New Europe College Yearbook 1994

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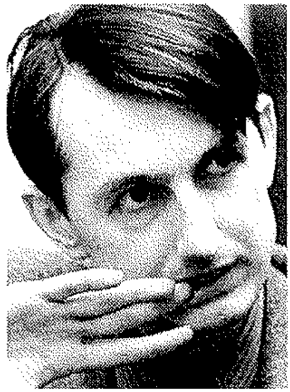

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Analytical Contents

A Theory of Internal Medium*

An Essay on the Reality of Philosophical Imaginary Concept in Exact Sciences

Abstract

To restore the classical relationship between science and philosophy, and to surpass the effects of the interiorization of Reichenbach's distinction in terms of a total split between philosophy and the "mature" science, this paper proposes an understanding of the scientific theory which comprises, in addition to formalism, some kind of reservoir of philosophical representations, of symbolisation operations, of cognitive and heuristic analogies, of constructive principles, of nutritive humus for thinking — that we call "reservoir of representations and procedures" or Imaginary. It is argued that the notion of **internal medium** dismissed the clear-cut distinction between *in statu nascendi* and "mature" science, for it supports the autonomy and the stability of the scientific theory *stricto sensu* in relation to external stimuli. Thus the conditions of a total intelligibility of a theory are provided by the very existence of its internal medium, which comprises all the acts, facts and thoughts needed to re-invent science, if all knowledge about it was to vanish. We made an inventory of the type of objects belonging to the Imaginary, and found that the relation between the reservoir and the theory is two-fold: when the imaginary influences the theory "formally", this can be done in a regulative way, either punctually (when Ideals are well articulated) or globally (when Ideals make up clusters); when its influence upon the theory is "substantial", an Ideal is converted into an element of the theory (*realisatio*). Finally, the over-articulation of the reser-

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voir according to one of the prominent overall orientations of the mind leads to the generation of either similars or identicals.

1. The Classical Relationship

I. There is a simple argument in favour of the idea that the relationship between natural sciences and philosophy is, to a great extent, unavoidable. Let us admit that the history of physics could be (presumably) reduced to the history of factual discoveries. But nowadays it seems universally admitted that facts are revealed by means of certain theories; the latter are not only evaluating facts — while positioning them —, but are even making facts *visible*. Therefore, the history of physics has to be, of necessity, the history of its theories, too. However, such theories, irrespective of their degree of formal autonomy, are only generated starting from very general presuppositions as regards the nature of the world, as well as the nature of thinking. These presuppositions express both epistemological preferences and ontological ones: *e.g.* there are atoms, rather than a plenum; there are discontinuities, rather than a continuum; the world is homogeneous, rather than hierarchical; language should be univocal rather than observe the rule of equivocation; there are associations (by contiguity) rather than (structural) configurations, and so on. Certainly, such being the case, the history of physics should necessarily be, at the same time, the history of the cognitive mentality on which the elaboration of theories has been based. And how could such cognitive-ontological preferences be argued ? What exactly is selecting them (for they are options, after all) throughout history? Thus, following a fairly lax thread of argumentation, the suggestion is put forward that the history of physics ought to reach the level of a total history (although, as a rule, even general histories do not reach this level), which should account not only for the nature of the subject acting within history, but also for the ontology of the historical act. Consequently, the history of physics (and, in principle, of any natural science) has a natural end in factual discoveries (*i.e.,* planets or elementary particles) and another one, no less natural, in the epistemological structure of the knowing (or transcendental) subject. As the structure of the transcendental subject is intricately connected, according to the antropic principle, to the few fundamental ontological suppositions concerning the nature of reality, the history of physics is supported, in effect, by a minimal ontology. It is important to understand that the latter, in the sense assigned to it by Heidegger, is not a regional one, for it naturally involves the nature of the *Dasein*.

2. The Declining Unity

However, if the connection between natural sciences and philosophy seems, in principle, unavoidable, it is no less elusive. Of course, we confer to the terms "science" and "philosophy" meanings which, as argued be George MacDonald Ross[1], are widely different from classical use, and which were imposed in the XIXth century. In the *siècle classique*, for instance, the activity which Aristotle would designate by the word *physica* was called by Newton, according to an already established tradition, *philosophia naturalis*. The latter was broader than the former, not only because it included the whole set of inanimate movements in nature, but also because it did not exclude what we now call metaphysics or ontology[2]. Nevertheless, aside from the metaphysical element, *philosophia naturalis* might correspond, broadly speaking, to present-day natural sciences (although, in such a case certain difficulties arise). This evolution, based on the exclusion of general ideas (*i.e.,* metaphysics) and on keeping under control a given experimental domain*, has entailed, in the XIXth century, the institutionalisation of the separation between science and the philosophical principles in which the latter was considered to be rooted**.

II. Two elements seem to have contributed to this evolution. First, Auguste Comte's general idea according to which religion and metaphysics belong to two historical stages which are irreversibly obsolete, outdated by a new secular religion, *i.e.,* the positive science (exposed in Auguste Comte's *Cours de philosophie positive,* 1830-42). More than one thinker rejected the idea of a positivism conceived as a secular religion, the attraction exerted by the idea that science outdated metaphysics was quite extraordinary and almost unanimously accepted. The second element involved was expressed in John Stuart Mill's *System of Logic* (1843), where philosophy was viewed as an essentially logical discipline; its precise aim was to define the circumstances under which a scientific theory could be considered as true. This concern was probably the source of the discriminating distinction between legitimate, justified

* In spite of the general belief, although *experimentum* can be translated by "experiment" and *experientia* by "experience", for Bacon the experimental method meant what the historical method meant for Aristotle, namely the assembling of a big mass of facts of experience. In effect, by preserving the etymology, the ideology shared by the Royal Society proclaimed the idea of a "plain historical method," where "historical" simply meant "empirical" (according to Bacon's heritage, which is explicitly assumed[3]).

** This phenomenon had not yet occurred in the 18th century. At Cambridge, where the new mathematics and science were dominating the curriculum, they were still part of the instruction in the field of arts; whereas the universities in Scotland, which were leading the fields of new scientific ideas, did not admit, on any account, the separation of science from its philosophical principles[4].

philosophy, which should be, essentially, a logical analysis, and illegitimate, unjustified metaphysics, associated with speculation. Of course, the ontological presuppositions were thus either included in the heuristical model used in scientific research, or else — if there was no other way of legitimating them — they were despised by the scientific community. In effect, the limitation of philosophy to what we now call philosophy of science, as well as the limitation of the philosophy of science to a logical analysis of the foundations of empirical science (both initiated by J.S. Mill) were based on a decisive presupposition, shared by both Gottlob Frege (*Begriffschrift*, 1879), and Bertrand Russel (*Principia Mathematica*, 1910-1913)*; it was considered that *the methodology by means of which philosophy investigates the foundations of empirical science is scientific, too*[5].

Frege was firmly convinced of the validity of the distinction between *a priori* cognition (i.e. mathematical cognition, the logical one) and *a posteriori* (scientific) cognition. The only legitimate philosophical reflection was, therefore, the logical analysis of the principles of empirical science, which, in its turn, was scientific. In this way, the legitimate nature of science excluded all the phenomena which could not be decided upon according to scientific criteria. Philosophy was considered legitimate only to the extent to which it was "scientific." According to Willard Van Orman Quine's analysis, this is the outcome of the acceptance of the firm distinction between an *a priori* cognition and an *a posteriori* one[6], which he himself rejects. To the extent to which such a distinction is given up, the strict border between philosophy and science (along the trend of thought represented by Mill/Frege/Russell) is cancelled in the following sense: scientific theories no longer appear as strictly determined by *evidence*; in other words, the conflict between two competing theories cannot be *exclusively* solved by taking into account empirical criteria. A broader philosophical context should be taken into consideration[7]. If a fairly lax distinction is made between the analytical plane and the synthetical one, the interesting consequence is the acknowledgement of a certain continuity between philosophy and science. On the contrary, its positive assertion seems to trigger off their complete separation.

The Divorce

III. A few conclusions can be drawn so far. If we take into account the meanings resulting from the institutional systems of the XIXth century, then,

* Although *Principia Mathematica* was written by B. Russel in collaboration with Alfred North Whitehead, only the former author was cited here, because it is only to him that such a conception can be unambiguously attributed. A.N. Whitehead's point of view is mainly expressed in *Science and the Modern World* (1926).

broadly speaking, two possible relationships appear to exist between philosophy and science, viz.

(α) science operates within a frame of concepts and within certain presuppositions which are all of an empirical origin; in other words, any scientific theory, by its nature, is strictly homogeneous. The only legitimate philosophy is the philosophy of science; in fact, the latter is only a logical analysis of the principles of science. It is a kind of epistemological awareness of the procedures derived by applying the "scientific method" to a certain domain.

(β) science operates within a frame of concepts and within certain presuppositions which are not of an empirical nature; in other words, any scientific theory functions within a heterogeneous "internal medium", of a hierarchical structure. In such a case, the conceptual considerations implied by legitimate philosophy are as broad as possible, for it is the nature of science which dictates that the major difference between two scientific theories should essentially be both conceptual (philosophical) and empirical (scientific).

According to the (α) type relationship, between philosophy and science there is no continuity; according to the (β) type relationship a certain continuity does exist, but each case should be considered separately.

In what follows, I will try to argue that the relationship between philosophy and science, as outlined above, was strongly influenced by its impact with the classical distinction made by logical empiricism between the context of justification and the context of discovery; eventually, this distinction has yielded another one, viz., between science *in statu nascendi* and mature science. Almost all the discussions about the nature of the relationships between philosophy and science have been predetermined by the "internal" distinction between "immature" science and "mature" science.

The Conversion of the Divorce Into Reichenbach's Distinction

IV. As I see it, the beginning of this distinction in Western culture go back such a long time that its origin cannot be accurately established. We can only choose an aleatory event and consider it to be its source. Let us only remember that in ancient times and in the Middle Ages the "normal" way of dealing with science (as a scientific discipline) necessarily involved the invocation of the predecessors. When Aristotle wanted to say something about atoms and vacuum, he was bound to refer to the history of atomism. In other words, a certain dominant orientation of the mind is quite tributary to the idea that **the history of the problem is a constituent part of the nature of the problem**[8]. This was the prevalent stream of thought in the 18th century[9]. It was Goethe's constant belief, and it was the basic presupposition of a fairly influential historiography of science[11]. What is more, this stream of thought can be identified as an underlying argument in a widely-spread class of representations, which could be illustrated by Leibniz's belief that "the history of those discoveries which are made not by hazard, but by reflection" may lead to a new logic of discovery, which he called *ars inveniendi*[12]. Even thinkers who used to criticise this idea, while favourable to the above-mentioned stream of thought, like William Whewell, admit that history provides lessons profitable to cognition[13]. In fact, this is just another way of saying that the history of a problem is a constitutive part of the nature of the problem. A much similar presupposition lies at the basis of Hegel's repeatedly expressed dislike of Rousseau's distinction between *état de nature* and *état social*[14]. Hegel argues that it is quite impossible to grasp an immediate essence of man, an absolute one, to which morals should be afterwards added, step by step; the study of man does not consist in accounting for a ready-made reality but in a reproduction of the act by means of which man has become what he is now. As a rule, with Hegel, an object exists only together with its development, as it actually contains all the moments of its own development. On the contrary, with Rousseau, human nature is previous to history; it can be separated from the malversations of history, and it can be accounted for irrespective of any previous or surrounding context. According to the former interpretation, an object contains its own genesis, i.e. it cannot be separated from its own development. According to the latter, the object is entirely defined prior to any development, so that it can be separated at any time from its history. In epistemological terms, this classical distinction was reworded by Franz Brentano, as the radical difference between the logical validity of an assertion and its psychological genesis. Brentano's pupil, Edmund Husserl, was, in his turn, permanently concerned with criticising psychologism and with strictly delimiting the logical plane[15]. Brentano's idea was that, in philosophy, principles should be expressed by ideal and fixed terms, which should be immutable, paratactic and independent of the flow of experience[16]. Such an idea is perfectly in agreement with the above-mentioned presupposition which we considered to have guided the stream of thought represented by Mill/Frege/Russell.

These two directions of the human mind are constantly illustrated in all the fields in which theoretical intelligence is compulsory. In linguistics, for instance, there are scholars like Noam Chomsky, who maintain that language is an innate capacity, devoid of any past which might involve some facts significant for its essence. But there are also other scholars, like Aaron Dolgopolsky*,

* In the 80s, Dolgopolsky discovered the parentship relations between six linguistic families of the Indo-European and Uralo-Jukagir tribes.

who states that there are similar words and grammatical structures allowing us to infer, starting from the languages spoken nowadays, the existence of *an original, historically determinable language*[17]. In the XIXth century, the stream of thought represented by Aristotle, Goethe and Hegel was marked by psychologism and historicism, whereas the one represented by Brentano and Husserl was influenced by logic and mathematics. It is certainly easy to notice that the former trend illustrates a (β) type relation between philosophy and science, while the latter illustrates an (α) type of relation.

V. In 1899, Hilbert expressed Euclidean geometry axiomatically. This "abstraction" of a mathematical branch from the historical context allowed a more authoritative and better grounded reiteration of Riemann's previous distinction between physical geometry and mathematical geometry. Along the line inaugurated in geometry by Minkovsky — in which Einstein himself joined in 1915[18] — Reichenbach maintained that mathematical geometry is a logical, analytical and *a priori* theory, whereas physical geometry is an application of mathematical geometry to the world of experience[19]. By asserting that geometry is an exact science, in fact we only refer here to mathematical geometry, while by asserting that it says something about the world, we actually refer to physical geometry. According to Carnap, the former is analytical and *a priori* while the latter is synthetical[20]. While steadily following this distinction, the representatives of logical empiricism suggested that no type of cognition could ever be *a priori* and synthetical at the same time (the fact that synthetical *a priori* judgements are possible had been the challenge of the first Kantian criticism); this has led to a strict delimitation between syntax (mathematical formalism) and semantics (empirical interpretation) in the structure of physical theories. An immediate consequence of the strict separation between fact and theory was the separation of the discipline from its history and the open assumption of the (α) presupposition (*i.e.*, the Mill/Frege/Russell tradition).

