DOI: 10.32703/2415-7422-2022-12-1-31-54

UDC 62.930.8:71:06-9/13

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Some methodological issues of the history of science and technology

Abstract. *Further development of the history of science and technology requires the solution of a number of methodological problems. The article considers the object and subject of the history of science and technology, its place in the system of sciences. Today, more and more people are turning to the factors that determine the interaction of the society with the environment (productive forces of the society), to study which in the historical aspect and called a special scientific discipline – the history of science and technology. The society as an object of knowledge is a biological organism of the highest level of organization of "cells" – individuals. It exists and develops in the environment due to its own entropy. The society organizes this removal through a specialized subsystem formed on the basis of technical devices – "technosphere". The success of such a process is ensured (through the information field) by another*

subsystem – the "noosphere". These subsystems include both ideal and material objects. The composition and development of the technosphere and noosphere are considered in the article. It is shown that the functioning of the technosphere is based on its interaction with the noosphere, which provides information about the environment and controls the effectiveness of interaction with it. It is formed by combining the mental structures of individuals through sign systems. The production process that ensures the functioning of the society begins with the noosphere, which through individual consciousness controls the actions of each individual, who through the means of production (technosphere) interacts with the natural environment. However, the gradual development of productive forces leads at some point to the fact that the information needed by the individual to perform all necessary actions for the benefit of the society, ceases to fit in his individual consciousness. As a result, there is a new social phenomenon – the social division of labor. On the one hand, there is a division of technological operations between different performers (technological division of labor), and on the other – the selection of individuals who coordinate the efforts of performers and receive impetus to work not directly from public consciousness, but through these persons (social division of labor). As a result, there are special relationships between individuals and their groups (production relations), and thus begins the class period of human existence. And it will continue until the development of productive forces leads to the full transfer of all technological functions to technical systems, which due to the direct interaction of the noosphere and technosphere will put an end to the social division of labor. However, the development of productive forces is also accompanied by the acceleration of entropy in the environment of mankind – the geobiosphere of the planet Earth, which is gradually making it less and less suitable for life. The cardinal solution to the problem is the prospect of humanity entering infinite space.

Keywords: *history of science and technology; technosphere; noosphere; productive forces; social division of labor; social consciousness*

Formulation of the problem.

The history of science (natural science) and technology has existed for a long time, and recently, due to the processes taking place in the scientific and technical spheres, it has received additional impetus to development. However, it is still impossible to say that this science has fully formulated its methodological basis - although a number of experts have paid considerable attention to these issues. Philosophy, which claims the role of "metascience" (both science and technology) solves its own problems. For example, philosophers of technology believe that technology has a different object and subject from technology and technical science: technology, technical activities and technical knowledge as a cultural phenomenon (object); development of technical consciousness that reflects this object (subject).

It seems indisputable to us that the development of science and technology must be based on a solid methodological foundation, which can be built only by going to some extent beyond the actual science - in the field of social sciences. Attempts to limit the empirical material to this science alone may, in our view, lead to formalistic exercises

that are devoid of heuristic value. Therefore, the creation of such a foundation will require joint research by experts in various fields of knowledge.

The defined facts, first of all, concern the scientific status of "history of science and technology". Accordingly, the question arises about the specification of the object and subject of this science, the nature of its links with other scientific disciplines. The question of the internal structure of the "history of science and technology" is important, as it combines two different social phenomena – "science" and "technology". Each of them needs a separate study, as there are certain features of formation and development. At the same time, they together, in a way, determine the nature of the evolution of society. That is why an unbiased analysis of the interaction between these social phenomena allows us to scientifically predict further social development.

History of science and technology as a scientific discipline.

History of science and technology belongs to the field of historical sciences. According to a stable definition, any historical study reproduces a certain process of development. However, the level of theoretical generalization of historical material may be different. The greatest degree of theoretical generalization is achieved, as a rule, in the field of economics. Thus, in historical research, preference should be given to "material communication" - economic relations as the basis of other processes in society. This approach has become decisive in historical science over time, because "as a method, it has given and continues to give very fruitful results ... scientists, even those who do not share the materialist view, have learned in part under the influence of this trend to pay special attention to the economic history which they had despised before" (Tarle, 1903).

However, historians primarily proceed from internal social relations; the relationship of the society with the environment, if taken into account, then at best as a secondary factor. However, today the historical role of those factors that determine the interaction of the society with the environment (technological structure, scientific and technical level, availability of natural resources, etc.) is becoming increasingly clear. To study them in historical development, perhaps, is called a special, very specific science, called *"history of science and technology"*.

The specific purpose of research in the history of science and technology and its study may be different. It seems appropriate to identify at least three goals and, accordingly, three approaches, each of which has its value and significance – depending on the tasks to be solved:

a) *Practical* – to use the positive and negative experiences of science and technology in the processes of their current functioning. This aspect of the history of science and technology plays a particularly important role in specific fields – in relation to both science and technology, as well as their relationship.

b) *Methodological* – to understand the internal laws of science and technology as certain social phenomena that ensure the success of their scientific analysis, and hence the forecast.

c) *Worldview* – mainly for the possibility of understanding the role of science and technology in social development and their interaction with other social phenomena. This allows us to better understand not only the processes of development of science and technology, but also social processes in general.

In particular, systematic and comprehensive ideas about science and technology as social phenomena, their functional structure, development and interaction allows a specialist in a particular field of science and in a particular field of technology to clearly define their place in the society as part of the latter, to correlate their problems and tasks with general tasks and prospects for the development of society as a whole. The study of this discipline, methodological and sociological problems considered in it, first of all has a positive effect on the formation of general historical ideas by specialists in various spheres of public life.

But, like any science, the history of science and technology will develop more successfully, the more clearly it will define its tasks and methods of solving them. And one of the most important is the question of the object and subject of this science.

The object and the subject of history of science and technology.

Despite its specificity and being a completely independent scientific discipline, *history of science and technology* is closely related to other social sciences, especially general history and social sciences (historical materialism, philosophy of history), which are part of the *social sciences*. As for the history of science and technology itself, today, as noted above, it is common to refer to *historical sciences.*

History of science and technology, as well as general history, has as its *object* the society in its development, but they consider it from different angles and aspects, according to which *the subject* of their research is significantly different. It is generally accepted that *the object* of cognition is a set of qualitatively certain phenomena and processes of reality, significantly different in their internal nature, basic features and laws of functioning and development from other objects of this reality. At the same time, *the subject* of knowledge is a certain holistic set of the most important in one respect or another components, aspects, properties and characteristics of the object of knowledge, which is directly studied by this research.

