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The Main Forms of Interdisciplinary Development of Modern Science

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THE PHENOMENON OF INTERDISCIPLINARITY in modern science is existing and developing in a vast diversity of different forms, ways and means of establishing and advancing of various interdisciplinary relations. On this strength we face the acute problem of general systematization and classification of the main forms of the phenomenon in question.

One could bring out a whole series of grounds for tackling the problem. But in doing so we must take into account that systematization and classification of the whole variety of interdisciplinary forms should be based on such a classificational foundation that could provide us with the possibility to reveal the natural, regular, governed-by-certain-laws interconnection of different types and ways of interaction of the modern scientific disciplines. In such case we could be also in a position to single out the basic mechanisms of the intercommunication, intercommunion, intercross, interdependence, interfusion, intergrowth, interlacing, intermarriage, intermutation, interosculation, interpenetration, intervention and other processes of interdisciplinary relations between different scientific formations existing in the "body" of contemporary science.[1]

It seems essentially obvious that such a classificational foundation could be most successfully found in the general unity of various scientific disciplines,[2] in a single nature of scientific knowledge and cognition, in the common ways of existence of different sciences and in the same means of production, justification and social institutionalization of scientific knowledge.[3] Of course, it is necessary to keep in mind that interaction of the scientific disciplines is impossible not only without their unity, but also without their essential difference, irreducibility to each other. The interdisciplinarity takes up its stand upon the unity of qualitatively different areas of scientific cognition. That is why the classification of the forms of interdisciplinarity comes down to the systematization of the types, manifestations of the unity of sciences.

As known,[4] science is a specific social system of socio-psychological and experimental-theoretical production of system-organized knowledge on regularities existing between phenomena of the reality. Such a concept of science gives us the opportunity to single out ihe following fundamental types of the unity of scientific disciplines and of the corresponding basic levels of interdisciplinary forms of scientific progress.

In the first place, the unity of sciences can be an ontological objective unity of their subject-matters. In other words, it can take the shape of material connection of the fragments of the reality which have been investigated by the given scientific disciplines.

In the second place, the unity of sciences can manifest itself in common epistemological structures of different scientific "bodies"—conceptual apparatus, theoretical constructions, methods and principles of creation, generalization, systematization. theoretical and experimental substantiation of the scientific knowledge.

In the third place, the unity of sciences can incarnate itself in the same structure and functioning of the social institutes of different scientific formations, in essentially similar socio-psychological forms of knowledge creation and organization as well as management of this process as a specific social one, and, at last, in the common social and ideological forms of axiological assessment, acceptance and distribution of the knowledge produced by this or that scientific community.

This three types of unity of scientific disciplines establish the corresponding most fundamental levels of the forms of inter-disciplinarity—ontological, epistemological and sociological (socio-institutional) ones.

Ontological, epistemological and sociological forms of interdisciplinarity are respectively independent from each other. But in the long run they inevitably interwork with each other so that their respectively autonomous existence, functioning and development result into closely interrelated moments of any sufficiently developed interdisciplinary scientific enterprise. Of course, interdisciplinary interaction of some sciences is able to begin at any of the three above-mentioned levels of interdisciplinarity. This notwithstanding cannot take the complete, mature form without acquiring some apt, fairly advanced forms relating to both other levels. For example, if a particular interdisciplinary formation arises from revealing some objective unity of one or another scientific discipline, then the complete, mature form of this interdisciplinary formation may be acquired by it. Only then the unity in question will begin to be discovered by conceptual, theoretical and methodological means which are adequate to the nature of this unity and also only then the production of knowledge on the unity will be properly organized at the sociological level, will be embodied in the social institutes which are adequate to the subject-matter and method of given interdisciplinary formation.

The fact that interdisciplinary interaction of sciences may begin at any of the three levels in no way signifies that they are all equal and have the same importance for the development of interdisciplinary researches. The most fundamental, determining form on interdisciplinarity is ontological. Neither epistemological nor sociological forms can exist without a certain objective unity of the subjects-matter of different scientific disciplines.