Thus, whatever referred to the study of the logical problems of science was called a *context of justification* and was admitted as relevant, whereas whatever was influenced by the historical change of theories was called a *context of discovery* and was transferred to the "insignificant" domain of empirical psychology[21]. Broadly speaking, the point of view of logical empiricism and of critical realism was that ideas do not differ from each other by the way they are engendered (*i.e.*, by history), but by the way they are grounded and validated[22]. In other words, **the history of the problem does not belong to the nature of the problem.** It is by all means significant to remind that such an assertion is the very opposite of the classical position I mentioned in paragraph **IV.**, according to which, on the contrary, the history of the problem does belong to the nature of the problem. Also, as far as the continuity of ideas is concerned, stress should be laid on the fact that, with Kant, the possibility of synthetical *a priori* judgements was in perfect agreement with his idea that science operates within a frame of concepts which are not of an empirical nature. Therefore, it is not at all surprising that the denial of any connection between the synthetical plane and the analytical one bears consequences upon the connections between philosophy and science. It is equally interesting to notice that any disengagement of science from its philosophical presuppositions has certain effects upon the relationship between science and its history. Philosophy and history establish the same kind of relationship with science.

"Revolutionary" Versus "Mature" Science

VI. It is quite true that the rigid distinction between the context of discovery and the context of justification (and especially the aim of such a distinction) was thoroughly criticised (Toulmin, Laudan, etc.)[23]. But it is by far more interesting to notice that, in order to preserve the continuity between philosophy/history and science, such a distinction was backed by the acceptance of the idea that an essential difference exists between science *in statu nascendi* and science having reached a "non-revolutionary" mature stage. Science, as it appears in the stages of deep revolutionary changes, establishes a close relationship with philosophical problems, because whenever a new theory is engendered, a conceptual change occurs of necessity. On the contrary, whenever science has reached a "normal" stage (in the acceptation of Kuhn)[24], or, as Heisenberg puts it, is in the process of "developing abstract structures" — which, being an "original phenomenon" of science, is a perfectly autonomous process[25] — then a disengagement of science from its philosophical problems equally takes place. Therefore, without denying the validity of Reichenbach's distinction, the idea can be put forward that science *in statu nascendi* (or "revolutionary" science) ought to be tackled according to the context of discovery, whereas "normal" science — once the evaluation criteria have been thoroughly established — should be analysed within a context of justification. In the former case, the active relationship between philosophy and science is (β) type. In the latter case, the relevance of philosophy for the evaluation and comprehension of science tends towards zero.

To summarise the way in which philosophically oriented thinkers have prevented an absolute separation between philosophy/history and science — which could have become irreversible if Reichenbach's distinction had been made absolute — consisted in postulating a significant difference between "revolutionary"/*in statu nascendi* science (that science which establishes a (β) type relation with philosophy) and "normal"/mature science (which establishes an (α) type relation with philosophy). I believe that the following demarcation criterion could be devised, viz. a science is *in statu nascendi* as long as it establishes a relationship of nourishing continuity with philosophy/history; ant it becomes a mature science as soon as the connections with its philosophical matrix (in the broad sense) are broken.

3. The Reconciliation Strategies

Pierre Duhem

VII. This criterion was first used as an epistemological key to the comprehension of the evolution of physics by Pierre Duhem. His argument was twofold: with a view to freeing physics from mechanism, which he assimilated to arbitrary metaphysics, Duhem claimed that it is only during its immature stages, i.e. before being entirely mathematized, that physics establishes an intimate, fairly close relationships with the prevalent metaphysics of a specific age[26]; on the other hand, he claimed that physics is not a purely abstract-conventional theory, but that by its total mathematization, it engenders a classification system of the world, which is *natural* in the sense that it is ontologically true[27]. Duhem believed that analytical thermodynamics retrieves the cosmos of natural places once propounded by Aristotle[28]. Such an idea suggests that a subtle convergence exists between physics and the philosophical attitude; with Duhem, the latter referred to Divine Providence. On the other hand, in spite of the distinction between immature science and mature science, which, as we have seen, Duhem tackled with subtle differences, the theorist was in favour of the principle according to which the history of the problem does belong to the nature of the problem. He combined this principle with his attachment to uniformitarianism and interpreted it in such a way as to make the above-mentioned distinction even more lax. In the histories he authored, Duhem argued in favour of the continuity between the concepts and representations of science and the philosophical theories. His theses did not refer solely to the absence of a scientific revolution; they also implied, in a decisive way, the relation between philosophy and science. Duhem viewed such a relation as a continuity, backed by a convergence (triggering off the re-actualisation of Aristotelianism in theoretical thermodynamics).

Edwin Arthur Burtt

VIII. The thesis about the temporary connection between science *in statu nascendi* and philosophy was warmly supported by Edwin Arthur Burtt in

The Metaphysical Foundations of Modern Physical Science (1924; 2nd enlarged ed.:1932). Burtt agrees that it is never facts which generate science, since facts are always the same; it is only the way of looking upon them that changes. Modern science was not suggested to human intelligence by the ostensive evidences of reality; it is the consequence of a metaphysical conversion. Burtt argues that Kepler's heliocentrism was not due to the obviousness of the measurements at his disposal (since the same observations led Tycho Brahe to a different representation of the world system), but, without any doubt, it was due to Kepler's "heliolatry". Burtt claims that Kepler became a follower of Copernicus owing to the cult of the Sun, which he shared for mystic reasons, not for scientific ones. Burtt's point of view as regards the relation between philosophy and science can be summarised as follows: philosophy is a scaffolding the scholar makes use of in order to specify his scientific choice proper; his theoretical construction once finished, the scaffolding is removed and thrown away as happens when the building of a house is finished. The building we call science is to function from now on independent of any scaffolding or, in other words, exempted from any contact with philosophy. It is obvious that, with Burtt, the relation between philosophy and science is similar to the relation between the catalyst and the outcome of the chemical reaction; moreover, such a relation exists only during the chemical reaction, namely *in statu nascendi*.

In my opinion, Burtt is already quite sensitive to the influence of the Mill/Frege/Russell tradition, and that is why he tries to adjust his philosophical penchant to the new conception (which was extremely restrictive) concerning the nature of the valid relationships science establishes with everything else. It is probably not by chance that, in order to describe those very legitimate relations, Burtt resumes the image of the ladder that is thrown away once you have arrived on top of the building, which Wittgenstein suggested in order to justify his obviously meaningless propositions (according to the rules that he himself had set forth) by which he outlined a restrictive doctrine of meaning[29]. In order to preserve a certain continuity between philosophy and science, many theorists admitted that such a relationship could be justified only during the period of genesis, when, they were to argue, the philosophical opinions and options of scientists act as catalysts in crystallising and formulating a theory.

Alexandre Koyré

IX. In a lecture delivered at a meeting of the American Association for the Advancement of Science in Boston in 1954, Alexandre Koyré vividly argued

against the thesis that the scaffolding can be removed, maintaining that the scaffolding is always removed only in order to be replaced by another scaffolding and that, in fact, there is a certain solidarity between a scientific theory and the philosophical presuppositions which Burtt had assimilated to Wittgenstein's ladder. Newton's followers, for instance, faithful to his "purely" scientific heritage, thought they could dispense with the God hypothesis, in which Newton (and Descartes before him) founded the veracity of his physical world; however, as Koyré claims, "privé de son support divin, le monde newtonien s'est avéré instable et précaire. Aussi instable et précaire que le monde d'Aristote qu'il avait remplacé"[30].

The following fact is relevant. Koyré elaborated his conception at a time when the (α) type of tradition was triumphant, and the discriminating distinction between genesis and justification had already begun to forge, by means of its constraints, the relationships between science and the other disciplines (for instance, history and theology). The vocation of Koyré's programme is fairly obvious in a *curriculum vitae* he made in February 1951 in order to be admitted to the Collège de France (where he was rejected). He supports there the thesis of the non-separability, in the human mind, of the philosophical thinking from the history of scientific thinking, on the one hand, and from religious thinking on the other hand, although philosophical thinking has always been immersed in religious thinking, either in order to confirm it, or in order to contradict it. In other words, just as Kant endorsed the unity of the knowing subject, Koyré starts from the idea of the absolute unity of the human mind. Consequently, although they become autonomous according to different justification rules, religion, philosophy and science have in common the fact that when they become a system, each of them propounds an image — or conception — of the world, to which they are constantly referring. Along this line, Koyré claims,

> "la mystique de Boehme est rigoureusement incompréhensible sans référence à la nouvelle cosmologie créée par Copernic"[32].

According to this programme, the non-separability, in mind, of the above-mentioned trinomial seems to be permanent. In his plans Koyré envisaged the following stages:

(a) Le système newtonien; l'épanouissement et l'interprétation philosophique du newtonianisme (jusqu'à Kant et par Kant);
(b) La synthèse maxwellienne et l'histoire de la théorie du champ;
(c) Les origines et les fondements philosophiques du calcul des probabilités;
(d) La notion de l'infini et les problèmes des fondements des mathématiques;
(e) Les racines philosophiques de la science moderne et les interprétations récentes de la connaissance scientifique (...)[33]

Koyré lived until 1964 and, out of this schedule, was able to cover, only partially, the first stage. I am not acquainted with the Koyré archives, but I venture to suppose that, according to the "unity of the mind" method Koyré formulated, his plan was impossible to fulfil. Firstly, although in principle the thesis of non-separability involves no temporal restrictions, Koyré actually considered only types of science *in statu nascendi*. This willing restriction is important. Secondly, the type of continuity present in his analysis, which is a *weak* version of the thesis on non-separability, in mind, of the religion/philosophy/science trinomial ought certainly to be changed when taking into account, say, Maxwell's electrodynamics or the restricted theory of relativity. It is my conjecture that the responsibility for this obstruction lies in the widespread belief that mature science no longer has any essential connection with philosophy. (This belief is proved by the acceptance of the distinction between science *in statu nascendi* and mature science; interweaving with the axiological accents of Reichenbach's distinction, this belief associates an (α) type position with mature science, and a (β) type position with immature science.) This obstinate thesis led to an extremely amazing historiographical situation, namely, that the history of scientific thinking has real jewels of erudition and sagacity for the age extending up to 1800 at the most; beyond that, namely in what is called the age of completely autonomous science, the histories of science are either chronologies (some of them, quite rich), or Whig histories (in the sense defined by Herbert Butterfield), or else case studies of the revolutionary period of recently emerged branches of science (in which the distinction between science *in statu nascendi* and science of "developing abstract structures" is still relevant, but, nevertheless, it is quite legitimate to take into account the philosophical presuppositions of its yet immature stage).

As far as I am concerned, I do not think that the explanation of this situation lies in the impossibility to propound a legitimate continuity between philosophy and science during the mature stages of a scientific theory. Rather, I believe that the researchers' vocation and expectation have been surreptitiously directed by the pressure exerted by Reichenbach's distinction in favour of the rejection of the association of a (β) type of thesis with the so-called mature science.

4. The Internal Medium Solution

Science Is Not A Finite Object

X. All the previous discussions involve the following state of the art: whenever mature science is referred to, theorists have in view the autonomy of

the discipline (expressed by W. Heisenberg in terms of releasing the original phenomenon of exact science, which consists, according to him, in "developing abstract structures"); the separation of philosophy from science in its mature stages is accounted for by the requirement to preserve autonomy. Nevertheless, I think that the idea of a strictly heterogeneous science as compared to the other activities of the human mind is based on a questionable presupposition, namely, that science could be equivalent to its formal products; or even that any science could be converted into the "everyday" language of a textbook, since it is, essentially, an ordered set of knowledge. But in my opinion, what we know about what we are doing is much less than we actually do. That is to say there is always an irreducible remainder, which depends on the activity and to which Einstein was drawing attention in the beginning of his article "On the Method of Theoretical Physics"(1933)[34]:

"If you want to learn from theoretical physicists something about the methods they make use of, I suggest you follow the following principle: do not listen to their words, but watch their actions".

The only drawback of this remarkable article seems to be the fact that it is quite unlikely, on the basis of the method set forth in it by Einstein, that anyone could re-invent physics if it disappeared. It is my intention to suggest that natural sciences are not completely contained in their finite expressions, namely, if need be, in textbooks/treatises. Because, in effect, science is not a (formal) object, but rather a (cognitive) process. Whatever is included in, or excluded from, the autonomy sphere of science decisively depends, in my opinion, on whatever we decide "science" to be, i.e. either an object or a cognitive activity. Certainly, in this way, its nature is obviously transferred from the finite set of its expressions to the "infinite" character of the act by which science is understood and made to function here and now. By this *transfer*, I only suggest, in fact, that the most appropriate metaphor characterising the "object" called science is not the book in which science is coded, but the cognitive structures of the mind, which bring science to life. I believe that science, like any other activity of the mind, lives only as long as it is understood; I also believe that this process, influenced by both innovation and continuity, accounts for its most real "physical" support. Consequently, the autonomy domain of science should be established with reference to this real "physical' support which accounts for its comprehension by the human mind. In my opinion, this is the natural **internal medium** of science.

