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WHAT DO WE EXPECT FROM BASIC SCIENCE?

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Abstract

Basic science was always ambiguously perceived by society and the state. Even in an academic circle closely connected with scientific activity, there is no common understanding of its goals and objectives. Nowadays, when the world is changing rapidly, and the number of challenges in all spheres of human activity is growing, questions about the goals of basic science and what it is capable of giving to mankind and particular state arise with renewed vigor. The aim of this work is to identify a model for the development of fundamental science in the Russian Federation. Research methods include contextual analysis of publications of Russian and foreign scientists and regulatory documents of the Russian Federation, and the structural and dynamic analysis of statistical data. Based on the analysis of the specific of the process and results of fundamental scientific research and the evolution of models determining its orientation and structure, it is concluded that the model for the development of fundamental science, currently adopted in the Russian Federation, requires adjustment. The results obtained can be useful for politicians and administrators in planning research activities at the state level and in scientific organizations.

Keywords: Applied science, basic science, interaction of basic and applied science, indicators of basic science development.

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1. Introduction

Public perception of basic science in recent years has become extremely confusing and even paradoxical. The social significance of this subsystem of social life and activity is widely recognized, but at the same time, the directly opposite tendency of undermining trust in basic science is clearly appeared (Krushanov & Mamchur, 2011).

Basic science is a field of knowledge that deals with theoretical and experimental scientific research of the fundamental nature phenomena. Its goal is the search for patterns that determining the form, structure, composition, structure and properties of natural phenomena, the flow and development of the processes conditioned by them. Basic science influences the formation of the philosophical world outlook and worldview principles, which serves to expand the theoretical, conceptual notions of the surrounding world, the universe in all their manifestations, including those encompassing the intellectual, spiritual and social spheres (Cherkesova, 2016).

Traditionally, basic research is more closely related to natural science. At the same time, the humanities have or seek to have an apparatus capable to embrace and articulate universal principles and methods of interpretation within their subject areas. The manifestation of this aspiration is an observable surge of interest in quantitative research using mathematical and statistical methods and models in the humanities.

2. Problem Statement

The main signs of fundamental research include: a) conceptual universality; b) spacial and time unity. UNESCO assigns the status of basic research to works that contribute to the discovery of the laws of nature, to the understanding of the interaction mechanisms of phenomena and objects of reality. OECD (2015, p. 29) defines basic research as "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view". Fundamental research should be clearly distinguished from strategic research, which is primarily aimed at understanding the basics of the ultimate applied goal (dos Remedios, 2006).

Basic science is engaged in prospective research, the results of which can give a return in a very remote time. The tasks of fundamental science do not include the practical implementation of its achievements and, especially, their commercialization. However, the absence of practical orientation and applicability should not be considered the distinctive feature of basic science, since in the process of solving fundamental problems new prospects, possibilities and methods of solving practical problems are naturally open, the results of fundamental research correct the development of all fields of applied science and technology, and all discoveries and technologies are based on the provisions of basic science by definition.

Traditionally, basic and applied research has been viewed as an activity that is different in nature, and therefore carried out by different institutions and financed from different sources. But, as stated in (UNESCO, 2015, p.9), "basic science and applied science are two sides of the same coin, being interconnected and interdependent".

Many important applications, derived from the results of basic research, were not expected at the time when the studies were being carried out, since it is characteristic of fundamental research that a) most

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applications can't be predicted; b) time period between the fundamental discovery and its possible applications is often too long in comparison with the criteria used by investors. (dos Remedios, 2006).

Llewellyn Smith (1997) pointed out that basic (pure) and applied sciences differ in their motives and methods, and most importantly, in the impact on the surrounding world and the sphere of human relationships, supporting the latter thesis with a quote attributed to the physicist Thomson:

- basic science is driven by interest, whereas applied science responds to special requests;
- basic science creates new methods, while applied science improves existing methods;
- "applied science leads to reforms, pure, science leads to revolutions and revolutions, political or scientific, are powerful things if you are on the winning side" (Rayleigh, 1943, p. 199).