General history has as its object the formation and interaction of various social formations as a certain objectively existing phenomenon, consisting of a series of successive interrelated events. Not only a certain functioning, but also the very existence of these entities directly depends on their production activities, which, in turn, depends on their internal organization in this process. Thus, general history actually considers historical progress as a process of changing *production relations*, which for general history are self-sufficient – taking into account the superstructures they have defined – political, legal, religious, etc.

After all, all existing processes are determined by the driving factors that ensure the interaction of society with the environment. The success and nature of interaction depends largely on the ability of society to influence the environment (directly related to *technology*) and the level of information about the environment necessary for the

success of such influence (which is now most fully embodied by *science* – especially natural science).

Since, despite the close relationship, science (science) and technology are different social phenomena, it seems logical at first glance that different sciences should also study their historical evolution. Accordingly, it would seem logical to conclude that the subject of research in the history of science is one – the study of the development of knowledge of laws and phenomena of nature, and in the history of technology – another: the study of the laws of development of productive forces. Therefore, it is sometimes believed that there are two sciences, but very close in research method.

Such a conclusion could be considered logical if the productive forces of society were really reduced to technology. However, it is man who is armed with the technique and the amount of knowledge necessary to create and put it into action, is the most important component of the productive forces. Therefore, what are called productive forces, these factors (information about the environment and the possibility of influencing it) are only in aggregate. Accordingly, even a separate study of the history of technology as a certain force of knowledge is transformed primarily into the history of knowledge that is materialized, in the history of the relevant natural sciences (Kuzin, 1990). Without such interaction, science becomes pointless and technology powerless.

Thus, *history of science and technology*, having the same object of study as *general history* (i.e. the society), its subject is not so much the historical development of society, or even a separate development of science and technology, and he also, as a phenomenon, of course , is of scientific interest), as *a whole*, the evolution of social productive forces that determine this development.

Natural science and its branches, which study certain phenomena of objective reality, social sciences, which are engaged in various types of processes in society, on their own provide only some conditions for the development of productive forces of society. Technology, as a collection of certain material objects, is, figuratively speaking, a useless "pile of iron", and only after the “revival” of a public person, it becomes an effective tool for connecting the society with the environment. And only in total all these factors are subject to study both for understanding the driving forces of history and for prognostic purposes. The latter is achieved by analyzing *the historical path* of technology development – the whole set of technical devices used by people, along with the amount of knowledge necessary for their creation and use as a whole, and in conjunction with other social phenomena.

The society in the environment.

Thus, *the object* of study of the history of science and technology as a historical science is *the society in its evolutionary development*. Given the relationship of the society with the natural environment, we will assume that society is a functionally integrated entity – *an organism of the highest level of biological organization* of “cells” – individuals that function in the environment like any biological organism due to removal into it own *entropy.*

Entropy in the world we know is constantly growing in all existing material formations. But if in inanimate matter it *rises* steadily as a result, then the fundamental feature of living matter (in which entropy is also constantly "generated") is, in the end, its *reduction* due to "removal" into the environment (Kabulov, n. d.).

It should be noted, however, that today among philosophers is quite widely represented the view that the whole universe is recognized as a self-developing system. In such a system there is a vector of growth and *complexity*, ie the development of all nature is *self-organization* or evolution with *increasing* organization of the universe and its parts, including the terrestrial biosphere (Popkova, 2008, pp. 315–317). These statements completely ignore even the indisputable realities, such as that the Sun – the source of life and development on Earth – must go out in full accordance with the second principle of thermodynamics (such realities will once befall other stars and galaxies).

The processes defined are difficult to call development in the general sense of the word. In fact, only systems that are truly self-organizing *(living)* can develop, or, according to V. I. Vernadskij, *"the evolutionary process is inherent only in living matter"* (Vernadskij, 1991, p. 238; Pylypchuk, O. Ya., Strelko, O. H., & Pylypchuk, O. O., 2021).). That is, *"living matter"* carries out its development *solely* through the removal of entropy (with its corresponding growth in the environment). In general, according to one of the creators of quantum mechanics, theoretical physicist E. Schrödinger, a living organism remains alive, only constantly extracting negative entropy from the environment. What is indisputable about metabolism is that the body manages to get rid of all the entropy that it is forced to produce while alive (Schrödinger, 2002, pp. 75–76). And the antientropic (non-entropic) nature of a living system implies that its first and necessary property is *material exchange* with the environment.

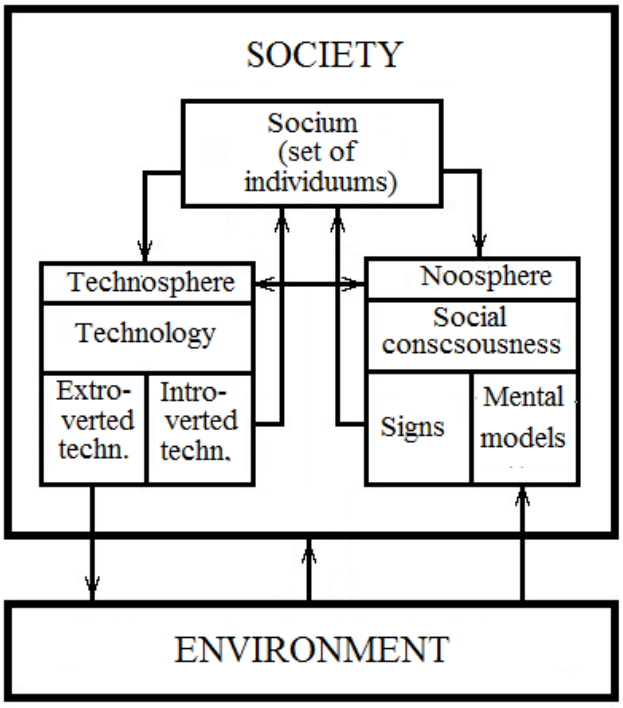

Figure 1. The interaction of the society with the environment.