The Homeostasis of Science

XI. The notion of **internal medium** was introduced in 1853 by C.P. Robins but it was completely clarified from a methodological point of view starting from 1854, by Claude Bernard. According to him, intricate organisms live *de facto* in two types of media, viz. an external medium, characterised by a certain type of variables, and an internal medium, characterised by other variables. The essential difference between the two types of variables is that external variables cannot be controlled by the organism, whereas internal variables are kept in a restricted field of variation according to a vital rule of self-preserved stability. Only this internal stability, as compared to the aleatory variations of the external medium, allows developed organisms to be emancipated from exterior whims. In other words, the achievement of an isolated and stable internal medium allows an organism to become *autonomous* from outside requirements. The condition of autonomy is the functioning of an internal medium. For instance, the real medium of a cell is not the outside world, but the internal medium consisting of blood, lymph and tissue[35]. *Homeostasis* is the term by which W.B. Cannon (1871-1945) named an organism's capacity to preserve internal stability (*Wisdom of the Body*, 1939).

The homeostasis of science consists in its capacity to establish accurate conditions of stability, i.e. of autonomy. To this end, science should form a complete internal medium. Consequently, when defining the relations between science and philosophy (but also between science and other activities of the mind), the actual problem is the following: does philosophy (or a certain acceptation of it) belong to the internal medium of science? In other words, is it with the help of philosophy or without it that science* acquires *autonomy conditions* from the exterior? In what follows, I suggest the following simple description as a definition of the internal medium of science: the internal medium of a discipline is the set of its *comprehensibility conditions*, such as they can be inferred from the act by means of which the cognizing subject understands that discipline. In my opinion, it is only *such* a broad definition that may allow an internal stability as remarkable as the one shown by Western science ever since the Greeks. On the other hand, I think that it is only by using the notion of internal medium *in this sense* that we can speak of a philosophical imaginary of natural sciences.

* It is unavoidable that language should deceive, if it is not closely scrutinized. It was almost unwillingly that I used the word "science" here in the acceptance of a finite object, having a strictly outlined "spatial' existence, whereas the affiliation relation was instinctively conceived as a placing side by side or a superposition. Let me make the necessary amendments without being able, however, to change the text. It seems that language tends to expand in space.

The Process of Reasoning Argument

XII. When we think, what is it that thinks within us? Could thinking be a method? I will try to answer this critical question strictly from the point of view which interests me here, viz. the internal medium. To this end, I will refer to the opinions of an almost forgotten logician, Edmond Goblot. The question whether thinking is a method or not was disposed of by Henri Poincaré in the following way: mathematical thinking cannot be reduced to formal logic[36]; whereas the latter can be reduced to a syllogism[37]. As the rules of syllogism allow neither creations, nor invention, nor demonstration, while thinking should be logical, how can the latter develop? Goblot claims that the rules governing logical operations are those propositions previously admitted as true, either obviously or by demonstration, or else as a postulate or a logical convention[37]. These rules are of two kinds: (i) some of them refer to the possibility of operations; (ii) the others refer to the necessity of the result. Thinking is governed by any previously acquired cognition considered valid for the topic investigated. This cognition acts upon the "purport" to be cognized by means of formal logic. In effect, Goblot claims, to demonstrate means to construct: "pour démontrer qu'une hypothèse entraîne une conséquence, *on construit la conséquence avec l'hypothèse*"[38]. Reasoning engenders this construction according to the rules imposed by previous cognition; by construction, a new object is achieved, the features of which are now accounted for by syllogism. The novelty is that syllogism, which is purely analytical, appears to belong to the construction, a property which had first to be constructed in order to be acquired by thinking. Therefore, the consequent is not syllogistically deduced by the antecedent, but is constructed by means of the antecedent[39].

Goblot agrees with the idea that reasoning is "l'art de diriger les syllogismes"[40], while suggesting that, among all possible operations, the mind chooses freely, in this way leaving a practically unlimited field to *logical invention*. This craft, Goblot claims, is as creative as the artist's craft; it is, literally, a ποιητικὴ τεχνή; the rules are not constraints, but levers: "Chaque vérité construite est un instrument pour en construire d'autres; à mesure qu'il avance, l'esprit forge lui-même ses outils pour quelque nouvelle opération"[41]. Leonardo da Vinci's case is an illustration of Goblot's words; with Leonardo, the simple mechanical machinery, especially the lever and the scales, are rational *models*, illustrating the fundamental relationships to which he seeks to reduce all problems of equilibrium[42].

As far as I am concerned, the conclusion seems to be the following: with Goblot, the internal medium of reasoning cannot be restrained to formal logic;

if it were so, then reason would not be creative, and therefore stability towards outside aggressiveness would be null. In order to be stable, reasoning needs a broader internal medium, which would equally include the capacity to construct, as well as any already admitted proposition considered relevant; it should also include certain procedures by means of which outside objects could be converted into internal objects. In fact, it is as if *thinking, in order to have a stable functioning, needed some kind of* **reservoir of representations, of operations, of analogies, of constructive principles, of symbolisation capacities and procedures** *that I propose to name* **imaginary**. Torn from its imaginary, which is a kind of food, of nutrient for thinking, reasoning remains accurate, but will soon lack fertility. Eventually things happen the way Poincaré said:

"... si tout devait sortir du principe d'identité, tout devrait aussi pouvoir s'y ramener".

5. The Imaginary Does Belong to the Internal Medium of Science

Is Reasoning Self-Evident?

XIII. In my opinion, this reservoir of representations obviously belongs to the definition of the internal medium of science. The argument is two-fold: firstly, in the absence of such a reservoir, the stability of the system could not be ensured (just as in thermodynamics, any modification of an extensive parameter of the reservoir leaves the conjugated intensive parameter unaltered); secondly, if we were to refer to physics, just as syllogisms are directed by reasoning, equations are brought to life and can be guided in directions which are latent in the formalism; however, such directions do not become visible, *i.e.* actual, unless one resorts to the reservoir of representations and procedures. Stability and fertility are the two criteria which could help, in principle, in determining (*a posteriori*) the autonomy domain of science, namely the expansion of its internal medium, i.e. the content of its own reservoir of representations and procedures.

Whenever science historians establish quite obvious professional affiliations, they constantly omit to explain why a specific reasoning, which seems fairly obvious in the light of formalisms, had to wait, arbitrarily, for quite a long time, before being actually assumed by someone. We know, for instance, that about 1629-30, Fermat had already devised a rule for determining the extreme values of an algebraic function. Well, we are told that "he was led to this discovery by his readings from Pappus; however, such a discovery could only have been made by a disciple of Viète"[43]; in his turn, Viète had been a

fervent reader of the Ancient mathematicians: the novelty of Viète's theory lies (among other things) in expressing approximation methods known ever since the Ancients, by the first known algorithm[44]. Something is not quite clear in this case; it is like a hidden parameter, which, in my opinion, would belong to the reservoir and which, had it only been known, could have awarded "stability" to the demonstration. In the same way, we are told that the success of the XVIIth century specialists in algebra and the progress made by infinitesimal calculus noticed in the works of the Bernoulli brothers were due to the conjunction between Diofant's analysis and procedures and the new mathematical mentality of the XVIth-XVIIth century, viz. in fact, to some small, almost unnoticeable changes brought to the work of the ancient scientist[45]. Everything would seem to be a simple and natural development of ancient texts. And yet! The Ancients were far from dull; if they *could* have made such developments, they would certainly have done it. Since they did not do it, granted the uniformity of human nature, such a fact can only be accounted for by the fairly different disposition of mathematical knowledge; such knowledge was understood in a *different* way, because the representation analogies, constructive principles, symbolisation capacities stored in the reservoir of representations and procedures have oriented the almost identical elements at hand in a *different* way from how the Ancients did. Copernicus, for instance, disposed of observation data* and mathematics** identical with those Ptolemy made use of. But then what was it that made him take such a different path? This question is by no means commonplace, for we are unable to see anything that we have not already imagined. To a great extent, we "discover" outside us only what we have already "built" inside us. In this case, as far as this cognitive metaphor is concerned, "outside" and "inside" express the limits of the internal medium: for the science of Ptolemaic astronomy, the internal medium was different from the internal medium of Copernicus' astronomical science. The difference consisted in the reservoir of representations, which was far from being identical in the two astronomies.

The Difference In Point of Cosmology

XIV. Yet another reason for expanding the internal medium can be suggested by taking into consideration the difference between what Aristotle

* Babylonian observations (Ptolemy used to say that astronomers have disposed of continuous observations ever since king Nabonassar, 747 B.C.) included by Hipparh and Ptolemy in the anthologies of Greek data were still extremely useful to Copernicus[46].

** Taking into account that he gave up equations, his mathematical technique is even closer to that of Hipparh[47].

called "movement" and what has been accepted in physics to bear this name ever since the XVIIth century. In Furetière's *Dictionnaire* (1690), movement is defined as a change of place[48], while with Aristotle movement* is the act of what is not God (in Koyré's rewording)[50]. The two definitions differ neither by clarity, nor by logic, nor even by what may be termed as physics; they only differ in point of cosmology. Aristotle's definition involves his cosmology in all its articulations. Namely, since God (viz. the motionless motor) is everywhere in his own place, no actualisation of his nature could ever "move" him; any other being, by an actualisation of its potential nature, tends to adjust its own nature to its own place; therefore it is doomed to move (if it is not already occupying its own place). This is the reason why a follower of Aristotle would consider meaningless an utterance like "a material point is displaced from A to B", which is the pattern circumstance of kinematics for us. Indeed, Aristotle's follower would wonder which is the *nature* of the "material point", since movement can be evaluated, when it is not violent, only by reference to the relation between the nature of the "material point" and its own place in Aristotle's hierarchical cosmos. On the contrary, movement as displacement in space in the simplest notion of transformations which can be imagined for a body lacking identity, reduced to its geometrical punctuality, placed in a perfectly homogeneous and void space (the Newtonian world). Of course, the scaffolding of the Newtonian world consists of the Euclidean mathematical space, so that, in this case, the immediate referent of movement is taken from a representation of the reservoir formalised long ago (by the time of Euclid, who *floruit* c.300 BC). Moreover, as far as movement in Aristotle's sense is concerned, its *physical* intelligibility is given only by translating it in terms of representations which would be accurate for Aristotle's non-homogeneous and hierarchical cosmos. Which means that, in this case, the internal medium of the theory should equally include cosmology.

Verbal Concepts Versus Mathematical Symbolisation

XV. It is fairly well-known that Scholastic thinkers drew from Aristotle's works the assertion that a body's speed, v, is directly proportional to the force moving it, F, and inversely proportional to the resistance of the medium, R. A modern thinker, Thomas Bradwardine, transcribes this relation (in *Tractatus proportionum*, 1328) as $v = F/R$ and rushes to the conclusion that v is not null even when $F < R$, which would prove, he argues, that Aristotle's assertion is

* Lalande remarks[49] that the equivalence established between Aristotle's κίνησις and movement is mistaken. The meaning we attribute now to the word "movement" is appropriate for what Aristotle called φορά, namely displacement in space (cf. *Ethica Nicomachea* X, IV, 1174^a 30).

absurd [51]. This type of reasoning, based on a transcription which has no historical justification, implicitly admits that science makes use of propositions whose meaning is autonomous from the reservoir of representations and procedures. However, Bradwardine's reasoning does not demonstrate, in fact, that Aristotle's assertion is absurd, but only that Aristotle's assertions were not constrained by a mathematical representation of their content. While Aristotle made use of *verbal* concepts, Bradwardine submitted them to *mathematical* symbolisation; it is obvious, however, that the two classes of concepts (verbal ones and mathematical ones) are moulded by different constraints. This conclusion is quite obvious in the calmness with which Galileo made two quite contradictory assertions. Such a calmness is rather puzzling to us. In the letter Galileo sent from Venice to Paolo Sarpi on October 16, 1604, he claimed, on the one hand, that in uniformly accelerated movement, speed is proportional to the space covered from the beginning of the movement, and, on the other hand, that space is proportional to squared time. But, *in terms of our sense of symbolisation of notions by means of mathematics*, the first assertion leads to a law of space which, as shown by Paul Tannery (1843-1904), is an exponential of time, and not, as Galileo claimed, a squared function of time[52]. The fact that he was not disturbed by this error (which he eliminated by an accurate calculation and an adequate geometrical construction only in 1638 when he published his masterpiece *Discorsi e Dimostrazioni Matematiche intorno à due nuove scienze, Attenenti alla Mecanica & i Movimenti Locali** seems to indicate that those consequences which, for us, are the immediate outcome of the logic of mathematical calculation do not spontaneously occur in the mind of someone whose thinking is not guided by mathematical representations [53]. In Galileo's case, it is absurd to state that he was not accustomed to mathematical thinking; but it is quite relevant for my argument that by means of a mathematical reasoning (in his 1638 book), Galileo succeeded to demonstrate the falseness of a purely verbal reasoning (in 1604).

Can We Notice What Really Is?

XVI. Galileo also seems to be the first who claimed an equivalence between free fall and uniformly accelerated movement (which had also been studied by the Mertonians). But this equivalence was also expressed, as any literary scholar could noticed, in Lucretius' *De rerum natura***, Book II,

* This title seemed vulgar to Galileo; it is due to his editor. Galileo's masterpiece has been preserved for his posterity under a title to which its author did not agree, but which he was no longer able to change.

** From 1417 onwards, the poem was accessible owing to the discovery made by Poggio Bracciolini (1380-1459).

lines 235 *sq.*, where the Latin poet postulated the necessity of the atoms' lateral declination:

> "So all things, though their weights may differ, drive
> Through unresisting void at the same rate,
> With the same speed…"[54]

The fact that this daring assertion — which was, in effect, contrary to the expectations of empirical good sense — did not draw the scholars' attention suggests that whatever we see is influenced, to a great extent, by what we have already understood about what we perceive. *Such pre-comprehensions are determined by the reservoir of representations.*

I will conclude my plea in favour of including the reservoir of representations and procedures in the definition of the internal medium — *i.e.*, of including the philosophical imaginary of science in the definition of the scientific theory — by resorting to two examples taken from modern physics.