Singling out these three main levels in the forms of interdisciplinarity: first, poses a philosophico-methodological problem like the need to show the regularities of the interconnection between them, and second, signifies that classification of the concrete forms of interdisciplinarity can develop further as systematization of its various ontological, epistemological and sociological forms, bearing in mind that within this or that context of relations between the disciplines crucial importance may attach to this or that concrete aspect of interdisciplinarity which is either ontological, epistemological or sociological.

Ontological Forms

Regional Concrete-Science Interdisciplinarity

In accordance with the division of the whole of scientific knowledge into fundamentally distinct (by their objects, above all) regions or areas of science like physics, chemistry, biology, the sciences of the Earth, astronomy, the social sciences, the sciences of man, the technical sciences, mathematics, philosophy, there is a necessity to draw a distinction and make a special study of regional interdisciplinary processes above all within these concrete sciences. The point is that the unity of everything that exists is realized, one might say, in the form of "condensations" of greater unity linked with each other by a unity that is weaker than it is within these "condensations" themselves. The unity of nature and society is not as great as the unity of either nature or of society. The unity of physical and biological nature is not as great as the unity of either physical or biological nature. The unity of physical and chemical phenomena is not as great as the unity of either physical or chemical phenomena, and so on. All of this provides the relevant ontologic foundation for singling out regional concrete-science interdisciplinarities. According to the "condensation" and the specific type of unity of this or that sphere of reality studied by some region of the sciences, there must necessarily exist a corresponding "condensation," consolidation and specification of interdisciplinarity.[5]

Within the sphere of regional concrete-science interdisciplinary there will be found a number of specific philosophical methodological problems, the main of which is the quest for the most fundamental unity of the whole aggregate of disciplines in the given region. This involves the reductionist approach,[6] whose substance is to explain the complex by reducing it to the simple, the superior, by reducing it to the inferior. It exists both in the disciplinary and in the interdisciplinary form. The interdisciplinary form of reductionism consists in an explanation of complex phenomena studied by one discipline in the light of simpler phenomena studied by another discipline. In the event of regional interdisciplinarity connected with the quest for the most fundamental unity of the whole region, reductionism amounts to an effort theoretically to substantiate and explain phenomena in the given sphere of reality studied by different disciplines of the region in the light of the principles and laws of one of these disciplines which proves to be the most fundamental.

There are substantial grounds for regional reductionist interdisciplinarity. The point is that the most fundamental phenomena and processes of some area of reality are included in its other phenomena and processes as component parts. But the specifics of the parts do indeed determine (even if partially) the specifics of the whole. However, as the general systems theory, cybernetics, biology and even physics and chemistry demonstrate ever more fundamentally, the specifics of the whole do not in any sense amount to a sum of the specifics of its parts. The latter determine the properties of the whole partially, instead of entirely. Because the whole is always more than the sum of its parts, reductionism is always less than and falls short of the ultimate cognition of the whole.

The systemization of all the interdisciplinary processes specific for the given region of the sciences and the definition of the tendencies in their future development are another important problem in the study of concrete-science interdisciplinarity. This kind of systematic exploration of the existing and potential interdisciplinarity of the given region can alone lead it out of the chaotic empirical state in which we now find it.

Borderland lnterdisciplinarity

The so-called borderland, or transitional, allied adjacent sciences are among the most developed forms of essentially ontologic interdisciplinarity. The objects of these sciences are formed at the “junction” between the superior and inferior levels in the motion of matter. They study the transitions from physical objects to chemical and biological objects, and from biological to social objects. They also study the transitions from inferior entities to superior ones within the boundaries of some single level of movement.[7]

There are now dozens of such sciences. Back in the 19th century, there emerged such borderland interdisciplinarities as astrophysics, physical chemistry, geophysics, psychophysics, etc. Throughout the first half of the 20th century there was fairly intensive formation of such sciences. We now find at the stage of formation social psychology[8] and sociobiology, although there is heated discussion with respect to the latter.[9]

The central problem facing such sciences which has yet to be given a sufficiently complete philosophical solution is to define the specifics of the subject-matter of the borderland interdisciplinary.[10] To this very day. some scientists say that the subject-matter of biophysics, for instance, consists of biological phenomena, but studied by means of physical methods,[11] whereas others insist that its subject-matter consists of physical processes but existing in a special biological form.[12] There appears to be more ground, after all, to assume that the subject-matter of any borderland interdisciplinarity always comes to a study of manifestations of the inferior in a superior mode of existence, that is, specific manifestations of the inferior which can exist only when included within the composition of the superior, and not in some form which is free and independent of the superior. This means that biophysics, for instance, is the physics of life, and not life studied by physical methods. In the phenomena of life, physical methods can be used to study only physical phenomena, even if these are specific and have been transformed by the phenomena of life.

