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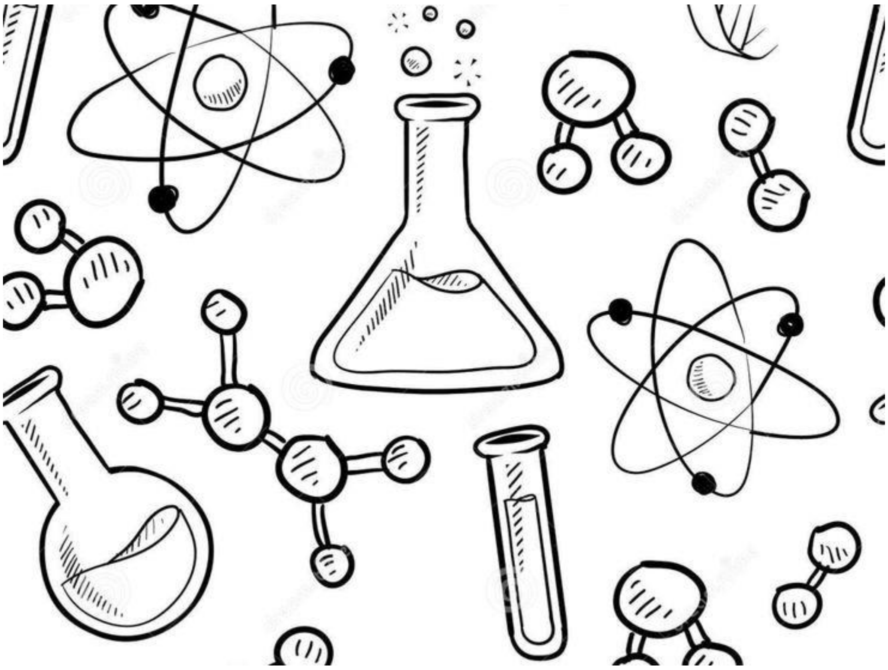
Zhuravleva Larisa Anatolyevna

MODERN PROBLEMS OF SCIENCE, TECHNOLOGY AND TECHNOLOGY

Training manual



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Reviewers

Doctor of Technical Sciences, head. department of modernization of technical means and irrigation technologies of FGBNU "Volzhniigim" N.F. Ryzhko

Candidate of Technical Sciences, Associate Professor of the Department of "Technosphere Safety and Transport and Technological Machines" of the N.I. Vavilov SSUGBI O.V. Kabanov

Translation: Zhuravleva L.A., Kireeva O.V.

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The textbook contains theoretical material on the main issues of scientific research. It is aimed at forming students' knowledge about the nature and methods of scientific research, about the ways of processing the data obtained as a result of research, about the sources of information and ways of writing and formatting scientific papers.

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Introduction

Science is a continuously developing system of knowledge of the objective laws of nature, society and thinking, obtained and transformed into the direct productive force of society as a result of special human activities. The concept of "science" has several basic meanings.

First, under science (Greek episteme, lat. scientia) we understand the sphere of human activity aimed at the development and theoretical schematization of objective knowledge about reality.

Secondly, science acts as a result of this activity — a system of acquired scientific knowledge.

Thirdly, the term "science" is used to refer to certain branches of scientific knowledge.

Science is the field of activity where the main goal is to obtain the most scientific knowledge. Science is defined as a sphere of human activity, the function of which is the development and theoretical systematization of objective knowledge about reality. In a narrow sense, the term "science" is also used to refer to certain branches of scientific knowledge.

Knowledge is a proven result of cognition of reality. Its true reflection in the human mind.

The main function of knowledge is the ideal reproduction in linguistic form of generalized ideas about the natural connections of the objective world.

The functions of knowledge are:

-generalization of disparate ideas about the laws of the nature of society and thinking;

-storage in generalized representations of everything that can be transmitted as a stable basis for practical actions.

Knowledge is a product of people's social activities aimed at transforming reality.

Cognition is the process of human thought moving from ignorance to knowledge.

Cognition is based on the reflection of objective reality in the human mind in the process of his social, industrial and scientific activities, called practice. The needs of practice are the main and driving force behind the development of cognition, its goal.

Man learns the laws of nature in order to master the forces of nature and put them at his service; he learns the laws of society in order to influence the course of historical events in accordance with them.

1 FEATURES OF SCIENTIFIC KNOWLEDGE AND ITS ROLE IN MODERN CIVILIZATION

The beginning of man-made civilization

Science plays a special role in modern civilization. The technological progress of the twentieth century, which led to a new quality of life in the developed countries of the West and East, is based on the application of scientific achievements. Science is revolutionizing not only the sphere of production, but also influencing many other spheres of human activity, starting to regulate them, rebuilding their means and methods.

However, this was not always the case, and science did not occupy such a high place in the scale of value priorities in all cultures.

In the development of mankind, after it overcame the stage of barbarism and savagery, there were many civilizations - specific types of society, each of which had its own distinctive history. The famous philosopher and historian A. Toynbee identified and described 21 civilizations. All of them can be divided into two large classes, according to the types of civilizational progress - traditional and man-made civilizations.

Man-made civilization is a rather late product of human history. It was only in the XV-XVII centuries that a special type of development was formed in the European region, associated with the emergence of man-made societies, their subsequent expansion to the rest of the world and the change in traditional societies under their influence. Some of these traditional societies were simply absorbed by the technogenic civilization, having gone through the stages of modernization, they then turned into typical technogenic societies. Others, having experienced the inoculations of Western technology and culture, nevertheless retained many traditional features, turning into a kind of hybrid formations.

The differences between traditional and man-made civilization are radical.

Traditional societies are characterized by a slow pace of social change. Of course, innovations also arise in them, both in the field of production and in the regulation of social relations, but progress is very slow compared to the life span of individuals and even generations. In traditional societies, several generations of people can change, discovering the same structures of social life, reproducing them and passing them on to the next generation. Types of activities, their means and goals can exist for centuries as stable stereotypes. Accordingly, in the culture of these societies, priority is given to traditions, patterns and norms that accumulate the experience of ancestors, canonized styles of thinking. Innovation is by no means perceived here as the highest value, on the contrary, it has limitations and is permissible only within the framework of centuries-old proven traditions. Ancient India and China, Ancient Egypt, the states of the Muslim East of the Middle Ages, etc., are all traditional societies. This type of social organization has survived to the present day: many third world states retain the features of a traditional society, although their collision with modern Western (man-made) civilization sooner or later leads to radical transformations of traditional culture and way of life.

As for man-made civilization, which is often referred to by the vague term "Western civilization", referring to the region of its origin, it is a special type of social development and a special type of civilization, the defining features of which are to a certain extent opposite to the characteristics of traditional societies. When the man-made civilization was formed in a relatively mature form, the pace of social change began to increase at a tremendous rate. It can be said that the extensive development of history is replaced by an intensive one; spatial existence is replaced by a temporary one. Growth reserves are no longer being drawn from the expansion of cultural zones, but from the restructuring of the very foundations of previous ways of life and the formation of fundamentally new opportunities.

The most important and truly epochal, world-historical change associated with the transition from a traditional society to a man-made civilization is the emergence of a new value system. The value is considered to be innovation itself, originality, and generally new. In a sense, the Guinness Book of World Records can be considered a symbol of a man-made society, unlike, say, the seven wonders of the world, which clearly demonstrates that each individual can become one of a kind, achieve something unusual, and it also calls for this. The Seven Wonders of the World, on the contrary, were designed to emphasize the completeness of the world and show that everything grandiose and truly unusual had already taken place. Further, personal autonomy occupies one of the highest places in the hierarchy of values, which is generally unusual for a traditional society. There, personality is realized only through belonging to a particular corporation, being an element in a strictly defined system of corporate relations. If a person is not included in any corporation, he is not a person.

In a technogenic civilization, a special type of personal autonomy arises: a person can change his corporate ties, he is not rigidly attached to them, he can and is able to build his relationships with people very flexibly, immerses himself in different social communities, and often in different cultural traditions.

Man-made civilization has existed for just over 300 years, but it has turned out to be very dynamic, mobile and very aggressive: it suppresses, subjugates, overturns, literally absorbs traditional societies and their cultures - we see this everywhere, and today this process is going on all over the world.

These worldview dominants were formed in the culture of man-made civilization at the pre-industrial stage of its development, during the Renaissance and then the European Enlightenment.

They expressed cardinal ideological meanings: the understanding of man, the world, the goals and purpose of human life.

Man was understood as an active being who is in an active relationship to the world. Human activity should be directed outward, towards the transformation and remaking of the external world, primarily nature, which man must subjugate. In turn, the outside world is viewed as an arena of human activity, as if the world were designed for a person to receive the necessary benefits for himself, to satisfy his needs. Of course, this does not mean that other, including alternative, worldview ideas do not arise in the New European cultural tradition.

Technogenic civilization in its very existence is defined as a society that is constantly changing its foundations. Therefore, its culture actively supports and values the constant generation of new patterns, ideas, concepts, only some of which can be implemented in today's reality, and the rest appear as possible programs of future life, addressed to future generations. In the culture of technogenic societies, one can always find ideas and value orientations that are alternative to the dominant values. But in the real life of society, they may not play a decisive role, remaining as if on the periphery of public consciousness and not moving the masses of people.

The idea of transforming the world and subjugating nature by man has been dominant in the culture of man-made civilization at all stages of its history, right up to our time. If you will, this idea was the most important component of the "genetic code" that determined the very existence and evolution of man-made societies. As for traditional societies, here the active attitude towards the world, which acts as a generic sign of a person, was understood and evaluated from fundamentally different positions.

For a long time, this worldview seemed obvious to us. However, it is difficult to find it in traditional cultures. The conservatism of activities inherent in traditional societies, the slow pace of their evolution, and the dominance of regulatory traditions constantly limited the manifestation of human activity and transformative activity. Therefore, this activity itself was interpreted rather not as outward-directed, to change external objects, but as inward-oriented, to self-contemplation and self-control, which ensure adherence to tradition.

The principle of transformative action, formulated in European culture during the Renaissance and Enlightenment, can be contrasted as an alternative model to the principle of ancient Chinese culture "wu-wei", which requires non-interference in the course of the natural process and the individual's adaptation to the prevailing social environment. This principle excluded the desire for its purposeful transformation, and required self-control and self-discipline of an individual joining a particular corporate structure. The wu-wei principle covered almost all the main aspects of human life. It expressed a certain understanding of the specifics and values of agricultural labor, in which much depended on external, natural conditions and which constantly required adjusting to these conditions - guessing the rhythms of weather changes, patiently growing plants, accumulating centuries of experience in observing the natural environment and plant properties. There was a well-known parable in Chinese culture that ridiculed a man who showed impatience and dissatisfaction with how slow the cereals were growing and began pulling the plants to speed up their growth.

But the wu-wei principle was also a special way of integrating an individual into the established traditional order of social relations, orienting a person to fit into a social environment in which freedom and self-realization of an individual are achieved mainly in the field of self-change, but not changes in established social structures.

The values of technogenic culture set a fundamentally different vector of human activity. Transformative activity is considered here as the main purpose of a person. The activity-active ideal of man's relationship to nature then extends to the sphere of social relations, which also begin to be considered as special social objects that a person can purposefully transform. This is connected with the cult of struggle, revolutions as the locomotives of history. It is worth noting that the Marxist concept of class struggle, social revolutions and dictatorship as a way to solve social problems arose in the context of the values of technogenic culture.

Closely related to the understanding of human activity and purpose is the second important aspect of value and worldview orientations, which is characteristic of the culture of the man-made world, the understanding of nature as an orderly, lawfully arranged field in which a rational being who has learned the laws of nature is able to exercise its power over external processes and objects, to put them under its control. It is only necessary to invent technology to artificially change the natural process and put it at the service of man, and then the tamed nature will satisfy human needs on an ever-expanding scale.

As for traditional cultures, we will not find such ideas about nature in them. Nature is understood here as a living organism in which a person is organically embedded, but not as an impersonal subject field governed by objective laws. The very concept of a law of nature, different from the laws that regulate social life, was alien to traditional cultures.

At one time, the famous philosopher and scientist M.K. Petrov proposed a kind of thought experiment: imagine how a person raised in the value system of traditional civilization would look at the ideals of the New European culture? Referring to S. Powell's work "The Role of Theoretical Science in European Civilization," M.K. Petrov cited the testimony of missionaries about the reaction of Chinese sages to descriptions of European science. "The sages found the very idea of science absurd, because although it is given to the ruler of the Celestial Empire to establish laws and interpret their execution under threat of punishment, it is given only to those who are able to "understand" these laws and obey them, and the "wood, water and stones" that European hoaxers are talking about, obviously this They do not possess the property of "understanding": laws cannot be prescribed to them and they cannot be required to comply with them."

The pathos of conquering nature and transforming the world, characteristic of man-made civilization, gave rise to a special attitude towards the ideas of the domination of force and power. In traditional cultures, they were understood primarily as the direct power of one person over another. In patriarchal societies and Asian despotisms, power and domination extended not only to the subjects of the sovereign, but was also exercised by a man, the head of the family over his wife and children, whom he possessed in the same way as the king or emperor possessed the bodies and souls of his subjects. Traditional cultures did not know the autonomy of the individual and the idea of human rights. As A.I. Herzen wrote about the societies of the ancient East, a person here "did not understand his dignity; therefore, he was either a slave lying in the dust, or an unbridled despot."

In the man-made world, one can also find many situations in which domination is carried out as a force of direct coercion and the power of one person over another. However, the relationship of personal dependence ceases to dominate here and is subordinated to new social connections. Their essence is determined by the universal exchange of results of activities that take the form of goods.

Power and domination in this system of relations presupposes the possession and appropriation of goods (things, human abilities, information as commodity values having a monetary equivalent).

As a result, in the culture of a technogenic civilization, there is a peculiar shift in emphasis in understanding the objects of domination of power and authority - from a person to a thing produced by him. In turn, these new meanings were easily combined with the ideal of an activity-transforming human destiny.

Transformative activity itself is regarded as a process that ensures a person's power over an object, dominion over external circumstances that a person is called upon to subjugate.

A person must transform from a slave of natural and social circumstances into their master, and the very process of this transformation was understood as mastering the forces of nature and the forces of social development. The characterization of civilizational achievements in terms of power ("productive forces", "power of knowledge", etc.) expressed an attitude towards the acquisition of new opportunities by man, allowing him to expand the horizon of his transformative activity.

By changing not only the natural environment, but also the social environment through the application of mastered forces, a person realizes his destiny as a creator, a world transformer.

This is due to the special status of scientific rationality in the value system of man-made civilization, the special importance of the scientific and technical view of the world, because knowledge of the world is a condition for its transformation. It creates confidence that a person is able, by revealing the laws of nature and social life, to regulate natural and social processes in accordance with their goals.

Therefore, in the New European culture and in the subsequent development of technogenic societies, the category of science acquires a peculiar symbolic meaning. It is perceived as a necessary condition for prosperity and progress. The value of scientific rationality and its active influence on other spheres of culture is becoming a characteristic feature of the life of technogenic societies.

The specifics of scientific knowledge

The main distinguishing features of science

Intuitively, it seems clear how science differs from other forms of human cognitive activity. However, a clear explication of the specific features of science in the form of signs and definitions turns out to be quite a difficult task. This is evidenced by the variety of definitions of science, the ongoing discussions on the problem of demarcation between it and other forms of knowledge.

Scientific knowledge, like all forms of spiritual production, is ultimately necessary in order to regulate human activity. Different types of cognition perform this role in different ways, and the analysis of this difference is the first and necessary condition for identifying the features of scientific knowledge.

An activity can be considered as a complexly organized network of various acts of transformation of objects, when the products of one activity pass into another and become its components. For example, iron ore as a product of mining production becomes an object that is transformed into the activity of a steelworker, machine tools produced at a factory from steel produced by a steelworker become means of activity in another production. Even subjects of activity - people who transform objects in accordance with their goals - can be represented to a certain extent as the results of training and education activities, which ensure that the subject learns the necessary patterns of action, knowledge and skills to apply certain means in their activities.

Activities are always governed by certain values and goals. Value answers the question: "what is this or that activity for?" The goal is to answer the question: "what should be gained in the activity". The goal is the ideal image of the product. It is embodied, objectified in the product, which is the result of the transformation of the object of activity.

Since activity is universal, its objects can function not only as fragments of nature that are transformed in practice, but also as people whose "properties" change when they are included in various social subsystems, as well as these subsystems themselves that interact within society as an integral organism. Then, in the first case, we are dealing with the "objective side" of man's change of nature, and in the second - with the "objective side" of practice aimed at changing social objects. From this point of view, a person can act both as a subject and as an object of practical action.

In the early stages of the development of society, the subjective and objective aspects of practical activity are not separated in cognition, but are taken as a single whole. Cognition reflects the ways in which objects can be changed in practice, including human goals, abilities, and actions. This view of the objects of activity is transferred to the whole of nature, which is viewed through the prism of practice.

It is known, for example, that in the myths of ancient peoples, the forces of nature are always likened to human forces, and its processes to human actions. Primitive thinking, when explaining the phenomena of the external world, invariably resorts to comparing them with human actions and motives. It is only in the process of a long-term evolution of society that cognition begins to exclude anthropomorphic factors from the characteristics of subject relations. An important role in this process was played by the historical development of practice, and above all, the improvement of tools and tools.

As the tools became more complex, those operations that had previously been directly performed by humans began to "materialize", acting as a sequential effect of one tool on another and only then on the transformed object. Thus, the properties and states of objects resulting from these operations no longer seemed to be caused by direct human efforts, but increasingly acted as a result of the interaction of natural objects themselves. So, if in the early stages of civilization moving goods required muscular efforts, then with the invention of the lever and block, and then the simplest machines, it was possible to replace these efforts with mechanical ones. For example, using a block system, it was possible to balance a large load with a small one, and by adding a small weight to a small load, lift a large load to the desired height. Here, no human effort is needed to lift a heavy body: one load moves the other independently.

This transfer of human functions to mechanisms leads to a new understanding of the forces of nature. Previously, forces were understood only by analogy with human physical efforts, but now they are beginning to be considered as mechanical forces. The above example can serve as an analogue of the process of "objectification" of the subject relations of practice, which, apparently, began already in the era of the first urban civilizations of antiquity. During this period, cognition begins to gradually separate the objective side of practice from subjective factors and consider this side as a special, independent reality. Such consideration of practice is one of the necessary conditions for the emergence of scientific research.

Science sets as its ultimate goal to anticipate the process of transformation of objects of practical activity (an object in its initial state) into corresponding products (an object in its final state). This transformation is always determined by essential relationships, the laws of change and development of objects, and the activity itself can be successful only when it is consistent with these laws. Therefore, the main task of science is to identify the laws according to which objects change and develop.

In relation to the processes of transformation of nature, this function is performed by natural and technical sciences. The processes of changing social objects are studied by social sciences. Since various objects can be transformed in activity - objects of nature, man (and his states of consciousness), subsystems of society, iconic objects functioning as cultural phenomena, etc. - they can all become subjects of scientific research.

The orientation of science towards the study of objects that can be included in an activity (either actual or potentially as possible objects of its future transformation), and their study as obeying objective laws of functioning and development is the first main feature of scientific knowledge.

This feature distinguishes it from other forms of human cognitive activity. For example, in the process of artistic exploration of reality, objects included in human activity are not separated from subjective factors, but are taken in a kind of "gluing" with them. Any reflection of objects in the objective world in art simultaneously expresses a person's value attitude towards the object.

An artistic image is a reflection of an object that contains the imprint of a human personality, its value orientations, which are fused into the characteristics of the reflected reality. To exclude this interpenetration is to destroy the artistic image. In science, the peculiarities of the life activity of a person who creates knowledge, her value judgments are not directly part of the generated knowledge (Newton's laws do not allow us to judge what Newton loved and what he hated, whereas, for example, Rembrandt's portraits depict the personality of Rembrandt himself, his worldview and his personal attitude to the depicted social phenomena a portrait painted by a great artist always acts as a self-portrait).

Science is focused on a substantive and objective study of reality. Of course, this does not mean that the personal aspects and value orientations of a scientist do not play a role in scientific creativity and do not affect its results.

The process of scientific cognition is determined not only by the peculiarities of the studied object, but also by numerous socio-cultural factors.

Considering science in its historical development, one can find that as the type of culture changes, the standards of presenting scientific knowledge, the ways of seeing reality in science, and the styles of thinking that are formed in the context of culture and influenced by its various phenomena change. This impact can be represented as the inclusion of various socio-cultural factors in the process of generating scientific knowledge proper. However, the statement of the connections between the objective and the subjective in any cognitive process and the need for a comprehensive study of science in its interaction with other forms of human spiritual activity do not eliminate the question of the difference between science and these forms (ordinary knowledge, artistic thinking, etc.). The first and necessary characteristic of such a difference is a sign of the objectivity and subjectivity of scientific knowledge.

Science in human activity highlights only its subject structure and considers everything through the prism of this structure. Just as King Midas from the famous ancient legend - no matter what he touched, everything turned to gold - so science, no matter what it touched, is for her an object that lives, functions and develops according to objective laws.

The question immediately arises here: well, then what about the subject of activity, with his goals, values, and states of consciousness? All this belongs to the components of the subjective structure of activity, but science is able to explore these components, because there are no prohibitions for it to explore any real-life phenomena. The answer to these questions is quite simple: yes, science can explore any phenomena of human life and consciousness, it can explore activity, the human psyche, and culture, but only from one angle - as special subjects that obey objective laws. Science also studies the subject structure of activity, but as a special object.

And where science cannot construct an object and imagine its "natural life", defined by its essential connections, its claims end there. Thus, science can study everything in the human world, but from a special perspective and from a special point of view. This particular perspective of subjectivity expresses both the boundlessness and the limitations of science, since man, as an independent, conscious being, has free will, and he is not only an object, he is also a subject of activity. And in this subjective being, not all states can be exhausted by scientific knowledge, even if we assume that such comprehensive scientific knowledge about a person and his vital activity can be obtained.

There is no anti-scientism in this statement about the limits of science. It's just a statement of the indisputable fact that science cannot replace all forms of knowledge of the world, of the whole culture. And everything that escapes her field of vision is compensated by other forms of spiritual comprehension of the world - art, religion, morality, philosophy.

By studying objects transformed into activities, science is not limited to the knowledge of only those subject connections that can be mastered within the framework of the types of activities that have historically developed at this stage of society's development. The purpose of science is to anticipate possible future changes in objects, including those that would correspond to future types and forms of practical world change.

As an expression of these goals, science develops not only research that serves today's practice, but also layers of research, the results of which can be applied only in the practice of the future. The movement of knowledge in these strata is no longer so much driven by the immediate demands of today's practice as by cognitive interests, through which society's needs for forecasting future ways and forms of practical exploration of the world are manifested.

For example, the formulation of internal scientific problems and their solution within the framework of fundamental theoretical physics research led to the discovery of the laws of the electromagnetic field and the prediction of electromagnetic waves, the discovery of the laws of atomic fission, the quantum laws of atomic radiation during the transition of electrons from one energy level to another, etc. All these theoretical discoveries laid the foundation for future ways of mass practical development of nature in production. A few decades later, they became the base for applied engineering research and development, the introduction of which into production, in turn, revolutionized engineering and technology - electronic equipment, nuclear power plants, laser installations, etc. appeared.