Obviously, the effectiveness of the system directly depends on the intensity of the process of its interaction with the environment. The desire to increase its efficiency inevitably leads to the complexity of the biological organism, which involves its internal structuring, ie the specialization of its subsystems and the organization of a certain internal relationship between them. In particular, those organs of the biological organism that specialize in interaction with the environment are particularly susceptible to development. However, at a certain stage to intensify this process in the living system there is a need to introduce additional intermediate material elements that are not directly related to the system itself, the complex of which for the society has become *technology*; "Technology occurs when intermediate means are introduced to achieve a goal" (Jaspers, 1986). For society in its interaction with the environment, technology becomes a kind of "shell" that separates and connects them – *the technosphere*, which today attracts special attention of researchers (Herrmann-Pillat). Perhaps it is the development of this term that gives historians of science and technology the opportunity to rethink their concept of technology, better integrate technology history and environmental history, and replace linear temporalities with multilevel models of historical change (Trischler, 2018).

We will try to present the multidimensionality of the existing process on the diagram (Fig. 1). In order to reduce entropy, the society organizes its interaction with the environment through technology. But for the successful material (material and energy) interaction of the society with the environment requires its information support. To this end, the society produces, processes and accumulates information about the environment, about itself as a certain objective reality and about the nature and features of the interaction between these objects. Accumulated information systematized in the mind, create some information "shell" of the society – its *noosphere.*

As for the technosphere, the technical devices that make up its material "substrate", being originally designed to interact with the environment, are no longer limited to the directly specified task. The fact is that this interaction is ultimately carried out by the society in its *entirety*, which is provided by intra-social ties: *material* and *energy* on the one hand, and *information* – on the other. Initially, these connections are made exclusively by "natural" means available to individuals. But in the process of quantitative growth of the society and with the expansion of its range of existence of these funds becomes insufficient. In the field of material interaction, this is the technique of transport and communication (and later some other types of it), which together represent the "intra-social" *introvert* technique – in contrast to the technique of *extrovert*, directly aimed at society's interaction with the environment. In general, they constitute (directly or indirectly) for the society its technosphere.

In the noosphere, the active *material* carrier of social consciousness (ideal) is the brain of each individual, in which due to information received from the environment and its processing, certain *mental structures* are created. In fact, to some extent, similar processes occur in any biological organism with a central nervous system. But it is characteristic of the society that the ideal processes in the mental structures of its components – individuals with the help of external material objects *(sign systems)*

merge into a certain holistic phenomenon – *social consciousness*, which is the noosphere in its actual existence.

Let's note that both the technosphere and the noosphere are not frozen. Their formation is evolutionary. In the process of development of the social organism, they undergo a certain evolution, which represents this development in terms of the interaction of society with the environment – their *history*.

Formation and evolution of the technosphere.

Prototechnics became a kind of rudiment of the technosphere (Fig. 2). A typical example of prototechnical devices is the cobweb, which is instinctively created by a spider from a material secreted by its glands (prototechnics I). In nature, there are many other cases of using your own body secretions to create a variety of "technical devices" (bees, caterpillars, etc.). In the future, "external" materials are also used, and eventually only they (for example, beavers for the construction of dams). These "technical devices" are mainly aimed at interacting with the environment of *a certain individual* – including his offspring (in the diagram – "prototechnics II a").

Note that the existing realities are also characterized *by biological superorganisms*, which necessarily create prototechnical devices ("prototechnics II b"). All currently known to us "social" insects that form "collective organisms" (ie bees, ants, termites) in one form or another build or use protective devices (from the environment) and other purposes. Prototechnics differs here primarily in that it is created by *collective* efforts, and different individuals play different roles in this *(polyethism)* (Kipyatkov, 1985, p. 16).

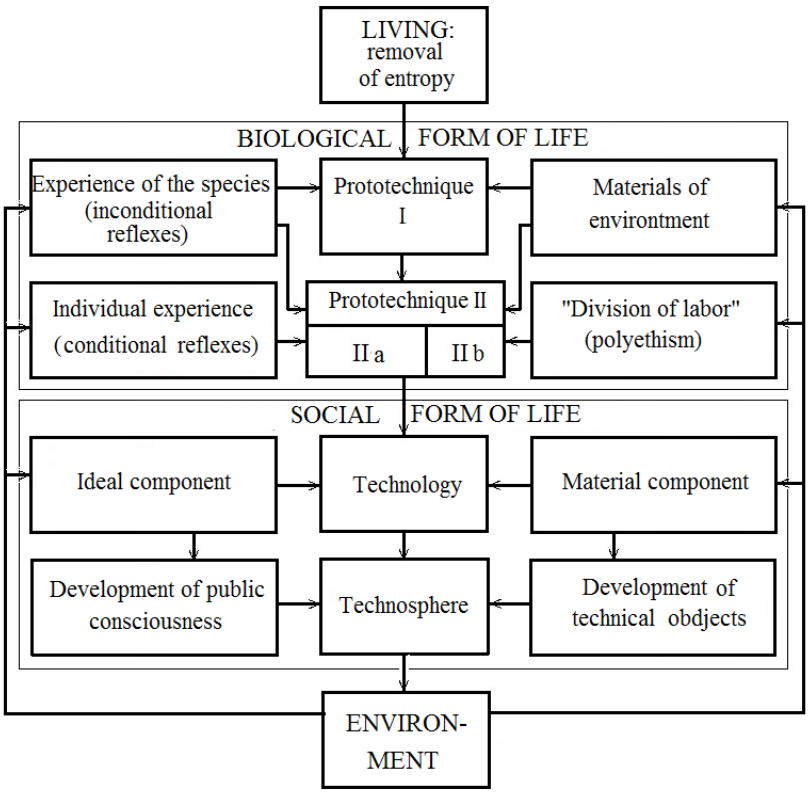

Figure 2. The formation of the noosphere.

However, technology (technosphere) as a social phenomenon, developing on the basis of prototechnics, is qualitatively different from it. Since technology, ensuring the interaction of society with the environment, serves to meet its needs (individual and social), its development in the process of progress of society is in accordance with changing these needs. The eminent German scientist in the theory of mechanisms and machines F. Reuleaux noted in the last century that with the help of technology we force "the internal processes of the material world to act and work for our purposes" (Reuleaux, 1885, p. 1). At the same time, the role of technology in the process of ensuring the functioning of society and the individual (as well as associations that historically arise within the social organism) determines its *structure* as some (relative) whole. Accordingly, it becomes the basis of the primary *classification* of types of technology (Griffen& Ryzheva, 2021).

