the history of culture, myths were followed (and, sometimes, paralleled) by doctrines, concepts, and theories, which emerged as essentially different forms of understanding the foundation of sociality. Nevertheless, at the heart of all these forms also lie cognitive–linguistic, i.e., essentially information-related, principles.

The development of all possible units of society and the accelerating socialization of humans gave rise, over time, to the spiritual life of society and to spirituality of people as a qualitatively new characteristic of living

beings. Here, I want to emphasize that all manifestations of spirituality: religion, morality, art, philosophy, or science, are immanently connected with human thinking (notably, with developed cognitive forms characterized by abstract thinking) and, undoubtedly, have an informational form. It is natural that man is connected in multiple ways with all types of information known in science [11, 12]. Much later, in the 20th century, this circumstance paved the way for an information analysis of life and animate nature on the Earth.

Being unique in nature on our planet, the phenomenon of spirituality quickly revealed an internal capacity for self-development, leading to an ongoing increase in the number of information varieties of spirituality. Following this path, social information has long been a complex system that lies at the core of development and improvement of society [13]. The cognitive revolution, which set the stage for social information, was, according to Harari, that turning point in the development of our distant ancestors when biology gave way to history. Since that period, man marched into the era of culture with all its diverse information channels, and tools.

Clearly, it is information that lies at the core of the major qualitative leaps in the world around us. Historically, the first (and the most radical) one of these leaps was the transition from inanimate to animate matter.

Here, I should stress that the functional–cybernetic concept of information sees the very appearance of this phenomenon (genesis of information) in the origin of the simplest living organisms that are capable of self-governance to increase the chances of survival in the environment. Given this interpretation, information appeared alongside life and represents a functional property of a special class of highly organized systems, i.e., living organisms, human society, and the technology that humans use for management and organization [10, p. 15]. Many scientists, however, share a different, attributive, concept, which treats information as an attribute of all matter, including inanimate matter [14, 15]. Nonetheless, the advocates of this extremely broad understanding of informational manifestations of matter recognize the essential distinction between animate and inanimate nature, with this distinction manifesting itself, in no small part, in the information aspect.

After this first leap, which created animate nature, there were many others that embodied the informational sophistication and improvement of organisms: the emergence of nerve cells (which specialize in informational reflection of the world), the nervous system, then the central nervous system and the brain as its headquarters for information processing and use, the emergence of mammals, primates, and, finally, humans. In this series of qualitative leaps, the formation of human society, culture, socialization, and spirituality are particularly noteworthy.

Today, a long time has passed since humans made their first steps on the path from biology to history (here, I prefer to use Harari's witty visual metaphor). The entire history of world civilization shows a steady progress in the information content of culture, both material and spiritual.

THE UNIQUE ROLE OF THE MODERN INFORMATION REVOLUTION IN THE DEVELOPMENT OF MANKIND

In many respects, the 20th century was, due to its special social dynamics, a remarkable period of rapid change in the life of society. It is no coincidence that in the second half of this century, Abraham Moles published his book *Sociodynamics of Culture* [16]: in those decades, this essential characteristic of social life of man manifested itself most vividly.

The revolution in science and technology (RST), which began in the 1940s, has been a major event of our time [17–20]. This revolution continues to expand and deepen to this day and keeps surprising mankind with new achievements. The impact of this revolution on the development of world civilization is truly inexhaustible and today we can hardly foresee all its implications. One of the most important and fruitful achievements of the RST has been the information revolution, also called the computer, or microprocessor, revolution [21]. It is the latter that is most closely associated with the latest, technological, stage in the RST.

The 20th century highlighted, for the first time in the history of civilization, the special role of information in the life of man and society. However, this is not what matters most. Having the latest technology at hand, the RST has opened effective ways to optimize the forms and properties of any and all information phenomena for the best use of the huge information flows in society.