The focus of science on studying not only objects that are transformed in today's practice, but also those that may become the subject of mass practical development in the future, is the second distinctive feature of scientific knowledge. This feature makes it possible to distinguish between scientific and ordinary, spontaneous empirical knowledge and to deduce a number of specific definitions characterizing the nature of science.

Self-monitoring questions

1. What is the specificity of scientific knowledge?
2. What are the challenges of survival in the man-made world?
3. Uncover the problem of the value of scientific and technological progress.
4. Explain the essence of the specifics of scientific knowledge.

2 SCIENCE AS A TRADITION. THE EVOLUTION OF APPROACHES TO THE ANALYSIS OF SCIENCE

One of the problems that significantly determined the development of the philosophy of science at the beginning of our century was called the demarcation problem (this term was introduced by Karl Popper). It's about defining the boundaries between science and non-science. Popper himself characterizes his interests in this field as follows: "At that time, I was not interested in the question of "when is a theory true?" or "when is a theory acceptable?" I have set myself another problem. I wanted to make a distinction between science and pseudoscience, knowing full well that science is often wrong and that pseudoscience can accidentally stumble upon the truth."

The most common answer to this question was that science differs from pseudoscience or from "metaphysics" in its reliance on facts, its empirical method. The concept, which was actively developing at that time within the framework of the so-called "Vienna Circle" and came from one of the greatest philosophers of the turn of the century, L. Wittgenstein, argued that only those propositions belong to science that are derived from true observation propositions or, equivalently, can be verified using these propositions. It followed that any theory claiming to be scientific must be deducible from experience.

Popper justifiably does not accept this thesis. Observation, from his point of view, already presupposes some theoretical attitude, some initial hypothesis. You can't just observe without having any prerequisites for it. Observation is always selective and purposeful: we start from a specific task and observe only what is needed to solve this problem. Popper illustrates the meaninglessness of "pure" observations as follows. Imagine a man who devoted his whole life to science, describing every thing that caught his eye. He bequeaths all this "priceless treasure" of observations to the Royal Society. The absurdity of the situation needs no comment.

It can be added that any developed theory is formulated not for real, but for ideal objects. In mechanics, for example, these are material points, absolutely solid bodies, ideal liquids, etc. The famous theory of the location of human economic activity, built by Thunen, proceeds from the idea of an isolated state with a single city on an absolutely homogeneous plain. The theory of central Crystaller locations also assumes an isotropic flat surface. In other words, the theory is based on assumptions that directly contradict experience. How, then, can it flow from experience?

What does Popper himself suggest? His idea is very simple and beautiful, although, as we will see below, it also encounters significant difficulties. The essence of the idea boils down to the following: "The criterion of the scientific status of a theory is its falsifiability, refutability, or verifiability." Any theory can be confirmed with facts if we specifically seek such confirmations, but a good theory should first of all provide grounds for its refutation. Any good theory, Popper believes, is a kind of prohibition, i.e. it prohibits certain events. The more a theory prohibits, the better it is, because the more it risks being refuted.

It is not difficult to see that Popper's entire concept has a pronounced normative character. It's about how a scientist should work in order to stay within the framework of science, and what requirements should be met by the theories he builds.

And what is science and what defines its boundaries, other than Popper's own criterion, is a question that simply does not arise in this context. "I am the state," the notorious French king declared at the time. "Science is Me," Popper actually asserts and sets the boundaries of science.

But science has a life of its own, and it soon turns out that Popper's criterion doesn't work. This may seem paradoxical: we do science ourselves, we seem to be the masters of the situation, but the criteria of scientific knowledge that we have established do not work. Maybe it's because not everyone recognizes these criteria, that they are not generally accepted? And if they are recognized and made public, then something will change? The paradox is that there is almost nothing. Science is more than the sum of coordinated human actions.

But let's return to K. Popper's criterion. History shows that theories live, develop, and even flourish, despite contradictions with experimental data. Here is a concrete example. In 1788, the great Lagrange wrote about Euler's equations: "We owe to Euler the first general formulas for the motion of fluids, written in simple and clear partial differential symbols. Thanks to this discovery, the whole mechanics of fluids was reduced to the question of analysis, and if these equations were integrable, it would be possible in any case to fully determine the movement of a fluid under the influence of any forces." Lagrange's hopes were not fulfilled: in some cases, Euler's equations were integrated, but the results of calculations sharply differed from observations. Did this lead to the abandonment of Euler's equations? Absolutely not.

Here is what the famous American mathematician and hydrodynamicist G. Birkhoff writes about this: "In hydrodynamics, such undoubted contradictions between experimental data and conclusions based on plausible reasoning are called paradoxes. These paradoxes have been the subject of many jokes. So recently it was said that in the nineteenth century, "hydrodynamicists were divided into hydraulic engineers, who observed what could not be explained, and mathematicians, who explained what could not be observed." As we can see, hydrodynamics not only exists, but is even capable of joking. "It is now commonly stated," Birkhoff continues, "that such paradoxes arise from the difference between real liquids with low but finite viscosity and ideal liquids with zero viscosity." So, the whole point is again about ideal objects, without which it is probably impossible to build a theory.

T. Kuhn's Normal Science

A sharp turn in the approach to the study of science was made by the American historian of physics Thomas Kuhn in his work "The Structure of Scientific Revolutions", which appeared in 1962. Science, or more precisely, normal science, according to Kuhn, is a community of scientists united by a rather rigid program, which Kuhn calls a paradigm and which completely determines, from his point of view, the activity of each scientist. It is the paradigm that Kuhn focuses on as a kind of transpersonal education. It is with the change of paradigms that he connects the fundamental changes in the development of science - scientific revolutions. But let's look at its concept in more detail.

"Normal science," Kuhn writes, "is "research that is firmly based on one or more past achievements-achievements that have been recognized for some time by a certain scientific community as the basis for the development of its further practical activities." It follows from the definition itself that we are talking about tradition, i.e. science is understood as a tradition.

The past achievements that underlie this tradition act as a paradigm. Most often, this refers to some fairly generally accepted theoretical concept such as the Copernican system, Newton's mechanics, Lavoisier's oxygen theory, etc. Kuhn primarily associates scientific revolutions with the change of concepts of this kind. Concretizing his idea of the paradigm, he introduces the concept of a disciplinary matrix, which includes the following four elements:

1. Symbolic generalizations such as Newton's second law, Ohm's law, Joule-Lenz law, etc.

2. Conceptual models, examples of which are general statements of the following type: "Heat is the kinetic energy of the parts that make up a body" or "All phenomena that we perceive exist due to the interaction of qualitatively homogeneous atoms in the void."

3. The values adopted in the scientific community and manifested in the selection of research areas, in assessing the results obtained and the state of science as a whole.

4. Samples of solutions to specific tasks and problems that the student inevitably faces in the learning process. Kuhn attaches special importance to this element of the disciplinary matrix, and we will discuss this in more detail in the next section.

What is the activity of a scientist within the framework of normal science? Kuhn writes: "Upon closer examination of this activity in a historical context or in a modern laboratory, it seems as if they are trying to squeeze nature into a paradigm, as into a pre-assembled and rather cramped box. The goal of normal science in no way requires the prediction of new kinds of phenomena: phenomena that do not fit into this box are often, in fact, completely overlooked. Scientists in the mainstream of normal science do not set themselves the goal of creating new theories, and they are usually intolerant of others creating such theories."

So, within the framework of normal science, a scientist is so rigidly programmed that not only does he not seek to discover or create anything fundamentally new, but he is not even inclined to recognize or notice this new thing. What does he do in this case? Kuhn's concept would have looked like an empty fantasy if he had not been able to convincingly show that normal science is capable of developing successfully. Kuhn, however, showed this, showed that tradition is not a brake, but, on the contrary, a necessary condition for the rapid accumulation of knowledge.

Indeed, the power of tradition lies precisely in the fact that we constantly reproduce the same actions, the same way of behaving over and over again under different, generally speaking, circumstances. Therefore, the recognition of a particular theoretical concept means constant attempts to comprehend more and more new phenomena from its point of view, while implementing standard methods of analysis or explanation. This organizes the scientific community, creating conditions for mutual understanding and comparability of results, and generates the "industry" of knowledge production that we observe in modern science.

But we are not talking at all about creating something fundamentally new. In Kuhn's figurative expression, scientists working in normal science are constantly busy "putting things in order," i.e. verifying and clarifying known facts, as well as collecting new facts that are predicted in principle or highlighted by theory. A chemist, for example, may be busy determining the composition of more and more new substances, but the very concept of chemical composition and the methods of determining it are already set by the paradigm. In addition, within the framework of the paradigm, no one doubts that any substance can be characterized from this point of view.

Thus, normal science is developing very rapidly, accumulating a wealth of information and problem-solving experience. And at the same time, it does not develop contrary to traditions, but precisely because of its traditionalism. We owe the understanding of this fact to Thomas Kuhn. He can rightfully be considered the founder of the doctrine of scientific traditions. Of course, attention had been paid to tradition in the work of a scientist before, but for the first time Kuhn made traditions the central object of consideration in the analysis of science, giving them the importance of the main constitutive factor in scientific development.

But in this case, how does the traditions themselves change and develop, and how do new paradigms arise? "Normal science," Kuhn writes, "does not aim to find a new fact or theory, and success in normal scientific research does not consist in this at all. Nevertheless, new phenomena, the existence of which no one suspected, are being discovered again and again by scientific research, and radically new theories are being invented again and again by scientists. The story even suggests that the scientific enterprise has created an exceptionally powerful technique in order to present surprises of this kind."

How exactly do new fundamental facts and theories appear? "They are created unintentionally during the course of the game according to one set of rules, but their perception requires the development of another set of rules." In other words, a scientist does not seek to obtain fundamentally new results, however, acting according to the given rules, he inadvertently, i.e. randomly and sideways, comes across such facts and phenomena that require changes in these rules themselves.

Let's summarize some results. It is not difficult to see that Kuhn's concept already marks a completely different vision of science compared to the normative approach of the Vienna Circle or K. Popper. The latter focus on the decision-making scientist who acts as a determining and driving force in the development of science. Science is actually considered here as a product of human activity. Therefore, it is extremely important to answer the question: what criteria should a scientist be guided by, what should he strive for? In Kuhn's model, there is a complete change of roles: here, science, represented by a paradigm, dictates its will to the scientist, acting as a kind of faceless force, and the scientist is just an expression of the demands of his time. Kuhn also reveals the nature of science as a transpersonal phenomenon: it is about tradition.

Is there anything to object to this rather simple and principled model? Two points are questionable. The first one was probably a stumbling block for Kuhn himself. How can a paradigm shift under the pressure of new facts be reconciled with the claim that scientists are not inclined to perceive phenomena that do not fit into the paradigm, that these phenomena are "often, in fact, generally overlooked"? On the one hand, Kuhn cites many facts showing that tradition prevents the assimilation of the new, on the other, he is forced to admit such assimilation. It looks like a contradiction.

The dubiousness of the second point is less obvious. Kuhn sharply contrasts work within the framework of normal science, on the one hand, and paradigm shift, on the other. In one case, the scientist works in a certain tradition, in the other, he goes beyond it. Of course, these two points are opposed to each other, but probably not only on the scale of science as a whole, but also in relation to any traditions of a more private nature. Kuhn mostly talks about science, and this overly globalizes our understanding of tradition.

In fact, it turns out that science is almost one tradition, and this makes it very difficult to analyze what is happening in science. Therefore, we will try to enrich our understanding of scientific traditions somewhat. This is absolutely necessary in the way of critical evaluation and improvement of Kuhn's concept, in the way of developing those undoubtedly important prerequisites contained in his model of science.

M. Polanyi's concept of implicit knowledge and the diversity of scientific traditions

It is not difficult to show that in scientific knowledge we are dealing not with one or several, but with a complex variety of traditions that differ from each other in terms of content, functions as part of science, and the way they exist. Let's start with the last one.

It is enough to look more closely at Kuhn's disciplinary matrix to notice some heterogeneity. On the one hand, he lists such components as symbolic generalizations and conceptual models, and on the other, values and patterns of solutions to specific problems. But the former exist in the form of texts and form the content of textbooks and monographs, while no one has yet written a training course outlining the system of scientific values.

We don't get our value orientations from textbooks, we learn them in much the same way as our native language, i.e. based on direct samples. Every scientist, for example, has some ideas about what a beautiful theory or a beautiful solution to a problem is, an elegantly staged experiment or subtle reasoning, but it's hard to talk about it, it's just as difficult to express in words as our ideas about the beauty of nature.

The famous chemist and philosopher M. Polanyi convincingly showed in the late 50s of our century that the prerequisites on which a scientist relies in his work cannot be fully verbalized, i.e. expressed in language. "The large amount of study time," he wrote, "that chemistry, biology, and medical students devote to practical studies is evidence of the important role that the transfer of practical knowledge and skills from teacher to student plays in these disciplines. From what has been said, we can conclude that at the very heart of science there are areas of practical knowledge that cannot be conveyed through formulations." Polanyi called this type of knowledge implicit knowledge. Value orientations can be safely counted among them.

So, traditions can be either verbalized, existing in the form of texts, or non-verbalized, existing in the form of implicit knowledge. The latter are passed on from teacher to student or from generation to generation at the level of direct demonstration of activity patterns or, as they sometimes say, at the level of social relay races. We will talk about these latter in more detail later. But what is important now is that the recognition of implicit knowledge greatly complicates and enriches our picture of the tradition of science. It is necessary to take into account not only values, as Kuhn does, but also many, many other things. No matter what a scientist does, setting up an experiment or presenting its results, giving lectures or participating in a scientific discussion, he often unwittingly demonstrates samples that, like an invisible virus, "infect" others.

By introducing implicit knowledge and corresponding implicit traditions, we enter a complex and little-explored world, the world where our language and scientific terminology live, where logical forms of thinking and its basic categorical structures are passed down from generation to generation, where the so-called common sense and scientific intuition are rooted. Obviously, we learn our native language not from dictionaries or grammars. To the same extent, you can be quite logical in your reasoning without ever opening a logic textbook. And where do we borrow our categorical concepts? After all, the child is already constantly asking his famous question "why?", although no one has given him a special course of lectures on causality. All this is a world of implicit knowledge. Historians and cultural scientists often use the term "mentality" to refer to those layers of spiritual culture that are not expressed in the form of explicit knowledge and nevertheless significantly determine the face of a particular epoch or people. But any science has its own mentality, which distinguishes it from other fields of scientific knowledge and from other spheres of culture, but is closely related to the mentality of the era.

The juxtaposition of explicit and implicit knowledge makes it possible to more accurately draw and realize the difference between scientific schools, on the one hand, and scientific directions, on the other, that has long been fixed in speech. The development of a scientific field may be associated with the name of one or another major scientist, but it does not necessarily imply constant personal contacts between people working in this field. The scientific school is another matter. Here, these contacts are absolutely necessary, because experience plays a huge role, directly transmitted at the sample level from teacher to student, from one member of the community to another. That is why scientific schools have, as a rule, a certain geographical location: the Kazan School of Chemistry, the Moscow Mathematical School, etc.

But what about the samples of solutions to specific problems, to which T. Kuhn attaches great importance? On the one hand, they exist and are translated as text, and therefore can be identified with explicit, i.e. explicit knowledge. But, on the other hand, we will have samples in front of us, not verbal prescriptions or rules, if the information that is not directly expressed in the text is important to us. Let's say, for example, that the text contains a proof of the Pythagorean theorem, but we are not interested in this particular theorem, but in how a mathematical proof should be constructed in general. This latter information is presented here only in the form of an example, i.e. implicitly. Of course, after reviewing the proof of several theorems, we will gain some experience and some skills of mathematical reasoning in general, but again it will be difficult to put it into words in the form of a fairly clear prescription.

In the light of the above, two types of implicit knowledge and implicit traditions can be distinguished. The former involve reproducing direct patterns of activity, while the latter involve the text as an intermediary. The former are impossible without personal contacts, for the latter such contacts are optional. It's all pretty obvious. It is much more difficult to contrast implicit knowledge of the second type and explicit knowledge. Indeed, after reading or hearing from a teacher the proof of the Pythagorean theorem, we can either repeat this proof or try to transfer the experience gained to the proof of another theorem.

But strictly speaking, in both cases we are talking about reproducing a sample, although it is hardly necessary to prove that the second way is much more difficult than the first. The difference can be demonstrated by the example of learning a foreign language. It's one thing, for example, to memorize and repeat a phrase, another thing is to construct a similar phrase using other words. In both cases, the original phrase plays the role of a sample, but when moving from the first to the second, there is a significant expansion of the possibilities of choice. While simply repeating the original phrase limits these possibilities to pronunciation features, creating a new sentence involves choosing the appropriate words from the entire arsenal of the language. We will return to this distinction later.

So, the introduced M.The Polanyi concept of implicit knowledge makes it possible to significantly enrich and differentiate the overall picture of the tradition of science. Let's take another step in this direction. It's not hard to see that implicit traditions can be based on both action patterns and product patterns. This is essential: it's one thing if you were shown the production technology of an object, for example, pottery, but another thing is if you were shown a ready-made jug and offered to make the same one. In the second case, you will have a difficult and not always feasible job to reconstruct the necessary production operations. In cognition, however, we are constantly faced with problems of this kind.

Let's look at some examples. We are used to talking about such methods of cognition as abstraction, classification, and the axiomatic method. But strictly speaking, the word "method" should be put in quotation marks here. It is possible to demonstrate at the level of a sequence of operations some method of chemical analysis or a method for solving a system of linear equations, but no one has yet been able to do this in relation to classification or the process of constructing an axiomatic theory. Euclid's "Principles" played a huge role in the formation of the axiomatic method, but it was not a sample of operations, but a sample of a product. The same is true with classification. Science knows a lot of examples of successful classifications, a lot of scientists are trying to build something similar in their field, but no one knows the recipe for building a successful classification.

Something similar can be said about methods such as abstraction, generalization, formalization, etc. We can easily demonstrate relevant product samples, i.e. general and abstract statements or concepts, rather formalized theories, but not procedures, not modes of action. By the way, they do not necessarily have to exist, because the processes of historical development are not always expressible in terms of purposeful human actions. We all know our native language, it exists, but this does not mean that it is possible to propose or reconstruct the technology of its creation.

We do not want to say that these methods and, in general, samples of cognitive products are something illusory, we are by no means going to minimize their importance. They underlie goal-setting, form the ideals that a scientist strives to achieve, organize a search, and determine the form of systematization of accumulated material. However, they should not be confused with traditions that define the procedural arsenal of scientific knowledge.

From all of the above, one more conclusion suggests itself: each tradition has its own sphere of distribution, and there are scientific traditions that do not go beyond a particular field of knowledge, but there are general scientific or, to put it more carefully, interdisciplinary ones. Generally speaking, this is quite obvious at the level of explicit knowledge: the methods of physics or chemistry are widely used not only in the natural sciences, but also in the social sciences, thus acting as interdisciplinary methods. However, the above makes it possible to significantly expand our understanding in this area.

Axiomatic constructions in geometry became at one time a model for similar constructions in other fields of knowledge. Modern physical theories have become an ideal for other disciplines seeking to theorize and mathematize. The idea arises that the same concept can act both as a Kuhnian paradigm and as a model for other scientific disciplines. We are talking about product samples. For example, ecology, which emerged in the last century as a branch of biology, has since brought to life many of its counterparts such as the ecology of crime, ethnic ecology, etc. Needless to say, all these disciplines have no direct relation not only to biology, but also to natural science in general.

At this point, T. Kuhn's concept begins to experience serious difficulties. In the light of his model, science looks like an isolated organism, living in its paradigm exactly in a spacesuit with an autonomous life support system. And now it turns out that there is no spacesuit and the scientist is exposed to all environmental influences. There is even a question that Kuhn could not possibly have raised: in which traditions does a scientist work primarily - in the field of special sciences or interdisciplinary?

And why is a biologist who uses the methods of physics or chemistry at every step and often dreams of theorizing and mathematizing his field according to a physical model, why is he still a biologist and not someone else? What is the reason for his Self-image? This question about the boundaries of science is not as simple as it might seem at first glance. To find the answer means to identify a special class of subject-forming traditions, with which science associates its specificity, its special position in the system of knowledge, and its Self-image.

Difficulties and problems in building models of science

Let us now summarize the overall results and try to formulate the main problems that we have to solve. T. Kuhn's concept is the first attempt to build a model of science as a transpersonal phenomenon. Kuhn is not interested in the scientist and his methods of work, but in the program that imposes its will on the scientist, dictating to him, in particular, the tasks that he sets and the methods that he uses. Within the framework of this model, a scientist begins to resemble a chess piece that moves according to certain rules, including the elementary rules of moves, and the principles of chess tactics and strategy.

What's wrong with this model? There can be a lot of quibbles. 1. Kuhn did not reveal the mechanism of scientific revolutions, the mechanism of formation of new programs, did not analyze the correlation of such phenomena as traditions and innovations. He could not do this, because his concept is too syncretic to solve such problems. 2. Kuhn understands the programs in which the scientist works too summarily and undifferentiated, which creates the illusion of great isolation of various scientific disciplines. However, awareness of the diversity of these programs leads, as we have seen, to the opposite difficulty, to the loss of clear disciplinary boundaries. 3. Kuhn's scientist is hard-coded, and Kuhn strongly emphasizes his paradigmality. However, if there are a lot of programs, then the scientist acquires freedom of choice, which should probably significantly change the picture. 4. Kuhn's model is non-specific and does not solve the problem of demarcation, because it is obvious that paradigmality is inherent not only in science, but also in other spheres of culture and human activity in general. But the solution to this problem should probably be sought not by formulating regulatory requirements for activities or their products, but by analyzing science as a whole, as a transpersonal education.

Overcoming all these difficulties involves building a richer model of science. But the main thing that should be done first of all is to show what exactly we are building a model of, what science is like as an object of our research. For example, various optical phenomena can be described and systematized, but building a general theory requires answering the question of what light is and what kind of phenomena it belongs to. One such answer was that light is a wave. We need to answer a similar question: what kind of phenomena does science belong to?

Self-monitoring questions

1. Karl Popper and the demarcation problem
2. Basic laws of change and development
3. Difficulties and problems of T.Kuhn's concept
4. The concept of implicit knowledge
5. What is the evolutionary nature of approaches to the analysis of science

3 THE STRUCTURE OF SCIENCE AS A TRADITION
Science and social memory

Science is connected not only with the production of knowledge, but also with its constant systematization. Monographs, reviews, and training courses are all attempts to bring together the results obtained by a huge number of researchers at different times and in different places. From this point of view, science can be considered as a mechanism of centralized social memory, which accumulates the practical and theoretical experience of mankind and makes it universally available. We are no longer talking about relay races that form the basic mechanisms of memory, but about more complex formations involving verbalized knowledge, writing, book printing, etc.

What is the specificity of a scientific discovery? Geographers have long solved this issue in relation to the discovery of new territories. Discovery refers to the first visit to this territory by representatives of peoples who speak written language, its description and mapping. Let's pay attention to the latter. The geographer connects all his observations with a map, i.e. with a certain model of the area under study, obtained during the previous development of cognition. In other words, the map both programs the geographer's work and records the results of this work. Maps and drawings of small areas probably appeared already in primitive man, but they played the role of situational means of communication, and this did not mean the emergence of science. Science appeared when all the maps were brought together, and they began to function as a means of universal social memory. Therefore, to put it on the map is to discover it for humanity.

