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Concerning the Synthesis of the Sciences

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A presentation of types of processes leading to a theoretical synthesis of contemporary scientific knowledge, e. g. a synthesis by law, by correspondence, or by opposition. Internal interbranch synthesis can be observed in four phenomena: 1) formerly, the sciences developed by differentiation, now by their integration; the other phenomena are: 2) "cementation", 3) "fundamentalization and 4) "pivotization" of sciences. External synthesis is seen in the relationships existing respectively between 1) natural and social sciences, 2) natural and technological sciences, and 3) natural sciences and philosophy. The various types of processes discussed are displayed in a table. (I. C.)

0. Introduction

One of the areas requiring research is the dialectics of contemporary scientific knowledge, its methodology and logic. A central problem in this area is that of the theoretical synthesis of scientific knowledge, which is bound up indissolubly with the problem of the classification of the sciences, their differentiation and integration. It is a broader problem, however, since it involves not only the interdisciplinary relationships and mutual links between different sciences, but also intradisciplinary processes aimed at theoretically linking up diverse empirical data. Such is the dialectics of scientific progress in this area that one of its contradictory trends is realised in present-day conditions through its very opposite: *the integration of sciences is today effected to an ever greater degree through their further differentiation, while a profound analysis of the subject contributes to theoretical synthesis.* We have here, therefore, a practical example of an element of dialectics noted by Lenin, notably a combination of analysis and synthesis.

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In our examination of the processes of the theoretical synthesis of contemporary scientific knowledge, we shall consider only one problem – that of the types of such processes. This is the subject of the present paper.

0.1 The Types of Synthetic Processes in Science

Let us consider the theoretical synthesis of sciences in terms of the participation in it of the natural sciences in their relationship with philosophy. The term theoretical synthesis of sciences refers to processes that are aimed at uniting and linking up previously isolated branches or elements of scientific knowledge. Any synthesis (S) presupposes a preceding analysis (A) as an essential historical and cognitive (logical) prerequisite:

$$A \rightarrow S \qquad (1)$$

The arrow here indicates the direction of scientific cognition. The character of A and S, and also the form of the transition from A to S, can differ substantially. The crux of the matter, however, is that at the beginning of the cognitive process the object of the investigation is seen by the observer, in his mind's eye, as something that is given, as an undismembered, chaotic whole (C). Cognition of the object requires that the investigator dismember it and isolate individual aspects of it as abstract moments; in short, the object must be analysed. This artifically (mentally or physically) disturbs or even completely disrupts the natural links that impart to the object its intrinsic integrity and account for the unity of all its aspects.

This being so, S signifies the reconstruction (again, mentally or physically) of the links disturbed during the A stage, the reconstitution of what was earlier dismembered, disunited, the linking of what was previously separated. Such a reconstitution of the object's initial integrity and specificity is, in a certain sense, a return at the concluding stage of cognition to its initial stage.

But whereas initially the object of investigation appeared to be a chaotic whole, something immediately given and undismembered, now, following its synthetic reconstruction, it reveals the inner unity of the diversity of its aspects, that is, it has been *mediated* by the preceding investigation. This return to the point of departure at a higher (concluding) stage of cognition can be expressed thus:

$$C \rightarrow A \rightarrow S \qquad (2)$$

When stage S has been attained, the investigations of an analytical character (A) continue, but are now subordinate to S.

We can identify the types of processes in the synthesis of knowledge in the natural sciences primarily on the basis of two independent characteristics (parameters): 1) the *areas* of scientific knowledge covered by the given S, and 2) the *character* of S itself.

The first of these parameters has two gradations: a) S of an external order (S_{ex}), in which the natural sciences figure as a component along with others (such as social and technical sciences), and b) S of an internal order (S_{in}), which does not transcend the boundaries of the natural sciences (including the mathematical sciences, such a mathematics and cybernetics). This internal S may be either interbranch (S_{inb}), relating to the relationship between individual natural sciences (the mathematical sciences included), or else intradisciplinary ("intimate") (S_{int}), taking place within the framework of a single science.

The second parameter concerns the contradictory character of S itself as a union not just of different elements, but of direct opposites. This leads to the following gradations of this characteristic: a) S of the antithesis of *the general and the particular* (the individual) $S^{p/g}$), which links sciences of a more general and less general (more particular) character, such as mathematics and the natural sciences; b) S of the antithesis of *inferior and superior* ($S^{i/s}$) stages of cognition, with the superior stage historically and logically arising out of the inferior in the history of the object or the history of its cognition; and c) S as the attainment of the *unity of opposites* ($S^{o/u}$) in a more generalised form, not necessarily associated with the above-mentioned manifestations of that unity. In the latter case the unity of opposites may imply an interrelationship between contradictory aspects of the object (for example, its stability and variability) or of human activity (abstract theoretical and practical industrial aspects of such activity).

All these gradations and the types themselves of S processes are to some extent tentative and are seldom evident in their pure form. There are no sharp boundaries between the various types of S; on the contrary, there are numerous transitional and intersecting types. However, the general character of S, specifically the means by which it is manifested in each concrete case (that is, its specific mechanism), depends primarily on its basic type.