The Different Fertility of Equivalent Formalisms

XVII. The first refers to the plurality of formalisms of analytical mechanics. As it is well-known, from a mathematical point of view, such formalisms are perfectly equivalent, which means that they yield identical predictions. However, they were different in their capacity to generate different specific theories, *i.e.*, the Hamilton-Jacobi equation lies at the origin of Schrödinger's theories, *i.e.*, the Hamilton-Jacobi equation lies at the origin of Schrödinger's equation, while Poisson's parentheses were the model for generating Heisenberg's matricial mechanics. The conclusion seems to be that, even when formalisms are considered equivalent from a mathematical point of view, they may differ, in principle, by a different capacity to generate, in a specific cognitive context, different theories, impossible to be *a priori* appreciated or specified. Another aspect of formalisms was noticed by R. Torretti, namely that the development of physics essentially depends on the combined play between mathematical theories and philosophical intuitions[55].

The Physical Significance

XVIII. The second example comes from David Bohm. He analyses the ontological presuppositions of quantum mechanics and of the theory of relativity and reaches the conclusion that, while the former presupposes discontinuity, a-causality and non-locality, the latter presupposes the contrary, viz., continuity, determinism (causality) and locality[56]. Therefore:

> "The philosophical concepts involved in these two theories have never been attuned, *although researchers are capable of finding equations by means of which to do that* [my italics]. But the physical significance has never been clarified[57].

It is quite significant that a physicist like Bohm (1917-1992), always guided by a strong ontological instinct, draws almost the same conclusions as a philosophically oriented historian of science, like Alexandre Koyré (1892-1964). Let us remember that, with Koyré, scientific thinking does not develop *in vacuo*, but within a frame of ideas, of basic principles, of axiomatic evidence[58]. This implies the fact — pointed out by Koyré in connection with Newton's theology — that a scientific theory holds or falls with the philosophical representations justifying it. The immediate outcome is that, with Koyré, scientific theories are compatible or not, depending on whether their philosophical scaffoldings (or the ontologies underlying them, according to Koyré's terminology) are compatible or not. As a consequence of such a view, the equivalence between two theories cannot be reduced to their mathematical equivalence. On the contrary, it *also* ought to imply the equivalence between the philosophical presuppositions justifying them ontologically. This is the point of view already expressed by David Bohm; according to him, it is impossible to attune by equation two conceptually different theories, except incompletely, for the meaning of such an attunement is never yielded by equations. How is it yielded then? In my opinion, it is yielded by the reservoir of representations; owing to the intelligence of the knowing subject (that cannot be formalised), this reservoir can give relevance to equations and guide them in such a way as to augment knowledge.

6. The Objects of the Imaginary

In this chapter, I shall try to suggest some of the "objects" which might be included in the reservoir of representations and procedures. Of course, such an investigation cannot be speculative and therefore it will essentially rely on the opinions on science (*i.e.*, on its internal medium) of authors that I will cite later. The motley aspect of the inventory I am going to make is, I think, unavoidable as there is no closing rule of the entities included in the reservoir; their number is an empirical question, not a theoretical one.

Weakly Articulated Objects: Grooves or Attitudes

XIX. In a lecture delivered in 1958 at Oxford University, at Trinity Term, F. Weismann also tackled the question of "conditions underlying the formation of our concepts"[59]. The philosophical aspects proper of scientific thinking are called "attitudes" by Weismann. According to him, they depend on historical circumstances, they are "a sort of inescapable grooves within which thought is bound to run" and are rendered manifest as criteria of reality, of acceptability, summarising the requirements which should be fulfilled by the principles of a theory in order to be considered satisfactory[60]. They are attitudes of the mind, and not objective truths, which means that they *are not* of a scientific nature and have the property of keeping thinking on fertile grounds. Among the "grooves" of thought through which formalism flows, Weismann counts the belief in a causal order of the world, in the comprehensibility of nature; the belief that, no matter how intricate phenomena could be, there is a simple way of accounting for them, which makes them completely comprehensible; the belief in the universal validity of mechanical explanation; the belief in the continuity of nature (*natura non fecit saltus*); and the belief in the rationality of existence. All these "grooves" of thought are subject to historical change. In this, they differ from other *channels* — in principle, of the same nature (such as invariance, equivalence, symmetry, complementarity, conservation, etc. principles) — which have somehow acquired a formal counterpart. For instance, until the time of Galileo, it was considered perfectly natural that movement (including uniform movement), in order to exist, should be the consequence of the action of a force; on the contrary, classical mechanics was based on the rather strange idea that uniform movement has no cause, which, of course, many scholars of the XVIIth century considered as an abdication from the causal comprehension of nature. The obvious problem here is an alteration of the representation concerning what is natural and what is not natural, what must have a cause and what must not. This alteration has been included in theory as the *inertia principle*, but, since the inertia principle can be neither checked nor falsified and was implicitly rejected by the general theory of relativity, it actually remains a constituent element of the reservoir of representations and procedures. Kepler's research was guided by the idea of finding a rule which could account for the succession of the planets' distance from the sun (the fourth, hypothetical, law); the reservoir of representations of Newton's natural philosophy no longer included this expectation-programme. In the same way, it is quite possible that, for a slightly altered internal medium of the theory, the criterion — which Einstein considered absolute and which stipulated a direct representation of physical reality in space and time — might prove as little universal, as little "theoretical" or "scientific" as the requirement concerning the cosmographical secret expressed by the presumed existence of Kepler's fourth law[61].

Some of the entities belonging to the reservoir of representations may be mere personal philosophical beliefs (Kepler's heliolatry, Einstein's determinism, etc.); however, it seems fairly relevant to me that they operate on formalism as coherent groups of criteria and requirements. Although each of the entities may be dealt with independently (e.g., Faraday's belonging to the Sandemanians sect), they operate grouped in a solidary structure according to certain configurations; nevertheless, the latter are not immutable. The non-subjective character of their action resides, I think, in this very solidarity.

Strongly Articulated Objects: the Cauchy Case

XX. However, whenever metaphysically articulated criteria are concerned, as in the case of those "logical and metaphysical justifications on which Leibniz founded the infinitesimal calculus" and which J.J. Baumann[62] decided to exclude from a sound exposition of the mathematical analysis*, their action can be a direct and singular one, as they are already quite well articulated. An example is furnished by the passage (of which scholars did not become aware before, say, 1850) from the continuity concept put forward by Leibniz — in the acceptance of which Cauchy kept thinking even in 1853 — to the continuity concept set forth by Weierstrass, viz., a more restrictive concept, on the basis of which Seidel "corrected" in 1847 a demonstration made by Cauchy in 1821, by introducing a lemma which instrumentalized or made effective the mathematical distinction between the two acceptances of the term "continuum". The epistemological deconstruction of this case of *méprise*, first pointed out by Abraham Robinson in *Non-Standard Analysis* (1966), was made in a splendid article by Imre Lakatos[63]. Lakatos' analysis showed that the very validity of mathematical theorems depends on the representations concerning the ontology of the discipline, which, although actually representing the underlying object of reasoning, are living a life of "cognitive instincts" rather than one of clearly (*i.e.*, formally) expressed things. The two ontological elements involved here are (i) Leibniz's notion of "real number," which also included infinitesimal numbers and infinite numbers which were not measurable, and (ii) his *principe de continuité*, which claimed that, if a variable has a property, then its limit will have that same property. These two ontological elements operated from the level of the reservoir up until the moment when they were instrumentalized as formal requirements at the level of the theory itself: Weierstrass required that mathematical analysis be expressed only by real numbers, while Bolzano made a clear-cut distinction between the rich

* Preserving only the calculus itself, which is a typical case of the XXth century manner of reducing the internal medium to strict formalism.

Leibnizian continuum and its *measurable* subset, *i.e.*, the Weierstrassean set of real numbers.

The Instrumentalization "law"

The above-mentioned instrumentalization process is fairly typical. It seems to illustrate a "law" of the relation between the reservoir of representations and procedures or imaginary and science itself (as represented by a scientific theory). In other words, any science is constantly fed by the *instrumentalized* substance of the contents of the reservoir. The "law" maintains that theory tends to invade the whole space of the internal medium until the whole reservoir is completely converted into elements of the theory. This conversion process obviously involves a tendency towards univocity, a loss of generality, a thinning of the contents of the reservoir — a phenomenon which we have just called instrumentalization. Eventually, when the reservoir is entirely converted into elements or structures of the theory (a process which cannot be *a priori* specified owing to the impossibility of having a closing rule), the reservoir disappears, the internal medium is completely covered by scientific theory, while the theory itself, in a way, "dies out," viz., ceases to expand; in W. Heisenberg's words, it becomes a *closed theory*.

The reverse process is also possible, *i.e.*, the possibility of a certain scientific theory to become, under certain circumstances, a world view, so that, as such, it will be able to enter the reservoir of representations and procedures in order to guide the elements of other theories by constraining them. Let us remember the criticism expressed by the Greeks against Aristotle because his physics did not reflect a shared common experience. Later on, during and after the Middle Ages, scholars became acquainted to such a great extent with the reality of Aristotelian physics that Galileo's kinematics was accused of not having any connection with reality, which was seen as Aristotelian in essence. Nowadays, reality based on the generalisation at the level of common sense of the idea that the surrounding world is accurately described by classical physics, made Niels Bohr consider quantum mechanics as an instrumental theory, owing to the fact that the world view it suggested was so remote from the world view yielded by classical mechanics that the former could not be actually real[64]. The conclusion seems to be that those theories which manage to reach common sense become instruments by means of which we instinctively form our view of the surrounding world. In other words, in a strong sense, the instruments by means of which we cognize the world have, in their turn, a tacit world view incorporated in their "functioning;" consequently, our world view depends on other world views, *i.e.*, on already established ones and so on.

The Closed Theory Criterion

XXI. With Heisenberg, for a scientific theory to be able to become an instrument *a priori* indispensable to any future theory, it is necessary and sufficient for that theory to be closed. The concept of a closed theory belongs to the permanent language of science, for the closed theory belongs to the unavoidable *presuppositions* of subsequent theories[65]. The features by which Heisenberg described a fulfilled closed theory[66] may serve as an indirect criterion for the stage in which the internal medium identified itself with the theory (making it become closed), *i.e.*, for the moment when the reservoir was completely instrumentalized in the form of elements on structures of the theory. These features are:

(i) internal non-contradiction;
(ii) completeness, *i.e.*, in the framework of its concepts, theory is no longer capable of any improvement;
(iii) theory contains its application field;
(iv) theory is a presupposition and a construction language for subsequent theories.

Criterion (i) applies to any formal system and translates the "reduction" of theory to the status of any logico-mathematical system. Criteria (ii) and (iii) according to the internal medium model express both the resorption of the reservoir in elements or structures of the theory, through its instrumentalization, and the quasi-complete transmutation of the reservoir into elements or frames of reality (a closed theory transforms its reservoir in theory and in reality at the same time). Finally, criterion (iv) suggests what happens to theories after they are closed.

The Fate of Theories: Factum or Forma

XXII. In my opinion, not all kinds of theories become a language for subsequent theories. Once, Pierre Thuillier made the not at all commonplace remark that, at first, the assertion that the Earth was round was not a factual statement, but a theory. Nowadays, after so many photographs taken from the outer space, this assertion is, for us, a fact. Therefore,

> "... les théories ne deviennent absolument vraies que lorsqu'elles ne sont plus des théories...",

but become facts[67]. Kuhn also remarked that, in spite of its falseness as a general theory of the world, "as far as stars are concerned, Ptolemaic astronomy is still widely used nowadays as an engineering approximation."[68] Alongside the same line, the remark can be made that geometrical optics, a perfectly closed theory, has not become, for this reason, the *language* of more powerful optical theories, although, obviously, its concepts have been integrated in other theories and its relations can be traced back as limit cases. In exchange, it is a striking case that geometrical optics has been completely "transformed" into construction techniques for industrial and laboratory optical instruments. For certain types of theories, such as geometrical optics (but also rational mechanics of the rigid solid body), criterion (iv) should be replaced with the following:

(iv)' theory becomes a fact of "everyday" experience, through its reduction to an efficient engineering set of instruments, or transforms itself into a presupposition and a construction language for subsequent theories.

It is quite important to notice that, from the standpoint of criterion (iv)', theories fall into two categories, viz., (ρ) theories which maintain a descriptive relation with experience become closed when they are transformed into *facti** and (σ) theories which establish a mediated and non-descriptive relation with experience become closed when they are transformed into a language and presupposition for subsequent theories, viz., when they become *formae*. Whatever is descriptive, immediate and mathematically weak is instrumental and leads, by closure, to *factum*. Whatever is non-descriptive, mediated and mathematically essential is structural and, by closure, leads to *forma*. Anyway, by closure, theories become instruments; but instrumental theories become factual instruments, while structural theories become theoretical instruments (generating forms). According to von Weizsäcker, analytical mechanics, classical electrodynamics, the special theory of relativity and quantum mechanics are theories which, by closure, are not transformed into facts, but, as proved by their historical evolution, have become generating forms of new conceptual structures, viz., *a priori* frames for the formation of new theories[71]. This contain a formal principle for preserving their vitality which confers on them the "dogmatic" possibility of being distributed to facts without being shared or exhausted. They seem to be real ontological objects, having a Platonic existence in the line of Gödel's realism.