For a long time, people could only store information in one place, i.e., in their brains. Harari gives three reasons that this ancient method of storing information is so imperfect: first, the brain's capacity is limited; "secondly, humans die, and their brains die with them," which is the reason that "any information stored in a brain will be erased in less than a century"; and, "thirdly and most importantly, the human brain has been adapted to store and process only particular types of information" that prevail in society [2]. To overcome these shortcomings of the primitive epoch, humans invented numbers and counting systems, writing, book printing, libraries and specialized information storages, as well as artistic and other ways to expand their information interactions with the environment. The entire history of human civilization and the development of culture correlates tightly with the evolution of ways to store and use information. How-

ever, none of the centuries before the 20th century compares with the latter in this respect.

The societal sphere that gave rise to the information revolution and facilitates its continuous deepening is, undoubtedly, world science. The relevant impulses appeared simultaneously in different fields of scientific knowledge. On the one hand, information theory and cybernetics vigorously promoted both the concept of information and the various information representations in the interpretation of phenomena, i.e., the development of an information approach in the understanding of reality as an unconventional phenomenon in the general scientific methodology [10, pp. 71–161]. On the other hand, it was science that experienced an information explosion during those same decades, when the number of scientific publications necessary for the work of scientists sharply exceeded the psychophysiological capabilities of a person, giving rise to such fields of knowledge as informatics (the theory of scientific information) and science studies [22–24]. Substantial progress has been achieved in understanding brain information processes, consciousness, thinking, cognition, etc., as well as their technical simulations [25, 26]. A qualitative leap in the development of electronic computers then occurred.

The information revolution reached its microprocessor stage in the 1970s, when man devised a universal control device based on a microminiature silicon crystal. This invention spurred the development of large and very large integrated circuits, paving the way for fundamentally new generations of computers [27–29]. However, more than that occurred. The widespread implementation of integrated circuits in technological equipment in all economic industries and the use of various intelligent terminals [30] for other, nonindustrial activities of man opened the path for the newest information technology in virtually all areas of society.

During the last few centuries in the history of the species *Homo sapiens*, a crucial contribution to social development has come from book printing and the accumulation of books in the various fields of culture. In this context, the world-known metaphor devised by the Canadian philosopher, sociologist, and culturologist Marshall McLuhan, that is, the Gutenberg galaxy is noteworthy [31]. Computer scientists have long emphasized the particularly rapid distribution of books (and other, derivative types of printed publications) precisely in the 20th century [22, pp. 83–108]. This spread of books presented a notable manifestation of the information revolution. On the other hand, the various aspects of books tangibly affect the progress of modern printing technology [32] and, hence, the material culture, as well as the spiritual life, of society. In this respect, constantly amplifying impulses of interconnection and mutual influence exist.

The persistent and lasting RST, which has continued for more than half a century and still demonstrates an enviable resource of transforming energy, has given rise to the special status of science: as a revolutionizing force, and, hence, a respectful attitude towards it. This attitude is often projected onto the people of science, or scientists. Apart from purely social reasons, there are other explanations, including those related to neurophysiology. As noted by Swaab:

"...two factors determine our lifespan: metabolism and brain size. The higher the metabolism, the shorter the lifespan. This ties in with the finding that top athletes at Harvard have shorter lifespans than their nonathletic classmates... A single organ, the brain, also affects length of life: The larger and more active it is, the longer your lifespan... Eminent scientists are said to have larger brains and to live longer [4].

This complex of facts is, of course, immanently linked to the information aspect of social development.

Naturally, the RST markedly enhanced the role and significance of the technical and technological component of scientific knowledge, including its semantic connection with the purely scientific fragments of theory and experiment as well as the entire system of scientific methodology. Clearly, the deepening of the information revolution (especially its microprocessor and computer aspects) caused the formation of complex scientific and technical disciplines in this field [33, 34]. These new branches of theory integrate organically, on the one hand, into the common array of technical knowledge and, on the other hand, into the currently crucial complex of information sciences. After all, in terms of science and methodology, an essential feature of the information revolution is the development of interrelated special disciplines that study information. The latter include, e.g., the widely known information theory, cybernetics, and informatics, as well as the presently hypothetical informology (an integrative, generalizing science in this field), which is yet to be developed [10, pp. 151–161]. Moreover, social practice gives birth to ever more completely new branches in this field, as exemplified by the science of the information economy [35].