I. Intimate Intradisciplinary Synthesis

1.1 Synthesis by Law and Synthesis by Correspondence

Primary theoretical synthesis involves discovering a law or building up a theory. Let us begin with the processes of cognition that take place within individual sciences and that are therefore connected with the intradisciplinary, intimate type of S(S_{int}). The simpliest of such processes is any transition from separate empirical data to their generalisation by building up a new theory or discovering a new law of nature. Consequently, this entails resolving the contradiction between the particular (p), that is, individual facts, and the general (g), that is, their theoretical generalisation in the form of theories, hypotheses, concepts, principles, or laws. This type of S may be designated as $S^{p/g}_{int}$. For a typical case it may be denoted as S_{pl} = S *par la loi* (S "through law").

The creation of any theory, like the discovery of any law of nature – the more so, the greater the area of phenomena covered by the theory or law – often leads to interdisciplinary S (S_{int}) as well as intradisciplinary S (S_{inb}). A law is a "form of universality in nature". Accordingly, the discovery of any law makes it possible to unite and link up previously disunited factual data, to generalise them theoretically, and, consequently, to effect their S.

This is illustrated by the discovery of the law of the conservation and transformation of energy by R. Mayer (1845), by the development of chemical atomism by J. Dalton (1803), and by the discovery of the periodic law by D. Mendelejev (1869), which led to tremendous S in physics and chemistry. S on a similar scale was brought about in 19th-century biology by T. Schwann and M. Schleiden's cellular theory (1838–1839) and C. Darwin's theory of evolution (1859).

In the 20th century, synthesis "through law" (S_{pl}) is represented in physics by A. Einstein's special theory of relativity (1905), by E. Rutherford and F. Soddy's theory of radioactive decay (1902), by M. Planck's quantum theory (1900), etc., and in biology, by T. Morgan's chromosome theory of heredity (1909) and later by the discoveries in physico-chemical genetics and molecular biology. All such synthetic generalisations in the contemporary natural sciences come under the type $S^{p/g}_{int}$, specifically under the type S_{pl}.

Among the types of theoretical S this type may be regarded as primary (initial), and, hence, the simplest and most widespread.

The development of primary theoretical synthesis takes the form of the extension of a theory or law. Scientific knowledge is known never to stop in its development at what has been achieved, but to continue forging ahead steadily. It advances from learning of one, less profound order to learning of another, more profound order, and so on ad infinitum. By virtue of this, a law of nature discovered through primary theoretical synthesis, or a scientific theory evolved in the same way, is taken a step further and extended through the discovery of new, broader laws of nature, the original law, discovered through primary S_{int}, turning out to be but one aspect of the new, broader law. In exactly the same way a widening of the boundaries of the primary theory takes in a broader range of phenomena, the original theory being incorporated in the new theory as a particular or limiting case.

Such a relationship between earlier (narrower) and later (broader) knowledge was expressed in physics by N. Bohr in the form of the correspondence principle. It may therefore be said that the transition from the inferior (*i*) to the superior (*s*) stage of knowledge is in this case effected by a definite type of intimate synthesis ($S^{i/s}_{int}$), more specifically by S_{ppc} = S *par le principle de la correspondance.*

In the 19th century examples of such S were provided, say, by J. Maxwell's electromagnetic theory of light and by the molecular-kinetic theory of gases. The same is true of relativistic physics, where Einstein discovered the fundamental law of the conservation and interrelationship of mass and energy ($E = mc^2$), and it is likewise true of the periodic law, where synthesis *par le principle de la correspondance* (S_{ppc}) was accompanied by intimate synthesis ($S^{i/s}_{int}$) by virtue of the fact that the new contents of the law (1913) embraced new physical discoveries: X-rays, radioactivity and the electron (1895–1897), the atomic nucleus (1911), and others. This synthetic broadening of the law resulted from H. Moseley's discovery of the atomic number, Soddy's discovery of isotopy, and K. Fajans, Soddy, and J. Russell's discovery of the shift rule. Subsequent theoretical synthesis (the linking of all the above-listed physical discoveries, concepts, and theories with the quantum theory) was accomplished by Bohr in his model of the atom (1913–1921). An even more momentous theoretical S began in physics at the end of the first quarter of the 20th century with the development of quantum mechanics.