Another important philosophico-methodological problem of borderland interdisciplinarity is to comprehend the specifics of the reductionism with which it is connected. In contrast to regional interdisciplinary reductionism, borderland reductionism amounts to the reductibility of the superior to the inferior not within the framework of a homogeneous region of disciplines but between the frameworks of such regions. Such reductionism is. within definite limits, just as successful as regional fundamental reductionism. It actually helps to derive, for instance, definite biological phenomena from physical and chemical regularities.[13] But it, too, has turned out to be not absolute and complete, but relative and partial. It does not bear on all the phenomena of the superior sphere, but only on a definite range of these.

Thus, quantum chemistry, being an explanation and prediction of chemical phenomena on the basis of the principles and theoretical structures of quantum mechanics and electrodynamics, requires the introduction of new propositions which do not follow from the postulates of quantum physics to explain even the simplest chemical system, namely, the hydrogen molecule. Many data in modern molecular biology also testify to the impossibility of fully deriving the specifics of microbiological processes from physical and chemical regularities. An important indicator of the impossibility of complete reduction of molecular biology to physics and chemistry is provided, in particular, by the operon theory of gene. According to K.F. Schaffner, "it would seem that though the operon theory was articulated at a level which is very close to the physico-chemical level, it *itself* is not physico-chemical theory. The operon theory was constructed, formulated, and tested in terms and using the techniques of neo-classical genetics, a science which does not require a reduction to physics and chemistry."[14]

System -Transborder Interdisciplinarity

In the event of borderland interdisciplinarity we have to deal with objective processes and entities which are a common field of two allied disciplines because the object of one of these in effect falls within the object of the other, constituting a specific cross-section, a layer of the inferior within the superior. At the same time, the ontological unity of various objects of the world also appears in the form of processes and systems which are common either to some entire sphere of phenomena studied by the corresponding region of sciences or to several or all of these spheres. Thus, the ontologic unity of the objects of social sciences largely assumes the form of specific systems and processes in social life which, in one way or another, whether immediately or otherwise, fall within the objects of all or a sizeable group of social sciences. Among such processes are, for instance, aim-pursuing human interaction, learning, perception and processing of information, organization and control of one or another human activity, etc.[15] Nowadays, such processes have already become the object of the corresponding theories, like theory of games, learning theory, information theory, organization theory, cybernetics, and so on. These scientific formations have inevitably to fulfill a highly extensive and specific interdisciplinary function.

The specific feature of this form of interdisciplinary consists in the fact that here the mechanism of science integration is interaction not only of allied disciplines but also of those which are located far from each other within the overall hierarchy of the system of sciences. The interaction of natural, technical and social sciences (global transborder interdisciplinarity) or of all the social, or of all the technical, or of all the biological, and so on, sciences (regional transborder inlerdisciplinarity) most frequently occur when such synthetic, complex sciences and theories take shape.

The object of transborder interdisciplinarity is always a specific system (or process) which in its abstract form turns out to be common to many concrete spheres of reality, and exists in these spheres in the form of manifestations specific in their material nature. Consequently, this object is one or another of kinds of abstract, universal systems and processes. Cybernetics, for instance, makes a study of abstract, universal control systems. Its basic task is to disclose the objectively existing, as well as capable (in virtue of the corresponding laws of the world) to exist, abstract structures of control, which are isomorphic with respect to the concrete material nature of the various biological, technical or social control systems.