What has been said in relation to geography can be generalized to scientific knowledge in general. The formation of science is the formation of mechanisms of global centralized social memory, i.e. mechanisms of accumulation and systematization of all knowledge acquired by mankind.

Unfortunately, these traditions are often not given enough attention, giving the main importance to research methods. However, this is not entirely legitimate. Of course, methods play a very important role. But the formation of new scientific disciplines is often associated not so much with methods as with the emergence of new knowledge organization programs. E. Haeckel, for example, is considered to be the founder of ecology, who expressed the idea of the need for a science that studies the relationship of organisms with the environment. A huge amount of information about such relationships had already been accumulated by this time in other biological disciplines, but it was Haeckel who gave the impetus to bring all this information together within the framework of one scientific subject.

Against the background of a general underestimation of knowledge systematization programs, one can also find directly opposite points of view. "The need for knowledge is only the grandmother of science," wrote our famous literary critic B.I. Yarkho, "but the mother is the "need to communicate knowledge." "Indeed," he continues below, "there is no scientific knowledge (as opposed to unscientific): when discovering the most reliable scientific positions, intuition, fantasy, and emotional tone play a huge role along with intelligence. Science, on the other hand, is a rationalized presentation of what is known, a logically formed description of that part of the world that we have managed to comprehend, i.e. science is a special form of communication (presentation), not cognition."

B.I. Yarkho, perhaps, falls into the opposite extreme. He distinguishes and opposes the processes of cognition in science, i.e. methods and methods of obtaining knowledge, on the one hand, and the processes of "presentation", fixation, and registration of knowledge, on the other. This, it seems to us, is true and leads to a deep understanding of the essence of science. But is it possible to agree with such a clear underestimation of the role of scientific methods? Are there really no scientific ways to gain knowledge, as opposed to unscientific ones? The answer can only be negative. The very fact of having a global social memory already means the emergence of new requirements for knowledge acquisition procedures.

The most important of these requirements is standardization. It is necessary, because otherwise the individual results will not be comparable. Science therefore requires a description of the samples and the formulation of the principles of research, the scientist must show how he came to this or that result and why he considers it true. Therefore, such phenomena as proof, justification, and description of working methods are necessary features of scientific knowledge that are closely related to the centralization of social memory.

A geographical map is a good illustration of one of the mechanisms of social memory. So let's go back to it again and look at some of its functions. Undoubtedly, the map gives us ways to record geographical observations. Each randomly selected area on the map can be considered as a memory cell in which information about the corresponding area of the earth's surface is recorded. This can be information about the terrain, vegetation, soil, the nature of roads, etc. Zoning is one of the ways to identify such cells. In this way, the map sets us uniform, standardized rules of reference, rules for attributing our information to a particular real area. But she organizes these individual pieces of information into a single whole, into a system of knowledge about the Earth's surface.

In these functions, the map partially resembles a classification, which can also be represented as a set of memory cells and also organizes knowledge about a certain set of objects. But if the cells on the map are distributed continuously, then the classification is a discrete set of cells. In addition, it is obvious that the methods of organizing cells are fundamentally different from each other. For example, in the same classification cell, we can describe objects that have never been geographically adjacent to each other. It is impossible to do this on the map in its classic version. But in both cases, we are dealing with a certain set of rules or patterns, with a certain program for fixing and systematizing knowledge. In fact, the formation of centralized social memory mechanisms is the formation of such programs.

Centralization of memory and unification of knowledge have many far-reaching consequences and, in particular, lead to a clash of different points of view, i.e. to a discussion, without which the development of science is impossible. Here it is appropriate to recall the relay concepts outlined above about a chess tournament and the tournament table, which generates a tournament struggle. In science, knowledge systematization programs play a similar, if not identical, role. They reveal contradictions and generate a struggle of ideas.

Research and collection programs

As part of science, it is rational to distinguish two groups of programs that are functionally different from each other. The programs of the first group define the ways of obtaining knowledge, i.e. the actual research activity. We will refer to them as research programs in the future. The programs of the second group are the programs of selection, organization and systematization of knowledge, which were already discussed above. For brevity, we will call these collection programs (from the Latin collector - collector). Strict differentiation of the selected groups can sometimes cause difficulties, because they are closely related and do not exist without each other.

Research programs are methods and means of obtaining knowledge. This includes verbalized instructions specifying the research methodology, samples of solved tasks, descriptions of experiments, instruments, and much more. When we talk about devices, we mean not just some things in themselves, but things that are closely related to certain programs for their use in scientific knowledge. A microscope can be used to hammer a nail, if necessary, but this obviously contradicts its existence as a microscope. Research programs should include methods for measuring certain parameters, as well as calculation methods, including symbolic expressions such as Newton's second law or Coulomb's law. Strictly speaking, any acts of obtaining and substantiating knowledge, reproduced at the level of relay races or at the level of descriptions, are research programs.

What are collection programs? I must say right away that this area is much less studied than the first one. First of all, this should include samples or verbal instructions that show what we want to know and what we want to know, what our selectivity is in relation to knowledge. These may be references to the object of study, which are traditionally associated with attempts to define the subject of certain scientific disciplines. These may be samples of tasks or questions that a scientist poses. Problem solving methods is a research program. The tasks themselves are collection tasks.

It immediately catches your eye that we are talking not about one, but about two programs, although at the sample level they may coincide. It's one thing to specify the object of research, another is a list of tasks. Obviously, the same object can be studied by formulating different tasks, and questions of the same type can be posed about different objects. We will call the indication of an object a reference program, because it determines what exactly knowledge refers to, i.e. its reference. Questions or tasks are part of the problematization program. At the level of intuition, I would like to link the list of questions not to the collection, but to the research program, but we must keep in mind that the presence of a question does not mean the possibility of any real research procedures. In addition, the selection and systematization of knowledge necessarily involves fixing what exactly interests us.

Here is a specific example of a collection program taken from a field geobotany course. "When describing rivers, the following shall be indicated: a) the boundaries of the site and its length, the catchment area, the main tributaries; b) the nature of the valley and the division of the slopes, the width, height and steepness of the slopes of the root bank and terraces; c) the width of the floodplain (the largest, smallest and predominant), the nature of its surface (manes and indentation of the elders, lakes, channels), swampiness, depth of groundwater, the nature of the lands located in the floodplain, the nature of the soils and vegetation of the floodplain, as well as the width of the river flood, the timing and depth of flooding during the usual, lowest and exceptionally high flood (the width of the floods is determined by the markers of high waters or by survey data)s". A similar list continues, but the above passage is quite enough to understand what is at stake.

Here is a verbalized collection program, which is a list of questions that we must answer when describing a river. This is a kind of scientific questionnaire that defines both the class of objects being studied and the corresponding problematization. It is characteristic that nowhere, with the exception of one case, is it specified exactly how to obtain the required knowledge: how to determine the catchment area, the steepness of the slopes, the depth of the groundwater, It is probably assumed that the specialist knows the appropriate methods. Only in one place, when it comes to the width of spills, the elements of the research program are embedded in the text: "the width of spills is determined by high-water marks or by survey data."

However, collection programs set not only criteria for the selection of knowledge, but also samples of their systematization. "The modern form of scientific articles," writes the famous modern physicist G. Bondy, "is a kind of straitjacket." What does he mean by that? Otherwise, it is likely that when writing articles, a scientist is forced to follow certain canons and observe some fairly strict rules. But these rules are not fully written down anywhere, it can only be about the power of direct samples, about implicit knowledge. Look at and compare the abstracts of PhD or doctoral theses with each other. They are different in content, but they are written according to the same scheme. You might think that they are following some kind of official instruction, but there is no such instruction.

We have already noted above that a geographical map or classification can be considered as a set of memory cells organized in a certain way. But the table of contents of any monograph or training course also shows us something similar: individual sections are also memory cells into which we enter certain information. The methods of organizing such cells are quite diverse, but quite often they are based on the following principle: some general picture of the studied reality is given, and memory cells are aligned with individual elements of this picture.

Without pretending to be complete, we will indicate at least some of these organization methods.: 1) The graphical method. It consists in constructing a graphical representation of an object, and its individual elements become memory cells for recording additional information. For example, you can draw a plan of a house or apartment and then put the appropriate dimensions on the drawing. A geographical map demonstrates exactly this way of organization; 2) The classification method: the set of objects under study, subject to certain rules, is divided into subsets, and knowledge is built relative to each of these subsets.

You can find many solid summaries or training courses with just such an organization of memory cells. For example, scroll through at least some course of descriptive mineralogy; 3) An analytical method of organization. It consists in the fact that the studied object is divided into parts or subsystems, and knowledge is grouped accordingly. This is how animal or plant anatomy courses are built, for example. Geographical zoning can also be the basis of an analytical way of organizing memory; 4) A disciplinary way. It is based on the fact that the same object can be described from the point of view of different scientific disciplines; 5) Categorical method. When describing any objects, our knowledge can be grouped according to the categorical principle, i.e. as knowledge about properties, about structure, about species and varieties, about origin and development. It is based on some categorical, i.e. the most general idea of reality.

Traditions, therefore, govern not only the direct course of scientific research. To a lesser extent, they determine the nature of our tasks and the form of recording the results obtained, i.e. the principles of organizing and systematizing knowledge. And samples are not only samples of setting up an experiment or solving problems, but also samples of scientific products. Having said this last, we have thus fixed another feature of implicit collection programs in comparison with research ones. The mechanism of their life is different, because they are determined not by the patterns of the activity itself, but by the patterns of its products. We have already discussed such differences in the second chapter.

The relay model of science

We will consider science as a social cummoid, which is a continuous implementation of two types of programs: research and collection. These programs are partially verbalized, but for the most part they exist at the relay level. They are closely connected and constantly interact with each other. As shown above, collection programs can additionally include programs of reference, problematization, and knowledge systematization.What does all this mean compared to T. Kuhn's model? First of all, science immediately appears to us as a very dynamic open system, and an individual scientist acquires relative freedom of choice. Let's look at this in more detail.

Let's imagine that we are working in some collection program that defines what we want to know and about what exactly. In this case, we are free to choose methods and can borrow them from other fields of science. At the same time, a biologist remains a biologist, and a soil scientist remains a soil scientist, although they widely use methods of physics or chemistry. The boundaries of a scientific discipline are set here not by methods, but by a collection program, more precisely, a reference program. Therefore, within a fairly wide range, the scientist is free to choose tasks. Obviously, by studying different objects, you can set similar tasks, which opens up the possibility of borrowing. For example, the problem of evolution has been actively penetrating all fields of science since the 19th century, without destroying the boundaries of scientific disciplines.

In other words, the scientist acquires some freedom in choosing individual elements of the collection program. This applies not only to questions, but also to ways of systematizing knowledge. The boundaries of science are determined primarily by what exactly we build knowledge about, i.e. by reference programs. By the way, there may be situations when a collection program requires the systematization of research methods, i.e. the systematization of research programs. In this case, the boundaries of a scientific discipline will be determined by the nature of the tasks and the methods of their solution.

The separation of research and collection programs and the recognition of their diversity leads to the fact that the Kuhn paradigm within the framework of the new model seems to dissolve, and the scientist breaks out into the sphere of science or culture as a whole. Yes, it is, of course, programmed and limited, but not by the theoretical concepts of its narrow field, but only by the entire set of samples of a particular epoch to which it belongs. He can borrow methods, the nature of tasks, ways of systematizing knowledge, he can build theories based on the model of already built theories in other fields of science. At the same time, he does not violate the boundaries of his competence at all and does not violate disciplinary boundaries. It's just that these boundaries become transparent for borrowing, and the results obtained in any field turn out to be multifunctional and potentially significant for science as a whole.

In his popular science lectures on quantum electrodynamics, R. Feynman writes the following: "I would like to emphasize one thing. The theories devoted to the rest of physics are very similar to quantum electrodynamics. Why do all physical theories have such a similar structure?". Feynman sees one possible reason in the limited imagination of physicists: "when we encounter a new phenomenon, we try to fit it into the existing framework." The last phrase is very reminiscent of T.The only difference is that we are talking about the "framework" set by samples of another discipline, another branch of physics. In the light of Kuhn's concept, this is impossible: individual disciplines do not interact there at all, but exist as if by themselves. The new model, on the contrary, considers science as a whole and looks for a source of development of individual disciplines in this whole. This orientation towards the whole is the main feature of the new model.

The picture looks something like this. There are many reference programs that serve as "crystallization centers" for all other programs, forming scientific disciplines. Any scientist who has associated himself with the study of a certain range of phenomena is nevertheless free enough to choose problems, research methods, and ways to systematize knowledge. Programs, with some changes due to a change of context, freely "roam" from one area to another. Therefore, combining all these programs in the work of a scientist or even within a particular discipline is quite situational and dynamic, and each change in one or another of them in any field of knowledge, whatever it may be caused by, can in principle have consequences for any other science.

The situation is similar with the products of scientific research, i.e. with knowledge. They are taken over by collection programs, but it is never possible to predict exactly which ones. The fact, for example, that tourmaline becomes electrified when heated, has entered the arsenal of both physics and mineralogy. The periodic table can be found not only in the chemistry course, but also in physics. Each collection program has the right to select everything that meets its criteria, regardless of the discipline in which the knowledge it is interested in was obtained. At the same time, there are some transformations of the knowledge itself, which, however, does not change anything in essence. It is important that the knowledge gained within a certain discipline does not become its "property" at all and may, in principle, be essential for completely different branches of science.

Continuing to develop the topic "What is science like?"one can compare a separate scientific discipline and a newspaper. Imagine a lot of newspapers with different profiles: political, economic, sports. Each has an editor who is the carrier of some collection program and selects the necessary information. However, this information may come not only from the newspaper's own correspondents, but also from a wide variety of sources, including reprints of materials from other newspapers. Each correspondent knows certain methods of obtaining information, but can also borrow methods from other correspondents. The editor is also able to improve his program under the influence of other newspapers. And how does a newspaper differ from science? She's a one-night stand. But take the files from many years ago and try to systematize the information in the light of some collection program. You may well get a historical description based on newspaper sources.

The proposed model has great potential to identify various possible variants and combinations and leads to a number of consequences, some of which we will consider both in this and in the following chapters. We will also try to refine and enrich this model somewhat. But one conclusion already suggests itself: it is impossible to understand the development of science by tracing the history of any one discipline. Meanwhile, this is how the history of science is written here. There is no history of physics or history of geography, there is a history of science as a whole.

Ways of forming science

The juxtaposition of research and collection programs allows us to identify two different paths in the development of individual scientific disciplines, depending on which programs dominate at the very first stages of their formation. Below we will present several facts that, on the one hand, can serve as a good illustration of the model proposed above, and, on the other, provide an opportunity to better understand the underlying differences that sometimes determine the specifics of a particular scientific field for a long time..

The development of experimental disciplines is usually dominated by research programs. Let us consider from this point of view the first steps in the formation of the doctrine of electricity. At the same time, we will deliberately simplify and coarsen the picture, discarding numerous theoretical constructions of this period, but this does not change anything in essence. The formation of the theory of electricity looks like a chain of interconnected experimental discoveries, due not so much to theoretical foresight as to the fixation of side effects of the experiment. The main milestones here are as follows: 1) The discovery and investigation of electrification by friction; 2) The discovery of conduction; 3) The discovery of the phenomenon of electric repulsion; 4) The discovery of such a phenomenon as capacitor discharge.

The fact that amber, when rubbed with fur, begins to attract hairs or small pieces of other materials, was noticed a long time ago and probably by accident. In any case, Plato has already mentioned this. In the Middle Ages, it was probably just as accidentally discovered that some other substances had similar properties. William Gilbert (1544-1603), an English physician, began to systematically and purposefully investigate this phenomenon, and it was his experiment with friction electrification that turned into a research program. They began to reproduce it with different bodies and in different versions, and in 1729 Stephen Gray discovered that when rubbing a glass tube with fur, the plug inserted into the tube also becomes electrified.

A new research program is emerging, now related to the reproduction of conduction rather than electrification. This program sort of branches off from the previous one, and there is a kind of branching of research programs. The next point of this branching is primarily associated with the name of the French scientist Charles Francois Dufay. In 1733, he continued Gray's experiments and suddenly noticed that pieces of metal, after coming into contact with an electrified glass tube, repel each other. The reproduction of these phenomena, i.e. the third research program, leads to the idea of the existence of two kinds of electricity. And so in 1745, the Dutch physicist Muschenbrook tries to charge water poured into a glass vessel through a conductor and unexpectedly receives a strong blow. "I thought the end had come," he wrote to Reaumur in 1746. The Leiden jar was obtained, which gave rise to another research program and played a significant role in the development of the theory of electricity.

What is important to us in this whole story? It is striking that the very first steps in the formation of the doctrine of electricity are associated with the consistent emergence of more and more new research programs. In any history of physics, this stage is described as a chain of discoveries. At the same time, it is obvious that the Muschenbrook experiment could not have been carried out before the discovery of conductivity, which Gray's experiments already suggest the research of Hilbert, who discovered that glass also electrifies, like amber. Before us is a branching bush of research programs, and it is he who holds together and unites all the knowledge gained like a framework.

Let us now turn to examples of a different kind. One of the founders of botany is considered to be the greatest ancient thinker, collaborator and follower of Aristotle Theophrastus (372287 BC).

Here are a few short excerpts from his famous work "Research on Plants". 1. "Carpenters say that there is a core in every tree; the fir is most visible.: it consists of circular layers, like a crust." 2. "The inhabitants of Ida, they say, distinguish between pines, and one pine is called "ideological", the other "seaside". According to them, more resin is obtained from the ideological one." 3. "Some say that Arabia is richer in frankincense, but it is better on the neighboring islands, which are ruled by Arabs."

There are a lot of passages of this kind, because they are found everywhere in the text of Theophrastus. What does this mean? First of all, "Research on plants" is a systematization of the vast experience related to plants that has already been accumulated in the ancient world. But it was not researchers who accumulated it, but practitioners. Theophrastus refers to carpenters, merchants selling incense or wood, simply to residents of a particular area who encounter native plants in their daily lives. But none of those he refers to have implemented research programs or set themselves cognitive goals. The situation may seem paradoxical: there was no research activity, but fundamental work appears. But there is no paradox here, it's just that collection programs rather than research ones dominate in this case.

Here are two more very similar examples. Here is what academician N.S.Shatsky writes about the emergence of regional geology: "Regional geology was born along with the geological map; however, even before the beginning of geological mapping, in the XVII and XVIII centuries. and even earlier, there were regional descriptions of a geological nature in the literature, for example, in geographical sketches, travels, etc., but they are not They were systematic and more often concerned only with subjects and phenomena that for some reason interested the authors. With the introduction of state geological mapping, a type of regional geological descriptions has finally been developed, which in the vast majority of cases represent explanatory notes to geological maps."

Similar thoughts about the formation of science are clearly visible in I. S.Melekhov's work "An Essay on the development of forest Science in Russia". The author connects the formation of forestry with the needs of shipbuilding: "The need for timber for shipbuilding and their rapid depletion in the areas of initial harvesting determined the need to describe forests." This idea is repeated by P. S. Pogrebnyak: "Russian forestry originated at the beginning of the XVIII century as the brainchild of the need for ship timber."

It may seem that we are talking about a rather trivial thing, about the role of practical inquiries in shaping science. But this is not the case. I. S. Melekhov's work shows well that the forest has always played a huge role in the life of the Russian people and practical knowledge about the forest began to form a long time ago. The role of the shipbuilder as a centralized and socially significant consumer of this knowledge consisted primarily in the fact that there was a government need for a systematic description of forests, the organization of all accumulated information, and the compilation of forest maps. In other words, a collection program has appeared.

The facts show that the formation of science, at least in the cases considered, is based on the process of systematization of knowledge, which, generally speaking, may already exist, but are scattered and not organized in any way. But who manages this process of systematization, who sets the appropriate program? Both Shatsky and Melekhov unanimously point to the role of a socially significant consumer of knowledge. The presence of such a consumer or customer greatly simplifies the task of explicating the program that may take place here. It is almost obvious that the consumer in these situations sets primarily two parameters of knowledge: he says exactly what he wants to know and about what. These two classes of characteristics are probably the basis of the primary systematization of knowledge. On the one hand, they define the reference of knowledge that interests us: what it is about, about the forest or about rocks. On the other hand, the type of content or representation: what we want to know about rocks, their physical properties or chemical composition. Of course, there is also a third question: How? How can we get the required knowledge? But this question is no longer of interest to the consumer, but to the manufacturer.

Obviously, the consumer's figure is not necessary at all if we already have samples of knowledge systems. Continuing the above passage, N.S.Shatsky writes: "The usual, most common type of regional descriptions includes a description of the stratigraphy and tectonics of the described area, characteristics of magmatic formations and minerals. These purely geological parts are usually preceded by a description of the relief and a review of the literature data on the structure of the area. Chapters describing the geological history are also very common..." It is easy to see that we have before us some basic instructions for constructing a geological description, i.e. a collection program. But it most likely only explicates that implicit program, which, without any instructions, generates standard texts that follow the same patterns in their structure.

Program conflict and the concept of a model

There are situations of conflict between research and collection programs. One of the products of this conflict is the widespread perception of ideal models. Let's consider this based on the arguments given in the book "Analysis of Complex Systems" by E. Quade.

The author illustrates the modeling method using this example. Imagine that the Martians are conducting research related to the manufacture and sending flying saucers to earth. When a dish is in the process of being manufactured, for a cost-determining specialist it represents only two numbers: its serial number and the number of Martian man-hours spent on its production. But now the plate is built, and it is being transported to the warehouse. At this stage, it can be characterized by a different set of numbers: linear dimensions and weight, as well as cargo classification according to transportation standards. Finally, the dish is launched and in flight. Here we can imagine it as a material point in space with a certain speed. Next, the saucer enters the Earth's atmosphere, and its description changes again, because now we have to take into account its shape, drag coefficient and speed.

Why do we call all these descriptions models? First of all, probably because of their incompleteness. After all, we know much more in each case, but we select only what is needed to solve the problem, i.e. to implement our research program. "Which model we build," the author writes, "depends on the questions we want to answer using the model and the decisions we have to make based on the model." In other words, the research program is very pragmatic in selecting the initial data, it selects only what is necessary to obtain a satisfactory solution.

But along with research programs, there are also collection programs that require coordination and systematization of knowledge. And now it turns out that the ideas about the object, which are quite justified from a pragmatic point of view in the framework of the implementation of research programs, do not fit into the general system of our ideas about the world. Speaking, for example, about the image of a flying saucer in the form of a material point, the author continues: "Any thinking person could object that this approach is completely unrealistic; that we neglect the size, shape, and material; that the diameter of the dish is 30 meters, that it is painted bright red, and that there is a crew of three Martians on it." And so, in order to reconcile such different ideas, concepts such as "ideal model", "abstraction", and "ideal object" appear, which capture what is pragmatically justified but does not fit into our picture of the world.

The collection program requires consistency, coherence of knowledge, its task is a universal synthesis and the construction of a unified picture of the world. Of course, she mostly builds this picture in parts, i.e. within individual scientific disciplines, but at the same time we constantly observe attempts to find the place of each science in the system of knowledge about the world as a whole. The research program, as we have already noted, on the contrary, is purely pragmatic and justifies certain ideas with success in solving specific tasks. And so the pragmatic attitude inevitably comes into conflict with the requirement of coherence. A good example is given by Galileo Galilei in one of his works. Builders everywhere build walls of houses on a plumb line, believing that two plumb lines are parallel. But we know that they intersect in the center of the Earth! Of course, we know, but what could this mean for the practice of builders? Obviously, there is nothing.