First of all, it should be noted here that the objects together constitute a set of technical devices that form the basis for direct interaction of the society (through individuals) with the natural and social environment – *consumer goods*. Their man-made nature led to the emergence of tools for the manufacture of these items (more broadly – *means of production*). With the change of social conditions there was a selection of other types of technology, which together and in the relationship form the basis of the technosphere (Fig. 3).

At the stage of primitive society such a division did not occur. In the process of reconstruction of the life of the Paleolithic community it was proved that life was not separated from production activities and did not stand out as an independent phenomenon. A fairly clear separation of the means of production from household appliances occurs only with the transition of the society from the collection to the production economy.

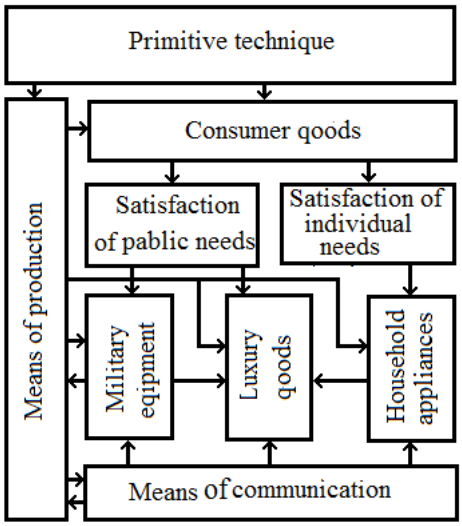

Figure 3. The types of technology and their relationship.

As for the *internal structure* of the means of production, there are different ways of grouping objects, and accordingly different classifications. In the most general form of production equipment, usually divided into three main groups: a) gun equipment; b) machinery; c) automatic equipment. Depending on the tasks solved by scientists, a

number of other principles of structuring this type of technology are possible (Garanina, 2020).

In the process of long-term social transformations to the technical devices designed for interaction of society with the environment, which are directly part of the technosphere, are added those designed for interaction between local social formations and individuals already *within* the social organism included in the technosphere. As for the social processes they provide, these types of technology can be divided into *"integrative"* and *"separative"* – respectively, two (unifying and dividing) trends that have occurred and are taking place in the development of society.

An essential condition for ensuring the integrity of any sufficiently complex system is the interaction of its elements (subsystems) in space and time, "as a result of which something disparate and spatially separated acquires a certain integrity and functionality" (Smotrickij, 2010). To do this, the elements of the system (or its subsystem) must have a developed ability to *exchange matter*, *energy* and *information*, ie the ability *to communicate* properly between them. As a result, another type of technical means (technical class), which has already been mentioned, arises and develops – *means of communication*. It naturally breaks down into two subspecies – technology to ensure communication in the *material* (ie material, and later – in the energy) sphere – *transport*, and technology to ensure communication in the *information* sphere – communication.

Integrative, unifying processes are leading, inherent in social development at all its stages. Separative, ie divisive processes are characteristic only of the historically limited period of internally disparate class society, ie are used by one or another social entity in relations not with the *natural* but with the *social* environment.

Weapons (military equipment) are one of the types of equipment that have played and continue to play an extremely important role in social processes. No less important than in inter-tribal (and later in inter-state) relations, weapons were also in the interaction within certain social formations, namely between the antagonistic social groups that make them up. Another specific type of technology, which also has a separatist character, are *luxury items*, which (regardless of their immediate functional purpose) act as a kind of social "punctuation marks".

Thus, technical objects are created in accordance with the needs of society at one stage or another of its development and constitute, together, such a social phenomenon as technology. As a phenomenon extremely complex and diverse, technology is often considered by researchers in a variety of aspects (Wolff, 2012). However, first of all, we can assume that technology is "a set of human activities created to carry out the processes of production and service of non-productive needs of society" (Larin, 2018, p. 6). However, this set is not yet the technosphere, as some philosophers think (who present the technosphere as a *self*-developing object). In this case, *the subject of its development* is ignored, because it is believed that the technosphere itself is an artificial environment created by the society, i.e. the same *set of technical objects* that people have surrounded themselves with (Popkova, 2018).

According to this statement, we have separate people with their "technical activities", and separately – the "technical sphere", which somehow "self-develops" as

the environment of this activity. In fact, the technosphere is not an environment for the society, but its *essential component*, which together with the set of technical means formed by *humans* as its *active principle* that separates and connects society with the real environment – the biosphere of the planet Earth. Therefore, the laws of technology development "lie outside its" own "logic". Accordingly, "technology can be presented as a system of self-development, only if it concerns the development of technical and technological production systems, which are human-technical structures" (Glozman, 2008). Successful independent functioning (and even more so "self-development") can be carried out only by a technical system (TS) with "intelligence", which "independently assesses the situation in the aggregate" TS – the world around it "and independently forms goal-oriented behavior". And this is definitely human intelligence. The use of what is called "artificial intelligence" solves only limited specific tasks. According to him, "the term" behavior "means a set of interrelated actions of the effectors of the technical system, carried out to achieve the goals set before the human vehicle" (Karpov, 1990, p. 7). Accordingly, it is necessary to approach technology as an aspect of human activity, and not to study technical actions within the typology of action (Wolff, 2012). Therefore, in our opinion, it is hardly possible to accept the correct conclusion that the technosphere (material basis of the society) is governed not so much by the will of people as by the "internal logic of technology development" (Rozin, 2017).

Formation and evolution of the noosphere.

The functioning in the environment of any biological organism with a central nervous system is directed and controlled by the latter. This applies to both the formation and application of prototechnical devices, carried out by instinct – a set of motor acts and complex behaviors inherent in an animal of a certain species in accordance with the program genetically laid down in its central nervous system. However, such a predetermined rigid program can be effective only under certain natural conditions that persist from generation to generation. In the process of their change, individual experience (learning) acquires a significant role. And the higher the animal on the "family tree" of the animal kingdom, the faster you can expect from it the ability to learn, a greater role of "trial and error" and, accordingly, greater independence from variations in environmental conditions. This ability to learn, learning then proved to be very useful in the formation of human *society.*

In the social organism, the formation of the program of action of each individual is carried out *solely* through the information and skills acquired by him from society in his individual experience. The program of action of a public person together with a set of ideas about the environment and thesociety is what is commonly called *social consciousness*. For its formation and functioning, the interaction between individuals includes *systems of signs* that connect the processes in their brains into a single whole, so that the receipt, storage, processing and use of information is a *social* process, creating a *noosphere* of the society.