The conclusion of the present discussion concerning the closure of theories is the following. On the one hand, theories are closed by the exhaustion, by the complete instrumentalization of the reservoir of representations and procedures characteristic of their internal medium. Metaphorically speaking, it is as if the whole atmosphere of vapours (*i.e.*, the reservoir) were condensed on a cold body (theory *stricto sensu*). On the other hand, a closed theory, beyond its

* Th.S.Kuhn argues that "... there are few areas in which a scientific theory, especially if it is expressed to a great extent mathematically can be directly compared to nature."[69]

existence in textbooks, is transformed into physical facts (if it was an instrument-theory) or into forms of cognition (if it was a form-theory).

The Imaginary Is Visible Only Through Theory Stricto Sensu

XXIII. In Ernest H. Hutten's opinion, physics has two salient features, *i.e.*, (1) a small number of basic concepts, and (2) an uninterrupted repetition of these concepts, in increasingly abstract forms, in the theories which follow each other (the succession of theories is never arbitrary, "the different theories are strongly connected to one another by their significance")[73]. Hutten's remark is relevant for the conceptual delimitation of what we have just called theory *stricto sensu*. Since the rule of formalism is to be manifest and directly visible and the rule of the reservoir is to be potential and operates obliquely (under the sign of *Apollo loxias*), in a disguised way, through the agency of other elements, according to the principle – already classical in the history of ideas – that "ideas are conveyed in a disguised way," any information concerning the reservoir can only be obtained through the agency of those elements which belong to theory *stricto sensu*. Consequently, a first step in outlining a theory of the reservoir of representations and procedures consists in a careful description of theories *stricto sensu*; this is what René Thom used to call the urgency of devising a morphology of physics[74]. After this morphology has been achieved (it will have to be a historical morphology), it will become obvious that the set of concepts "spontaneously" organises on two fundamental levels: a first one, which depends to the greatest extent on theory *stricto sensu*, given by the abstract aggregation structures (the "formalism" of the theory); and a second one, which defines a first border of the internal medium (although, in my opinion, the internal medium is not limited to this level), called by Imre Lakatos "research programme," and by Larry Laudan "research traditions."* At this second level, the abstract structures of theory can develop, together with the elements of the theory, "free" combinatory plays, enriching the theory as a conceptual and operant substance. In what follows, while referring to an extremely familiar research tradition (viz., the mechanistic approach to the world), I would like to show in what sense an authentic research tradition is not reducible to, say, Lakatos' description of the "research programme"[75], but belongs, in effect, to the field we have called the reservoir of

* It is by no means crucial whether we decide to use one term or another. According to the spirit of language, it is more natural to call the content of Querie XXXI from *Opticks* (1717) a *research programme* (just like R. Boscovici's "cosmology"), and to call *research tradition* the mechanistic way of comprehending reality.

representations and procedures (*i.e.*, actually, the philosophical imaginary of the discipline under discussion).

The Mechanistic World View

XXIV. Lakatos' idea was that the evaluation unit of a theory should not be considered in isolation, but rather as a "research programme," containing a "hard core" (conventionally chosen), endowed with a "positive heuristic," able to define the problems of interest, to build a protection belt of the hard core by means of a (replaceable) system of auxiliary hypotheses, capable of foreseeing anomalies and to convert them into relevant examples[76]. Let us see now what could a mechanistic research programme mean. First of all, the meanings inventoried by Dijksterhuis for the mechanistic approach are of a confusing variety,[77] viz., the world is a machinery (rather than an animate body); all explanation should be provided in terms of action by contact or in terms of mechanical models; everything should be eventually accounted for in terms of atoms and of the progress of central forces; mechanics is the basic science; broadly speaking, all scientific cognition should be mathematical, verified by experiment[78]. For our purpose, it is enough to admit that mechanism represents the world as a collection of solid particles moving in space and time and that these particles are set in motion by forces which depend on the distance between them. It is also natural* to admit that the explanatory ideal is to reduce everything either to the movements of the particles or to the stable mechanical movements describing their aggregation. Depending on the way in which this phrasing of mechanism, applied to a given physical circumstance, will generate the protection belt of auxiliary hypotheses, the scheme of "research programme" put forward by Lakatos will be rendered more or less well, but anyway reasonably.

However, if the mechanistic approach of the world were reduced to *mechanical approach*, Lakatos' scheme would amply suffice. But in effect, the "mechanical method" made use of in physics represents only the "precipitate," the "achievement," the instrumentalized "condensed" result of a universal attitude of the mind (I call it universal because it can be attested by specific reasonings in any cultural area, any time).

(α) The Atomism Case

XXV. Let as take an example. Atomism seems to be closely connected to the mechanical method and, in fact, so it is. Why? Because the mechanical

* From a mechanistic point of view.

method claims to understand an object by dividing it into ever smaller units, until they loose their individuality, remaining as mere homogeneous and equal "points"; the object will be reconstructed by imagining those aggregation forces between the "points" thus obtained, in compliance with the criterion of Occam's razor, so that the reconstructed object can be considered the mechanical "draught" of the real one. Thus, according to this description, "we presuppose, almost unconsciously, that everything consists of small construction elements similar to atoms"[79]. To what extent can this intrinsic "atomism" of physical reasoning coexist with a radical philosophical rejection of atomism is obvious in an almost tragic way in the work of Pierre Duhem.

But the roots of mechanical "atomisation" are even deeper. Newton, for instance, included mechanism among hypotheses[80]. But mechanism, such as used by Newton on several occasions in his reasonings, is implicitly codified by him in the four Rules which he considers indispensable to a natural philosophy based on mathematical principles[81]. Except for the first Rule, which is Occam's razor, and of the last one, concerning the criterion of validity of hypotheses in relation to the propositions inductively deduced from phenomena, Rules II and III express the conditions of mechanism and, at the same time, of mathematization which, not at all strangely, are interrelated. Let us look more deeply into this relationship.

(β) The Postulates of Arithmetic

XXVI. In order to see clearly in what sense the conditions of existence of mechanism are related to the criteria which make the mathematization of reality possible, a brief survey of the notion of physical quantity is necessary. The possibility of mathematizing physics is advocated by Duhem by the remark that the postulates of arithmetic also define the most general concept of quantity[82]:

(a) there are quantities which are bigger or smaller than others; corollary: given two unequal quantities, a third one can be always found, which, added to the smaller one, would equal the bigger one;

(b) the order of adding quantities is indifferent;

(c) any quantity can be conceived as a sum of other quantities; in other words, the sum of some quantities defines another quantity, the number of quantities involved in the sum being indifferent.

It is fairly relevant that the postulates of arithmetic enjoy an immediate and natural mechanistic interpretation through the postulates of quantity. Postulate (c) can be understood as a postulate of superposition or linearity (indeed, big numbers do not change "quality"); on the other hand, summings are independent from each other, viz., they do not influence each other. With Newton, this has already become a physical principle: it is the principle of independence of the action of forces. Postulate (b) implies the lack of "qualitative" identity of a quantity. Which means, in fact, that a unit quantity can be defined so that any quantity can be expressed by paratactic summings of those units (in an adequate number). In arithmetic, any big number consists of small numbers, *i.e.*, the units making up the number should have the same nature as the number itself. This is, clearly, the atomistic postulate, since it admits that any entity can be decomposed in uniform, irreducible and identical atomistic units.

(γ) Newton's Rules for the Physical Reasoning

XVII. But let us go back now to Newton's philosophising Rules; Rule II, which asserts that the identical creates only the identical (the principle of the uniformity of nature) is solidary with the arithmetical principle stipulating that the sum of any numbers is also a number. Rule III contains several assertions, the most interesting of which are:

(i) the properties of the whole are also those of every part in which it can be divided;

(ii) taken out of their context, the parts into which the body is divided are perfectly separable and independent;

(iii) any divisible body is infinitely divisible; the sum of divisions yields the whole [since, according to (i), properties are preserved by summing, then (iii) implicitly asserts that effects are linear in relation to superposition; this is the principle of superposition].

Consequently, Rule III contains the atomistic postulate [cf. (b)], by (i) and (ii), but also the principle of superposition [cf. (c)], by (iii). The conclusion that can be drawn is the following: **a discipline, in order to be mathematized, should define its objects in compliance with the postulates of quantity**. But the latter also belong to arithmetic, which, therefore, implies the atomistic principle and the superposition principle. Consequently, according to Newton (and Duhem), the possibility of mathematizing a discipline depends on the condition that *the discipline's ontology admits postulates solidary with the postulates of existence of arithmetic; in their turn, the latter are naturally solidary with the principles of the mechanistic method of apprehending the world*. In order to be mathematized, the reality must be mechanistic.

(δ) Mathematical Analysis and the Mechanistic Idea

XVIII. This conclusion is very much in agreement with the ideas expressed by René Thom concerning the reasons of the success of mathematical prediction in physics. The remarkable symmetry between explanation and prediction, claims Thom, cannot be a universal ideal of sciences, for it only applies to those disciplines whose objects are liable to description in a space of analytical structure (*i.e.*, are, in effect, describable in terms of analytical space) for which processes can be formulated in terms of analytical functions. That is why "our possibilities of quantitative prediction are severely limited to domains which are close to physics and mechanics"[83]. After all, if mechanics is a branch of physics, the mechanistic principle, understood as a mathematical approach of nature starting from a representation of the object analysable in homogeneous, uniform and independent constituent parts[84] (which, as shown above, means *exactly* mathematizable, in general), is nothing else but physics mathematizable by mathematical analysis. As long as the object, "atomised" according to the procedures of Rule III (that is, implicitly, to the postulates of quantity and mechanism), is equivalent to a structure of points in the analytical space, its interactions with other objects of the same structure can be expressed as relations of the differential equations type[85]. In fact, **the differential and integral calculus expresses the mechanistic idea in its most general form**. Reciprocally, what we call the mechanistic world view is nothing but the unavoidable world of our analytical reasonings. The opposite would be a holistic thinking (*i.e.*, a non-mechanistic one). This accounts for the fact that, when Bohm outlined a mathematics of adequate transformations of the implicit order, he resorted to algebra and to matrix algebra [86], giving up the description of processes by differential equations (be they ordinary ones or with partial derivatives) and, implicitly, their decomposition in parts solidary with the points of analytical space. In his turn, Hermann Cohen believed that active thinking in infinitesimal calculus is not a mere organising of pre-established data, but consists in the production of certain typical objects, co-substantial to its nature, viz., movement, acceleration and, in a broad sense, the laws of nature. In Cohen's conception, the infinitesimal calculus is not an artifice of calculation, but a true unit, previous to quantity and number[87].

All this long (but nevertheless rather hasty) discussion was meant to suggest that mechanism is not only a research programme in the acceptation of Lakatos; it is so only in a very instrumental sense. Taken in a proper sense, the mechanistic world view is a constant attitude of the mind, deeply solidary, for instance, with the type of mathematics by means of which we describe the objects susceptible to being approached according to the mechanical model. Consequently, mechanism is not a "philosophy", it is something at the same time *cosmological* (for its "objects" make up a complete cosmos, although, as compared to the Stoics' astrobiological cosmos[88], the former has a poor ontology), *mathematical* (for mathematical analysis is a "mechanics" of the behaviour of the points, on the real or complex axis, associated to the points of the analytical space) and *physical* (for it is capable of connecting by valid predictions the real world and the mechanically valid objects). In such a case, what would be the meaning of the notion of reservoir of representations and procedures? Something rather strange, indeed. From the standpoint of the internal medium, I can only provide the commonplace assertion that any crucial theory of physics is placed under the sign of a *overall orientation of the mind*. In other words, physical thinking is an aspect of a thinking which is not self-centred, but shares with other directions of the mind the same dominant line of thought. Still more relevant is the conclusion which can be drawn concerning the reservoir's functioning. When a "research programme," *i.e.*, an overall orientation of the mind is concerned, the way in which objects are generated on the theoretical level has the following noteworthy features: the mathematical object is generated simultaneously with the "physical" (mechanical) object and, in effect, non-separable from it. In fact, the principles of natural philosophy are mathematical because natural philosophy has acquired a mechanistic acceptation and because, simultaneous and non-separable, whatever is mechanistic is also analysable in the sense of mathematical analysis.

7. The Imaginary Census Paper

How Do Themata or Ideals Operate?

XXIX. The end of the previous section showed the way in which a widely comprehensive research tradition operates, *i.e.*, by activating an *overall orientation of the mind*. At the level of the reservoir of representations and procedures, this activation generates a dramatic modification, viz., from a repertoire, the reservoir becomes a generator. It functions "upwards" on the *genesis* of the ontology of the theory. As far as the mechanistic "programme" is concerned, our analysis suggested that any element of reality of the theory is generated simultaneously with, and non-separable from, a corresponding mathematical act; the objects of the mechanical world are mathematical objects and, at least as far as mathematical analysis is concerned, the reciprocal assertion is equally true.

Let us try to see how the reservoir operates when its behaviour is similar to that of a repertoire, namely when its constituent elements can be considered relatively independent, for they do not operate as elements integrated in an *overall direction of the mind*. I have already mentioned to a few such general

"philosophical attitudes," suggested by F. Weismann (paragraph VII). A general theory and an inventory of the (in principle, independent) elements belonging to the reservoir of representations and procedures were supplied by Gerald Holton in two celebrated books, *Thematic Origins of Scientific Thoughts* (1973) and *The Scientific Imagination. Case Studies* (1978).

Holton's idea is the following: there are certain general ideas or representations, certain thematic motifs, which obviously direct scientific activity; therefore, it is quite natural that exact science should no longer be considered to have only two essential sides (called by Holton the **x-y** plane – the analytical element –, but also a third one, viz., the thematic side – the vertical axis, **z**). "Normal" science develops only in the factual-analytical plane; geniuses, however (*i.e.*, revolutionary science or science *in statu nascendi*), insistently refer to axis **z**, too[89]. First of all, the population of the thematic axis was called by Holton *themata* (in the plural), by which he understands certain "persistent motifs," recurrent, atemporal themes (with Weismann, "attitudes" were not independent from historical circumstances), which are stable, common to the whole culture (sciences and humanities make use of the same *themata*), coming

"... from the less specialised ground of our general imaginative capacity."[90]

Therefore, *themata* come from the most general, the less specialised background of human imagination and are

"fundamental presuppositions, notions, terms, methodological judgements."