1.2 The Synthetic Resolution of the Conflict Between Rival Theories

This case is of particular interest in examining various types of intimate (intradisciplinary) S_{int}. Such is the character of S_{int} that it reveals the unity of opposites, a unity that man observes twice and differently each time. The first time, when man first comes up against it, it appears to him such as it actually is in reality – a real contradiction. In nature, indeed in life, opposites coexist and act in indivisible unity. Man, however, cannot at once appreciate their unity and begins by trying to dismember that unity into opposite parts, to analyse them so as to gain an understanding of each side of the contradiction separately, apart from the other and even in contrast to it. But this is done merely to find a way of subsequently combining, uniting what was earlier divided into parts: S here too follows A and reconstitutes the object of the investigation in its initial integrity and specificity. It is reconstituted, however, no longer as something given immediately but as something reconstructed from earlier separated opposite parts, each of which has been studied separately. In this way the unity of opposites is observed by man in his mind's eye for the second time, now as the final point of cognition, whereas the first time it was the initial point. This enables man to overcome his previously distorted and one-sided interpretation of both sides of the contradiction, while the object itself now emerges as intrinsically integral, rid of everything injected by the subject in the course of his investigation, in short, the object now appears as a unity (u) of opposites (o).

This type of intimate S may be designated as S_{po} = S *par l'opposition.* In the general case it will have the designation $S_{int}^{o/u}$.

Concrete facts show that scientific advances very often and quite logically take place in the S_{int} plane *par l'opposition* (S_{po}). This is true of the history of various scientific theories that concern one and the same natural object. Every such object is intrinsically contradictory, presenting a unity of opposites. But since this unity cannot be reflected in human knowledge immediately and directly, there first arise two diametrically opposite theories about the same object, which can arise either simultaneously or consecutively. Both theories, however, are one-sided and contain only part of the truth. Nevertheless, having arisen, they come into sharp, irreconcilable contradiction, giving rise to an acute struggle between their supporters. Situations may arise in which one or the other of these one-sided rival theories will score a temporary victory and gain the upper hand. But such victories always prove transient in the history of science. Since each of the conflicting theories expressed only part of the truth, the correct theory has to take into account and reflect both conflicting aspects of the natural object under investigation in their true internal relationship.

For this reason the struggle between the two rival one-sided theories ultimately results in the collapse of both and the emergence of a new theory, which overcomes the bias and narrow-mindedness of both earlier ones. Accordingly, such a new theory is invariably dialectic even if its authors do not employ dialectic terminology, as was the case with Darwin and Mendelejev, Einstein and de Broglie. The essence of such synthetic theories lies not in their wording for formulas, but in their contents, since they reflect a real contradiction existing in the natural object itself in the form of a unity of hitherto disunited antipodal aspects.

This being so, the new theory emerges not through a compromise or convention between the supporters of directly opposite views, nor through a reconciliation of the conflicting standpoints and an eclectic compounding of pieces from one theory with pieces from the other. It results from the acute struggle itself, which lays bare the weaknesses and faults of both initial extreme concepts and gives rise to a fundamentally new theory, thoroughly different from them.

From this it follows, for example, that the present-day quantum-mechanical theory of light cannot be regarded as a simple combination of the earlier opposite theories, the corpuscular and the wave theory. Similarly, Darwin's doctrine cannot be treated as a mere sum-total of Cuvier's theory of catastrophes and Lamarck's superficial evolutionary theory. Nor did Butlerov's theory of the chemical structure of organic compounds arise as a reconciliation of the theory of radicals and the theory of types in organic chemistry, the former theory having taken into account the constancy of the chemical bonds between the atoms in an organic molecule, while the latter took into account the opposite moment of the variability (reactivity) of those bonds. Again, the conflict between the concepts of the discrete and the continuous, which developed in the physics and chemistry of the 19th century, was resolved in the 20th century by the establishment of new physical and chemical theories, in which the discrete and the continuous, the corpuscular and the wave-like, the atomistic and the variable composition of chemical compounds are not antipodal, as was the case in the 19th century, but merge into one whole.

2. Internal Interbranch Synthesis

2.1 The Progress of Natural Sciences from Their Differentiation to Their Integration

Now let us consider the processes of theoretical S that take place within the framework of the natural sciences as a whole (including the mathematical sciences). In this case internal interbranch synthesis (S_{inb}) takes place as an interlinking of individual natural and mathematical sciences by various means. The most general form of such interlinking is their classification or systematisation. A deeper understanding of the problem of the classification of the sciences in its artificial (according to form) and natural (according to contents) interpretation requires, above all, that consideration be given to the fact that the process of the development of human knowledge and activities, which proceeds from analysis to synthesis, has encompassed the area of science itself.

Scientific knowledge was born originally as a single, undivided, and undifferentiated science under the aegis of philosophy. This was an abstract, natural philosophical world outlook, not based on the knowledge of any specific natural or social phenomena. This outlook is aptly summed up by the Heraclitean proposition "everything is in a state of flux, a state of change."

It was towards the end of ancient times – in what is known as the postclassical (Alexandrian) period – that the first differentiation of the sciences began. But it was only in the Renaissance that it gained appreciable development. From what was once the only science, philosophy, there now branched off a group of mathematical sciences (mathematics, mechanics, and astronomy, the latter being at that time the mechanics of celestial bodies). This was followed by the branching off in the 17th century of physics and chemistry; in the 18th and the beginning of the 19th century, of geology and biology, and in the 19th century, of anthropology. In these conditions the tendency towards the analytical dismemberment of sciences, towards their differentiation clearly prevailed over the tendency towards their synthetic association, their integration.