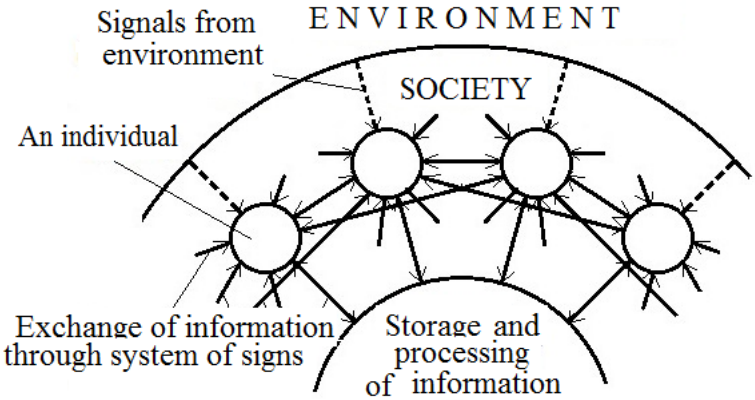

Figure 4. The "neural network" of society.

Thus, in the noosphere, the connection between individual mental structures is provided by external agents – sign systems that include the informational mental process of the individual into *a single social process*, forming a kind of "neural network" of society (Fig. 4). With the introduction of universal "external" codes (regardless of the form of their expression), the human brain, remaining an individual organ, becomes *a social organ*. Mental processing of information from individual (for each individual) becomes public (for a holistic social superorganism). As a result of such a process, what is usually called *"social consciousness"* arises, and on the individual (as its concrete being) – such specifically human phenomena as *thinking* and *consciousness.*

It should be noted that if the actualization of social consciousness is carried out in an *ideal* form with the help of individual human consciousness, then social consciousness itself includes *material* objects. They store information through the "objectification" of the ideal in a variety of objects; when used, it returns to the realm of the ideal through its "objectification" (Ilenkov, 2009). It is sometimes believed that the evolution of human cognition corresponded to the technological expansion of its space-state, increasing its degrees of freedom by tracking invariances and conjunctions in its relations with the world, which should be described as "infosphere" (Wilson, 2017).

Social consciousness, arising on the basis of "socialization" of conditioned reflexes of individuals, determines the development of society. At the same time, it is changing, significantly transforming the nature of the noosphere. However, understanding its essence makes it possible to predict the ways of this development, although some researchers have doubts about this (Lahoz-Beltra, 2018). The same changes that have taken place in the noosphere so far, in particular, in relation to that part of it that is part of the productive forces of society, are presented in the diagram (Fig. 5).

The formation of the noosphere is based on the same animal *instinct* as in the process of biological evolution, which is supplemented by *conditioned reflexes*. Basic social consciousness, which appears simultaneously with the formation of the social organism, can be defined as *ordinary consciousness*, which corresponds to the above–mentioned undifferentiated, syncretic state of technology.

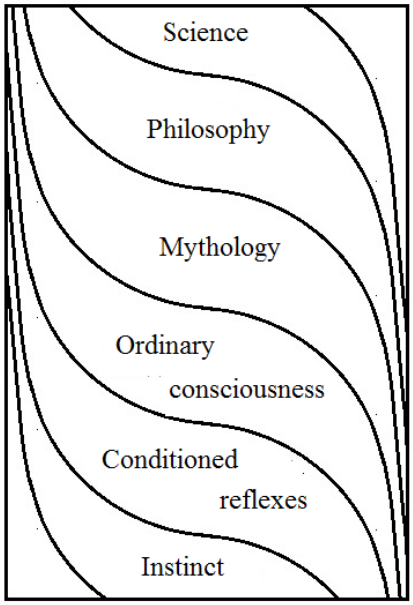

Figure 5. The evolution of public consciousness.

It must be noted that at an early stage of civilizational progress, in the process of human transition from "appropriating" to "producing" economy, from the ordinary consciousness stands out and its part, which is aimed at direct interaction of society with the environment. Since both objects are a certain integrity, such a separation requires the formation in one form or another of *systemic* ideas about the environment and the society. In other areas of life, everyday consciousness remains dominant, but it is constantly evolving, because it is always made of certain adjustments from the emerging systemic ideas.

According to the objective historical realities, the forms of social consciousness on which society's interaction with the environment was based were constantly evolving. At the same time, we recall that when we talk about the "history of science and technology", it should be borne in mind that man began to use and subordinate substances and forces of nature long before the emergence of science. Science is the result of the long-term development of knowledge, which has acquired various forms in the history of mankind. For example, Auguste Comte believed that human thinking is historically characterized by three forms. The first – theological (religious) – explains to man all phenomena by the action of supernatural forces. The second – metaphysical – explanation is found in the action of some "essences" and "causes". Thus, it destroys religious beliefs and prepares the formation of the third form. It is in the third – positive – form that everything is explained scientifically (Kont, 1899).

As for the direct replenishment of knowledge about the world around us, at different stages of development there was a predominance of one of three points:

– obtaining information through the operation of objects directly in the process of life *(practice)*;

– "remote" observation of these and other processes *(contemplation)*;

– purposeful influence on the objects of study to obtain information about them *(experiment)*.

On the basis of the information thus obtained, they were organized into a holistic system, the nature of which was determined by the level of knowledge. Initially, systematization was carried out by "imposing" on the natural environment in its ideal reflection as the organizing beginning of those systemic connections that were known (or rather, familiar) to man in the immediate area of its existence (zoomorphism), and later – in the form of social relations. (anthropomorphism). In its most developed form, such a system is called *mythology* (based on the original element – *the image*). The next step was *philosophy*, which on the basis of seemingly a priori elements – *categories* – perfectly constructed the world. The corresponding scheme in the form of a more or less integral system of elements *(categories)* again "imposed" this construction on reality – as *a picture* that allegedly fully reflected it, although in the most general form. And only at the third, *scientific* stage with the achievement of a fairly high level of knowledge, the world in its full diversity becomes the basis for generalizations in systematically related *concepts*. In all three cases of obtaining and organizing knowledge there is a combination of *practical* approaches (obtaining knowledge directly from the outside world) and *theoretical* (construction based on the acquired knowledge of a system – a generalized ideal model of the world, its elements or aspects) (Griffen, Ryzheva, Nefodov, & Hryashchevskaya, 2021). However, regardless of the methods of cognition, its results, in the end, formed the basis for the functioning of social production.

Development of production and division of labor.