In the 1970s and 1980s, information and communication technologies (ICTs), reinforced with biotechnology, marked the beginning of the trend, when it became increasingly important to turn the results of scientific research into specific products. Entire industries were built on the basis of the concept of developing new products and services from basic research as quickly as possible. According to Oosterlinck, Debackere, & Cielen (2002), as a result of changes in the economy, the strict separation of basic and applied research has weakened and their boundaries outdated and sometimes became artificial.

Hameri (1996) argues that the incentives of pure science and applied industrial and technological policies rarely give significant synergy, and the distinction between basic and applied research remains valid, although this classification is outdated. Speaking about the need for a well-organized and focused interaction between the academic community and industry, he assumes that the desire for general welfare should be a priority and considers fundamental research as a potential source of benefits, which, however, can only be realized through interaction with industry.

Nelson (1959) pointed to the non-market nature of fundamental science, due to the fact that the production of new basic knowledge is characterized by non-competitiveness and non-exclusivity of the use of knowledge and, hence, leads to market failure, since no private entity is interested in producing such a product.

Expressing concern about the fact that science becomes a commodity, commercializes, and serves the authority's interests more and more, that basic knowledge has lost its self-value, and that truth as an ideal of scientific knowledge is replaced by a criterion of efficiency and practical utility, Mamchur (2011, p. 88) writes, that "in the fundamental component, even if it is carried out simultaneously in the same research project with applied and technological developments, the first place is their adequacy to reality, their verity".

The reason for concern is also too much gap between the basic and applied sphere. Thus, Konyaev (2013, p. 127), considering the separation of basic science from applied results, writes that "the appearance of ever more sophisticated and complex mathematical objects, unfortunately, does not lead to an adequate development of the technique of experiment, which leads to a "hanging" of new theories of reality in the "empirical vacuum". Commenting on the progress in the mathematical physics development, Konyaev (2013) warns that this path can lead to a complete loss of the empirical foundations of physical science.

Trying to draw a line between fundamental and applied research, one should keep in mind that fundamental research in one area in another field can be considered as applied. In the case of contradictions in new scientific discoveries and the currently accepted "classical" notions appear, it stimulates the

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modification of basic science, but also new deep research is required to fully understand the processes and mechanisms underlying this or that phenomenon, to further improve the methods or principles of their study.

In Vedeneeva (2017) the astrophysicist Kovalev is cited who argues that "fundamental research should be completely free and fully open for cognition of nature. Firstly, because it is difficult to stop the scientific thought, and secondly, it is very difficult to predict where tomorrow there will be a breakthrough" (Where are we going, what are we proud of, para. 2). The absence of restrictions and pre-set directions for the study of basic science can to some extent be regarded as a guarantee that important issues will not missed out of the scope of its attention.

At the same time, (Lebedev, 2005) warns, that in the modern world the freedom of research should not be viewed as an absolute right, but as something that must comply with certain limitations and with the responsibility of scientists towards society. Modern science is not just the curiosity of individuals, but a complex social institution that has a profound impact on the life of man and society, therefore the idea of unlimited freedom, unquestionably progressive when firstly appeared, can no longer be taken without taking into account the social responsibility, which is indissolubly connected with this freedom. However, in our opinion, the social responsibility of basic science should not be interpreted as its responsibility for the welfare of society and, especially, as a responsibility for the recoupment of the funds invested in this sphere.

3. Research Questions

In the framework of this study, the following issues are investigated:

- what are the existing models describing and structuring the field of basic scientific research and their interrelations with applied science and technology;
- which of the existing models is most consistent with the model of basic science that is being implemented in the Russian Federation;
- what are the possible directions for improving the model being implemented.

4. Purpose of the Study

The purpose of the study is to identify the model for the development of basic science in the Russian Federation, which can contribute to development of goal-setting, planning, targeting and financing the basic research in the Russian Federation.

5. Research Methods

The research methodology includes a contextual analysis of publications of Russian and foreign scientists engaged in basic research in various fields of scientific knowledge, and regulatory documents that determine the position of fundamental science in the Russian Federation, as well as an analysis of statistical data.