A deep understanding of what occurs in the body of modern science is very indicative and crucial for understanding the nature of the very phenomenon of the information revolution: after all, scientific cognition always remains one of the fundamental, essential areas of information development in society. In other words, without this understanding, we would not see the complete picture of the functions and role of the information revolution in the global community.

However, we should also bear in mind the existence of many notable important manifestations of the information revolution in society beyond scientific cognition. By the way, one of these manifestations was mentioned above (although indirectly, through the

prism of its scientific study): since the information economy is referred to as a new branch of science, this means that society already has an actual object of research for the new discipline. In other words, in the reality of today (in the form of ontological phenomena), both the information sector and its economy do exist in society. It goes without saying that both these phenomena are highly important for the semantics of the concept of the information revolution.

It is also telling that this RST aspect routinely manifests itself in people's everyday life. A computer and a microcalculator at work, at school, at home; an Internet browser, a mobile phone, a digital camera, an ATM and electronic payments in shops; an e-book, an e-ticket, e-offices at universities, distance learning, electronic medical technology, etc.: today, information technology embraces literally all spheres of social life. Tomorrow holds even more promise...

It should be noted that not all the outcomes and impacts of the information revolution have been beneficial for people. In the 1960s, scientists came up with the term *information diseases,* by which they meant, primarily, the neuroses caused either by a deficit of information or, on the contrary, its overabundance in society, leading to an information overload on the psyche [10, pp. 102–103]. Apparently, all mental illnesses contain a tangible information component. Today, e.g., we need to investigate the role of information factors in the development of depression (the number of patients with depression is increasing constantly; today, there are more than 300 million such patients worldwide and each year about 800000 commit suicide). Another socially hazardous phenomenon is cybercrime: experts believe that every day (!) cybercriminals worldwide write thousands of harmful programs. Recent decades have seen an increase in the deliberate spread of computer viruses that affect large segments of Internet users. The cyberattacks inflicted by hackers cause great damage to the information security of society. The future is threatened by the growing amounts and varieties of adverse effects of information technology; one should consider these effects in an overall assessment of the social role of the information revolution.

Harari presented many interesting and revealing facts about the past and present of mankind in his book, on the one hand, and considerations about its future, on the other hand. All these facts and considerations are in one way or another related to information and its role in society. Here are a few examples.

—Before the industrialisation of agriculture, most of the food produced in fields and farms was "wasted" feeding peasants and farmyard animals. Only a small percentage was available to feed artisans, teachers, priests, and bureaucrats. Consequently, in almost all societies peasants comprised more than 90% of the population... Today in the United States, only 2% of the population makes a living from agriculture, yet this 2% produces enough not only to feed the entire American population, but also to export surpluses to the rest of the world [2].

—The Internet, for example, came into wide usage only in the early 1990s, hardly 20 years ago. Today, we cannot imagine the world without it [2].

Now, a few words about the future (which is intertwined with the real achievements of modern science).

—It's unclear whether bioengineering could really resurrect the Neanderthals, but it would very likely bring down the curtain on *Homo sapiens*. Tinkering with our genes won't necessarily kill us. However, we might tinker with Homo sapiens to such an extent that we would no longer be *Homo sapiens* [2].

—There is another new technology that could change the laws of life: cyborg engineering. Cyborgs are beings that combine organic and inorganic parts, such as a human with bionic hands. In a sense, nearly all of us are bionic these days, since our natural senses and functions are supplemented by devices such as eyeglasses, pacemakers, orthotics, and even computers and mobile phones (which relieve our brains of some of their data storage and processing burdens). We stand poised on the brink of becoming true cyborgs, of having inorganic features that are inseparable from our bodies, features that modify our abilities, desires, personalities and identities [2].