In the latter half of the 19th century the situation began to change radically: the tendency towards the S of sciences, towards their integration became more pronounced, and in the 20th centruy it became the prevailing tendency. The classification of the sciences put forward by F. Engels (1873) was based on the idea of the general connection and development of the forms of the motion of matter and a corresponding connection between the sciences studying these forms. Just as the superior forms of motion (*s*) develop ("are derived") from the inferior (*i*), so the corresponding sciences were "deduced" one from another, transition forms taking the place of the former sharply delineated boundaries.

These transition forms began to develop especially at the end of the 19th century and, even more so, in the 20th century. The transition form between physics and chemistry became known as physical chemistry; between chemistry and biology, as biochemistry, and between chemistry and geology, as geochemistry. With the further progress of the natural sciences, these intermediate regions between the basic sciences began to be filled in more and more, and the continued differentiation of sciences led to their synthetic integration. The newly-emergent interdisciplinary branches of scientific knowledge formed links between the principal sciences.

The progress of science and technology created a multitude of new sciences and scientific disciplines situated on the borderlines between previously disunited regions or else intersecting them. This shows that in the field of the classification of the sciences the process of development proceeded according to (1). The further differentiation of the sciences in contemporary conditions is leading to their integration rather than to their separation, as was the case in the past. In this way opposites under certain conditions pass one into the other.

2.2 The "Cementation" of Sciences

Since the renunciation of the classification of the sciences according to form in favour of their classification according to contents concerns primarily the nature of the transition phases between two kindred sciences in their general row, it is here that we shall begin our consideration of the interbranch S of sciences (S_{inb}). From the logical standpoint this case to a certain extent corresponds to the case of intimate synthesis ($S_{int}^{o/u}$), where we have a transition from isolated aspects of a contradiction (o) to their unity (u). The "cementation" of kindred sciences is a process of "bridgebuilding" between previous disunited sciences, which are only outwardly neighbours.

For example, since the law of the conservation and transformation of energy had revealed that the chemical and physical forms of motion (energy) are capable of being converted into one another, there had to arise a special interdisciplinary branch of knowledge concerned with this conversion, with its "mechanism", the laws governing it, the forms in which it takes place, and the conditions for it. Such a *transitional* science, organically linking the formerly disunited sciences of physics and chemistry, did indeed arise in the seventies (chemical thermodynamics, founded by W. Gibbs, J. Van't Hoff and others) and the eighties (S. Arrhenius's theory of electrolytic dissociation and D. Mendelejev's chemical, or hydrate, theory of solutions). This was the science of *physical chemistry.*

In the 20th century it became clear that physics borders upon chemistry not at one point, but at least at two points, if the discrete types of matter are considered in their sequence along the ascending line of development. The first such point is at the transition from the simpler, more elementary physical objects to the chemical as comparatively more complex and advanced; the second, at the transition from chemical objects (this time relatively simpler) to physical objects (this time relatively more complex and advanced). The second transition is covered by classical physical chemistry. The first has become the subject matter of *chemical physics.* In this way there has been a double "cementation" of physics and chemistry through the emergence of two transitional sciences between them.

In much the same way *biochemitry* arose at the turn of the century as a transitional science linking the previously disunited sciences of chemistry and biology. The principal, or ultimate, goal of biochemistry is biosynthesis, that is, artificially preparing the living. Thanks above all to molecular biology and bio-organic chemistry, which deals with biopolymers, science has now approached this task. The "cementation" of chemistry and biology is thus preceeding further.

Similarly, the 20th century saw the birth of *geochemistry* (thanks to the work of A. Fersman, F. Clark, V. Goldschmidt, and others) as a transitional science between chemistry and geology. But the process of "cementation" is proceeding to the next stage, at which the components of "cementation" are the transitional sciences themselves. This gave rise in the 20th century to *biogeochemistry* (thanks to the work of V. Vernadsky), which has linked biochemistry and geochemistry, and through them chemistry, geology, and biology. This might be called a "cementation" of sciences of the second order. An example of "cementation" of an even higher order is furnished by *molecular biology.*

In all these cases the interbranch S of sciences (S_{inb}) takes the form of a transition from isolated sciences (o) to their unity (u). Accordingly, this type of S may be designated as $S_{inb}^{o/u}$. A typical instance is S *par la cementation* = S_{pc}.

2.3 The "Fundamentalisation" of Sciences

The transitional sciences considered above are a particular case of the general type of intermediate sciences arising at the junction between two or more formerly disunited sciences. Another instance of the intermediate sciences are the sciences arising through the extension of the methods of some sciences to the study of objects in others. Such an extension is possible because all the natural objects representing higher stages in the evolution of matter arose historically from objects at lower stages and strucutrally contain those objects in their primordial state. That is why physical and chemical methods are applicable to the investigation of biological and geological objects, and the methods of physics are applicable to studying chemical objects.