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6. Findings

6.1. Evolution of the models of basic science development

The ratio between the fundamental and applied components of scientific research is reflected in a number of models that have evolved from a simple linear connection to the matrix structure (Stokes, 1997). For a long time, a linear model of the interaction of science and technology could be considered adequate to the actual situation in science. This model is schematically represented as a chain consisting of three links:

Basic (pure) science → applied science / technology → growth of society welfare.

It is believed that the idea of this model belongs to Francis Bacon. The alternative model was put forward by Adam Smith. This model is also linear in form, but in content it is the opposite of the previous one, because it supposes the market is main driving force for technology development and the source of technological innovation is the previous technology.

According to (Stokes, 1997), in the matrix model scientific research is distinguished by two criteria: the search for fundamental knowledge and the possibility of immediate use (Figure 01). The names of researchers in each quadrant, whose results are widely recognized, confirm that modern society needs all kinds of scientific research.

		Considerations of use	
		No	**Yes**
Quest for basic understanding	**Yes**	Pure basic research) (Bohr)	Use – inspired basic research (Pasteur)
	No	No exploration and systematization (Linné)	Pure applied research (Edison)

Figure 01. The matrix model of Stokes (Stokes, 1997, p. 73)

The non-market nature of basic science results is a weighty argument in justifying the mandatory and powerful participation of the state in the advancement of basic science. Llewellyn Smith (1997) substantiated this position, saying that financing of fundamental science is important for society as a whole, but it does not represent an interest for any individual investor. Those who make fundamental discoveries, as a rule, do not benefit from this, because the laws of nature can't be protected by patent law, applied use takes a long time and is unpredictable, and the cultural and educational values of science do not bring direct profits.

However, according to dos Remedios (2006), "currently, governments around the world seem to believe that an emphasis on applied research will lead to national wealth creation. In so doing they are undervaluing the many and real contributions made by fundamental research to that same end. Most

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scientists believe that the best way to enhance the capacity of a nation is to create a strong applied research culture based a vibrant and dynamic fundamental research foundation." (para. 2)

Einhaäupl (2001) mentioned that politicians and officials "increasingly emphasize the need for "programmatic", "mission-oriented" or "strategic" fundamental research distinguished from pure basic research", and analyzing why the basic research becomes the subject of political discussion, he pointed to the following facts:

- the growth of the scientific system in all developed countries, which took place in the last decades of the 20th - early 21st century, combined with increased costs for basic research and an increase in the deficit of public funds;
- the lack of a linear innovation process from basic research to new products and economic growth (Why is basic research a matter of political discussion?, para. 4).

On the one hand, basic research has partly become an indicator of prestige: only powerful, sustainable economies can afford to carry out costly research, and results obtained without any future payback guarantees can be considered as their potential. On the other hand, the interests of economic development of each country, including the most economically powerful ones, require ensuring the effectiveness of public investment, and when the investment in basic science is based not only on state but also on private financing, the demand for returns becomes decisive. In accordance with modern provisions of financial management, investment in fundamental science is high risky, and this dictates high requirements for future incomes.

Since the bygone hopes that basic research will linearly contribute to technological innovation and economic growth have not been realized, there is a risk of a reduction in the funding of basic science and, as a consequence, a threat to the generation of innovations.

This aspiration should be countered by legislative support of basic research. In working out the means of such support, it is necessary to take into account not only the direct impact of basic research on economic growth, but also that by financing basic research, the state, as well as private business:

- creates the basis for improving the health, safety and quality of life of people;
- creates jobs both directly for persons engaged in research, and indirectly for persons involved in the innovation process;
- supports industry, supplying it with orders and stimulating the increase of its competitiveness due to the use of new technologies, equipment and materials necessary to create an appropriate material base for scientific research;
- enhances national security by ensuring not only the development of weapons and means of defense, but also the following use of advanced achievements for civilian purposes;
- forms highly qualified personnel for all spheres of life and activity – scientists, engineers, medics, workers, etc.;
- promotes development of regions and increase the stability of the local economies, as scientific centers attract highly skilled labor and innovative business.