—Of all the projects that are currently under development, the most revolutionary is the attempt to devise a direct two-way brain-computer interface that will allow computers to read the electrical signals of a human brain, simultaneously transmitting signals that the brain can read in turn. What if such interfaces are used to directly link a brain to the Internet, or to directly link several brains to each other, thereby creating a sort of Inter-brain-net? What might happen to human memory, human consciousness and human identity if the brain has direct access to a collective memory bank?... Such a cyborg would no longer be human, or even organic. It would be something completely different. It would be a so fundamentally different kind of being that we cannot even grasp the philosophical, psychological, or political implications [2].

The horizons of the information revolution are quite amazing!

THE GLOBAL ENVIRONMENTAL CRISIS: CAUSES AND SOLUTIONS

At all times, the relationship between man and the environment has been among the crucial aspects of the life of humans and society. Originally, man lived in a purely natural environment, which then became a natural–social one. However, the environment of man has not ceased to be natural: after all, human society itself exists in nature, being a manifestation and a natural development of the latter.

Long ago, our distant ancestors "were insignificant animals with no more impact on their environment than gorillas, fireflies, or jellyfish" [2]. The change occurred very quickly by the standards of nature; this change was associated with the position of man in the food chain, which rests on the principle of "who eats who" in nature (as known in classical ecology as trophic chains of different regions).

—Genus *Homo*'s position in the food chain was, until quite recently, solidly in the middle. For millions of years, humans hunted smaller creatures and gathered what they could, all the while being hunted by larger predators. It was only 400000 years ago that several species of humans began to hunt large game on a regular basis, and only in the last 100000 years, with the rise of *Homo sapiens,* that man jumped to the top of the food chain. That spectacular leap from the middle to the top had enormous consequences. Other animals at the top of the pyramid, such as lions and sharks, evolved into that position very gradually, over millions of years. This enabled the ecosystem to develop checks and balances that prevent lions and sharks from wreaking too much havoc. As lions became deadlier, gazelles evolved to run faster, hyenas to cooperate better, and rhinoceroses to be more ferocious. In contrast, humans ascended to the top so quickly that the ecosystem was not given time to adjust. Moreover, humans themselves failed to adjust. Most of the top predators of the planet are majestic creatures. Millions of years of dominion have filled them with self-confidence. *Sapiens* by contrast is more like a banana republic dictator. Having so recently been one of the underdogs of the savannah, we are full of fears and anxieties over our position, which makes us doubly cruel and dangerous. Many historical calamities, from deadly wars to ecological catastrophes, have resulted from this overly hasty jump [2].

A lot has been written about the current environmental crisis; here is another, ingenuous view of its underlying causes. Clearly, there is something to think about.

As repeatedly emphasized, this crisis, unlike the previous ones, is global in nature and is closely intertwined with other global problems of our time [36–38]. Of course, both these aspects follow from the nature of man, as Harari so brightly discusses.

How radically has the face of life on the planet changed during the domination of *Homo sapiens*?

—Today, the continents are home to almost 7 billion *Sapiens*. (There are many more of them today: E.S.) If you took all these people and put them on a large set of scales, their combined mass would be about 300 million tons. If you then took all our domesticated farmyard animals: cows, pigs, sheep and chickens, and placed them on an even larger set of scales, their mass would amount to about 700 million tons. In contrast, the combined mass of all surviving large wild animals, from porcupines and penguins to elephants and whales, is less than 100 million tons. Our children's books, our iconography and our TV screens are still full of giraffes, wolves, and chimpanzees, but the real world has very few of them left. There are about 80000 giraffes in the world, compared to 1.5 billion cattle; only 200000 wolves, compared to 400 million domesticated dogs; only 250000 chimpanzees, in contrast to billions of humans. Humankind really has taken over the world [2].

The origins of these tremendous changes are rooted in the lifestyle of man.