The idea of the real picture of the world, on the one hand, and of ideal models or ideal objects, on the other, arise as a result of the clash of pragmatism and attitudes towards the coherence of knowledge. These ideas can be considered as a kind of protective belt of pragmatism in its collision with the requirement of coherence.

Self-monitoring questions

1. The structure of knowledge and its content
2. Paradoxes of reflection, the problem of research position
3. Reflexive symmetry and connections of scientific disciplines

4 STRUCTURE AND DYNAMICS OF SCIENTIFIC RESEARCH

The concepts of empirical and theoretical (main features)

There is an extensive methodological literature on the theoretical and empirical problem.

A fairly clear fixation of these levels was carried out already in the positivism of the 30s, when an analysis of the language of science revealed a difference in the meanings of empirical and theoretical terms. This difference concerns the means of research. But besides this, it is possible to distinguish between two levels of scientific knowledge, taking into account the specifics of the methods and the nature of the research subject.

Let's take a closer look at these differences. Let's start with the specifics of the means of theoretical and empirical research. Empirical research is based on the direct practical interaction of the researcher with the studied object. It involves the implementation of observations and experimental activities. Therefore, the means of empirical research must include instruments, instrumentation and other means of real observation and experiment.

In theoretical research, there is no direct practical interaction with objects. At this level, an object can only be studied indirectly, in a thought experiment, but not in a real one.

In addition to the means that are associated with the organization of experiments and observations, conceptual means are also used in empirical research. They function as a special language, which is often called the empirical language of science. It has a complex organization in which empirical terms and terms of a theoretical language interact.

The meaning of empirical terms are special abstractions that could be called empirical objects. They should be distinguished from the objects of reality. Empirical objects are abstractions that actually highlight a certain set of properties and relationships of things. Real objects are represented in empirical cognition in the image of ideal objects with a rigidly fixed and limited set of features. A real object has an infinite number of features. Any such object is inexhaustible in its properties, connections and relationships.

Take, for example, the description of the experiments of Biot and Savard, in which the magnetic effect of an electric current was detected. This action was recorded by the behavior of a magnetic needle located near a rectilinear current wire. Both the current wire and the magnetic needle had an infinite number of features. They had a certain length, thickness, weight, configuration, color, were located at some distance from each other, from the walls of the room in which the experiment was conducted, from the Sun, from the center of the Galaxy, etc.

From this endless set of properties and relationships, in the empirical term "live wire", as it is used to describe this experience, only such features have been identified: 1) be at a certain distance from the magnetic needle; 2) be straight; 3) conduct an electric current of a certain strength. All other properties are irrelevant here, and we abstract from them in the empirical description. In the same way, the ideal empirical object that forms the meaning of the term "magnetic needle" is constructed according to a limited set of features. Each feature of an empirical object can be detected in a real object, but not vice versa.

As for theoretical knowledge, it uses other research tools. There are no means of material, practical interaction with the studied object. But the language of theoretical research is also different from the language of empirical descriptions. It is based on theoretical terms, the meaning of which is theoretical ideal objects. They are also called idealized objects, abstract objects, or theoretical constructs. These are special abstractions that are logical reconstructions of reality. No theory can be built without the use of such objects.

Examples of these are a material point, an absolutely black body, an ideal commodity that is exchanged for another commodity strictly in accordance with the law of value (abstracting from fluctuations in market prices here), an idealized population in biology, in relation to which the Hardy-Weinberg law is formulated (an infinite population where all individuals interbreed equally likely).

Idealized theoretical objects, unlike empirical objects, are endowed not only with those features that we can detect in the real interaction of objects of experience, but also with features that no real object has. For example, a material point is defined as a body devoid of dimensions, but containing the entire mass of the body. There are no such bodies in nature. They act as a result of mental construction, when we abstract from the insignificant (in one way or another) connections and features of an object and build an ideal object that acts as a carrier of only essential connections. In reality, the essence cannot be separated from the phenomenon, one manifests itself through the other. The task of theoretical research is to know the essence in its purest form. An introduction to the theory of abstract, idealized objects makes it possible to solve this problem.

Empirical and theoretical types of cognition differ not only in the means, but also in the methods of research activity. At the empirical level, real experiment and real observation are used as the main methods. Empirical description methods also play an important role, focusing on the objective characterization of the studied phenomena, which is maximally purified from subjective layers.

As for theoretical research, special methods are used here: idealization (method of constructing an idealized object); thought experiment with idealized objects, which replaces the real experiment with real objects; special methods of theory construction (ascent from the abstract to the concrete, axiomatic and hypothetical-deductive methods); methods of logical and historical research and others .

All these features of tools and methods are related to the specifics of the subject of empirical and theoretical research. At each of these levels, a researcher can deal with the same objective reality, but he studies it in different subject areas, in different aspects, and therefore its vision and its representation in knowledge will be given in different ways. Empirical research is basically focused on the study of phenomena and the dependencies between them. At this level of cognition, essential connections are not yet distinguished in their pure form, but they seem to be highlighted in phenomena, they appear through their concrete shell.

At the level of theoretical knowledge, the essential connections are distinguished in their pure form.

The essence of an object is the interaction of a number of laws that this object obeys. The task of theory is precisely to dissect this complex network of laws into components, then recreate their interaction step by step and thus reveal the essence of the object.

By studying phenomena and the connections between them, empirical cognition is able to detect the effect of an objective law. But it captures this action, as a rule, in the form of empirical dependencies, which should be distinguished from the theoretical law as a special knowledge obtained as a result of the theoretical study of objects.

Empirical dependence is the result of an inductive generalization of experience and represents probabilistically true knowledge. The theoretical law is always reliable knowledge. Obtaining such knowledge requires special research procedures.

For example, the Boyle-Marriott law is known, which describes the correlation between pressure and gas volume: $PV = const$, where P is the gas pressure and V is its volume.

It was first discovered by R. Boyle as an inductive generalization of experimental data, when an experiment revealed a relationship between the volume of a gas compressed under pressure and the magnitude of this pressure.

The history of the discovery of this law is very interesting and instructive. As an empirical dependence, it was obtained largely by chance, as a side result of a dispute between two famous eighteenth-century physicists, R. Boyle and F. Linnus. The dispute was over the interpretation of Boyle's experiments, which revealed the phenomenon of barometric pressure. Boyle performed the following experiment: he immersed a tube sealed on top and filled with mercury in a cup of mercury. According to the principle of communicating vessels, it was to be expected that the mercury level in the tube and in the cup would be equalized. But experience has shown that only some of the mercury is poured into the cup, and the rest stands in the form of a column above the surface of the mercury in the cup. Boyle interpreted this experience as follows: the pressure of air on the surface of mercury in a cup keeps a column of mercury above this surface. The height of the column is an indicator of atmospheric pressure. Thus, the principle of a barometer, a device that measures pressure, was proposed.

However, F. Linnus raised the following objections: air consists of light particles, it is like a thin and malleable liquid that cannot withstand the pressure of heavy mercury particles. Therefore, the air cannot hold the mercury column. It is held by the attraction of mercury to the upper end of the barometric tube. Linnus wrote that when he plugged a barometric tube with his finger on top, he felt the threads of gravity when he dipped it into a cup. In itself, this historical fact is very significant. It shows that the same result of an experience can receive different interpretations and be used to confirm different concepts.

To prove to Linnus that air can hold a column of mercury, Boyle set up a new experiment. He took a glass tube curved in the form of a siphon with a soldered short knee and began gradually filling it with mercury. As the mercury column increased, the air in the knee was compressed, but not completely displaced. Boyle compiled a table of the ratio of air volume and mercury column and sent it to Linnus as proof of the correctness of his interpretation.

It would seem that the story of explaining barometric pressure is over. But it got an unexpected sequel. Boyle had a student, a young man named Townley, whom Boyle taught the basics of physics and mathematics. It was Townley who, studying the table of Boyle's experiments, noticed that the volumes of compressed air are proportional to the height of the mercury column pressing on the air. After that, Boyle saw his experiences from a new perspective. A column of mercury is a kind of piston that compresses air, and the weight of the column corresponds to pressure. Therefore, the proportion in the tabular data means the relationship between the pressure and the volume of the gas. This was how the $PV = const$ ratio was obtained, which Boyle confirmed with many experiments with pressures greater and lower than atmospheric pressure.

But did this dependence have the status of a reliable law? Obviously not, although it was expressed in a mathematical formula. It was a dependency obtained by inductively generalizing the results of experience and therefore had the status of a probabilistically true statement, rather than reliable knowledge, which is a theoretical law.

If Boyle had moved on to experiments with high pressures, he would have found that this relationship was broken. Physicists say that the $PV = const$ law is applicable only in the case of very rarefied gases, when the system approaches the model of an ideal gas and intermolecular interactions can be neglected. And at high pressures, interactions between molecules (van der Waals forces) become significant, and then Boyle's law is violated. The dependence discovered by Boyle was probabilistically true knowledge, a generalization of the same type as the statement "all swans are white," which was true until black swans were discovered. The theoretical law $PV = const$ was obtained later, when an ideal gas model was constructed.

This law was derived by physicist D. Bernoulli (academician of the St. Petersburg Imperial Academy) in 1730. He proceeded from the atomic concepts of gas and presented gas particles as material points colliding like elastic balls.

Bernoulli applied the laws of Newtonian mechanics to an ideal gas in an ideal pressure vessel and calculated the formula $PV = const$. It was the same formula that R. Boyle had previously obtained. But its meaning was already different. Boyle's $PV = const$ correlated with the scheme of real experiments and tables of their results. Bernoulli's theory was related to the theoretical model of an ideal gas. In this model, the essential characteristics of the behavior of any gases at relatively low pressures were expressed. And the law directly describing these essential connections already acted as reliable, true knowledge.

So, having identified empirical and theoretical knowledge as two special types of research activities, we can say that their subject matter is different, i.e. theory and empirical research deal with different sections of the same reality. Empirical research studies phenomena and their correlations; in these correlations, in the relationships between phenomena, it can detect the manifestation of a law. But in its pure form, it is given only as a result of theoretical research.

It should be emphasized that an increase in the number of experiments does not in itself make empirical dependence a reliable fact, because induction always deals with unfinished, incomplete experience. No matter how many experiments we do and generalize them, a simple inductive generalization of experimental results does not lead to theoretical knowledge. Theory is not built by inductive generalization of experience. This fact, in all its depth, was realized in science relatively late, when it reached sufficiently high levels of theorization.

So, empirical and theoretical levels of cognition differ in the subject, means and methods of research. However, the isolation and independent consideration of each of them is an abstraction. In reality, these two layers of cognition always interact.

The structure of empirical research

Having identified the empirical and theoretical levels, we have obtained only a primary and rather rough idea of the anatomy of scientific knowledge. The formation of more detailed ideas about the structure of scientific activity involves analyzing the structure of each of the levels of cognition and clarifying their interrelationships.

Both the empirical and theoretical levels have a rather complex system organization.

In them, it is possible to identify special layers of knowledge and, accordingly, cognitive procedures generating this knowledge.

Let us first consider the internal structure of the empirical level. It is formed by at least two sublevels: a) direct observations and experiments, the result of which is observational data; b) cognitive procedures, through which the transition from observational data to empirical dependencies and facts is carried out.

Experiments and observational data

The difference between observational data and empirical facts as special types of empirical knowledge was fixed back in the positivist philosophy of science of the 1930s. At that time, there was a rather intense discussion about what could serve as the empirical basis of science. At first, it was assumed that they were the direct results of experience - observational data. In the language of science, they are expressed in the form of special statements - entries in observation protocols, which were called protocol sentences.

The observation protocol indicates who observed, the time of observation, describes the devices, if they were used in the observation, and protocol sentences are formulated as statements such as: "NN observed that after turning on the current, the arrow on the device shows the number 5," "NN observed a bright spot of light in a section of the sky (with x,y coordinates) with a telescope," etc.

If, for example, a sociological survey was conducted, then the questionnaire with the respondent's response acts as an observation protocol. If measurements were carried out during the observation process, then each recording of the measurement result is equivalent to a protocol sentence.

An analysis of the meaning of protocol sentences has shown that they contain not only information about the phenomena being studied, but also, as a rule, include observer errors, layers of external disturbing influences, systematic and random errors of instruments, etc. But then it became obvious that these observations, due to the fact that they are burdened with subjective layers, cannot serve as a basis for theoretical constructions.

As a result, the problem was posed of identifying such forms of empirical knowledge that would have an intersubjective status and would contain objective and reliable information about the phenomena under study.

During the discussions, it was found that such knowledge is empirical facts. They form the empirical basis on which scientific theories are based.

The facts are recorded in the language of science in statements such as: "the current in the circuit depends on the resistance of the conductor"; "a supernova broke out in the constellation Virgo"; "more than half of the respondents in the city are dissatisfied with the ecology of the urban environment", etc.

The very nature of fact-fixing statements emphasizes their special objective status in comparison with protocol sentences. But then a new problem arises.: How is the transition from observational data to empirical facts carried out and what guarantees the objective status of a scientific fact?

Setting this problem was an important step towards clarifying the structure of empirical cognition. This problem was actively developed in the methodology of 20th century science. In the competition of different approaches and concepts, she revealed many important characteristics of scientific empiricism, although today the problem is far from being definitively solved.

Positivism also made a certain contribution to its development, although it is worth emphasizing that its desire to limit itself only to studying the internal connections of scientific knowledge and to abstract from the relationship between science and practice sharply limited the possibilities for an adequate description of research procedures and methods for forming the empirical basis of science.

It seems to us that the activity-based approach opens up more possibilities for analysis. From the standpoint of this approach, we will consider the structure and functions of each of the marked layers of the empirical level of cognition. Let's start with a more detailed analysis of the sublevel of observations, which ensures direct contact of the subject with the processes under study. It is important to immediately understand that scientific observation is of an activity nature, assuming not just passive contemplation of the processes under study, but their special preliminary organization, ensuring control over their course.

The activity-based nature of empirical research at the observational level is most clearly manifested in situations where observation is carried out during a real experiment. Traditionally, experiment is contrasted with observation outside the experiment. Without denying the specifics of these two types of cognitive activity, we would nevertheless like to draw attention to their common generic features.

To do this, it is advisable to first consider in more detail what is the feature of experimental research as a practical activity, the structure of which actually reveals certain connections and states of reality of interest to the researcher.

The subject structure of experimental practice can be considered in two aspects: firstly, as an interaction of objects proceeding according to natural laws, and secondly, as an artificial, human-organized action. In the first aspect, we can consider the interaction of objects as a certain set of connections and relations of reality, where none of these connections is actually highlighted as being investigated. In principle, any of them can serve as an object of cognition. Only taking into account the second aspect makes it possible to identify one or another connection in relation to the goals of cognition and thereby fix it as a subject of research. But then, explicitly or implicitly, the totality of objects interacting in experience is organized, as it were, in a system of a certain chain of relationships: a number of their real connections turn out to be insignificant, and only a certain group of relationships that characterize the studied "slice" of reality is functionally distinguished.

Let's illustrate this with a simple example. Let's assume that within the framework of classical mechanics, the motion of a massive small body suspended from a long non-stretchable thread relative to the earth's surface is studied. If we consider such a movement only as the interaction of natural objects, then it appears as a cumulative result of the manifestation of a wide variety of laws. Here, such natural connections as the laws of oscillation, free fall, friction, aerodynamics (gas flowing around a moving body), the laws of motion in a non-inertial frame of reference (the presence of Coriolis forces due to the rotation of the Earth), etc. are "superimposed" on each other. But as soon as the described interaction of natural objects begins to be considered as an experiment to study, for example, the laws of oscillatory motion, a certain group of properties and relationships of these objects is isolated from nature.

First of all, interacting objects - the Earth, a moving massive body, and a suspension thread - are considered as carriers of only certain properties that functionally, by the very way they are "included" in the "experimental interaction", stand out from all other properties. The thread and the body suspended from it appear as a single object - a pendulum. In this experimental situation, the Earth is fixed 1) as a reference body (for this purpose, the direction of gravity is selected, which sets the equilibrium line of the pendulum) and 2) as a source of force that sets the pendulum in motion. The latter, in turn, suggests that the gravity of the Earth should be considered only in a certain aspect. Namely, since, according to the purpose of the experiment, the movement of the pendulum is represented as a special case of harmonic oscillation, thus only one component of gravity is taken into account, which returns the pendulum to the equilibrium position. The other component is not taken into account, since it is compensated by the tension force of the thread.

The described properties of interacting objects, coming to the fore in the act of experimental activity, thereby introduce a strictly defined group of relations, which is functionally isolated from all other relations and connections of natural interaction. In essence, the described motion of a massive body suspended by a thread in the Earth's gravity field appears as a process of periodic movement of the center of mass of this body under the action of a quasi-elastic force, which is one of the components of the Earth's gravitational force. This "grid of relationships", which comes to the fore in the considered interaction of nature, is the object structure of practice within which the laws of oscillatory motion are studied.

In the system of scientific experiment, each of these structures stands out due to the fixation of interacting objects according to strictly defined properties. This fixation, of course, does not mean that all other properties except those of interest to the researcher disappear from objects of nature. In real practice, the necessary properties of objects are highlighted by the very nature of their operation. To do this, the objects brought into interaction during the experiment must first be verified by practical use for the existence of properties that are stably reproduced in a future experimental situation.

Thus, it is easy to see that the experiment with the oscillation of a pendulum could be carried out only insofar as the previous development of practice had strictly revealed that, for example, the gravity of the Earth in a given place is constant, that any body with a suspension point will oscillate relative to the equilibrium position, etc. It is important to emphasize that the isolation of these properties has become This is possible only due to the appropriate practical functioning of the objects in question. In particular, the property of the Earth to be a source of constant gravitational force has been repeatedly used in human practice, for example, when moving various objects, driving piles with the help of falling cargo, etc. Such operations made it possible to functionally identify the characteristic property of the Earth "to be a source of constant gravity."

In this sense, in experiments on the laws of pendulum oscillation, the Earth acts not just as a natural body, but as a kind of "artificially manufactured" object of human practice, because for the natural object "Earth" this property has no "special privileges" compared to other properties. It really exists, but it comes to the fore as a special, distinguished property only in the system of a certain human practice. Experimental activity is a specific form of natural interaction, and the most important feature defining this specificity is precisely the fact that fragments of nature interacting in an experiment always appear as objects with functionally distinguished properties.

In advanced experimental forms, such objects are artificially manufactured. These include, first of all, instrument installations, with the help of which experimental research is carried out. For example, in modern nuclear physics, these can be installations that prepare particle beams that are stabilized according to certain parameters (energy, pulse, polarization); targets bombarded by these beams; devices that record the results of the interaction of the beam with the target. For our purposes, it is important to understand that the manufacture, alignment, and use of such installations themselves are similar to the operations of functional extraction of properties from natural objects used by the researcher in the experiments with a pendulum described above. In both cases, only some properties are distinguished from the entire set of properties possessed by material objects, and these objects function in the experiment only as their carriers.

From such positions, it is quite legitimate to consider natural objects included in an experimental situation as "quasi-assembled" devices, regardless of whether they were obtained artificially or naturally originated in nature regardless of human activity. So, in an experimental situation for studying the laws of oscillation, the Earth "functions" as a special instrument subsystem that, as it were, "prepares" a constant gravitational force (similar to how a man-made accelerator with a rigidly fixed operating mode will generate pulses of charged particles with preset parameters). The pendulum itself plays the role of a working device here, the functioning of which makes it possible to record the oscillation characteristics. In general, the Earth plus pendulum system can be considered as a kind of quasi-experimental installation, the "operation" of which allows us to study the laws of simple oscillatory motion.

In the light of this, the specifics of the experiment, which distinguish it from interactions in nature "by itself", can be characterized in such a way that in the experiment, interacting fragments of nature always act as instrument subsystems. The activity of "endowing" natural objects with the functions of instruments will be further referred to as the creation of an instrument situation. Moreover, we will understand the instrument situation itself as the functioning of quasi-appliance devices, in the system of which a certain fragment of nature is being tested. And since the nature of the relationship of the test fragment with quasi-assembly devices functionally distinguishes from it a certain set of characteristic properties, the presence of which in turn determines the specifics of interactions in the working part of the quasi-assembly installation, the test fragment is included as an element in the instrument situation.

In the experiments with the oscillation of a pendulum discussed above, we dealt with significantly different instrument situations, depending on whether the purpose of the study was to study the laws of oscillation or the laws of motion in a uniformly rotating system. In the first case, the pendulum is included in the instrument situation as a test fragment, in the second it performs completely different functions. Here he appears in three ways.:

1) The very movement of the massive body (the test fragment) is included in the functioning of the working subsystem as its essential element (along with the rotation of the Earth);

2) The periodicity of the movement of the pendulum, which in previous experiments played the role of the studied property, is now used only to ensure stable observation conditions. In this sense, the oscillating pendulum already functions as a cooking instrument subsystem.;

3) The property of the pendulum to maintain the plane of oscillation allows it to be used as part of the recording device. The oscillation plane itself acts as a kind of arrow here, the rotation of which relative to the plane of rotation of the Earth fixes the presence of the coriolis force. This kind of functioning of natural fragments interacting in experience in the role of instrument subsystems or their elements highlights, as it were, "pushes" to the fore, the individual properties of these fragments. All this leads to the functional isolation of the one that represents the studied connection of nature from the set of potentially possible object structures of practice.

This kind of connection acts as an object of research, which is studied both at the empirical and theoretical levels of cognitive activity. The selection of an object of research from the totality of all possible connections of nature is determined by the goals of cognition and at different levels of the latter finds its expression in the formulation of various cognitive tasks. At the level of experimental research, such tasks act as a requirement to record (measure) the presence of some characteristic property in the tested fragment of nature. However, it is important to immediately understand that the object of research is always represented not by a separate element (thing) inside the instrument situation, but by its entire structure.

Using the examples discussed above, it was essentially shown that the corresponding object of study - whether it be the process of harmonic oscillation or motion in a non-inertial frame of reference - can only be identified through the structure of the relationships involved in the experiment of natural fragments.

The situation is similar in more complex cases, such as experiments in atomic physics. Thus, in the well-known experiments on the detection of the Compton effect, the subject of the study - "corpuscular properties of X-ray radiation scattered on free electrons" - was determined through the interaction of the X-ray flux and the graphite target scattering it, provided that the radiation was detected by a special device. And only the structure of the relationships of all these objects (including the recording device) represents the studied slice of reality. These kinds of fragments of real experimental situations, the use of which sets the object of research, will be referred to as objects of operation in the future.

This distinction will avoid ambiguity when using the term "object" in the process of describing cognitive operations of science. This difference captures the essential fact that the object of research does not coincide with any of the individual objects of operation in any experimental situation. We also emphasize that the objects of operation, by definition, are not identical to "natural" fragments of nature, since they act in the experimental system as peculiar "carriers" of certain functionally distinguished properties. As it was shown above, operating objects are usually endowed with instrument functions and in this sense, being real fragments of nature, at the same time act as products of "artificial" (practical) human activity.

In this case, observations are not just a fixation of some features of the test fragment. They also carry implicit information about the connections that gave rise to the observed phenomena.