In design and task, general systems theory is the broadest possible one of the concrete transborderline interdisciplinarities. It is based, L. Bertalanffy emphasizes, on the fact that "the world, i.e., the total of observable events, shows structural uniformities, manifesting themselves by isomorphic traces of order in the various levels or realms."[16]

System-Complex Interdisciplinarity

Alongside transborder systems and processes, the ontologic unity of the world is also expressed in the presence in its various spheres of entities and processes that constitute a single, integral and interconnected complex of qualitatively distinct subdivisions, which are such that each of these can be the object of a corresponding scientific discipline or even of a group of disciplines. The existence of transborder type of systems and processes, as has been shown, is determined by links and law-governed relations among many or all spheres of reality which are universal and isomorphic in the sense of their being independent of the qualitative specifics of these spheres. The existence of the system-complex formations and processes under consideration is determined by another type of objective links and regularities. The specifics of these links and regularities consist in the fact that they determine a conjunction and interaction of diverse departments, parts, and elements, as a result of which some sufficiently global inseparable-integral entity is formed. Consequently, these are special systems-forming and systems-organizing links and regularities. Their operation results in that the changes occurring with such system-complex entities are governed not so much by general universal physical, chemical, biological and other laws, as by modified manifestations of these laws, while the modifications themselves are determined by the systems integrity of the given entity, by the systems links prevailing within it.

A study of any system-complex entity as a rule starts with the comprehension of its individual parts and large departments by corresponding independent sciences. Here, the systems-forming relations between these departments as a rule remain in the background. Initially, the system-complex entity does not appear in the cognition as such, as the systemic. Its individual departments are analyzed not as its departments, but as absolutely autonomous formations. Thus, for a long time science made a study through its corresponding disciplines not of the biosphere, but of its individual and independent departments. Only today, the complex of sciences of the biosphere is beginning to reveal systems-forming links between its individual departments.[17] Similarly, for a long time linguistics studied language phenomena simply as such, altogether leaving in the background the social and psychological aspects of language and its objective systems character, which includes not only the purely linguistic but also psychological and social processes.[18]

However, sooner or later, the objective system-complex nature of this or that entity is inevitably discovered by science or by the sciences studying its individual departments. In such cases, there begins a specific process or complex of processes whose general orientation is a theoretical re-establishment of the objective integrity and systems nature of the complex entity which has evaporated or which has not yet been discovered in the course of earlier theoretical studies of the given entity. This process constitutes a peculiar—system-complex—form of interdisciplinarity.

This form acquires ever greater specific gravity among the ever more extensive processes of interdisciplinary development in modern science. A sizable number of present-day interdisciplinary scientific formations are nothing but system-complex sciences (if not actually, then at any rate potentially: both in terms of objective grounds and the overall tendency of their development).

As for the object of such interdisciplinarity, in general form it is the specific, systems-forming and systems-organizing links and regularities thanks to which the complex of some subdivisions of reality appears as an integral system. Only as a result of the discovery of these regularities can a complex of some disciplines elaborate a common theoretical structure to link up these disciplines in a single systems interdisciplinary entity. It goes without saying that this process leading to the formation of system-complex interdisciplinarity is extremely complicated and labor-intensive. In effect, to this day there is not a single sufficiently mature and fully formed system-complex interdisciplinarity. All of these are at the stage of more or less successful formation. It appears that the science of science has made the greatest headway in its formation as a system-complex interdisciplinarity.[19]

Epistemological Forms

Epistemological interdisciplinarity, while being objectively based on this or that ontological unity of the objects of different disciplines, operates with relative independence from the ontological forms of interdisciplinarity. although it does reach its state of flowering only when the latter are correspondingly developed. What is more, as an aggregation of "soft" structures of science, which are relatively independent of its "rigid" structures, epistemological interdisciplinarity emerges much more easily than ontological and sociological interdisciplinarity. It may link up some disciplines without waiting for the level of their development to enable them to reflect the objective community of their subjects-matter. In principle, such a "soft" link between disciplines, having barely clung to perhaps a very weak comprehension of the "rigid" unity of their subjects-matter, leads to a disclosure of profound objective links and regularities of the unity of these subjects-matter. The "soft" structures of one science, being more developed than those of another, are frequently capable of pulling up to the surface of scientific analysis, by means of empirical material from that other science, the "rigid" structures of both sciences to the extent to which they objectively coincide with each other. Therein lies the tremendous heuristic role of the epistemological interdisciplinary interaction of the sciences. Strictly speaking, interdisciplinary development of modern science is most frequently embodied in epistemological forms rather than being really based on an already recognized ontological unity of disciplines.