—The industrial revolution opened up new ways to convert energy and to produce goods, largely liberating humankind from its dependence on the surrounding ecosystem. Humans cut down forests, drained swamps, dammed rivers, flooded plains, laid down tens of thousands of kilometers of railroad tracks, and built skyscraping metropolises. As the world was molded to fit the needs of Homo sapiens, habitats were destroyed and species went extinct. Our once green and blue planet is becoming a concrete and plastic shopping center [2].

Unfortunately, man never knows when enough is enough...

How will people live in this antinatural world of concrete and plastic? We are now beginning to see the terrifying side of our progress, and this effect is accumulating...

—In fact, ecological turmoil might endanger the survival of *Homo sapiens* itself. Global warming, rising oceans and widespread pollution could make the earth less hospitable to our kind and the future might consequently see a spiralling race between human power and human-induced natural disasters. As humans use their power to counter the forces of nature and subjugate the ecosystem to their needs and whims, they may cause an increasing number of unanticipated and dangerous side effects. These are likely to be controllable only by even more drastic manipulations of the ecosystem, which would result in even worse chaos [2].

Today, we are beginning to see the terrifying imbalances in the various systems of nature; tomorrow these imbalances may present a fatal danger. Man has made irresponsible steps: I cannot put it better. Suffice it to recall the reckless, deadly experiments with nuclear, chemical, or biological weapons on the global arena of the planetary theater. It seems that mankind simply let the genie out of the bottle and observes it with fascination: How will it all end? However, it is crystal clear that nothing good will come out of these games.

Today, the global environmental crisis, coupled with global problems of a different nature, unfolds amidst the globalization on a planet torn apart by acute contradictions. What will the future of mankind look like on this risky stretch of the road?

I quote again from Harari's book.

"Many call this process "the destruction of nature". However, it's not really destruction, it's change. Nature cannot be destroyed. Sixty-five million years ago, an asteroid wiped out the dinosaurs, but in so doing opened the way forward for mammals. (It is on this path that man eventually appeared. –E.S.) Today, humankind is driving many species into extinction and might even annihilate itself. However, other organisms are doing quite well. Rats and cockroaches, for example, are in their heyday. These tenacious creatures would probably creep out from beneath the smoking rubble of a nuclear Armageddon, ready and able to spread their DNA. Perhaps 65 million years from now, intelligent rats will look back gratefully on the decimation wrought by humankind, just as we today can thank that dinosaur-busting asteroid" [2].

Yes, such a future may be awaiting our species...

To avoid these prospects, at the turn of the 20th and 21st centuries, scientists worldwide proposed a set of measures to be taken as an antidote against all crises in society, which materialize in the global problems (including, social and environmental ones). This agenda is known as the concept of sustainable development, as continuously enriched by the world community [39–42]. International forums are convened on a regular basis to discuss the intermediate results and clarify the tasks. The most important documents of the recent years include the *Sustainable Development Goals for 2030*, approved at a UN Summit, and the Paris Agreement on Climate Change (2015).

The environmental aspect of the global problems and, hence, sustainable development embraces the numerous disasters and problems associated with the increasing pollution of soil, water, and the atmosphere; the disappearance of rivers; the reduction of forest area; the desertification of lands; the continuous reduction of biodiversity; adverse climate changes; etc. Scientists have suggested a special agenda, within the framework of prevention of a catastrophe on the planet, aimed at drafting and implementing a global legislative act, i.e., an environmental constitution of the Earth [43, 44]. A consistent effort to make the economy and, more broadly, all aspects of society friendly to the environment is vitally important. At the same time, one should bear in mind the deep and multifaceted connection of all these processes with the progress of informatics [45, 46].

The aggravation of the global environmental crisis was caused by the deepening of the RST and the intensification of the consumer psychology in society. Today, both these trends continue in full force... Will mankind be able, in these conditions, to cope with environmental disasters and pave the way for sustainable development? As history shows, the world civilization of the future depends in large part on the current morality and philosophical perspective of society.