Active interaction of society with the natural environment is carried out in the form of production. Accordingly, production equipment (means of production) is the most important type of technical devices. Therefore, the study of the evolution of the means of production, in particular, changes in their structure, is the most important task in the history of science and technology, which studies the development of the productive forces of the society.

The structure of the means of production in general is represented by the scheme (Fig. 6). It follows logically from the tasks that society solves in the production process. The ultimate goal of the production process is to obtain the necessary objects of society from material taken from nature, through the impact on the latter.

According to the scheme, the production entity must, for this purpose, organize a direct *transformative action* on the subject of labor, *supply of energy* required for these transformations, and *control* over the process that ensures the desired result.

All three functions performed by the production entity in this process have been constantly changing with the improvement of technology and its technical means. The main stages in the development of all three production functions are summarized in Table 1. In particular, to increase productivity, all three functions of the subject of production were gradually transferred *from man to technical devices and systems*.

Virtually all of these changes began at an early stage of human civilization. They took place throughout the process of transformation of production, at all stages of technical revolutions, characterized by the transfer of technology to new production functions, previously performed exclusively by man (Rozin, 2001, p. 121).

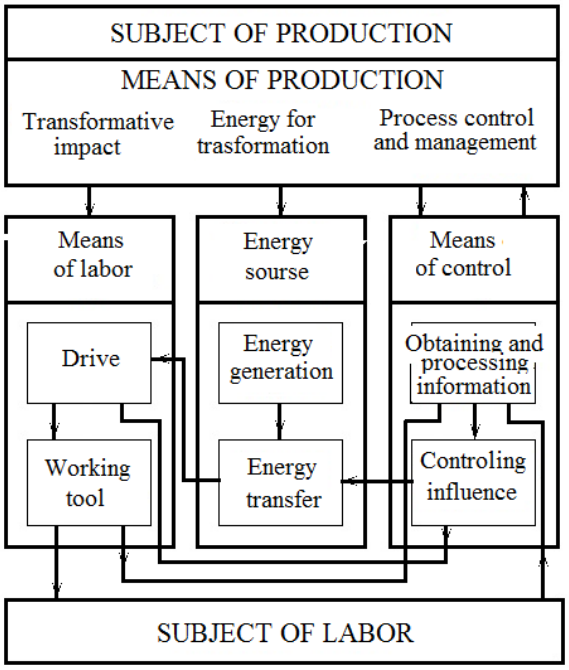

Figure 6. The structure of means of production.

Table 1. The main stages of development are summarized in the table.

Working tool	**Energy**	**Control and Management**
Improving the tool and skills of mastering it Specialization of the tool Tool with holder (manual drive) Kinematic connections between energy source and tool (mechanical drive) Technology development - mechanical - thermal - chemical, etc. Electric drive Combined multifunctional tool (including non-contact)	Human muscular strength The power of animals Accumulated solar energy (mechanical) - the wind - water Accumulated solar energy (chemical) - steam engine - engine internal burning Energy of chemical bonds (fuel cells) Nuclear energy - disintegration - synthesis	Organoleptic control Testing Instrumental control Remote and non-destructive testing Automatic control of individual processes Integrated automation, control and management Computer control (automated production control systems) “Deserted” production management (“artificial intelligence”)

With the beginning of *industrialization*, development in all respects accelerates sharply. In particular, the kinematics of the working body is significantly complicated. This process was most clearly characterized by textile production, where the product requires a rather complex manipulation of many identical objects – textile fibers and

threads. Advances in this field have given impetus to the spread of complex kinematic devices in other fields. In the future, intellectual efforts were aimed at solving the energy problem. Finally, automation issues have become paramount at the present stage. At the same time, the priority of one of the directions does not exclude the continuation of the development of others.

In-depth study of the issue, in our opinion, also includes a brief historical overview of the realities associated with changing *the subject of labor*. The first were *natural* materials – stone and wood. They were later joined by bones, leather and other materials of animal origin. Then came the turn of *artificial* materials that do not exist in nature (in the so-called "pure" form), but are obtained in some way from natural. In this context, the first was clay (ceramics), then metals. And much later there were *synthetic* materials, especially plastics of various types, obtained by molecular rearrangement of raw materials. New opportunities were brought by the use of *composite* materials, the synergistic properties of which arose due to the integrated use of different raw materials. Finally, in our time, technical progress requires so-called *nanomaterials*, the structure of which is designed in accordance with the required properties of raw materials at the micro level.

Of course, technological progress has become possible only through the constant development of the noosphere – increasing the level of knowledge about the properties of natural objects and the appropriate organization of society. But the need for survival left humanity little time for individual development of already accumulated but poorly systematized knowledge and skills. Initially, as already mentioned, in *the economics of gathering* and primitive forms of hunting (during the Upper Paleolithic), the technical complex had a syncretic, undivided nature, which corresponded to the equally undivided everyday social consciousness. Each member of the community could do any work: "the simplicity and primitivism of primitive technology lead to the fact that related actions can be performed by all members of the community, that is, all light a fire, make bows, arrows, etc." (Ortega y Gasset, 1993). Accordingly, there was no *social division of labor* – except for the "natural" gender and age. The situation changes significantly with the gradual transition to a *"producing economy"*, which requires the development of more information.

The complexity of technology required appropriate training of workers with increasing costs of time, effort and money, which provide for all members of society became impossible. The way out was found through *the division of various technological* operations between individuals, i.e *the social division of labor*. At the same time, due to the strengthening of cooperation in production, there was what was later called the *"separation of mental and physical labor"*. If before each member of the society in the process of production under the influence of public consciousness determined their actions and directly (more precisely, through tools) influenced the object of labor, now there are certain individuals who act indirectly through labor, *through others*, defining and coordinating them actions.

That is, in the society there is a technological ("horizontal") division of labor, supplemented by social ("vertical") (Fig. 7). In other words, on the one hand these processes lead to technological specialization of direct performers, and on the other

there is a group of people whose social prerogative was not only the management of general production processes but also the development of the noosphere in general and *technical consciousness* of the society in particular, as productive work is preceded by the activity of consciousness to create an ideal image of this process. Such "activity of consciousness" had a historically definite character, and it was largely determined by general ideas about the world (Gorokhov, 2015, p. 14).