In accordance with the general epistemological structure of science there is a need to single out within the system of the epistemological forms of interdisciplinarity its following types, which are more or less mature and frequently occur in real interdisciplinary processes: interaction of the conceptual apparatuses of the sciences, interaction of scientific disciplines by means of their laws and the structures of their laws, interaction of disciplinary theoretical structures, and interaction of the methods of individual disciplines.

These types constitute the main levels of the epistemological interaction of the sciences. In principle, this interaction may start at any of these levels, although most frequently it begins either at the conceptual or the methodological level. But at whatever level it may start, it cannot always remain only on one of these. Sooner or later, it is bound to include within itself the whole system of these levels, thereby being converted into a concrete but systems form of epistemological interdisciplinarity which is complete from the standpoint of all these levels.

For lack of space, below I give only the most general definitions of the concrete epistemological forms.

In the first place, we must take into consideration the specific processes of development of the epistemological structures related to the above-mentioned ontologic forms of interdisciplinarity.

Regional Foundationalization of Disciplines. It is a process in the course of which the "soft" structures of the most foundational, basic discipline of the region penetrates all the other sciences of the given region. This is. therefore, epistemological reduction of the disciplines of the given region to the epistemostructures of its most basic discipline. For present-day physics, for instance, it is the "microphysicalization" of the whole of physical knowledge.

Regional interaction of epistemostructures. It is a process of the mutual development of the "soft" structures of all the disciplines of the region. It results in the corresponding systems of concepts, theoretical structures and efforts which are common to the whole given region.

The foundationalization of borderland interdisciplinarities. It is the influence of the "soft" structures of the inferior and more basic, foundational from two bordering, adjacent sciences on such structures in the superior and less basic science. In the case of biophysics, for instance, it is the physicalization of its "softness."

Interaction of epistemostructures in borderlands. It is not only foundationalization, that is, the transformation of the "soft" structures of borderland sciences on the basis of the "softness" of its inferior component, but also the influence of the superior "softness" on the inferior. For biophysics, or biochemistry this is not only its physicalization or chemicalization but also its biologization.[20]

Epistemological system-transborder interdisciplinarity. It is a process of the formation of specific epistemostructures of system-transborderline sciences. For instance, the formation of concepts, laws, principles, theoretical structures and methods of cybernetics.

Epistemological system-complex interdisciplinarity. It is the shaping of specific epistemostructures making it possible to realize on a theoretical level the objective system-complex integrity of some subdivisions of reality which had earlier appeared only as separate objects of the independent disciplines.

In the second place, investigating epistemological forms we are bound to take into account the transborder epistemological processes. They are the various concrete processes in the development of the "soft" structures of all the sciences or of the greater part of them. The most important of these processes at the present time are the following:

Mathematization, which is the application in this or that science not only of the mathematical structures elaborated in mathematics itself or in other essentially mathematized disciplines, but also the elaboration of specialized mathematical structures by the given science itself. Modern mathematization largely becomes more than a mere borrowing of mathematics by the given science, and includes the creation by that science itself of fundamentally new mathematical structures which are more adequate to the specifics of its object than the borrowed structures.

Physicalization, which is the influence of physical epistemostructures on the epistemological equipment of all the other sciences. In modem science, physicalization must become not only an application of universal physical ideas and methods in other sciences, but also the elaboration by the given science itself of its specific physical aspect, its comprehension of the physics of its own object, and the elaboration of methods precisely for that object. Otherwise, physicalization, like mathematization, incidentally, threatens to become a vulgarization of the specifics of the given science or to boil down to meaningless trivialities.

Biologization. It is the influence of the epistemostructures elaborated by modem biology on the epistemostructures of other sciences.