—Seventy thousand years ago, *Homo sapiens* was still an insignificant animal minding its own business in a corner of Africa. In the following millennia it transformed itself into the master of the entire planet and the terror of the ecosystem... Unfortunately, the Sapiens regime on earth has so far produced little that we can be proud of. We have mastered our surroundings, increased food production, built cities, established empires and created far-flung trade networks. However, did we decrease the amount of suffering in the world? [2].

Harari's explicitly negative answer to this question speaks volumes.

Summarizing this section, I want to stress one fundamental point related to the information nature of science as a form of public consciousness, which is especially important at the time of the RST. Among the basic information tools to overcome the current crisis, mankind must use the achievements of all fields of modern science, i.e., not only natural sciences, mathematics, engineering, and medicine but also all the knowledge accumulated in social sciences and humanities. The transdisciplinary interaction between the various fields of science to explore and address the critical sociocultural problems has become possible today due to the strengthening of scientific integration. I emphasize that the development of informatics [47] lies in that same methodological plane of scientific and technological progress.

THE NOOSPEHRIC STRATEGY FOR THE FUTURE OF MAN AND PLANET

The brain, which once distinguished our distant ancestor from nature, plays an important role as an organ of functioning and development of the mind. This understanding gives me the opportunity to touch on another important issue, i.e., the *noospheric strategy* of sustainable development (the *noosphere* is, as is known, the sphere of the mind).

This term was proposed in 1927 by Édouard Le Roy (as he stressed, the new concept was devised in cooperation with Pierre Teilhard de Chardin). However, his thinking was also greatly influenced by Vladimir Vernadsky's theory of the biosphere (a few years earlier Le Roy attended his lectures at the Sorbonne, at which Vernadsky argued that biogeochemical phenomena initiated the emergence of the biosphere). Vernadsky immediately picked up the new concept and began to use it much more vigorously than Le Roy and Teilhard. Consequently, it was Vernadsky who established the foundations of the noosphere concept [48–51]. However, his interpretation of the noosphere diverged substantially from the content invested in this concept by the two French scientists. All these developments occurred in the first half of the 20th century, long before global problems and sustainable development appeared on the agenda.

The turn of the millennia came amidst a fundamentally different situation in the world, and under these conditions, scientists who were familiar with Vernadsky's creative legacy could not help but recall his noosphere concept: it turned out that the agenda of sustainable development essentially coincided (at least in the main points) with the semantic characteristics of the sphere of the mind. This was how the noospheric strategy of sustainable development came into being [40, 52]. It is no exaggeration to say that the future of world civilization hinges on the implementation of this strategy.

Recently, the author of this article published a detailed review of Vernadsky's noosphere concept in *Scientific and Technical Information Processing* and, most importantly, of how this concept is readjusted in the modern world [51, pp. 6–8]. Of course, it makes no sense to repeat this material here, but in what follows, I largely rely on my recent publication.

Modern science is still far from a clear understanding of the noosphere. This path one interprets the sphere of the mind always depends on how one understands what the mind is. Below, I use this most important feature to distinguish between the different points view shared by scientists.

(1) The mind is understood as the human mind that arose in nature in the course of natural evolution. This understanding of the noosphere was shared by its pioneers: Le Roy and Teilhard de Chardin. However, was the origin of man and his mind a purely natural phenomenon? A more accurate interpretation is to combine natural manifestations with supernatural, deep causes. One can better understand this ambiguous point of view if one recalls that Teilhard, a world-renowned archeologist and paleoanthropologist, a member of archeological expeditions on different continents, and one of the discoverers of *Sinanthropus*, was also a Catholic theologian and a member of the Jesuit order; thus, it is no coincidence that his famous book about man contains a section on merging science and religion [53, pp. 222–223]. Nevertheless, scientific content definitely prevails in his book: the talented scientist draws a picture of the origin of man and his mind, consistent with the scientific views of the 20th century (Teilhard de Chardin died in 1955).