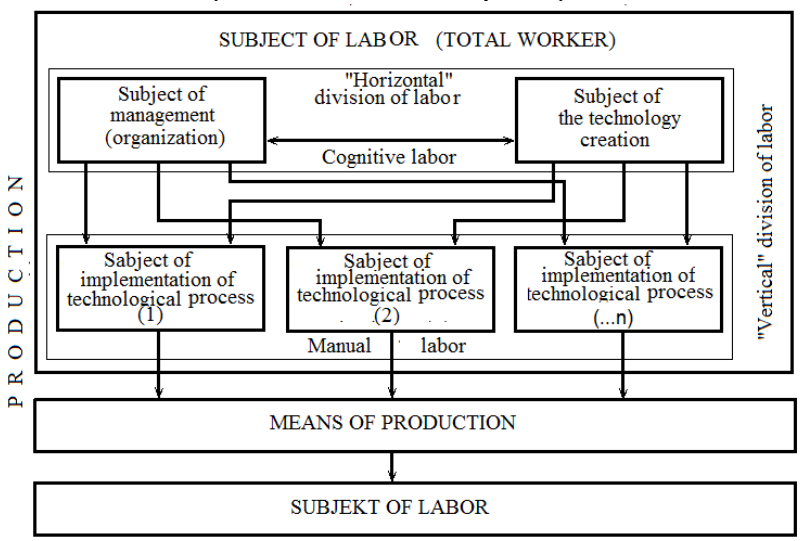

Figure 7. The technological and social division of labor

The role of public consciousness in technological progress.

With regard to the problems of development and functioning of technology, the mythological "model of the world" foresaw an *irrational* – in our view today – a component of almost any technology. In other words, in order to achieve this goal, man also used *magical* actions arising from the aforementioned mythological "theoretical picture" of the world around him.

For a long time, technical consciousness has developed due to the infiltration of general worldviews, regardless of the intentions of both those who dealt with technical problems and those who developed these ideas. Moreover, the division of mental and physical labor caused a negative attitude of the latter to the application of their knowledge in the field of practical activities. They, like Aristotle, were convinced: "Science is considered to be wisdom that is chosen for its own sake and for the purpose of knowledge, and not that which attracts because of its consequences".

Natural philosophy, having replaced mythology, also in its systems created a holistic picture of the world, only if it replaces unknown to its real connections with ideal, fantastic phenomena, which, according to F. Engels, "filled gaps only in the imagination "fiction"". However, in contrast to mythology, these "fictions"were not so much the result of expanding the partial to the general, as an intuitive generalization of previous experience on specific phenomena. Such general ideas created *methodological preconditions* both for further research and for technical consciousness.

In the process of studying reality and "processing" existing information, humanity receives *two* useful results for cognition: *a system of specific knowledge* about the

surrounding reality and *methodological methods of cognition*, which together reflect the isomorphism of existing laws in this reality. Later, the former *were formalized* in the form of *a system of sciences*, the latter *systematized* partially in the form of certain laws of *quantitative* change (mathematics), and to some extent in the form of methodology – much less defined *qualitative* "laws" (such as logic, dialectics, synergetics, etc.).

The fundamental imperfection of philosophical systems led to their frequent change and reduction of their role in the cognitive process, and their gradual replacement by *scientific knowledge*. The needs of the development of technology also played an important role in the emergence and development of scientific knowledge, although, as before, it was based mainly on the practical experience and intuition of its creators. The latter was largely based on the intellectual atmosphere of the society, which was formed due to scientific knowledge. It is in this sense that technical knowledge follows the natural sciences and draws from it the necessary information.

However, science (natural science) has never aimed to determine the development of technology with its achievements; she solved her own problems. The creators of technical innovations also used their own developments. Yes, steam engines were invented by people who had no idea about thermodynamics; theoretical electrical engineering began to develop when many electrical devices were already successfully used. However, further *improvement* of technical devices objectively required scientific developments as a guarantee of progress. Nowadays, a number of technical advances are generally based on them (for example, in computer science or nanotechnology).

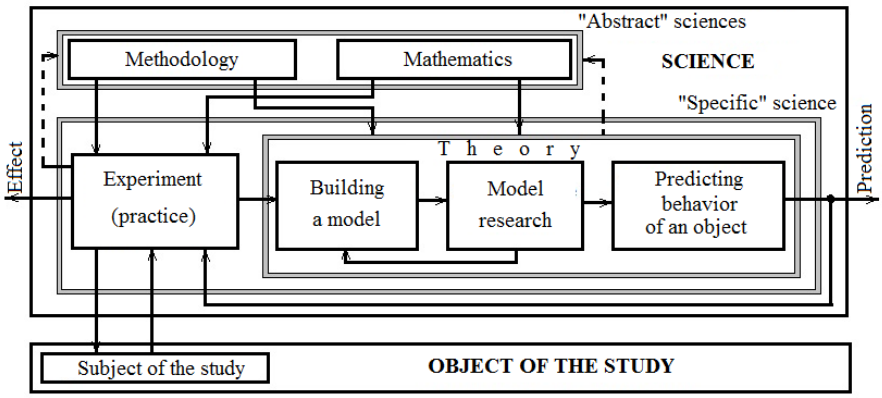

Figure 8. The process of scientific cognition.

In principle, the process of scientific cognition has the form shown in the diagram (Fig. 8). Experimental impact on the object allows you to get some information on which to build a theoretical model of the object. Studies of the model (usually accompanied by its refinements) allow to predict the behavior of the object, which in subsequent studies is again compared with the results, giving rise to new refinements of the model. The generalized results of previous scientific researches in the form of methodological recommendations and mathematical processing play a significant role in the whole iterative process.

However, experimental effects on the object often lead to unexpected results – a new, hitherto unknown *effect*. Provided that if the "effect" is practically useful, it goes into the stage of *technical* development. By creating objects based on such "effects", technology uses them for utilitarian purposes (often without even fully understanding their inner essence). Thus, since science took shape as an independent social phenomenon, engineering and technical practice has focused on the application of scientific discoveries, using not so much its theoretical achievements as various phenomena that took place first in scientific experiments and then on a production scale. The corresponding "effect" in its technical application becomes an object for *technical sciences* and is important for the development of the technosphere.

Thus, at the present stage of progress of human civilization, science has taken on the function of providing society with a system of necessary information, especially for the development of productive forces (Melnik, 2010, p. 13). At the same time, archaic knowledge of the world continues to play a role. In everyday consciousness, elements of mythological ideas are quite common, which is sometimes believed to penetrate even the technical sciences in order to reconcile with their revolutionary dynamics and destructive influence (Zwart, 2022).