Cybernetization. It is the application of the ideas and methods of cybernetics in other sciences.[21]

Informatization. It is the application of concepts, theoretical structures and methods of the theory of information in other fields of science.[22]

Logization and formalization.[23] It is the application of the structures of logic, especially mathematical logic, in other sciences, the conjunction of formalization of logic and formalization of the concrete content of this or that science and the transfer of formalized languages from one field of science to others.

Automatization of scientific cognition.[24] It is the elaboration of methods for staging experiments with the use of automatic technical systems, and also the methods for processing the results of experiments with the use of computers,

Modelization of science.[25] It is the application in various sciences of the method of modelling and development in this context of relevant methods of specific model epistemological conceptions.

Systems analytization.[26] It is the use in the sciences of systems-structural, structure-functional methods, systems analysis, and elaboration of the required epistemological problems.

General conceptualization and unification of scientific language.[27] It is the formation of concepts and the creation of a language common to all the sciences. The main thing in this process is unification of the language of science as an expression of the objective processes of interconnection between various branches of scientific knowledge. Here, the common language of science can be worked out only as a result of interaction among all the scientific disciplines, and not through a reduction of the whole scientific language to the language of some single science.

Integration of the empirical and the theoretical.[28] It is the formation in all the sciences of ever closer unity of empirical and theoretical levels of cognition, and also mutual exchange by the sciences of empirical and theoretical material: use of empirical material provided by one science to elaborate the theoretical structures of another, and the use of the theory of one discipline for processing the empirical material of another.

The important place among epistemological forms is occupied by the most extensive means of epistemological interaction of sciences.

These forms of interdisciplinarity encompass (in one way or another) as their own elements all the regions and areas of scientific cognition, all the disciplines. These forms establish various mutual links among the scientific disciplines, thereby inevitably promoting to a greater or lesser degree the entry of these disciplines into closer interaction with each other.

Classification of sciences. Considering that classification of the sciences is the establishment of a definite connection, of an hierarchical coordination and subordination of scientific regions and spheres which are part of these regions, and disciplines relating to the various regions and spheres, it inevitably operates as the special broadest epistemoform of interdisciplinarity. It is a constantly developing interdisciplinary entity. At every stage of its development, it reflects the degree attained in the scientific comprehension of the breakdown of reality (as well as the cognition of reality) into separate subdivisions, and also realization of the links between the individual subdivisions of reality as well as of science. Considering that the classification of the sciences has important practical functions to perform, including functions in the sphere of organization of the structure of scientific institutions and interrelations between them, its constant improvement is among the most important problems in the further development of interdisciplinarity.

Concrete-Scientific Picture of the World.[29] Such the broadest form of interdisciplinarity as a scientific picture of the world holds the peculiar place among the varied processes of interdisciplinary development of modern science. Its structure and functions, as a specific interdisciplinary entity, have not been adequately studied. However, it is quite probable that it now constitutes the most substantial form of the broadest front of interaction among the sciences. In the most general terms, it emerges as some interdisciplinary theoretical system generalizing the most essential empirical data and the most important theoretical constructions of all the regions and areas of scientific cognition, and of a!l the scientific disciplines in principle. However, it is a multiple, hierarchical entity. The first thing that stands out within the structure of the concrete-science picture of the world is the physical picture of the world, its most fundamental and theoretically elaborated level. On top of this, super-structured and interacting with it are the general picture of biological processes and the general picture of social processes. Here, the regional pictures of the world always have a tendency, as physics and biology show in particular, to grow into elaborate regional theories (general theoretical physics, general theoretical biology).

For lack of space I cannot go into any detailed analysis of the structure and functions of the concrete-science picture of the world, but 1 must mention at least two of its key interdisciplinary functions. First, the concrete-science picture of the world helps the initial elaboration of theories in disciplines which are dominated by the empirical level in the comprehension of reality. For instance, geology structures its primary theory of geological processes by making use of the physical picture of the world. Second, the concrete-science picture of the world creates the necessary conceptual climate for transferring various epistemostructures and above all methods from one field of science to others.