We could say they are some sort of fields, sufficiently inarticulate in order not to generate notions, but articulate enough to direct already existent notions and to precipitate meanings when the tension of certain *themata* requires it. The factual-analytical plane operates within the horizon of these *themata*. In Kant's terminology, ideas are constitutive to science while ideals are regulative, since they cannot be given any real object in experience, and they are only meant to direct aims. Although there is no indication in this respect in Holton's works, *themata* can be probably understood in a regulative sense as ideals directing the factual-analytical activity[91]. *Themata* are in a reduced number and occur only seldom, but, as Holton insists,

"the **z** dimension is never absent even in the most exact of the sciences"[92],

which suggests that they can be neither proved, nor rejected. As a rule, Holton expressed his *themata* as antinomic pairs: evolution/devolution; plenum/vacuum; hierarchy/unity; reductionism/holism; symmetry/asymmetry. Each *thema* operates upon concrete research as a field of regulative forces: it directs reasonings, orders experience, selects priorities depending on a better illustration of its ideal presence.

The Equivocation Example

XXX. Let us take an example: in Aristotelian and Scholastic tradition, the transplantation of methods and models from one area of cognition to another is an ontologically justified methodological interdiction. Ontologically, this tradition goes back to the idea of a hierarchical and naturally non-homogeneous cosmos with natural places, sublunary world, untouchable stars, progressive orbs, etc. Methodologically, this transplantation of methods amounted a false attribution of a category, explicitly prohibited by Aristotel and many scholastics[93]. From a social point of view, this partitioning perfectly corresponds to the ideal of social orders (aristocracy, clergy, etc.). In the field of education, the interdiction of trespassing the category led to the division of the curricula according to distinct teaching disciplines. Thomas Aquinas, for instance, considered that the same attribute predicated about God and his creation did not convey the same meaning, although obviously, there was a certain analogy between meanings. This essential relation, resulting from the rule forbidding category trespassing was called "equivocation" in his writings. On the contrary, Duns Scotus claimed that certain attributes of God (*e.g.*, existence and will) had *exactly* the same meaning when predicated about man and about God. Duns Scotus was in favour of the univocity of language, which he tried to impose on all sciences. The theology of equivocation — based on *analogia entis* — once eliminated, the Nominalist XIVth century caused a great breach by putting forward — in the name of univocity — the ideal of a system of the whole cognition based on a unique method. But, according to the regulative field of this ideal, the imposing of the idea of universal method should have triggered the erosion of the notion of hierarchical and non-homogeneous cosmos, which, in the XVIIth century was indeed replaced by the uniform, void and homogeneous universe of Galileo-Newtonian physics. Of course, it was only natural that philosophers in favour of the idea of oneness of method set forth in the XVIIth century should all believe that "God shared with his creation some genuine predicates literally and unequivocally", which is a legacy of the Nominalist approach[94]. Still more relevant is the fact that the idea of the existence of a universal method, to which had led, as already shown, the rejection by Duns Scotus of Aquinas' equivocation, engendered a remarkable intellectual fever in the XVIth and XVIIth centuries. For instance, in the XVIIth century, the idea was guilelessly supported[95] that Greek mathematicians possessed a method of analysis by which they obtained rather "automatically"

their theorems and demonstrations. It was still this wrongly channelled fever, nevertheless accurately oriented (towards founding a universal method of sciences, irrespective of their specific object of study), which resulted in the idea of algorithm, illustrated by Viète, and eventually in the idea of mathematical analysis. This way, the idea of the method as instrument of discovery became prominent, and the birth of algebra was challenged to take place[96].

The God's Ubiquity Example

XXXI. Still as a voluntary ideal (in the sense of A. Funkenstein) functioned the notions of omnipresence and omnipotence of God. Marin Mersenne (1588-1648) rejected the idea of natural places in the world by arguing that, since the world is a free creation of God, there is no natural place, but only a place of God's free will[97]. The Newtonian notion of absolute space as *sensorium Dei* is solidary with the arguments in favour of God's spatial ubiquity, supported in Platonicist circles at Cambridge[98]. Examples could be multiplied.

The conclusion of the present section is the following: Whenever general philosophical attitudes operate in a relatively independent way, they influence the factual-analytical plane as a field of regulative forces. They are, in Funkenstein's sense, *ideals* operating on every argument or procedure. Therefore, the task of the historian of science consists in identifying the part of the ideal from that of each of the arguments which edify or structure a theory. Unfortunately, although well articulated at the level of discourse, when incorporated in arguments, ideals are vague and, practically, imperceptible[99]. This accounts for the fact that the presence of ideals (which actually translates the existence of the reservoir of representations and procedures, *i.e.*, of the philosophical imaginary), even when it is recognised, arouses increasingly vague characterisations. B. d'Espagnat, for instance, claimed that theoretical physics is supported by three pillars, *i.e.,* experiment, mathematics and "a set of general ideas on the basis of which work can be done"[100], whereas George Cantor claimed that "without a small metaphysical grain, it is not possible to found an exact science"[101]. These remarks are no doubt true. They are accurately commented upon by J.W. Dauben, when speaking of the religious dimension of Cantor's mathematics:

"The religious dimension Cantor attributes to the *transfinite* should not be rejected as a mere aberration. (...) The theological aspect of the set theory elaborated by Cantor, — although not pertinent for grasping its mathematical content, is obviously essential for the full comprehension of his theory and for the developments he chose to give it."[102]

Now it is time to sum up the modalities of action of the reservoir of representations and procedures (the philosophical imaginary) on the theory *stricto sensu* (the factual-analytical plane).

8. A Summarising Survey of the Operation of the Imaginary

The Classical Relationship Revisited

XXXII. The present paper began by pointing out the different treatment enjoyed by the distinction between science *in statu nascendi* and mature science, in relation with the traditionally accepted continuity between philosophy and religion. Most historians have adopted the cautious point of view according to which only science *in statu nascendi* enjoys a real continuity between science and religion. It is only to science *in statu nascendi* that it is legitimate to apply the classical image of the philosophical tree put forward by Descartes in a famous letter to Picot:

> "Ainsi toute la philosophie est comme un arbre, dont les racines sont la Métaphysique, le tronc est la Physique, et les branches qui sortent de ce tronc sont toutes les autres sciences..."

The most relevant argument brought by the historians of the genesis of science in favour of the legitimate character of this image was the idea that when they appeared "the sciences existed in relation to the enterprise of natural theology"[103]. Consequently, the natural internal medium of the genesis of science was extended to what is called, more accurately, "secular theology"[104]. Anneliese Maier, for instance, was in favour of an argument of continuity (though, of course, also reduced to *statu nascendi*) in a strong sense. According to her, the transition from the Scholastic theory of forms and qualities to the mechanistic world view is by no means a result of the pressure of the new experimental observations; according to her, this process was primarily achieved in ontology.

> "... speculative remarks, philosophical theories were prevalent. They yielded, to a great extent, the impulse towards an experimental and calculating approach; the results of these disciplines had a backward, fertilising, confirming or correcting action on philosophical reflection."[105]

As far as I am concerned, the position I claim in this essay is not a cautious one; it tends to award a strong meaning to Alexandre Koyré's assertion, according to which scientific thinking has never been really separated from philosophical thinking because scientific thinking does not develop *in vacuo*.

The immediate question is: *where* does it develop? Koyré thought that scientific thinking developed within a frame of ideas, of basic principles, of axiomatic evidence, which all belong to philosophical thinking. In effect, they belong to human thinking *tout court*. I will not reproduce Koyré's argument directed against the scaffolding theory (E.A. Burtt), but it might be appropriate to remind that astrology, which, as a science, enjoyed a tremendous development during the Renaissance, disappeared as if by enchantment in the XVIIth century, not because any catastrophic factual invalidation, but because its astrological cosmos (with which its world representation was solidary) collapsed once for all, irrespective of astrology's efficiency as a science[106]. In the same way, alchemy, another great loosing science of the XVIIth century, in spite of its having been widely practised by many a mechanist (Newton, Boyle, etc.), suddenly began to decline owing to the same "extraneous" set of circumstances; its central thesis, *i.e.,* transmutation, was well supported by the peripatetic doctrines of qualitative transformation; however, in spite of Boyle's efforts, the rewording of transmutation in terms of mechanics (as was also the case of the Eucharist mystery, as a matter of fact) failed[107]; it should be understood that all this happened *completely independently of its virtues or failures*. The internal medium which conferred a meaning to both astrology and alchemy triggered by its collapse the inevitable collapse of the specialised theories that it made use of for legitimating representations and procedures. So that, in the light of these examples, Koyré's thesis seems perfectly valid.

Passing now to what is called "mature science," *i.e.*, science "autonomous" from the philosophical content, new light should be shed on a fact we have got used to neglecting, namely, that the laws of our sciences are quite simple and obvious; they are natural results of "natural lights" only if they are framed in a certain system of presuppositions which, when we are thinking, or when we walk along the street, make us feel we are moving in the *same* universe, a familiar universe both "inside" and "outside". It should be added that this familiarity key is a direct consequence of the unification of the two mental spaces (outside/inside) by a same, unique, comprehensive internal medium. On the other hand, the internal medium, which fixes the meaning of the notions of space, time, movement, etc., and owing to which the world in which we move and think appears to us so obvious, so natural, so at hand, is not a result of the methodical observation of natural phenomena and therefore does not have a scientific nature.

Consequently, according to this line of argumentation, I think that the internal medium theory makes useless the rigid distinction between science *in statu nascendi* and the so-called mature science, viewed as free from extra-scientific presuppositions. Of course, the reservoir of representations and procedures is by no means universal, neither is it an invariant of its discipline. It is equally true that it is very different, from the point of view of its effect on theory, to have the regulative metaphors of natural/secular theology as a reservoir or to have as norms those constraints — which have become almost constitutive ones — of several abstract ontological principles, which, from the point of view of the ontological imaginary involved, are rather poor*. But, as far as the principle is concerned, it is quite the same thing: any theory develops within frames of thought which are transcendental to it. In other words, formal thinking can only be stirred to activity by something which cannot be formalised yet (otherwise it would not stir thinking to activity).

Theories and Imaginary

XXXIII. Moreover, according to the internal medium theory, any science is fed by two procedures: a **formal** one, directing the elements or structures of the theory towards the reservoir of representations and procedures; and a **sub-**

* In the case of Einstein's general relativity, the reasonings involving constitutive constraints
of an ontological nature could be rendered as follows:
Only by means of Newton's gravitation law, so he argues, it is impossible to obtain a coher-
ent representation of the universe as a whole. A concordance with the best established *observation*
facts cannot be obtained unless a supplementary term is added to Poisson's equation relating the
gravitational potential with the density of matter; an equation with partial derivatives, therefore a
local and deterministic one, which, in order to be applied to the universe as a whole, should be
endowed with specific limit conditions. Which ones? For a finite system, the field should vanish
at infinite. But, from Poisson's equation, it results that, at the infinite, the density of matter should
be null; therefore the Newtonian universe is actually finite in an infinite space. Which is not con-
venient. The question arises: what prevents the dispersion of matter? This can be prevented if, at
the borders of the system the gravitational potential is very big; this hypothesis is, however,
incompatible with the well-established observation according to which the observed stars speed
are small as compared to the light speed. Consequently, the only solution within Newtonian
mechanics consists in introducing in Poisson's equation a term proportional with the potential
(which represents an ontological leap!). In this case, the system has no longer a centre, is in equi-
librium, and its mass is uniformly distributed to the infinite.

Einstein tries to understand this supplementary term starting from the idea that it is possible
to consider the world as a closed continuum as far as its spatial dimensions are concerned. This
construction, with clear ontological results, was essentially yielded by Einstein's decision to avoid
the limit conditions, owing to the insuperable difficulties to which they led.

This aspect of *Kosmologische Betrachtungen zur allgemeine Relativitätstheorie* (1917) is
commented upon by Jacques Merleau-Ponty as follows: Einstein

> "*a priori* established that space is closed; he wonders in what circumstances such a hypothe-
> sis is compatible with the equations of the field and eventually discovers that this compatibil-
> ity can be ensured by introducing a supplementary term in these equations in a formally anal-
> ogous way to that in which, the term, when introduced in Poisson's equation, frees Newton-
> ian cosmology of its contradictions"[108].

stantial one, instrumentalizing certain entities of the reservoir, which afterwards "fall" into the theory and acquire a theoretical status.

The former procedure can be reasonably described by the metaphor of the regulative field of forces, viz., the population of the reservoir does not "touch" the population of the theory but directs it in the way in which the magnetic field, for instance, directs iron scraps. I call it "regulative" because, in this acceptation the reservoir element which "moulds" theory is an ideal in the Kantian sense of the word: there is no given object neither in theory nor in experience that corresponds to it.

The latter procedure will be called, from now on, *realisatio* because it consists in transforming a — so far — ideal element into an element of reality of the theory: it is *achieved* by instrumentalization of regulative principles into constitutive ones.

In the case of the *formal* relation between the reservoir and the theory, we have already distinguished between the circumstance in which the elements of the reservoir are ideal ones (*themata*, attitudes, etc.), practically independent from each other, and the circumstance in which they are virtually integrated in an overall orientation of the mind (in which case they do not act independently, but in an integrated way, like a *cipher* in Karl Jaspers' sense). While dealing with independent ideas, the factual-analytical plane of the theory is directed either

(a) *punctually*, when the ideals are well articulated (as happens with ideals described in Amos Funkenstein's analyses), or

(b) *globally*, when the ideals are weakly articulated (e.g., religious beliefs lacking a dogmatic rigidity).