And science, despite all the contradictions of its development, continues to assert itself as the main means of obtaining and systematizing knowledge, i.e the formation of the part of social consciousness that is directly "responsible" for society's interaction with the environment – despite all the problems that arise (Carrier & Gartzlaff, 2020). In the future, it is likely to be replaced by another form of cognition, but today there is no good reason to thoroughly discuss this issue, although such attempts are sometimes made (Sismondo, 2017).

The material presented above concerns first of all the modern productive forces of the society, which (to paraphrase K. Marx) can be called their prehistory. In the cognitive plan of studying the development of productive forces (both noosphere and technosphere) analysis of its *patterns* will better understand the future prospects. After all, it will be what can truly be considered the true history of the productive forces of *all mankind*. It will begin just when the true history of civilization, that is, when the "ultimate goal" will be achieved – the transformation of all mankind into a truly *single* social organism. This will create the foundations for solving the main problem that is becoming clearer before us – space travel.

K. Tsiolkovsky's statement: "The earth is the cradle of humanity, but you can not live forever in the cradle", is well known. The removal of entropy from society into the environment is a prerequisite for its existence. Limiting the range of human existence within our planet will inevitably (and soon) will lead to unacceptable levels of environmental entropy. Only boundless space can provide humanity with conditions for further development. However, it should be noted that there is a point of view according to which such an idea of "escape" from our "used" planet is a kind of "quasi-religious form of cosmism". It does not solve anything, but only "encourages the disregard for earthly, environmental and even physical restrictions" (Sideris, 2017). However, other solutions to the problem are palliative in nature, which have a short-term perspective and do not solve the problem of a global nature.

However, the release of humanity into space will be possible only with a qualitatively different level of development of productive forces, ie with the successful solution of two interrelated tasks:

– the formation of the now fragmented humanity is truly a single social organism with the complete exclusion of social differentiation, and hence the full disclosure of the unique personalities of the individuals who make it up, which provides a new quality of *the noosphere*;

– transfer of all production processes to the self-reproducing *technosphere*, i.e complete reliance on the latter direct material interaction of the society with the environment – a kind of "delegation" to it of all technical functions of entropy removal while maintaining only the society's goal-setting, overall control and innovation.

Conclusions.

Thus, the object of study of the history of science and technology (as a historical discipline) is the society, and a specific subject – the evolution of its productive forces. Existing accents allow us to understand the driving forces of social development and create the basis for its scientific forecast. Human society, as a complex "biological system" is a kind of "superorganism". In the process of its existence and development, it creates two specific subsystems through which it communicates with the environment. Direct material interaction of the society with the existing environment is carried out through a certain shell – *"technosphere"*, formed on the basis of a set of technical devices. Their species meet the requirements of society as a whole and the needs of individual social groups. Information support of this interaction is through another shell – the "noosphere". It is created by uniting individual consciousness (with the help of sign systems) into a single social consciousness, through which the analysis of the environment and society as a whole is carried out. Together they form the productive forces of society, ensuring its existence and development. Thanks to them, society as a biological system carries out the entropy that is "generated" in the process of activity in the environment. Increasing entropy makes the environment less and less habitable. Solving the problem that arises for society itself requires its significant rationalization. However, according to modern realities, the existing problem can be radically solved only by entering the boundless outer space.

Funding.

This research received no external funding.

Conflicts of interest.

The authors declare no conflict of interest.

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Деякі методологічні питання історії науки та техніки

Анотація. *Подальший розвиток історії науки і техніки потребує вирішення низки методологічних завдань. У статті розглянуто об'єкт і предмет історії науки і техніки, її місце в системі наук. Сьогодні дедалі частіше звертаються до чинників, що визначають взаємодію суспільства з середовищем (продуктивні сили суспільства), вивчати які в історичному аспекті й покликана особлива наукова дисципліна – історія науки і техніки. Суспільство як об'єкт пізнання становить біологічний організм вищого рівня організації з "клітин"-індивідів. Він існує та розвивається у навколишньому середовищі за рахунок винесення в нього власної ентропії. Суспільство організує це винесення за посередництвом спеціалізованої підсистеми, утвореної на основі технічних пристроїв – "техносфери". Успішність такого процесу забезпечується (через*

інформаційне поле) ще однією підсистемою – "ноосферою". Вказані підсистеми включають до свого складу як ідеальні, так і матеріальні об'єкти. В статті розглянуто склад та розвиток техносфери й ноосфери. Показано, що функціонування техносфери опирається на її взаємодію з ноосферою, котра постачає інформацію про середовище та контролює ефективність взаємодії з ним. Вона формується на основі об'єднання ментальних структур індивідів через знакові системи. Виробничий процес, що забезпечує функціонування суспільства, починається з ноосфери, що через індивідуальну свідомість управляє діями кожного індивіда, який через засоби виробництва (техносферу) взаємодіє з природним оточенням. Однак поступовий розвиток продуктивних сил призводить в певний момент до того, що інформація, потрібна індивіду для виконання усіх необхідних дій на користь суспільства, перестає вміщуватись в його індивідуальній свідомості. В результаті виникає нове суспільне явище – суспільний розподіл праці. При цьому з одного боку відбувається розділення технологічних операцій між різними виконавцями (технологічний розподіл праці), а з іншого – виділення окремих осіб, котрі координують зусилля виконавців та отримують імпульс до роботи не безпосередньо від суспільної свідомості, а через вказаних осіб (соціальний розподіл праці). Як наслідок виникають особливі відносини між індивідами та їх групами (виробничі відносини), а отже розпочинається класовий період існування людства. І він продовжиться доти, доки розвиток виробничих сил не приведе до повної передачі усіх технологічних функцій технічним системам, що внаслідок безпосередньої взаємодії ноосфери і техносфери покладе край соціальному розподілу праці. Однак розвиток виробничих сил супроводжується також прискоренням винесення ентропії в середовище існування людства – геобіосферу планети Земля, що поступово робить її все менш придатною для життєдіяльності. Кардинальним рішенням проблеми визнається перспектива виходу людства в безмежний космічний простір.

Ключові слова: *історія науки і техніки; техносфера; ноосфера; продуктивні сили; суспільній розподіл праці; суспільна свідомість*

Received 13.01.2022
Received in revised form 10.03.2022
Accepted 01.04.2022