Concrete-Scientific Style of Cognition.[30] The scientific picture of the world is an interdisciplinary entity connecting various disciplines and above all the major regions of the sciences through a generalization of their content. It is a contental (nonformal. contrary to formal) interdisciplinary amalgamation, the amalgamation of sciences from the standpoint of what is being cognized, from the standpoint of the chief results of the scientific mastering of the world. An amalgamation of the sciences from the standpoint of how cognition is effected, by means of which methods, approaches, logical instruments and forms results in an interdisciplinary entity like the concrete-scientific style of thinking in the given historical epoch. This type of the broadest concrete-methodological amalgamation of the sciences contains a generalization of the most important methodological advances in physics, chemistry, biology, the social sciences, the sciences of man, and mathematics.

Philosophical Picture of the World. This picture is the philosophical world outlook of the given historical epoch. It is the broadest possible interdisciplinary entity of the sciences in the event that it is a philosophical generalization of the concrete-science picture of the world, a comprehension of the most important advances in the concrete sciences through the prism of philosophical categories. Of course, not every philosophy will be so bold as to produce a generalization of the advances in the concrete sciences. Discussions at the 15th World Philosophical Congress in Varna in September 1973 showed that some philosophers contended that philosophy is not a science at all, that science has no need for any philosophy.[31] Of course, such philosophers will not and cannot produce a philosophical picture of the world as the broadest possible interdisciplinary entity. But it is produced by other philosophers who insist on the intimate link between philosophy and science.

Philosophical Methodology of Science. Comprehension of the methodological advances in the concrete sciences through the prism of philosophical categories and methodological advances in philosophy itself yields a specific interdisciplinary methodological entity. It is an interdisciplinary entity because it operates more or less effectively in the concrete sciences, helping them to solve their own methodological problems. The philosophical methodology of science acts as the most global methodological interdisciplinarity, just as the philosophical picture of the world gives the most global contental amalgamation of the sciences.

Socio-organizational Forms

The interdisciplinary development of the sciences can also proceed without the formation of relevant scientific establishments or any complex scientific communities. However, this or that form of interdisciplinarity becomes truly mature and a really fruitful process of interaction among the sciences only when it is invested with socio-organizational forms that are adequate to its tasks and potentialities. Within the overall system of forms of interdisciplinarity, socio-organizational ones have the peculiar functions of realizing in practice the potentialities for extending and deepening the scientific getting hold of reality which are latent in this or that concrete interdisciplinary formation.

Below I have to confine myself to a few brief remarks on the most important socio-organizational forms.

First of all, it might be well to point out such the oldest and simplest method of socio-organizational cooperation among the disciplines as an exchange of resources for researches (exchange of scientific personnel, scientific-experimental equipment, etc.).

Next are the forms of planning and organization of researches: coordination of the research activity in different sciences, organization of the complex research projects, working up of the unified scientific-technological policy at the national or regional levels, international scientific-technological policy as the most global and broadest socio-organizational form of interdisciplinarity.

The growing ties between science, technology, material production, social progress and the development of the human personality and individuality are becoming a most characteristic feature of contemporary development of science. This has produced new socio-organizational forms of integration of science and the life of society: science-production associations, applied and even basic research oriented upon practice, and so on. These forms are inevitably interdisciplinary, and include a specifically interdisciplinary aspect. This springs from the impossibility of determining the social and ecological consequences of this or that scientific or technical achievement only on the strength of the knowledge worked out by the scientific discipline effecting the achievement. It is now quite obvious that the practical application of science should proceed not only from the content of this or that scientific accomplishment but also from its immediate and remote social and ecological consequences. It is just as obvious that without the involvement of the most diverse disciplines neither the full scope nor the correct form of any, whether immediate or the most remote social consequences of the application of the achievements in this or that discipline can be determined. It is for this reason that of late much attention has been given to the interdisciplinary analysis of the social consequences of modern scientific and technological progress. As the UNESCO Conference on the Scientific and Technological Revolution and the Social Sciences (Prague, September 6-10, 1976) noted. “UNESCO tries to establish close collaboration between the social and natural sciences to improve the understanding and analysis of the social aspect of the scientific and technological revolution.” The state of things here is such that one could risk prognosticating the emergence in the near future of special interdisciplinary departments of science whose main function will be an evaluation of the immediate and longterm perspectives of the social influence exerted by the various branches of scientific and technical progress. For the time being, the essentially interdisciplinary evaluation of the social consequences arising from the application of science and technology has gone forward in forms which are organically connected with the forms of the practical application of science, which have either already taken shape or are in the process of formation. It is also expressed in the form of some specific socio-organizational processes within the body of science, which are common to all science in scope. I have merely remarked on these processes, without giving any detailed description, for lack of space.