Such a penetration of the methods of an inferior science (n^i) into the sphere of a superior science (n^s) has always stimulated scientific progress greatly; for this has made it possible to reveal the genetic and structural relations between these sciences (between n^s and n^i). This has therefore been the same theoretical synthesis of scientific knowledge, effected in a specific manner.

Revealing these genetic and structural relationships between an inferior (n^i) and a superior (n^s) science is sometimes described by the term "reduced". It is said that the higher is reduced to the lower; the complex, to the simple.

The tracing of these relationships between n^i and n^s may be characterised as the *fundamentalisation* of n^s by means of n^i.

One of the first vivid examples of the process of the "fundamentalisation" of some sciences by others was provided by the emergence of *astrophysics* in the sixties of the 19th century (thanks to R. Bunsen and G. Kirchhoff). In this way physics "fundamentalised" astronomy. In the same way the techniques of physics were later applied to the study of our planet, which gave rise to *geophysics*, a borderline science between physics and geology. The application of physical techniques to the study of life initiated the science of *biophysics* on the borderline between physics and biology. In this context one has but to recall how two physical techniques – the electron microscope and "labelled atoms" – were introduced into chemistry and biology, to realise how powerful an impetus to the synthesis of sciences is furnished in our day by physics.

Theoretical synthesis may in this case be designated as $S_{inb}^{i/s}$, while S itself may be defined as S_{pf} = S *par la fondamentation.*

2.4 The "Pivotisation" of Sciences

By "pivotisation" we mean the process of the permeation of particular natural sciences by more general, abstract (mathematical) sciences, which reflect some general aspect (quantitative, general structure, control and selfcontrol processes, etc.). The corresponding general (abstract) science therefore acts as a pivot piercing the particular natural sciences, penetrating them.

The role of such a pivot has long been played by *mathematics*, which is used in all the other sciences both as a method of investigation and as a means of expressing the results achieved, while lately it has also come to be used as a technique for building up mathematical hypotheses in the quest for new knowledge. Since the middle of the 20th century a similar role has come to be played by *cybernetics*, which deals with control and selfcontrol processes.

To justify the characterisation of S "through pivotisation" (S_{pp} = S *par la pivotation*), let us recall the primary S "through law" (S_{pl}). The discovery of an internal pivot piercing these phenomena, as it were, and constituting their common essence. In this (but only in this) respect S "through pivotisation" is similar to S "through law", and it may therefore be designated $S_{inb}^{p/g}$.

In addition to the intermediate (intersecting) sciences, which arise through the superimposition of some particular natural sciences upon others, it is now also possible to visualise the formation of sciences through the intersection of more general (mathematical) sciences with more specific (natural) sciences. Typical of such intersecting sciences are *biomathematics* and *biocybernetics*. All this illustrates the devious paths of the theoretical S of sciences, the ways in which they link up.

So much for the process of internal theoretical synthesis (S_{in}).

3. External Synthesis

3.1 The Position of Natural Science in the General System of Scientific Knowledge

In keeping with the division of the world into three main interrelated regions – nature, society, and thought – all scientific knowledge is divided into three main branches: 1) the natural sciences, 2) the socio-economic sciences, and 3) the science of thought, of the human spirit – the philosophical and psychological sciences. But apart from these sciences, there is also dialectics as a general science whose universal laws of motion embrace all three of the above-mentioned principal regions of the world and, hence, the three main groups of sciences.

This leads us to a general expression for the external, interdisciplinary S_{ex} of all the sciences, which involves the whole of natural science as an essential component. The external S of sciences (S_{ex}) implies above all revealing and strengthening the links of the natural sciences with other sciences in three main directions: 1) with the social sciences and, through them, with social life itself, 2) with the technical sciences and, through them, with technology and production, and 3) with philosophy, with dialectics and, through them, with people's world outlook and the method of their thinking. Here we find new forms and variants of the emergence of intermediate, specifically transitional, sciences, without whose participation there can be no S of sciences. For example, *bionics* arose in the 20th century as a science at the intersection of biology and engineering. This makes S_{ex} more profound, ramified, and detailed.

We shall now consider the relationship between the natural sciences and other branches of scientific knowledge and human activity from the standpoint of S_{ex}.

3.2 The Relationship between the Natural and Social Sciences

The main link between the natural and social (especially, economic) sciences is provided by the *technical* sciences. They are directly connected with the natural sciences, since their aim is putting to practical use the laws of nature discovered by the natural sciences. And gaining a knowledge of these laws is the principal aim of the natural sciences. At the same time, the technical sciences are connected with the socio-economic sciences, for technology utilises the laws of nature to achieve aims dictated by the interests and requirements of people's socio-historical practical activities. Such is the dual bond of technology (and the technical sciences) with the natural sciences (with learning the laws of nature) and with social life, which, as Lenin pointed out, defines the aims of people's practical activities. The external S_{ex} of the natural and social sciences is effected primarily via the technical sciences, thereby embracing all three groups of sciences: natural, social, and technical. We also, however, know of direct links and transitions between the natural (mathematics included) and social sciences.