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6.2. Model of basic science development in the Russian Federation

From the standpoint of the above provisions, the current Russian model for the development of basic science can be analyzed. Currently, the main documents that determine the position of basic science in Russian Federation are a) Programme of Basic Scientific Research in the Russian Federation for the Long-term Period (2013-2020) (On the Programme of Fundamental Scientific Researches in the Russian Federation for the Long-Term Period (2013-2020), 2012) , b) Strategy for Scientific and Technological Development of the Russian Federation (On the Strategy for Scientific and Technological Development of the Russian Federation, 2016. The Programme determines the amount and the structure of funding for basic research. The Strategy (On the Strategy for Scientific and Technological Development of the Russian Federation, 2016) includes “the basic research, predetermined by the internal logic of the science development, ensuring the readiness of the country to the great challenges that have not yet been manifested and not received wide public recognition, and the possibility of timely assessment of the risks caused by scientific and technological development” (para. 21) into the number of priority directions of scientific and technological development and this can be considered a recognition of the leading role of fundamental research.

In the first edition of the Programme (On the Programme of Fundamental Scientific Researches in the Russian Federation for the Long-Term Period (2013-2020), 2012, General provisions, para. 3), the following thesis was formulated: "Only by creating a competitive economy, it is possible to achieve the competitiveness of science". However, in the edition adopted in 2015 (On Amendments to the Programme of Fundamental Research in the Russian Federation for a Long-Term Period (2013–2020), 2015, Changes, para. b), the phrase took a different view: "only by creating a competitive science, the competitiveness of the economy can be achieved." This "chicken-and-egg story" clearly shows that the discussion on the interaction between science, including the basic, and the economy is far from complete.

The Programme recognizes the fundamental science as an integral part of the cultural and intellectual potential of the country hence the logic of its development should not be determined only by economy. However, in general, the provisions of the Programme are formulated in the context of a linear model of the relation between science and technology. This can be observed in the statement, that fundamental science should provide, along with obtaining new knowledge about nature, man and society, conducting basic research on priority applied areas, and in formulating one of the objectives of the Programme as "improving the effectiveness of research and its use for development prospective technologies necessary for the implementation of strategic objectives of the country's socio-economic development" (On the Programme of Fundamental Scientific Researches in the Russian Federation for the Long-Term Period (2013-2020), 2012, Objective of the Programme, para. 1). This vision of the role of basic science is relatively well corresponding with studies of the "Pasteur" quadrant of the Stokes’ model - basic research focused on the use of its results, but hardly leaves room for research in the spirit of Carl Linné aimed at streamlining and systematizing knowledge, or of Nils Bohr, aimed at investigation of nature, far ahead of the technology.

Fig. 2 shows the dynamics of financing of fundamental and applied research from the budget of Russian Federation. It can be seen that the amount of funding on applied research is growing at a faster pace and in recent years more than double exceeds the expenditures on basic science.

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In Fig. 3, it is possible to trace the dynamics of internal operating expenditures on science, which include the costs for wages, insurance contributions to extra-budgetary funds and noncapital material costs regardless the financing sources. It can be noted that the amount of federal budget's expenditures on basic research (Fig. 2) is close to the internal operating expenditures on fundamental science (Fig. 3), whereas for applied research, internal operating expenditures exceed the budget financing more than twice. This allows concluding that

- extra-budgetary sources of financing of basic science are extremely insignificant, which confirms the lack of interest of the business in the basic results that can't be transformed into benefits on the short-term horizon;
- capital expenditures on the basic research are negligible. The latter fact makes to doubt, that the research belonging to the "Pasteur" quadrant has opportunities to be carried out, because the experimental work requires complex and expensive equipment. Only desk studies can be carried out without large capital expenditures, but their results usually have no chance of an instant transformation into advanced technology.