Technization and industrialization of researches is the interdisciplinary development of science through its growing links with technology in the sphere of scientific research itself and the transformation of the production of scientific knowledge into a process which is industrial in scope and mode. The technization and industrialization of knowledge also proceed as a specific interdisciplinary socio-organizational process. Besides, they go to create a totally new material and organizational basis for a form of interdisciplinarily like complex (combined) research.

Cosmization of science[32] is interdisciplinary development of science connected with theoretical and practical getting hold of cosmic space. More and more sciences are at present launched out on a voyage of cosmic orbits, adventures and discoveries. And here they more and more lightly interact with each other in a form of interdisciplinary by their essence concrete cosmic research projects. The scope of these projects encompasses both the most advanced of science like physics, chemistry, mechanics, astronomy, geology, meteorology, biology, psychology, law. economy and others. Moreover, it is exceedingly important that cosmic researches are carried on not only as complex, but also as large interdisciplinary and now more and more often international projects.

Ecologization of scientific enterprises is inclusion within both the theoretical and practical projects of this or that science of essentially interdisciplinary aspects connected with the need to determine the impact of these projects on the state of this or that biospheric environment or of the biosphere as a whole.

Sociologization and axiologization of science is inclusion of social and axiological aspects within any of the scientific disciplines. Any modern science now begins to develop and be practically applied not only in the light of its own needs, but also of certain social requirements and values, of the various social consequences of its development and application. Even in the definition of new lines of basic research, which had earlier, as a rule, been derived from the internal logic of the development of the science itself, the question now ever more frequently and inevitably arises whether some research can be started only on the strength of the fact that it springs from the internal logic of the development of the science, or whether its results could lead to substantial undesirable social consequences. With respect to modern genetics, for instance, many scientists believe that it is already undesirable to adopt an unconditional claim to absolute freedom in the quest for scientific truth.[33]

The single process of the sociologization and axiologization of scientific cognition inevitably unites the individual disciplines and operates as a powerful factor in the integration of the natural and social sciences. In order to bring out their social and value aspects, the sciences must inevitably exchange information and to work out some common criteria for the social and value consequences of their development.

The humanization of science[34] is the pivoting of the whole of science on the problem of man, the adoption as the main line of development both in the social and in the natural and technical sciences their increasing orientation upon complex (combined) researches into man. upon theoretical comprehension of the whole of man's multi-aspect (biological, social, emotional and intellectual) integrity and the practical development of every aspect of this integrity. The human aspects of science are increasingly established as the real center of all the theoretical and practical aspirations of science round which the whole global process of its development and application is crystallized, ranging from the most intricate and abstract theoretical constructions to the simplest and most concrete practical applications.

That being so, the center of all the aspirations of science, including the interdisciplinary aspirations, being found, it remains nothing to do but to complete this survey of the basic forms of interdisciplinary development of modern sciences. If anything of importance in these forms has been missed, it still has to be contained in this center of interdisciplinarity, so that in principle it could be derived from it by means of the relevant logical reasoning, however protracted and difficult this may be.

Biographical Note: S.N. Smirnov was affiliated with the Institut Filosofi (ANSSR) in Moscow when he wrote this essay. The book in which it appeared included contributions of leading scientists and philosophers from the former USSR, CSSR, and GDR. It was directed at philosophers and scientists interested in the problems of general methodology. The book was closely related to preceding volumes of an international and interdisciplinary nature published in co-editions by Academia in Prague and Elsevier in Amsterdam. *Time in Science and Philosophy* appeared in 1971, *Entropy and Information in Science and Philosophy* appeared in 1975.

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