But then the question arises: is this true for any observations? After all, they can be obtained outside the experimental study of the object. Moreover, observations may be random, but as the history of science shows, they are very often the beginning of new discoveries. In all these cases, where is the practical activity that organizes the interaction of the studied objects in a certain way? Where is the control on the part of the cognizing subject over the conditions of interaction, control that allows us to separate the variety of connections of reality, functionally identifying exactly those whose manifestations are subject to research?

Self-monitoring questions

1. Scientific research. Structure and dynamics.
2. The structure of theoretical and empirical research.

5 THE DYNAMICS OF SCIENTIFIC KNOWLEDGE
The interaction of the scientific worldview and experience

The first situation can be implemented in two ways. Firstly, at the stage of formation of a new field of scientific knowledge (scientific discipline) and, secondly, in theoretically developed disciplines, during the empirical discovery and research of fundamentally new phenomena that do not fit into existing theories.

Let us first consider how the worldview and empirical facts interact at the stage of the emergence of a scientific discipline, which initially goes through the stage of accumulation of empirical material about the objects under study. In these conditions, empirical research is purposefully based on the established ideals of science and the emerging special scientific picture of the world (the picture of the reality under study). The latter forms that specific layer of theoretical concepts that provides the formulation of empirical research tasks, the vision of observation and experimental situations, and the interpretation of their results.

Special pictures of the world as a special form of theoretical knowledge are the product of a long historical development of science. They emerged as relatively independent fragments of the general scientific picture of the world at the stage of the formation of a disciplinarily organized science (the end of the XVIII - the first half of the XIX century). But in the early stages of development, in the era of the formation of natural science, there was no such organization of science yet. This fact is not always adequately understood in methodological research. In the 80s, when the issue of the status of special paintings of the world was intensively discussed, three points of view were expressed: special paintings of the world do not exist at all and they should not be distinguished as special forms of theoretical knowledge; special paintings of the world are pronounced autonomous entities; their autonomy is extremely relative, since they act as fragments of the general scientific picture the world.

However, all three points of view can be confirmed in the history of science, only they relate to its different stages: the pre-disciplinary science of the 17th century, the disciplinarily organized science of the 19th - first half of the 20th century, and modern science with its increasing interdisciplinary connections. These stages should be distinguished.

The first of the sciences that formed a holistic picture of the world based on the results of experimental research was physics. In its embryonic forms, the emerging physical picture of the world contained (especially in the pre-Galilee period) many natural philosophical layers. But even in this form, it focused on the process of empirical research and the accumulation of new facts.

As a typical example of such an interaction between the worldview and experience in the era of the formation of natural science, one can point to the experiments of V. Hilbert, in which the peculiarities of electricity and magnetism were studied.

V. Gilbert was one of the first scientists who opposed the ideological attitudes of medieval science to a new ideal - the experimental study of nature. However, the worldview that guided Gilbert's experiments included a number of ideas borrowed from the Aristotelian natural philosophy that prevailed in the Middle Ages. Although V. Hilbert criticized the concept of the peripatetics about the four elements (earth, water, air and fire) as the basis of all other bodies, he used the concepts of metals as thickenings of the earth and electrifiable bodies as thickenings of water. Based on these ideas, Hilbert put forward a number of hypotheses regarding electrical and magnetic phenomena.

These hypotheses did not go beyond the framework of natural philosophical constructions, but they served as an impulse to set up experiments that revealed real facts. For example, the idea of "electric bodies" as the embodiment of the "element of water" gave rise to the hypothesis that all electrical phenomena are the result of the outflow of "fluids" from electrified bodies. From this, Hilbert suggested that electrical outflows should be delayed by barriers of paper and cloth, and that fire should destroy electrical actions, since it vaporizes the outflow. This gave rise to the idea of a series of experiments that revealed the facts of the shielding of an electric field by certain types of material bodies and the facts of the effect of flame on electrified bodies (to use modern terminology, it was essentially discovered that the flame has the properties of a conductor).

Similarly, the idea of a magnet as a condensation of the Earth was generated by W. Hilbert's famous experiments with a ball magnet, through which it was proved that the Earth is a ball magnet, and the properties of terrestrial magnetism were clarified. The ball magnet experiment looks very elegant even by the standards of modern physics experiments. It was based on an analogy between a spherical magnet (a terrell) and the Earth. Hilbert studied the behavior of a miniature magnetic needle placed at different points on the terrela, and then compared the data obtained with the facts of the orientation of the magnetic needle relative to the Earth known from the practice of navigation. From comparing these data, Hilbert concluded that the Earth is a spherical magnet.

The initial analogy between Terra and the Earth was suggested by Hilbert's picture of the world, in which the magnet, as a kind of metal, was considered as the embodiment of the "nature of the earth." Hilbert even in the name of the ball magnet (terrell - earth) emphasizes the commonality of the matter of the earth and the magnet and the naturalness of the analogy between the globe and the ball magnet.

By targeting observations and experiments, the worldview is always affected by them in reverse. It can be stated that the new facts obtained by V. Hilbert in the process of empirical research of the processes of electricity and magnetism generated a number of quite significant changes in the worldview originally adopted by V. Hilbert. By analogy with the idea of the earth as a "big magnet", V. Hilbert includes in the picture of the world the idea of planets as magnetic bodies. He expresses a bold hypothesis that the planets are held in their orbits by the forces of magnetic attraction. This interpretation, inspired by experiments with magnets, radically changed the idea of the nature of forces. At that time, the force was considered as a result of the contact of bodies (the force of pressure of one load on another, the force of impact). The new interpretation of force was a precursor to future representations of the mechanical worldview, in which the transmission of forces over a distance was considered as a source of changes in the state of motion of bodies.

The facts obtained from observation can not only modify the existing picture of the world, but also lead to contradictions in it and require its restructuring. It is only after passing through a long stage of development that the worldview is cleansed of natural philosophical layers and turns into a special worldview, the constructs of which (unlike natural philosophical schemes) are introduced according to signs that have an experimental basis.

In the history of science, physics was the first to carry out such an evolution. At the end of the XVI - the first half of the XVII century . she rebuilt the natural philosophical scheme of the world that dominated medieval physics, and created a scientific picture of physical reality - a mechanical picture of the world. New ideological ideas and new ideals of cognitive activity developed in the culture of the Renaissance and the beginning of Modern times played a decisive role in its formation. Conceptualized in philosophy, they appeared in the form of principles that provided a new vision of the facts accumulated by previous knowledge and practice about the processes studied in physics and allowed creating a new system of ideas about these processes.

The most important role in the construction of the mechanical picture of the world was played by the principle of the material unity of the world, which excludes the scholastic division into the earthly and heavenly worlds, the principle of causality and patterns of natural processes, the principles of experimental substantiation of knowledge and the installation of combining experimental research of nature with the description of its laws in the language of mathematics.

Having ensured the construction of a mechanical picture of the world, these principles turned into its philosophical justification.

Formation of particular theoretical schemes and laws

In advanced science, theoretical schemes are created first as hypothetical models, and then justified by experience. Their construction is carried out through the use of abstract objects previously formed in the field of theoretical knowledge and used as a building material when creating a new model.

Hypotheses and their prerequisites

It is only at the early stages of scientific research, when the transition from a predominantly empirical study of objects to their theoretical development is underway, that constructs of theoretical models are created by directly schematizing experience. But then they are used as a means to build new theoretical models, and this method begins to dominate science. The previous method remains only in a rudimentary form, and its scope is sharply narrowed. It is mainly used in situations where science is confronted with objects for the theoretical development of which sufficient funds have not yet been developed.

Then the objects begin to be studied experimentally, and on this basis, the necessary idealizations are gradually formed as a means to build the first theoretical models in a new field of research. Examples of such situations are the early stages of the formation of the theory of electricity, when physics formed the initial concepts - "conductor", "insulator", "electric charge", etc. and thereby created the conditions for the construction of the first theoretical schemes explaining electrical phenomena.

Most theoretical schemes of science are constructed not by schematizing experience, but by translating abstract objects that are borrowed from previously established fields of knowledge and connected to a new "network of connections." Traces of such operations can be easily detected by analyzing theoretical models of classical physics. For example, the objects of the Faraday model of electromagnetic induction "lines of force" and "conducting substance" were abstracted not directly from experiments on the detection of electromagnetic induction phenomena, but were borrowed from the field of knowledge of magnetostatics ("line of force") and knowledge about the conduction current ("conducting substance"). Similarly, when creating a planetary model of an atom, the concepts of the center of potential repulsive forces inside the atom (nucleus) and electrons were derived from theoretical knowledge of mechanics and electrodynamics.

In this regard, the question arises about the initial assumptions that guide the researcher in the selection and synthesis of the main components of the hypothesis being created. Although such a choice is a creative act, it has certain grounds. Such grounds are created by the researcher's accepted picture of the world. The concepts introduced in it about the structure of natural interactions make it possible to discover common features in various subject areas studied by science.

Thus, the worldview "suggests" where abstract objects and structures can be borrowed from, the combination of which leads to the construction of a hypothetical model of a new area of interaction.

The goal-setting function of the worldview in hypothesizing can be traced to the example of the formation of the planetary model of the atom.

This model is usually associated with Rutherford's name and the history of its formation is often described in such a way that it arose as a direct generalization of Rutherford's experiments on the scattering of p-particles on atoms. However, the actual history of science is far from this legend. Rutherford carried out his experiments in 1912, and the planetary model of the atom was first hypothesized by the Japanese physicist Nagaoka much earlier, in 1904.

Here, the logic of forming hypothetical variants of the theoretical model, which is created "from above" in relation to experience, is clearly manifested. Sketchily, this logic can be represented as follows in relation to the situation with the planetary model of the atom.

The first impulse to its construction, as well as to the promotion of a number of other hypothetical models (for example, the Thomson model), was the changes in the physical picture of the world that occurred due to the discovery of electrons and the development of the theory of electrons by Lorentz. Along with ether and atoms of matter, a new element "atoms of electricity" was introduced into the electrodynamic picture of the world. In turn, this raised the question of their relationship to the atoms of matter. The discussion of this issue led to the formulation of the problem: are electrons not part of an atom? Of course, the very formulation of such a question was a bold step, since it led to new changes in the worldview (it was necessary to recognize the complex structure of the atoms of matter).

Therefore, the concretization of the problem of the ratio of atoms and electrons was associated with entering the sphere of philosophical analysis, which always occurs with radical shifts in the worldview (for example, J. J. Thomson, who was one of the initiators of raising the question of the relationship between electrons and atoms of matter, sought support in the ideas of Boskovich atomistics to prove the need for information in the picture of the world of "atoms of matter" to "atoms of electricity").

The subsequent development of physics reinforced this idea with new experimental and theoretical discoveries. After the discovery of radioactivity and its explanation as a process of spontaneous atomic decay, the idea of the complex structure of the atom became established in the worldview. Now the ether and the "atoms of electricity" have begun to be considered as forms of matter, the interaction of which forms all other objects and processes of nature. As a result, the task arose - to build an "atom of matter" from positively and negatively charged "atoms of electricity" interacting through the ether.

The formulation of such a problem prompted the choice of initial abstractions for constructing hypothetical models of the atom - these should be abstract objects of electrodynamics. As for the structure in which all these abstract objects were immersed, its choice was also to some extent justified by the picture of the world. During this period (the end of the 19th - the beginning of the 20th century), the ether was considered as a single basis for the forces of gravity and electromagnetic forces, which made it natural to draw an analogy between the interaction of gravitating masses and the interaction of charges.

When Nagaoka proposed his model, he assumed that the rotation of moons and rings around Saturn could serve as an analogue of the atomic structure: electrons should rotate around a positively charged nucleus, similar to how satellites rotate around a central body in celestial mechanics.

Using an analog model was a way of transferring a structure from celestial mechanics that was connected to new elements (charges). The substitution of charges in place of gravitating masses in an analog model led to the construction of a planetary model of the atom.

Thus, in the process of putting forward hypothetical models, the worldview plays the role of a research program that ensures the formulation of theoretical problems and the choice of means to solve them.

After the hypothetical model of the studied interactions is formed, the stage of its substantiation begins. It is not limited only to verifying those empirical consequences that can be obtained from a law formulated with respect to a hypothetical model. The model itself must be justified.

It is important to pay attention to the following circumstance. When abstract objects are immersed in new relationships during the formation of a hypothetical model, this usually leads to their being endowed with new features. For example, when constructing a planetary model of an atom, a positive charge was defined as an atomic nucleus, and electrons were endowed with the characteristic of "stably moving in orbits around the nucleus."

Assuming that the hypothetical model created in this way expresses the essential features of a new subject area, the researcher thereby assumes: first, that the new, hypothetical features of abstract objects have a basis precisely in the area of empirically fixed phenomena that the model claims to explain, and, secondly, that these new features are compatible with others the defining features of abstract objects, which were justified by the previous development of cognition and practice.

It is clear that the validity of such assumptions should be proved specifically. This proof is done by introducing abstract objects as idealizations based on new experiences. The features of abstract objects, hypothetically introduced "from above" in relation to experiments in the new field of interactions, are now being restored "from below". They are obtained within the framework of thought experiments corresponding to the typical features of those real experimental situations that the theoretical model is designed to explain. After that, they check whether the new properties of abstract objects are consistent with those justified by previous experience.

This whole complex of operations provides substantiation of the features of abstract objects of the hypothetical model and its transformation into a theoretical scheme of a new field of interactions. We will call these operations constructive introduction of objects into the theory.

The theoretical scheme that satisfies the described procedures will be called structurally sound.

Procedures for constructive substantiation of theoretical schemes

Constructive justification provides a link between theoretical schemes and experience, and hence a connection with the experience of physical quantities of the mathematical apparatus of the theory. It is thanks to the procedures of constructive justification that the rules of conformity appear in theory.

Let us trace the features of constructive justification procedures and their role in the development of theory using the historical example of the planetary model of the atom that we are analyzing.

It is known that after Nagaoka proposed the hypothesis of the planetary structure of the atom, contradictions were discovered in his model. V. Wien in 1905 showed that the sign of an electron "to move in orbit around the nucleus" contradicts its other fundamental feature "to emit during accelerated motion." Since the motion in a closed orbit is accelerated, the electron must radiate, lose its energy and fall on the nucleus. Therefore, an atom, if it were arranged as the planetary model suggests, could not be stable.

This paradox was a fairly typical illustration of the discovery of an unconstructive element in a hypothetical model (in this case, it was the idea of an electron orbit). However, the question of the constructiveness of ideas about the atomic nucleus remained open. However, Nagaoka's model was rejected after criticism from Wine, and for some time many physicists did not even mention it when discussing the problem of atomic structure.

She gained her second life after Rutherford carried out experiments with a-particles, which proved the existence of an atomic nucleus. It is characteristic that Rutherford referred to Nagaoka's ideas as early as 1911, and, apparently, he set up his experiments hoping to test a variety of models of the atomic structure, including the rejected planetary model. In any case, he placed the recording equipment in a special way in his experiments, believing it possible that a-particles could scatter at large angles after their interaction with atoms. Having discovered this type of scattering in the experiment, Rutherford interpreted it as evidence of the existence of a positively charged nucleus inside the atom.

Now it has become possible to constructively introduce those features of the atomic nucleus that were postulated by the planetary model.

The core was defined as a center of potential repulsive forces capable of scattering heavy, positively charged particles at large angles. Characteristically, this definition can be found even in modern physics textbooks. It is not difficult to find that it is a concise description of a thought experiment on scattering heavy particles on an atom, which, in turn, acts as an idealization of Rutherford's real experiments. The features of the "atomic nucleus" construct, introduced hypothetically, "from above" in relation to experience, have now been obtained "from below" as an idealization of real experiments in the atomic field. Thus, the hypothetical object "atomic nucleus" received a constructive justification and could be given an ontological status.

The proof of the core's existence led to the restoration of the planetary model, although all the paradoxes of the unstable atom discovered by Wine had not yet been resolved. But now the problem has been specified. The weak link of the model, the representation of the electron orbit, was clearly identified. This abstract object, introduced at the stage of hypothesis formation, had no correlate in any of the experiments in the atomic field.

It is significant that the desire to localize and then eliminate an unconstructive element - the "electronic orbit", based on the analysis of the specifics of atomic experiments, was the main impulse that purposefully rebuilt the Rutherford model into a quantum mechanical model of the atom.

Thus, the detection of non-constructive elements not only reveals the inadequacy of the representation of the structure of the reflected object in the hypothetical model, but also indicates specific ways to rebuild the model.

In classical physics, constructive reasoning procedures were carried out intuitively. They were not explicitly explained as a methodological requirement. Only the transition to modern physics was accompanied by the identification of a number of significant aspects within the framework of methodological reflection. The latter, in my opinion, found its expression (although not fully adequate) in the rational aspects of the observability principle, which was an important methodological guideline in the construction of the theory of relativity and quantum mechanics. The heuristic content of this principle can be interpreted as a requirement for the constructive introduction of abstract objects into theoretical models.

Constructive substantiation of the hypothesis leads to a gradual restructuring of the initial versions of the theoretical scheme until it is adapted to the relevant empirical material. The theoretical scheme, rebuilt and justified by experience, is then compared with the worldview again, which leads to the refinement and development of the latter. For example, after Rutherford substantiated his ideas about the nuclear structure of the atom, such ideas entered the physical picture of the world, giving rise to a new range of research tasks - the structure of the nucleus, the features of the "matter of the nucleus", etc.

Thus, the generation of new theoretical knowledge is carried out as a result of the cognitive cycle, which consists in the movement of research thought from the foundations of science, and primarily from experience-based representations of the worldview, to hypothetical versions of theoretical schemes. These schemes are then adapted to the empirical material they claim to explain. In the process of such adaptation, theoretical schemes are rebuilt, saturated with new content and then re-compared with the worldview, exerting an active reverse effect on it. The development of scientific concepts and ideas is carried out through the repeated repetition of the described cycle. In this process, the "logic of discovery" and the "logic of hypothesis justification" interact, which act as interrelated aspects of theory development.

The logic of constructing advanced theories in classical physics

In the science of the classical period, developed theories were created through the consistent generalization and synthesis of particular theoretical schemes and laws.

In this way, the fundamental theories of classical physics were built - Newtonian mechanics, thermodynamics, and electrodynamics. The main features of this process can be traced by the example of the history of Maxwellian electrodynamics.

When creating the theory of the electromagnetic field, Maxwell relied on previous knowledge about electricity and magnetism, which were represented by theoretical models and laws expressing essential characteristics of certain aspects of electro-scale interactions (theoretical models and laws of Coulomb, Ampere, Faraday, Biot and Savard, etc.).

In relation to the foundations of the future theory of the electromagnetic field, these were particular theoretical schemes and particular theoretical laws.

The initial program of theoretical synthesis was set by the ideals of cognition accepted by the researcher and the picture of the world, which determined the formulation of tasks and the choice of means to solve them.

In the process of creating Maxwellian electrodynamics, creative search was focused, on the one hand, by the ideals and norms that had developed in science, which the theory was supposed to satisfy (the ideal of explaining various phenomena using a small number of fundamental laws, the ideal of organizing theory as a deductive system in which laws are formulated in the language of mathematics), and on the other hand, the accepted Maxwell's Faraday picture of physical reality, which set a single point of view on a very diverse theoretical material to be synthesized and generalized. This picture posed the task of explaining all the phenomena of electricity and magnetism as the transfer of electric and magnetic forces from point to point in accordance with the principle of proximity.

Together with the formulation of the main task, she outlined a range of theoretical means to ensure the solution of the problem. Analog models and mathematical structures of continuum mechanics served as such tools. The Faraday worldview revealed similarities between the transfer of forces in these qualitatively different types of physical processes and thus created the basis for the transfer of the corresponding mathematical structures from continuum mechanics to electrodynamics. It is significant that an alternative research direction to Maxwell's, associated with the names of Ampere and Weber, proceeded from a different picture of the world when searching for a generalizing theory of electromagnetism. In accordance with this picture, other means of theory construction were used (analog models and mathematical structures were borrowed from the Newtonian mechanics of material points).

The synthesis undertaken by Maxwell was based on the use of the operation of applying analog models, which is already known to us. These models were borrowed from continuum mechanics and served as a means to transfer the corresponding hydrodynamic equations into the created theory of the electromagnetic field. The application of analogies is a universal operation of constructing a new theory both in the formation of particular theoretical schemes and in their generalization into a developed theory. Scientific theories are not isolated from each other, they develop as a system where some theories supply building materials for others.

The analog models that Maxwell used-incompressible fluid current tubes, vortices in an elastic medium-were theoretical circuits of continuum mechanics.

When the equations associated with them were translated into electrodynamics, mechanical quantities were replaced in the equations by new quantities. This substitution was possible due to the substitution of new objects in the analog model instead of abstract objects of mechanics - lines of force, charges, differentially small current elements, etc. Maxwell borrowed these objects from the theoretical schemes of Coulomb, Faraday, Ampere, schemes that he generalized in the new theory he created. The substitution of new objects into the analog model is not always realized by the researcher, but it is carried out necessarily. Without this, the equations will have no new physical meaning and cannot be applied in a new field.

Once again, we emphasize that this substitution means that abstract objects translated from one system of knowledge (in our example, from the system of knowledge about electricity and magnetism) are combined with a new structure. (a "grid of relationships") borrowed from another system of knowledge (in this case, from continuum mechanics). As a result of this connection, the analog model is transformed. It turns into a theoretical scheme of a new field of phenomena, a hypothetical scheme at first, requiring its own constructive justification.

Features of the formation of a scientific hypothesis

The movement from the picture of the world to the analog model and from it to the hypothetical scheme of the studied field of interactions forms a kind of rational outline of the process of hypothesizing. This process is often described in terms of the psychology of discovery and creative intuition. However, such a description, if it claims to be meaningful, must necessarily involve clarifying the "mechanisms" of intuition. It is significant that along these paths, researchers immediately encountered the so-called Gestalt switching process, which forms the basis of intellectual intuition.

A detailed analysis of this process shows that intellectual intuition is significantly characterized by the use of certain model representations, through the prism of which new situations are considered. Model representations define an image of a structure (gestalt), which is transferred to a new subject area and organizes previously accumulated elements of knowledge about this area in a new way (concepts, idealizations, etc.).

The result of this work of creative imagination and thinking is a hypothesis that allows us to solve the problem.

Further consideration of the mechanisms of intellectual intuition has clearly established that a new vision of reality, which corresponds to Gestalt switching, is formed by substituting new elements (ideal objects) into the original model-representation (gestalt), and this allows us to construct a new model that sets a new vision of the processes under study.

The gestalt here is a kind of "casting mold" by which the model is "cast."

This description of hypothesis generation procedures is consistent with research on the psychology of discovery. But the process of advancing scientific hypotheses can also be described in terms of logical and methodological analysis. Then its new important aspects are revealed.

First, we note once again that the search for a hypothesis cannot be reduced to trial and error alone; in forming a hypothesis, the foundations adopted by the researcher (ideals of cognition and the picture of the world) play an essential role, which target creative search, generating research tasks and outlining the field of means to solve them.

Secondly, we emphasize that the operations of hypothesis formation cannot be transferred entirely to the sphere of individual creativity of a scientist. These operations become the property of an individual insofar as his thinking and imagination are formed in the context of a culture in which samples of scientific knowledge and patterns of activity for their production are transmitted. The search for a hypothesis, which includes the choice of analogies and the substitution of new abstract objects into an analog model, is determined not only by historically established means of theoretical research. It is also determined by the cultural translation of certain patterns of research activities (operations, procedures) that provide solutions to new problems. Such patterns are included in scientific knowledge and assimilated in the learning process. T. Kuhn rightly noted that the application of theories already developed in science to describe specific empirical situations is based on the use of certain patterns of mental experimentation with theoretical models, patterns that form the most important part of the paradigms of science.