In case (a) ideals punctually assist each and every reasoning and argument, so that, in principle up to the limit of separability, the historian's task is to separate the "ideal" from the "theory" in the case of each and every scientific argument. In case (b) the weakly articulated ideals tend to aggregate in clusters which, by this subarticulation solidarity, create eidola of world views which claim to represent overall orientations of the mind. If punctual assistance seems to be better described by the metaphor of the regulative field of forces, the clusters' action seems to me better suggested by Weismann's metaphor, according to which "attitudes" are like "grooves" through which factual-analytical thinking can be "directed" to flow into creative reasoning. Stress should be laid on the fact that the reservoir actions by *themata* (or ideals), and by clusters of weakly articulated attitudes are separate ones. Ideals never get in "touch" with "directed" objects. In fact, these analogical procedures of directing something which is separate and pre-existing bear a striking resemblance, if they are followed step by step, with the procedures of magic, as described by Hubert and Mauss.[109] According to these authors, magic is a completely rational social code, based on three principles, *i.e.,*

- the metonymic principle (*pars pro toto*);
- the homeopathic principle (*similia similibus*);
- the heteropathic principle (*similia contraribus*).

Well, in many cases, arguments can be propound (which I shall do on another occasion) that ideals direct factual-analytical reasonings according to similar principles. Certainly, this does not happen always.

Last but not least, the reservoir of representations and procedures can be over-articulated according to one of the prominent overall orientations of the mind, in which case, besides the already natural orientation action through preferential flowing channels (an action achieved by the clusters of under-articulated attitudes), a new type of action occurs which is extremely spectacular and has proved to be most fertile on the cognitive level. Unlike the ideals' regulative action, based on separation and pre-eminence, the action of the overall orientations of the mind is a generative one and, according to the elements involved in generation, a non-separable one. As it is probably easy to understand, the generation is not of a historical nature; it is an ontological generation, *i.e.,* the objects of theory are generated at the same time as their description procedures, within theory.

As I see it, two fundamentally different types of generation are possible. The former is the generation of similars (in relation to the generator), distinct and independent from each other, according to the model described by Lucian Blaga in *The Divine Differentials* (1940). Mainly as regards the interesting relationship between the Jewish-Christian theological-dogmatic heritage and modern science, Blaga put forward the theory of dogmatic generators, according to which some structures of Jewish-Christian dogmatic thinking — taken over as such, *methodologically*, by abandonment of the divine content[110] — have provided quite fertile conceptual frames for science, thus trespassing the classical interdiction of the School, which was against the secularisation of theology, viz., "do not apply the sacred to the profane"[111]. Yet another remark should be made, namely that the generation of independent similars seems to be submitted to the rule of multiplication by fractal ramification, because it involves an infinite ramification done by a rule of internal homothety[112].

The latter generation type refers not to the generation of differential similars, but to the production of identicals connected to each other by morpho-dynamical transformation rules, such as those suggested by D'Arcy Wentworth Thompson in his book *On Growth and Form* (1917) (second edition,

much augmented, 1942)[113]. With D'Arcy Thompson, any two forms which can be connected point by point by continuos transformations are morphologically identical. For instance, the skulls of most mammals, including man, can be derived from each other by mathematical deformations (like, for example, the pteropod's conical shell can be reduced to a logarithmic spiral by a simple mathematical operation). Which means that, according to the generation rules, they are all identical. This type of generation was illustrated with an exuberant argumentation sagacity by Ioan P. Couliano in his morpho-dynamical analysis of the continuity links between Christianity and various gnosticisms[114]. In his last articles, the scholar extended these conclusions to the whole cultural sphere while suggesting that religion, philosophy and science do not build their specific ideal objects differently, since they are, in D'Arcy Wentworth Thompson's terms, somewhat like the ox's and the sheep's metacarpi, transformable into each other. As far as their generating mechanism is concerned, religion, philosophy and science are non-separable[115].

It is certainly useful to add the following remark. The action of the independent ideals is subject to exhaustion; this can happen *formally,* by the historical loss of faith in the absolute veracity of the ideal, or *substantially*, by the instrumentalization process that we defined as *realisatio*. The following two solidary "laws" are applied to independent ideals:

⇒ Any theory tends to become a closed theory, in other words, tends to exhaust its reservoir of representations and procedures (its imaginary);

⇒ Any reservoir of representations and procedures (*i.e.,* imaginary) pertaining to a theory tends to be wholly *achieved* through it (*realisatio*).

It is worth adding three brief remarks. By closure, any theory is transformed either in objects of the physical world or in *forms* of cognition of a great heuristic power.

Eventually, the faculties by which we apprehend the world are actually residues of closed theories which by a complete *realisatio* have entirely passed in our flesh.

Our perceptions are theory-laden because our senses are, in effect, instrumentalized theories which are irreversibly interiorized.

On the contrary, the action of the prominent overall orientations of the mind (*i.e.,* of over-articulated ideals) is inexhaustible: in principle, the non-separable generation action is not limited. The rule which may seem to express best this way of functioning of the spirit is that it is distributed, without being divided*.

* The phrasing belongs to Constantin Noica: "The being is rendered manifest — openly and not cryptically — everywhere in what is distributed without being divided" (*Devenirea întru ființă*, vol. II: *Tratat de ontologie*, 39, București: Editura științifică și enciclopedică, p. 390).

It is, properly speaking, a regimen of the overall orientation of the mind in which the primary substance continuously generates "secondary" existences; in this process, however, the primary substance does not diminish. According to Philon of Alexandria, this was the defining feature of the original substance understood in a *dogmatic* way[116].

The fact that this conclusion has reached an inexhaustible dogmatic notion seems to suggest that the methodological solipsism is the most obvious expression of the actual functioning of the theory of the internal medium.

9. Notes

1. George MacDonald Ross, "Science and Philosophy", *in*: R.C. Olby, G.N. Cantor, J.R.R. Christie and M.J.S. Hodge (eds.). *Companion to the History of Modern Science*, London, New York: Routledge, 1988, Chap. 52, pp. 799-815.

2. *Idem, loc.cit.*, pp. 801-2.

3. *Ibid.*, pp. 805-6.

4. *Ibid.*, p. 804.

5. *Ibid.*, p. 808.

6. Willard Van Orman Quine, "Două dogme ale empirismului" (1951), reproduced in its Romanian version in: Ilie Pârvu (ed.) *Epistemologie. Orientări contemporane* ("Materialismul dialectic şi ştiinţele moderne", vol. XV), Bucureşti: Ed. Politică, 1974, pp. 33-60.

7. *Ibid.*, p. 58; but also G. MacDonald Ross, *loc.cit.*, paragraph 3 *ad finem*.

8. Helge Kragh, *An Introduction to the Historiography of Science*, Cambridge, London, New York, etc.: Cambridge University Press, 1987, Chap. 1: "Aspects of the development of the history of science".

9. An extremely significant example is provided by French chemistry. In his article "Chimie", published in 1792 in the 3rd volume of a *Dictionnaire de chimie de l'Éncyclopédie Méthodique* (T. I: 1786, ..., T. III: 1792), Fourcroy distinguishes chemistry from other sciences only owing to its history. This style will be predominant in France in the XIXth century too, as it is obvious if we compare the number of pages devoted in the big treatises of the time to the history of the discipline, on the one hand, and to the theoretical aspects proper, on the other hand.

10. "The history of science is science itself" (J.W. Goethe, *Zur Farbenlehre*, 1810) (quoted from memory).

11. Pierre Duhem illustrated this point of view in a poignant way by trying to make use of the equation "the history of the discipline = the nature of the discipline" as a constraining element in the assessment of the evolution of physics (since theory must tend towards a natural classification, and since thermodynamics, just like Aristotle's hierarchical universe, is a theory of natural places, theoretical physics consequently should be unified by, and in the terms of, analytical thermodynamics). *Inter alia, Notice sur les Titres et Travaux Scientifiques*, Bordeaux, Imprimeries Gounouilhou, 1913, pp. 108-25.

12. G.W. Leibniz, *Matematische Schriften*, Berlin, 1849-1863, Bd. 5, p. 392 (*apud* H. Kragh, (*n8*), p. 5).

13. W. Whewell, *History of the Inductive Sciences*, London: Cass, vol. 1, 1967, p. 42.

14. See Émile Bréhier, *Histoire de la philosophie*[5], t. III, Paris: Quadrige/PUF, 1986, p. 508

15. *Ibid.*, pp. 968-9.

16. *Ibid.*, p. 972.

17. *Cf.* Françoise Monier, "Ainsi parlaient les premiers hommes", in: *L'Express International*, No. 2093, 22 août 1991, pp. 32-35.

18. Peter Galison, "Re-Reading the Past from the End of Physics", in: L. Graham, W. Lepenies, P. Weingart (eds.), *Functions and uses of disciplinary histories*, Dordrecht; Boston; Lancaster: D. Reidel Publishing Company, 1983, pp. 39 *sq.*

19. H. Reichenbach, *Philosophie der Raum-Zeit-Lehre*, Berlin: W. de Gruyter, 1928, p. 121, *apud* Ilie Pârvu, *Teoria ştiinţifică*, Bucureşti: Ed. Ştiinţifică şi Enciclopedică, p. 15.

20. R. Carnap, *Philosophical Foundations of Physics*, New York: Basic Books, 1966 (*apud* Ilie Pârvu, (*n19*), p. 16).

21. Karl R.Popper, *Logica cercetării*, Bucureşti: Ed. Ştiinţifică şi Enciclopedică, 1981, p. 76.

22. Mircea Flonta, *Perspectivă filosofică şi raţiune ştiinţifică*, Bucureşti: Ed. Ştiinţifică şi Enciclopedică, 1985, p. 34.

23. For a survey of how this distinction is placed in more recent thinking, see Thomas Nickles, "Discovery", in R.C. Olby *et al.* (eds.), (*n1*), chapter 11, pp. 148-165. An epistemological analysis of Reichenbach's distinction, in Stephen Amsterdamsky, "Contextul justificării şi contextul descoperirii" (1971), reproduced in: Ilie Pârvu, (anthology), *Istoria ştiinţei şi reconstrucţia conceptuală*, Bucureşti, Ed. Ştiinţifică şi Enciclopedică, 1981, pp. 328-49.

24. Th.S.Kuhn, *Structura revoluţiilor ştiinţifice*, Bucureşti: Ed. Ştiinţifică şi Enciclopedică, 1976, ch.II: "Calea spre ştiinţa normală", pp. 53-56 *passim*.

25. Werner Heisenberg, *Paşi peste graniţe*, Bucureşti: Editura Politică, 1977, p. 305.

26. Pierre Duhem, "Quelques réflexions au sujet des théories physiques", *Revue des questions scientifiques* 31 (janvier 1892), par. 7. The text is reproduced in Pierre Duhem, *Prémices philosophiques*, Leiden; New York; København; Köln: E.J. Brill, 1987, pp. 24-7.

27. Pierre Duhem, *La théorie physique. Son objet — sa structure*, Paris: Librairie Philosophique J. Vrin, 1989, pp. 32 *sq.*

28. Pierre Duhem, *Physique de croyant* (1905), paragraph IX: "De l'analogie entre la théorie physique et la Cosmologie péripatéticienne" [text reproduced in Pierre Duhem (*n27*), pp. 462-72]. About the relation between the evolution of physics and divine Providence, see Pierre Duhem, *Les origines de la statique*, t. 2, "Conclusion", Paris: Librairie scientifique A.Hermann, 1906.

29. Ludwig Wittgenstein, *Tractatus logico-philosphicus*, 1921: proposition 6.54.

30. Alexandre Koyré, "De l'influence des conceptions philosophiques sur l'évolution des théories scientifiques", in: *Études d'histoire de la pensée philosophique* (1961), Gallimard, 1971, pp. 253-69 (here I quoted p. 264).

31. Alexandre Koyré, "Orientation et projets de recherches", in: *Études d'histoire de la pensée scientifique* (1966), TEL Gallimard, 1973, pp. 11-15.

32. *Ibid.*, p. 11.

33. *Ibid.*, p. 15.

34. Article reproduced in Albert Einstein, *Cum văd eu lumea* (anthology by M. Flonta, I. Pârvu), Bucureşti, Humanitas, 1992, p. 73.

35. W.F. Bynum, E.J. Browne, Roy Porter (eds.), *Dictionary of the History of Science*, London and Basingstoke: The Macmillan Press Ltd., 1983, *s.v.* "internal environment", p. 211, col. 1.

36. H. Poincaré, *La Science et l'Hypothèse*, Paris: Ernest Flammarion Éditeur, 1927, p. 10.

37. Edmond Goblot, *Traité de logique*[5] (1917), Paris: Librairie Armand Colin, 1929, p. 274 (Chap. XI, paragraph 171).

38. *Ibid.*, par. 169, p. 272.

39. *Ibid.*, par. 172, p. 276.

40. Duhamel, *Des méthodes dans les sciences de raisonnement*, Paris: Gauthier-Villars, t. I[er], 1, 6-8, *apud* Ed. Goblot, *op. cit.*, p. 276.

41. Ed. Goblot, *op. cit.*, paragraph 173, p. 276.

42. Alexandre Koyré, "Fizica în secolul al XV-lea", representing Ch. III: "Fizica" from René Taton (ed.), *Istoria generală a științei*, vol. II: *Știința modernă. De la 1450 la 1800*, București: Editura Științifică, 1971, p. 93.

43. Jacques Itard, "De la algebra simbolică la calculul infinitezimal", in: René Taton (ed.), (*n42*), p. 238.

44. *Ibid.*, p. 227.

45. *Ibid.*, p. 233.