First of all, the row of the natural sciences may be continued towards the higher stages of world development. In that case biology will be followed by history, the link between them being mediated by a transitional discipline based on the labour theory of anthropogenesis, founded by Engels (1876). This theory mediates the transition of the evolution process from the stage of nature to the stage of man as a thinking and social being. Thanks to this, an objective basis was found that makes it possible to link the two main areas of scientific knowledge: the natural sciences and the humanities. This completes the picture of the general synthesis of the sciences.

In speaking of the application of mathematics, cybernetics, and other such abstract sciences to specific sciences, we must consider the latter as most certainly including the social, technical, and psychological sciences. Cybernetics pierces (thereby effecting synthesis "through pivotisation" – S_{pp}) not only modern biology (especially, molecular biology), but also the technical sciences, the social sciences, and psychology. To an even greater extent this is true of contemporary mathematics, with its notions concerning the structures and models of various systems, and with its research methods that are applied to the economic sciences, to "concrete sociology", linguistics, psychology, and other humanities.

Special mention should be made of the sciences that arose earlier still on the borderline between the social and natural sciences, such as statistics and geography, which are of a two-fold character: either socio-econonomic or physical.

All such processes may be described as S "through connection with the humanities" (S_{ph} = S *par les humanites*). Since from the labour theory of anthropogenesis we know that the transition here is from an inferior development stage (i) to a superior (s), the formula of this S may be written as $S_{ex}^{i/s}$.

3.3 The Relationship Between the Natural and Technical Sciences

The splitting of the whole into antagonistic parts may be observed throughout the history of civilisation from its inception to our day. It was on the basis of the priority development of science with relation to production and technology that the contemporary scientific-technological revolution began in the middle of this century. This revolution is distinguished not only by the harnessing of atomic energy, but also by the broad development of automatic control and cybernetics, rocketry and space exploration, molecular biology and bionics, macrochemistry and laser techniques. The principal and most important feature of the revolution is the organic merging of scientific and technological progress, progress in the natural sciences stimulating progress in technology, while the latter, for its part, has a most pronounced influence on developments in the natural sciences.

This has opened up the prospect of removing the ageold antithesis between science and practice, and of merging them in the common stream of social progress, where science and technology, the natural sciences and production all become different aspects of the single forward-march of history. In other words, here, too, we observe the unity of opposites.

This is providing a basis today for an even fuller S of the natural and technical sciences, an S that could therefore be termed S "through connection with technology" and the technical sciences: S_{pt} = S *par la technique.* When we consider that S_{pt} synthesis is based on the unity of such opposites as theory and practice, we see that the designation of this S may serve to symbolise theory and practice and may be written as $S_{ex}^{o/u}$.

The scientific-technological revolution may thus be said to be, basically, a profoundly synthetic process, and this character is imparted by it to science.

3.4 The Relationship Between the Natural Sciences and Philosophy in Their Historical Development

When the relationship between the natural sciences and philosophy is considered in the light of the general advance of human knowledge, as represented by (2), it becomes possible to identify three different types of such relationships, each of them corresponding to the three members (or stages) in formula (2). As human knowledge progressed, there were repeated recurrences of forms historically long since passed by science.

1) At first (in ancient times) philosophy and the natural sciences were indivisibly united in a single as yet undifferentiated science. This was the stage of ***natural philosophy***. Philosophy at that time dissolved the rudiments of knowledge in the natural sciences, imparting to them the coloring of speculative doctrines. Subsequently this form recurred more than once, attaining its highest development in the classical German philosophy at the end of the 18th century and the beginning of the 19th (from Kant to Hegel). Epigones later produced various similar systems of natural philosophy (such as W. Ostwald's Philosophy of Nature). However, any attempt to revive natural philosophy in any of its forms in our day is cer-

tain to fail and constitutes a step backwards. The motto of natural philosophy is the science of sciences.

2) In the Renaissance and later at the stage of analyses (A), which was marked by a one-sided differentiation of sciences, there began the branching off the specific sciences (first the natural and mathematical, then the social, and, finally, in our day, psychology and formal logic) from the formerly single tree of science and, hence, from philosophy. However, this undoubtedly progressive process produced a wide rift between the natural sciences and philosophy in view of the one-sided analytical approach prevailing at the time. This was the *positivistic* stage. It reached its most striking expression in the 19th century in the works of A. Comte and his followers, and also the English positivists. To a certain extent this was a backlash provoked by the speculative natural philosophy of the German idealistic philosopher of the early 19th century. Like the concepts of natural philosophy, the concepts of positivism are continually being revived again and again, today in the form of neopositivism. The motto of positivism is: science is a philosophy in itself.

Evidently, both of these extreme interpretations of the relationship between philosophy and the natural sciences – the interpretation of natural philosophy and positivism – cannot contribute to the synthesis of contemporary scientific knowledge. Both approach this problem one-sidedly, substituting for the unity of opposites (science in general and the specific sciences) either the absolutisation of the role of philosophy or its relegation to the background by creating a wide rift between it and the specific sciences.