Kuhn also pointed out the analogy between the problem-solving activity in the process of applying theory and the historically preceding activity of developing initial models, on the basis of which theoretical problems are then solved.

The analogy Kuhn noted is an external expression of a very complex process of accumulation, convolution in the available composition of theoretical knowledge of activities for the production of this knowledge.

Paradigmatic patterns of working with theoretical models arise in the process of theory formation and are included in its composition as a set of certain solved problems, in the image and likeness of which other theoretical problems should be solved. The transmission of theoretical knowledge in culture also means the transmission in culture of patterns of problem-solving activities. These samples depict procedures and operations for generating new hypotheses (according to the scheme: world view - analog model - substitution of new abstract objects into the model). Therefore, during the assimilation of already accumulated knowledge (in the process of forming a scientist as a specialist), some very general schemes of mental work are also assimilated, ensuring the generation of new hypotheses.

The cultural translation of schemes of mental activity that ensure the generation of hypotheses allows us to consider the procedures for such generation, abstracting from the personal qualities and abilities of a particular researcher. From this point of view, we can talk about the logic of forming hypothetical models as a moment in the logic of forming a scientific theory.

Finally, and thirdly, summarizing the features of the process of forming hypothetical models of science, we emphasize that this process is based on the combination of abstract objects drawn from one field of knowledge with a structure (a "grid of relationships") borrowed from another field of knowledge. In the new system of relations, abstract objects are endowed with new features, and this leads to the appearance of new content in the hypothetical model, which may correspond to the connections and relationships of the subject area that have not yet been explored, for which the hypothesis is intended to describe and explain.

The noted feature of the hypothesis is universal. It manifests itself both at the stage of formation of particular theoretical schemes and during the construction of a developed theory.

In the process of creating the theory of the electromagnetic field, this feature of the formation of new theoretical meanings manifested itself already at the very first stages of Maxwell's research. Maxwell began his theoretical synthesis by searching for generalizing laws of electrostatics. For this purpose, he used the hydrodynamic analogy of current tubes in an ideal, incompressible fluid. Replacing these tubes with electric lines of force, he constructed a hypothetical scheme of electrostatic interactions, and presented Euler's equations as a description of the behavior of electric lines of force.

When abstract objects borrowed from the Faraday model of electrostatic induction were substituted into the analog model, these objects (lines of force) were immersed in a new network of connections, thereby being endowed with new features - electric lines of force appeared as detached from the charges generating them. Potentially, it contained a new, although at first hypothetical, idea of an electric field (it introduced an idealization of a field that exists relatively independently of the charges that generate it).

The idea of the independent existence of electric lines of force could turn from a hypothesis into a theoretical statement only if the new feature of the lines of force received a constructive justification. Proving the validity of this feature was, in principle, a simple matter, given the possibility of the following thought experiment with the Faraday scheme of electrostatic induction. In this scheme, the lines of force were depicted as arising in an idealized dielectric bounded by ideal charged plates, and depended on the amount of charge on the plates (an ideal capacitor).

The mental variation of charges on the lining of an ideal capacitor and the statement of the fact that, along with this, the electrical energy in the dielectric decreases and increases, made it possible to make the ultimate transition to the case when all the electrical energy is concentrated in the dielectric. This corresponded to the idea of a set of field lines that exist even when the charges that generate them are eliminated. Now the lines of force, "detached" from the charges, turned out to be an idealization based on real experience.

This new content of the theoretical scheme was objectified by its mapping onto the picture of reality under study, proposed by Faraday and accepted by Maxwell. This picture includes the idea of an electric field as a special independent substance that has the same status of objective existence as charged bodies. Subsequently, this idea of an independent electric field, not tied to charges, helped Maxwell in interpreting the final equations, when the idea of the propagation of electromagnetic waves arose.

Paradigmatic patterns of problem solving

The interaction of the operations of hypothesizing and its constructive justification is the key point that allows us to answer the question of how paradigmatic patterns of problem solving appear in the theory.

Having posed the problem of samples, Western philosophy of science could not find the appropriate means to solve it, since it did not identify and did not analyze, even in the first approximation, the procedure for constructive substantiation of hypotheses.

When discussing the problem of patterns, T. Kuhn and his followers focus on only one side of the issue - the role of analogies as the basis for solving problems. The operations of forming and substantiating theoretical schemes arising in this process fall out of the scope of their analysis.

It is very significant that within the framework of this approach, fundamental difficulties arise when trying to figure out the role of the rules of conformity and their origin. T. Kuhn, for example, believes that in the work of the scientific community, these rules do not play such an important role that they are traditionally attributed by methodologists. He specifically emphasizes that the main thing in solving problems is to find analogies between different physical situations and apply the formulas already found on this basis. As for the rules of conformity, according to Kuhn, they are the result of subsequent methodological retrospection, when a methodologist tries to clarify the criteria used by the scientific community by applying certain analogies.

In general, Kuhn is consistent in his position, since the question of procedures for the constructive justification of theoretical models does not arise within the framework of his concept. To discover this procedure requires a special approach to the study of the structure and dynamics of scientific knowledge. It is necessary to consider the theoretical models included in the theory as a reflection of the object in the form of activity. In relation to a specific study of the nature and genesis of theoretical models of physics, this approach focuses on their special vision: theoretical models are considered both as an ontological scheme reflecting the essential characteristics of the reality under study, and as a kind of "convolution" of subject-practical procedures, within which these characteristics can be fundamentally identified. It is this vision that makes it possible to discover and describe the operations of constructive justification of theoretical schemes.

With other theoretical and cognitive attitudes, these operations escape the field of view of the methodologist.

But since the constructive justification of theoretical schemes ensures the appearance of correspondence rules in theory, determining their content and meaning, Kuhn's difficulties in determining the ways of formation and functions of these rules are not surprising.

It is characteristic that T. Kuhn, when discussing the problem of samples, refers to the history of Maxwellian electrodynamics. Analyzing it only in terms of the application of analog models, he believes that the main results of the Maxwell study were obtained without any construction of compliance rules. But this conclusion is very far from the real facts of the history of science. The fact is that in the process of constructing his theory, Maxwell at one stage obtained field equations that are very close to the modern mathematical scheme for describing electromagnetic phenomena.

However, at this stage he was unable to correlate some fundamental quantities appearing in the equations with the real relations of objects of empirical situations (the theoretical scheme introduced with the equations did not find constructive justification). And then Maxwell had to abandon this generally promising apparatus, starting anew the process of theoretical synthesis. In his research, the search for mathematical structures describing electromagnetic interactions was constantly reinforced by explication and justification of the introduced theoretical schemes.

If we trace the formation of the classical theory of the electromagnetic field from this point of view, then the following logic of Maxwell's research is revealed. Maxwell gradually generalized the theoretical knowledge gained by his predecessors about certain areas of electromagnetic interactions. The theoretical material that he summarized was grouped into the following blocks: knowledge of electrostatics, magnetostatics, stationary current, electromagnetic induction, force and magnetic action of currents.

Using analog models, Maxwell first obtained generalizing equations for a particular block of knowledge. In the same process, he formed a generalizing hypothetical model, which was supposed to provide an interpretation of the equations and assimilate the theoretical schemes of the corresponding block of knowledge.

After constructive substantiation and transformation of this model into a theoretical scheme, Maxwell connected a new block of knowledge to generalization. He used a previously applied hydrodynamic or mechanical analogy, but complicated and modernized it so as to ensure the assimilation of new physical material. After that, the justification procedure that we already know was repeated: the constructive content was revealed inside the new analog model, which was equivalent to the explication of a new generalizing theoretical scheme. It was proved that with the help of this scheme, the particular theoretical models of the new block are assimilated, and the corresponding particular theoretical laws are derived from the new generalizing equation. But the rationale did not end there either.

The researcher needed to make sure that he did not destroy the previous constructive content with a new generalization. To do this, Maxwell re-derived all the partial laws of the previously synthesized blocks from the obtained generalizing equations. It is significant that in the process of such a conclusion, each new generalizing theoretical scheme was reduced to particular theoretical schemes equivalent to those previously assimilated.

At the final stage of theoretical synthesis, when the basic equations of the theory were obtained and the formation of the fundamental theoretical model was completed, the researcher produced the last proof of the validity of the introduced equations and their interpretations: on the basis of the fundamental theoretical scheme, he constructed the corresponding partial theoretical schemes, and from the basic equations he obtained in a new form all the partial theoretical laws generalized in them. At this final stage of the formation of the Maxwell theory of the electromagnetic field, it was proved that, based on the theoretical model of the electromagnetic field, theoretical circuits of electrostatics, direct current, electromagnetic induction, etc. can be obtained as a special case, and the laws of Coulomb, Ampere, Biot-Savard, the laws of electrostatic and electromagnetic induction can be derived from the equations of the electromagnetic field. By Faraday, etc.

This final stage simultaneously appears as a presentation of a "ready-made" theory. The process of its formation is now reproduced in reverse order in the form of the unfolding of theory, the derivation of the corresponding theoretical consequences from the basic equations. Each such conclusion can be regarded as an exposition of some method and result of solving theoretical problems.

The meaningful operations of constructing theoretical schemes, which act as a necessary aspect of the substantiation of theory, now acquire a new function - they become models of operations, focusing on which the researcher can solve new theoretical problems. Thus, problem solving patterns are automatically included in the theory during its genesis.

After the theory is built, its further fate is connected with its development in the process of expanding the field of application of the theory.

This process of theory functioning inevitably leads to the formation of new patterns of problem solving in it. They are included in the theory along with those that were introduced in the process of its formation. The primary samples are also modified with the development of scientific knowledge and the change in the previous form of the theory, but in a modified form they are usually preserved in all further expositions of the theory. Even the most modern formulation of classical electrodynamics demonstrates techniques for applying Maxwell's equations to specific physical situations using the example of deducing Coulomb, Biot-Savard, and Faraday laws from these equations. The theory preserves traces of its past history, reproducing the main features of the process of its formation as typical tasks and methods of their solution.

Features of the construction of developed, mathematized theories in modern science

With the development of science, the strategy of theoretical search is changing. The construction of modern physical theories is carried out by the method of mathematical hypothesis.

Application of the mathematical hypothesis method

The first aspect of these problems is related to the search for the initial grounds for the hypothesis. In classical physics, the picture of the world played a major role in the process of hypothesizing. As developed theories were formed, they received experimental justification not only through direct interaction with experiment, but also indirectly through the accumulation of experimental facts in theory. And when physical pictures of the world were presented in the form of developed and experience-based constructions, they set such a vision of the reality under study, which was introduced correlatively to a certain type of experimental and measuring activity. This activity has always been based on certain assumptions, which implicitly expressed both the features of the object under study and the extremely generalized scheme of activity through which the object is being developed.

In physics, this pattern of activity was expressed in ideas about what should be taken into account in measurements and what interactions of measured objects with devices can be ignored. These assumptions underlie an abstract measurement scheme that corresponds to the ideals of scientific research and correlatively introduces advanced forms of the physical picture of the world.

For example, when the followers of Newton considered nature as a system of bodies (material corpuscles) in absolute space, where instantaneously propagating effects from one body to another change the state of each body in time and where each state is strictly determined (in the Laplace sense) by the preceding state, the following abstract measurement scheme was implicitly present in this picture of nature. First, it was assumed that in measurements any object can be distinguished as its own unique body, the coordinates and impulses of which can be strictly determined at any given moment in time (the idea of deterministic motion of bodies in the Laplace sense). Secondly, it was postulated that space and time do not depend on the state of motion of material bodies (the idea of absolute space and time). This concept was based on the idealizing assumption that in measurements that reveal the space-time characteristics of bodies, the properties of clocks and rulers (rigid rods) of a physical laboratory do not change from the presence of the bodies themselves (masses) and do not depend on the relative motion of the laboratory (frame of reference).

Only the reality that corresponded to the described measurement scheme (and simple dynamical systems corresponded to it) was accepted in the Newtonian worldview as nature "by itself."

It is significant that modern physics has adopted more complex measurement schemes. For example, in quantum mechanics, the first requirement of the Newtonian scheme is eliminated, and in the theory of relativity, the second is eliminated. In this regard, more complex subjects of scientific theories are introduced.

When confronted with a new type of objects, the structure of which was not taken into account in the current picture of the world, cognition changed this picture. In classical physics, such changes were carried out in the form of the introduction of new ontological concepts. However, the latter were not accompanied by an analysis of the abstract measurement scheme, which forms the operational basis of the introduced ontological structures. Therefore, each new picture of physical reality underwent a long period of substantiation by experience and specific theories before it received the status of a picture of the world. Modern physics has provided examples of a different way of building knowledge. It builds a picture of physical reality by explicating a measurement scheme within which new objects will be described. This explication is carried out in the form of advancing principles that fix the features of the object research method (the principle of relativity, the principle of complementarity).

The picture itself may not have a complete form at first, but together with the principles that fix the "operational side" of the vision of reality, it determines the search for mathematical hypotheses. The new strategy of theoretical search has shifted the emphasis in the philosophical regulation of the process of scientific discovery. In contrast to classical situations, where the promotion of a physical picture of the world was primarily oriented by "philosophical ontology," in quantum-relativistic physics, the center of gravity was shifted to epistemological issues. Therefore, in the regulatory principles that target the search for mathematical hypotheses, the provisions of a theoretical and cognitive nature (the principle of correspondence, simplicity, etc.) are clearly presented (in a form concretized in relation to physical research).

In the course of mathematical extrapolation, the researcher creates a new apparatus by rearranging some already known equations. The physical quantities included in such equations are transferred to a new apparatus, where new connections are obtained, and hence new definitions. Accordingly, abstract objects are borrowed from already established fields of knowledge, the signs of which were represented by physical quantities. Abstract objects are immersed in new relationships, due to which they are endowed with new features. A hypothetical model is created from these objects, which is implicitly introduced along with a new mathematical apparatus as its interpretation.

Such a model, as a rule, contains non-constructive elements, and this can lead to contradictions in theory and to inconsistencies with the experience of even promising mathematical tools.

Thus, the specificity of modern research does not consist in the fact that the mathematical apparatus is first introduced without interpretation (an uninterpreted apparatus is calculus, a mathematical formalism that belongs to mathematics, but is not an apparatus of physics). The specificity lies in the fact that a mathematical hypothesis most often implicitly forms an inadequate interpretation of the created apparatus, and this significantly complicates the procedure for empirical verification of the hypothesis put forward. Comparing the consequences of equations with experience always involves interpreting the quantities that appear in the equations. Therefore, experience does not test the equations themselves, but the system: equations plus interpretation. And if the latter is inadequate, then experience can discard, along with interpretation, very productive mathematical structures corresponding to the features of the objects under study.

To substantiate a mathematical hypothesis by experience, it is not enough to simply compare the consequences of equations with experimental data. It is necessary each time to explicate hypothetical models that were introduced at the stage of mathematical extrapolation, separating them from the equations, substantiate these models constructively, re-verify them with the created mathematical formalism, and only after that verify the consequences of the equations with experience.

A long series of mathematical hypotheses creates a danger of accumulation of non-constructive elements in the theory and loss of the empirical meaning of the quantities appearing in the equations. Therefore, in modern physics, at a certain stage of theory development, intermediate interpretations become necessary, providing operational control over the theoretical structure being created. In the system of such intermediate interpretations, a constructively grounded theoretical scheme is created that ensures adequate semantics of the apparatus and its connection with experience.

All the described features of the formation of modern theory can be illustrated by referring to the material of the history of quantum physics.

Quantum electrodynamics is a convincing evidence of the heuristic nature of the mathematical hypothesis method. Its history began with the construction of a formalism that makes it possible to describe the "microstructure" of electromagnetic interactions.

The creation of this formalism is quite clearly divided into four stages. Initially, the apparatus of the quantized electromagnetic radiation field (a field that does not interact with the source) was introduced. Then, at the second stage, the mathematical theory of the quantized electron-positron field was constructed (field sources were quantized). At the third stage, the interaction of these fields was described in the framework of perturbation theory in the first approximation. Finally, at the final, fourth stage, an apparatus was created that characterizes the interaction of quantized electromagnetic and electron-positron fields, taking into account subsequent approximations of perturbation theory (this apparatus was associated with the renormalization method, which makes it possible to describe interacting fields in higher orders of perturbation theory).

At a time when the first and second stages of constructing the mathematical formalism of the theory had already been completed and the apparatus describing the interaction of free quantized fields by perturbation theory methods began to be successfully created, paradoxes were discovered in the very foundation of quantum electrodynamics, which called into question the value of the constructed mathematical apparatus. These were the so-called paradoxes of the measurability of fields. In the works of P. Jordan, V. A. Fock, and especially in the joint study of L. D. Landau and R. Peierls, it was shown that the main quantities that appeared in the apparatus of the new theory, in particular, the components of electric and magnetic tension at a point, have no physical meaning. Fields at a point cease to be empirically justified objects as soon as the researcher begins to take into account quantum effects.

The source of the measurement paradoxes was an inadequate interpretation of the constructed formalism. This interpretation was implicitly introduced in the very process of constructing the apparatus by the method of mathematical hypothesis.

The synthesis of quantum mechanical formalism with the equations of classical electrodynamics was accompanied by the borrowing of abstract objects from quantum mechanics and electrodynamics and their unification within the framework of a new hypothetical construction. In it, the field was characterized as a system with a variable number of particles (photons) arising with a certain probability in each of the possible quantum states. Among the set of classical observables that were necessary to describe the field as a quantum system, the most important place was occupied by the field strengths at a point. They appeared in the theoretical model of the quantized electromagnetic field due to the transfer of abstract objects from classical electrodynamics.

This transfer of classical idealizations (abstract objects of Maxwell-Lorentz electrodynamics) into a new theoretical model has created crucial difficulties in mapping it to empirical situations in the study of quantum processes in the relativistic domain. It turned out that it is impossible to find recipes for the connection of field components at a point with the real features of experiments and measurements in which quantum relativistic effects are detected. Classical recipes assumed, for example, that the magnitude of the electric voltage at a point is determined through the recoil of a point test charge (the pulse acquired by it serves as a measure of the field strength at a given point). But if we are talking about quantum effects, then due to the uncertainty ratio, the localization of the test charge (the exact coordinate) leads to an increasing uncertainty of its momentum, which means that it is impossible to determine the field strength at a point. Further, as shown by Landau and Peierls, the uncertainties that arise when transmitting the pulse from the test charge to the recorder were added to this. Thus, it was shown that the hypothetically introduced model of a quantized electromagnetic field lost its physical meaning, which means that the associated apparatus also lost its meaning.

Self-monitoring questions

1. The dynamics of scientific knowledge.

2. The logic of constructing advanced theories in classical physics.

3. What are the features of the construction of developed, mathematized theories in modern science?

6 PHILOSOPHY OF TECHNOLOGY SUBJECT OF PHILOSOPHY OF TECHNOLOGY

What is the philosophy of technology?

This question can be answered in two ways: first, by defining what is special about the philosophy of technology in comparison with other disciplines that study technology, and, secondly, by considering what technology itself is.

In the twentieth century, technology has become the subject of study in a wide variety of disciplines, both technical, natural and social, both general and private. The number of specialized technical disciplines is increasing at an astonishing rate nowadays, as not only various branches of technology, but also various aspects of these industries become the subject of their research. The increasing specialization in engineering stimulates the opposite process of development of general technical disciplines. However, all of them, both private and general, focus on certain types, or on certain aspects, of certain "slices" of technology.

Technology as a whole is not the subject of research in technical disciplines. Due to their increasing influence on nature (including on a global scale), many natural sciences are forced to take technology into account and even make it the subject of special research, of course, from their own special scientific (for example, physical) point of view. In addition, it is impossible to conduct modern natural science experiments without technical devices. Due to the penetration of technology into almost all spheres of modern society, many social sciences, primarily sociology and psychology, turn to a special analysis of technical development. The historical development of technology has traditionally been the subject of the study of the history of technology as a special humanitarian discipline. As a rule, however, historical and technical research is specialized in individual branches or stages of development and does not capture in the field of its analysis questions about trends and prospects for the development of modern technology.

Thus, the philosophy of technology, firstly, explores the phenomenon of technology as a whole, secondly, not only its immanent development, but also its place in social development as a whole, and also, thirdly, takes into account a broad historical perspective. However, if the subject of the philosophy of technology is technology, then a legitimate question immediately arises: what is technology itself?

The technique must be understood

- as a set of technical devices, artifacts - from individual simple tools to the most complex technical systems;
- as a set of various types of technical activities for the creation of these devices - from scientific and technical research and design to their manufacture and operation, from the development of individual elements of technical systems to system research and design;
- as a set of technical knowledge - from specialized prescription and technical to theoretical scientific, technical and system engineering knowledge.

Today, the field of technology includes not only the use, but also the production of scientific and technical knowledge itself. In addition, the process of applying scientific knowledge in engineering practice is not as simple as it is often thought, and is associated not only with the application of existing knowledge, but also with the acquisition of new knowledge. "The application is not a simple application of science to special purposes," wrote A. Ridler, a German engineer and rector of the Berlin Polytechnic. - Before making such an application, it is necessary to take into account the numerous conditions of this case. The difficulty of the application lies in correctly finding the actual conditions of the given case. The conventionally accepted state of things and the neglect of certain given conditions deceive about the present reality.

Only application leads to full understanding; it forms the highest stage of knowledge, and general scientific knowledge forms only a preliminary stage to it... Knowledge is the daughter of application. It takes exploration and ingenuity to apply."

Thus, modern technology, and above all technical knowledge, are inextricably linked with the development of science. Today, no one needs to prove this thesis. However, in the history of the development of society, the relationship between science and technology has gradually changed.

Technology in historical retrospect

Regardless of the moment when science began, technology can definitely be said to have originated with the emergence of Homo sapiens and has been developing independently of any science for a long time. Of course, this does not mean that scientific knowledge has not been used in technology before. But, firstly, science itself did not have a special disciplinary organization for a long time, and, secondly, it was not focused on the conscious application of the knowledge it created in the technical field.

Prescription and technical knowledge has been opposed to scientific knowledge for quite a long time, there was no question about special scientific and technical knowledge at all. "Scientific" and "technical" actually belonged to different cultural areas. In the earlier period of the development of human civilization, both scientific and technical knowledge were organically interwoven into the religious and mythological worldview and were not yet separated from practical activities. Prescription and technical knowledge has been opposed to scientific knowledge for quite a long time, there was no question about special scientific and technical knowledge at all. "Scientific" and "technical" actually belonged to different cultural areas. In the earlier period of the development of human civilization, both scientific and technical knowledge were organically interwoven into the religious and mythological worldview and were not yet separated from practical activities.

In the ancient world, technology, technical knowledge, and technical action were closely related to magical action and mythological worldview. One of the first philosophers of technology, Alfred Espinas, in his book The Emergence of Technology, published at the end of the 19th century, wrote: "The painter, the caster, and the sculptor are workers whose art is valued primarily as a necessary part of the cult. ...The Egyptians, for example, were not far behind the Greeks of the Homeric era in mechanics, but they did not leave the religious worldview. Moreover, the first machines were apparently donated to the gods and dedicated to a cult before they could be used for useful purposes.