46. Arthur Koestler, *Les somnambules. Essai sur l'histoire des conceptions sur l'univers* (English original: 1959), Calmann-Lévy, 1960, p. 653, n. 1, ch. I.

47. Alexandre Koyré, "Revoluția copernicană" (text revized by René Taton), in: René Taton (ed.), (*n42*), p. 74.

48. Furetière, *Dictionnaire* (1690), *apud* André Lalande, *Vocabulaire technique et critique de la philosophie*[16], PUF, 1988, *s.v.* "mouvement" — Critique, p. 659 A.

49. *Ibidem*.

50. Alexandre Koyré, *Études galiléennes* (1939), Hermann, 1966, p. 21: "...le mouvement est l'être — l'acte — de ce qui n'est pas Dieu."

51. *Cf.* G.Beaujouan, "Știința în Occidentul medieval creștin", in: René Taton (ed.), *Istoria generală a științei*, t. I: *Știința antică și medievală. De la origini la 1450* (1957), București: Ed. Științifică, 1970, p. 620.

52. For a more technical discussion, see George Polya, *Matematica și raționamentele plauzibile*, vol. I: *Inducția și analogia în matematică* (1954), București, Ed. Științifică, 1962, pp. 228-231.

53. Another explanation is provided by Al. Koyré: the Ancients, he argues, were frequently mixing the role of time and the role of space; for the case of Leonardo, who commits the same error, see Al. Koyré, *loc.cit.* (*n42*), p. 100; for Galileo, see *Études galiléennes*, edition quoted at (*n50*). pp. 89 *et seq.*

54. *De rerum Natura of Titus Lucretius Carus*, translated by Rolfe Humphries, Indiana University Press, 1968. In Latin the text we are concerned with is in Liber Secundum, 235 *et sq.*

55. R.Torretti, "Mathematical Theories and Philosophical Insights in Cosmology" (1979), *apud* Ilie Pârvu, *Introducere în epistemologie*, București: Ed. Științifică și Enciclopedică, 1984, p. 197.

56. David Bohm, *La plénitude de l'univers* (French translation after *The Wholeness and the Implicate Order*, 1980), Editions du Rocher, 1990, p. 173 (Chap.VII, paragraph 2).

57. David Bohm, *La danse de l'esprit ou le sens déployé* (French translation after *Unfolding Meaning*), Les Editions Séveyrat, 1988, p. 16.

58. Alexandre Koyré, (*n30*), p. 256.

59. D.Waismann, "The Decline and Fall of Causality", represents Chap.V., pp. 84-154 from A.C.Crombie (ed.), *Turning points in physics*[2], Amsterdam: North-Holland Publishing Company, 1960.

60. *Ibid.*, paragraph 4, pp. 95-8 (the attitudes listed below are listed on pp. 95-6 and 105).

61. *Ibid.*, paragraph 12, p. 147.

62. J.J.Baumann, *Die Lehre von Zeit, Raum und Mathematik*, volume 2, Berlin: G.Reiner, 1869

63. Imre Lakatos, "Cauchy and the continuum: the significance of non-standard analysis for the history of mathematics" (paper delivered at the International Logic Colloquium, Hanover, 1966), reproduced in: Imre Lakatos, *Mathematics, Science and Epistemology. Philosophical Papers*, vol. 2, Edited by John Worrall and Gregory Currie, Cambridge: At The University Press, Chap. 3, pp. 43-60.

64. Ernst Cassirer, *L'Idée de l'histoire; Les inédits de Yale et autres écrits d'exil*, Cerf, coll."Passages", 1988, p. 12 (the lecture from which we quoted is entitled "L'idéalisme critique comme philosophie de la culture," and was held at Warburg Institute, London, on 26 May, 1936).

65. "The *a priori* validity of the concepts of a previous closed theory are based on the fact that they represent conditions of the possible subsequent theories" (Ilie Pârvu, *Teoria științifică*, București: Ed. Științifică și Enciclopedică, 1981, p. 133). In von Weizsacker's terms, "the general empirical laws provide the conditions for any experience"; or, as Heisenberg puts it, "we can express the result of an experiment only by the concepts of a previous closed theory" (*apud.* I. Pârvu, *op. cit.*, p. 132).

66. Werner Heisenberg, "Conceptul de 'teorie închisă' în științele moderne ale naturii" (1948), translated from German and reproduced in: Ilie Pârvu (ed.), *Istoria științei și reconstrucția conceptuală* (anthology), București: Ed. Științifică și Enciclopedică, 1981) pp. 41-46 (the interesting part is pp. 44-46).

67. Pierre Thuillier, *D'Archimède à Einstein. Les faces cachées de l'invention scientifique*, Fayard, 1988, "Introduction," p. iii.

68. Thomas S.Kuhn (*n24*), p. 112.

69. *Ibid.*, p. 69.

70. A competent and complete discussion — although obviously a much broader one — on this distinction and on the features of the structural, organisational and generating theories can be found in Ilie Pârvu, *Arhitectura existenței. Paradigma structural-generativă în ontologie*, vol. I, București: Humanitas, 1990, Section I, Ch.1 and 2, pp. 41-63.

71. *apud* I.Pârvu, (*n.55*), p. 377.

72. Kurt Gödel, "Ce este problema continu-ului a lui Cantor ?", *American Mathematical Monthly 54* (1947), pp. 515-25, reproduced in Romanian translation in: Ilie Pârvu (ed.), (*n6*), pp. 317-38; the interesting remarks about Godel's Platonic realism can be found at pp. 332-3.

73. Ernest H.Hutten, *Ideile fundamentale ale fizicii* (English original from 1967), București: Ed. Enciclopedică română, 1970, p. 157.

74. René Thom, "La science malgré tout...", in: *Encyclopaedia Universalis*, vol. 17: *Organum*, 1973, pp. 6 *et seq.*

75. Imre Lakatos, *The methodology of scientific research programmes. Philosophical Papers*, Vol.I, Edited by John Worrall and Gregory Currie, Cambridge; London; etc.: Cambridge University Press, 1978. Mainly Chap. 1, paragraph 3 *a* and *b*, pp. 47-52 and Chap. 2, paragraph 1*d*, pp. 110-7.

76. *Ibid.* pp. 110-111, Of course, in this way, Lakatos defines an internal medium of the theory including everything which, with Popper, Watkins and Agassi, had been external metaphysical remarks (*op. cit.*, p. 111).

77. E.J. Dijksterhuis, *The Mechanization of the World Picture. Pythagoras to Newton* (1950), Princeton; New Jersey: Princeton University Press, 1986; see mainly "Introduction" and "Epilogue".

78. The heterogeneity of the enumeration was justly criticised, and even mocked at, by Gerd Buchdahl, especially on the basis of the argument that a method cannot be a world view and modern science is not "a kind of timeless 'thing' or 'being'" ("On the Presupposition of Historians of Science", *History of Science* 1 (1962), p. 69).

79. Ernest H.Hutten, (*n72*), p. 167.

80. Isaac Newton, *Principiile matematice ale filozofiei naturale* (translated by Victor Marian after the IIIrd edition from 1726), Editura Academiei Republicii Populare Române, 1956, "Scolie generală", p. 418.

81. *Ibid.*, Cartea a III-a: Reguli de filozofare, pp. 314-15.

82. Pierre Duhem, (*n27*), pp. 159 *et sq.*

83. René Thom, "The Role of Mathematics in Present Day Science," in: *Logic, Methodology and Philosophy of Science*, VI, Warsawa: Polish Scientific Publishers, 1982, p. 9 (*apud* M. Flonta, *Imagini ale științei*, București: Editura Academiei Române, 1994, p. 134).

84. E.J.Dijksterhuis, (*n76*), p. 498. The same opinion is shared by David Bohm (*n56*), *passim*.

85. Jacques Merleau-Ponty, Bruno Morando, *Les trois étapes de la cosmologie. Comment a évolué la conception de l'univers de l'Antiquité à nos jours*, Robert Laffont, 1971, p. 98.

86. David Bohm, *The Wholeness and the Implicate Order*, London:Routledge, 1980, Chap.6: Appendix (*A4* and *A5*). The French translation, (*n56*), had omitted this chapter.

87. This conception of Hermann Cohen, taken from his work *System der Philosphie: Logik der reinen Erkenntnis* (1902), is briefly described in É. Bréhier (*n14*), p. 939.

88. René Berthelot, *La pensée de l'Asie et l'astrobiologie*, 1938, Avant-propos, pp.7-8.

89. Gerald Holton, "The Thematic Imagination in Science" (1964), article reproduced in: G. Holton (ed.), *Science and Culture: A Study of Cohesive and Disjunctive Forces*, Houghton Mifflin Company Boston, The Riverside Press Cambridge, 1965, pp. 88-108 (here I quoted from paragraph IV, p. 104).

90. *Ibid.*, paragraph VI, p. 106.

91. The term of "ideals" was used by Amos Funkestein in order to define these regulative values which operate like normative urgencies. Funkestein states that his ideals are different from Holton's *themata* by the fact that ideals "can be articulated precisely as a demand." More than that, they are susceptible to a precise phrasing. (Amos Funkenstein, *Theology and Scientific Imagination from the Middle Ages to the Seventeenth Century*, Princeton, New Jersey: Princeton University Press, 1986, p. 21, n.(5).

92. G. Holton, *op. cit.* at (*n86*), p. 103.

93. According to Aristotle, the translation of methods from one science to another leads only to category-mistakes: *Analytica posteriora*, Book I, Chap.VII, 75^b6 is directed against the Platonic view of mathematics as a universal method (Aristotle rejects the possibility of applying arithmetical demonstration to the properties of geometry, unless the magnitudes in question are numbers). This view was held in the Middle Ages and declined as a consequence of the nominalist revolution: in Gerson's *De concordia metaphysicae cum logica* (1426) the practice of treating logic as a metaphysician and theology as a logician was denounced as the *mal du siècle*.

94. A. Funkenstein, *op. cit.*, p. 25 (for the rest of the analysis, see also the following pages).

95. Jaakko Hintikka, "Discurs asupra metodei lui Descartes" (1978), reproduced in Romanian translation in: I. Pârvu (ed.), (*n23*), p. 148.

96. John A. Schuster, "The Scientific Revolution", in: R.C.Olby *et al.* (eds.), (*n1*), pp. 233-4.

97. John Hedley Brooke, "Science and Religion", represents Chap. 50 of R.C. Olby *et al.* (eds.), (*n1*), p. 767.

98. Alan Gabbey, "Newton and the Natural Philosophy", represents Chap. 16 of: R.C. Olby *et al.* (eds.), (*n1*), p. 252, paragraph 3.

99. A. Funkenstein, *op. cit.*, pp. 21-2.

100. *apud* M. Flonta, (*n22*), p. 60.

101. *apud* Tony Lévy, *Figures de l'infini. Les mathématiques au miroir des cultures*, Seuil, 1987, p. 12.

102. J.W. Dauben, *Georg Cantor. His Mathematics and Philosphy of the Infinite*, p. 291 (*apud* T. Lévy, (*n97*), pp. 14-5.

103. John A. Schuster, "The Scientific Revolution", (*n92*), p. 226.

104. "Secular theology was much more than just a *theologia naturalis*" because "The secularisation of theology — even in the simplest, first sense: that theological discussions were carried on by layman — is a fact of fundamental social and cultural importance". (Amos Funkestein, (*n88*), pp. 3-4: "Introduction", paragraph *A*.)

105. Anneliese Maier, *Die Mechanisierung des Weltbildes im 17. Jahrhundert*, Lepzig: Verlag von F. Meiner, 1938, p. 4 (*apud* M. Flonta, (*n82*), p. 122).

106. J.R. Ravetz, "The Copernican Revolution", paragraph 2 and paragraph 5 represents chap. 14 of (*n1*), pp. 201-16; I quoted pp. 205; 213). See also Ioan P. Couliano, *Éros et magie à la Renaissance. 1484*, Paris: Flammarion, 1984, IIIe Partie, chap.VIII, paragraphe 1.

107. Alan Gabbey, (*n24*), p. 253, but also paragraph 4, *passim*.

108. Jacques Merleau-Ponty, *Cosmologia secolului XX* (1965), București: Ed. Stiințifică și Enciclopedică, 1978, p. 36.

109. H. Hubert et M. Mauss, "Esquisse d'une théorie générale de la magie", *L'Année Sociologique 7* (1902-3) pp. 1-146, Paris: Alcan, 1904: Chap.III, iii, 1.

110. Lucian Blaga, *Eonul dogmatic* (1931), *passim*.

111. The Dominican Ioannes of Saint-Gille (died after 1258) condemned vividly those who "...venant à la théologie, peuvent à peine se séparer de leur science (...). Qui a appris la métaphysique, parlera toujours de points et de lignes en théologie" (*apud* Etienne Gilson, *La philosophie au Moyen Age*[2], Payot, 1986, p.741; see also pp.712 *et sq*.

112. H.-R. Patapievici, *Cerul văzut prin lentilă*, București: Nemira, 1994, chap. IV, 23: "Creștinismul și știința" and chap. IV, 24: "Fractali, omotetii și religii".

113. D'Arcy Wentworth Thompson, *On Growth and Form*, Cambridge University Press (An Abridged Edition Edited by John Tyler Bonner), 1992, mainly chap. VII, VIII and IX.

114. Ioan P. Couliano, *The Tree of Gnosis. Gnostic Mythology from Early Christianity to Modern Nihilism*, Harper San Francisco, 1992 (translation completely revized by the author of the 1990 French edition).

115. Ioan P. Couliano, "Introduction to the Eliade Guide to Religion" (March 4th, 1991) (text lent to the author by the courtesy of Tereza Petrescu, I.P. Couliano's sister).

116. L. Blaga, *Opere*, vol. 8: *Trilogia cunoașterii*, București: Ed. Minerva, 1983, pp. 204-205.