3) Dialectical philosophy provides the only correct solution of the problem. It treats the relationship between philosophy and the natural sciences in the spirit of the unity of opposites (the general and the individual). Given such an approach, philosophy – understood as the science of the most general laws of all motion taking place in nature, society, and thinking (dialectics) and as the science of the most general laws of thinking (dialectic logic) – forms a pivot for all branches of human knowledge and know-how. It pierces all these branches without creating any intermediate sciences between itself and the specific sciences. Any scientific discipline, any of its theoretical problems, any law or principle, any method of scientific research, and any scientific discovery may under certain conditions become an object of philosophical study.

Hence, there is not – and cannot be in principle – any distinct philosophical region of the natural sciences or of any other specific sciences, a region serving as an intermediate, independently existing scientific discipline, as some positivists and natural philosophers claim. What they call the "philosophy of the natural sciences" or the "philosophy of science" is actually only a mode of examining the subject-matter of a particular branch of knowledge, of its method and of its problems from a philosophical standpoint.

Such being the approach, dialectical philosophy does indeed pierce all scientific knowledge in general, forming its pivot. For this reason it serves as a most powerful instrument in linking all the branches of that knowledge and, hence, a most important instrument of the theoretical S of sciences.

General Table: Types of Processes of Synthesis of Sciences

Area of synthesis		Character of synthesis as transition: from the particular (p) to the general (g) p/g	from an inferior stage of knowledge (i) to a superior (s) i/s	from disunited aspects of a subject of sciences (o) to their unity (u) o/u
Internal synthesis S_{in}	Intimate S_{int}	S_{pl} = synthesis "through law" $S^{p/g}_{int}$	S_{ppc} = synthesis "through the principle of correspondence" $S^{i/s}_{int}$	S_{po} = synthesis "through opposites" $S^{o/u}_{int}$
	Interbranch S_{inb}	S_{pp} = synthesis "through pivotisation" $S^{p/g}_{inb}$	S_{pf} = synthesis "through fundamentalisation" $S^{i/s}_{inb}$	S_{pc} = synthesis "through cementation" $S^{o/u}_{inb}$
External synthesis S_{ex}		S_{pph} = synthesis "through philosophy" $S^{p/g}_{ex}$	S_{ph} = synthesis "through humanities" $S^{i/s}_{ex}$	S_{pt} = synthesis "through technology" $S^{o/u}_{ex}$

S effected with the participation of philosophy may be described as S "through the connection with philosophy" (S_{pph} = *S par la philosophie*). It may be designated as $S_{ex}^{p/g}$, for the relationship of the sciences here takes the form of a unity of the general, represented by philosophy as a general science, and the specific, represented by the specific sciences, including the natural sciences.

4. Conclusion

4.1 Types of Processes of Theoretical Synthesis. General Table

Let us now compare the above-described characteristics and the formulas of the various types of theoretical S, both those that take place within the natural sciences (S_{in}) and those that link the natural and other branches of scientific knowledge (S_{ex}).

The two independent parameters of theoretical S that we have chosen are: 1) the area of its spread, and 2) its character, determined by the transition from earlier disunited moments (sciences, aspects of the subject, degrees of knowledge) to their S.

All the characteristics and formulas obtained of the various types of theoretical S may be presented in the form of a general table. Here the first parameter is given vertically; the second, horizontally. The table summarises the synthetic interpretation of the types of S processes. The table itself is therefore an instance of theoretical S of the second order.

The types of synthetic processes in science listed above do not by any means, in our view, exhaust all the possibilities and are not the only ones possible. This particular list of types is determined exclusively by the parameters of synthesis chosen, and this is reflected in the table. The choice of other parameters would have led to different types, which there is no possibility to discuss here. But within the framework of the parameters chosen the above table may be considered sufficiently complete.

Each type of theoretical S represented in it, just as any of their relationships (vertically or horizontally), is an expression of this or that principle of dialectics. This is true above all of the core of that principle, the doctrine of the *unity of opposites.* Just as the progress of knowledge from A to S, with the subsequent combination of A and S, is a concretisation of the proposition concerning the contradictory character of the process of knowledge, which proceeds from disunited opposites to the discovery of their unity, so does this take place in the S of scientific knowledge as a whole.

All the parameters of this S represented in the table horizontally are actually different expressions of the unity of opposites, which are linked up precisely by S. This applies to such opposites as the general (g) and the particular (p), as the superior (s) and the inferior (i), as – in the general case – the advance from disunited opposites (o) to their unity (u).

The principle of the unity of opposites is borne out most strikingly in overcoming the gap between rival theories, in intimate synthesis within a science (S_{pc}), in the external S of science with practice, with technology (S_{pt}), and in the general S of all scientific knowledge through its penetration by a single dialectics, just as the general penetrates the particular (S_{pph}).