(2) Other scientists the mind of society put at the epicenter of the noosphere rather than of individual man, and the quintessence of this mind is science as an integral intellect of mankind. This is the concept proposed by Vernadsky. As he emphasized, it is science that makes mankind a geological force (because now man can transform nature).

(3) The same concept of universal intellect is readjusted to the new, modern era: the mind of mankind is fundamentally capable of solving global problems and maintaining the sustainable development of society; however, unfortunately, it will take a very long time and a lot of effort due to complicated conditions and prerequisites. This position is shared by Arkadii Ursul [40, 52] and the International Academy of the Noosphere (Sustainable Development), of which he is president.

(4) Other scientists deny the ability of the human mind to solve global problems due to the animal nature of humans, their greed, and fundamental insatiability, which will inevitably lead to the extinction of mankind. This interpretation of the noosphere is advocated by M.A. Bulatov and his associates [54]. Their point of view has already been criticized on the pages of *Scientific and Technical Information Processing* [50].

(5) The mind is not human at all but is attributed to all nature on the Earth (Gaia), or perhaps, to the supreme intelligence of the Creator, the divine environment of the Universum [3, pp. 256, 261, 316]. This exotic concept came from the pen of R.K. Balandin.

(6) In the future, a new version of the noosphere may be created by a different biological species (which will triumph over man in interspecific competition); this could be the mind... of rats. I think, the reader has guessed that this is one of Harari's witty hypotheses [2].

Clearly, I have listed here not all the possible interpretations because the world science of today is very diverse, and, as Kozma Prutkov said, "one cannot embrace the boundless." However, I believe that I have outlined the main approaches to understanding the essence of the mind and, hence, the noosphere. It is important that in any case, these issues are relevant to the information problem. The fact is that the information essence of the noosphere manifests itself in a variety of ways (since, by definition, the noosphere is always related to the mind, thinking, and cognition, i.e., to information).

Now, I would like to say a few words about my own perspective on the mind as the essence of the noosphere. Very briefly, I agree with point 3. The relevant arguments and clarifications can be found in my other publications.

Our time has made the problem of the noospheric future of man especially urgent and even acute. Here, I would like to quote the concise and evocative words written by the founder of the Club of Rome Aurelio Peccei:

—In my lifetime, the course of human history has decisively and suddenly changed. However, the plain fact is that, in the matter of few decades, a plurimillenial epoch of slow human development has ended and a new dynamic epoch begun. We are so stunned by the momentous events that marked this change that we wonder whether the new age will be glorious or terrible. In reality, it is *the human condition on Earth that has changed*. Man, from having been one of the many creatures on the planet, has now cast his uncontrolled empire over it [55, p. 63].

Exactly the same thing has been shown by Harari with extensive factual evidence.

As early as in the 1970s, Peccei formulated, in very clear terms, the main threat to world civilization:

—Now, for the first time, we must also consider a new factor that has forcefully entered human destiny: *man's own formidable and ever-growing material power.* It is a power that grows exponentially, for it grows by rapid accumulation year after year. It represents, however, a most questionable development, for it can be used either intelligently and with restraint for man's own good, or recklessly, towards his ultimate downfall [55, pp. 63, 64].

This is a very clear reminder that man should be reasonable...

At the same time, this outstanding humanist of the epoch of RST and aggravating global problems emphasized the importance of the socioecological aspect of further development on the planet. He wrote about the threat to most remaining higher species of plants and animals. Peccei believed that the destiny of man has never depended so much on his attitude to all living creatures on the Earth. In fact, by breaking the ecological balance and irreparably reducing the life-supporting capacity of the planet, humans themselves can wipe their own species as effectively as an atomic bomb [55]. However, in the overall analysis of the agenda of world civilization, Peccei neither absolutized nor isolated the knot of environmental problems, showing its inseparable ties to all the other aspects of global development. It should be noted that all the research work of the Club of Rome (and those areas in science that were inspired by its ideas) followed in this vein. In this context, I should emphasize that a complex, systematic understanding of the nature of global problems and, hence, the agenda of sustainable development is a very important methodological feature of the noospheric strategy, designed to lead mankind towards a better future [50].