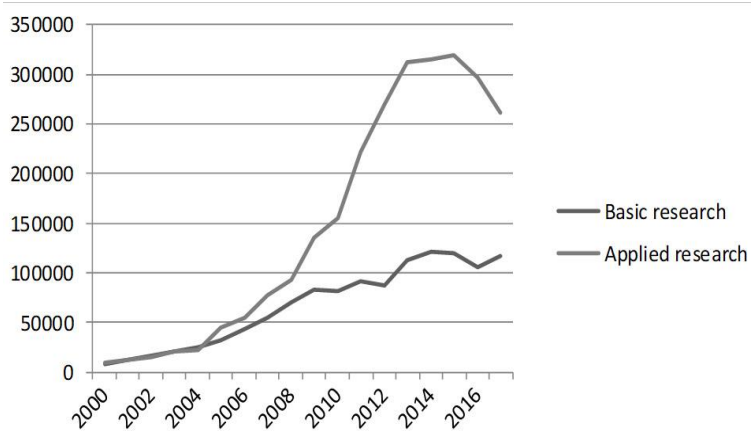

Figure 02. Dynamics of expenditures of the Russian Federation budget for scientific research, million rubles

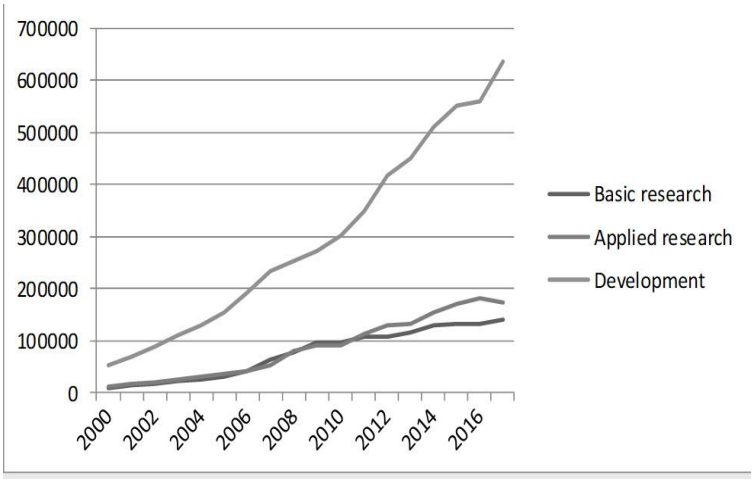

Figure 03. Dynamics of internal current expenditures on research and development in the Russian Federation, million rubles

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The Programme (On the Programme of Fundamental Scientific Researches in the Russian Federation for the Long-Term Period (2013-2020), 2012) sets indicators of publications, engaging the young scientists, patent activity and funding. Target dynamics of these indicators is shown in the Table 01.

Much attention given to bibliometric indicators for measuring and evaluating the development of science, including basic, corresponds to modern world trends. In general, such criteria coincide with the interests of basic science, which require a broad communication and information space, rather than keeping the advanced achievements which promise the commercial success in secret or immediate legal protecting of such results. Mindeli & Chernykh (2016) revealed that in the period 2000 to 2006, when the world faced with a boom of scientific publications, a clear trend developed in the Russian Federation was the outstripping growth in the financing of applied research with a weakly expressed positive dynamics in the financing of basic research and a proportional relation has established between the proportion of basic science funding of and the proportion of Russian scientific publications in the world. It may be concluded that basic research carried out in the country are relatively more productive, noticeable and significant from the standpoint of the world science than applied research.

Table 01. Indicators of the Programme of Fundamental Scientific Research in the Russian Federation for the Long-term Period (2013 – 2020) (On the Programme of Fundamental Scientific Researches in the Russian Federation for the Long-Term Period (2013-2020), 2012, Appendix 1)

Indicator	Target value	
	2013	2020
Number of publications in leading Russian and international journals based on research results, units	54070	59014
Number of citations per 1 publication of Russian researchers in scientific journals indexed in the database WEB of Science, units.	2,7	4
Number of publications in the world scientific journals indexed in the database WEB of Science, units	16502	17757
Proportion of researchers under the age of 39 years in the total number of researchers, %	32	34
Number of patents registered in Russia, units	1973	2142
Number of patents registered abroad (including CIS), units	64	106
Internal expenditures on research and development (per 1 researcher), thousand rubles	272	280

The patentability of the results of the basic research, as already mentioned, is limited. Certainly, the historical example of Louis Pasteur who patented the results of his research can be inspiring for many generations of scientists, but it should be remembered that Louis Pasteur proposed free acquaintance with the invented technology to all interested persons and explained patent by the aspiration to prevent the commercial gain of dishonest people (Yanovskaya, 1960). As known, Jonas Salk, who developed a vaccine against poliomyelitis, answering the question of who owns the patent, said “There is no patent. Could you patent the sun?” (Palmer, 2014, para. 1).