The belt drill was apparently invented by the Hindus to light a sacred fire, an operation that was performed extremely quickly, because it is still performed up to 360 times a day on certain holidays. The wheel was a great invention; it is very likely that it was formerly dedicated to the gods. Geiger believes that the prayer wheels used today in Buddhist temples in Japan and Tibet, which are partly wind-driven and partly hydraulic, should be considered the most ancient... So, all the technology of this era, the author concludes, had the same character. She was religious, traditional and local." The science of the ancient world was not only non-specialized and non-disciplinary, but also inseparable from practice and technology. The most important step towards the development of Western civilization was the ancient revolution in science, which distinguished the theoretical form of knowledge and exploration of the world into an independent sphere of human activity.

Ancient science was complex in its very desire to cover the theoretically conceptualized and philosophically discussed subject of scientific research as fully as possible. Specialization was just beginning to take shape, and in any case, it did not take organized forms of discipline. The concept of technology was also significantly different from the modern one. In antiquity, the concept of "tehne" embraces both technology, technical knowledge, and art. But it doesn't include theory. Therefore, the ancient Greek philosophers, for example, Aristotle, do not have special works on "tehne".

Moreover, in ancient culture, science and technology were considered as fundamentally different types of activities. "In ancient thinking, there was a clear distinction between episteme, on the comprehension of which science is based, and tekne, practical knowledge that is necessary for business and related to it," wrote one well-known researcher. - Tekne had no theoretical foundation, ancient technology was always prone to routine, dexterity, skill; technical experience was passed on from father to son, from mother to daughter, from master to pupil. The ancient Greeks made a clear distinction between theoretical knowledge and practical craft."

In the Middle Ages, architects and artisans relied mainly on traditional knowledge, which was kept secret and which changed only slightly over time. The question of the relationship between theory and practice was solved in a moral aspect - for example, which style of architecture is more preferable from the divine point of view. It was engineers, artists, and practical mathematicians of the Renaissance who played a crucial role in the adoption of a new type of practically oriented theory. The very social status of artisans, who reached the highest levels of Renaissance culture in their work, has also changed. In the Renaissance, the tendency towards an all-encompassing consideration and study of the subject, which had already emerged in the early Middle Ages, was expressed, in particular, in the formation of the ideal of an encyclopediously developed personality of a scientist and engineer, equally knowledgeable and able in various fields of science and technology.

In Modern science, one can observe a different trend - the desire to specialize and isolate certain aspects and sides of the subject as subject to systematic research by experimental and mathematical means. At the same time, the ideal of a new science capable of solving engineering problems by theoretical means and a new technology based on science is being put forward. It was this ideal that eventually led to the disciplinary organization of science and technology. Socially, this was due to the formation of the professions of a scientist and engineer, increasing their status in society.

At first, science took a lot from the master engineers of the Renaissance, then in the XIXXX centuries, the professional organization of engineering activities began to be based on the patterns of the scientific community. The specialization and professionalization of science and technology, along with the simultaneous technification of science and the scientific identification of technology, resulted in the emergence of many scientific and technical disciplines that developed in the 19th century into a more or less orderly edifice of disciplinarily organized science and technology. This process was also closely related to the formation and development of a specially scientific and science-based engineering education.

So, it can be seen that in the course of historical development, technical action and technical knowledge are gradually separated from myth and magical action, but initially they are not based on scientific, but only on everyday consciousness and practice. This is clearly seen from the description of the technical formulation in numerous manuals on craft techniques aimed at consolidating and transferring technical knowledge to a new generation of craftsmen. There is nothing mystical or mythological in the recipes anymore, although we are not yet facing a scientific description, and the technical terminology has not yet settled down.

In modern times, there is an urgent need to train engineers in special schools. This is no longer just the transfer of skills accumulated by previous generations from master to pupil, from father to son, but an established and socially anchored system for the transfer of technical knowledge and experience through the vocational education system.

How was a rational generalization formed in technology?

The first stage of rational generalization in craft technology in its individual branches was associated with the need for training within each individual type of craft technology. Such reference books and teaching aids were not yet strictly scientific, but they had already gone beyond the mythological picture of the world. The society realized the need to create a system of regular craft training. For example, the fundamental work of the German scientist and engineer George Agricola "On Mining and Metallurgy in twelve books" (1556) was, in fact, the first industrial and technical encyclopedia and included practical information and recipes gleaned from artisans, as well as from his own multifaceted engineering practice - information and recipes related to the production of metals and alloys, exploration and mining, and much more. The genre of technical literature of a later time may include "machine theaters" and "mill theaters" (for example, "General Machine Theater" by Jacob Leipold in nine volumes). Such publications actually served as the first textbooks.

Further development of the rationalization of technical activities could only follow the path of scientific generalization. The engineers were guided by the scientific picture of the world, but in real technical practice the world of "approximation" prevailed. The scientists demonstrated samples of accurate calculations, developing more and more advanced scientific instruments and devices, which only later entered the field of industrial practice. At that time, the relationship between science and technology was also determined in many ways by random factors, such as personal contacts between scientists and practitioners, etc. Up to the 19th century, science and technology developed along independent trajectories, being essentially separate social organisms, each with its own special value systems.

One of the educational institutions for the training of engineers was the Mining College, established in 1773 in St. Petersburg. Its programs already clearly focus on the scientific training of future engineers. However, such technical schools were more focused on practical training, and scientific training in them lagged significantly behind the level of scientific development. Teaching methods in engineering educational institutions of that time were more like a craft apprenticeship: practical engineers explained to individual students or their small groups how to build a particular type of structures or machines. New theoretical information was reported only in the course of such explanations. Even the best engineering textbooks published during the 18th century are mostly descriptive: mathematical calculations are extremely rare in them. The situation is gradually changing, as due to the urgent need for regular scientific training of engineers, there is a need for a scientific description of technology and the systematization of accumulated scientific and technical knowledge. For these reasons, textbooks for higher technical schools are becoming the first truly scientific technical literature.

Textbooks on applied mechanics were one of the first attempts of this kind to create scientific technical literature. However, it took almost a century for the semi-theoretical description of all existing machines from the point of view of descriptive geometry, laid down by Gaspard Monge in the engineering training program at the Paris Polytechnic School, to turn into a genuine theory of mechanisms and machines.

The second stage of the rational generalization of technology was to generalize all existing areas of craft technology. This was accomplished in the so-called "General Technology" (1777) by Johann Beckmann and his school, which was an attempt to summarize techniques of technical activity of various kinds, as well as in the French Encyclopedia, a compendium of all sciences and crafts that existed at that time. In his work "Introduction to Technology or on the knowledge of workshops, factories and manufactories..." Johann Beckmann tried to present a generalized description not so much of the machines and tools themselves as products of technical activity, but of this activity itself, i.e. of all the technologies that existed at that time (crafts, productions, the design of factories, as well as the machines used in them, tools, materials, etc.).

If private technology considered each technical craft separately, then the general technology formulated by Beckman tried to systematize various productions in technical crafts in order to facilitate their study. The classic expression of the desire for this kind of synthetic description is the French Encyclopedia, which was an attempt, according to the creators, to collect all the knowledge "scattered over the earth", to familiarize all living people with them and pass them on to those who would replace them. This project, according to Diderot, should overturn the barriers between crafts and sciences, and give them freedom.

However, all of these attempts, regardless of their claims to be scientific, were, in fact, only a rational generalization of accumulated technical experience at the level of common sense.

The next stage of the rational generalization of technology finds its expression in the emergence of technical sciences (technical theories). Such a theoretical generalization of individual fields of technical knowledge in various fields of technology occurs primarily for the purpose of scientific education of engineers while focusing on the natural science picture of the world. At first, scientific technique meant only an application to the technique of natural science. In the 19th century, "technical knowledge was torn from centuries-old craft traditions and grafted onto science," wrote the American philosopher and historian E. Layton. - The technical community, which in 1800 was artisanal and differed little from the medieval one, is becoming a "crooked mirror image" of the scientific community. At the forefront of technological progress, artisans have been replaced by new figures - a new generation of scientific practitioners. The new technician replaced the oral traditions passed from master to pupil with college education, and created a professional organization and technical literature based on the scientific model." So, technology has become scientific, but not in the sense that it now meekly fulfills all the prescriptions of the natural sciences, but in the sense that it develops special technical sciences.

This line of development was most clearly expressed in the program of scientific training of engineers at the Paris Polytechnic School. This educational institution was founded in 1794 by mathematician and engineer Gaspard Monge, the creator of descriptive geometry. The program focused on the deep mathematical and natural science training of future engineers. It is not surprising that the Polytechnic School soon became a center for the development of mathematics and mathematical natural sciences, as well as technical science, primarily applied mechanics. Many engineering educational institutions in Germany, Spain, the USA, and Russia were subsequently created on the model of this School.

Technical sciences, which were formed primarily as applications of various fields of natural science to certain classes of engineering tasks, in the middle of the twentieth century formed a special class of scientific disciplines that differ from natural sciences both in terms of object and internal structure, but also have a disciplinary organization.

Finally, the highest level of rational generalization in engineering today is systems engineering as an attempt at a comprehensive theoretical generalization of all branches of modern technology and technical sciences, focusing not only on the natural sciences, but also on the humanities education of engineers, i.e., focusing on the systemic picture of the world.

System engineering is a special activity for the creation of complex technical systems and in this sense is primarily a modern type of engineering and technical activity, but at the same time includes a special scientific activity, since it is not only the field of application of scientific knowledge. It also develops new knowledge. Thus, in system engineering, scientific knowledge goes through a full cycle of functioning - from its acquisition to its use in engineering practice.

A systems engineer must combine the talents of a scientist, designer and manager, and be able to bring together specialists of various profiles to work together. To do this, he needs to understand many special issues. Therefore, the list of disciplines studied in US universities by a future systems engineer makes an impression with its diverse and multifaceted content.: Here you can find general systems theory, linear algebra and matrices, topology, complex variable theory, integral transformations, vector calculus, differential equations, mathematical logic, graph theory, circuit theory, reliability theory, mathematical statistics, probability theory, linear, nonlinear and dynamic programming, regulatory theory, information theory, cybernetics, modeling methods optimization, methodology of system design, application of engineering models, design, analysis and synthesis of circuits, computer technology, biological and socio-economic, environmental and information computing systems, forecasting, operations research, etc.

This list shows how extensive the training of a modern systems engineer is. However, the main thing for him is to learn how to apply all the knowledge gained to solve two main system engineering tasks: ensuring the integration of parts of a complex system into a single whole and managing the process of creating this system. Therefore, an impressive place in this list is given to systems and cybernetic disciplines, which allow the future engineer to master the general methods of research and design of complex technical systems, regardless of their specific implementation and material form. It is in this field that he is a professional specialist.

System engineering is a product of the development of traditional engineering and design, but it is a qualitatively new stage associated with the increasing complexity of the designed technical systems, the emergence of new applied disciplines, and the development of system principles for the research and design of such systems. Of particular importance in it are activities aimed at organizing, scientific and technical coordination and management of all types of system engineering activities (such as, on the one hand, component design, construction, debugging, technology development, and, on the other, radio electronics, chemical technology, engineering economics, development of means of communication between humans and machines, etc.), as well as aimed at joining and integrating parts of the designed system into a single whole. It is the latter that forms the core of the system engineering and determines its specificity and systemic nature.

The last two stages of the scientific generalization of technology are of particular interest for philosophical analysis, since it is at these stages that the truly global influence of technology on the development of modern society can be traced. In formulating the main objectives of his work, Franz Reulot emphasizes, first of all, the enormous influence that technology based on scientific foundations has on the current cultural conditions of the world. "It has made us capable of achieving much more financially than was possible for humanity a few centuries ago... Everywhere in modern life, around us, and with us, scientific technology is our real servant and companion, never tirelessly, and only when we are completely convinced of this, even if only for a short time, are we deprived of its help." And although there are still voices against the steady development of technical devices, those who submit them continue to travel by rail, make phone calls, etc., enjoy all the benefits of the victorious technical civilization and do not delay the main movement at all. So, the essence of the scientific method in technology is as follows: "If we bring inanimate bodies into such a position, such circumstances that their action, in accordance with the laws of nature, corresponds to our goals, then they can be forced to do work for animate beings and instead of these latter." When this task began to be carried out consciously, the latest scientific technology emerged.

The process of scientific identification of technology would be unthinkable without the scientific training of engineers and the formation of a disciplinary organization of scientific and technical knowledge based on the model of disciplinary natural science. However, by the middle of the twentieth century, differentiation in the field of scientific and technical disciplines and engineering activities had gone so far that their further development became impossible without interdisciplinary technical research and system integration of engineering activities themselves. Naturally, these system-integrative trends are reflected in the field of engineering education.

Many different scientific and technical disciplines and their corresponding fields of engineering practice are being formed. Narrow specialists have appeared who know "everything about nothing" and do not know what is happening in the adjacent laboratory. The emerging so-called universalists, on the contrary, know "nothing about everything." And although the status of these universalists in the system of disciplinary organization of science and in the structure of specialized engineering activities is still not clearly defined, without them today it is simply impossible not only to solve specific scientific and engineering problems, but also the further development of science and technology as a whole. Engineering tasks themselves are becoming complex, and when solving them, it is necessary to take into account a variety of aspects that previously seemed secondary, for example, environmental and social aspects. It is when interdisciplinary, systemic problems in technology arise that the importance of the philosophy of technology increases significantly, since they cannot be solved within the framework of any one already established scientific paradigm. Thus, the disciplinary organization of science and technology, which became traditional in the twentieth century, should be complemented by interdisciplinary research of a completely new level. And since the future development of science and technology is laid in the process of training and educating professionals, it becomes necessary to form a new style of engineering and scientific thinking precisely in the process of engineering education.

In addition, a layer of exploratory, actually fundamental research, i.e. technical theory, is being formed in the field of engineering and technical sciences. This leads to specialization within individual fields of technical science and engineering. In itself, a very important and necessary division of labor also creates a number of problems of cooperation and the joining of various types of engineering tasks. Naturally, this trend finds its expression in the field of engineering education.

This leads to the fact that the design installation penetrates into the field of science, and the cognitive installation penetrates into the field of engineering. Just as the philosophy of science does in relation to scientific knowledge and scientific theory, the philosophy of technology begins to perform a reflexive function in relation to technical knowledge and technical theory.

Unfortunately, the idea of the need to turn to the history of technology and science, not only to study cultural patterns and knowledge of the past, but also to search for new technological solutions, is still very, very slowly but more and more clearly penetrating the engineering consciousness. This applies, for example, to ancient medical technologies, where centuries-old verification by tradition is complemented today by rigorous scientific analysis. The history of technology, understood not only as the history of individual technical means, but also as the history of technical solutions, projects and technical theories (both successful and unrealized, which at one time seemed to be a dead end) can become a valid basis not only for the realized present, but also for the foreseeable future. Knowing and anticipating is not so much a historical task as a philosophical one. Therefore, philosophy and the history of science and technology should occupy one of the important places in modern engineering education.

In this case, the philosophy of technology has similar tasks in relation to technology as the philosophy of science in relation to science. Its role naturally increases with the transition from simple systems to complex ones, as well as from specialized technical activities to system and theoretical research and design types. The processes taking place precisely at these stages of the development of technical, or rather scientific and technical activities, require the greatest degree of philosophical understanding.

In the complex cooperation of various types and spheres of modern engineering, three main areas can be distinguished that require different training of relevant specialists. Firstly, these are production engineers who are called upon to perform the functions of a technologist, a production organizer and an operational engineer. Such engineers need to be trained taking into account their primary practical orientation. Secondly, these are research and development engineers who must combine the functions of an inventor and a designer, which are closely related to research work in the field of technical science. They become the main link in the process of combining science with production. They need thorough scientific and technical training. Finally, and thirdly, these are systems engineers or, as they are often called, "general-purpose system engineers", whose task is to organize and manage complex engineering activities, comprehensive research and system design. The training of such an organizational engineer and generalist requires the broadest systemic and methodological orientation and interdisciplinarity. Interdisciplinary and general humanitarian education is especially important for such engineers, in which the philosophy of science and technology could play a leading role.

Thus, it is the last two stages of rational generalization in technology that are of the greatest interest for philosophical and methodological analysis, namely, the methodology of technical sciences, engineering, and then system design. It is in this area that the interests of the philosophy of technology and the philosophy of science are particularly closely intertwined. The philosophy of science provides the philosophy of technology with the means of methodological analysis developed in it on the basis of natural scientific, primarily physical, knowledge; the philosophy of technology provides new material - technical sciences - for such analysis and the further development of the methodological tools themselves. That is why in the future we will focus on the "intersection" of the philosophy of science and the philosophy of technology.

The problem of science and technology correlation

In the modern literature on the philosophy of technology, the following main approaches can be identified to solve the problem of changing the relationship between science and technology:

(1) Engineering is considered as an applied science;

(2) the processes of science and technology development are considered as autonomous but coordinated processes;

(3) Science has developed, focusing on the development of technical devices and tools;

(4) The technology of science has always overtaken the technology of everyday life;

(5) There was no regular application of scientific knowledge in technical practice until the end of the 19th century, but it is typical for modern technical sciences.

The linear model

For a long time (especially in the 50s and 60s of our century), one of the most widespread was the so-called linear model, which considers technology as a simple application of science or even as an applied science. However, this point of view has been heavily criticized in recent years as being too simplistic. Such a model of the relationship between science and technology, when science recognizes the function of producing knowledge, and technology recognizes only its application, is misleading, since it claims that science and technology represent different functions performed by the same community.

For example, O. Mayer believes that the boundaries between science and technology are arbitrary. In thermodynamics, aerodynamics, semiconductor physics, and medicine, it is impossible to separate practice from theory; they are intertwined here into a single subject. Both the scientist and the technician "use the same mathematics, can work in the same kind of laboratories, and both can see their hands dirty from manual labor." Many scientists have made contributions to technology (Archimedes, Galileo, Kepler, Huygens, Hooke, Leibniz, Euler, Gauss, Kelvin), and many engineers have become recognized and famous authorities in science (Geron Alexandrsky, Leonardo da Vinci, Stevin, Guericke, Watt, Carnot). Today, theorists and practitioners "are more clearly identified by academic degree or job designation, but if we look at their actual work, the labeling again turns out to be arbitrary. Many, probably the majority of modern scientists turn to work for technical purposes, while academic engineers occasionally engage in research that has no technical application in mind at all. At the level of a social organization, the distinction between science and technology is also arbitrary. If a school, academy, or professional organization has the word "science" or "technology" in its name, it is more an indicator of how this concept is defined on a modern scale of values than an expression of the real interests and activities of their members. More often, however, science has a higher social status than technology, and professional organization is an effective tool for achieving and maintaining this status." According to Mayer, scientific and technical goals are often pursued simultaneously (or at different times) by the same people or institutions that use the same methods and means. This author believes "that there is simply no practical criterion for distinguishing science and technology."

It is sometimes believed that the main difference between science and technology is only in the breadth of horizons and the degree of generality of problems: technical problems are narrower and more specific. However, in reality, science and technology make up different communities, each of which is differently aware of its goals and value system.

Such a simplified linear model of technology as an applied science, i.e. a model postulating a linear, consistent trajectory from scientific knowledge to technical discovery and innovation, is considered inadequate by most experts today.

The evolutionary model

The processes of science and technology development are often considered as autonomous, independent from each other, but coordinated. Then the question of their relationship is solved as follows: (a) it is believed that science at some stages of its development uses technology instrumentally to obtain its own results, and vice versa - it happens that technology uses scientific results as a tool to achieve its goals; (b) the opinion is expressed that technology sets the conditions for choosing scientific options, and science, in turn, sets the conditions for choosing technical ones. The latter is called the evolutionary model.

Let's consider each of these points of view sequentially.

The first point of view emphasizes that the idea of technology as simply an applied science should be discarded, since the role of science in technical innovation is of relative rather than absolute importance. According to this point of view, technological progress is guided primarily by empirical knowledge gained in the process of the immanent development of technology itself, and not by theoretical knowledge introduced into it from the outside by scientific research.

For example, the American philosopher of technology G. Skolimovsky divides scientific and technical progress. In his opinion, the methodological factors that are important for the growth of technology are completely different from those factors that are important for the growth of science. Although in many cases technical achievements can be considered as based on pure science, the original problem was not technical at all, but cognitive. Therefore, in the study of technological progress, one should proceed, from his point of view, not from the analysis of the growth of knowledge, but from the study of the stages of solving a technical problem. The growth of technology was expressed in the form of the ability to produce more and more diverse technical objects with more and more interesting characteristics and in a more and more efficient way.

Of course, technology cannot be considered as an applied science, and progress in it cannot be considered as a simple appendage of scientific discoveries. This point of view is one-sided. However, in our opinion, the opposite position is no less one-sided, which emphasizes only the empirical nature of technical knowledge. It is quite obvious that modern technology is unthinkable without deep theoretical research, which is carried out today not only in natural sciences, but also in special technical sciences.

In the evolutionary model of the relationship between science and technology, three interrelated but independent spheres are distinguished: science, technology and production (or, more broadly, practical use). The internal innovation process takes place in each of these areas according to an evolutionary pattern.

For Stefan Toulmin, for example, it is obvious that the disciplinary model of the evolution of science developed by him is also applicable to the description of the historical development of technology. Only in this case, we are no longer talking about the factors of changing the population of theories or concepts, but about the evolution of instructions, projects, practical methods, manufacturing techniques, etc. A new idea in technology often leads, as in science, to the emergence of a completely new technical discipline.

Technology is developing by selecting innovations from the stock of possible technical options. However, if the criteria for selecting successful options in science are mainly internal professional criteria, in engineering they will often be external, i.e. to evaluate innovations in technology, not only the actual technical criteria (for example, efficiency or ease of manufacture) are important, but also originality, constructiveness and the absence of negative consequences. In addition, the professional orientations of engineers and technicians differ, so to speak, geographically: in some countries, engineers are more focused on science, in others on commercial purposes. Socio-economic factors play an important role in the speed of innovation in the technical field.

According to this author, to describe the interaction of three autonomous evolutionary processes, the scheme that he created to describe the processes of science development is valid, namely: creation of new variants (mutation phase) - creation of new variants for practical use (breeding phase) - dissemination of successful variants within each sphere to a wider sphere of science and technology. (the phase of diffusion and dominance). Technology and production are connected in a similar way.

Toulmin also denies that technology can be considered simply as an applied science. Firstly, the very concept of "application" is unclear. In this regard, Kepler's laws may well be considered as a special "application" of Newton's theory. Secondly, there are cross-links between science and technology, and it is often difficult to determine whether the "source" of a scientific or technical idea is in the field of science or in the field of technology. It can be added that the relationship between science and technology varies from culture to culture. In ancient culture, "pure" mathematics and physics developed without caring about any applications in technology. In ancient Chinese society, despite the poor development of mathematical and physical theories, handicraft techniques were very fruitful. After all, technology and craft are much older than natural science. For many millennia, for example, metalworking and medical art have developed without any connection with science. The situation has changed only in the last century, when technology and industry were really revolutionized by science. But this does not mean, according to Toulmin, that the very essence of technology has changed, but only that the new, closer partnership of technology and science has led to an acceleration in solving technical problems that were previously considered unsolvable.