To what extent are the noospheric ideas associated with humans? In other words, could another biological species that will wipe out mankind on Earth eventually become the center of this strategy?

In principle, one cannot rule out such a possibility: interspecific competition is known to be a crucial factor of evolution in the biosphere and the strongest species wins this game. However, one must be realistic about the comparative capabilities of different species. Today, the strongest weapons belong to the information domain, and here man apparently has no rivals on this planet. However, this outcome is still possible because humans may somehow destroy their own species (from a lack of mindfulness...). Given this tragic finale, the law of natural selection will lead the game, and, after a likely prolonged struggle, the strongest of the surviving species will come out as the winner. Then, the noosphere will certainly change its face.

Until this happens (hopefully, it never will), our species should try its best to survive on the Earth and take care of nature. In this context, it is clear why Ursul speaks about the inseparable unity of two principles that underlie the noospheric strategy of sustainable development: anthropocentrism and biosphere-centrism [40, pp. 147–148]. The public consciousness most often ties these two principles to two competing ethical orientations: anthropocentrism and ecocentrism. In fact, mankind needs both these vectors, which direct the semantics of the development of world civilization, because mankind takes a keen interest in the sustainable coevolution of society and nature. People will never forget about themselves (about their own life and interests), but they must also remember nature, its integrity and safety. The planet on which humans live cannot be "of no importance" to them: we cannot separate our future from that of our planet.

The noospheric future of mankind lies very far ahead. Academician Vernadsky, who believed this future was much nearer, was overly optimistic. Today, virtually everyone agrees that given the current level of public consciousness, we cannot even dream of a near noospheric future. However, as Peccei said, the glorious time of mankind lies inevitably ahead unless... a catastrophe comes first in which humans themselves destroy their future.

CONCLUSIONS

The fact that *Homo sapiens* was once set apart from all other living beings because of its brain (i.e., mind) not only gave a name to our biological species but also became a semantic dominant throughout the development of this species. It was man who contrived a qualitatively new language and logical thinking, devised a social organization of life on the planet, and discovered the mechanisms of socialization of individuals and the secrets of spirituality. The grand achievements of mankind are the creation of world culture and science as an integral intellect of society and the core of noospheric development. The mind has won all these victories because man has long realized the value of information among all other resources and learned to use it.

The information revolution, which was launched by mankind in the 20th century and is deepening today, marks a new step on our way towards mastering the inmost secrets of the universe. The exceptionally high methodological status of information in the science of our epoch is especially important for informatics as a vigorously developing field of knowledge. Moreover, informatics today is, in a sense, the face of science, treated as an integral organism in the system of human culture. At the same time, the role of the information approach in the modern general scientific methodology reflects the importance of information as a factor, like matter and energy. In broader terms, on a societal scale, this approach follows in the vein of the history of human civilization.

The rapidly growing power of man has brought about a global environmental crisis with its increasing adverse effects on mankind itself. This phenomenon has many different manifestations in various areas of animate and inanimate nature, with global climate change becoming increasingly tangible. The nature of the planet that gave life to *Homo sapiens* is being destroyed, quickly and thoughtlessly. To make things worse, the environmental crisis is accompanied by global problems of a different nature, all of which result from man's way of life. The globalization in the various areas of social life on the Earth, which is an essential feature of the recent decades in the development of the world community, also leads to considerable costs and negative consequences. Plans to implement a sustainable development program fail chronically...

The hope of mankind remains with the transition to the noosphere (even in the very distant future). The sphere of the mind: the social embodiment of the essential characteristic of our biological species, is meant to resolve the contradictions accumulated by mankind over millennia (including bloody conflicts, blatant injustices in the distribution of resources, lack of spirituality, and, of course, all environmental disasters). If this transition does not occur, then mankind is doomed to an imminent catastrophe. It is also symbolic that the content of the noosphere concept is organically connected with information; science plays a very special role here.

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