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The indicator of the proportion of researchers under the age of 40 should be connected with the educational and scientific activity of the higher school (universities), which should provide research stuff for other scientific organizations and also be leading scientific centers. Statistics ((Federal State Statistics Service) show that, since the beginning of the 21st century, the proportion of research and development stuff recruited immediately after graduating the university did not exceed 14.5% (Table 02). Undoubtedly, a powerful source of scientific stuff, hiding under the heading "other", which gives 68% to 73% of the new stuff of scientific organizations, as well as the reasons of the personnel dismiss, requires detailed study. According to statistics up to 2/3 of the total dismiss occurs at own will and about 1/3 leaves scientific organizations for the "other" reasons. The decline in the number of scientific stuff was overcome in 2013, but replenishment of earlier losses at a new level of quality remains up to date and topical.

Rodionov, Kushneva, & Rudskaya (2013), describing directions of the university's development aimed to increase its competitiveness and ensure high positions in international rankings, do not call the conduct of basic scientific research among the obvious priority. However, all mentioned areas "increasing the intellectual potential of the university, engaging of the leading scientists and teachers and increasing academic mobility, supporting young scientists, international promotion of the scientific and innovation results, and finally encouraging teachers and researchers to increase the effectiveness of their activity" (Rodionov, Kushneva, & Rudskaya, 2013, p. 97) ¬ may and should be considered in relation to the development of basic science. Also, should be taken into account that the image of scientific quality in the universities may be developed only on specific institutional levels (Akopova & Chernyavskaya, 2014).

Table 02. Stuff movement in research and development in the Russian Federation, persons

Year	**For the beginning Of the year**	**Recruited**				**Dismissed**			
		Total	Including			Total	Including:		
			Graduated The university	Other scientific	Other		At own will	Stuff reduction	Other
2001	890718	132757	14122	21549	97086	137932	93587	3542	40803
2003	867456	120298	13777	20702	85819	129284	89513	5917	33854
2005	826007	109973	13495	15618	80860	122773	81623	6598	34552
2007	814329	105758	14150	19778	71830	118952	80536	4617	33799
2009	745978	93526	13235	13529	66762	97071	58295	5776	33000
2011	741183	94939	13725	11881	69333	100849	62848	2973	35028
2013	725591	94550	11075	13210	70265	93112	59214	2015	31883
2015	737210	100290	11662	14026	74602	98643	58285	4238	36120

Taking in to account that the main independent result of basic research is scientific discovery it should be recalled that in the Russian Federation the authorship of scientific discovery is not protected by law (Civil Code of the Russian Federation, 1994, Article 1259). In a number of countries, a state system for identifying and centralizing the scientific discoveries registration has been established, aimed at securing the author's and state priority. Such a system creates favorable conditions for the wide use of

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scientific discoveries, stimulates the interest of scientists in basic scientific research, the development of scientific creativity. The implementation of such a system in the Russian Federation, in our opinion, would be more in line with the interests of basic science. It will contribute to the achievement of a Programme's general aim ¬ restoring the leading positions of Russian basic science in the world - more productively than the targets in terms of registered patents.

7. Conclusion

The model for the development of fundamental research in the Russian Federation is based on a linear model, and does not take into account the complexity of the modern field of basic science, which includes a wide range of research that differ in degree of predictability and possible terms for practical use of their results. Modern basic research is capital intensive, and since private business is not interested in financing it because of high risk, financing should be carried out mainly from the state budget.

The target indicators of the publication activity established in the program documents determining the development of basic science in the Russian Federation till 2020, correspond to the world trends. However, to consolidate the priority of the basic results, a system which does not restrict the access to information the scientists need for the further research, should be built, and the formation of a new generation of scientific personnel requires the clarification of the status of the basic science in universities.

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