Another famous philosopher of science, Derek de Solla Price, explained the interaction of science and technology in a similar way, trying to separate the development of science and technology by highlighting differences in the intentions and behavior of those involved in scientific and technical creativity. A scientist is someone who wants to publish articles, but for a technician, a published article is not an end product. Price defines technology as research, the main product of which is not a publication (as in science), but a machine, medicine, product or process of a certain type and tries to apply the models of publication growth in science to explain the development of technology.

Thus, in this case, the philosophers of science are trying to transfer models of the dynamics of science to explain the development of technology. However, such a procedure, firstly, still requires special justification, and, secondly, a meaningful analysis of the development of technical knowledge and activities is needed, rather than searching for supporting examples for an a priori model obtained on a completely different material. Of course, this does not mean that many of the results obtained in modern philosophy of science cannot be used to explain and understand the mechanisms of technological development, especially the question of the relationship between science and technology.

Engineering sciences and technical sciences

According to the third point of view mentioned above, science has developed, focusing on the development of technical devices and tools, and represents a number of attempts to explore the way these tools function.

The German philosopher Gernot Boehme cites as an example the theory of a magnet by the English scientist William Hilbert, which was based on the use of a compass. Similarly, the emergence of thermodynamics based on the technical development of the steam engine can be considered. Other examples are the discoveries of Galileo and Toricelli, to which they were led by the practice of engineers who built water pumps. According to Boehme, technology is by no means an application of scientific laws, rather, technology is about modeling nature according to social functions. "And if they say that science is the basis of technology, then we can also say that technology provides the basis of science... There is an initial unity of science and technology of Modern times, which has its source in the Renaissance era. At that time, mechanics first appeared as a science, as the study of nature in technical conditions (experiments) and with the help of technical models (for example, clocks, etc.)."

This statement is partly true, since the progress of science depended to a large extent on the invention of appropriate scientific instruments. Moreover, many technical inventions were made before the advent of experimental natural science, for example, the telescope and the microscope, and it can also be argued that major architectural projects were implemented without any help from science. Undoubtedly, the progress of technology is greatly accelerated by science; it is also true that "pure" science uses technology, i.e. tools, and science was a further extension of technology. But this does not mean that the development of science is determined by the development of technology. Rather, the opposite statement applies to modern science.

The fourth point of view challenges the previous one, arguing that the technique of science, i.e. measurement and experiment, is always ahead of the technique of everyday life.

This point of view was held, for example, by A. Coire, who disputed the thesis that Galileo's science is nothing more than the product of the activity of a craftsman or engineer. He emphasized that Galileo and Descartes had never been people of craft or mechanical arts and had created nothing but mental constructions. Galileo did not learn from the artisans in the Venetian shipyards, on the contrary, he taught them a lot. He was the first to create the first truly accurate scientific instruments, the telescope and the pendulum, which were the result of physical theory. When creating his own telescope, Galileo did not just improve the Dutch telescope, but proceeded from optical theory, striving to make the invisible observable, from mathematical calculation, striving to achieve accuracy in observations and measurements. The measuring instruments used by his predecessors were still craft tools compared to Galileo's instruments. The new science replaced the vague and qualitative concepts of Aristotelian physics with a system of reliable and strictly quantitative concepts. The merit of a great scientist is that he replaced ordinary experience with a mathematically based and technically perfect experiment. Cartesian and Galilean science were of great importance to technicians and engineers. The fact that the world of "approximation" and "almost" in the creation of various technical structures and machines by artisans is being replaced by the world of a new science - the world of precision and calculation - is the merit not of engineers and technicians, but of theorists and philosophers. Louis Mumford expressed about the same point of view: "At first, the initiative did not come from engineers-inventors, but from scientists... The telegraph was actually discovered by Henry, not Morse; the dynamo by Faraday, not Siemens; the electric motor by Oersted, not Jacobi; the radio telegraph by Maxwell and Hertz, not Marconi and Deforests..."The transformation of scientific knowledge into practical tools, from Mumford's point of view, was a simple episode in the discovery process. A new phenomenon has grown out of this: deliberate and systematic invention. For example, a long-range telephone became possible only thanks to systematic research in Bell laboratories.

This point of view is also one-sided. It is well known that neither Maxwell nor Hertz had in mind the technical applications of the electromagnetic theory they developed. Hertz conducted natural science experiments that confirmed Maxwell's theory, rather than designing radio receivers or radio transmission equipment invented later. It took significant efforts by many scientists and engineers before such equipment acquired a modern look. It is true, however, that this work was associated with serious systematic scientific (more precisely, scientific and technical) research. At the same time, technological innovation is not necessarily the result of a movement that begins with scientific discovery.

По нашему мнению, наиболее реалистической и исторически обоснованной точкой зрения является та, которая утверждает, что вплоть *до конца XIX века регулярного применения научных знаний в технической практике не было, но это характерно для технических наук сегодня.* В течение XIX века отношения науки и техники частично переворачиваются в связи со "сциентификацией" техники. Этот переход к научной технике не был, однако, однонаправленной трансформацией техники наукой, а их взаимосвязанной модификацией. Другими словами, "сциентизация техники" сопровождалась "технизацией науки".

For most of its history, technology had little to do with science; people could and did make devices without understanding why they worked the way they did. At the same time, natural science until the 19th century solved mostly its own problems, although it often started from technology. Engineers, proclaiming a focus on science, were guided by it only slightly in their direct practical activities. After many centuries of such "autonomy," science and technology came together in the 17th century, at the beginning of the scientific revolution. However, it was only by the 19th century that this unity bore its first fruits, and only in the 20th century did science become the main source of new types of equipment and technology.

In the first period (pre-scientific), three types of technical knowledge are consistently formed: practical and methodological, technological and constructive-technical.

In the second period, the emergence of technical sciences takes place (from the second half of the XVIII century to the 70s of the XIX century), firstly, the formation of scientific and technical knowledge based on the use of knowledge of natural sciences in engineering practice and, secondly, the emergence of the first technical sciences. Of course, this process is still taking place today in new areas of practice and science, however, the first examples of this method of forming scientific and technical knowledge relate specifically to this period.

The third classical period (until the middle of the 19th century) is characterized by the construction of a number of fundamental technical theories.

Finally, the fourth stage (present) is characterized by the implementation of comprehensive research, the integration of technical sciences not only with natural sciences, but also with social sciences, and at the same time there is a process of further differentiation and "spin-off" of technical sciences from natural and social sciences.

However, a simple empirical statement of certain historical stages is insufficient to conduct a methodological analysis of technical knowledge. It is necessary to give a theoretical description of the functioning and genesis of the technical sciences. And for this, it is important to determine their specifics.

The specifics of natural and technical sciences

The identification of the specifics of technical sciences is usually carried out as follows: technical sciences are compared with natural (and social) sciences and the correlation of fundamental and applied research is considered in parallel. In this case, the following positions can be highlighted:

(1) Technical sciences are identified with applied natural sciences;

(2) Natural sciences and technical sciences are considered as equal scientific disciplines.;

(3) Both fundamental and applied research are distinguished in the technical sciences.

Technical sciences and applied natural sciences

Technical sciences are often identified with applied natural sciences. However, in the conditions of modern scientific and technological development, such an identification does not correspond to reality. Technical sciences constitute a special class of scientific (scientific and technical) disciplines that differ from natural sciences, although there is a fairly close relationship between them. Technical sciences emerged as applied fields of natural sciences research, using, but also significantly modifying borrowed theoretical schemes, developing the initial knowledge. Besides, it wasn't the only way they occurred. Mathematics played an important role here. There is also no reason to consider some sciences more important and significant than others, especially if it is not clear what to take as a starting point.

According to J. Agassi, the division of science into fundamental and applied according to the results of research is too trivial. "There is, of course, an intersection," he wrote. - The research that is known as fundamental and which is pure science in the near future is eventually applied. In other words, fundamental research is the search for certain laws of nature, taking into account the use of these laws." This intersection shows that this division is not the only one, but still, from Agassi's point of view, it is sufficient, only it has a different basis.

He identified two kinds of problems in science - deducibility and applicability - and showed differences in the work of applied scientists and inventors. In applied science, in contrast to "pure" science, the problem of deducibility is the search for initial conditions that, together with these theories, provide conditions that can be clarified by practical consideration. From his point of view, "invention is a theory, not a practical activity, although with a practical end."

Strictly speaking, the term "applied science" is incorrect. Designating technical science as applied, one usually proceeds from the opposition of "pure" and applied science. If the goal of "pure" science is "to know," then applied science is "to do." In this case, applied science is considered only as the application of "pure" science, which discovers laws, thereby achieving an understanding and explanation of nature. However, this approach does not allow us to determine the specifics of the technical sciences, since both natural and technical sciences can be considered both from the point of view of developing new knowledge in them, and from the point of view of applying this knowledge to solve any specific tasks, including technical ones. In addition, natural sciences can be considered as a field of application, such as mathematics. In other words, the division of sciences by field of practical application is relative.

According to Mario Bunge, the division of sciences into "pure" and applied sciences still makes some sense: "this line must be drawn if we want to explain the differences in point of view and motivation between a researcher who is looking for a new law of nature and a researcher who applies known laws to the design of useful devices: whereas the first He wants to understand things better, and the latter wants to improve our skills through them."

As concrete historical examples show, in real life it is very difficult to separate the use of scientific knowledge from its creation and development. As a rule, engineers consciously or unconsciously use and formulate general statements or laws; mathematics acts as a common analytical tool and language for them. Engineers are constantly putting forward hypotheses and designing experiments for laboratory or field testing of these hypotheses. All this is usually labeled and perceived as science.

Engineers use a scientific method rather than ready-made scientific knowledge. In addition, a powerful layer of fundamental research is gradually forming in the technical sciences themselves, and now fundamental research with applied purposes is being conducted in the interests of technology itself. All this shows the conventionality of the boundaries between fundamental and applied research. Therefore, it is necessary to talk about the difference between fundamental and applied research in both natural and technical sciences, and not about the opposition of fundamental and applied sciences, invariably referring to the first of them - natural sciences, and the second - technical sciences.

Technical and natural sciences are equal partners

Today, an increasing number of philosophers of technology adhere to the, in our opinion, the only correct point of view that technical and natural sciences should be considered as equal scientific disciplines. Each technical science is a separate and relatively autonomous discipline with a number of features. Technical sciences are a part of science and, although they should not be far removed from technical practice, they do not coincide with it. Technical science serves technology, but it is primarily a science, i.e. it is aimed at obtaining objective, socially translatable knowledge.

As shown by E. Leighton, the formation of the technical sciences is associated with a broad movement in the 19th century - giving engineering knowledge a form similar to science. Among the results of this trend was the formation of professional societies similar to those that existed in science, the emergence of research journals, the creation of research laboratories, and the adaptation of mathematical theory and experimental methods of science to the needs of engineering. Thus, twentieth-century engineers borrowed not only the results of scientific research, but also the methods and social institutions of the scientific community. With the help of these tools, they were able to generate the specific knowledge necessary for their professional community. "Modern technology includes scientists who 'make' technology and technicians who work as scientists." Their work (if they work, for example, at a university and do not perform practical duties) is "pure" science, although they publish their results in relevant technical journals. "The old view that basic science generates all the knowledge that a technician then applies simply doesn't help in understanding the specifics of modern technology."

Indeed, today no one will be surprised by the fact that "targeted research conducted in industrial laboratories by researchers with engineering degrees leads to important scientific breakthroughs or that scientists working in universities or academic centers come to important technological discoveries." Therefore, technical sciences should be fully considered as independent scientific disciplines, along with social, natural and mathematical sciences. At the same time, they differ significantly from the latter in the specifics of their connection with technology.

Technical and natural sciences have the same subject area of instrumentally measurable phenomena. Although they may explore the same objects, they conduct research on these objects in different ways.

Technical phenomena play a crucial role in the experimental equipment of natural sciences, and most physical experiments are artificially created situations. The objects of technical sciences also represent a kind of synthesis of "natural" and "artificial". The artificiality of the objects of technical sciences lies in the fact that they are products of conscious purposeful human activity. Their naturalness is revealed primarily in the fact that all artificial objects are ultimately created from natural (natural) material. Natural science experiments are artifacts, while technical processes are actually modified natural processes.

The implementation of an experiment is an activity for the production of technical effects and can be partially qualified as engineering, i.e. as the construction of machines, as an attempt to create artificial processes and states, however, in order to obtain new scientific knowledge about nature or confirm scientific laws, rather than to study the patterns of functioning and creation of technical devices themselves. Therefore, pointing out the engineering nature of the physical experiment, one should not lose sight of the fact that modern engineering activity has been significantly modified under the influence of the thought experiment developed in Modern science.

A natural science experiment is not so much the construction of a real experimental setup as, above all, an idealized experiment, operating with ideal objects and schemes. Thus, Galileo was not only an inventor and passionate advocate of the use of technology in scientific research, but he also rethought and transformed technical action in physics. The rapid expansion of the field of mechanical arts "provided new controlled, almost laboratory situations in which he could be one of the first to observe natural phenomena... they are not easily discernible in the pure state of nature." The goal of physics is to isolate a theoretically predicted phenomenon in order to obtain it in its pure form. This is why the physical sciences are open to applications in engineering, and technical devices can be used for experiments in physics.

By the beginning of the twentieth century, the technical sciences had formed a complex hierarchical system of knowledge, from highly systematic sciences to a collection of rules in engineering manuals. Some of them were based directly on natural science (for example, resistance of materials and hydraulics) and were often considered as a special branch of physics, others (like kinematics of mechanisms) developed from direct engineering practice. In both cases, engineers borrowed both theoretical and experimental scientific methods, as well as many of the values and institutions associated with their use. By the beginning of the twentieth century, technical sciences that had grown out of practice had assumed the quality of genuine science, characterized by the systematic organization of knowledge, reliance on experiment, and the construction of mathematized theories. Special fundamental research has also appeared in the technical sciences.

Thus, natural sciences and technical sciences are equal partners. They are closely related both in the genetic aspect and in the processes of their functioning. It was from the natural sciences that the first initial theoretical positions, methods of representing objects of research and design, basic concepts were translated into technical sciences, and the very ideal of science was borrowed, the attitude towards the theoretical organization of scientific and technical knowledge, the construction of ideal models, and mathematization. At the same time, it is impossible not to see that in the technical sciences all the elements borrowed from natural science have undergone a significant transformation, as a result of which a new type of organization of theoretical knowledge has emerged. In addition, technical sciences, for their part, significantly stimulate the development of natural sciences, having the opposite effect on them.

However, today such a statement is no longer enough. To determine the specifics of technical knowledge and technical sciences, it is necessary to analyze their structure. On this basis, the classification of sciences itself can then be revised and deepened. It is not entirely correct to say that the basis of technical sciences is only exact natural science. This statement can be considered true only in relation to the historically first technical sciences. Currently, scientific and technical disciplines represent a wide range of different disciplines - from the most abstract to highly specialized ones, which focus on using knowledge not only of natural sciences (physics, chemistry, biology, etc.), but also of social sciences (for example, economics, sociology, psychology, etc.). Regarding some scientific and technical disciplines, it is generally difficult to say whether they belong to purely technical sciences or represent some new, more complex unity of science and technology. In addition, some parts of the technical sciences may be fundamental, while others may be applied research. However, the same is true for the natural sciences.

Creative and non-creative elements take place in both natural and technical sciences. We must not forget that the process of practical application itself is not a unidirectional process, it is implemented as a sequence of iterations and is associated with the development of new knowledge.

Fundamental and applied research in technical sciences

Applied research is such research, the results of which are addressed to manufacturers and customers and which is guided by the needs or desires of these customers, fundamental research is addressed to other members of the scientific community. Modern technology is not as far from theory as it sometimes seems. It is not only an application of existing scientific knowledge, but also has a creative component. Therefore, from a methodological point of view, technical research (i.e. research in technical science) It's not very different from the scientific one. Modern engineering requires not only short-term research aimed at solving special problems, but also a broad long-term program of fundamental research in laboratories and institutes specifically designed for the development of technical sciences. At the same time, modern fundamental research (especially in the technical sciences) is more closely related to applications than it was before.

The modern stage of the development of science and technology is characterized by the use of fundamental research methods to solve applied problems. The fact that the research is fundamental does not mean that its results are not utilitarian. Work aimed at applied purposes can be very fundamental. The criteria for their separation are mainly the time factor and the degree of generality. It is quite legitimate today to talk about fundamental industrial research.

Let us recall the names of great scientists who were both engineers and inventors: D. W. Gibbs, a theoretical chemist, began his career as a mechanical inventor; J. von Neumann began as a chemical engineer, then studied abstract mathematics and later returned to engineering; N. Wiener and K. Shannon were both engineers and first-class mathematicians. The list can be continued: Claude Louis Navier, an engineer of the French Bridge and Road Corps, conducted research in mathematics and theoretical mechanics; William Thomson (Lord Kelvin) successfully combined his scientific career with constant research in the field of engineering and technological innovations; theoretical physicist Wilhelm Bjerknes became a practical meteorologist.

A good technician is looking for solutions, even if they are not yet fully accepted by science, and applied research and development is increasingly being carried out by people with a background in basic science.

Thus, in scientific and technical disciplines, it is necessary to clearly distinguish between research involved in direct engineering activities (regardless of the organizational forms in which they take place) and theoretical research, which we will further refer to as technical theory.

In order to identify the features of technical theory, it is compared primarily with natural science. G. Skolimovsky wrote: "technical theory creates reality, while scientific theory only explores and explains it." According to F. According to Rappa, a decisive turn in the development of technical sciences consisted "in linking technical knowledge with mathematical and natural science methods." This author also distinguishes between the "hypothetical-deductive method" (idealized abstraction) of natural science theory and the "projective-pragmatic method" (general scheme of action) of technical science.

G. Boehme noted that "technical theory is formulated in such a way as to achieve a certain optimization." Modern science is characterized by its "offshoot into special technical theories." This is due to the construction of special models in two directions: the formulation of theories of technical structures and the concretization of general scientific theories. We can consider as an example the emergence of chemical technology as a scientific discipline, where special models were developed that linked more complex technical processes and operations with idealized objects of fundamental science. According to Boehme, many of the first scientific theories were, in fact, theories of scientific instruments, i.e. technical devices: for example, physical optics is the theory of the microscope and telescope, pneumatics is the theory of the pump and barometer, and thermodynamics is the theory of the steam engine and engine.

Mario Bunge emphasized that in technical science, theory is not only the pinnacle of the research cycle and a guideline for further research, but also the basis of a system of rules prescribing the course of optimal technical action. Such a theory either considers the objects of action (for example, machines), or refers to the action itself (for example, to the decisions that precede and control the production or use of machines). Bunge also distinguished between scientific laws that describe reality and technical rules that describe the course of action and indicate how to act in order to achieve a certain goal (they are instructions for performing actions). Unlike the law of nature, which tells us what the shape of possible events is, technical rules are norms. While statements expressing laws may be more or less true, rules may be more or less effective. Scientific prediction tells us what will happen or can happen under certain circumstances.

The biggest difference between physical and technical theories lies in the nature of idealization: a physicist can focus on the simplest cases (for example, to eliminate friction, fluid resistance, etc.), but all this is very essential for technical theory and must be taken into account by it. Thus, technical theory deals with a more complex reality, since it cannot eliminate the complex interaction of physical factors taking place in a machine. Technical theory is less abstract and idealized, it is more closely related to the real world of engineering. The special cognitive status of technical theories is expressed in the fact that technical theories deal with artificial devices or artifacts, while scientific theories relate to natural objects. However, the juxtaposition of natural objects and artifacts still does not provide a real basis for the distinction being made. Almost all phenomena studied by modern experimental science are created in laboratories and in this regard represent artifacts.

According to E. Leighton, technical theory is created by a special layer of intermediaries - "scientists-engineers" or "engineers-scientists". For information to pass from one community (scientists) to another (engineers), it needs to be seriously reformulated and developed. So, Maxwell was one of those scientists who consciously tried to make a contribution to technology (and he really had a great influence on it). But it took an almost equally powerful creative effort by the British engineer Heaviside to transform Maxwell's electromagnetic equations into a form that could be used by engineers. Such an intermediary was, for example, the Scottish scientist-engineer Rankin, a leading figure in the creation of thermodynamics and applied mechanics, who managed to link the practice of building high-pressure steam engines with scientific laws. For this kind of engine, Boyle's law is not applicable in its purest form. Rankin proved the need to develop an intermediate form of knowledge - between physics and technology. The machine's actions should be based on theoretical concepts, and the properties of materials should be selected based on firmly established experimental data. In a steam engine, the material being studied was steam, and the laws of action were the laws of the creation and disappearance of heat, established within the framework of formal theoretical concepts. Therefore, the operation of the engine depended equally on the properties of steam (installed practically), and on the state of heat in this steam. Rankin focused on how the laws of heat affect the properties of steam. But according to his model, it turned out that the properties of steam can also change the effect of heat. The analysis of the effect of steam expansion allowed Rankin to discover the causes of loss of engine efficiency and recommend specific measures to reduce the negative effect of expansion. The model of technical science proposed by Rankin ensured the application of theoretical ideas to practical problems and led to the formation of new concepts based on the combination of elements of science and technology.

Technical theories, in turn, have a great negative impact on physical science and even, in a certain sense, on the entire physical picture of the world. For example, the (essentially technical) theory of elasticity was the genetic basis of the ether model, and hydrodynamics was the vortex theory of matter.

Thus, in the modern philosophy of technology, researchers have been able to identify fundamental theoretical research in the technical sciences and to conduct a primary classification of the types of technical theory. The division of research in the technical sciences into fundamental and applied allows us to identify and consider technical theory as the subject of a special philosophical and methodological analysis and proceed to the study of its internal structure.

Dutch researcher P. Kroes argued that a theory dealing with artifacts necessarily undergoes a change in its structure. He emphasized that natural science and scientific and technical knowledge are equally knowledge about manipulating nature, as both natural and technical sciences deal with artifacts and create them themselves. However, there is also a fundamental difference between the two types of theories, and it lies in the fact that within the framework of technical theory, the most important place belongs to the design characteristics and parameters.

The study of the correlation and interrelation of natural and technical sciences is also aimed at substantiating the possibility of using methodological tools developed in the philosophy of science in the process of natural science research in the analysis of technical sciences. At the same time, most of the works analyze mainly the connections, similarities and differences between physical and technical theory (in its classical form), which is based on the application of mainly physical knowledge to engineering practice.

However, in recent decades, many technical theories have emerged that are based not only on physics and can be called abstract technical theories (for example, systems engineering, computer science, or design theory), which are characterized by the inclusion of a general methodology in fundamental engineering research. To interpret individual complex phenomena in technical developments, completely different, logically unrelated theories can often be used. Such theoretical studies become complex by their very nature and go directly not only into the sphere of "nature", but also into the sphere of "culture". "It is necessary to take into account not only the interaction of technical developments with economic factors, but also the connection of technology with cultural traditions, as well as psychological, historical and political factors." Thus, we get into the sphere of analyzing the social context of scientific and technical knowledge.

Now let us consider sequentially: firstly, the genesis of the technical theories of classical technical sciences and their difference from physical theories; secondly, the features of the theoretical and methodological synthesis of knowledge in modern scientific and technical disciplines; and thirdly, the development of modern engineering and the need for a social assessment of technology.

Self-monitoring questions

1. The subject of philosophy of technology
2. The problem of science and technology correlation
3. What is the structure of physical and technical theories
4. The problem of science and technology correlation
5. The specifics of natural and technical sciences
6. What is the need for a social assessment of technology
7. Formation of the engineering profession

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