The *principle of development* – as applied to the study of the external world and as interpreted in the context of the process of knowledge – also pierces the entire S of sciences. Here we take into account progress from the inferior to the superior both of the object itself and of the cognition of that object by man. What is especially important is to take into consideration the development of the forms of the motion of matter in nature, which makes it possible to understand the process of the formation of the transitional sciences that form the basis of interdisciplinary S – both internal (S_{pc}) and external (S_{ph}) – and of the subsequent development of a scientific theory or law in accordance with the correspondence principle (S_{ppc}). The transitions between the development stages of the object – and, accordingly, between the stages of its cognition – in this case signify transitions from one quality to another and are, therefore, *discontinuous transitions* mediated in scientific knowledge in the form of interdisciplinary transitional sciences.

Finally, the entire theoretical S of science as a whole and of all its parts proceeds as a process of the internal linking of hitherto disunited branches of knowledge. The key to the presentation and solution of such problems is the principle of *universal connection.* Hence, the extremely important, sometimes decisive, role of the intermediate (linking, junctional) science, which take the form either of transitional or of intersecting sciences.

4.2 Concretising the Notion of Analysis and Synthesis Processes in the Development of Science

At the outset we adopted the most general scheme of the progress of knowledge from A to S, as expressed in (1) and (2). But this was only an initial scheme, which did not reflect the detailed aspects of the general progress of knowledge. The real picture is much more complicated. Stage A does not arise at once in its developed form, but is originally rudimentary (a). This rudimentary state (a) is distinguished by the fact that A is completely divorced from S, there being even no elements (rudiments) of synthesis. When analysis reaches the developed stage (A), it begins to be supplemented by rudimentary synthetic techniques (s), which serve to verify the validity of its results. The A stage is therefore marked by the presence of elements of synthesis, which are completely subordinated to the prevailing A.

Later, when S becomes sufficiently developed, it does not immediately merge with A in a single cognitive process of thought, but remains for some time something like an external neighbour of A, from whose one-sided domination it has achieved liberation without yet itself attaining domination in science. This state may be designated as A + S.

Finally, at the stage of superior S, developed analysis (A) becomes subordinate to S, which is now dominant.

Let us put in brackets the method that plays the subordinate role at a given stage in the development of science. Formulas (1) and (2) may then be written as follows:

$$\overline{a \longrightarrow A\,[s]} \dashrightarrow \overline{(A + S) \longrightarrow S\,[A]} \qquad (3)$$

$$C \dashrightarrow \overline{a \dashrightarrow A\,[s]} \dashrightarrow \overline{(A + S) \longrightarrow S\,[A]} \qquad (4)$$

Here the small letters a and s denote the elementary (rudimentary) forms of analysis and synthesis, while the horizontal braces cover the stages that in (1) and (2) schematically represent stage A and stage S. In expressions (3) and (4) they have been spelled out.

It should be noted that once the stage of developed analysis (A[S]) has been reached, there appear signs of the unity and interaction of analysis and synthesis, although these are not yet pronounced. Later, at the initial stage of synthesis, A still remains the preceding stage of investigation which prepares the subsequent synthesis and passes into synthesis. It is only at the stage of superior synthesis that synthesis itself merges organically with analysis and is effected through it as through its opposite. At the same time analysis, as a subordinate moment with respect to superior synthesis, is effected through synthesis.

Thus A in the history of science represents not some homogenous stage of knowledge, but a series of consecutive steps in its own development from the rudimentary form (a) to the developed form dominating the elements of synthesis (A[s]), then to a form of co-existence with a sufficiently developed form of synthesis (A + S), and, finally, to a form of subordination to superior synthesis (S[A]). This series may be written as follows:

$$a \longrightarrow \boldsymbol{A}\,[s] \dashrightarrow (\boldsymbol{A} + S) \longrightarrow S\,[\boldsymbol{A}] \qquad (5)$$

Similarly, S in the history of science is not some integral, homogeneous stage of knowledge, but is likewise a series of consecutive steps in its own development from its elements (S), which are subordinate to A, to its developed form of co-existence with A, and, finally, to its superior form, in which A becomes the subordinate moment. This is represented by the last three members of (5):

$$A\,[\boldsymbol{s}] \dashrightarrow (A + \boldsymbol{S}) \longrightarrow \boldsymbol{S}\,[A] \qquad (6)$$

The bold type in (5) and (6) places the emphasis on analysis and synthesis respectively. We see that the development of both methods proceeds in a mutual relationship, so that their developed and superior forms dominate their opposites, which are subordinate to them.

In the conditions of contemporary science superior theoretical S is effected on the basis of complete unity with A. Consequently, at this (superior) stage of scientific knowledge there is no longer any isolation of stage A from stage S, as was the case in the past in the history of science and as this is reflected in (1) and (2) and, accordingly, in (3) and (4).

This means that in working on a problem of an analytical nature, the scientist must not lose sight of the initial integrity of the object of his investigation; he must always bear in mind that his aim is merely to achieve an analytic examination of the links within a single object – not to dismember that object into isolated, disunited parts of one whole.

Such is the role of processes of synthesis in presentday scientific knowledge, and such are the types of these processes.